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BOTANY

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EDITOR'S NOTE

At the meeting of the Committee on Publications of the Ninth Pacific Science Congress, it was agreed that the increasing number of communications and papers presented at each Congress has become a very difficult problem for the Publication Committee and the editorial staff to cope with and that too much time is required to complete the publication of the Proceedings; therefore, it was recommended that the following principles governing publication be followed:

a. That invited contributions to the scheduled symposium be published in full;

b. That reports of the Standing Committees be published in full;

c. That other papers submitted to the Congress during its sessions be published in abstract only, the abstract not to exceed 500 words;

d. That papers which, though listed on the program or included in the pre-Congress abstracts published in advance but not actually submitted to the Congress at its sessions, should be disregarded;

e. That authors be asked to indicate by a definite and early date[1] whether they prefer to publish their papers in sources other than the Congress Proceedings; that if this is done, the Congress should be acknowledged;

f. That all proof reading be the responsibility of the editorial committee, and that this committee shall consider the manuscripts in their hands by a definite date as final;[2]

g. That authors be held responsible for submitting their material in good English;

h. That on matters arising during the course of publication and not specifically covered in the statement of policy the editorial committee is empowered to act.

In accordance with the resolutions of the Committee, the editorial board has edited the reports and manuscripts where necessary to bring uniformity and consistency to the format. Typographical and grammatical errors as well as errors in phraseology, spelling, or technical terms have been corrected, wherever possible, but in cases where the exact meaning of the original copy was not clear, the text has been left as submitted by the autor.

In order to reduce the cost and bulk of the publication, appendices, illustrations, and exhibits whenever considered not vital to the text have been eliminated.

If an author requested to publish elsewhere, his paper has been mentioned in the footnote under the respective titles, but if an author who presented a paper at the Congress failed to submit his manuscript either in full or in abstract, his paper and the discussions thereon have been eliminated entirely.

It was also decided that, in order to complete the publication of the Proceedings as soon as possible, each division be published in a separate volume. Short volumes or the ones that do not require too much editorial work will be released first. Therefore, among the twenty volumes planned, any volume may appear first. They will not appear in consecutive order.

The editorial board wishes to thank all authors who were prompt in submitting their revised manuscripts in good form and, in particular, members of the Standing and Organizing Committees, too numerous to be named, who have helped in collecting the manuscripts pertaining to their respective divisions.

The Board wishes in particular to thank Dr. F. Raymond Fosberg for going over and correcting the Special Symposium on *Climate, Vegetation, and Rational Land Utilization in the Humid Tropics* under UNESCO;

Mr. Saman Buravas of the Royal Mines Department for helping by redrawing charts and maps in order that they might reproduce clearly when printed;

Mr. J. Alan Tubb of the FAO Regional Office, for his assistance in going over and clarifying some of the papers in the Fisheries and Oceanography volumes and in translating some of the French papers;

Dr. Pradisth Cheosakul of the Department of Science for editing the Chemistry in the Development of Natural Resources volume;

Last but not least, the Board wishes to thank the *Thai Watana Panich Press* for their cooperative efforts, far beyond the requirement of the contract, in devoting all their resources to printing these volumes.

[1] January 1, 1958, in the case of the Ninth Congress.

[2] March 1, 1958, in the case of the Ninth Congress.

ABBREVIATIONS

APFC	—	Asia-Pacific Forestry Commission
CAA	—	Civil Air Administration
CSIRO		Commonwealth Scientific and Industrial Research Organization (Australia)
ECAFE	—	Economic Commission for Asia and the Far East
EQUAPAC	—	Equatorial Pacific (oceanographic survey)
FAO	—	Food and Agriculture Organization
IACOMS	—	International Advisory Committee on Marine Sciences
ICA	—	International Cooperation Administration
ICAO	—	International Civil Aviation Organization
ICSU	—	International Council of Scientific Unions
IGY	—	International Geophysical Year
IPFC	—	Indo-Pacific Fishery Commission
IRC	—	International Rice Commission (FAO)
JCRR	—	Joint Commission on Rural Reconstruction (Taiwan, China)
NORPAC	—	North Pacific (oceanographic survey)
PHILCUSA	—	Philippine Council for United States Aid
PIOSA	—	Pan-Indian Ocean Scientific Association
SEATO	—	South-East Asia Treaty Organization
SPC	—	South Pacific Commission
UN	—	United Nations
UNESCO	—	United Nations Educational, Scientific and Cultural Organization
UNICEF	—	United Nations International Children's Emergency Fund
USDA	—	United States Department of Agriculture
USIS	—	United States Information Service
USOM	—	United States of America Operations Mission
WHO	—	World Health Organization
WMO	—	World Meteorology Organization

PARTICIPANTS*

ASHTON, PETER SHAW, Botanist, State Forest Office, Brunei.

AUBERT DE LA RUE, EDGAR, Geologist, National Centre for Scientific Research, 18 rue Ribera, Paris XVI^{e}, France.

BALASIRI, DAROON, Instructor, School of Pharmacy, University of Medical Science, Bangkok, Thailand.

BANK, THEODORE POUL, II, Executive Director, Institute for Regional Exploration, University Station, Box 2143, Ann Arbor, Michigan, U.S.A.

BARTLETT, STEPHEN, Head of F&M Department, National Institute for Research in Dairying, University of Reading, Reading, England.

BELARDO, LUZ OLIVEROS, Dean, College of Pharmacy, The Philippine Women's University, Manila, Philippines.

BOONJAVATANA, CHAROEN, Supervisory Unit, Department of Teacher Training, Ministry of Education, Bangkok, Thailand.

BRYNE, BRIAN, Teacher, Mt. Hermon, Darjeeling, India.

BURKILL, HUMPHREY MORRISON, Director, Botanic Garden, Singapore.

CALDWELL, ARTHUR FRANCIS, Department of Pharmacy, Faculty of Medicine, University of Malaya, Singapore.

CAPELL, ARTHUR, Reader in Oceanic Linguistics, University of Sydney, Sydney, N.S.W., Australia.

CHANTARASRIKUL, ANONG, Bangkhen Experimental Station, Department of Agriculture, Ministry of Agriculture, Bangkok, Thailand.

CHUMDERMBHADEJSUK, SHALAM, Srisuriyothai School, Ministry of Education, Bangkok, Thailand.

CROCKER, ROBERT LANGDON, Professor of Botany, University of Sydney, Sydney, N.S.W., Australia.

DASANANDA, SALA, Deputy Director-General, Rice Department, Ministry of Agriculture, Bangkok, Thailand.

DOTY, MAXWELL S., Professor of Botany, University of Hawaii, Honolulu 14, Hawaii.

DOUGLAS, BRYCE, Senior Scientist, Smith Kline and French Laboratories, Philadelphia, c/o Chemistry Department, University of Malaya, Singapore 10.

EGLER, FRANK EDWIN, Aton Forest, Norfork, Connecticut, U.S.A.

FELDMANN, JEAN, Professeur à la Faculté de Sciences de Paris, Laboratoire de Biologie Végétale Marine, Faculté de Sciences de Paris, 195 rue St. Jacques, Paris 5^{e}, France.

FOSBERG, F. RAYMOND, Botanist, U.S. Geological Research Council, Washington 25, D.C., U.S.A.

GAUSSEN, HENRI MARCEL, Professor, University of Toulouse, rue Raymond IV 21, Toulouse, France.

HARRISSON, TOM H., Curator, Sarawak Museum, Brunei.

HEIM, ROGER, Director of the National Museum of Natural Sciences, Museum National D'Histoire Naturelle, 57 rue Cuvier, Paris 5^{e}, France.

HO, PHAM HOANG, Chargé de covas à la Faculté, Université de Saigon, 12 Hong Thap Tei, Saigon, Vietnam.

HOERNER, GODFREY RICHARD, Chief University Advisor, Kasetsart University/Oregon State College ICA Contract, Bangkhen, Bangkok, Thailand.

HORMCHONG, TWEE, Instructor, College of Education, Ministry of Education, Bangsaen, Thailand.

HU, SHIU-YING, Botanist, Arnold Arboretum, Harvard University, 22 Divinity Ave., Cambridge, Mass., U.S.A.

HÜRLIMANN, JOHANN H., Botanist, Ciba J.A., Friendensgasse 51, Basle, Switzerland.

JALAVICHARANA, KAHN, Chief, Plant Industry Division, Department of Agriculture, Bangkhen, Bangkok, Thailand.

JIRAWONGSE, VICHIARA A., Lecturer, Department of Pharmacy, Chulalongkorn University, Bangkok, Thailand.

---

* Initials or names in italics represent Thai titles.

JOHNSON, J. HARLAN, Professor of Geology, Colorado School of Mines, Golden, Colorado, U.S.A.

KASHEMSANTA, *M.C.* LAK, Director-General, Department of Agriculture, Ministry of Agriculture, Bangkok, Thailand.

KETUSINH, OUAY, Professor, Department of Physiology, Siriraj Hospital, Dhonburi, Thailand.

KÜCHLER, A.W., Professor of Geography, University of Kansas, Lawrence, Kansas, U.S.A.

LOETSCH, FRITZ, Professor, Hamburg University, Bundes forschungsanstalt Forstwirtschaft, Reinbek bei, Hamburg, Germany.

McHALE, THOMAS RILEY, Economist, 24 Blackstone Blud., Providence, R.I., U.S.A.

MEKAYONK, VICHIT, Suan Sunantha College, Bangkok, Thailand.

NA-THALANG, SOMBOON, Director, Rubber Division, Department of Agriculture, Ministry of Agriculture, Bangkok, Thailand.

OGAWA, HUSATO, Researcher, Laboratory of Plant Ecology, Institute of Polytechnics, Osaka City University, Manami-Ogimachi, Kitaku, Osaka, Japan.

PAPENFUSS, GEORGE F., Professor, Department of Botany, University of California, Berkeley 4, California, U.S.A.

PAVANARIT, SRIROT, College of Education, Department of Teacher Training, Ministry of Education, Bangkok, Thailand.

PHUMXUSRI, PRASIDHI, Agriculturist, Mae Malai Farm, Mae Rim, Chiang Mai, Thailand.

PICHAISIRI, SOMSUGDI, Instructor, Department of Teacher Training, Ministry of Education, Bangkok, Thailand.

PROWSE, GERALD ALBERT, Botanist and Algologist, Fish Culture Research Station, Batu Berendam, Malacca, Federation of Malaya.

RAYMOND, MARCEL L., Taxonomist, Montreal Botanical Garden, 4101 East, Sherbrooke Street, Montreal, Canada.

RICHARDS, PAUL WESTMACOTT, Professor of Botany, University College of North Wales, Bangor, Great Britain.

RUHLE, GEORGE CORNELIUS, Park Naturalist, Hawaii National Park, Hawaii, U.S.A.

RYTHER, JOHN HOOD, Marine Biologist, Woods Hole Oceanographic Institution, Woods Hole, Mass., U.S.A.

SACHET, MARIE-HELENE, Bibliographer, Pacific National Research Council, Washington 25, D.C., U.S.A.

SAMAPUDDHI, KRIT, Royal Forest Department, Bangkok, Thailand.

SANSUKH, SOMSAK, Teacher, College of Education, Department of Teacher Training, Ministry of Education, Bangkok, Thailand.

SANTOS, JOSE VERA, Head, Department of Botany, University of the Philippines, Quezon City, Philippines.

SCAGEL, ROBERT FRANCIS, Associate Professor, Department of Biology and Botany, and Institute of Oceanography, University of British Columbia, Vancouver 8, B.C., Canada.

SEIDENFADEN, GUNNAR, Danish Minister, Danish Legation, Bangkok, Thailand.

SETYODIWIRYO, KUSNOTO, Director, Botanic Gardens of Indonesia, Djl. Bubulak 25, Bogor, Indonesia.

SILVA, PAUL CLAUDE, Associate Professor, Department of Botany, University of Illinois, Urbana, Illinois, U.S.A.

SMITINAND, TEM, Chief, Section of Botany and Zoology, Forest Products Research Division, Royal Forest Department, Bangkok, Thailand.

STEINER, MONA LISA, Chairman of sub-committee on Vernacular Names of Plants, 2833 Park Avenue, Pasay City, Philippines.

SUVAGONDHA, CHAMLONG, Professor and Dean, School of Pharmacy, Bangkok, Thailand.

SUVARNASUDDHI, KHID, Deputy Director-General, Royal Forest Department, Bangkok, Thailand.

SUVATABANDHU, KASIN, Department of Agriculture, Bangkok, Thailand.

THIRAWAT, SUKHUM, Chief, Division of Forest Control, Royal Forest Department, Bangkok, Thailand.

THONGUMPHAI, KHAJORN, Teacher, Chachoengsao Teacher Training College, Chachoengsao, Thailand.

TRINANDWAN, SA-KORN, Teacher, College of Education, Ministry of Education, Bangkok, Thailand.

TROLL, CARL TH., Professor, University of Bonn, Universität, Geographisches Institut, Bonn, Germany.

TUYAMA, TAKASI, Professor, Laboratory of Botany, Faculty of Science, Ochanomizu University, Otsuka, Bunkyoku, Tokyo, Japan.

VALLARTA, MARIA T., Head, Department of Botany, The Philippine Women's University, Manila, Philippines.

VAN STEENIS, C.G.G.J., Professor, Flora Malesiana Foundation, Marelaan 55, Oegstgeest, Netherlands.

VESTAL, EDGAR F., T.A. Plant Protection Advisor, USOM, Bangkok, Thailand.

WALKER, EGBERT H., Department of Botany, Smithsonian Institution, Washington 25, D.C., U.S.A.

WEATHERWAX, PAUL, Visiting Professor, College of Education/Indiana University ICA Contract, Bangkok, Thailand.

WYCHERLEY, PAUL RENODEN, Botanist, Rubber Research Institute of Malaya, P.O. Box 150, Kuala Lumpur, Malaya.

YEN, DOUGLAS ERNEST, Scientific Officer, Vegetable Station, D.S.I.R., Robinson Road, Otahuhu, New Zealand.

YODA, KYOJI, Researcher, Laboratory of Plant Ecology, Institute of Polytechnics, Osaka City University, Minami-Ogimachi, Kitaku, Osaka, Japan.

BOTANY

Standing Committee Chairman: F. R. FOSBERG
Organizing Committee Chairman: M. C. LAKSHANAKARA KASHEMSANTA

Standing Committee Reports

REPORT OF THE CHAIRMAN OF THE STANDING COMMITTEE ON PACIFIC BOTANY

F. R. FOSBERG

Chairman, Pacific Vegetation Project, Washington, D.C., U.S.A.

The Standing Committee on Pacific Botany, established under this title by the Eighth Pacific Science Congress, succeeding the former Standing Committee on Pacific Plant Areas, includes the following members (arranged alphabetically):

Theodore P. Bank II (U.S.A.) (Chairman, Subcommittee on Pacific Ethnobotany).
Nancy T. Burbidge (Australia).
Pierre Dansereau (Canada) (Chairman, Subcommittee on Pacific Plant Ecology).
Maxwell S. Doty (Hawaii) (Chairman, Subcommittee on Pacific Algae).
Ramon Ferreyra (Peru).
F. Raymond Fosberg (U.S.A.) (Chairman, Standing Committee).
Hiroshi Hara (Japan).
Ir. Kusnoto Setyodiwiryo (Indonesia).
H. J. Lam (Netherlands) (Chairman, Subcommittee on Pacific Plant Areas).
E. Looho (Indonesia) (Chairman, Subcommittee on Medicinal Plants).
Lucy B. Moore (New Zealand) (replacing the late W.R.B. Oliver).
Eduardo Quisumbing (Philippines).
Carl Skottsberg (Sweden) (Chairman, Subcommittee on Nature Protection).
Mona Lisa Steiner (Philippines) (Chairman of Subcommittee on Common Names of Pacific Plants).
Kasin Suvatabandhu (Thailand) (Secretary, Standing Committee).
Egbert H. Walker (U.S.A.) (Chairman, Subcommittee on Botanical Bibliography).
John Wyatt-Smith (Malaya).

The committee has functioned principally through its eight subcommittees. The reports of these subcommittees (which follow) speak for themselves, and material contained therein will not be repeated here. Their accomplishments are amply sufficient to justify continuation of this method of functioning of the Standing Committee. It is therefore recommended that the Botany Division of the Ninth Congress consider very carefully the lines of effort that it wants the next Standing Committee on Pacific Botany to emphasize and that it recommends for each such line or field the establishment of a special subcommittee, as was done in 1953.

The present Standing Committee is composed of the chairmen of the subcommittees and sufficient other members to give it wide geographical representation. No members were selected from countries that were represented already by subcommittee chairmen. When Professor Kusnoto had to resign the chairmanship of his Subcommittee on Medicinal Plants because of pressure of other duties, on his recommendation Dr. Looho was appointed to replace him, but he continued as a Committee member. We deeply regret the loss by death of one of our members, Dr. Oliver, chairman of the predecessor of this committee. Miss Moore was asked to replace him.

The principal efforts of the Chairman were to assist the Organizing Committee of the Ninth Congress with the planning of the botanical program and to compile a list of Pacific botanists.

To accomplish the first aim, a visit was made to Bangkok in April, 1956, when the program was thoroughly discussed and names were suggested of people who might agree to organize symposia and to be chairmen of sessions. Most of these people have responded to the invitations of the Organizing Committee, resulting in the rather ambitious program of the Botany Division, and, incidentally, in the excellent representation of Pacific botanists at the Congress. Where possible, the activities of the subcommittees have been tied into the program. If certain fields have been neglected, it was because the program could scarcely have been made longer. Cooperation with other divisions was recommended where it seemed appropriate.

The second of the tasks was more difficult, and the product is admittedly imperfect. A request was sent to all Standing Committee members and a few others for lists of names from their several geographic areas. This resulted in a few lists. To these were added names known to the Chairman, encountered in the literature, or found in published address lists. The resulting list was duplicated and circulated to a geographically representative group of botanists for criticism, additions, and corrections. The result was gratifying and enabled us to get together the list that is before you and which will be mailed to all those appearing in it. It is hoped that it will contribute substantially to the primary aim of the Standing Committee, to stimulate communication and cooperation between the botanists interested in the Pacific Basin.

A word is in order about the scope and limitations of this list. It was arbitrarily limited to those branches of botany that have a definite regional aspect, and that are not properly included in agriculture or other strictly practical fields which may have the resources to compile lists that will better serve their purposes. Thus many names were excluded in such fields as plant physiology, genetics, plant chemistry, cytology, agronomy, etc. Reliance usually had to be placed on printed sources for such information. Undoubtedly serious errors were made. We humbly ask forgiveness and hope that a future list may rectify all errors and omissions.

We take great pleasure in acknowledging our gratitude to the Pacific Science Council Secretariat and the National Science Foundation for financial help that made the production of this list possible. Copies will be distributed to all people whose names appear on the list and to libraries of institutions known to be interested in Pacific Botany. Persons or institutions not listed or which do not receive copies may receive them by requesting them, so long as the copies last.

We wish also to express our gratitude to the Pacific Science Board of the National Research Council for continuously making facilities and space available for the functioning of the Standing Committee, and for help in numerous ways.

It is customary for the reports of standing committees to include summaries of work in the field accomplished or undertaken during the period of the Committee's activity. We have asked Committee members for such information on their areas. A few have responded, and their contributions are briefly summarized here, along with some other widely known current activity. This is only a sampling of the field, and details and most names are purposely omitted, as it is impossible to list all of them. Several of the reports submitted by Committee members seem sufficiently comprehensive that it is desirable to append them in full to this report, in which cases little in the way of summary is included.

By far the most comprehensive and widespread program in the Pacific Area is that of the Flora Malesiana, whose able editor is with us and may care to give us current news of it. Under its auspices have appeared many preliminary revisions of groups as well as a number of the final treatments for the Flora. The Flora malesiana Bulletin continues to be the world's most informative botanical news organ, as well as containing much valuable bibliographic information.

Revision of Cheeseman's Manual of the Flora of New Zealand is complete, and the book is in press. For further information on New Zealand, see Miss Moore's report.

The C.S.I.R.O. in Australia is carrying out extensive botanical and ecological survey work in the Northern Territory and in New Guinea, and botanists in other parts of Australia continue to be very active. It should be specially noted that the botanical exploration of the subantarctic Macquarie Island, recommended by the Second Pan-Pacific Science Congress, has been carried out by a group from the C.S.I.R.O.

Along the Pacific side of South America, work on the flora and vegetation of Peru, centered at the Universidad de San Marcos, Lima, and that on Colombia, centered at Bogotá, Medellin, and especially at the U.S. National Herbarium, is especially active and productive. The Flora of Panama is being continued by the Missouri Botanical Garden.

In the U.S., work on a manual of California plants is going on at the Rancho Santa Ana Botanical Garden and New York Botanical Garden. At the several campuses of the University of California, Jepson's Flora of California is drawing toward completion, and much work in systematic, biosystematic, and ecological fields is being done. Pomona College and affiliated institutions also form an active center of taxonomic and ecological work, especially on plants of arid southwest North America. Work on the vegetation of Alaska has been carried out under various auspices, especially in connection with work on permafrost by several military sponsored agencies and the U.S. Geological Survey.

In Japan there has been much activity in many institutions, principally on the vegetation and flora of Japan. Especially valuable as a basis for all other such work are Hara's bibliographic checklist of the flora of Japan and an English language revision of Ohwi's Flora of Japan, the latter in cooperation with several U.S. Institutions.

We have no news of the status of recent botanical work in mainland China, but the Flora of China Project of the Arnold Arboretum, U.S.A., is being continued under the direction of Dr. Shin-ying Hu. (See accompanying report by Dr. Hu.)

For a report of progress on a flora of the Ryukyu Islands see the accompanying report by E.H. Walker.

In Thailand aquatic and economic plants are under study by our Thai colleagues, and a Danish expedition has been studying and collecting the flora.

At the University of Hawaii is a project on Pacific Pandanus, as well as active work on algal ecology and ocean productivity.

The Pacific Vegetation Project has continued its investigations on the vegetation and flora of Micronesia, as well as some other Pacific areas and on coral atolls generally, sponsored by the U.S. Geological Survey. A by-product of this is the volume, *Island Bibliographies*, published by the Pacific Science Board.

On other insular areas, work on the flora of New Caledonia has continued at Zurich and by R. Virot at Paris, on that of Fiji at the U.S. National Herbarium and at Suva, and on the food plants of the Pacific at the University of Marseilles and the South Pacific Commission. Finally, we must mention the completion and publication of two magnificent volumes on the vegetation and the origin and affinities of the flora of Juan Fernandez by our eminent colleague, Carl Skottsberg of Gothenburg, Sweden.

Mention should be made of the status of the volume on the Vegetation Provinces of the Pacific Basin, based on the symposium at the Eighth Pacific Science Congress. Manuscripts are in hand for the greater part of the chapters, but about a third are still not available. They are mostly reported in various stages of completion. It is hoped that this work can be promptly brought to a conclusion, as all indications are that the volume is much needed and would immediately be widely used. Experience with this volume tends to discourage attempts at cooperative works of this sort, as it seems to be necessary to spend time out of all proportion merely to urge unenthusiastic collaborators to complete their promised contributions.

CONCERNING THE FLORA OF JAPAN, ENGLISH TRANSLATION

E. H. WALKER

Smithsonian Institution, Washington, D.C., U.S.A.

An American serviceman, Leopold Charette, initiated the translation into English by J. Ohwi of his Flora of Japan (in Japanese, 1953). Fred Meyer, formerly at the Missouri Botanical Garden, and E.H. Walker, Smithsonian Institution, are editors, and the project is currently sponsored by the Missouri Botanical Garden. Funds have been provided by the National Science Foundation, U.S.A. Dr. Ohwi recently submitted a treatment of the Pteriodophyta, a group not included in the original flora, in English. With the permission of the editors, he then translated this into Japanese for publication in Japan. This came from the press in November, 1957. (A copy was circulated through the audience.)

STATUS OF THE FLORA OF CHINA PROJECT

SHIN-YING HU

Arnold Arboretum, Jamaica Plain, Massachusetts, U.S.A.

HISTORY

This project was initiated in 1953 as a coopera-tive project between A Continental Development Foundation and the Arnold Arboretum of Harvard University. Over thirty thousand dollars has been invested in it.

ACCOMPLISHMENT

1. A complete index to the species of the flowering plants has been prepared. This is in card catalogue form and it consists of approxi-mately 100 thousand cards each covering names, synonyms, important literature references, au-thentic collections, and the distribution.

2. The preparation of a bibliographical enu-meration of the plants of China has commenced. The treatment of the Compositae is now complete. The manuscript consists of about 1,500 typed sheets, double spaced. That of the Orchidaceae is almost done.

PUBLISHED FLORA AND MANUSCRIPT

1. A model of the flora, a treatment of the Malvaceae, was published in 1955 and distributed in 1956. It shows what can be done.

2. Manuscript for the next issue covering Palmae, Araceae, Ericauloneceae, Conmelina-ceae, and Panderderaceae is at hand.

PROBLEMS

The supporting foundation can no longer provide financial support to the Project. The undertaking itself is a tremendous task. Now moral and financial support are required for its continuation.

REPORT ON THE BOTANICAL SECTION OF THE PROGRAM FOR SCIENTIFIC INVESTIGATION OF THE RYUKYU ISLANDS

E. H. WALKER

Smithsonian Institution, Washington, D.C., U.S.A.

The SIRI program of the Pacific Science Board and the U.S. Army was designed to provide basic scientific information for the development of the southern Ryukyu Islands. As botanist on this program, I spent the three summer months of 1951 in Okinawa and the Southern Ryukyus mainly collecting herbarium material for use in eventually preparing a Flora of the area.

In 1952, the U.S. Civil Administration and the Government of the Ryukyus mimeographed an issue of 200 copies of a Flora of Okinawa, originally prepared by the Okinawans, Sonohara, Tawada, and Amano, and edited by me. In 1954, they issued my book of some 300 pages *Important Trees of the Ryukyu Islands*, dealing with 209 species, each illustrated, the text in both Japanese and English in parallel columns. In 1953, I attended the Eighth Pacific Science Congress as delegate from this program and contributed two papers dealing with Okinawa and the Southern Ryukyus, and on my return made further collections in Okinawa. With assistance from this program, a herbarium was established at the University of the Ryukyus in 1955 and encouragement given to the training in America of an Okinawan botanist to become its curator.

In 1954, a new Flora of Okinawa and the Southern Ryukyus was started. It is based upon all available specimens, which have now grown to occupy some ten cases in the U.S. National Herbarium in the Smithsonian Institution, and on critical studies by many contributors. As now being prepared it will contain keys, brief characterizations, and critical notes. The thoroughness of this work was greatly increased by the opportunity to select and borrow critical herbarium specimens from Japanese and Taiwan herbaria and to make collections in Okinawa of palms and bamboos while enroute to this Congress.

Besides the material results of this program, so useful in the development of the Ryukyus and of our scientific knowledge of this area, such as the publications and critically studied scientific specimens, certain intangibles may be noted. Especially significant is an increased understanding, goodwill, and cooperation between the botanists and institutions of Japan, Okinawa, Taiwan, America and some European countries. Surely the investment in this program is bringing rewarding returns.

BOTANY IN INDONESIA, 1953-1957

KUSNOTO SETYODIWIRYO

Director, Botanic Gardens of Indonesia, Bogor, Indonesia.

This is a brief report of botanical activities in Indonesia during 1953-1957.

The staff of the Treub Laboratory was engaged in conducting the following scientific investigations.

INVESTIGATIONS IN THE FIELD OF GENERAL BOTANY

(a) Research with growth hormones, isolation of growth promoting compounds of a fern, application of a new Ageratum test, application of commercial growth hormones for the rooting of cuttings of cultivated plants.

(b) Investigations on the interaction between epiphytes, micro-organism, and host-plants in order to clarify a supposed symbiotic effect. Microscopy of the lutoids in Hevea latex.

(c) Cytological investigations of the *Amorphophallus* and *Corypha*. Description of the meiotic divisions, the explanation of a new phenomenon found in the meiotic prophase in the genus *Corypha*, in respect of the function of the nucleolus. Study on the pollen grain mitosis of *Rafflesia arnoldi*, and the establishment of the number of chromosomes. Study on the sterility of *Monodora myristica*. *Allium* spp. were used to test the effect of the digitonin on the nuclear division.

(d) Genetical investigations with *Digitalis* spp. carrying out interspecific crossing between *D. lanata* and *D. lutea*. Observation of different *Digitalis* spp. cultivated on higher sea-level.

(e) Anatomical investigations on the leaf and root structure of *Fagraea borneensis* and *Smilax* sp.

INVESTIGATIONS IN THE FIELD OF BIOCHEMISTRY

(a) Investigations of the chemical composition of latex in the family of Apocynaceae.

(b) Determination of the rubber hydrocarbon constituent of *Balanophora* sp.

(c) Investigations on the cardiac glycosides of *Thevetia peruviana*, *Antiaris toxicaria* and various other plants of the families of Asclepiadaceae, Apocynaceae, Moraceae. Test for the presence of alkaloids and saponins in plants collected in Indonesia.

INVESTIGATIONS IN THE FIELD OF MICROBIOLOGY

(a) Isolation of pure cultures of *Pseudomonas* sp. collected from diseased Hevea and Digitalis plants.

(b) Investigation of *Xanthomonas* sp. isolated from infected rice plants.

(c) Obtaining of new material for the collection of fungi and bacteria maintained in the laboratory for scientific and industrial purposes. Exchange of samples with institutions abroad.

Lectures. Delivering a course on the cultivation methods of orchids in 1956. Lectures on Cytology and Genetics at the Faculty of Agriculture of the University of Indonesia. The same lectures, and also on Biochemistry, were given at the Biological Academy, established by the Ministry of Agriculture in October, 1955, in Bogor.

Excursions. An excursion was carried out to the islands of Timor, Roti, etc. in order to collect medicinal plants; another excursion in Java, Celebes and in the Lesser Sunda Islands to collect cytological material of monocarpic palms.

Guest research workers in the Treub Laboratory. Prof. Dr. Koernicke, Germany, Prof. Dr. F. Fagerlind and G. Wibom, Sweden, Prof. Dr. P. Buchner, Italy, and Dr. P. Surany, U.S.A., have visited and worked for varying periods. Dr. H.P. Bottelier, Holland, worked in the Treub Laboratory on a Fellowship for six months.

Exhibition. The Treub Laboratory has participated in the Agricultural and Horticultural Exhibition at Pasar Minggu near Djakarta in 1954, with a show material on the effect of the growth hormones and the symbiosis between epiphytes, microorganism, and host plants.

HERBARIUM BOGORIENSE

In 1953, a combined expedition of Dr. A. Kostermans of the Forestry Service and Dr. W. Meyer of the Herbarium went to the island of Nunukan in North East Kalimantan (Borneo) and the adjacent mainland. The collections amounted to 1,500 numbers of Phanerogams and 600 Cryptogams. Two other members of the staff, Mr. Groenhart and Mr. Van Borssum Waalkes, made a trip to West-Central Sumatra and the Mentawei Islands. The Herbarium received 4,630 plants in exchange, whereas more than 14,000 specimens were sent abroad as duplicates and more than 8,000 sheets were loaned for study purpose. One part of Volume 2 of *Reinwardtia* appeared with monographies and papers on Phanerogams.

In 1954, a guest worker, Dr. Alston from the British Museum in London, made collecting trips, sponsored by the Herbarium, to South Borneo, Sumatra, North Celebes, Ternate, and Ambon. A trip by Mr. A. Groenhart was made to Banten in West Java. The collections of the expedition of Dr. Kostermans of the Forestry Service to Central Kalimantan, amounting to 1,500 field numbers, were ceded to the Herbarium. More than 3,000 duplicates were received from abroad, in exchange for almost 12,000 duplicates, sent abroad to twenty Institutes. One big volume appeared of *Reinwardtia* containing numerous articles on Phanerogams and Cryptogams.

In 1955, an expedition of Dr. A. Kostermans went to Central Kalimantan for three and one-half months. The collections, consisting of about one thousand field numbers, are incorporated in the Herbarium collections. Furthermore, an expedition of Dr. Kostermans to Central Sumatra for the purpose of collecting timber for research in cellulose for rayon, brought back more than 600 field numbers for the Herbarium. Dr. Kostermans was accompanied during the first part of this trip by Mr. Anwari Dilmy, Keeper of the Herbarium. The two gentlemen accompanied Prof. Kusnoto, the Director of the Botanic Gardens to Padang Tinggi, West Coast of Sumatra, for the official opening ceremonies of the Branch Garden there. Plans were outlined as to how to investigate the extensive area of virgin forest surrounding this new Garden. Almost 20,000 specimens have been sent abroad, on loan and as gifts, to thirty Institutes, whereas 3,000 specimens—apart from the Kostermans collections—were received in exchange. One back-volume, containing the plates of Ebenaceae of Bakhuizen's monography appeared, and one part of *Reinwardtia*, containing numerous taxonomical articles. The Herbarium building underwent big repairs and improvements and is now in a good condition.

In 1956, Mr. Van Borssum Waalkes made an expedition to Timor. Mr. Jacobs made a combined trip with Dr. Meyer from the Agricultural Faculty at Pajakumbuh to Mount Korintji in Central Sumatra, whereas one guest-worker, Mr. Forman from Kew, made trips to East Java with Mr. Dilmy, and to Sumatra. Dr. Kostermans, who made an expedition to the mountain region in Central Kalimantan, brought back about 800 field numbers and living plants of these unexplored regions. The collections are incorporated in those of Herbarium Bogoriense. Two parts of *Reinwardtia* appeared this year with articles on Cryptogams and Phanerogams. Mr. Dilmy and Dr. Kostermans attended the UNESCO Symposium in Ceylon.

In 1957, Mr. Forman made a trip to North Celebes. Dr. Kostermans collected in East Java, especially bamboos. Mr. Dilmy made a trip to the U.S.A. and Europe, sponsored by the Ford Foundation and UNESCO. Two volumes of *Reinwardtia* appeared. In 1956 more than 10,000 specimens were sent out in exchange, and about 1,000 specimens were received. In 1957, exchange and loan of material was carried on as usual and is still increasing. Dr. Kostermans worked up the Lauraceae of Madagascar, which appeared in a series of articles in Bogor and Brussels. A monograph on Durio by Dr. Kostermans, assisted by a student of the Biological Academy, Mr. Sugeng, has been completed.

The botanical activities of the Bureau of Horticulture at Pasar Minggu, near Djakarta, include the following:

(1) *Distribution of fruit trees.* An attempt is being made to establish the correlation between the distribution of fruit trees with ecological factors, viz. rainfall, soil-type, hours of sunshine, water-table, temperature. As an example of these investigations, it has been found in various grape-growing centres that it is very probable that a minimum of 70% of sunlight is required for success.

(2) *Cabbage breeding.* A scheme on the breeding of high quality cabbage varieties capable of seeding in the tropics is being worked out. Crosses between high quality non-seeding varieties and lower quality seeding varieties have been carried out. A vernalisation project on non-seeding high quality varieties is being planned.

(3) *Virus free potato seed stock.* In connection with the problem of keeping a virus-free seed stock collection of potatoes, insect free chambers are being built in a glasshouse. Various plant-indicators are already multiplied for the

purpose. Import of wild and cultivated species of South America is being planned.

(4) *Citrus decline.* An investigation into the cause of citrus decline is going on. Indications are very strong that the decline is not due to soil, but to other sources. Nematodes have been isolated from roots of plants. Budding trials on lime ("djeruk nipis") with scion material from declined citrus trees shows stem-pitting and vein clearing in the leaves.

The division of Phytosystematics, -geography, and -sociology of the Faculty of Agriculture, University of Indonesia, Bogor, put it as one of the objectives of botanical investigations by the senior students of the Faculty, the study of the main features of phytogeography and -ecology in Indonesia. Several reconnaissance expeditions have been undertaken in 1953 to the Lawu Mountain (3,300 meter above sealevel) in East-Central Java, and Sumatra, in 1954 to Central and East Java, Banten (West Java), and the islands in the Bay of Djakarta. We have got the opinion that in all probability the site factors climate and soil series, together with the geographical location, have an important influence on the structure and floristic composition of our tropical plant communities. After the departure of the Head of the Division, Prof. Dr. S. Bloembergen, at medio 1955, in a very limited scale ecological surveys in tropical rain forests have been carried out in East Kalimentan and the Mount of Lawu. Further botanical investigations are planned. Recently, Mr. G.A. de Weille, staff member of the General Research Station at Medan (North Sumatra), has taken his doctor's degree in agriculture at the Agricultural Faculty of Bogor, on a thesis entitled "Blister blight control in its connection with climatic and weather conditions".

Since 1953 the Central Research Stations Association (C.P.V.) at Bogor has published the following articles of botanical interest in English:

(1) Schweizer, J., The physiology of latex as basis for tapping systems (1953).

(2) Wiersum, L.K., Results of some preliminary experiments on stimulation of latex yields (1953).

(3) Vollema, J.S. and Lasschuit, J.A., The mildew resistant clone LCB 870 (1953).

(4) Vink, A.P.A. and Alphen de Veer, E.J. van, Mechanical and chemical lalang control (1953).

(5) Zeehuizen, J.J. and Arentzen, A.G.J., Divergencies between strain and modulus determinations (1953).

(6) Zeehuizen, J.J. and Schoon, Th. G. F., Preoculation of the yellow fraction by alkaline salts of weak acids with preservative properties (1953).

(7) Zeehuizen, J.J. and Schoon, Th. G. F., Oxalic acid as a coagulant in the processing of rubber (1953).

(8) Zeehuizen, J.J. and Schoon, Th. G.F., The influence of glyoxal on the vulcanization characteristics of natural rubber (1954).

(9) Wiersum, L.K., Observations on the rooting of *Hevea* cuttings (1955).

(10) Wiersum, L.K., Physiological investigations into the process of yield stimulation of latex (1955).

(11) Paardekooper, E.C., Results of testing of *Hevea* seedlings obtained by hand pollination during 1927-1944 (1956).

(12) Paardekooper, E.C., The occurrence, properties and possible application of juvenile type buddings (1956).

(13) Paardekooper, E.C., Further data on early selection in *Hevea* (1956).

(14) Knaap, W.P. van der, Results of tea clone experiments at Pasir Sarongge (1955).

(15) Knaap, W.P. van der, Notes on disease incidence of *Exobasidium vexans* Massee on tea (1955).

BOTANY IN NEW ZEALAND, 1953-1957

LUCY B. MOORE

Botany Division, C.S.I.R., Wellington, New Zealand.

PERSONAL NOTES

First must be mentioned the death of the veteran botanist Dr. W.R.B. Oliver on 16 May 1957. Dr. Oliver published a revision of the genus *Aciphylla* in October, 1956, (*Trans. Roy. Soc. N.Z.* **84**, pp. 1-18), and was active in field work until the end of that year, making a collecting trip to Norfolk Island in November. He was able to carry on a limited amount of herbarium work until within a week or two of his death. Another loss to New Zealand botany was the death, in July, 1957, of Mr, G.O.K. Sainsbury who, having completed studies on New Zealand and Tasmania mosses, was working actively on collections from some Pacific Islands and from Malaya. The herbaria of both these collectors are at Dominion Museum.

Distinguished botanical visitors to New Zealand during the years under review included Dr. F.W. Went, Dr. H. Godwin, Professor R. D'O. Good, Dr. W.M. Hiesey, and Dr. J.W. Gregor, all for rather short periods. There was a good representation of Australian botanists for the A.N.Z.A.A.S. meeting in Dunedin in January, 1957, and the International Grasslands Congress in November, 1956, and the Empire Forestry Conference now meeting here have also brought numbers of plant scientists to our country.

Dr. H.H. Allan was one of the twelve biologists to receive the honorary degree of Doctor of Philosophy at the Linnaean Jubilee celebrations in Uppsala in May, 1957.

With the appointment of Dr. W.R. Philipson to the recently established Chair of Botany at Canterbury University College, we have, for the first time, a full Professor of Botany at each of the four main University institutions.

Dr. G.H. Cunningham, F.R.S., retired from the directorship of the Plant Diseases Division of D.S.I.R. at the end of September, 1957. The name of his successor has not been announced.

INSTITUTIONS AND SOCIETIES

Apart from the purely botanical departments in the four University Colleges and two of the museums, the Botany, Crop Research, Grasslands, Plant Chemistry, and Plant Diseases Divisions of D.S.I.R., and the Forest Research Institute, increasing amounts of work of direct botanical import are coming from several other bodies, some of which employ one or more professional botanists, e.g., Dominion Physical Laboratory, Soil Bureau and N.Z. Oceanographic Institute of D.S.I.R., soil conservation service under Department of Agriculture, and certain local bodies known as Catchment Boards.

Several rather recently formed societies meeting annually discuss botanical problems, e.g., N.Z. Genetical Society (established in 1949), N.Z. Ecological Society (established in 1951), N.Z. Microbiological Society, N.Z. Association of Agricultural Scientists, and N.Z. Geological Society. The last three formed since 1953.

In 1953, Botany Division, D.S.I.R., transferred to Christchurch, though a small Sub-Station is retained temporarily in part of the old quarters in Wellington.

CRYPTOGAMS

ALGAE

In 1956, Chapman published a systematic account of the marine Myxophyceae and Chlorophyceae (*Jour. Linn. Soc.* **55** No. 360, pp. 333-501). Dellow worked on ecology in Auckland; Naylor investigated anatomical and life history problems in brown seaweeds and produced a check list of marine algae for Dunedin. Mason's checklist of N.Z. Charophyta appeared in 1956. E.A. Flint is currently working on soil algae as part of a team dealing also with fungi, bacteria, yeasts, amoeboid and ciliate protozoa, and actinomycetes.

FUNGI

In systematics, there has been a steady flow of papers from Cunningham and Dingley. G.B. Cone has continued her collecting of agarics but has not reached publication. A textbook on *Forest Fungi*, prepared by M.E. Lancaster, was published for Forest Service in 1955. A study of Australasian Cyttariaceae (Rawlings, *T.R.S.N.Z.* **84**, pp. 19-28) has interests across the Pacific.

Mycorrhiza and the rhizosphere generally have been studied in relation to practical problems.

Here might be mentioned the work on plant viruses at Plant Diseases Division, including some very fundamental probing under R.E.F. Matthews.

Lichens

In Dunedin, there is great interest in this group, cheifly by Wm. Martin and the chemist J. Murray. Unfortunately there has been no N.Z. lichenologist amongst the scientists with the N.Z. Antarctic party at McMurdo Sound.

Bryophytes

Mrs. Hodgson's work on *Hepaticae* continues. An important landmark was the publication in 1955, of Sainsbury's *Handbook of the New Zealand Mosses*, with illustrations by Nancy M. Adams (*Roy. Soc. N.Z. Bull.* 5, 490 pp., 76 pl.).

Pteridophytes

Cytological work on ferns is in hand both at Auckland and Canterbury University Colleges. J.D. Lovis of Leeds spent a year, 1955-1956 here, continuing his investigation of *Asplenium trichomanes* and comparing southern hemisphere forms with those of the north. W.F. Harris' *Manual of the Spores of New Zealand Pteridophytes* appeared in 1955 (*D.S.I.R. Bull.* 116. 186 pp., 10 pl. 4 fig.).

PALYNOLOGY

The appearance of Harris' Manual, of Cranwell's account of pollen of N.Z. monocots in 1953, and of Couper's "Upper Mesozoic and Cainozoic Spores and Pollen Grains" (*N.Z. Geological Survey Paleont. Bull.* 22, 1953, 77 pp. 9 pl.) testify to the interest in this field. The lack of the dicot pollen atlas promised by Cranwell is still acutely felt, but, meanwhile, Harris and Moar continue to publish work on fresh pollen and that in recent deposits. Atmospheric pollen studies seem to have been discontinued meanwhile. Geologists are using plant microfossils increasingly for solving chronological problems which still concern us here. Questions of the very recent history of the vegetation, e.g., in the last 50,000 years, are also much to the fore and C^{14} dating services are rather generously available. At this very important early stage in sketching the outlines of ecological change, there seems to have been less than full appreciation of Faegri's advice that only a trained field botanist will be able to utilise the pollen analysis technique fully, and some very poorly substantiated statements have been used as evidence in papers by geologists and physicists.

TAXONOMY OF FLOWERING PLANTS

Revisions of individual genera continue to appear, but Allan's new Flora, Zotov's account of the grasses of New Zealand, and Healy's manual of the adventive plants in New Zealand are all awaited. Preparation is well ahead at least with the first of these.

A noteworthy event has been the flowering and fruiting in cultivation of *Tecomanthe speciosa*, plants having been established by cuttings from the only known wild plant on Great Island of the Three Kings group.

EXPERIMENTAL TAXONOMY AND CYTOLOGY

Experimental and cytological studies are helping to clear up taxonomic problems in certain groups, e.g., Baylis on *Solanum*, Brownlie on ferns, Connor on *Agropyron*, Brockie on *Epilobium*, Rattenbury on several genera, and Hair on conifers in particular (studies not confined to N.Z. material) and in general on a long-range project of a chromosome atlas of New Zealand plants.

GENETICS

This is mostly on plants of economic importance, e.g., crop plants, pasture grasses, and timber trees. Bannister's study of a progeny of *Pinus radiata* is giving positive results after only six years. Godley is working on dioecy in indigenous plants.

ANATOMY

Lively and varied interest is indicated by these titles from A.N.Z.A.A.S. meeting: "Aspects of leaf development in Dicotyledons," B.F. Slade; "Transformation of vegetative shoot-apex into the Primordium of a flower," W.R. Philipson; "Effect of various treatments on the Anatomy of the stems and roots of apple trees," D.W. McKenzie. A paper by R. Licitis-Lindbergs on branch abscission and disintegration of the female cones of *Agathis australis* Salisb, (*Phytomorphology* **6**, 1956, pp. 151-167) cleared up problems that have long awaited attention.

PLANT PHYSIOLOGY

A most spectacular change in emphasis in botanical research here is the increasing interest in plant physiology. This does not stem at all obviously from leadership in the University, but seems to come from practical requirements in a country where the national economy is based directly on pasture production. This has become, for instance, important in the Dominion Physical Laboratory, an extract from whose current programme reads (D.S.I.R. Annual Report, 1957, p. 48) "measurement of mechanical properties of plants and the investigation of the relationship between these properties and the plant's environment; investigation of the moisture movement through a soil caused by thermal gradients; setting up plant cabinets to provide adjustable controlled environments for growing plants; development of equipment for the measurement of the amount of heat and water vapour carried vertically by atmospheric turbulence; measurement of the transpiration rate of plants under different soil moisture conditions and in different environments; and, investigation of how evaporation over a pasture is influenced by pasture length."

It seems strange that these projects are undertaken by a laboratory which has no trained botanist on its staff. It does, however, work closely with Grasslands Division, which is studying various other aspects of physiology of pasture plants. Basic work on photosynthesis is coming from the Plant Chemistry Laboratory.

Isotopes have been used in various investigations and at A.N.Z.A.A.S., Dr. Cone reported results using N^{15} to support the evidence from cultural studies that nitrogen fixation occurs quite generally in foliage of pioneer shrubs and some weeds and trees.

Walker and his co-workers have demonstrated the importance of added sulphur for optimum plant growth in many areas. Jacques' long-term studies on roots continue, and there is much activity in seed research in relation to pasture plants, forest species, and weed control. An aspect of plant chemistry that has been given some newspaper publicity is a survey of extracts of indigenous plants at Auckland University College for the Cancer Research Project.

ECOLOGY

Descriptive ecological surveys continue to hold an important place. The National Forest Survey, after ten years of intense activity, has reached the stage where a full report on "all essential phases of the volumetric survey of merchantable-quality indigenous forests" is about to be released. The same organisation, within the Forest Service, is now proceeding with three related projects: (1) Ecological survey to lead to regional forest accounts accompanied by mile-to-the-inch forest-type maps; (2) Protection forest survey covering almost a third of the total land area of New Zealand, where the vegetation is non-commercial forest, mostly above 2,000 ft. altitude, and unoccupied shrublands, grasslands, and moorlands that lie above forests; here the prime management objective must be regulation of the water yield; (3) Exotic-forest survey (*F.R.I. Annual Report* 1957, 24).

Out of the Forest Survey arose Holloway's outstanding paper "Forests and Climates in the South Island of New Zealand" (*T.R.S.N.Z.* **82**, 2, 1954, 329-410). This put forward the hypothesis that "the forests, as a whole, are in an unstable condition consequent on comparatively recent changes in regional climates and that, as a result, and active redistribution of species is in progress with resultant development of a wide range of new, though by no means stable, forest types." Evidence is set out to show that the forests of the whole of the South Island are comprehensible in terms of this hypothesis which is shown not to be in conflict with evidence derived through studies of the soils or through study of Polynesian traditions. This paper is obviously one of the highlights of botany in New Zealand in recent years.

Regional or local ecological surveys include several on tussock grasslands (Barker, A.P.; An ecological study of tussock grassland. *D.S.I.R. Bull.* **107**, 1953. Tussock Grassland Research Committee: The high-altitude snow-tussock grassland in the South Island of New Zealand. *N.Z.J. Sci. Tech.* **36**, 1954. Riney, T.A., and Dunbar, G.A.: Criteria for determining Status and Trend of High Country grazing lands in the South Island of New Zealand. Soil Conserv. and Rivers Control Council, 1956. Wardle, P., Mark, A.F.: Vegetation and Climate in the Dunedin District. *T.R.S.N.Z.* **84**, 1956. Miller, F.L. *et. al.*: Shotover River Survey. Otago *Catchment Board Bull.* 1. 1956). In this connection, Gradwell's studies on frost action in high country are relevant. In the North Island, there are accounts of forests of Taranaki and West Taupo, and of a rather different kind, Druce's detailed account of a single catchment of a few acres which is to be reserved for long-term studies of soil formation and change.

The "General Survey of the Soils of North Island" (1954), the publication of a map showing the North Island soil-forming ash showers, and a pamphlet on "Soil Pattern in New Zealand" will all help plant ecologists.

Turning to ecology of seashore, Chapman's "Mangrove and Salt Marsh flats of the Auckland Isthmus" is in the press and intertidal studies include Dellow's comprehensive account of the shores of the Hauraki Gulf and those of G.A. Knox and E.J. Batham in the South Island.

Field work has not been confined to the main island and there have been expeditions to or reports on Auckland, Chatham, Three Kings, Kermadec, and Pitcairn Islands, and New Caledonia. R. Cooper of Auckland Museum was working during the winter of 1956 on taro and kumara in several parts of the Pacific, and it is understood that he has a generous Rockefeller grant for similar work further north.

PESTS AND DISEASES

Members of the Plant Diseases Division produced a manual on "Plant Protection in New Zealand" (704 pp. 477 illustrations, 1956); and in 1954, Chamberlain presented a comprehensive account of plant virus diseases in New Zealand. At Forest Research Institute, a full-time Forest Biology Survey was commenced early in 1956, the overall purpose being "to maintain a continual and systematic inspection of all forests for the presence of newly introduced insects and fungi, and to detect any dangerous increases in the numbers of existing pathogens." Research into the incidence and effects of "noxious animals" especially deer and possums, has been stepped up, but the teams working on the relations of these animals to vegetation are not as strong botanically as could be wished. A spectacular drop in the number of rabbits (without infection with myxomytosis) has coincided with a series of better-than-average seasons, leading to striking vegetation changes in some of the more rabbit-ridden dry districts. These effects too, have been quite inadequately documented owing to the shortage of field botanists.

Manuka blight, a disease of Leptospermum caused by a scale insect, has spread partly by natural dispersal and partly by deliberate transfer, until now, ten years after first being noticed, it occurs throughout New Zealand. Affecting one of the commonest and most widespread of shrub species, it will certainly have direct effects on forest regeneration, though it has been welcomed by farmers whose poorer pastures have always been subject to invasion by manuka.

A most dangerous addition to the weed flora is water hyacinth, which has recently been found to seed freely in many waterways and has already entailed an expensive control programme.

On the other side of the picture, plant quarantine provisions have been much improved with the recent installation of modern methyl bromide fumigation plants at several main ports.

CONSERVATION

At the time of the setting up of the National Parks Authority in 1953, there were five National Parks, variously controlled. To these have been added three more (Mount Cook, 151, 800 acres; Nelson Lakes, 139,833 acres; and Urewera 119,614 acres, and it was enlarged in 1957). Moves are afoot to secure reserves in other places, especially in Chatham Islands and in the country west of Lake Taupo, both regions where active agricultural developments have now been made possible by use of modern machinery and, in the volcanic country, by the use of cobalt to keep stock healthy. In both places, the remnants of highly characteristic vegetation are dwindling rapidly.

REPORT OF THE SUBCOMMITTEE ON BIBLIOGRAPHY

E. H. WALKER

Smithsonian Istitution, Washington, D.C., U.S.A.

The subcommittee members were selected to represent as many countries and branches of botany as possible. When completed the committee represented continental United States, 6; Hawaii, 2; Japan, 1; Free China, 1; New Zealand, 2; Australia, 1; and Holland, 1; a total of 14 members. The majority are taxonomists, but phytogeography, ecology, economic botany, history of botany, and library science are represented.

As there was no previous committee on whose activities a program could be built, the first activity was to circularize the members and a few others for their ideas of the possible aims and activities of the subcommittee. Following is a summary of some of the suggestions submitted. Some members pointed out the need for defining more specifically boundaries of the area to be included, its present limits being a bit indefinite. Severval asked that a survey be made of the areas and fields now covered by bibliographies, their perspectives and adequacy, thus revealing where there are gaps to be filled. In order that such information be made available to users, it was suggested that a regulary appearing bibliographical serial be established. Some pointed out the need for a guide for doing bibliographical work and the establishment of certain standards and procedures. For the benefit of workers without access to adequate libraries, cooperation between individuals and institutions for loans and microfilming, as well as certain bibliographical research were suggested. It was further proposed that editorial assistance and guidance be established to aid authors to prepare their bibliographic manuscript, so they will be of maximum value to researchers and librarians, the principal users of bibliographic tools. Close cooperation with established bibliographic enterprises, notably the Society for the Bibliography of Natural History in England and Biological Abstracts, was suggested. An enlarged new edition of E. D. Merrill's *Bibliography of Pacific Botany* was proposed. Several of these needs would be provided by establishing a bibliographic service at some centrally located institution, closely linked with similar work at other institutions, thus broadening the service. Finally, careful consideration was urged for the adoption of modern new techniques in bibliographic procedures so as to broaden their usefulness and to conserve limited funds.

Two progress reports were issued by the subcommittee, including summaries of these suggestions and reports on various known activities of the members of the committee and other pertinent endeavors. These were mimeographed and distributed by the staff of the Pacific Science Association to the members of the subcommittee and others, especially to the chairmen of the other subcommittees and standing committees, and to certain institutions. The present report constitutes in effect the third report.

It may be well here to report on various projects in this field. The chairman aided Mrs. Ida K. Langman in obtaining a National Science Foundation grant which enabled her to spend nearly a year searching in Mexican libraries for material for her extensive bibliography of Mexican botany. She is now extending her work by similar searches in American libraries. The chairman has rendered some assistance as a member of the editorial board for the vegetational bibliographies being prepared by Jack McCormick at the American Museum of Natural History. He reports little recent progress due to other obligations. It was found that the Subcommittee on Algae is deeply involved in bibliographic work, recognizing that this is fundamental to the development of any field of study, especially in its initial stages. Just how the Subcommittee on Bibliography can aid in the bibliographic work of the other subcommittees remains to be worked out.

For several years Robert Cooper, botanist, and Enid Evans, librarian, both at the Auckland Museum, have been preparing a bibliography of New Zealand botany. Their major problem seems to be finding someone with access to literature on that area who has the time, ability, and resources to run down known-to-exist items not available to them. Thus the establishing of the bibliographic service proposed above seems urgently needed.

Two most important bibliographies have been issued during the existence of this subcommittee. First is the bibliography in volume five of the *Flora Malesiana* prepared by Mrs. Van Steenis-Kruseman. It will be of inestimable value to workers over a wide area. Participation in its subsequent improvement has been solicited by distributing separately bound interleaved reprints to key workers. The second important contribution is *Island Bibliographies* by M.H. Sachet and F. R. Fosberg. This is in effect a cover title for three separate bibliographies, entitled: (1) Annotated Bibliography of Micronesian Botany, (2) Bibliography of Land Ecology and Environment of Coral Atolls, and (3) Selected Bibliography of the Vegetation of the Tropical Pacific Islands. This was duplicated by the National Research Council.

R.T. Hoogland of Canberra, Australia, has revealed that, as opportunity permits in connection with work on his New Guinea collections, he is accumulating material for a botanical bibliography on that great area. Miss Nancy Burbidge, also of Canberra, is accumulating bibliographic material in connection with preparation of a generic list of Australian plants. Edwin H. Bryan of the Bishop Museum maintains several valuable bibliographic files on various subjects in the Pacific and has submitted two papers for the bibliography symposium of the Congress.

The chairman of this subcommittee, in cooperation with F.R. Fosberg and M.H. Sachet, and under grant from UNESCO, has prepared a manuscript supplement to Merrill's *Botanical Bibliography of the Islands of the Pacific*. Dr. Merrill, on retiring from his long and highly productive work on Pacific botany, turned over his materials accumulated for another edition of his well-known Pacific bibliographies to E. H. Walker and F. R. Fosberg. The UNESCO grant was insufficient and other obligations too great to permit the preparation of the supplement that will eventually be needed, but this limited work will go a long way in the eventual preparation of that work. It is in effect a token recognition of Dr. Merrill's legacy to Messrs. Walker and Fosberg.

Work on the needed supplement to the Merrill and Walker *Bibliography of Eastern Asiatic Botany* may begin in the near future, because of as yet informal encouragement by the National Science Foundation and the American Institute of Biological Science. Encouraging promises of full cooperation by Japanese and Chinese botanists were received by the chairman on his recent visit to those countries. The promises are bright that this supplement will better meet the needs of the Oriental botanists than did the original work.

Time prevents reporting here on various projects that may come within a broader definition of bibliographic work. The term is not confined to the preparation of bibliographies, but embraces all work with books. It would scarcely be justified to attempt to enumerate here the botanical works that have been or are being prepared in this area or the library developments that are pertinent to bibliographic work in its widest sense, but such would indeed be very illuminating and profitable.

In June, 1956, the chairman of this subcommittee was asked by the Chairman of the Organizing Committee on Botany of the Ninth Pacific Science Congress to convene a symposium on Bibliographic Problems in Natural History in the Pacific to be held at this Congress. This constitutes the culminating activity of this subcommittee. The objective of this symposium will be to receive the ideas of its participants through a limited number of distributed and delivered papers and through free discussion at both formal and informal gatherings. The results will then be summarized. It is hoped that from the various reports of the Subcommittee on Bibliography and the coming symposium a more concrete program for the development of this work in the Pacific may be formulated and implemented.

DISCUSSION

F.E. EGLER: I would like to draw your attention to a bibliography project now centered at the American Museum of Natural History (New York 29). This project is essentially the responsibility of Dr. Jack McCormick of that institution. It is, or was until recently, entitled *Regional Vegetation Literature*. It is not an all-botany bibliography, but one concerned specifically with vegetation (plant community) publications with special emphasis on identifying the localities at which studies have been made. The area involved at present is North America and South America, and this is part of our specific area. I understand that they are seeking collaborators for different countries. Publication of the first of a new series of publications is already far advanced.

F.R. FOSBERG: The supplements to Merrill's *Bibliography of the Pacific Islands* and to *Island Bibliographies* were aided by a small financial grant by the UNESCO Humid Tropics Committee. No provision was made for their publication, but there is some indication that funds may be available for their publication. I would suggest that this session could appropriately adopt a recommendation that these supplements be published so that they would be of help to others.

M.S. DOTY: The phycology sub-committee has recognized "bibliography" as perhaps the foremost of the barriers to phycological research which might be lowered by efforts of the sub-committee. Thus, after consultation with Dr. Walker, compilation of bibliographies was begun on a form adoptable to his extension of E.D. Merrill's *Bibliography of Pacific Botany*. This material should be considered for inclusion in the present "First supplement . . . " to that publication.

C.G.G.J. VAN STEENIS: Naturally I want to support publication of bibliographies. However, it would be very desirable to have them in printed form, instead of less well surveyable and more bulky mimeograph. Has Dr. Fosberg tried to have them published in the Bernice Bishop Museum Bulletins or *Philippine Journal of Science* which have a wide circulation in the Pacific area?

REPORT OF THE SUBCOMMITTEE ON ALGAE

M. S. DOTY

University of Hawaii, Honolulu, Hawaii.

Two mimeographed circulars were prepared and sent to members of the subcommittee. These evoked considerable interest and demand. We suggest the practice be continued, but duplication and distribution should be done by the Pacific Science Association Secretariat in Honolulu.

Participation in bibliographic matters was begun. This was after conferences and correspondence with the Bibliography Subcommittee Chairman and with a local group assembled in Honolulu to make a report to that subcommittee. In conformation with the style used by E.H. Walker of that subcommittee, bibliographic materials have begun to be assembled in Honolulu regarding algae in the Pacific. It is planned that this information will be made available to anyone at cost or, eventually, be duplicated. We do not anticipate duplicating the various efforts to publish bibliographic materials but, rather, assist in their extension and help make them available to prospective users.

The major phycological problems have been sought by correspondence with the subcommittee members and enumerated in the mimeographed information bulletins distributed to the subcommittee. These suggestions were to promote floristic studies, develop bibliographic sources, facilitate exchange of ideas and materials, and encourage functional studies of the algae.

It is further suggested the Standing Committee on Botany of the Pacific pass a resolution strongly favoring adherence to the International Botanical Code of Nomenclature and in particular to those pre-eminent principles the type method and priority.

REPORT OF THE SUBCOMMITTEE ON COMMON NAMES OF PACIFIC PLANTS

MONA LISA STEINER

Pasay City, Philippines.

INTRODUCTION

The complex problem of common names of plants, their variability, recording, and stability in some respects, was brought before a session of the Eighth Pacific Science Congress. Although standardization was undertaken successfully in some regions, it was pointed out that standardization of common names of plants in the Pacific Basin is not feasible, because too many language groups are encountered in this part of the world. It was consequently agreed that a subcommittee on Common Names of Economic Plants be established, which would work towards the compilation of a list of common names of plants in active use in the Pacific Basin together with their botanical equivalent, to be listed in form of a dictionary.

As such a vast task can not be accomplished *uno actu*, the project was divided into the following groups: foodplants, forest trees, weeds and forage plants, and ornamentals. For the Ninth Pacific Science Congress, only foodplants were worked on.

A list of basic foodplants, based on Philippine material, was prepared and sent to botanists interested in vernacular names and familiar with certain regions in the Pacific. Only generally used foodplants were included, not famine foodplants or those of local occurrence. Varieties and hybrids were generally not listed, also not all names of products, as those of the coconut, for instance, could fill a book.

In the beginning only tropical plants were included, but later on it was apparent that even in the tropical Philippines many temperate zone foodplants are being cultivated and that a separation was impractical. In the first attempt, China, Japan, and other countries not directly bordering the Pacific, such as Thailand, were not included; but as the compilation progressed, it became evident that such additions might prove very useful, as few references are available in Roman script in those languages.

MEMBERS OF THE COMMITTEE

Miss Marie Neal Bishop Museum, Honolulu 17, Hawaii.	Polynesia.
Mr. B.E.V. Parham Department of Agriculture, Suva, Fiji.	Fiji.
Mr. R.E. Dwyer Director of Agriculture, Papua, Port Moresby.	Papua.
Dr. F. Raymond Fosberg c/o National Research Council, Washington, U.S.A.	Micronesia.
Dr. Shiu-ying Hu Arnold Arboretum, Jamaica Plain, Mass., U.S.A. (since 1957).	China.
Mr. H. Ando Hiroshima University, Sendamachi, Japan (since 1957).	Japan.
Mr. Faustino Miranda Instituto de Bilogia, Casa del Lago, Chapultepec.	Mexico.
Miss N. Burbidge Canberra, Division of Plant Industry, Australia.	North Australia.

Mr. H. Keith — (North) Borneo.
has resigned on account of transfer.

Mr. Jacques Barrau — Melanesia.
Laboratoire d'Agronomie Tropicale, Marseille, France.

Ida Langmann — West Coast of North America.
Academy of Science,
Philadelphia, U.S.A.

Dr. Mona Lisa Steiner — Philippines.
2833 Park Avenue, Pasay City, Philippines, chairman.

ACCOMPLISHMENTS

As many references as possible were scanned in Manila for vernacular names of foodplants in the Pacific Basin and combined with published and unpublished lists of vernacular names sent by members of the committee and others as listed in the bibliography. Sincere gratitude is herewith expressed here for all the valuable cooperation.

The Pacific Basin was then divided into various regions, such as Micronesia, Polynesia, Malanesia, and the locality or region in which a common name is being used is then indicated. Sometimes numerous languages are encountered within one region, yet frequently one name is of more general usage, while others are of local occurrence only. In the Philippines, for instance, one language of about 80 has been selected as the National Language, namely Tagalog, and this language can be understood all over the country. The various common names of a region have been compiled, but the more generally used name has been underlined. In addition to the various Malayan, Polynesian languages, etc., the common names of foodplants in Chinese, Dutch, English, French, German, Japanese, and Spanish were added.

Although the chairman is well aware that such a compilation can never be complete, an attempt has been made to compile all the gathered information in the form of book. With the valuable assistance of the National Research Council in the Philippines and the aid of Dr. Patrocino Valenzuela 200 copies of *A PRELIMINARY COMPILATION OF VERNACULAR NAMES OF FOODPLANTS IN THE PACIFIC* (195 pages) were mimeographed in February, 1957, and sent to all members of the committee and institutions that might aid in this undertaking. Members of the committee have then been asked to check the vernacular names given, fill in gaps, also to underline the most generally used name in a certain region. The preliminary compilation thus checked and filled in was to be returned to the chairman before the Ninth Pacific Science Congress.

Since the compilation was sent out, much new material was gathered by the chairman who went on six months leave in Europe. Particularly, the common names in the major languages were filled in. Among those who returned a checked copy was Mr. H. Ando, Hiroshima University who added more Japanese names. Dr. Shiu-Ying Hu, Arnold Arboretum, is preparing Chinese equivalents. Other new additions, too, are waiting to be included. After the various additions and revisions are made and incorporated, it is hoped that the first volume of the compilation will come out in print.

SUGGESTIONS

1. The arrangement of compiling plants alphabetically within families was more practical for the compiler, but should not be followed in the final work. The scientific names are to be arranged alphabetically.

2. No personal acknowledgements have been made in the preliminary report, but all used references, printed and unpublished, were included in the bibliography. The final dictionary, however, should have special acknowledgements.

3. So far no cross index has been made, but as soon as all the new information has been gathered, a cross index should be prepared.

4. A taxonomist of standing should check the validity of the used scientific names and their synonyms.

5. Other workers should be appointed to work on forest trees and medicinal plants while the work on foodplants is to be completed.

6. A fund should be made available for the printing of the revised and enlarged compilation of common names of foodplants. It should also be distributed through the Pacific Science Association.

REPORT OF THE SUBCOMMITTEE ON ETHNOBOTANY

T. P. BANK II

Institute for Regional Exploration, University Station, Ann Arbor, Michigan, U.S.A.

The Subcommittee on Ethnobotany of the Standing Committee on Pacific Botany was organized in 1954-55 and is composed of twenty-five members.

The Chairman has circulated a request for information about significant ethnobotanical studies currently underway in various parts of the Pacific area. Replies have been slow, but those that have been received form the basis of the following report.

SOUTH PACIFIC

Dr. Toichi Mabuchi of Tokyo reports that the Japanese Society of Ethnology plans to begin a field study soon on rice agriculture in Southeast Asia, notably in Thailand and Cambodia, which will require three years. He is continuing his own studies of aboriginal tribes of central Formosa and has investigated the correlations between social organization and agriculture. Mr. Kokichi Segawa, who is now in Brazil for the Japanese Government, has been collaborating with Gordon Bowles in the compilation of *An Illustrated Ethnography of the Formosan Aborigines, Vol. I: The Yami* by Segawa and Kano, and this work includes ethnobotanical illustrations and descriptions.

Thor Heyerdahl has continued his field work in the Pacific searching for new evidence for diffusion. Dr. George F. Carter suggests that the discussions at Bangkok "might well include some review of this ... with a call for further re-examination of the botanical evidence for diffusion."

Carter urges that botanists and anthropologists collaborate to "get that ethnobotanical dictionary moving, and to include in it meanings or names, whenever possible, and to put in the plant usages, and most especially ritual usages."

Dr. Jonathan L. Hartwell, Laboratory of Chemical Pharmacology at the U.S. National Institutes of Health, is collaborating with various colleagues in an extensive survey of the literature, both from America and abroad, and folklore, pertaining to medicinal plant uses. The purpose is primarily pharmacological—to open up leads for experimental work on the isolation of active substances from plants. He is especially interested in plants used for the treatment of cancers, tumors, warts, and corns, and he requests that botanists and anthropologists who are similarly interested communicate with him for an exchange of information.

Dr. Harold St. John, who is a subcommittee member, will not be at Bangkok but will submit papers to two sections, on taxonomy and vernacular names. He is currently in the field for three months studying *Pandanus* in Netherlands New Guinea, Australian New Guinea, Papua, and Queensland. From this and his other extensive work with *Pandanus* will undoubtedly come future ethnobotanical reports.

Dr. Robert Ornduff writes from Berkeley that his current sphere of activity is non-ethnobotanical, that he is doing biosystematic work with *Senecio* species from New Zealand, as well as with Californian Composite genera and the genus *Senecio* in the western United States. He is also collaborating with anthropologists at Reed College in a project on the Warm Springs Indian Reservation in Oregon.

Jacques Barrau has prepared a paper on "Notes on the significance of some vernacular names of food plants in the South Pacific Islands" which is of considerable interest to ethnobotanists.

R.D. Hoogland writes from Australia that "Botanists in Australia have paid very little attention to ethnobotany. Apart from the enormous amount of work still needed in local taxonomy and the pressure on economic aspects, this can probably partly be accounted for by the small aboriginal population and the seemingly little use made of the native flora."

"The latter seems to be the case also in New Guinea. In comparison with the islands of Indonesia, where the native flora is extensively used in medicine, very little use is made by the New Guinea natives of their vast resources in this field. During my collecting trips in New Guinea, I have tried to collect material of native drugs for chemical testing and found it very difficult to get any at all. Others have noticed the same, e.g., D'Alberts (1880); Professor Baas Becking tells me that he has the impression that this applies to the whole of Melanesia."

Anthropologists have been working in various areas in New Guinea and have assembled various ethnobotanical data, none of which, however, has been published in recent years. These data apply in particular to food-plants, both cultivated and collected in the forest. Others have been working in Sumatra and Borneo (from Australia—ed.)."

Robert Suggs is currently doing archaeological work in the Marquesas. Previously he indicated to Professor Bartlett that he would try to collect as much ethnobotanical information as he could and would seek native names for the plant specimens he hoped to bring back.

George Carter adds a further note to the effect that Heyerdahl's Galapagos expedition "demonstrated that the Peruvians had sailed to those islands and used them as fishing stations for hundreds of years. Since this was presumably done with balsas, it strengthens his case that the Peruvians were fully capable of sailing into the the Pacific and returning... (linguistic similarities in Polynesia and South America) the total culture picture suggests extremely long continued contacts, with some of the later ones coming *from* America."

Jonathan Sauer writes from the University of Wisconsin that he is continuing his work with grain amaranths, and with Sasuke Nakao has published further data and interpretations of Asiatic grain amaranths, crops domesticated by the American Indians and introduced to Asia by unknown means (*Land and Crops of the Nepal Himalaya*, ed. H. Kihara, pp. 141-146. Kyoto, 1956).

Dr. Sauer is also continuing to grow specimens of pot-herb amaranths collected in seed from various parts of Southeastern Asia, preparatory to systematic study, and he reports that he is currently engaged in a monographic study of all species of *Canavalia* (sord-bean and jack-bean) from all parts of the world, with special emphasis on the aboriginal cultivated varieties. He invites workers to send him specimens of *Amaranthus* or *Canavalia* and promises to identify them and give a report to the collectors.

Dr. Tom Harrisson indicates that he has collected considerable information on the ethno-ecological aspects of primitive agriculture in Borneo and that he is willing to exchange information. He is reporting on ethnobiological lore in Borneo at the Congress.

Harold C. Conklin is currently in the Philippines to study tropical forest agriculture and will present a number of papers at the Bangkok meetings.

Professor Bartlett, now an emeritus professor at Michigan, is principally engaged in compiling a gigantic annotated bibliography on the subject *Fire in Relation to Primitive Agriculture and Grazing in the Tropics*. Volume 1 has already been distributed and is about out of print; volume 2 is out and ready for distribution (A-G, Tropics in general; H-J, South Asia and Oceania—a total of 873 pages); and he has enough material already gathered for a third volume of equal proportions. He is also actively advising ethnobotanists, archaeologists, and botanists who are in the field or about to take to the field as to what problems still need to be attacked. He writes that "sweet potatoes introduced into the Orient by the Spanish should be compared in every way, cytologically, chromatographically, and otherwise, with those that spread into Polynesia from New Zealand." He is especially interested in the possibilities of tracing sweet potato migrations by means of chromatography. He also wants someone to study native gardening carefully all along the Southeast Asia coast.

As an appendix, a brief report is attached covering studies on *Manihot esculenta* by Dr. David Rogers who is continuing this work at the New York Botanical Garden, in addition to editing *Economic Botany*.

NORTH PACIFIC

In Hokkaido, Japan, Dr. Robert Austerlitz has been working for several seasons with Gilyak and Ainu informants. His project is primarily a linguistic study, but he has developed an active interest in ethnobotany and has compiled a large annotated list of plants used for foods, medicines, poisons, and handicrafts. His specimens and field identifications have been checked by Dr. M. Tatewaki of the Botanical Institute at the Hokkaido University.

T.P. Bank II is continuing studies of Aleut and Pacific Eskimo plant lore. Recently he spent a year in Hokkaido to compare this material with what is known about Ainu plant uses. He is especially interested in Eskimo-Aleut migrations, Aleut medical knowledge, and the question of cultural diffusion across the North Pacific.

Bank is commencing an ethnobotanical and toxicological study of aconite poison whaling in the North Pacific, in collaboration with workers at Hokkaido University. Part of the study will include an evaluation of the variation of toxicity in various races of *Aconitum* and the significance of this to anthropological questions pertaining to the use of aconite poison by primitives in the North Pacific region.

Archaeological studies by Bank and others at Michigan have also utilized ethnobotanical methods for determining chronology of cultural events in the Aleutians. Radiocarbon dating of archaeological deposits and pollen analysis have indicated that the Aleuts arrived in the Aleutians at least 3,500 years ago at a time when the climate may have been appreciably colder. Preliminary results of pollen studies show that the beginning of amelioration of climate toward the onset of the thermal maximum in the Aleutians may have occurred between 4,900 and 4,000 years ago.

Others are doing botanical and ecological work in the Aleutian area, including Robert Kindschy, Jr. at the University of Idaho, who collected ethnobotanical data among the Nikolskian Aleuts in 1957.

No reports have been received from ethnobotanists at the University of Washington, but presumably studies are being continued among the Indians of that region and in southeastern Alaska.

APPENDIX

SUMMARY OF STUDIES ON *MANIHOT ESCULENTA*

DAVID ROGERS

New York Botanical Garden, New York, U.S.A.

PURPOSE

1. To provide a convenient classification of the cultivars of *Manihot esculenta.*

2. To demonstrate relationships among the varieties.

PROCEDURE

1. Assemble cultivars in museum plots for ready study of the varieties.

2. Classify, using morphological characteristics, in a framework of taxonomic categories.

DISCUSSION

Jamaican and Central American cultivars represent the range of material so far studied. In Jamaica, a collection of 107 named varieties were brought together from all parts of the island at Bodles Experimental Farms. After considerable study, forty-five cultivars were recognized. In Costa Rica, at the Inter-American Institute of Agricultural Sciences at Turrialba, Dr. Jorge Leon had collected the locally occurring cultivars. To this collection were added variants from other Central American countries, Cuba, a few from the East Indies, and several from Brazil. In this collection about twenty-five cultivars are found to be distinct.

The cultivars from both areas fit into a framework of sub-specific categories of two convariants (equivalent to subspecies) and several sub-convariants (comparable to series).

The classic divisions of *Manihot esculenta* (sweet vs. bitter) have been set aside in this work. No morphological categories are coordinate with such a division.

Work is in progress to publish a key to the cultivars studied, and proposals for continuation of the studies in South America are being made.

SUPPLEMENT TO THE REPORT OF THE SUBCOMMITTEE ON ETHNOBOTANY

RECOMMENDATIONS

The distinctions between ethnobotany on the one hand and economic botany on the other are not always clear. This has been brought out during the present Congress, where papers representing both points of view are presented in a symposium on the ethnobotany of Thailand and contiguous countries. Indeed, ethnobotanical reports are distributed throughout various sessions dealing with a number of diverse disciplines, including anthropology, botany, linguistics, conservation, and agriculture. This is not a deadly sin, but it does make for a lack of coordination and a scattering of thoughts and conclusions, when perhaps the true function of the study of ethnobotany is to bring them together.

Ethnobotany should deal with verbal traditions only, except for those traditions which have recently found their way into the literature, whereas economic botany is more concerned with the modern concepts of the science of plants and of their uses. The word "primitive" has various connotations among different people, but perhaps it is still our best key to the content of ethnobotanical study. Ethnobotany is the study of the interrelations of *primitive* man and plants, in the sense that *primitive* denotes a lack of any written language and therefore the preservation of traditions by verbal means only.

Chemical analysis of useful plants is not usually considered a part of ethnobotanical work, but the study of plant debris in archaeological deposits, studies of plant patterns in the vicinity of old village sites, pollen analysis, and radiocarbon dating are all related to our main objectives in the study of ethnobotany.

With this rather brief definition of the content of our study, the following specific recommendations are made in the hope that they will stimulate a more thorough consideration of how ethnobotanical research can contribute most to the solution of problems in the various disciplines of which ethnobotany is a part.

1. A summary of our state of knowledge of Southeast Asian ethnobotany is clearly needed. It is important that we should not leave ethnobotany in its present unorganized state of dispersed data throughout monographs which are actually in content anthropological, botanical, geographical, linguistical, or agricultural. For example, a great deal of plant lore is included in folklore and written literature of Southeast Asia but was nevertheless not put there for the purpose of transmitting the oral traditions pertaining to plants; it includes scattered references to plant uses compiled by casual travelers, biologists, linguists, and others. Often, this material is not the sort that is recovered by Occidental scholars but, if found, is more likely to be assembled by native scholars. One objective of Thai ethnobotanists might reasonably be to round out a regional monograph on ethnobotany that would stress man's relationship (traditional) to the environment through trial and error.

2. A matter that is frequently neglected in making dictionaries is adequate attention to primitive gardening and agriculture. Although there are dictionaries of primitive tribes which have valuable ethnographic content, there are many languages that have no records of plant names, implements used in gardening, and so forth. A comparative study of gardening in Eastern Asia has not been made, but such a monograph would be extremely useful.

3. Because of its inter-disciplinary nature, ethnobotanical study is frequently pursued by persons with a variety of training, with a result that many different field methods are employed, and the data are not presented in any uniform manner. The effective worker should be enough of a botanist to make careful and systematic collections for identification of the plants and precise meaning of the words. Nothing is more frequently commented upon by botanists than that the materials collected for identification by non-botanists are too often hopelessly inadequate. Every contributor to ethnobotany, whether he be a linguist, anthropologist, or geographer, should become enough of a botanist to discriminate critically between related plants and to have at least as discerning an eye as one who is frequently referred to—somewhat condescendingly—as a *tribesman*. The ethnobotanical worker cannot always be a linguist, but he should equip himself with at least the basic knowledge of approved linguistic field recording techniques and train himself to distinguish at least the major sound units of the language with which he is working. He should of course attempt to fit his botanical data into a cultural context, which presupposes at least a basic knowledge of the culture he is

entering and a strong curiosity about the part which plants play in this culture.

4. International cooperation is indispensable. Authorities are not numerous for most plant groups; linguistic information for many tribes is scarce. The field worker is faced with the discouraging task of either identifying everything himself with the help of plant keys, which are hard to find, or else seeking out the appropriate specialists and requesting their cooperation. It would be of inestimable service to field workers if rosters of specialists could be compiled for each major region in the Pacific Basin and for Southeast Asia. This is a service that could be performed by the ethnobotanists themselves.

5. The program in ethnobotany of the Pacific Science Congress might best be used as a basis for indicating what might be done by scholars in Siam and elsewhere, who themselves may not have an adequate means of securing identifications of all materials but who because of their linguistic abilities with vernacular names are in a strategic position to cooperate with international agencies. As a step in this direction, a list of suggested research, compiled by Professor H.H. Bartlett (U.S.A.), is appended.

6. One phase of ethnobotanical endeavor that has received but little attention in Southeast Asia is the securing of chronological correlations with plant materials preserved at or near archaeological sites. Although pollen analysis might not be feasable in some parts of the tropics, because of poor preservation of the pollen, it nevertheless should be attempted. Dendrochronology may also prove practical in some areas. Ethnobotanists should be encouraged to work with the identification of plant materials from archaeological sites and seek comparative ethnographic correlations for their material. They can and should contribute to the rapidly growing collections of plant materials for radiocarbon dating of cultural and biological events, and especially they could be of service in insuring that the proper precautions are taken during collection of the materials so that contamination from biological sources is avoided.

APPENDIX

A List of Suggested Ethnobotanical Research for Southeast Asia Compiled by Professor H.H. Bartlett, University of Michigan, Ann Arbor, Michigan, U.S.A.

1. Listing of plants mentioned in old Siamese vernacular literature, with notes on identity, utility, ceremonial importance, etc.

2. Listing of plants mentioned in old Siamese translations of Indic Buddhist literature, etc., with parallel listing of Siamese and Indic (Sanskrit, Pali, Prakrit) plant names.

3. Notes applying to *specific* geographic *localities* on the utilization by the Siamese of local plants of all sorts.

4. Descriptions, for specific localities, of ancient traditional Siamese horticulture, village gardening, industrial preparation, marketing and utilization of plant products, especially indigo and other dye plants, palm sugar, starch, glue, tannin, etc.

5. Descriptions, with local names, and utilization of the cultivated or wild varieties of any of the following: bamboo, rattan, upland rice, yam, other root crops, coconut, pot herbs ("greens"), spices, narcotic plants (for example, betel nut palm; betel pepper), fruit trees, etc.

6. Materials or house-building botanical source, geographic origin, mode of transportation, etc.

7. Plants traditionally used in medicine, and the lore concerning them.

8. History of the ancient pharmacopoeia.

9. Plant poisons and the lore concerning them, with reference to vernacular literature. (Control of insect pests, rodents, rice birds, predatory animals, etc.)

10. Descriptions of primitive agriculture of any localized ethnic or linguistic minority groups, and of their village gardening, with notes on specific plants, vernacular names, utilization, etc.

11. Description of sacred trees and groves, and botanical identification of the species concerned.

12. Ceremonial uses of plants. Use of plants in religious rituals.

13. Traditional ornamental gardening in specific localities.

14. Materials used in basketry.

15. Textile plants; history, traditional utilization.

16. Utilization of seaweeds for food or other purposes.

17. The plant lore of weeds and wild plants.

18. Effect of population impact on remaining forest areas in Siam; extent of man-made grasslands; utilization of same for grazing, etc.

19. History and method of use of *lontar* palm leaves as writing material in Thailand, illustrated by *lontar* manuscripts.

20. Ancient methods of making indigo (and other dyes) with information on the plants used.

21. The geography, mode of growth, harvesting, and utilization of floating rice in deep flood-waters of Siam.

22. The sources and preparation of spices and perfume used by local tribes.

23. The varieties, cultivation and utilization of Pandanus in Thailand.

24. The process of manufacturing sugar from the sugar palm (or other source).

25. The enrichment of abandoned dry rice lands with useful woody plants by aboriginal tribes.

26. The useful plants of the Semang (or other people) of Thailand.

27. Sacred forests in Thailand.

28. Sacred trees in Thailand.

29. The use of fungi as food in Thailand.

30. Food plants of the silkworm in Thailand.

31. The identification and use of fish-poisoning plants in Thailand.

32. Native systems of classifying plants.

33. Plants used as sources of drinking water.

34. Plants producing gums, resin, and rubber, and methods of utilization of the products.

35. Primitive methods of making fermented drinks.

36. Plants used as emergency and famine foods.

37. Village horticulture.

38. Plants used for thatch.

REPORT OF THE SUBCOMMITTEE ON PACIFIC PLANT AREAS

Compiled from letter by H.J. Lam of Rijksherbarium, Leiden, Netherlands.

Since the last Pacific Science Congress in 1953, the chairman of the subcommittee has been unable to devote a significant amount of time to the project of preparation of distribution maps which was the task of this subcommittee.

The Philippine Journal of Science has offered to publish the maps and accompanying text, if it were carried to a point where this is indicated. The main problem outstanding seems to be that of securing funds to employ a competent botanist to do the actual work of compiling the maps. Prof. Dr. S. Bloembergen, formerly of Java, is known to be available for this task, if funds, to the extent of $1,000 per year for half time, or $3,500 per year full time, can be made available.

Office space and facilities in the Rijksherbarium, as well as the close cooperation of Dr. Lam, will be made available.

It is urged that efforts be made to find the necessary funds to carry this project forward.

REPORT OF THE SUBCOMMITTEE ON NATURE PROTECTION

C. SKOTTSBERG

Gothenberg, Sweden.

During the Seventh Pacific Congress, Auckland, N.Z., 1949, I resigned as Secretary to the "Standing Committee for the Protection of Nature in and around the Pacific" and was succeeded by Dr. F.R. Fosberg. During the Eighth Congress, Manila, 1953, the Standing Committee for Pacific Botany was organized with Dr. Fosberg as Chairman and Mr. Kasin Suvatabundhu as Secretary, while I was to take charge of a Subcommittee on Nature Protection. Of the former local representatives few could be counted on any longer so that new members had to be found.

JAPAN

As was pointed out on former occasions, the Imperial Japanese Government has long been actively protecting the natural resources of Japan, and there has been no reason for the Pacific Congresses to make recommendations. Through the Japan Nature Protection Society, the general public is engaged in the movement, and among the directors and trustees are many representatives of cooperative bodies such as the National Parks Association, the Ornithological Society, the Forestry Association, Landscape Society, Alpine Club, etc.

PHILIPPINE ISLANDS

(DR. QUISUMBING in letter to PROF. VAN STEENIS, Dec. 10, 1954).

"There are three categories that could be included in the matter of conservation, areas or localities, rare species and interesting species. The matter... is really a very serious one.... One of the greatest difficulties that we are encountering in the Philippines is the matter of kaingin (shifting agriculture) and also the vast cutting for the lumber industry. Many of the areas... cut for timber have been declared agricultural lands, to place people from congested areas.... Doubtless in this project many species are liable to be destroyed and perhaps disappear for good. A national committee has been appointed by the President of the Republic to reserve certain forests... and we have many reservations now. The difficulty ... is that cutting for kaingin purposes continues and it is very difficult to police these areas for lack of forest guards and on account of the fact that these people in the remote barrios need a place where they can expand and cultivate crops even temporarily."

Conservation of areas. "In Mindanao we have a sizeable area covered by *Lansium domesticum*. The Japanese had killed some of these trees during the occupation and some of the natives in that particular area went as far as killing trees to collect the fruits.... I have indicated to our authorities that the area should be preserved. In another area in the province of Zambales, *Vanda Lamellata* var. *boxalli* is very common on trees. I have seen this place before devastation...with the trees covered by this orchid in flower. As most of these areas are private lands we find difficulties in having them preserved. Even if the government would expropriate the land, it is difficult to control the vandals; the orchids are collected in bud and brought to Manila by peddlers. There is also a project now of conserving strips of forests in the central portion of the island of Leyte.

I am going to submit a list of plant species included in the law for conservation, but as my files have been destroyed I shall look into the original law to get the names. One is *Lilium philippinense*, which was very common in the grassy area in the pine belt of mountain Province. In early days it was indeed a sight to see this lily when in bloom. The Igorots have been gathering plants and brought to Baguio for sale. ...Another species in the list for conservation is *Phoenix hanceana* var. *philippinensis* which is found only on the island of Pabtan. The main species is reported from Southeastern China, Thailand, and Formosa."

INDOMALAYA

(according to letters to PROF. VAN STEENIS).

Malaya. J. Wyatt-Smith, Forest Botanist, Kepong. Oct. 11, 1954.

"The position as I see it is that it is impossible with the present botanical knowledge of this region to consider reservation for the preservation of isolated species or endemics except in very special circumstances. Future collections, exploration and taxonomic studies may well reveal the occurrence in abundance of a hitherto "rare" species and endemics may no longer be endemics through being found in other countries or by being reduced in taxonomic studies. Further, if I am not committing botanical heresy, is it so vital to preserve isolated endemic species in a genus unless there is something very special about them which is of interest phylogenetically? Endemic genera and single representatives in a country or outliers of a genus by all means."

"I am wholeheartedly in support of preserving large areas of all forest types throughout the country, and thereby preserving complete associations together with the rest of the plants and animals, etc., making up the synusia. With this in mind several Jungle Reserves have already been constituted in Malaya and many more are under discussion (see *Malayan Forester*, Vol. XIII, 1950, pp. 92-94, and Malayan Annual Reports), and steps are also being taken to preserve certain areas such as Jugra Hill which is the only place in the Federation where *Shorea gratissima* is found."

"As regards preservation of 'existing isolated rare' species..., the Malayan Nature Society is a fairly influential body and preservation and conservation has already come under discussion. I am Secretary of the Selangor branch and closely connected with the main committee... so I am in some sort of position to push anything you consider desirable in this connection."

Singapore Island. J.W. Purseglove, Director, Botanic Gardens, Singapore.

"I am in complete agreement that everything possible should be done to preserve plant species which are in danger of extinction and I will do all I can to help in this matter. The total area of Nature Reserves in Singapore is approximately 8,500 acres controlled by a Nature Reserve Board of Management of which I am ex-officio Chairman. The area reserved is a noteworthy achievement of a small colony of some 224 sq. miles with a population of over 1 million. I doubt if we can hope for any further reservation on this island."

Further information on Singapore Island is given in a circular "Nature conservation on Singapore Island and in particular the threat to the Pandan Nature Reserve", signed by H. Burkill, Chairman, Nature Reserve Board, Botanic Gardens, Singapore, 1957. The circular gives the history of the forest reserves, which are characterized as follows.

"Each of Singapore's Reserves, besides the general purposes of recreation and education, was created for a particular biological reason. Rare plants exist in all of them. Bukit Timah is the classical collecting area for a very large proportion of Malaya's flora. It is the type locality for probably more species of plants than any other area of comparable size in the world. It is the only remaining piece of primary lowland forest on Singapore Island. Kranje typifies the transition from muddy fore-shore to a dry land vegetation, whereas Pandan is typical tidal mangrove. These two form a series in the land-building character of mangrove vegetation. With the total exploitation of other mangrove areas in South Johore, Pandan is the last remaining piece of typical mangrove. It is moreover the most southerly of continental Asia. Labrador conserves a primitive species of fern, *Dipteris conjugata*, which is found elsewhere in Malaya only above 3,000 ft. altitude. Pandan is the type locality for many marine animals and all the Reserves and the Water Catchment Area are sanctuaries for wild animals."

Of great general interest is Mr. Burkill's answer to the proposals to utilize Pandan:

"Proposals have been made to clear the whole of the Pandan Reserve for the establishment of prawn ponds. This is the second attempt to remove control of the area from the Nature Reserves Board for commercial exploitation, the previous one in 1956 being successfully resisted. It is not the purpose of these notes to set out the arguments for these proposals. Suffice it to say that the Nature Reserves Board is unwilling to cede the area since it is a legally constituted body with a duty to perform."

The following general remarks regarding Malaya may also be quoted from Mr. Purseglove's letter to Dr. van Steenis (see above).

"With the present state of collecting within the Malaysian region, are we justified in assuming that a plant is in danger of extinction because it has only been found in one small area? Until much more collecting has been done and the flora and its distribution known more fully than at present, the possibility of rare and interesting species or species at present only recorded from one small locality turning up in an area at present little collected would seem to be considerable. I think that the most we can do at the moment is to list those species which reputable botanists consider in danger of extinction and do what we can to preserve them, the method of preservation being dependent upon local conditions."

"Unless a sufficiently large area is preserved ecological conditions will be altered which might result in the loss of species. In secondary communities reservation may result in a change in vegetation with resulting loss, especially when a plant may depend for its continuance on biotic factors. It would be difficult to look after a large number of small areas and see that they are adequately patrolled, even if money and staff are available. Making a small reserve without adequate patrol and advertising the presence of the species might lead to its more rapid extinction. The possibility of preserving the plant in cultivation might be considered."

INDONESIA

In addition to the late Dr. K.W. Dammerman's beautifully illustrated work, "Preservation of Wild Life and Nature Reserves in the Netherlands-Indies," published for the Fourth Pacific Science Congress in 1929, comprehensive reports appear in the Proceedings of the Fifth Congress, Vol I, 1933, but after that no further report was received until 1949, when a few remarks by Dr. A. Hoogerwerf were included in the Proceedings, Vol. IV, 1953, referring to the work done by the Netherlands Indies Association for Nature Protection which issued annual reports.

It would have been of particular interest to obtain official statements as to what happened during the Japanese occupation and the following insurrection which ultimately led to the establishment of the Republic of Indonesia. It is, however, good to learn from a letter to Dr. van Steenis, written Oct. 25, 1954 by the Director of Kebun Raya Indonesia (formerly Buitenzorg Botanical Garden), Prof. I. Kusnoto, that the efforts made by his predecessors to convince the government of the necessity of plant protection by law will be renewed, and that everything will be done in order to intensify plant conservation. A restriction on the export of rare species, among them orchids, is planned, as well as the protection of the localities for rare species, by setting aside such areas as reserves. For detailed information the departmental Head of the Herb. Bogoriense and the Chief of the Botany Division of the Forest Research Station should be approached.

Sumatra. Dr. W. Meijer recently published a paper on "Natuurbescherming in Midden-Sumatra" (Natuur en Landschap 101, 1956), containing an interesting reconnaissance of protected natural monuments such as Harankloof, a lowland virgin forest at Pantji conserved since 1930 and locality for *Rafflesia Arnoldi*, Aneikloof, type locality for *Amorphophallus titanum*, etc. The forest reserve on Mount Sago, 2,000 meters, is now being investigated scientifically. An area of 10 hectares, 1,000 m. above sea level, included 150 different kinds of trees, almost equalling Tjibodas on Java in richness. Nature conservation in Sumatra is an enormous task, but wholeheartedly supported by the Governor and the Director of the Forest Service. The immensely interesting extinct volcano Mt. Singgalang has recently been proposed as a forest reserve.

BRITISH NORTH BORNEO

(The late G.H.S. WOOD, Forest Botanist, in letter to DR. VAN STEENIS, Oct. 5, 1954).

"Regarding the preservation of species and ecological types I am following Malayan practice. This is primarily the making within forest reserves of virgin jungle reserves of 50 to 100 acres which will not be interfered with in any way. Constituted forest reserves at present occupy only 3% of the total land area of North Borneo, but it is anticipated that large areas now being worked as concessions will become forest reserves. No jungle reserves have so far been made but it is expected that creation of such reserves will be made obligatory on concession areas and constituted reserves. The object is to keep samples of ecological and physiognomic types rather than particular species undisturbed."

"Forest reserves are also being made in forest stands which are not necessarily economic (or forseeably so); hence numerous species are being preserved intentionally or not. An example of this kind is Tabawan Island in Darvel Bay, which I recently visited with Mr. Wyatt-Smith. This island supports a peculiar forest type dominated by *Casuarina sumatrana*, *Calophyllum* spp. and an unidentified tree, known locally as bangkan; only three scarce Dipterocarpaceae are recorded so far."

"You will appreciate that in general forests on the flat land of the east coast of North Borneo are undisturbed and offer considerable scope for retention as forest reserves containing selected virgin jungle reserves. On the west coast, both flat land and mountainous slopes up to 3,500 ft. have suffered severely from either permanent or shifting cultivation. Undoubtedly some species have already become extinct and more will follow, and little can be done to protect individual species. But priority is given to the formation of forest reserves on the west coast before the remaining virgin stands, particularly at low altitudes, are destroyed; hence the great majority of species will survive apart from those which are very local."

"It is expected that it will be easy to reserve areas over 3,500 ft. on mountains on the west coast. A Land Utilization Committee is planned for North Borneo and I shall propose that the whole of Mt. Kinabalu-Mt. Tambuyukon area and the Mt. Trus Madi area should be reserved as national parks (game and forest reserves) quite apart from the formation of other forest reserves in the mountains. Proposals have already been made for a national park in the Ulu Segama area. On the other hand little can be done on the flat coastal fringe of the west coast which is now relatively densely populated. In this area few untouched samples of lowland forest remain on well-drained ground, and existing swamp forest (either in forest reserves or outside) is threatened with conversion to padi land. Generally speaking we have so little information on the distribution of rare or local species that even if it were economically feasible to make reserves for them one would not know where to make them. In the case of tree species it is easier, for there is justification in preserving them as part of a particular forest type and very often this means that the rest of the distinctive associated synusium of lianes, under-storey trees, and shrubs is also preserved. In this connection you may be interested to know that most limestone hills on the east coast (with their economic importance as producers of birds' nests, which are controlled by the Forest Department) are being included within forest reserves. As we become acquainted with other ecological types I earnestly hope that they can be similarly treated, but no one can deny that large areas at present under forest in North Borneo must ultimately be lost to permanent agricultural land as the population increases. Only careful choice of forest reserves can preserve most of the species."

(August 3, 1955.) "It has occurred to me that the project suggested in your letter of March 8, 1955, might be easily extended by enlisting the aid of either FAO or UNESCO, the former being particularly active in Malaysia. I know the idea is not new but some sort of census or survey of existing or potential areas of purely scientific value would be of great and permanent value. To start with, some idea of the extent of such areas might be obtained, followed by detailed surveys with estimation of animal and plant populations. Being of primarily scientific turn of mind, I am particularly interested in such a project and I am sure the aid of many scientific bodies could be brought to bear on the preservation of species which would otherwise be liable to extinction."

A few days later (August 9, 1955), Mr. Wood sent a circular letter to seven timber trading companies of North Borneo.

"Gentlemen,

Reservation of virgin jungle plots.

This matter was raised at a meeting with representatives of the main timber firms in Sandakan on 6.8.55. A number of Forest Reserves have been constituted, which help the preservation of much of the native flora and fauna of North Borneo, but it is desirable to make as many of these as possible in widely scattered areas even if they are small. In concessions concessionaires are asked to provide details of any areas which they do not wish to exploit (e.g. inaccessible areas on hills, swampy areas, etc.). These inaccessible areas are often the home of rare plants. On his recent tour Professor H.G. Champion said that such virgin jungle reserves should not be less than 50 acres, with a substantial surround; further details can be found in Chapter XIV of the North Borneo Forest Manual. Naturally reserved areas of this sort are just as desirable in forest which is commercial and provide a yardstick for regeneration procedure in adjacent exploited areas. The reservation of virgin forest in North Borneo will allow the preservation of most native species, especially in the national parks on Mt. Kinabalu and in Ulu Segama, but additional widely scattered small areas of virgin jungle left in concession are of great value."

"Please send lists of any areas of this sort which you wish to abandon under the terms of your agreement."

(November 26, 1955.) "Further to my letter of 3.8.55... another point has occurred to me regarding the conservation of rare species and vegetation types. You may be aware that present day silvicultural treatment in forest reserves throughout the tropical belt of the Commonwealth are tending more and more to the elimination of weed trees by poisoning. From a scientific point of view this is serious, because many of the weed trees include rare species which one wishes to protect. If forest is logged but not silviculturally treated, there seems to be little reason why such species should not persist, but systematic poisoning may eliminate them in the long run."

"I have a feeling that large climbers would be more affected than under-storey trees, for not only are they broken when large commercial trees are felled, but they have to be ruthlessly poisoned if they are not to inhibit the young commercial saplings of the new crop. If this is the case one can foresee a time when forest reserves (other than protection and ecological reserves) would be largely composed of commercial trees alone."

"I may be wrong in my assessment of the recuperative powers of the under-storey trees, but quite frequently one meets examples of species which are so rare in the restricted localities in which they do occur that I hesitate to predict their future in the event of intensive silvicultural treatment."

"It strikes me that this problem is much worse in Malaysia than in Africa, for here we have so many endemic species of limited range."

SARAWAK

(MISS WINIFRED BROOKE,
c/o The Museum, Kuching, in letter to
DR. VAN STEENIS, October 13, 1954).

"I have consulted Mr. F.G. Brown, B. Sc., Conservator of Forests here, and he has given me information regarding reserves."

"At present very little is known regarding species and their localities in this country and there is little danger of exterminating any of them. *Rafflesia* can only be protected by keeping the exact localities concealed and by education regarding the imaginary character of its advantages as a medicine in childbirth (suppose they are imaginary). It grows in a forest reserve. About one-fifth of this country consists of forest reserves where normally no trees can be felled although the department may destroy useless species. It could no doubt give and enforce, to a reasonable extent, orders for the protection of any species of tree or plant found peculiar to a reserve and not as in the case of *Rafflesia* of a special value to the local people."

"Several species of Conifers grow on the summit of Mt. Poi and according to Beccari on that of Matang, and he mentions other interesting species on Matang. Mt. Poi is a forest reserve and Matang is kept very largely in its natural state by the Water Board as Kuching obtains her supplies from there."

"Hunting and the collection of forest products, gums, fruits, etc. is permitted in the reserves; and the fauna, especially the birds in them and elsewhere, are in considerable need of protection."

"The Governor of Sarawak, Sir Anthony Abell, is encouraging a project to make Santubong Peninsula a national park, also a small lake in the north of the country. The matter is, I believe, well under way."

"When and if we have real information regarding a rare species with a limited range I consider that now is the time to arrange to protect it because at present it would be no hardship to anyone to avoid felling, digging up or building on a particular strip of ground; others equally suitable abound except possibly for air-strips; later on, if the country develops, it might seriously interfere with work or planning to protect some small locality near an industrial or agricultural project."

NETHERLANDS NEW GUINEA

(F. RAPPARD, Head of Forestry Service,
Hollandia-Haven, in letter to DR. VAN STEENIS,
October 26, 1954). Summary in English.

"I have discussed your letter on 'protection of rare plants in Netherlands New Guinea' with (my assistant) Versteegh and (Professor) Lam. We haven't at present the slightest idea what are rare species, nor shall we know for a couple of decades, and if we try to do something it will remain a useless project. The only way to get some results will be to create some reserves where lumbering is forbidden, but such areas will be in the high country. Proposals have already been made, also for establishing one coastal reserve."

TERRITORY OF PAPUA AND NEW GUINEA

(J.S. WOMERSLEY, Chief of Division of
Botany, Dept. of Forests, Lae, in letter to
DR. VAN STEENIS, August 28, 1956).

"Firstly, I would agree with you that the fundamental definition of 'rare' in terms of plant species, at least as far as New Guinea is concerned, will prove exceedingly difficult to determine for the practical work of this Committee (C. of Pacific Botany). In fact, I would hesitate to say that anyone species in New Guinea today is so rare that a real possibility of its extinction exists. As an example of this I could quote *Dendrobium johnsonii*, which immediately after the war was believed to be an exceedingly rare orchid which was faced with extinction due to considerable export of plants made immediately prior to 1940.

However, further investigation has shown that this orchid is as common as any almost throughout the whole island within its own altitudinal range."

"I am more concerned at this stage, at least for New Guinea, in the establishment of national parks of considerable size which could provide refuges against the pressing tide of agricultural development for the unique flora and fauna. The same problem has concerned the Animal Ecologist, Mr. K. Slater, in considering how the rare species of Birds of paradise may be protected against agricultural development of the land. Of course the very terrain of New Guinea ensures the protection of the flora and fauna although serious disturbances can be caused even to high mountain forest if agricultural development interferes with water-sheds and streams."

"There is also, at least in the Trust Territory, the problem of land ownership which is quite clearly vested with the indigenous people unless land is (a) purchased by the Administration, or (b) declared waste and ownerless. Virtually all land purchases to date have been designed to provide agricultural or residential land and only very few areas have been proclaimed waste and ownerless. This position appears to me to ensure, at least for several generations, that much of the existing forested areas quite unsuited to native agriculture will remain more or less in their present state."

"However, I cannot concede that this removes the necessity to find some means of proclaiming flora and fauna reserves to protect the wild life of the Territory."

"In answering your specific questions I feel the project is very real particularly in those countries of Malaysia where the population density is so great that there is real danger of rare species becoming extinct."

"To your second question I shall be happy to join you as a collaborator with the proviso that at this stage and with our relatively limited knowledge of the distribution of plants in New Guinea, I would not be prepared to assert that any particular species was so rare that it needed protection. We already have embodied in our Customs Ordinance adequate power to limit the commercial exploitation of our indigenous flora, e.g. by collecting of live orchids. Specimens of flora, fauna and minerals are prohibited exports except by consent of the administrator or his nominated delegate."

WESTERN AUSTRALIA

(MR. C. A. GARDNER, in letter to DR. COSTIN.)

Regarding plants threatened with extinction.

"I think that we can safely say that a number of our species are threatened with extinction in the near future, and that a number are already extinct. Such are plants endemic to a small area. I very much doubt that the following will be seen again:

Philotheca ericoides (Harv.) F. Muell
Darwinia carnea C.A. Gardn.
Cryptandra eriantha Diels.
Leschenaultia hirsuta F. Muell
Calcadenia Drummondii Benth.

Species threatened with extinction in the near future include

Marianthus ringens (Drum & Harv.) F.M.
Casuarina fibrosa C.A. Gardn.
Boronia capitata Benth.
Hemigenia viscida S. Moore
Asterolasia grandiflora (Hook.) Benth.
,, *squamuligera* (Hook.) Benth.
Dryandra vestita (Ripp.) Meisn.
,, *speciosa* Meisn.

The above are a few that come to mind. I will keep your request in mind, and add to this from time to time. With large scale operations in agricultural development, it is inevitable that many of our localized endemics must disappear."

EASTERN AUSTRALIA

(J.H. WILLIS.)

The following lignose species may be in danger of disappearing:

Acacia peuce F. Muell
Choristemon humilis H.B. Williamson
Eucalyptus serrulata Blakely and Beuzeville, a unique type in the genus *Eucalyptus*

NEW ZEALAND

(MISS L.B. MOORE.)

Three Kings Islands.

List of species in danger, according to observations in 1951 by Mr. Baylis:

Alectryon grandis Cheesem. (Sapindaceae, 3 or 4 adult trees)

Brachyglottis arborescens W.R.B. Oliver (Compositae)
Elingamita Johnsonii Baylis (perhaps a dozen trees)
Hebe insularis (Cheesem.) Ckn. & Allan (Scrophulariaceae, recorded as spreading)
Paratrophis Smithii Cheesem. (Moraceae, recorded as spreading)
Pittosporum Fairchildii Cheesem. (recorded as spreading)
Plectomirtha baylisiana W.R.B. Oliver (Anacardiaceae, only the type tree known)
Rapanea dentata W.R.B. Oliver (Myrsinaceae, perhaps a dozen trees)
Tecomantha speciosa W.R.B. Oliver (Bignoniaceae, only the type plant known)

The reason for recovery was the removal of the goats.

POLYNESIA AND MICRONESIA

(from F. R. FOSBERG.)

Island floras are peculiarly vulnerable to destructive forces of many sorts, as the areas occupied by species are frequently very restricted and populations are often very small. As has been many times reiterated, most endemic island species of plants are in danger of extinction if present tendencies toward disturbance and destruction of island habitats are not checked.

In general the actual situation seems to continue to deteriorate throughout the insular world, judging by what personal observations we have been able to make and from reports of others, mostly from small indications that would be useless to detail here. There are a few brighter spots in the general scene. Major gains and losses have been listed in a report on the conservation situation for Oceania included in the report of the Standing Committee for Pacific Conservation, given elsewhere in the Congress and need not be repeated here.

Work progresses slowly on the preparation of a file of information on the most immediately threatened species in Oceania which could serve as a guide for immediate action to save some of these. Reliable and up-to-date information is not easy to obtain, however. Contributions of such information are earnestly solicited.

CALIFORNIA

(J. TH. HOWELL.)

"The distribution of the plants considered in this report is that given by Jepson in his Manual of the Flowering Plants of California. As a by-product of the analysis of that work for the present report, I published a 'Tabulation of California endemics' (Leaflets West. Bot. 7, 1955), in which I discuss matters relating to this important and distinctive feature of the California flora.

Genera endemic in California.

(a) Known to occur in a State or National Park:

m *Sequoiadendron* Buchholz (Taxodiaceae)
Sedella Britt. & Rose (Crassulaceae)
m *Draperia* Torrey (Hydrophyllaceae)
m *Phalacroseris* Gray (Compositae)
m *Orochaenactis* Cov. (Compositae)
m *Gilmania* Cov. (Polygonaceae)
Oreonana Jepson (Umbelliferae)
m *Whitneya* Gray (Compositae)
m *Holozonia* Greene (Compositae)

To these will perhaps have to be added the following which probably can be found in a preserve:

m *Heterogaura* Rothrock (Onagraceae)
Pseudobahia Rydb. (Compositae)

(b) Not known in a Park or other Preserve, "National Forests" not considered:

m *Etosperma* Swallen (Gramineae)
m *Odontostomum* Torr. (Liliaceae)
m *Carpenteria* Torr. (Saxifragaceae)
Acanthomintha Gray (Labiatae)
m *Holocarpha* Greene (Compositae)
m *Crockeria* Greene (Compositae)
m *Tracyina* Blake (Compositae)
m *Neostapfia* Davy (Gramineae)
m *Hollisteria* S. Wats. (Polygonaceae)
m *Lyonothamnus* Gray (Rosaceae)
Monolopia DC. (Compositae)
m *Blepharozonia* Greene (Compositae)
m *Eastwoodia* Brandagee (Compositae)

Genera preceded by an m are monotypical.

The following trees, endemic in California, are found in a State or National Park:

Abies magnifica Murr
Cupressus macrocarpa Hartw.
,, *Sargentii* Jepson
Pinus balfouriana Jeffrey
,, *monophylla* Torrey
,, *muricata* Don.
,, *ponderosa* Dougl. var. *Jeffreyi* Vasey
,, *sabiniana* Dougl.

Pinus torreyana Parry
„ *tuberculata* Gord.
Sequoiadendron giganteum (Ldl.) Buchholz
Torreya californica Torr.
Lithocarpus densiflora (Hook.&Arn.) Rehd.
Quercus chrysolepis Liebm.
„ *Douglasii* Hook. & Arn.
„ *lobata* Née
„ *morehus* Kellogg
Platanus racemosa Nutt.
Aesculus californica (Spach) Nutt.
Fraxinus dipetala Hook. & Arn.

These are not found in Parks or other Preserves:

Abies bracteata (Dougl.) Nutt.
Cupressus Forbesii Jepson
„ *goveniana* Gord.
„ *macnabiana* Murr.
„ „ var. *Bakeri* Jepson
„ *nevadensis* Abrams
„ *pygmaea* Sargent
„ *Sargentii* var. *Duttonii* Jeps.
Pinus contorta Dougl. v. *Bolanderi* Vasey
„ *Coulteri* Don.
Pseudotsuga macrocarpa Mayr.
Taxus revifolia Nutt.
Quercus dumosa Nutt. var. *Macdonaldii* Jeps.
„ *Wislizenii* A. DC.
Juglans californica Wats.
„ *Hindsii* Jepson
Lyonothamnus californicus Gray
Acer negundo L. var. *californicum* Sargent

The California Floral Province, extending from southern Oregon to northern Baja California, with exclusion of considerble areas in the eastern part of the State related floristically to the Columbia Plateau, Great Basin or Sonoran Desert, was proposed by me in 1957 (Leaflets West. Bot. 8:5). The number of endemic genera is 65."

MAINLAND OF CHILE

National Park of Talinay, Prov. of Coquimbo.

Visited on April 30, 1955, by Dr. and Mrs. Skottsberg, accompanied by Mr. Carlos Jiles, a resident of Ovalle. The forest was found in primeval condition and in no way threatened; it is, in fact, in better condition than the nearby quite similar Frai Jorge forest north of the mouth of Limarí River and has been much less visited than this. The latter has been well surveyed by Messrs. Muñoz and Pisano, and before by Dr. and Mrs. Skottsberg (publication in Acta Horti Gotoburg 18, 1950). A corresponding survey of Talinay ought to be undertaken. The composition is the same in the two places, but Cerro Talinay is about 30 m. higher (700 m.) and makes an impression of being even more humid; both are enveloped in fog and the vegetation drips with water. Neither is of difficult access; in the case of Talinay a motor road leads to the foot of the mountain, and from there the ascent is made on foot through dense chaparral, where, in places, *Puya chilensis* is dominant. The forests are famous as consisting of a highly hygrophilous community, surrounded on all sides by xerophytic vegetation and separated from the south Chilean rain forests by many degrees of latitude. The great Panamerican Highway will pass one km. from Talinay, and it is expected that the peculiar forest will be of great touristic value. It should be remembered that the soil cover of delicate ombrophilous herbs and bryophytes, where the foot sinks deep, cannot bear any traffic at all without getting damaged and that the extreme rain forest type with lianas and epiphytes covers only a narrow strip. The distance from the Highway to Frai Jorge is about 20 km.

THE JUAN FERNANDEZ ISLANDS

In my Report for 1933-38 to the Sixth Pacific Congress I told of the establishment, in 1935, of the Juan Fernandez National Park, the first of its kind in Chile. Even if, as little was done to enforce the regulations, an efficient conservation of the native vegetation still remaining wasn't in any way ensured, nothing like the devastation that has taken place in the last twenty years could be expected. That much would have happened between 1917, when I surveyed the islands, and 1935, could be foreseen; the intentional introduction to Masatierra of one of the dangerous pests from the mainland, a European species of *Rubus* (so far determined *ulmifolius*) had been reported, and the renewal of Masafuera as a convict settlement in 1927 ought to have left its marks. In order to find out what had happened and to make a comparison between 1917 and now, I returned to the islands in December, 1954, and spent three months there. Also this time I was accompanied by Mrs. Skottsberg.

Masatierra. The settlement remains a fishing village, but it had grown considerably, from about 200 to about 600 people, which is too much, as too many persons are not engaged in the fishing industry. As before, the population concentrates around Cumberland Bay, the only harbor. The lack of suitable land and the exceedingly broken topography forbids agriculture if not on a miniature scale, and horticulture showed little increase, even if small cultivations had extended into the valleys east of the Colonial Valley, but this had little to do with the destruction during the thirty-eight years that had passed since our previous survey. I do not think that the number of cattle, about 250, was much greater than before; the difference was that there was almost no pasture left, and we shall see the reason. Sheep had been introduced and allowed to increase without any restriction at all. The whole island lay open to them; they had invaded the drier forest type and the brushwood of the high ridges; through the action of a number of enterprising individuals the national park had been turned into a sheep farm. The official figures stated about 3,750 sheep, of which 3,100 grazed the lower treeless western part and the remainder the denuded slopes of the easternmost valley of Frances, but in addition numerous others were observed also in other valleys and on the high ridges so that the total number must have exceeded 4,000. Certain areas had been turned into a desert, and the valley systems of Frances, Ingles, and Villagra offered a horrible sight. Once the soil formed by the easily disintegrating basalt, had been deprived of its plant cover, native (as in Villagra) or not, erosion set in with full force. Horses are of slight importance as communication between the coves is so much easier by motor boat; the old trails to Villagra and Frances are seriously damaged and almost dangerous; the lower part of Villagra, in 1917 covered by native grassland, had changed beyond recognition, and the zig-zag trail across Salsipuedes to Ingles valley, worn deep into the rock, had been completely effaced.

Goats, introduced in the 16th century, had become naturalized and must have been very plentiful once, but in the 19th century their number had become so much reduced that they were protected—for sentimental reasons because they descended from the goats of Alexander Selkirk, with whom Defoe's Robinson Crusoe was identified. In 1916-17 few were shot because they had retreated to places of extremely difficult access, and in 1955 they were scarce and not seen by us. But there was good help for this; under the pretext of providing goat's milk a small herd of angora goats had been imported to the colony, where they took to the mountains at once, multiplied and spread. One day I counted sixty on one of the steep ridges above the settlement; being pure white, they are easily discernable even from a large distance, and some were seen later on the most inaccessible precipices. They are private property so that hunting them is illegal. Two more additions to the fauna should be mentioned, *Nasua rufa*, introduced to help combat the big rats, and rabbits. *Nasua* prefers the dense forest and is said to be scarce; it is an excellent climber and accused of liking birds' eggs.

It is hardly probable that, in old times, much damage was done in the native forest after the wild pigs had been exterminated, except where logging was practised, until the arrival of the terrible Chilean pest, the shrub *Aristotelia chilensis* (maqui) some time before 1854. In 1917, it filled all the valley bottoms and lower slopes above the everywhere denuded coastal belt, penetrating the native forest and preventing, by its deep shadow, the endemic trees—all native trees are endemic—from germinating, so that their disappearance from the lower forest belt was foreseen already by Johow in the 90's. The maqui had continued its progress and advanced into the upper forest belt, reaching the ridges in 500-600 m. in many places; the fruits are dispersed by the thrush. Another Chilean shrub, *Ugni Molinae*, locally known as murtilla, introduced on purpose because of the aromatic berries during the latter half of the 19th century, was, in 1917, practically confined to the barren slopes above the Colony. It had increased tremendously and invaded the native shrub along the steep ridges, the home of many of the rare endemic genera and species of plants, some of them now on the verge of extinction. All our good old collecting grounds were more or less ruined. A special list of rare and vanishing species has been prepared.

One of the most precious and scientifically interesting forest products, the endemic and monotypical palm *Juania australis*, since long protected by law, has almost entirely disappeared from the accessible parts of the forest belt, but freshly manufactured curios of it were still offered for sale.

The Pangal Canyon, the only typical canyon in Masatierra and a gem, will serve as an example illustrating the changes since 1917. Toward the sea was a fine stand of *Boehmeria excelsa* along the stream, and the interior had fine native forest with stately tree-ferns right up to the terminus, a verical cliff wall with a cascade. Of all this vegetation, nothing remains; the outer slopes are naked, full of weeds and grazed by cattle; the interior, a jungle of maqui; the waterfall is reached using the tunnels made by the cows.

The bramble-berry, introduced in the 20's by a colonist living in the Anson valley, to be used as a living fence around his orchard, had destroyed it and spread like wild-fire up the valley; the small open place at the foot of Mt. Yunque, often visited by us and surrounded by fine forest, was now changed into an impenetrable thicket. From here it spreads by man and birds—the fruit being edible—in all directions and pioneer specimens florish on the high ridges above 500 m. If nothing is done to stop it, it will invade the island; the people complains of the "zarzamora," but nothing has been done. It may be too late now and will, in any case, cost a lot of money and labor, a matter for the high authorities on the mainland.

It goes without saying that the changes also affect the fauna. The endemic land birds are decreasing, and the peculiar pacific land shells will not, I presume, find the maqui a suitable biotope. The insect life, mostly small inconspicuous forms, is still surprisingly rich, at least on the higher forested ridges; numerous genera and perhaps some 90% of the species are endemic.

Whether fires have played any important role I cannot tell, but I was told that in 1930, a fire swept Ingles valley, and very likely this is true. It is, anyhow, ruined; the pasture is gone, and sheep and cattle left to starve to death. They cannot get out.

Santa Clara Island, a satellite of Masatierra, has, as far as we know, never borne any forest growth, but was once covered by grassland sprinkled with a few dwarf rosette trees belonging to the endemic genera *Rea* and *Dendroseris*. All this is gone with the exception of some specimens growing in inaccessible gorges. The islet is overstocked with sheep and looks like a desert; in 1955 the sheep numbered about 500, but we saw no goats, once said to be numerous—"Goats Island" is an old name for the place. The detached rock Morro del Spartán, separated from the islet by a narrow channel not crossed by sheep or goats, gives some idea of what the scenery must have been in bygone time. This morro is the type and only locality for *Chenopodium Sanctae Clarae*, of which half a dozen specimens were observed.

All visitors agree that Santa Clara lacks freshwater, but rain falls during the winter months when some water must be found, otherwise sheep could not exist. According to recent information the owner of the sheep was going to evacuate the island.

Masafuera. The law says that no permanent habitation shall be set up on this island; and when, in 1930, the convict station was abandoned, Masafuera was left uninhabited. However, in 1940, a fishing colony was established at the entrance to Casas valley and took possession of the government buildings. Langust fishing, the principal industry of Juan Fernandez, is profitable around this island, and the colony, though living under rather primitive conditions, was prosperous. No cultivations of any kind exist now, there were only about thirty head of tame cattle, a few horses, and twenty sheep, so that the damage done was negligible. In 1917, the marks of the first penal settlement were very conspicuous; the accessible forest patches had been logged and grazed; huts had been built in the uplands; potatoes and vegetables were grown, but the high land south of the Vacas valley, crowned by the summit, 1,570 m. above sea level and extremely wet, was covered by an impenetrable fern forest and showed almost no sign of human activity. In 1917, good forest groves were found in the upper gorges of the valleys all along the east side of the island—the western side is a precipice—between 300 and 700 m. above sea level, the maqui was rare, and the grassland higher up, with its extensive fields of big ferns and bands of *Gunnera* along the streams and scattered stout specimens of *Dicksonia*, made the impression of a peculiar fern savanna above 900 m. Goats were very plentiful, and many plant species confined to places they could not reach. And now, in 1955, this wonderful island offered a very sad sight. The forests had been logged and were full of maqui; the first brambleberry shrubs had made their appearance. We had difficulty in recognizing places we used to know so well and now found utterly ruined, a result of a series of devastating grass and bush fires. The dates given were 1939, 1942 or 1943, and 1944, and one of them, which swept the Inocentes ridge to the highest summit of the island, was not accidental. Another fire had run over the Barril ridge across to the gorges on the western side. The fern savanna was gone; charred *Dicksonia* trunks told the story. Forest groves of small size in the hanging gorges cut into the west wall of the island are still unharmed. The only large patch of closed wood is at the northern end. This was visited. It is of a dry type on the flat ridge between two valleys. In this part, natural *Stipa* grassland, very monotonous, covers extensive areas; otherwise the upland is overrun by *Anthoxanthum odoratum* and *Rumex acetosella*, just as it was in 1917, and the native Alpine species are scarce except close to the edge of the west wall in 1,100-1,400 m.

PROBLEMS CONFRONTING BOTANICAL INSTITUTIONS IN THE TROPICS

KUSNOTO SETYODIWIRYO and ANWARI DILMY

Botanic Gardens, Bogor, Indonesia.

If we may compare botany to a tree, we can say that it has its roots in Europe but that it is coming into flower in the tropics. Most of its flowers, however, are still in bud. To cause these buds to open is, in brief, the task of botanical institutes in the tropics. We mean: to realise the splendid possibilities for scientific research provided by the wealth of tropical forms.

With respect to the taxonomic study of a tropical flora, the task of an institute in the tropics is more complicated than that of an institute in a temperate climate. The latter can be merely a "working" herbarium where botanists deal with the material that comes to their hands. But a tropical institute not only has to elaborate material for the purpose of compiling taxonomic publications, it also must supply the material itself, by collecting it on expeditions in the field, an undertaking that may be too expensive or too complicated for an institute in a temperate climate.

In the course of history, every botanical institution has had its ups and downs, but this must not divert our attention from distinguishing the two kinds of herbaria: the "working" herbaria and the "supplying" herbaria. An example of a working herbarium is the Kew Herbarium. Here botanists are preparing and publishing revisions, but their material must come from somewhere else. An example of a supplying herbarium is the one at Sandakan. Here no proper taxonomic work is performed, but material is collected for the Kew botanists and others. The Bogor Herbarium has always both produced taxonomic studies and supplied material; the same is true for the herbaria at Singapore and Manila.

A modern taxonomic publication, especially if the author aims at a high standard, is the result of the cooperation of many people. Specialists are spread all over the world; the type material of Malaysian plants is scattered over at least a dozen herbaria, and for good results so much collaboration is necessary that we sometimes wonder whether the task of the Keeper of a modern herbarium is anything else than shipping and inserting material and sending botanists abroad. In any case, if we wish not to botanize alone but to contribute to international botany, our best policy is to show how we can be most useful to others. This can be done by utilizing the specific advantages of the site of our institute.

We need people who are able to collect critically and to make notes in English to go with the material, thus giving important information to the herbarium taxonomist. The collector must be prepared to take at least three duplicates—a dozen or more is still better. Further, it is extremely useful for him to have so much knowledge of the existing forms that he can pre-identify the material collected. At Bogor, Mr. Nedi and Mr. Noerta perform this work. Although lacking advanced schooling, they have accumulated extensive knowledge during field work with botanists and continued training themselves in recognizing families and genera. They are invaluable because in this respect they have achieved what a professional botanist achieves only after long, long experience. Therefore, if a man is found who shows talent in recognizing plants, he should be taught and encouraged, no matter what his status is. Even a common labourer could thus become one of the treasures of the institute.

Finally, duplicates of the material collected must be distributed. This is by no means easy. The material must be divided into adequate portions and labels must be copied carefully. All this material must be packed and shipped. The dispatch of duplicates is not one of the minor occupations of the Bogor Herbarium staff; we need mention only that in 1956 we shipped a total of seventy-four packing cases of duplicate specimens.

A herbarium connected with an important tropical garden has another special function to fulfill, namely to collect and depict garden material and to give information asked for. A tropical garden containing many "wild" species can provide more direct knowledge than a garden in a temperate climate.

Because the functions of a tropical garden are, as we have seen, quite varied, it can easily be understood that we must prepare ourselves not to lose our heads when we have to face difficulties resulting from lack of funds or lack of trained staff. The most important thing is to keep what we have. We therefore consider the alcohol and the corrosive sublimate that preserve our specimens to be the life blood of the tropical herbarium. Almost equally important are the tins and the paper that protect them against breakage and dust.

It is similarly important to improve our material. When material required for a revision is sent out on loan and later returned and inserted, the new identifications by specialists will help us in turn to identify new specimens by comparison.

As apparent from the above, a well-trained technical staff is of the utmost importance. A herbarium with only a botanist is nothing. A herbarium with good technical staff is at least something. This contradiction holds good especially in the tropics.

The work of a botanist will stimulate other activities: collecting and distributing duplicates and gaining information from living material. Of course he should work and publish, but he must remain aware of the fact that an excellently prepared and annotated plant specimen, widely distributed, is better than a second-rate publication.

With respect to the creation of new local institutions, it is well to recall the function peculiar to the tropical herbarium, namely to supply material to the great international body of science. A library as extensive as that at Bogor is necessary to operate a "working" herbarium, and it must be kept up to date. But a properly functioning "supplying" herbarium requires only an active botanist with a few willing local men, the necessary collecting and drying equipment, and facilities for shipping the material.

The tree of botany has become too large to be tended by one institute only. For efficient growth, proper flowering, and plentiful fruit, many gardeners are necessary, each endeavouring to be the right man in the right place.

DISCUSSION

C.G.G.J. VAN STEENIS: I congratulate Prof. Kusnoto on his excellent exposition of the functions of tropical herbaria. I am glad to learn that the Bogor institution intends to combine supply of material to other herbaria with work on the flora, as indeed all tropical institutes should.

S.Y. HU: One must be careful to collect and distribute enough duplicates of each specimen.

P.S. ASHTON: May not too many specimens for identification or as representatives of local collections embarrass the major herbaria and strain their facilities?

C.G.G.J. VAN STEENIS: Well annotated, fertile material will always be gratefully received by the herbaria in the temperate regions.

H.M. BURKILL: The large herbaria still need such material, even of common species. Duplicate specimens are the best currency available to botanical institutions.

PROBLEMS OF BOTANICAL INSTITUTES IN THE TROPICS†

A. KOSTERMANS

Botanist of the Forest Research Institute, Bogor, Indonesia.

The problems discussed here deal with Botanic Gardens and Herbaria. Those problems may be divided into three categories: Time, Climate, and Man.

Botanical investigation in its initial state was taxonomical and started outside the tropics, although its aim was the study of tropical plants. For centuries, materials, which served as bases for descriptions, floras, etc., have been heaped up, first in European and later also in American herbaria. Tropical institutes, like the Botanic Gardens in Bogor, the Calcutta Botanical Garden (in a lesser way), the Rio de Janeiro Garden, were more or less considered transit-institutes to facilitate collections to be sent abroad. As soon as foreign botanists withdrew from such institutes, the work came usually more or less to a standstill.

The reasons are obvious: tropical institutes are usually situated in countries where science is in its initial stage or the local population has not yet reached the stage of development for pure scientific research. These comparatively young nations have other, more important problems, which confront them. The repercussions of a weak economy were felt several times during the English and Dutch Colonial period; in poor times, the Bogor Institute was deprived of its staff, and work came to a standstill, while the collections were neglected.

One of the main difficulties, confronting the Herbaria of young countries, is that most of the type material is abroad and not represented in the country itself. This is a big handicap, as it is a time and money consuming work to study such specimens abroad, as several European Herbaria are unwilling to send material on loan for fear of damage and loss (which is quite understandable). On the other hand, we should never forget, that because collections were kept outside the tropics, many of the older collections are still in good condition. Without these collections, progress in taxonomy would be much hampered.

The young tropical countries, which will take up now the completion of taxonomic and floristic work are confronted with almost insurmountable difficulties. We will mention only a few. Taxonomy in Europe and America is not very much appreciated by the "man in the street," who considers it a waste of time and money and hence these governments pay poor salaries for too few jobs, and funds for working are scarce. As these conditions prevail in European countries, we can imagine, that they are far worse in tropical countries.

There is only one remedy: education. The wealth of the vegetation in the tropics can never be made useful to man without thorough investigation, which must be carried out in botanical institutes and must start with inventory, which means taxonomic work.

Besides lack of funds, there is a lack of qualified botanists. The jobs are not attractive, as payment is poor and the study long and difficult. For a taxonomic botanist, knowledge of four or five foreign languages is an absolute must, which means that a student in Indonesia, who is taught only one foreign language in secondary school, has to spend much time and energy to make up for the other languages, and this is often a hopeless task.

Then comes problem of maintaining existant herbaria and collections of new material.

It is certainly not true that in the humid tropics the dried material deteriorates very quickly. That depends on how the material has been preserved and how it is stored. Attack by insects is successfully checked by poisoning the specimens with an alcoholic solution of corrosive sublimate. Bulky parts of specimens, like fruit, where the sublimate does not penetrate, are likely to be attacked and part of this material should be conserved in spirits. The glueing of the specimen on the mounting sheet by means of a poisoned glue prevents further attack of insects. We could observe that the material in the Singapore Herbaria was far less attacked than that in Bogor; in Bogor the material was not glued on (nowadays the method of glueing has been adopted too). The glueing does not interfere much with taxonomic investigation, as tepid water easily loosens the parts, which can be taken off for investigation. On the other hand, the advantages of glueing are enormous. Not only is the deterioration of the plant checked, not only is insect damage less, but the damage caused by handling is reduced to a

† Presented by Kusnoto Setyodiwiryo.

minimum. The damage done by handling and dispatching the Bogor material has done so much damage that the material must be considered poor in comparison with that of Singapore.

As herbaria in the tropics are usually open buildings, infection is more likely than in colder climates. This may be prevented by storing in tin boxes with tight fitting lids; an insect repellant might help to chase insects.

There is, however, a great danger for specimens on loan from abroad which are often not poisoned. To young workers this is often not known, and the stored material may be finished by insects in a couple of weeks. Storage of such material is only possible in hermetically sealed boxes, provided with an insecticide. As the material, however, is handled, this is not much good. The safest way, which we have adopted in Bogor, is to poison the loaned specimens in a pure alcoholic corrosive sublimate solution, wherein the mounted sheet is immersed for a short period. The sheet remains clean, and the poisoning is invisible.

Upkeep of a collection—provided the funds are there—does not add any problems, as this routine work is within reach of a lower-paid official. In Bogor, however, we have trouble in filing the material properly. Personnel doing this have practically no inkling of scientific names, and mistakes are numerous. Again, this is a problem which could easily be eliminated by a better paid official with a higher education.

Next comes the collecting of new material. If the herbarium in a tropical country wants to stand on its own legs, it should collect as much material as possible to replace type specimens as far as possible. A condition, as prevailing in Bogor, where only half or less of the known and described plants are represented is an unsatisfactory condition.

Collecting, however, is possible only by means of a team of qualified botanists with ample funds. So long as these two requisites are not fulfilled, the work should be postponed, as we have learned from experience in the Forest Research Institute that indiscriminate collecting is a waste of time and money.

A "Botanical Survey," as set up by the Indian Government to initiate and guide an over-all survey, has much to commend itself, provided it has enough funds and qualified personnel (which is for the time being not the case in Indonesia).

As matters stand in Indonesia, where no flora is extant and most of the type material is not available in the country, the only alternative was to continue the taxonomic survey in the way it has been done for almost 200 years. A body has been created, the Flora Malesiana Foundation, initiated and under the able directorship of C.G.G.J. Van Steenis in Leiden and Kusnoto Setyodiwiryo in Bogor, to publish the flora of not only the area of Indonesia, but also the Philippines and Malaya. The bulk of the scientific work is done in Leiden, where a botanical staff has at its disposition an adequate library and necessary herbarium material. The funds for this important work are provided by the Indonesian Government. Moreover, the Bogor Botanic Gardens take an active part by providing herbarium material.

It is in this way only, that botanical investigation may be carried on in Indonesia. In the future, Indonesian taxonomists should take an active part in this large scale important work. For the time being, Indonesia may contribute by increasing its activity in collecting material all over the area and in providing the means (funds and help) to support the foreign taxonomists, who work on this flora on a non-profit base.

Again it is proved here that more than any other science taxonomy is international, and the whole world benefits from the scientific cooperation of nations.

The two main problems of the Botanic Gardens in Bogor are lack of funds and (as is the case with numerous, also extra-tropical gardens) a difficulty in getting the collections properly named. For a large garden as that of Bogor which consists mainly of woody plants (amongst which are several undescribed ones), a qualified taxonomist is urgently needed. If a professional botanist is added to the Garden Staff, the danger that the importance of the collection will decline is eliminated. With a non-botanical staff, the trend is more to raise ornamentals, and the scientific collection may be neglected.

Continuous collecting of seeds and seedlings of botanical, more than of ornamental or business interest, is an absolute must. This is, even under prevailing circumstances, always possible, provided the staff is convinced of the scientific importance of the Garden.

DISCUSSION

C.G.G.J. VAN STEENIS: I consider the material at Singapore and Bogor to be of similar quality. Glueing specimens to sheets was developed to reduce accidental loss (or theft) of portions of the specimens, but this practice is most troublesome to research botanists. Despite the greater cost in paper and space, wrapping each specimen in a separate cover is the best protection against friction damage and loss of detached fragments.

G.A. PROWSE: Better fungicides and insecticides are required.

P.R. WYCHERLEY: 8-hydroxy-quinoline-potassium sulphate may be used as a substitute for, or in addition to, mercuric chloride. Paradichlorobenzene is a valuable insecticide in herbarium cabinets.

G. SEIDENFADAN: Taxonomic research is the essential basis for economic development of natural resources; governments must realize this and give adequate financial support. Institutes must correct the opinion that such work is a waste of money and ensure that, although their facilities may be limited, they are devoted to fundamental work.

C.G.G.J. VAN STEENIS: We should all endorse His Excellency's statement, may we record this? (There were no dissenting voices, and the meeting appeared to be in general agreement.)

A BRIEF HISTORY OF BOTANIC GARDENS WITH SPECIAL REFERENCE TO SINGAPORE†

J.W. PURSEGLOVE

Professor of Botany, Imperial College of Tropical Agriculture, Trinidad.‡

This paper is a précis of PURSEGLOVE: History and Functions of Botanic Gardens with special reference to Singapore: *Tropical Agriculture* **34**(3), July 1957.

Botanic Gardens are places at which to study plants. The earliest were herb gardens, the first being that at Pisa founded in 1543. From then through the Linnean era to the present day, gardens have developed on scientific concepts, accumulating not only living plants but herbarium material and literature, some on a world-wide basis, some on a local basis.

Though many gardens were established in the 16th and 17th centuries in Europe, the earliest botanic garden in the tropics is thought to have been that at Pamplemousses in Mauritius, established in 1735. In that century and the next, many tropical gardens were set up, chiefly with the object of studying plants of economic importance either local or introduced. In Asia, the gardens at Calcutta were founded in 1786; at Penang (the first of three), about 1796; Buitenzorg (Bogor), 1817; Peradeniya, 1821; and at Singapore (the first of three), in 1822. These gardens and the men who have served in them have laid the foundation for the scientific study of Asian botany and of much of the forest and agricultural economy of the tropics. One has only to consider the tremendous value to the world the following tropical agricultural plants have and peculiarly that most of them were removed from their natural habitat to alien lands: Hevea, cacao, quinine, coffee, cloves, nutmegs, sugar, bananas, limes, vanilla, cassava, sweet potatoes, maize, and many others.

In Malaya, the first Penang Gardens were founded soon after the establishment of a trading station by the East India Company in 1786. Similarly the first gardens in Singapore were founded but three years after the trading post was set up. The attention of both was given to the growing of nutmegs, cloves, and other crops of commercial value. Of the surviving successors to these Gardens, that at Penang is now a pleasure gardens; and only that at Singapore is a botanic garden in a true sense. This latter came into being in 1859 as the garden of an Agri-horticultural Association. Within a few years, the government had taken over its administration; and its work expanded to include a study of the flora of the Malay Peninsula, as well as work on crops of possible economic value, such as Cinchona, coffee, eucalyptus, ipecacuanha, tea, maize, sugar-cane, colanuts, mahogany, oil palm, cacao, and, of course, the classic pioneering of Hevea.

The Singapore Gardens made the greatest progress in laying the foundation for agriculture and forestry in Malaya under Ridley in the two decades following 1888 when he arrived as Director. Ridley also conducted the most extensive research into the flora of the country. He founded *The Agricultural Bulletin of the Malay Peninsula* in 1891 to be superceded by *The Agricultural Bulletin of the Straits and Federated Malay States* in 1901.

Through the researches of the Botanic Gardens, the Departments of Forestry and of Agriculture were set up to extend the work of their respective lines. This did not mean that the Botanic Gardens ceased their interest in these matters. The work of all generations of members of the Department has had a bearing on the evaluation of Malaya's inherent wealth in its vegetation and in its agri-horticultural potential which is now made known through its serial publication, *The Gardens' Bulletin*, and *The Revised Flora of Malaya*. Even during the Japanese interregnum in Malaya, work at the Gardens continued under the direction of Japanese botanists. Though this period was fraught with difficulty, the herbarium and library suffered no loss, but the living collection of plants was sadly reduced. In the post-war years, the Gardens quickly regained their former good condition, but these latter years have been characterised by lack of trained staff.

The work of a botanic garden is botanical, horticultural, and educational. For the first purpose, the garden must be a museum of living plants to compliment the herbarium, a museum of dried plants. In the Singapore Gardens, some 3,000 perennial species grow, not counting hybrids. The herbarium contains about 400,000

† Presented by H.M. Burkill.
‡ Formerly Director of Botanic Garden, Singapore.

sheets, mostly of Malaysian origin, whose quality and quantity are constantly being increased by loans for revision and by exchanges of duplicate material. Collecting is done in Malaya and in neighbouring countries where the vegetation has botanical affinities. This work leads to taxonomic studies which are necessary preliminaries to the preparation of floras. With the complexity of Malaysian botany, this work is a tremendous undertaking. Over the past one and a half centuries that Malaysian botany has been studied, an immense amount of information has been gathered. In 1921-24, Ridley published the first *Flora of the Malay Peninsula*. So much more data are now available that this work is in urgent need of being superceded by a revised Flora, a work which has already been begun. Similarly the Singapore Gardens is throwing in its lot with the immensely more difficult task in the preparation of a regional flora, *The Flora Malesiana*. It is only from such undertakings that man can live, for, to quote Linneus "Science, and in the first place botany, is the only reliable basis of private as well as national economy."

On the horticultural aspect, the exchange of seed and the acquisition of species of possible value from other countries are equally important activities. It is the natural sequel to the botanical research just mentioned. From it has arisen, for example, the immense and vitally important Hevea planting industry. Besides Hevea, there are numerous other plants, of less apparently over-riding importance but nevertheless of value commercially (e.g. oil palm, cacao), medically (e.g. *Rauwolfia* spp.), and aesthetically (e.g. Mucuna, cacti, orchids). The work on agricultural plants is now the responsibility of the Department of Agriculture, but nevertheless the Gardens continues to play an important part. Horticulturally Malaya's relatively seasonless climate is a difficulty for many spectacular ornamental do not receive the required stimulus to flower. Breeding work has been done on some groups of plants to select responsive varieties, and the main breeding work at present being done is on orchids.

Educationally the Gardens help to increase people's, in particular children's, interest in plants. School parties regularly visit, and the Gardens supplies material to schools and the University for teaching and planting. A considerable amount of advisory work is also done and active encouragement is given to such bodies as the Singapore Gardening Society, the Malayan Orchid Society, and the Malayan Agri-Horticultural Association.

In addition to the foregoing, the Gardens has the responsibility of running the Nature Reserves on Singapore Island in which all wild life is protected. The botanical and educational aspects of the Gardens' work are represented in this activity.

The future, with political maturity of Malaya and Singapore, holds two cogent problems. Firstly, there is the question of trained staff, for much will depend on the new recruits who will have to take over the duties heretofore exercised by overseas men, and who it is to be hoped will carry on the traditions of competent research built up over the past century. Secondly, there is the question of finance, a satisfactory solution to which rests on the ability of the staff to demonstrate to politicians and the public the worthwhile role the Gardens plays in the economy and prestige of the country. Two and a half centuries ago the following lines were written about botany: "It is certain, however, that this Science, like all Sciences, flourishes sometimes more and sometimes less, all in accord with the inclination of Rulers and the Favour of Government." (Commelijn) How true it is still today!

DISCUSSION

P.W. RICHARDS: The collections of living plants in the tropical gardens must not be neglected, nor limited to economic or ornamental species. Visiting botanists find them invaluable for a wide range of studies.

J.H. HÜRLIMANN: Private institutions are faced with the same difficulties as official organizations, and so their utility is limited.

SOME CURRENT PROBLEMS OF THE BOTANIC GARDENS, SINGAPORE

H.M. BURKILL

Botanic Gardens, Singapore.

ADMINISTRATION

In a period of transition of administrative authority such as is going on in Singapore at present, it is an advantage to maintain a sense of humour. Many odd things crop up, like the zealous Treasury official who, at an application for funds to buy some more herbarium cabinets, quoted Government's General Orders which require a Director of a department to review his department's records when they become five years old with a view to destroying those of no further import. Strictly correct, of course, but when do botanical records (herbarium specimens) reach an age for destruction? Or again, another official dealing with equipment for the Gardens wanted to know how many persons normally sat on a garden seat. He had plainly yet to learn the facts of life—that in Singapore's predominantly adolescent population, "two's company; three's none!"

These points will serve to show that in the growing political responsibilities of the new nations of Southeast Asia there is now a cadre of administrative officers with everything to learn in the shortest of time. Rome was not built in a day. An intelligent inquisitiveness is a healthy sign amongst this new band of administrators, but the simplest way of learning is by coming to see and personal discussion, and one could wish that this, disrupting though it may at times be to normal routine, was more often practised. Though it may be adequate to copy one's predecessors, it is desirable that those who hold the purse-strings and those who run the department maintain a close liasion. Thus one may hope to avoid the unpredictable response to a normal contingency and gain the advantage of both parties speaking and thinking alike.

PERSONNEL

Every branch of scientific endeavour throughout the world is short of trained personnel. The Botanic Gardens, Singapore, has not been unaffected. The normal compliment of qualified staff is four botanists, i.e. a Director, an Assistant Director, a Keeper of the Herbarium, and a Botanist, and two horticultural Curators. From 1946 to the end of 1954, except for a short period in 1948-49, there was no Assistant Director. From 1952 to 1956, the post of botanist was vacant. From 1946 to 1954, the horticultural branch was virtually down to one officer, as one Curator was seconded for duty as Agricultural Officer. These shortages have created much difficulty in carrying out a full programme of research and have thrown additional burdens on the existing staff. This Department is not in the process of "empire-building"; its full establishment of botanical officers has remained unchanged for 33 years, and its compliment of Curators has been reduced to one since the Penang Botanic Gardens were handed over to the Department of Agriculture in 1946.

For the first time since 1946, a full compliment of senior staff was at work from December, 1954, though one post was vacant but held temporarily by a re-engaged pensioner in the absence of any qualified younger man suitable for permanent appointment. For two years this position was maintained and even the vacant post was filled. Then in 1957, the Singapore Government introduced a policy of accelerated Malayanisation of the public service. This resulted in the loss of one botanical and one horticultural officer, of which only the latter has been replaced. Further losses are expected. It is not intended to discuss politics, but it is essential if the situation is to be understood. Briefly, it is that local men are coming forward in greater numbers for higher training. Facilities are now available at the University of Malaya and abroad by means of awards to qualify local men for appointment to posts hitherto held by officers from overseas. For the expatriate officer, the element of uncertainty, the offer of compensation for loss of career, the knowledge that sooner or later he will have to retire, and the younger he goes the better chance he will have of starting again in new employment are all cogent reasons for the loss of trained man power in government service in Singapore. Many expatriate officers have and are leaving before local men are ready to fill their posts. Some or all of these reasons apply to the Botanic Gardens though it is apparent there will be no claim for appointment from local persons for some years.

Now most biological work is essentially long term—particularly that of the botanist. Plant collections and written notes and papers are only a part of the botanical archives an institution possesses. Equally important are the personal experiences, the stored-up impressions and ideas of its officers. Much of this information does not get onto paper and published till towards the end of a man's career. Let me take two examples: *The Flora of Malaya* (Ridley, 1922-25) and the *Revised Flora of Malaya* (Holttum, Vol. I 1953, Vol. II 1955) could never have been written by any other authors in as complete and competent a form from the available collections and literature alone simply because such works are the better for the authors having had first hand personal experience. Ridley was in Malaya for 24 years; Holttum, for 31 years.

The point I come to then is that frequent change of staff where it involves a complete break of environment in research workers' careers is bad for the institution. It may be bad also for the individual, but that is outside the present issue. The changes which are now taking place in the Singapore Botanic Gardens through political circumstances are in danger of seriously putting the clock back. It can never, of course, go completely back, but it does mean that over the next ten years or so there will be an unfortunate break in that intangible quality, personal experience, which is such an important asset to any institution.

I have no solution to offer. Advice has been tendered. Recommendations have been made. The government has realised the situation. Decisions have been taken. Events are running their course.

How is the loss to be made good? The physical loss of bodies and the abstract loss of minds will no doubt eventually be recovered. For the former we depend on the University of Malaya and overseas universities where Malayans are training, but for the present, prospects are not good for only a few students are coming forward to take botany. For the latter, there can be no progress till the former is made good, and then only time will tell.

This shortage of trained personnel has caused the introduction of a new concept of recruitment. Whereas it was previously accepted that persons arranged their own training and, except for a few fortunates who could obtain scholarships, paid for it privately, this liability now devolves to a considerable extent on Government and on public funds. Further, whereas it was usual to appoint a man already trained, it is now accepted that a promising but untrained or partly trained man is appointed to a post (or is anyhow bespoke for the post) and then trained for it. This is no doubt the easiest way of creating a corps of qualified man in the shortest possible time and is in accordance with Government's increasing concern with scientific matters.

In the subordinate cadres, the position has been much easier except where specialised knowledge is required. Librarians appear to be hard to come by, and the Departmental library has been without adequate management for a long time. This throws out of gear all the normal services that one expects of a librarian such as receipts, loans, and exchanged; referencing and cataloguing; binding; pest control and prophylaxis; rack arrangement; and the assistance expected by botanical officers in locating literature. The solution to the shortage of librarians lies in training, but Malaya at the present time does not offer any facilities and few students are going overseas to study for librarianships.

One point on which this meeting might raise discussion is on the nature of the basic training required by a librarian of a botanical library. To run such a library, in my opinion, the librarian must have had some botanical training so that he may know the difference between, for example, agriculture, horticulture, and botany in their general meaning or between a phanerogam and a cryptogam in a more technical sense. With such knowledge he can without troubling the botanical staff carry out the functions of a librarian of a botanical library. I would therefore expect in the position I now find myself in the matter of recruiting a librarian to start with someone with some knowledge of botany and to train him in library techniques. In this way I would ensure having a librarian capable of handling botanical literature.

On the other hand, there is a body of opinion amongst librarians that a librarian should be a librarian and nothing else. I am assured that the botany around him would look after itself. But in a specialised library it surely calls for specialised knowledge to classify competently the constant inflow of literature, particularly if one considers that it is part of a librarian's duty to maintain a subject card index. The librarians' opinion to which I have just referred indicates a severe limitation of usefulness, but it is a position which now holds in Singapore and perhaps in general elsewhere. It is a matter on which I would greatly welcome comments.

With regard to other subordinate grades we are in no particular difficulty for the departmental organisation provides the means of training whereby a youngster can earn and learn his way to positions of responsibility. In fact the Botanic Gardens of Singapore in some respects are rather like an old family concern; out of the twenty-six botanical and horticultural posts on the staff, no less than nine are filled by fathers or sons of present or past employees of the Department. I myself take pride in being in this category.

COLLECTING

The Botanic Gardens, Singapore, is the only botanical institution in the British Territories of Southeast Asia. It is true there are other herbaria, but they tend to be specialised, with the result that the sphere of activity of the Department has been spread over the Malay Peninsula and Borneo. Recently occasional visits have been possible to Borneo, but till 1955 these were restricted by shortage of staff. In Malaya, with ease of access, quite a different problem has arisen. For the past nine years there has been armed insurrection in the country by a small proportion of the population which has taken to the forests. The trouble was incipient from the end of the war, but gained official cognisance in June, 1948, with the euphemistic title of "Emergency." For some years it reached serious proportions and even now is the cause of difficulties and restrictions in several parts of Malaya.

This state of affairs has had a very important effect on collecting and botanical exploration, as it has been impossible to penetrate the forests. At times it has been forbidden, or unwise, to stop one's car on the main roads to have a look at the roadside vegetation. To wander into the forest would have been an invitation of trouble with either the police or military on patrol or from the insurrectionists. In either case, one would have been at the receiving end. Planters, miners, foresters, and surveyors have had to work accompanied by armed escorts. I know only too well from personal experience the physical and mental limitation such a condition imposes.

The consequence has been that collecting has been severely restricted to those areas one could safely visit and these on the whole are the areas best known botanically, i.e. the vicinity of towns and hill stations. The less accessible centre of the Malay Peninsula is where exploration is most wanted, for example, Gunong Kerbau, Gunong Tahan, Ulu Kelantan, and the Trengganu plateau.

Armed conflict such as Malaya is experiencing has been or is a feature in most of the countries of Southeast Asia during the past decade. It is something with which some at this meeting may have had close personal experience. It is something which all of us can deplore, though, I fear there is nothing this meeting can do to alleviate it. It has been the biggest obstacle in the past ten years to sociological, industrial, and research progress.

The situation improves in Malaya, and botanical exploration into the more remote parts of the country may soon be possible again, though the pre-war style of expedition lasting a month or more with men and equipment to match is likely to be little more than a pipe-dream—except on rare occasions, for even some dreams come true! But in general we will have to work on the principle of light excursion lasting not more than a few days or on single-day collecting trips.

An aspect of some importance is the need for botanists to have some familiarity with the types of vegetation of neighbouring countries. A foreign correspondent writes that he cannot plan a trip to Malaya as he is unable to obtain the necessary currency exchange. A Malayan correspondent says his proposed trip to another country is limited by the same curbs. I would like to suggest that exchange of botanists between institutions of neighbouring countries should be encouraged in much the same way as students and university lecturers are exchanged. The free provision of herbarium amenities is naturally simple, but the principle may well be expanded to the offer on a reciprocal basis of facilities for field work, transport, subordinate assistance, and lodging.

VISITING RESEARCH WORKERS

Many scientists call at Singapore on their way to other countries. Few stay to work. If tropical botany is to be better understood by botanists from institutions in temperate countries, it is very desirable that some botanists come to work for short periods at tropical herbaria. They thus acquaint themselves with some of the problems of tropical botany, carry their impressions back to their home institutions, and interest their colleagues. In the last few years, we (Botanic Gardens and the University of Malaya) have been fortunate in obtaining grants to permit two young botanists to come to Malaya for a year each. It is hoped that this may be repeated regularly to the advantage of all concerned. There are certainly numberless lines of investigation ready for working on. The grants have come from the British Government Colonial Welfare and Development Scheme, but there are International Agencies which could or should furnish some assistance. Claims for assistance are more than their funds can stretch to, and botanical matters do not usually rank high in priority. Plants are fundamental to life, and their study is man's first science. It is our duty to raise the sociological status of botany in the minds of the world's administrators.

DISTRIBUTION AND EXCHANGE

Botanical security can be achieved only by ensuring permanent accessibility to collected material, which are the basic botanical archives. Essentially, the problem is one of availability and adequate distribution.

The development of botany in the countries of Southeast Asia at the present time is still very much interwoven with herbaria of the temperate world. The connections of the Malaysian flora are especially strong with Kew, British Museum, Leiden, and the Arnold Arboretum. Many other links exist between tropical Asia, tropical Africa, and temperate countries.

For our part, our system of distribution of duplicates may help to perpetuate this dependence on Europe, but it is a system which cannot be changed if we are to continue to make the best uses of our material and if we are to follow the principle of distribution for security sake. That our top duplicates go to those institutions where experts are working on the groups of plants concerned is a general policy. For us it usually means to Kew, Leiden, and the British Museum. The longer we send to them, the more important their Malayan collections become; the more important their Malayan collections are, the more reason we have for adding to them and keeping them up-to-date. This is a sort of cleft stick in which we find ourselves, albeit not an unpleasant one, nor an unprofitable one. This is the position which we at Singapore hope to maintain at least for the foreseeable future till there is a capacity and talent amongst the local population for things botanical. Thereafter one would wish that such distribution be maintained as a feature of cooperation for mutual benefit. The extent of distribution of duplicates of the higher plants after sending to these museums takes a wide range. All is done on free exchange, but it is limited to those herbaria of Europe, N. America, and Australia with Malaysian affiliations and to herbaria of the Indo-Pacific region, with whom we are in exchange. There is, I believe, a growing opinion that a regional flora cannot be considered as peculiar to a water-tight compartment. The time is coming when the floras of the tropics may have to be taken as a whole. I am thinking, therefore, that our system of distribution is inadequate and that we may have to exchange our material for tropical African and tropical American material also, if the expanding requirements of taxonomic study are to be readily met. This will impose greater demands on storage space and the limited numbers of duplicates available for distribution. It is perhaps worth mentioning that during the past three years for every number collected by our staff and laid in our herbarium there has been an average of 4½ duplicates available for distribution. We could without difficulty distribute double that, and we would do so were it not for the difficulty of handling so many duplicates in the field. Any increase in the number of exchanging institutions has obvious drawbacks.

It is, however, not so much the normal run of current collections which give rise to the greatest concern, but the type specimens, the classical botanical archives. The Singapore Herbarium has about 1,000 type sheets, many are holotypes, others are iso-types. There may or may not be duplicates elsewhere; but of the older ones, it is likely that distribution was much more limited than one would now-a-days deem desirable. But whatever their distribution elsewhere, we have an obligation to ensure their availability to present and future botanists. Several herbaria with valuable collections suffered losses during the late war. The Singapore Herbarium was fortunate to have had no damage, for which the actions of Professors Tanakadate and Kwan Koriba, Dr. Holttum and Mr. Corner must be recognised. But preservation whether from war damage or from accident is a problem concerning all herbaria housing valuable material. For ourselves, we have recently had most of our type sheets microfilmed and propose to distribute positive copies to certain herbaria for their reference as well as for safe custody. Except for an adequate distribution, this is perhaps the nearest approach to a satisfactory solution that one could have, expedient though it is.

LOANS

Free exchange and free loan are, in general, principles to be commended. Loans from the Singapore Herbarium since 1946 have involved

39,000 sheets or about 10% of the total herbarium collection. These loans, totalling nearly 100 lots, are looked on with favour as most of them are for revision purposes, and the sheets thus come back annotated with the current taxonomic name.

The increasing complexity of taxonomic revision is reflected in the length of time these loans are out; for those sent out and returned, the average has been twenty-two months. Seven were out over four years; two over five years; and one over six years. Of the material currently out on loans, there are 11,000 sheets issued in thirty-two different consignments covering genera or sections or, for a few, the whole material of orders. Three have been out over nine and one-half years; two over eight years; and two over seven years. I cannot help but think that something has gone wrong with these! What of the fervent instructions of loaning herbaria—that the loan is only for three months?

The accusing finger can no doubt be pointed at the Singapore Herbarium too. It is a common problem, but the point I would make is that the extensiveness of loans now out is apt to cause considerable embarrassment in handling current collections, as there is much which cannot be matched. It is not necessarily a temporary problem, but is likely to grow with the expansion of botanical study.

BOTANIC GARDEN OR PUBLIC PARK

Most botanical institutions have attached to them some extent of land, garden, estate experiment station, or whatever the appropriate title might be, where plants may be grown under observation. A botanic garden usually attracts many visitors, though basically it is a research station rather than a pleasure garden. The Singapore Gardens were laid out originally as the latter on formal lines of landscaping, in all eighty-six acres, when in 1882 the Government took them over as part of a botanical institution. The design has remained unchanged for almost 100 years.

Problems inherent in the setup of the Singapore Gardens are these:

(1) Space;

(2) Pressure of the public.

With regard to the first, the Gardens are but four miles from the centre of the city and are in a built-up residential district. Expansion is impossible. With the old Economic Garden which was attached to the Botanic Gardens, the area was 188 acres which was close enough to 200 acres, often considered an optimum size. In 1925, the Economic Garden of 102 acres was excised for a college football field. The Frenchman's characterisation of the British "Toujours le Sport" is justly applied. But the result is that chiefly in regard to tree species, planting is greatly restricted. If the lawns of the gardens were planted over, more desirable introductions could be tried, but concession has to be paid to appearance and to horticultural considerations. The need for an arboretum is paramount at the present time. The acquisition of additional land has been considered off and on for the past thirty years since the Economic Garden was lost and is now coming to a head again with further demands on the Gardens.

The other problem has many facets. The Gardens are one of the few open spaces within the City Area. In fine weather on week-ends or public holidays, many thousands of people visit them. In general the public's behaviour is perfectly satisfactory, but in their train is the time-old trouble of the few anti-social individuals against whom restrictions have to be imposed which affect all visitors to the Gardens: the bicyclists, who as a class, are pests; the poachers who try to catch fish in the Gardens lake; the pilferers who break cuttings off plants so that the plants have to be removed; the orchid fanciers who remove orchid pollenia for fertilising their own blooms and thus cause our plants on display to fade quickly. These are the troublemakers; their kind is common throughout the world.

Of our own domestic horticultural problems, the biggest is monkeys. They are utterly destructive. All horticultural practices are fair game for interference. Anything special has to be established under a wire cage or behind an electrified fence. Any attempt to reduce their numbers is a signal for outcry; ones office is beset with holy matrons and true citizens defending their birth right, for to the public the Botanic Gardens are a place to come to feed the monkeys.

The amenities which the public has in the Gardens are undoubtedly appreciated, and it seems to me that the best possible balance is struck between botanical/horticultural requirements and the public's usage as a park. With more children learning biology in the schools, it is gratifying to have orderly parties conducted by teachers. This is a good augury, for there are many too many people who look upon plants as something to cut down or pull up according to size, and it is a function of a botanic garden, rather than a park, to foster a love of plants in the predominately destructive human mind. In the following section I refer to a very closely related subject.

NATURE CONSERVATION

This subject is dealt with in another symposium, but as it is a problem confronting the Botanic Gardens, Singapore, it is correctly mentioned here, if but briefly.

In Singapore, the preservation of small sample areas of vegetation of the indigenous flora (and fauna) is a major problem. There are five areas covering about 8,000 acres constituted nature reserves by law under a board of trustees with the Director of Botanic Gardens as Chairman. Though this legislation was enacted as recently as 1951 and even more recent land utilisation planning has respected the areas as reserves, it is proving difficult to maintain them intact against catch-penny commercialism, demands for resources they contain (granite), and expanded development plans hitherto unforeseen.

Two of the reserves are type localities for species of plants and marine animals. All are essential for education and research, in addition to their obvious attractions as places for recreation and open air enjoyment. Their very accessibility from the city adds greatly to the amenities they offer, but this too adds to the covetousness with which certain persons would seek to destroy them for commercial exploitation. Though there is a growing land hunger in Singapore, there are yet other similar areas of unreserved land elsewhere on the Island awaiting rational utilisation.

SUMMARY

None of the problems described here are insuperable. Some indeed are axiomatic in running an organisation. Some, given goodwill and patience, will resolve themselves. Others are due to force majeur. Solutions to the first two kinds lie in our own hands. For the third, we must adapt ourselves as good citizens and good biologists.

DISCUSSION

G.A. PROWSE: Men of long proven, practical experience are being ousted by others with better academic records but less knowledge of and training in the particular subject. This occurs where inexperienced administrators fail to appreciate the relative merits of experience and proper qualifications. Better mutual understanding between institutions and the authorities they serve is required.

P.R. WYCHERLEY: All papers have referred to the shortage of trained staff. In Southeast Asia especially, too few students are attracted to botany; many graduates seek employment elsewhere, although they are sorely needed in botanical, agricultural, and forest research stations.

K. SETYODIWIRYO: Botany is a poorly paid profession in Indonesia, hence the few young scientists entering the field.

H.M. BURKILL: Many Singapore graduates become teachers. We must raise the sociological status of botanists.

E.H. WALKER: We need better advertisement of the importance of botanical work which should promote more recognition and reward for those engaged in plant science. These difficulties are very general.

C.G.G.J. VAN STEENIS: The exchange of botanists between different tropical institutes and between them and the temperate region herbaria, as suggested by Mr. Burkill, will greatly benefit the development of tropical botany. Tropical institutes must not be left to develop in isolation; personal contacts are invaluable to all. Bogor and Singapore have laid a good foundation in accommodating visiting specialists; this successful enterprise must be extended. Specimens are sometimes out on loan for many years, because the monographers are often university teachers who cannot devote all their time to taxonomic revision. Planning when the specimens are required by the borrower will help, and herbaria should remind borrowers of the outstanding loan periodically after a reasonable time for study has been allowed.

R. HEIM: Young botanists must be encouraged to take up taxonomy. Botanists must aid the establishment of reserves and parks to retain living specimens of the flora, as well as planting formal botanical gardens. The wide distribution of duplicate specimens cannot be emphasized too strongly.

E.H. WALKER: I endorse the need for new taxonomic studies. Some of the problems of loaned specimens and exchanges of specialists could be resolved if there were regular conferences of the directors of botanical institutes to advance cooperation.

P.S. ASHTON: The working taxonomist and collector must be able to visit not only herbaria but also the different source areas in the region, irrespective of political boundaries. A pooling of resources is needed so that botanists in poor countries may reap the benefit of facilities established by their richer neighbors.

E.H. WALKER: There is a lack of curators in the herbaria I have recently visited in the Pacific area. Funds have been cut, and although the senior men may remain, whole groups of essential assistants have been unwisely dispensed with. Individual institutes probably cannot work out their own salvation. General guidance, coordination of plans, and assistance in bringing their needs to the notice of the authorities are all necessary.

M.S. DOTY: I would remind you that we can pass resolutions for the attention of the Pacific Science Association or of UNESCO, whose support will add more weight to our conclusions.

PROBLEMS FACING THE HERBARIA IN THAILAND

KASIN SUVATABANDHU

Department of Agriculture, Ministry of Agriculture, Bangkok, Thailand.

Anybody may realize that Thailand, land of freedom and land of smiles in Southeast Asia, is an agricultural country. She is very rich in natural resources. Her soil is fertile and suitable for various kinds of cultivation. Rice and teak are famous and recognized by many customers. The population is too little in comparison with the vast area. Her economy is dependent on plants and plant products.

In Thailand, as in many other tropical countries, botanical knowledge which is of basic importance is still in its initial state. Speaking in general, the Thai people have a great interest in plants, their economic value, and even the ecological relations. Courses in botany are offered in the university, but these are only for the scientific background of medical, pharmaceutical, biological, and agricultural students. The teaching for the advancement of Botany is still in the future. The Thai flora still receive scanty attention. No botanic gardens exist in the kingdom, but there are a few reserved parts of the forest. As a matter of fact, botanical works such as a survey and systematic study have been made, but for the use of other institutions which are considered the main arteries of the country's economy, i.e., Royal Forest Department and Department of Agriculture.

In 1906, the Royal Forest Department started the systematic study of plants, but these were mainly timbers of economic importance and some other forest products. A herbarium was also built up. In 1920, the Botanical Section of the then Ministry of Commerce was formed with the object, in the first place, of making a survey throughout the kingdom of plants yielding or likely to yield, economic products. This survey was to include an enquiry into the properties, quantities, and accessibility of such plants. Again the herbarium was built up. This Section is now under the Division of Plant Science, Department of Agriculture. A great deal of work has been done on the flowering plants of Thailand, but it is still incomplete. Studies of ferns and mosses have been made to a lesser extent, but the lower plants, fungi, and algae are almost unknown.

One might question why botanical studies and work have not developed further in Thailand. Shortages of trained scientific personnel and scientific literature as well as inadequate funds are all responsible.

The most important of these is the shortage of personnel. In the two mentioned botanical sections, there are only a few members of the official staff, and work progressed very slowly. Collections which are necessary and important are made on a small scale. There are too few duplicates to offer to other institutes. The main factor is the difficulty of finding persons interested in making a career of this purely scientific work. There is a demand for persons in various fields of applied science such as medicine, engineering, architecture, agriculture, etc. Pure science has thus far not attracted sufficient students and knowledge of the country's vegetation is still very scant. The shortage of trained personnel creates other problems in developing this botanical knowledge such as limited advanced study and little coordination with other institutions.

At present official persons in various fields have begun to realize the importance of botanical knowledge. We hope that in the future this kind of purely scientific work will have the full support of the government, as a part of the country's economic development.

DISCUSSION

C.G.G.J. VAN STEENIS: The lack of a botanic garden on a scientific basis in Thailand is amazing in view of the agricultural nature of the economy. Indonesia and Malaya are examples of how botanic gardens, with their herbaria and libraries, have aided agricultural development by knowledge of the flora. The establishment of a botanical garden requires careful long-range planning, for slow but sure growth is needed. This is a government responsibility. I propose that this section endorse any resolution supporting the establishment of a botanic garden by the Thai Government. (There was general agreement that a botanic garden is an urgent necessity for any tropical country, including Thailand, which lacks such an institute for the botanical study and development of its agricultural and forest resources.)

M.L. STEINER: Our attempts to rehabilitate the gardens in Manila have failed. The trees and shrubs we planted are destroyed. The promises of help from the authorities have come to nothing, how can we press the point with them?

J.H. HÜRLIMANN: This illustrates that it is primarily a matter of education; there will be no understanding until the value has been learned.

C.G.G.J. VAN STEENIS: Government, not private, action is needed. The government may stand in need of education in this matter.

E.H. WALKER: Vigorous action is needed on all fronts. Private associations must do their best to maintain any existing establishment, to marshal public opinion, and to interest larger organizations in obtaining effective support from the authorities.

INTERACTION AND COOPERATION BETWEEN TROPICAL AND TEMPERATE HERBARIA

C.G.G.J. VAN STEENIS

Flora Malesiana Foundation, Oegstgeest, Netherlands.

Not long ago I was struck by a plea to monographers by Brother Alain (Havana) who complained of the fact that monographers frequently study less material than desirable and often confine their work to the revision of the material of some large, European herbaria (Taxon 6, 1957: 46-47). He pointed to the deficiency in this respect of Radlkofer's monograph of the Sapindaceae in the Pflanzenreich.

It is true that in many monographs of this series only a very limited amount of material was borrowed from institutes outside Berlin-Dahlem, and that for essential material only.

Two decades ago when working at Bogor, Java, I had a similar complaint about Malaysian material, and I wrote to Berlin to ask if we could receive timely notice as to which families or genera were under revision in order to loan our material for examination by the monographer. The answer was unsatisfactory, as it was argued that the monographers could generally not master large loans from all herbaria abroad and did not solicit to ticket all specimens, as their facilities and specially their time were restricted.

Nearly all of the monographs therefore suffer, in varying degree, from incompleteness. And the same holds for various other revisions generally. The reference to Radlkofer's work is not a particularly good example as it was essentially finished before 1910 and remained, as far as I know, in Radlkofer's desk for decades. Radlkofer did not add much to it in later years, and the final posthumous editing was performed by the redaction of the Pflanzenreich.

This situation looks lamentable and dangerous to the progress of international taxonomical work. It is partly due to the fact that tropical collections are accumulating so fast that many large herbaria are overcrowded. Furthermore, the number of herbaria is still increasing.

On the other hand, monographers are still scarce—or monographic work is not sufficiently envisaged to be the major source of creative work —and the available time of each monographer, in contrast with the dynamism of collections, remains static, i.e. twenty-four hours in a day and night.

A long experience with the Flora Malesiana revisions, which cover only a part of the tropics, has taught that completeness in ticketing all sheets —which is generally a multiple of all collecting numbers—of all herbaria in the world containing Malaysian plants is an impossibility. And from this experience I infer that such a procedure for a monograph of even only a medium-sized family would lead to insurmountable personal, technical, and financial difficulties; it requires an immense amount of time from the side of the monographer to cope with the routine work involved.

To give a slight idea of what colossal numbers of sheets must be revised for a monograph, in a study of Cyperus only for Malaysia and from a limited number of herbaria, about 17,000 sheets passed through the hands of Mr. Kern for comparison or identification and ticketing! For Fimbristylis, the number of sheets was about 8,000.

The historical development of plant taxonomy and distribution of collections has led to the present situation of rather few large world herbaria in which collections are presented and worked on from *all* parts of the world, and rather few very large herbaria which are more or less concentrated on certain major regions of the World (Africa, New World, Old World, Australia, etc.). Whether we like it or not, this situation has to be accepted.

Most of these institutes have less scientific staff members than would be desirable; some are even ridiculously understaffed. Generally staff members must, by necessity, perform official and routine work and are left little time for monographic work.

Combining this need of time on the side of the monographers with the just mentioned immense increase in sheets, there is an absolute necessity for them to use their time as efficiently as possible, resulting in limiting their work primarily to essential material and to that which is immediately available, rather than to strive towards completeness in ticketing all specimens of their group they can lay hands on. After all, a revision or monograph derives its value from its usefulness, from keys that work, from the degree of accuracy by which genera and species are delimited and described, and not from immense lists and enumerations of specimens from this or that herbarium.

I have touched on this subject in my preparation of the *Flora Malesiana* (ser. I, vol. 1, p. lxv) in a chapter on the policy of distributing duplicates as advocated and applied by the late Dr. Merrill in the Philippines who was in a similar position as we were at Bogor and Brother Alain in Cuba. Dr. Merrill has recommended that the tropical collectors and institutes take the initiative and distribute duplicates to the large world herbaria, specially to those from which it can be expected that they will name them immediately or in future, and to those where already large, authentic collections are represented from the region where the new collections are made. Of course the tropical institutions cannot expect to come on terms of an exactly balanced exchange, as the world herbaria have generally little to offer in this respect. Dr. Merrill did this always on what he called a "free exchange basis," that is: both parties give what they are able to produce. As far as material is concerned, the tropical institutions will therefore be largely the donating party.

But their effort is materially rewarded in several respects: firstly, the collections, provided they have been preliminarily identified to families and preferably to genera, come into "scientific circulation," they are "available" and will come more easily under the eyes of monographers, interested staff members, or visitors of the large institutes. Secondly, wide distribution of duplicates safeguards collections against calamities. Thirdly, the reward to the donating party will exist in the ultimate naming of its collections by specialists. Fourthly, its initiative and diligence provides the donating institution with favourable contacts abroad and with specialists; it will stir up interest in tropical plants. In passing I may give the practical hint of printing at the bottom of each duplicate label a request that any new identification of the sheet be kindly brought to the notice of the donating institution.

The history of the exploration of the Philippine flora, through the impetus of Dr. Merrill, proves the wisdom of the policy just mentioned. Even though the calamity of war came over Manila and destroyed what had been built during two decades of extremely hard, intelligent, and diligent work, the liberal way in which duplicates had been distributed still guarantees the possibility of writing a complete Flora of the Philippines.

The rich collections assembled in tropical centres must be brought to the notice of the workers and visitors of the big world herbaria. This is the duty of tropical assembling places, and besides a duty it is a great privilege, because tropical botany will, for at least half a century to come, not only be mostly dependent on, but will also benefit from contributions of the great scientific centres in the temperate regions of the globe.

I believe that Brother Alain has touched on a subject worthy to explain during this Congress which serves to cultivate goodwill, understanding, tolerance, and cooperation. On one hand I believe he underestimates the labour involved in monographical work; on the other hand, he underestimates the extreme value of tropical herbaria taking the initiative in their own hands. Tropical herbaria should recognize the extreme value of a very liberal policy of distributing duplicate specimens of good material of native plants to the world herbaria. Specialists, on the other hand, are invited to give timely notice, preferably in Taxon, of the subject of their intended monograph or revision. In this way a satisfactory interaction and cooperation can be realized.

DISCUSSION

E.H. WALKER: The collection at Manila was destroyed by fire during the war, fortunately many duplicates are in the Smithsonian Institute. This illustrates the need for wide distribution of duplicates. Breakdowns in the loan of this material call for more cooperation between directors.

PROBLEMS IN A SPECIALIZED BOTANICAL DEPARTMENT

G.A. PROWSE

Fish Culture Research Station, Batu Berendam, Malacca, Federation of Malaya.

While a botanical department of a freshwater fish culture research station is not strictly speaking the same thing as a botanical institution, many of the problems are similar, while others will be peculiar to the station itself. For that reason it seems worthwhile bringing these problems before a meeting of this kind, with the hopes that the ensuing discussion may result in their solution, or at least suggestions of their solution.

Taxonomy. Limitations of staff make it necessary that a botanist working in such a station as ours undertakes taxonomic studies on the various plant groups, although unlike other botanical institutions, he is at least limited to those plants in an aquatic environment. The botanist here, however, cannot afford to confine himself to one particular group and must spread his efforts, although inevitably he finds himself taking a greater interest in one of the groups. Because of this he finds himself dependent on the goodwill and cooperation of others elsewhere, and various problems necessarily arise.

LITERATURE

In common with other institutions, a newly-opened fish culture research station always finds itself short of the relevant reference works. This is as true in the botanical department as elsewhere. Many essential books are scarce or out of print, while others are so expensive as to be beyond the department budget. It is vitally necessary, particularly when describing a new species, that the botanist should have all the available reference works at hand. The lack of this is seen in the appalling number of synonyms for many organisms. Photo copying seems to be the answer to this lack of relevant literature, and it can take several forms. Photostats are large and easily read, but they are comparatively expensive and are better bound for storing. Microfilms are cheaper but necessitate a special reader and are troublesome to store, and it is not always easy to refer to a page and illustrations at the same time. Microcards, where they have been printed, are much better, and are ideally used with a special reader but are quite easy to read with a dissecting microscope. Furthermore they are black print on white background, and are easy to store in filing cabinets, being the same size as a filing card. In cases where microcards have not been made, microtape can be made from an existing microfilm and gummed on to a filing card to make what is in effect a microcard. The extra cost is very little. All these methods may be beyond the budgetary limit when numerous large works have to be copied.

COLLABORATION OF WORLD AUTHORITIES

Lack of literature at hand means that either we must borrow, or else send material elsewhere for identification. With the macrophytes, particularly the flowering plants, good herbarium specimens should present little difficulty. With the microscopic plants, however, especially the algae, numerous special problems arise. Drawings of the organism, in as many aspects as possible, or good photographs are often valuable, but there is always the danger that the artist's interpretation is not strictly accurate, and a photograph always lacks depth of focus. Nevertheless, in the absence of the actual organisms themselves, these can be a very good second best.

The despatch of actual material is a little more difficult and entails special methods. The usual method of preserving algae is in 5% formalin, and for things like desmids or diatoms, where the structure of the cell wall is important, or for the Chlorococcales, it seems perfectly adequate. For cell contents such as in *Spirogyra*, it often causes distortion, while the more delicate flagellates may become almost unrecognisable, and colonial forms may break up. In such cases Picric acid, or one of the compound preservatives might be better and it would be necessary to experiment. The flagellates in particular are a difficult problem as they so easily become unrecognisable.

Permanent slides suggest themselves as an answer, and they are particularly important for the preservation of holotypes. The mounting of the frustules of diatoms is too well known to cause much concern. With other algal groups it is not so easy. The serial dehydration necessary for many mountant fluids often leads to the distortion or complete loss of the organism concerned.

A direct mountant is indicated, and in this respect I have found Polyvinyl alcohol very useful. It both fixes and mounts the living organism and can be diluted with water to the required strength to prevent plasmolysis. It will set hard, although in the wet Malayan climate I have found it better to encourage its drying-out in a desiccator. Its main disadvantage is that objects become so transparent in it, and it may be necessary to add a dye. Glycerine mounts, while easily prepared and useful, are too fragile to send by post. More experiments are obviously needed to find the best permanent mountants for the algae.

The ideal way would be to send living material, for then it could be examined in the living state and even cultured. Naturally this presupposes despatch by air, and if it is possible to send the material direct from airport to airport without intervening postal delays, so much the better. The problem is to keep the organisms alive and in reasonable condition throughout the journey. Drastic variations in temperature are nearly always harmful to algae, and these are just what they seem to be subjected to when carried from country to country. To overcome that, it would be necessary to insulate the container as much as possible, or even enclose it in a thermos flask, with consequent increase in air-charges. As containers for the water samples, I have found polythene bags very useful, as there is little danger of them breaking, and several of them could be packed inside a single larger container. Another problem is bacterial action, which can become quite serious in the time taken for the sample to reach its destination. Field collections of water samples inevitably contain some bacteria, and these are certain to multiply. Perhaps the careful use of one of the antibiotics may overcome this difficulty. A further serious difficulty is oxygen deficiency in the water. It must be remembered that the algal specimens will be travelling in the dark, and therefore any oxygen used up in their respiration cannot be replaced by that due to photosynthesis. Furthermore, in natural field collections there are bound to be a number of small animals which will further deplete the oxygen supply. The tubes or polythene bags should not be more than half full, and any dense suspensions should be diluted with well oxygenated water. Living samples have been successfully sent over long distances, but they have usually been pure cultures with very few organisms in the container. Thus if a pure culture, particularly bacteria-free, could be maintained, it would be no difficulty to put a minute drop in $\frac{1}{3}$ tube of sterile culture solution. The establishment of such cultures, while essentially part of the work of a fresh-water fish culture research station, is outside the scope of this paper.

The foregoing should give some idea of the problems which occur in such a specialized botanical department as ours at Malacca, and I have no doubt there are many other such departments with similar problems. I have indicated some of the possible ways of solving these problems, but I am hoping to gain much information and advice from the discussion which will follow.

DISCUSSION

E.H. WALKER: Some of the problems are bibliographical, and I hope, as I have mentioned from time to time, you will support the meeting on this subject.

M.S. DOTY: Polythene bags are permeable to air, although not to water. The amount of water may be profitably reduced until it forms only a thin film which can absorb the maximum oxygen.

G.A. PROWSE: Desmids and flagellates are the most difficult.

M.S. DOTY: Some fixatives are of value.

E.H. WALKER: Cooperation between institutes and airlines are needed to improve transit facilities.

H.M. BURKILL: The use of the diplomatic bag has been advantageous in difficult cases.

E.H. WALKER: We need scientific attaches.

J.H. HÜRLIMANN: They could help in the numerous quarantine difficulties.

P. WEATHERWAX: Soil samples are often unacceptable to the health authorities, but they can be sent through with cooperation. What are conditions like in the freight holds of aircrafts?

M.S. DOTY: Specimens must go in the pressurized part of the plane; the freight holds are freezing. Packages should be clearly labelled to this effect, and, if possible, be put in the hands of the second officer of the aircraft, who can also reduce delays or unfavorable storage on the ground at intermediate stops.

THE VARIOUS TECHNICAL ASPECTS OF BOTANICAL RESEARCH IN NEW CALEDONIA†

ROBERT VIROT

Muséum National d'Histoire Naturelle, Paris, France.

This note aims essentially at suggesting a few measures which would enable the conditions of botanical research within our territory of the Southwest Pacific Islands to be improved.

SYSTEMATICS

In this field, efforts should be directed, above all, towards enabling the investigator—who is not always an expert—to have the means of making a *rapid and exact* determination of the specimens he has gathered or, inversely, towards providing him with a precise representation of the morphology of the species he wishes to obtain.

In this connection, it should first of all be made clear that no adequate reference herbarium exists on the spot at present. The material which can be utilized is limited, in this case, to fragmentary collections provided exclusively by metropolitan and foreign botanists. The investigators thus find that they are almost always obliged to have the necessary determinations made, or confirmed, by the competent services of the Natural History Museum in Paris, this leading to a considerable loss of time. As a palliative to this difficulty, the following measures would appear to be highly recommendable:

a) the drawing up of several basic herbaria, as complete as possible, centralised in Noumen at the seat of the scientific and administrative bodies who are the most directly interested: Institut Français d'Océanie, Commission du Pacifique Sud, Service des Eaux et Forêts, Service de l'Agriculture, Musée néo-calédonien. Botanists who are collectors "de passage" should always undertake to enrich these herbaria by the deposit of duplicates; and where only one specimen of a new species is gathered, this should be provisionally represented by a full-sized photographic reproduction;

b) the opening, *for each species*, of an identical file, the number of these corresponding to the basic herbarium and which will contain, in addition to the classical elements, a very detailed morphological description, a synonymy, vernacular names, general, chorology, list of the known neo-caledonian localities, ecology, etc. A photographic documentation *carried out in the natural* state and referring not only to the leguminous aspect as a whole (port), but also to details: leaves, flowers, fruits.

Another problem, of primary importance, is that of a practical bibliography. The only flora published up to the present—that of A. Guillaumin (1948)—was intended by the author as a preliminary work only, destined to meet immediate needs. Consisting of synoptic tables only and totally deprived of illustrations, it is accessible only to investigators who are already well-informed. In addition, the rigid framework of its presentation does not lend itself easily to amplifications, a disadvantage which is particularly inconvenient when one realises that there still remains a great deal to be done before the floristic inventory of New Caledonia is complete. In our opinion, the ideal formula to adopt is to be found in the drawing up of a flora carried out on the principles which inspired O. Degener for the publication of his *New Illustrated Flora of the Hawaiian Islands*; a perforated sheet—movable—for the description of each species, the recto being reserved for the text (diagnosis, ecology, chorology, etc.) and the verso for several sketches of their features. It is clear that such an arrangement would allow for the easy insertion of additional sheets concerning new species in the same way as it would allow for the replacement of obsolete keys of determination by up-to-date documentation.

RESEARCHES ON THE TERRAIN

Cartography. For the moment, the topographical Services of New Caledonia put two types of terrestrial maps at the disposal of the public: 1:40,000 maps and 1:10,000 maps. Utilized specially for the delimination of mining and agricultural concessions, the 1:40,000 maps cover only a fraction of the area of the Grande Terre. Further, their planimetric representation is

† Presented by J.H. Hürlimann.

simplified in the extreme. Indeed, we find only the contours of the coast and the waterways and roads, with a few summary particulars with regard to swamps, the European settlements, the large forest areas, etc. As regards the relief, dotted lines indicate the position of the principal ridges and the peaks mentioned are mostly defined, not by their altitude, but by their order number within the triangulation framework. Although the 1:10,000 maps in curves are of course more exact, they exist only in scattered sheets and cannot therefore serve for purposes of general study.

However, all these gaps are shortly to be satisfactorily solved, thanks to the publication of a new map under the auspices of the Institute Géographique National. Drawn up from aerial surveys, this map, the final scale of which is not yet fixed (1:50,000 or 1:1,000,000), will cover not only the Grande Terre as a whole but also the islands geographically dependant on it: Pine island, the Loyalty group, etc.

We would also mention the excellent geological map 1:100,000 in 10 sheets (Grande Terre and Pine Island) drawn up following on the work of the mission led by P. Routhier from 1946 to 1949. Already partially on sale, within the programme of publications of the Office de la Recherche Scientifique et Technique Outre-Mer, it represents, a considerable advance compared with our previous knowledge in the subject and will be of inestimable service to the ecologist.

Ecology. While the equipment of the pedological section of the French Institute of the Pacific Islands now enables very complete analyses of soils to be carried out, nothing positive has as yet been accomplished in the field of micro-climatological researches. The local National Meteorological Service—whose observation stations are, incidentally, almost all placed in the low-lying regions near the shores—directs its activities mainly towards objectives that are primarily practical: definitions of the characteristics of the general climate, weather forecasts with a view to the improvement of the conditions of air and maritime traffic, etc.

The accelerated developments of the ecological discipline requiring data which are more and more exact, from now on the serious study of the dynamics of the leguminous groups of New Caledonia, cannot be envisaged without the support of more solid arguments than the sporadic measurements carried out up to now by naturalists in the course of their movements. In the United States, for instance, the use of automatic and portable micro-climatological stations placed within the various strata of given groups has already given very encouraging results. Noted every week, the tapes of the registering instruments thus constitute homogeneous series of continued observations. This technique, it seems to us, should find a perfect application within the limits of our Southwest Pacific territory, more particularly within the upper zones of the mountainous regions where it is not always easy to remain for sufficiently long periods.

Transport. At the present time the roads accessible to motor traffic are limited to two arterial roads—running along the East and West Coasts—and communicating with one another by three or four transversal roads. In very many cases this arrangement hinders, in particular, the rapid approach to areas of work situated in the mountain groups. Very often, long and fatiguing distances over extremely varied ground have to be covered on foot in order to reach the goal which has been set. During the ascension, the investigator, obliged to mobilise all his physical forces in overcoming natural obstacles, can devote only a small part of his intellectual faculties to detailed scientific observation. Heavy rains or intense sunshine often add to this depressing picture.

In the absence of suitable landing ground, the light airplane would not be suitable to radically overcome these difficulties, but the helicopter, to which the problem of a large landing ground does not apply, certainly represents the solution for the future. Incidentally, one of these helicopters used experimentally by a local industrial company for mining prospection has, up to the present, given entire satisfaction. Thus put down in the area of work without any previous fatigue, the investigator finds himself able to give of his very best during the time he remains on the spot and, afterwards, also during the descent towards the lower lying regions.

PHYTO-SOCIOLOGY AND A MAP OF LEGUMINOUS GROUPS

The transport difficulties of which we have just spoken have very considerably retarded the inventory of the neo-Caledonian vegetation. Indeed, great progress still remains to be made in the knowledge of nature and the distribution of the leguminous groups. In order to attain this end, it will be necessary to call in the assistance of aerial photography on a large scale and in colour. Personally, in the course of flights at low altitude, we noted the clearness with which certain masses physiognomically very individualised, such as the Mangrove, the herbaceous belts of the sandy beaches, and the photophileous forest of *Melaleuca Leucadendron*, were to be distinguished, thanks to their morphology and their colouration. Of course, a general map, made up from an assembly of aerial clichés, does not in any case do away with the classic analytical surveys made on the spot; but, *judiciously interpreted*, it possesses the enormous advantage of enabling us to give the precise localisation of the large laguminous formations and, as a consequence, to rationally coordinate the researches on the ground.

DISCUSSION

M.S. DOTY: I fear helicopters may prove out of the question; it costs US $400 to fly one for an hour.

J.H. HÜRLIMANN: I admit we may not be able to realize all our hopes, but the possibility is noted.

NOTES ON THE TECHNIQUES EMPLOYED FOR THE COLLECTION OF BOTANICAL SPECIMENS IN PAPUA AND NEW GUINEA†

J.S. WOMERSLEY

Division of Botany, Department of Forests, LAE.

The collection of botanical specimens in tropical countries has always presented a number of problems not faced by collectors in temperate latitudes. The normally high humidity combined with temperatures usually exceeding a minimum of 75 degrees fahrenheit bring with them the problem of rapid fungal and bacterial growth. A large number of tropical plants, particularly those of the rain forests, develop abscission tissue with extreme rapidity in the leaf petioles and petiolules. An inspection in any herbaria of the specimens of tropical plants will reveal how widespread this is.

Various botanists in the tropical world have met these problems in a variety of ways. Eleven years experience in Papua and New Guinea has produced the techniques and procedures which will be described below, but before doing so it is necessary to give some background regarding the nature of the country, its people, and transportation.

In New Guinea, botanical collecting has been and still largely is associated with geographical exploration. As yet little has been done toward the exhaustive compilation of the flora of a limited area. The botanist and his equipment must therefore be mobile. Road transport is available to a limited but rapidly increasing extent. Air transport particularly by light aircraft carrying loads up to 1,200 pounds weight is widely available. Water transport descending in size from coastal vessels of about 300 tons to canoes is generally available in coastal areas. Canoes and small launches may be used to some extent on most lowland rivers. A few areas may be reached by float plane, landing on lakes.

Using the most appropriate transport, the botanist gets himself into the general area he plans to visit. Further progress is on foot with human porterage as transport for the collecting equipment. Fortunately, in most areas the local inhabitants are prepared to assist parties by carrying equipment and supplies. The rate of pay varies rather widely throughout New Guinea. The maximum load is about 40 pounds per adult, or where a load is carried jointly by two men, a total of 80 pounds weight. Equipment must therefore be of a size and weight which allows it to be made up into suitable sized bundles for carrying.

The actual equipment used differs somewhat from that of a botanist in temperate countries. Most of the flora is woody so that an axe is indispensable if justice is to be done with this great group of plants. One is led to suspect that at least as far as New Guinea is concerned the difficulty of falling large trees has sometimes turned the attention of botanists away from the tree storey. Lane-Poole, when collecting in New Guinea in the 1920's and being almost exclusively concerned with the forest flora, used a rifle successfully to bring down branches of forest trees. A shot gun can also be used to good advantage at times. Secateurs are extremely useful for cutting the actual specimens, while heavy gloves or a machete facilitate the collection of thorny palms and trees.

As the specimen is finally prepared, usually represents but a fragment of the original plant, adequate descriptive field notes are essential. The value of the collections is greatly enhanced and frequently identification facilitated if wood samples are collected. General practice in New Guinea is to obtain a wood sample of all plants having a woody stem. If this exceeds 6 inches in diameter, the sample is usually trimmed to 15 inches long with a cross section of 4 inches by 4 inches. Bark is retained wherever possible. Where weight is a serious consideration, the wood sample may be reduced in size.

Turning to the specimens of foliage, every effort has to be made to collect flowering and fruiting material of each species. Most tropical herbaria have a considerable quantity of sterile or inadequately fertile material which can be only partially identified and must await the recollection of more adequate material. This does not mean that under certain circumstances such as a collector in a "new" country or where a plant appears to have some special interest, specimens lacking flowers or fruit should not be collected. I can repeat, though, that a wood sample in such cases

† Presented by H.M. Burkill.

can be of immense value in identifying the collection.

The technique adopted for preparing the botanical specimens in Papua and New Guinea is based on the formalin technique of Schultes, used successfully by him in South America. However certain modifications have been made. At the base camp are required newsprint, folded, but preferably clipped to 18 inches by 12 inches; frames, 18 inches by 12 inches constructed as a lattice from wood 1 inch by ¼ inch thick; a rectangular tank, the inside dimensions of which are 18½ by 12½ inches by 12 inches deep, fitted with a lid; strong string; sisalkraft; (a waterproof bituminous paper); and concentrated formalin.

Actual collecting requires newspapers, frames (or wire press), strong cord (leather straps deteriorate too quickly), and labels. The specimens, suitably pruned to display the essential parts to best advantage, folded in the case of large or compound leaves, are numbered by attaching a number bearing manilla tag, the number on the tag corresponding of course to the relevant number in the field note book. Soft pencil or crayon is most suitable for numbering on the tag. Do not use ordinary ink. A pad of folded newspaper is opened so that all but the lowest sheet is folded on the left. The lowest sheet is reversed so that the fold is on the right. The numbered specimens of each collection are now placed singly between the sheets. Wherever possible, ten or more replicates of each collection should be obtained. With this number it is convenient to confine a single packet of paper to each collection. The reversed bottom sheet is finally folded around the packet thereby providing closure at both edges. The packets are then placed between a pair of wooden frames and pressure exerted by means of several turns of strong string at each end. A bundle not exceeding twelve inches in thickness is desirable. These bundles are then transported to the base camp.

The next step consists of preserving the specimens from fungal and bacterial action by immersing them in formaldehyde solution of 4% concentration by weight, specific gravity about 1.014 at 75 degrees fahrenheit. The formalin can be prepared by diluting a concentrated formaldehyde solution. As normally received in New Guinea, this rarely exceeds 35% formaldehyde by weight and should be broken down in the proportion of one part of concentrate to eight parts of water. An alternative procedure has recently been adopted with success using the solubility of paraformaldehyde in hot water made alkaline with hexamine. This produces a formaldehyde solution, the specific gravity of which is adjusted to 1.014 after cooling. Solution can readily be effected by adding about one ounce of hexamine to three gallons of water which is heated to the boiling point. After removing from the fire, slowly stir in three pounds of powdered paraformaldehyde. Due to the formaldehyde vapour produced, this can be most unpleasant. An alternative which works equally well is to place the paraformaldehyde powder at the rate of one pound per gallon in a one gallon, wide mounthed, plastic, screw top bottle. The hot water, which contains hexamine at the rate of one ounce to three gallons of water, is then added to each bottle, the lid screwed, on and the bottles shaken intermittently until solution is complete. After cooling, the specific gravity is adjusted as before. The use of paraformaldehyde has obvious advantages over concentrated formaline where weight is a factor to be considered.

Having prepared the formalin solution, the rectangular tank, the inside of which has been coated with bitumastic paint, is half filled with 4% formaldehyde. The prepared bundles of specimens referred to above are immersed, a stone may be used to stop the bundle floating, the lid put on and the whole lot left for 18-24 hours. The following day the bundle of specimens is removed; the free liquid is drained off; and it is securely wrapped in waterproof sisalkraft paper. In this condition, specimens have been kept without deterioration for three months.

The bundles of formalin preserved specimens are sent by whatever transport is available to the divisional headquarters at Lae. Here the bundles are opened, the specimens placed between drying pads which are interspersed with corrugates for ventilation, and dried in cabinets heated with 150 watt globes. Drying is complete in 24-36 hours. Where succulents or palms having a waxy epidermis are being collected, the addition of a liquid detergent to the formalin at the rate of about one tablespoonful to each gallon is advantageous in accelerating the penetration of the leaf tissues by the formalin. Probably no harm would accrue from the general use of a little detergent with the formalin.

The main attraction of this method as used in New Guinea is that the collector does not have to spend time while in the field in tending drying ovens or racks. For the successful use of the method, though, access to some central drying facility is essential.

DISCUSSION

C.G.G.J. VAN STEENIS: For herbarium work, it is essential that the morphological characters of the specimen should be well preserved. Dehiscence of leaves, leaflets, and floral members must be prevented by rapid killing. Alcohol and/or formalin are excellent, but whatever facilities are available such as heat may be used if circumstances dictate. I agree with Drs. Prowse and Walker, field characters must be recorded at collection. Otherwise such valuable information as scent, color, and glossiness will be denied to the herbarium botanists who compile the floras for practical use. It is essential that every duplicate specimen should have a full copy of the original field label.

E.H. WALKER: The original field labels on the Manila specimens were destroyed in the fire; the duplicates lack this information, which is now permanently lost. Hence the need, despite the labor involved, of providing every duplicate specimen with a copy of the field notes.

Symposium: *Vegetation Types of the Pacific.*

VEGETATION STUDY AND RECORDING†

PIERRE DANSEREAU

Institut Botanique, Université de Montréal, Montréal, Canada.

Many methods are used for describing vegetation, although much of the available literature is appallingly unmethodical in the sense that the standards are poorly defined. No valid criticism of method or approach, on the other hand, can be made without an honest effort to evaluate purpose and scope which are an ultimate measure of adequacy.

This symposium on vegetation types of the Pacific does not hope to provide a complete inventory of all synecological work, even less an accurate description of all known plant communities. Research on vegetation has been very widely scattered and many bioclimatically important areas have not been studied at all. Nor was it possible to request a uniform approach of all the participants in this joint effort. It has seemed more useful to pick contributors who had a good deal of field knowledge and who had already made a contribution to the description and interpretation of Pacific landscapes and to give them a free rein in their own course. The resulting papers are sure to be somewhat heterogeneous, and their divergence in method will no doubt be pointed out by Frank E. Egler.

It seems to me, however, that some reflections on structure variation are an appropriate preface to this presentation and that examples from various parts of the Pacific can be usefully quoted in view of subsequent correlation with the geological, historical, climatic, dynamic and other interpretations which are forthcoming. At previous congresses (New Zealand, 1949, Philippines, 1953), I have made similar contributions which by now have been amply discussed with many colleagues. I feel that a further step can be undertaken at this time, and I will therefore offer some elaborations upon the system which I have previously proposed (1951, 1952, 1953, 1957a, 1957b).

THE FEATURES OF STRUCTURE

Spatial distribution of the biomass is a function of life-form, size and coverage, which in turn may vary seasonally (relative deciduousness) and which may be caused by diverse assemblages of leaf-type and texture classes. Table 1 repeats my earlier attempts (1951, 1952, 1957a) to provide a simple, practical scale for grading actual stands of vegetation or for abstracting therefrom a number of well-individualized types.

I have previously discussed in some detail the choice of the alternates presented under each of the six criteria that appear in Table 1. But I now find that systematic application by myself and by others gives me cause to introduce certain modifications or to suggest some alternatives. Therefore Table 2 is offered as a new key to the system, and Fig. 1 shows how the symbols (now simplified) can be plotted on squared paper (8 squares high, 25 squares long).

These modifications improve the system in a number of ways.

Life-form. Inasmuch as the former "trees" and "shrubs" did not necessarily refer to plants at the adult stage of their development but only to woody individuals of a certain height, at a certain time, it is best to designate by a single symbol all such individuals. This leaves category 1 with only 5 instead of six alternatives. It will also be noted that the symbols now proposed for lianas (L) and epiphytes (E) are much easier to draw.

Stratification. In substituting this heading for "size," a more objective picture is conveyed, and the sliding scale principle is better applied. Thus, all symbols followed by the same figure (1 to 7) will situate that life-form at the same level (e.g. in the same layer) as all other life-forms coupled to the same figure. This was not so previously: e.g., Tt and Ht were 23 metres apart. Now, the synusiae are well separated, and the layers are united!

Figure 2 shows some types of vegetation that had been previously plotted with the 1951 key. Although this may be an improvement in practical procedure, it still does not allow to show a certain number of features (see *1*, Table 8), which, for certain purposes, it may be desired to illustrated.

Coverage. Therefore, some of these features

† Presented by F.E. Egler.

are added here and shown in Figs. 3, 4, and 5. The two diagrams previously published (*1*, Figure 13) and now re-plotted show in their upper layer a certain total crown coverage that could very well be the result of different stem growths. Inasmuch as the system so far has made little provision for emphasizing the closeness of stems, a new means is now offered to show this. Figs. 3, 4, and 5 outline two different approaches: one by direct drawing of independent stems and crowns (and modification of the crown symbols from circles to ellipses) and the other by drawing lines that show *how many times closer the stems are* than the normal coverage symbol allows for.

A further refinement can be introduced to represent the principal outlines of crowns as indicated in Fig. 6. There would be no particular merit in extending such categories to herbs, lianas, epiphytes or bryoids, inasmuch as leaf type pretty well determines outline anyway.

Of course there always remains another alternative, which would consist in prolonging the strip many times: 50, 75, 100 or more squares, instead of 25, would allow an almost literal representation of the principal life-form types along this linear transect.

Function. Relative deciduousness (or leafing periodicity) is of course quite important for it affects volume at different seasons. But there is another item of great importance to vegetation analysis, the *dispersal* function. This has been discussed at some length by Dansereau and Lems *(6)*. It is very remarkable that the different layers show such marked contrasts in the distribution of, for instance, wind- and animal-dispersed species.

In a recent paper, Keay *(8)* analyzes a second-growth forest in Nigeria where he finds that wind-disseminated tree species are dominant. On the contrary, in the Canary Island laurel forest, bird-dissemination is the rule at the tree level. In the temperate forests of the Pacific, a very large number of trees are dispersed by wind: from Alaska to northern California, the tallest members of the needle-leaved forest *(Picea, Tsuga, Sequoia, Pinus)* have very light diaspores, whereas a greater number of the shrubs and herbs have fleshy fruits. The Mediterranean area of California, on the other hand, has a vast array of oaks and some fleshy-fruited trees like *Arbutus.* A similar situation obtains in New Zealand, with the northern forest rich in fleshy fruits, the southern rich in nuts and small winged diaspores.

CORRELATIONS OF STRUCTURE

Although this system was devised essentially, in fact exclusively, in order to show the *features* of vegetation and *later and otherwise* relate them to environmental elements (causal or not), in actual recording it is found useful to plot a certain number of the latter, for instance site conditions. Table 3 offers a small repertory of the usual alternatives: climate, relief, qualities of soil, land use.

THE MAPPING OF STRUCTURE

The problems of mapping are very numerous and each scale presents its own difficulties. No easy rules can be established (and surely none are explicitly recognized) when it comes to stripping a large-scale map (say 1 inch = 1 mile) of its detail if the information is to be relayed to a smaller scale (for instance, 1 inch = 8 miles). As a matter of fact, it is rarely a matter of omitting detail; it is more likely a matter of interpreting the units of the large-scale map so as to lump them into units of a greater order of magnitude. This involves a judgment, something which is not strictly a matter of record or observation, of compilation of features that already lie on the map itself, but something that is essentially classificatory. An example of this is provided by the excellent maps of the Toulouse group, for instance Gaussen's *(1)* Perpignan sheet. The colours represent each a "series" (we would say a *sere*): a number of plant communities, usually of increasingly complex structure, which lead to a terminal stage.[1] The intensity of the colour, on the other hand, does indicate changes of structure. This procedure appears to me worthy of standardization and lends itself to a very useful procedure. Thus, for instance, the kauri forest area of New Zealand or the highland pine region of the Island of Luzon (Philippines) in their developmental stages from grassland or scrub to mature forest could be represented by a series of structure diagrams, and on a map by the corresponding colours.

Schmid *(9)* had already recognized the desirability of producing structure diagrams in the margin of vegetation maps in order to show the range of variation which must of all necessity be involved in any one category of vegetation type [except on a very large-scale map which really attempts to show the exact status of the plant-

[1] This is generally the climatic climax although occasionally an edaphic or topographic climax. See *(3)* for a fuller discussion of this topic.

cover (Pflanzendecke) at one time!].

It is hoped that the present schemes lend themselves to fairly wide application and can be used to reveal at a glance the many-sided aspects of vegetation types that play an important rôle in the landscape. It may well remain to demonstrate to the biologist and, to the paleontologist what the historical and physiological conditioning of these types really is. It is granted, of course, that such considerations are fundamental, but the fact that they are virtually disregarded in the present instance, should not disguise the urgency of a better comparative understanding of the functional aspect and distribution of vegetation types as they are to be observed in the living landscape at present.

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Table 1.
Six categories of criteria to be applied to a structural description of vegetation types.

1. LIFE-FORM

T	trees
F	shrubs
H	herbs
M	bryoids
E	epiphytes
L	lianas

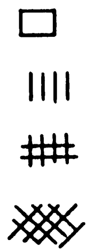
2. SIZE

t	tall	(T: minimum 25 m)
		(F: 2-8 m)
		(H: minimum 2 m)
m	medium	(T: 10-25 m)
		(F,H: 0.5-2 m)
		(M: minimum 10 cm)
l	low	(T: 8-10 m)
		(F,H: maximum 50 cm)
		(M: maximum 10 cm)

3. COVERAGE

b	barren or very sparse
i	discontinuous
p	in tufts or groups
c	continuous

4. FUNCTION



d	deciduous
s	semideciduous
e	evergreen
j	evergreen-succulent; or evergreen-leafless

5. LEAF SHAPE AND SIZE

n	needle or spine
g	graminoid
a	medium or small
h	broad
v	compound
p	thalloid

6. LEAF TEXTURE

f	filmy
z	membranous
x	sclerophyll
k	succulent; or fungoid

Table 2.

A revised scheme of the six categories of criteria to be applied to a structural description of vegetation types.

1. LIFE-FORM

W	erect woody plants
L	climbing or decumbent woody plants
E	epiphytes
H	herbs
M	bryoides

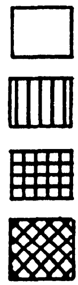
2. STRATIFICATION

1	more than 25 metres
2	10-25 metres
3	8-10 metres
4	2-8 metres
5	0.50-2 metres
6	0.10-0.50 metres
7	0.0-0.10 metres

3. COVERAGE

b	barren or very sparse
i	interrupted, discontinuous
p	in patches, tufts, clumps
c	continuous

4. FUNCTION



d	deciduous
s	semideciduous
e	evergreen
j	evergreen-succulent; or evergreen-leafless

5. LEAF SHAPE AND SIZE

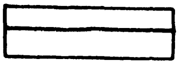
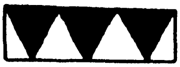
n	needle or spine
g	graminoid
a	medium or small
h	broad
v	compound
p	thalloid

6. LEAF TEXTURE

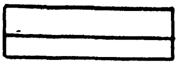
f	filmy
z	membranous
x	sclerophyll
k	succulent; or fungoid

Table 3.
Categories and symbols for recording site conditions.

a. UTILIZATION

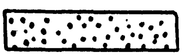
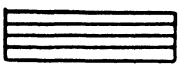
virgin	
pastured	
lumbered	
harvested	
ploughed	
burned	

b. SOIL STRUCTURE

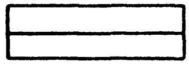
soft	
medium	
hard	

c. SOIL TEXTURE

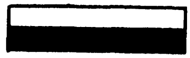
(A, B, C horizons)

bedrock	
boulders	
pebbles	
sand	
silt	
clay	
organic	

d. DRAINAGE

excessive	
good	
deficient	

e. RELIEF

flat	
depressed	
rolling	
abrupt	

f. EXPOSURE

use symbols of compass,

N, S, E, W

e.g.: NW

g. CLIMATE

use Köppen symbols

e.g.: Dfc

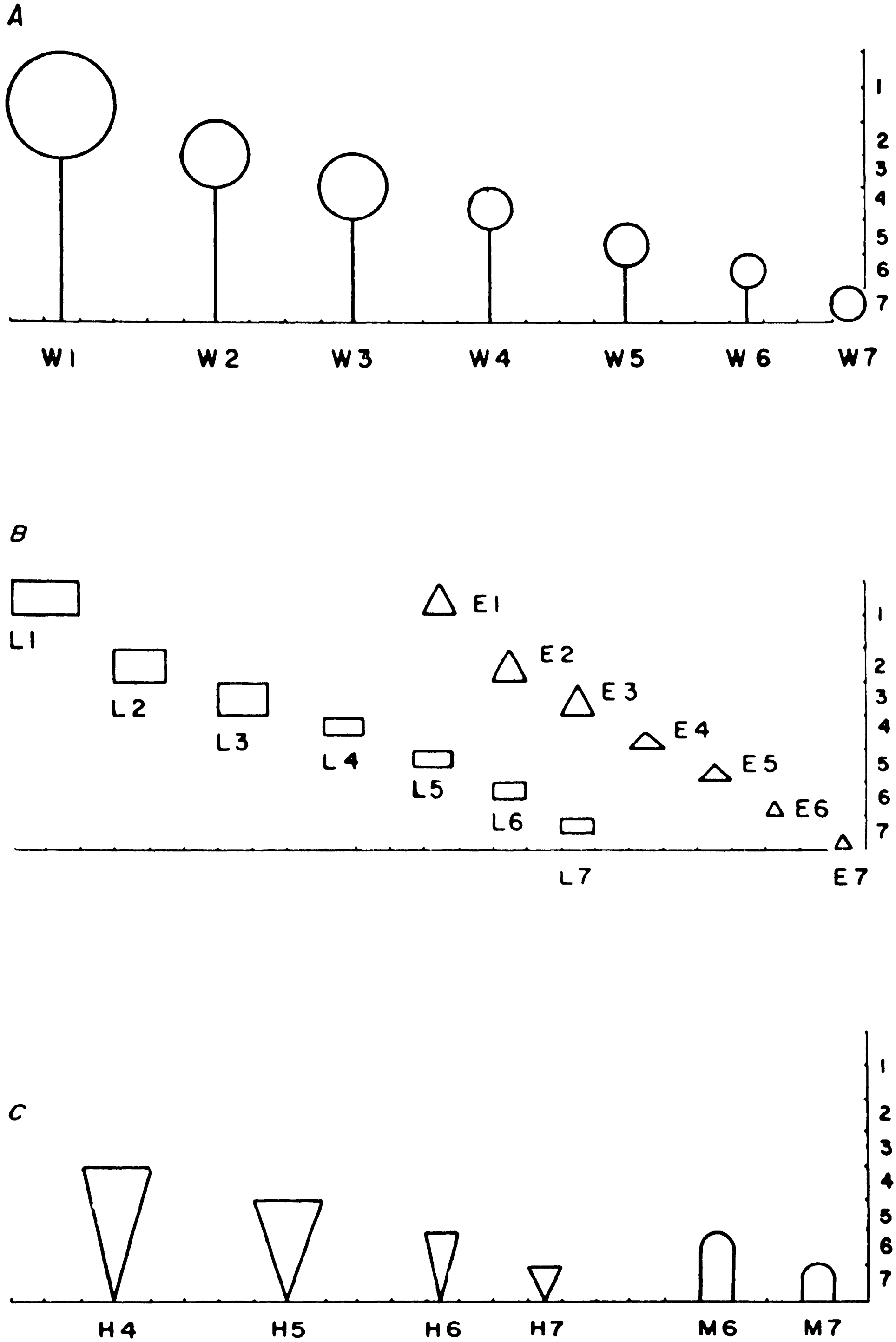
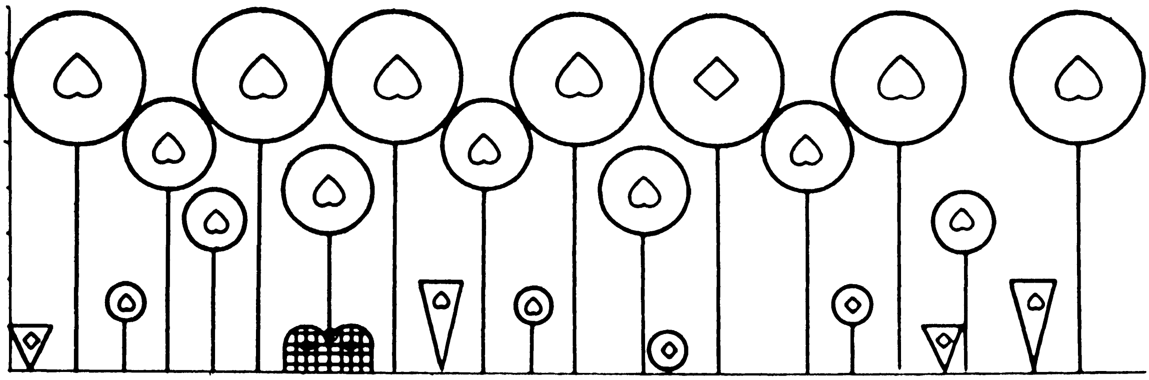
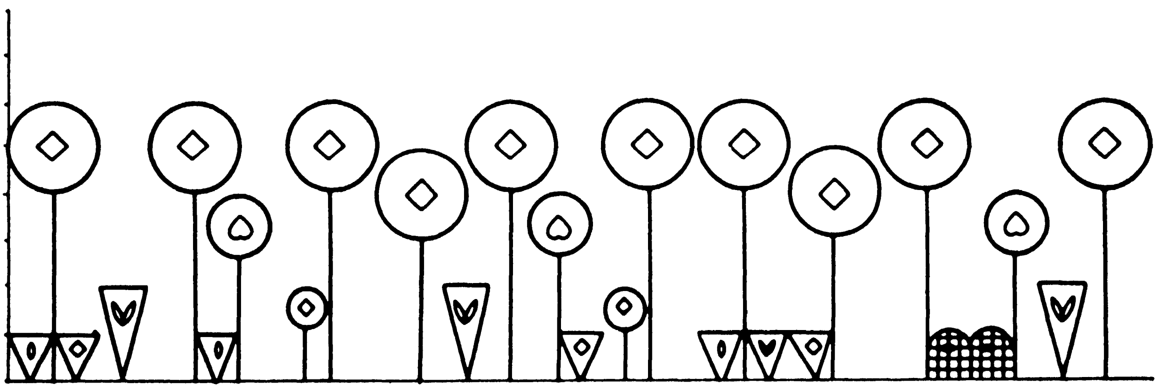


Fig. 1. —A graphic representation of all the symbols combining criteria 1 and 2 of Table 2. This is a new scheme, superseding the one proposed in 1951.



Aceretum rubri W1dhze(azb) W2dhzi W3dhzp W4dhzi
W6dhzi(azb) H6dhzb W7dazb H7dazb
M7enxp



Betuletum populifoliae W2dazi W3da(h)zb W4dhzb
W6dazb H6dvzb H7dg(a,v)zp
M7enxp

Fig. 2. —A red maple stand and a wire-birch stand plotted according to the new scheme (Table 2 and Fig. 1). (Compare with Figs. 13 and 14 of the 1951 version.)

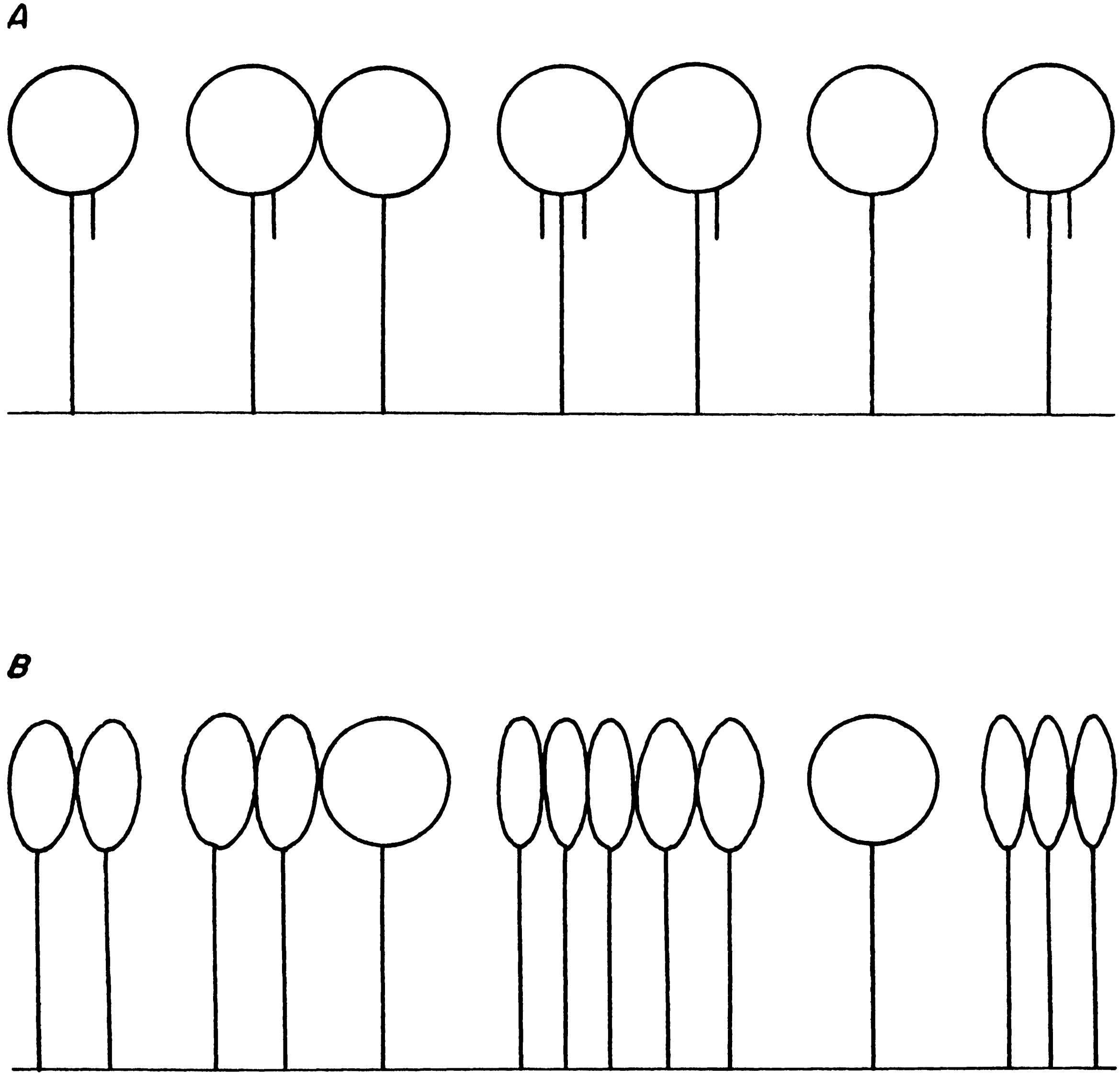


Fig 3. —The upper layer of the red maple stand (see Fig. 2), showing different distribution of stem and crown spaces corresponding to identical coverage and illustrating two ways in which the stand can be plotted.

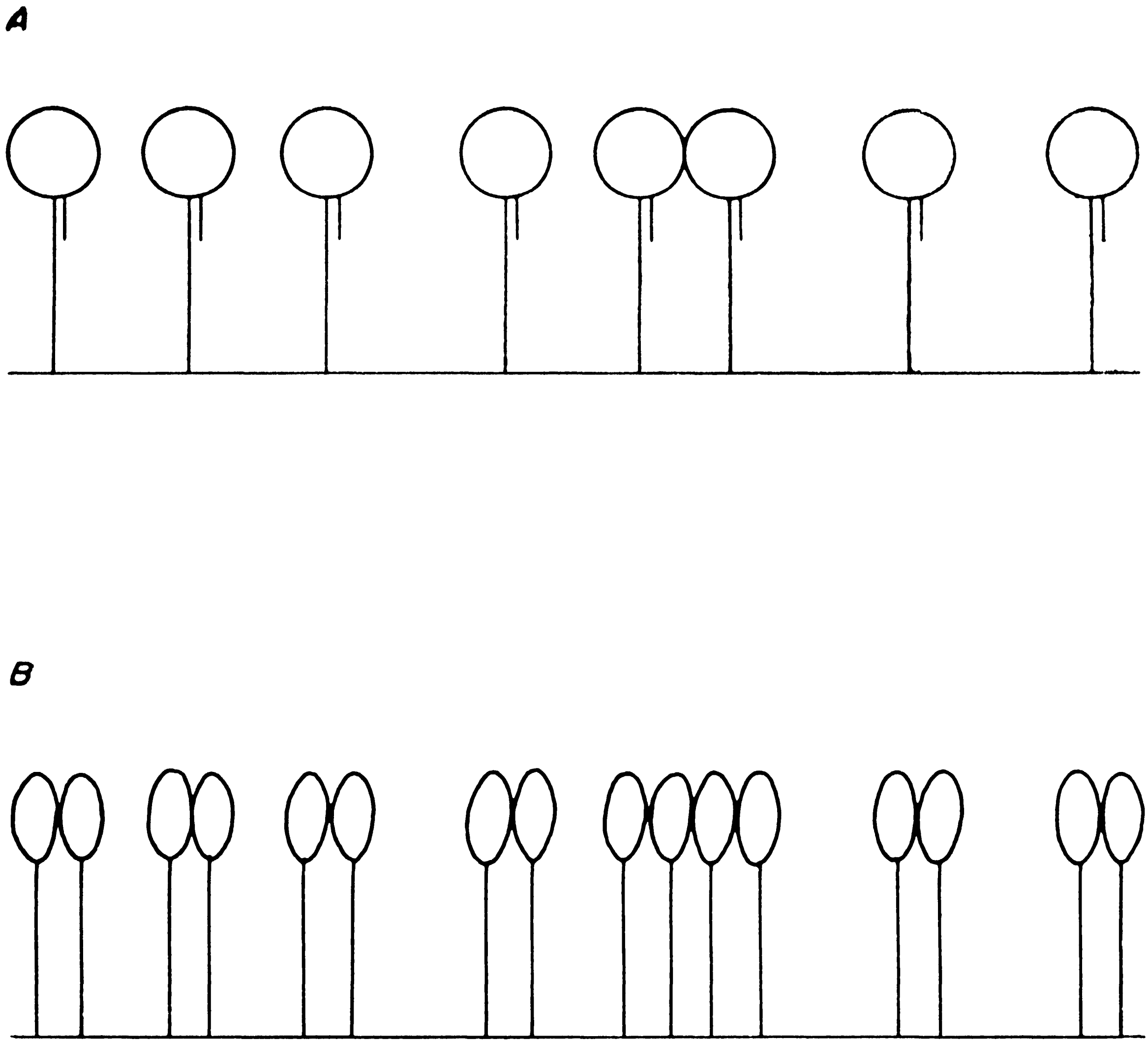


Fig. 4. —The upper layer of the wire-birch stand of Fig. 2, illustrating variations in stem within an identical total crown coverage and two ways in which these differences can be plotted.

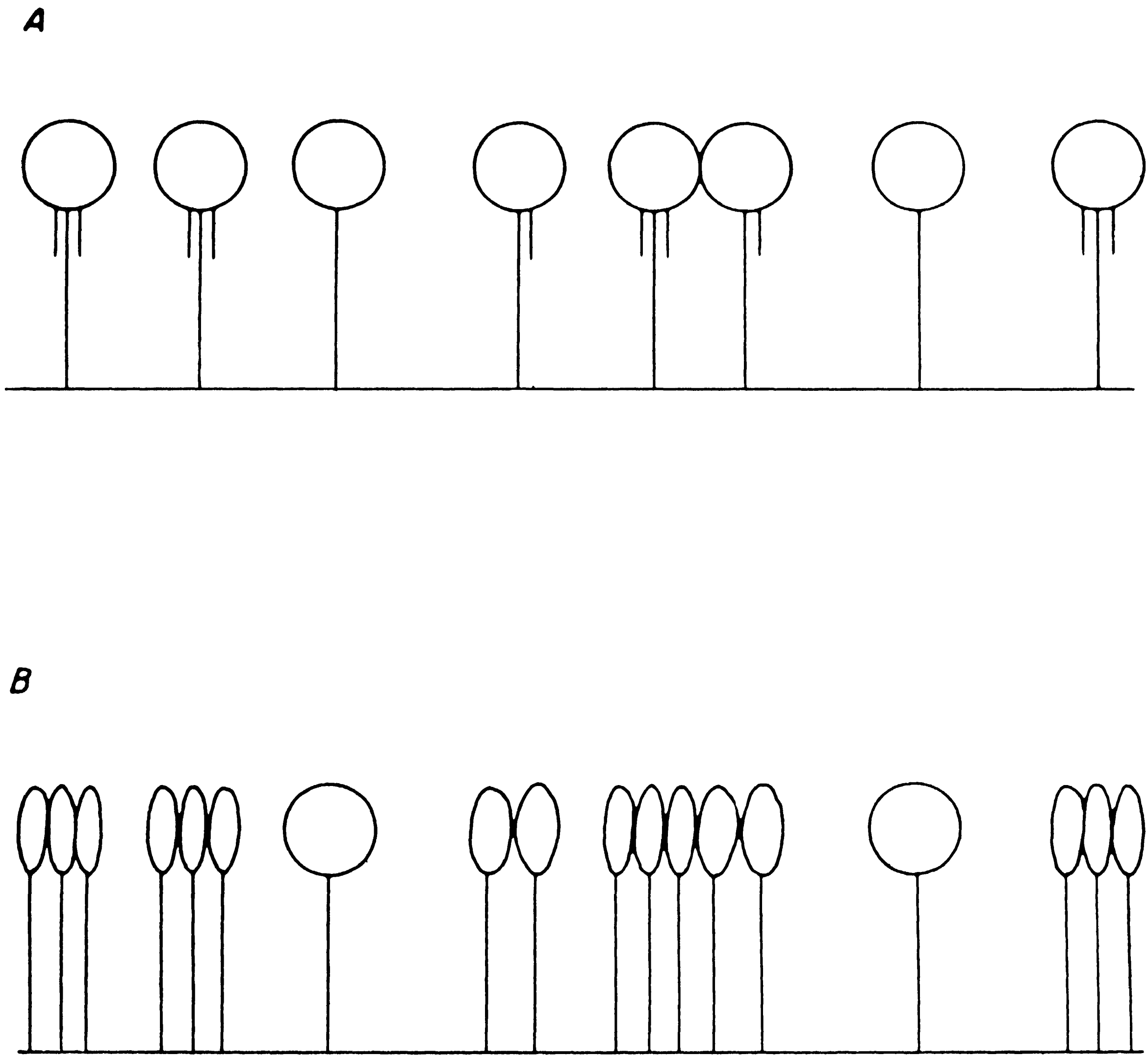


Fig. 5. —Another variant of crown-stem distribution in a wire-birch stand (see Figs. 2 and 4).

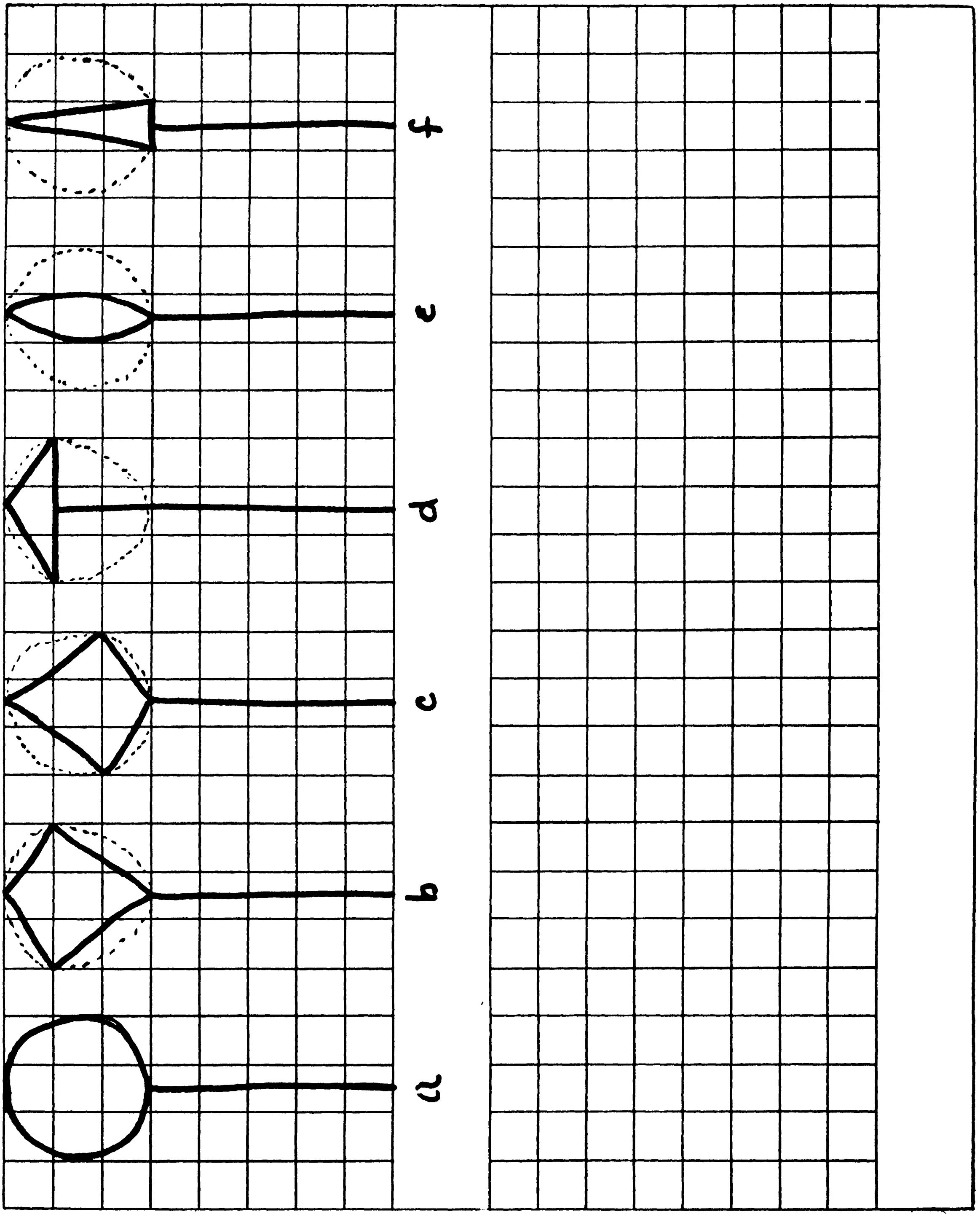


Fig. 6. —A series of crown outlines for tall woody types (W 1, 2, 3), which can fit the perimeter of the symbols in Fig. 1.

GRADING AND INTEGRATION OF EPIPHYTE COMMUNITIES†

T. HOSOKAWA, M. OMURA, and Y. NISHIHARA

Department of Biology, Kyushu University, Fukuoka, Japan.

INTRODUCTION

It is possible to say that there may be considerable subjectivity in classifying vegetation, even if we adopt the abstract method of Zürich-Montpellier's school, attaching great importance to characteristic species, which is commonly employed in continental Europe. We have a strong urge to find some more objective method of classifying vegetation. Fortunately, our attention was called to Goodall's objective method *(1)* for the classification of vegetation. This method is based on positive interspecific correlation of major component species by making use of the values of their frequency. We modified his method to some degree *(1)*, and used it and Sörensen's method *(5)* for classifying epiphyte vegetation growing on beech trees in Mt. Hiko, Southwest Japan.

METHODS

The concept on which the modified method of classifying vegetation is founded is that if there is neither species of positive nor of negative interspecific correlation of significance level in any given plant group, such a group is conceived of as being of homogeneous construction. Then, the epiphyte vegetation is classified objectively by four procedures according to this method of consideration, practically almost the same as Goodall's methods *(1)* of separating groups.

(a) Procedure I.—The species of higher frequency, as well as of positive interspecific correlation of $P < 0.001$ level of significance were used for separating groups by excluding all quadrats in which the single correlated species did not occur, until this particular species was no longer present in a given group. One of the final groups of residue was considered in its possible combination with another group, if there was not recognized any species of positive interspecific correlation which reached a high significance level in a newly combined group. We expect, however, that there may exist some species of negative interspecific correlation of $P < 0.001$ or $0.01 < P < 0.001$ level of significance even in such a final group conceived to be certainly homogeneous as judged by positive interspecific correlations of significance level.

(b) Procedure II.—The species of lower frequency and simultaneously of positive interspecific correlation of a high significance level which is quite the same as Procedure I, were used for separating groups by excluding all quadrats in which the single correlated species occurred, as well as by excluding those in which it did not occur (Procedure I). Recombination of the final groups of residue was made by the same method as Procedure I.

(c) Procedure III.—As a substitute for positive interspecific correlation, the species of higher frequency and of negative interspecific correlation of high significance level were used for separating groups like Procedure I. In this case too, we may expect some species of positive interspecific correlation of the same level of significance remaining in the final groups.

(d) Procedure IV.—As a substitute for the species of higher frequency, we used those of lower ones for separating groups. The treatment is quite the same as Procedure II.

Procedure I is clearly the best one for classifying the vegetation of epiphytes, as shown in Table 1, notwithstanding the difference that exists among the three series of methods different in quadrat size and number found in random sampling on five beech trees: one standing at the peak, Kitadake, of 1,150 m alt.; two at the ridges of 925 m and 930 m alt.; and the other two at the mountain-slopes of 910 m and 960 m alt.

The smaller the quadrat size, the more numerous the groups become. Fig. 1 shows the similarity of correlation among all the groups recognized in the three series of groupings by means of the sampling data of the different kinds of quadrat size. Each group is designated by the names of two important species which bear the highest and the next best figures of positive indicator value. However, if there are only a very few or not any species having positive indicator values of significance level in a group, we indicate it by enclosing the name of the species not reaching significance

† Presented by F.E. Egler.

Table 1.

Success of different procedures in dividing data, which were obtained from different sampling sizes of quadrats, into homogeneous groups.

No. of quadrat	Size of quadrat	Procedure	No. of group	No. of interspecific correlation with P*	
				0.01~0.001	<0.001
150	1500 sq cm	I	7	1	0
		II	7	2	2
		III	4	24	15
		IV	5	7	2
282	1000 sq cm	I	9	3	0
		II	7	2	1
		III	6	10	8
		IV	7	4	2
423	500 sq cm	I	10	3	2
		II	11	2	6
		III	8	5	8
		IV	6	4	6

* The table shows the number of Positive (in Procedures III & IV) and negative (in Procedures I & II) interspecific correlation of significance level in the final groups.

level in parenthesis within a rectangular frame of broken line. The degree of independence of every epiphyte-group classified in these ways is expressed by the species number of positive (in Roman type) and negative (in italics) indicator values *(1, 2)* of significance level ($P < 0.01$), which are shown beneath the rectangular frame (Fig. 1) in which is written the group name. The similarity of correlation among the groups, depending on the three simultaneous series, is expressed by using the "Quotient of Similarity" (= QS, *5*). In Fig. 1, the highest value of this Quotient between one group of one series and a group of the other series is shown near the connected line between groups, and the correlations between them are shown by various forms of lines. Only the major connection-lines of similarity, excluding minor ones, are shown. In comparing groups between two series with each other, to which both groups belong, the thick line indicates the closest correlation where the highest similarity is recognized between the two groups. The thick broken lines having a triangular arrowhead indicate that a given group from which the arrow-headed broken line started has the highest value of QS correlating with the group indicated within those of the other series. According to QS, especially the groups centering around those having the highest values of QS, as shown in Fig. 1, we may regroup the epiphyte groups of each series into four group-types.

Of every group in the series (Series 1) which resulted from the Procedure I of arranging the data obtained from the smallest size of quadrat (500 sq cm each), Table 2 shows the ecological distribution concerning vertical position and exposure on trees and topographical positions of host trees. The state of ecological distribution of every group in the other two series, both Series 2 and 3 obtained from Procedure I, which resulted from the data of larger quadrat (1,000 sq cm — Series 2, and 1,500 sq cm — Series 3) is not so different from that of the smallest sampling series (Series 1) shown in Table 2.

As shown in Fig. 1, in each series, several somewhat homogeneous groups were recognized as the result of objective classification of epiphyte vegetation in terms of interspecific correlation, while there were some groups which had few species of positive indicator value of significance level. In order to make clear the correlational similarity of floristic composition among the independent groups of each separate series, Sörensen's grouping method *(5)* based on the value of QS was performed. An outline of this method is shown in Fig. 2 and Table 3. For example, we will explain the method of integration of those epiphyte groups in the Series 1 derived from sampling data of the smallest quadrat (See Table 3 and Fig. 2). The order of arrangement of the epiphyte groups was the same as that (Series 1) of Fig. 1. At the level of QS = 40 (Table 3 and Fig. 2), the *Homalia japonica - Homaliodendron scalpellifolium* group (Group 1) and the *Thuidium cymbifolium - Homaliodendron scalpel-*

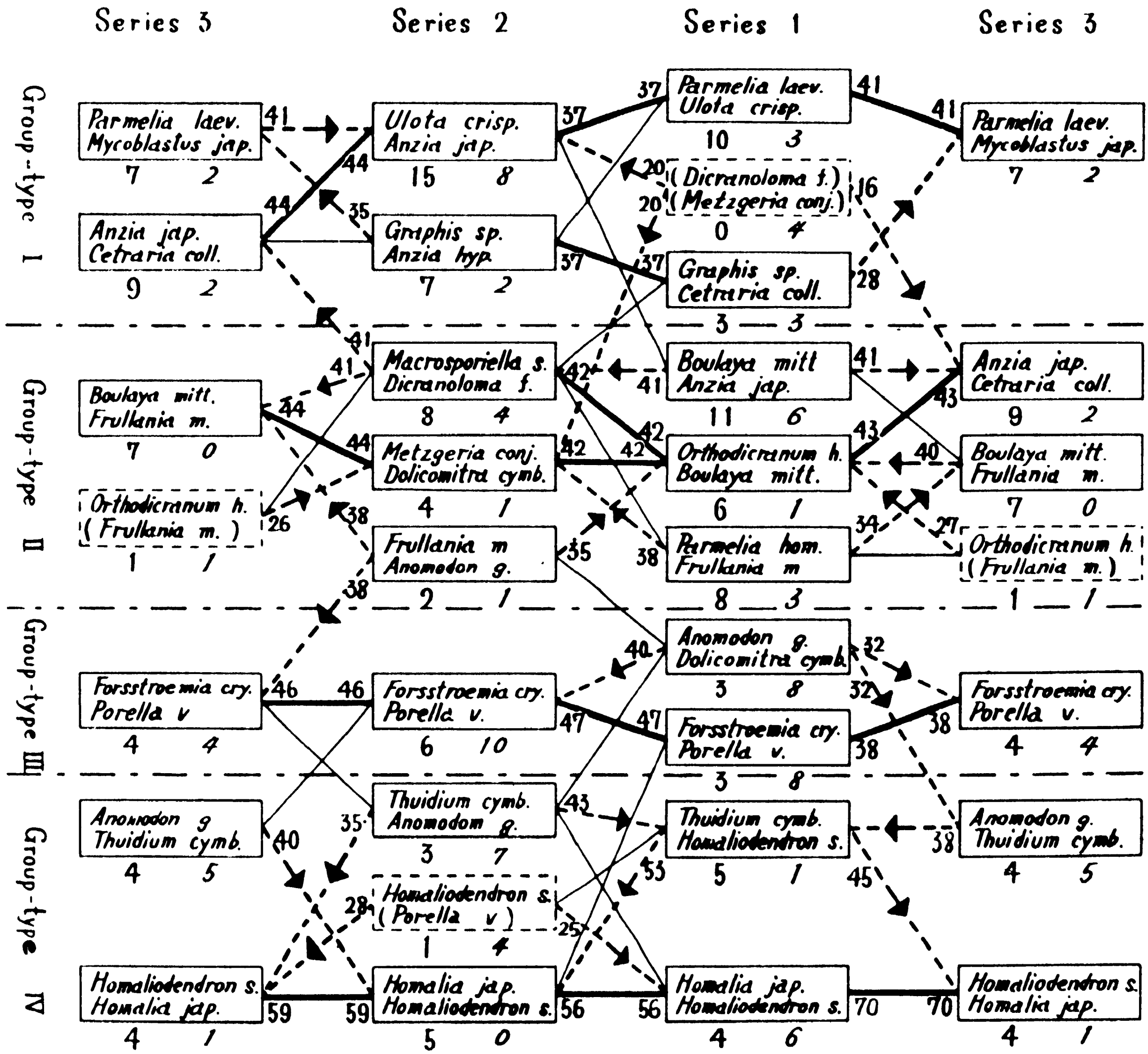


Fig. 1.—Classificatory schema of epiphyte communities, depending on Procedure I on the basis of the data obtained from the three kinds of sampling sizes of quadrats (Series 1 means the grouping resulted from 423 quadrats of 500 sq cm; Series 2, that of 282 quadrats of 1,000 sq cm; and Series 3, that of 150 quadrats of 1,500 sq cm). The numerical figure written in Roman type beneath every rectangular frame in which is shown the group name, indicates the number of species which has the positive indicator value of significance level in that corresponding group, and that of italic type is of negative indicator value. The numerical figures situated near a connected line indicate the value of Quotient of Similarity between the groups connected with the line.

lifolium group (Group 5) were unified (QS = 42) into one group (Group 2), and at the same time Groups 3 and 4 (QS = 41) were combined into one group (Group c); at the QS = 30 level, the Group b and e (QS = 32) into the Group B, and the Group c and d (QS = 33) into the Group C; and so on. The number of groups differs to some degree at different levels. Noting Fig. 1 and Table 3, we may say that the group which has only a few species bearing indicator value of significance level among the component species, correlates with the other groups by the lower value of QS. Though the number of groups differ much in the different series which differ from each other by the size of

Table 2.

Showing the state of the ecological distribution of epiphyte groups by the numbers of quadrats. Vertical distribution on trees: trunk-bases (Tb), trunks (T), lower parts of crowns (Cb), interior parts of crowns (C), and top-most parts of crowns (Ct). The distributed side on trees: open side (O), intermediate side (M), and sheltered side (S). Distribution related to topography, viz., topographical distribution of host trees on which the epiphytes grow: a beech tree standing at the peak, Kitadake, of 1,150 m (F_1), at the ridge of 930 m (F_2) and 920 m (F_3), and at the slope of 910 m (F_4) and 960 m (F_5) alt. The figures having a thick underline indicate the predominant position of a given group.

Group type	Habitat / Group	Vertical distribution on trees					Distributed side on trees			Distribution related to topography				
		Tb	T	Cb	C	Ct	O	M	S	F1	F2	F3	F4	F5
I	*Parmelia laevior* / *Ulota crispula*	0	0	2	9	13	20	1	3	5	7	5	3	4
I	*Dicranoloma flagiliforme* / *Metzgeria conjugata*	2	3	4	12	7	9	8	11	13	8	2	4	1
I	*Graphis sp.* / *Cetraria collata*	7	3	6	8	1	12	7	6	6	17	0	1	1
II	*Boulaya mitteii* / *Anzia japonica*	0	6	32	29	4	34	24	13	15	16	20	9	11
II	*Orthodicranum hakkodense* / *Boulaya mittenii*	1	7	7	7	0	8	8	6	18	3	1	0	0
II	*Parmelia homogenes* / *Frullania moniliata*	8	13	33	10	1	25	23	17	30	13	10	3	9
III	*Anomodon giraldii* / *Dolicomitra cymbifolia*	4	37	17	5	0	4	23	36	3	10	12	27	11
III	*Forsstroemia cryphaeoides* / *Porella venusta*	6	48	17	0	0	33	23	15	0	15	15	18	23
I	*Thuidium cymbifolium* / *Homaliodendron scalpellifolium*	14	6	0	0	0	6	2	12	0	2	7	8	3
I	*Homalia japonica* / *Homaliodendron scalpellifolium*	26	8	0	0	0	9	12	13	0	1	2	19	12
Total no. of quadrat		68	131	118	80	26	160	131	132	90	92	74	92	75

quadrat for drawing data from the epiphyte vegetation, the larger the size of the quadrat, the fewer the number of groups becomes. Notwithstanding the difference of series, however, in any case the epiphyte vegetation is classified roughly into two groups (e.g., Fig. 2): one is of epiphytes growing on trunks and trunk-bases, and the other those of the interior parts of crowns and the top-most parts of crowns.

At a certain level where we can determine the value of QS, as we hoped, as a given criterion of integration of epiphyte groups, we can unify those groups into the higher rank of group at a given level, as well as we can understand the degree of similarity of floristic composition among those groups. Moreover, it is certainly noteworthy that the order of arrangement of those groups (Figs. 1 and 2) which are naturally arranged in the case of classifying vegetation, such as their ordering positions from the top-most parts of crowns down to the trunk-bases, is quite in accord with the environmental gradient.

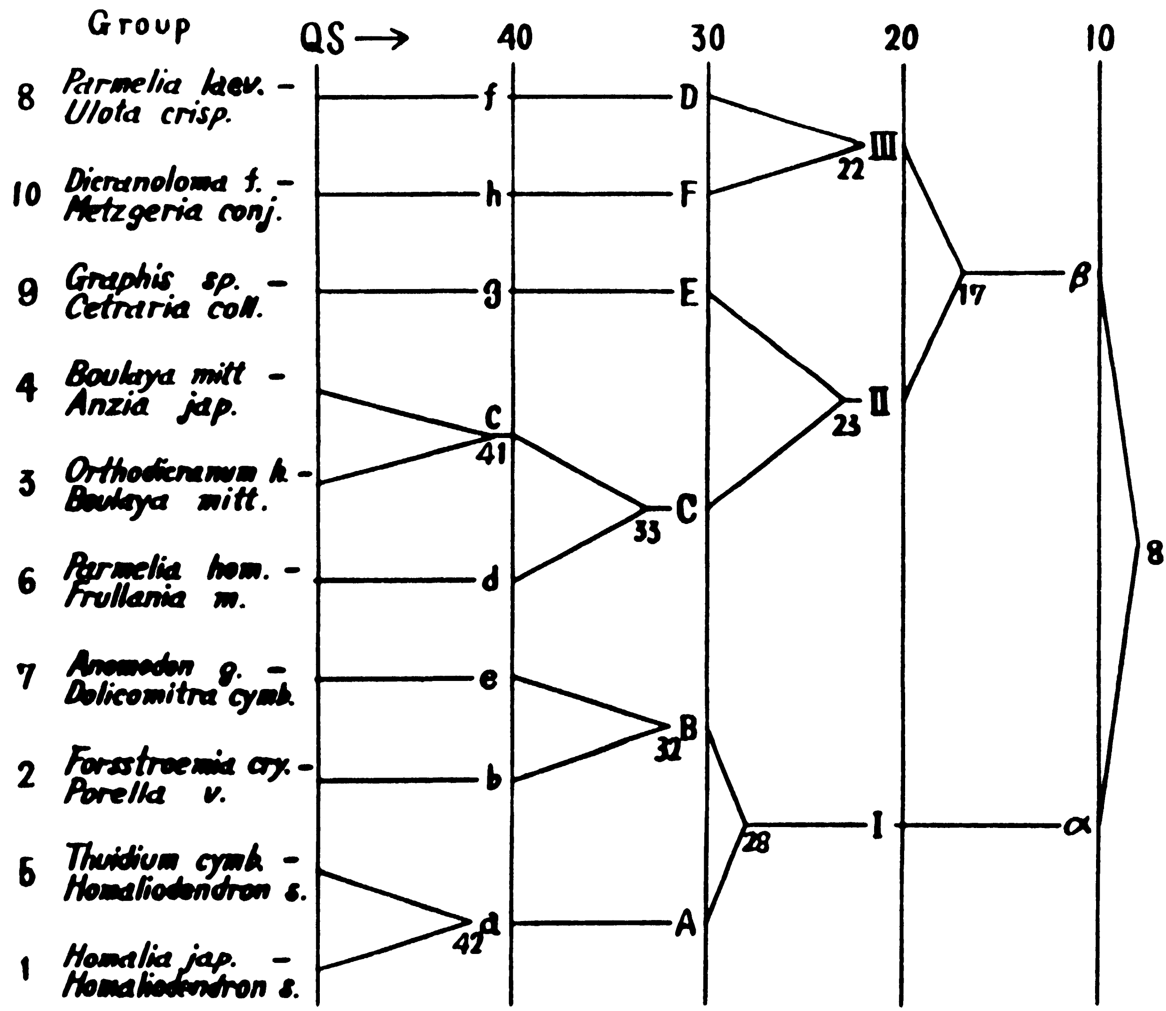


Fig. 2.—Series 1 of Sörensen's grouping method, in which the integration was performed at the foundation of final groups which were recognized in terms of classifying the epiphyte vegetation through Procedure I on the basis of the data obtained from 423 quadrats of 500 sq cm.

COMPARISON BETWEEN EPILIAS AND THE GROUPS OF THE PRESENT TREATMENT

In order to compare those groups resulting from such methods of treatment with the five epilias *(3)* of epiphyte communities which we have studied and designated to the same epiphyte vegetation in the beech forests of Mt. Hiko *(4)*, and moreover to make clear the correlation between those five epilias and the groups based on the present treatment, we selected six corresponding epiphyte-groups (the Group A, B, C, D, E, and F in Figs. 2 and 3) at the level of QS = 32 (Fig. 2) in the series of sampling with the smallest size of quadrat (Series 1). Comparison was made between them by using the values of QS of each one (Fig. 3). Here the correlational similarities among those groups are clearly recognized. Indication of the similarity between an epilia and a group, which is shown by the lines and the numerical figures of QS, was done in the same way as in Fig. 1. What is written beneath each epilia-name surrounded with a rectangular frame is the number of the characteristic species, and similarly that of the epiphyte-group name means

Table 3.

Showing the values of QS between the epiphyte groups at four different levels in Series 1, which is shown in Fig. 2.

		a.	b.	e.	d.	c.	g.	f.	h.		
10.			24	31	9	5	6	2	5		a.
8.	22			32	12	12	14	5	6		b.
9.	12	21			14	13	10	4	7		e.
4.	18	24	26			33	21	11	11		d.
3.	22	28	23	41			25	26	20		c.
6.	11	11	21	30	35			21	12		g.
7.	7	4	10	12	13	14			22		f.
2.	6	5	14	12	11	12	32				h.
5.	7	4	6	6	10	12	36	27			
1.	3	0.07	5	2	3	6	25	21	42		
	10.	8.	9.	4.	3.	6.	7.	2.	5.	1.	

	I.	II.	III.	
		10	5	I.
			17	II.
				III.

F.						
D.	22					
E.	12	21				
C.	16	19	23			
B.	7	5	12	13		
A.	5	2	6	7	28	
	F.	D.	E.	C.	B.	A.

the species number of the positive (in roman type) and negative (italic) indicator value of significance level. From these figures and the connected line, the correlational correspondence between each epilia and group is comprehensible to us. It is possible that the epilia or group which has correspondingly fewer characteristic species or fewer species bearing significant indicator value among the component species, in either case, does not necessarily show any correlational correspondence between such epilia and group.

Accordingly, because of the success of our several years of varied studies of corticolous vegetation in the beech forests of Mt. Hiko, Southwest Japan, we would draw the conclusion that the following four distinct communities of epiphytes, which are considerably developed there can be recognized: the *Thuidium cymbifolium-Homaliodendron scalpellifolium* epilia *(3)* or *Thuidium cymbifolium-Homaliodendron scalpellifolium* group (at the lower part of tree trunks), the *Pterobryum arbuscula - Anomodon giraldii* epilia or *Forsstroemia cryphaeoides - Anomodon giraldii* group (on trunks), the *Cetraria collata* f. *nuda - Boulaya mittenii* epilia or *Boulaya mittenii - Frullania moniliata* group (at the upper part of trunks and on boughs in crowns), and the *Ulota crispula-Pertusaria* sp_2 epilia or *Parmelia laevior - Ulota crispula* group (at the top-most part of the crowns). It will be probable that the other three remains shown in Fig. 3, viz., the *Graphis* sp_1 - *Pertusaria* sp_1 epilia, *Graphis* sp. -*Cetraria collata* group, and *Dicranoloma fragiliforme - Metzgeria conjugata* group, are all unlikely to be developed into independent social units or groups.

CONCLUSION AND SUMMARY

In cases where it is difficult to distinguish plant community individuality, as in corticolous communities consisting chiefly of bryophytes and lichens, it seems to us to be possible to make a classification of such vegetation and to systematize the communities objectively. This would be

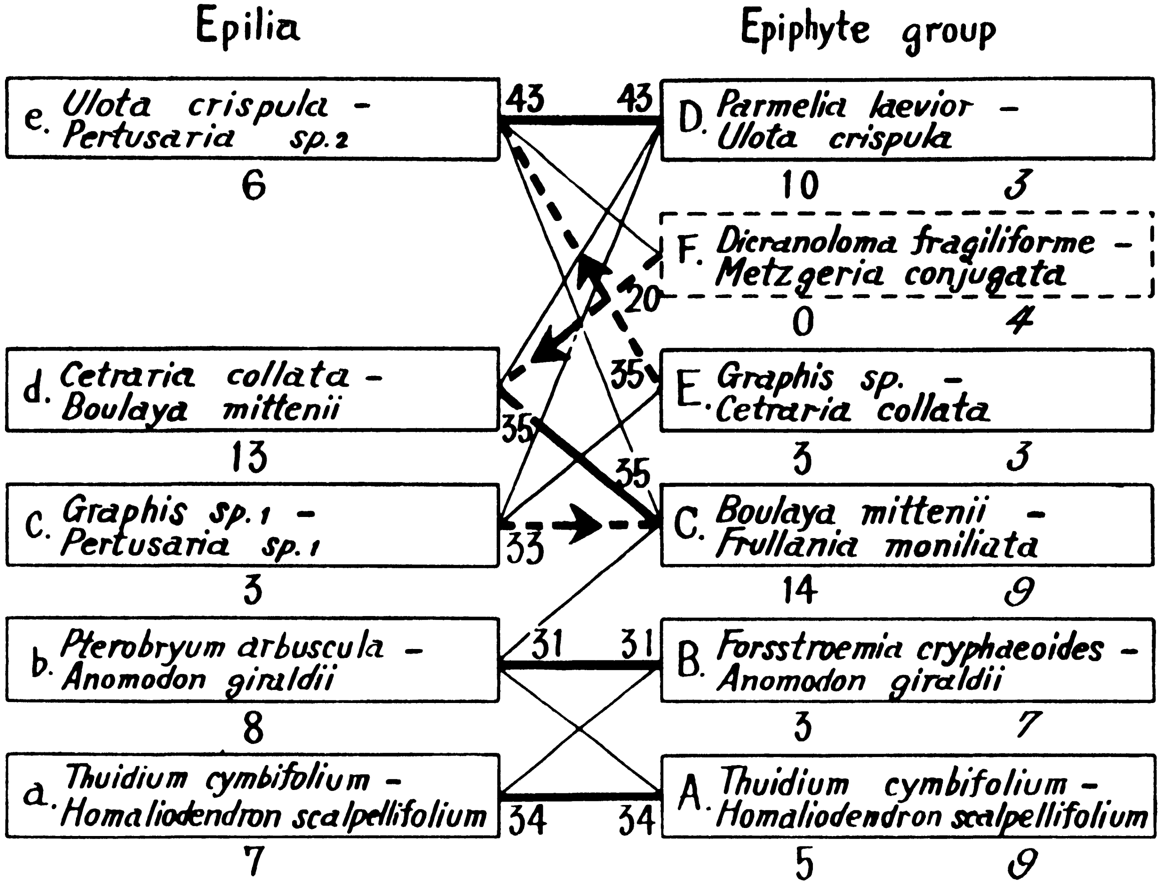


Fig. 3.—Classificatory schema of epiphyte communities, showing so as to make comparison between each epilia and group by means of the value of QS. Indication of correlational similarity between them is the same to Fig. 1.

done on the basis of floristic composition, by classifying the communities into some homogeneous groups by making use of the value of interspecific correlation based on the frequency of major component species and in the light of the indicator value of significance level *(1, 2)*. These groups would then be integrated into an appropriate number of groups of higher rank at a wanted level in accordance with the value of "Quotient of Similarity" (=QS, *5*) which is based on the frequency of component species.

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VEGETATION MAPPING IN THE PACIFIC REGION

A.W. KÜCHLER

University of Kansas, Lawrence, Kansas, U.S.A.

Let me begin with a brief report on what has been accomplished so far in mapping the vegetation of the Pacific Region. As you can imagine, the accomplishments are not at all uniform, but they are nevertheless very promising. There are, of course, numerous vegetation maps of very small areas. I shall ignore these here and report to you only on maps of countries.

In North America, a vegetation map of British Columbia was published recently, and maps of Mexico and Guatemala have been available for some time. A map of Alaska is now in press, and there has been a small map of the United States for a long time; a larger one is now in preparation. Most of the Central American states remain to be done. This is a relatively favourable report, especially if we include the work now in progress.

In South America, conditions are much less satisfactory, and Peru is the only country of which a reasonably detailed vegetation map exists.

The most favourable report comes from Australia. That continent has now been mapped, and the new vegetation map by Williams has been published recently. New Zealand has also been mapped, as well as New Guinea. On the other hand, the various Pacific islands have been mapped very unevenly, if at all.

In Asia, progress varies from one country to the next. The new Soviet map covers a large part of the Asian continent. Indonesia, the Philippines, and Taiwan have vegetation maps that need some further work. There are good but small maps of Korea, Manchuria, Thailand, and Burma. The greatest gaps are China and Japan, Malaya, and North and South Vietnam.

Actually, vegetation maps are now available for the entire Pacific Region, and the International Bibliography of Vegetation Maps which I hope to publish some time soon contains over 200 references to countries bordering on the Pacific Ocean. The scale and quality of these maps vary within wide limits, and many of the vegetation maps are too small or too generalized to be of much use. But modern vegetation maps can be useful instruments in a variety of scientific investigations, as well as in planning and managing the use of our lands. This has been demonstrated many times.

If, therefore, it is evident that vegetation maps are useful, I should like you to consider the possibility of preparing a vegetation map of your home land if a good one at a large scale does not already exist. If you are not in the position to prepare such a vegetation map, you can perhaps encourage one of your colleagues to do so.

The maps should be useful to as many people as possible and not just to those of one country. For this reason, a certain degree of coordination is valuable. In addition to suggesting that new and large scale vegetation maps be made of every country of the Pacific Region, I should therefore like to propose that the vegetation be mapped in its major physiognomic and structural features, and that these broader types be refined according to their floristic character by listing the dominant genera or species wherever that is feasible. Structure and floristic composition are the two basic features which all vegetation types on earth have in common. They should therefore be given priority on vegetation maps. If other features are to be added, such as ecological aspects of the habitat, they might well be in the nature of a supplement rather than primary information. Such supplementary information may be given wherever this is feasible and useful, but I think it should be *only in addition to* the two basic features of physiognomy and floristic compositon, and *not instead of them.*

Of course, there are many ways to make a vegetation map, and it is quite possible that authors may wish to adapt their maps to the circumstances of their respective countries. The possibilities of variation are greater than many authors realize; and while a vegetation map should not be cluttered, there is, nevertheless, no need to ignore any chances to make the map content more meaningful.

Those who wish to make large scale maps will find interesting and stimulating models in Carl Troll's vegetation map of the Nanga Parbat area in the western Himalaya, or in Heinz Ellenberg's vegetation-site map of Leonberg, Germany; both maps are at the scale of 1:50,000. Larger scale phytosociological maps, as published under the direction of Louis Emberger or Reinhold Tüxen, are perhaps not yet feasible for the Pacific Region as they require more detailed information than is generally available. As far as I know, only some Japanese scientists have successfully attempted to prepare such maps, and only in very limited numbers.

Inspiration for small scale maps may be gained by studying Kurt Hueck's map of Germany or Henri Gaussen's map of France, both at 1: 1,000,000. More recently, our Soviet colleagues have published vegetation maps of their country at 1:4,000,000, and Williams published his new map of Australia at 1:6,000,000. My own map of the United States is at 1:14,000,000, and this small scale is justified only because the map was included in an atlas.

The preparation of a new vegetation map of the United States at a larger scale is now in progress, but I do not expect to complete the manuscript for another three or four years. For the large countries of Australia, Canada, China, the Soviet Union, and the United States, scales of 1:4,000,000 or 1:6,000,000 can be justified, but for smaller nations a scale of 1:1,000,000 should be the minimum.

I mentioned that many vegetation maps of the Pacific Region are of too small a scale or too generalized to be very useful. This need not be discouraging because the field of vegetation mapping is developing only now. The scale can always be enlarged and more details can be added. Far more significant are the map content, its organization, and representation. A consideration of these features is fundamental and, indeed, imperative before preparing a vegetation map.

Today I should like to present to you two problems for discussion. The first one is that of the map content. Some authors argue that a vegetation map should contain nothing but information on vegetation; others want to show more, especially ecological features and also land-use data. A strong case can be made for both sides. I do not propose here that a decision should be taken in support of one approach to the exclusion of the other. Both approaches are valuable and justifiable. But I do feel that the matter should be discussed now so that those who return home to prepare or promote a vegetation map of their area will see more clearly what problems they will have to face.

The argument for showing only vegetation on a vegetation map is strong and logical. Vegetation is so complex that the map can always be filled with as much detail as the scale permits. If the over-all character of the vegetation is simple, then further detail can be shown by introducing various structural aspects of the vegetation, differences in the lowest synusia, floristic variations, transitions associations, sub-associations, variants, sub-variants, and other features. The map is then filled to capacity, and the entire information refers only to vegetation. By excluding all other kinds of information, the vegetation can be described in the greatest possible detail.

But there are others who feel that some detail of the vegetation can or should be sacrificed in order to introduce ecological information. There is, of course, no doubt that such information is revealing and valuable, and therefore should be given.

However, the introduction of non-vegetational data creates a conflict: what part of the vegetational information is to be sacrificed for the sake of ecological data, and also, how much ecological information may be introduced without undermining the character of the map as a vegetation map? A further problem is the kind of ecological information to be shown in a vegetation map. Should it be any kind, whatever the author happens to favor at a particular time and place, or should it be so organized that a logical system can be applied? If so, what specific ecological data are to be selected as it is impossible to indicate the environment comprehensively?

Usually, vegetation maps with ecological information lack unity, but they are nevertheless very numerous. This shows that many authors place much value on this approach. On the other hand, there are only very few vegetation maps that are based on a strictly organized system which includes both vegetational and environmental features. I am thinking of the works by Heinz Ellenberg and Henri Gaussen. There are also vegetation maps which are strictly vegetational but which have strong and definite ecological implications. The maps by Reinhold Tüxen and his collaborators belong in this class. On the maps by Hueck, or by Lavrenko and Sochava, ecological information is sometimes given, sometimes implied, and sometimes omitted. Carl Troll fits the vegetation into the landscape, so that his vegetation map, too, is ecological in character; his method is most enlightening but is most readily applied to mountainous terrain on large scale maps.

The fact that the most interesting or the most valuable vegetation maps were not made in the Pacific Region is not at all a cause of concern. What really counts is the basic ideas on which a vegetation map rests. Once grasped, these ideas can be applied in the Pacific Region as well as anywhere else. The problem of the map content is well worth discussing because the character and the usefulness of the maps depend on it.

The other feature I wish to present to you for discussion is the use of color. Several authors have shown that the judicious application of color and color patterns can greatly enrich the map content. Many years ago, Rübel in Switzerland proposed a color scale for Swiss vegetation maps. This scheme turned out to be too limited and was not often applied. Much later, Emil Schmid, also of Switzerland, was careful to select harmonizing colors to facilitate map reading but refrained from proposing definite colors for given vegetation types as Rübel had done. Schmid has made more of a contribution than it seems because many vegetation maps have disturbing color schemes. Clashing colors make map reading difficult and easily suppress important features on the map.

Sochava of the Soviet Union briefly discusses the use of color on vegetation maps and proposes that the color scale used on the Soviet map be employed elsewhere, too. But he failed to indicate just how he arrived at his color selections, and therefore it is not possible to use his ideas systematically in other countries.

The only person who so far has presented a complete and logical color system for use on vegetation maps is Henri Gaussen of France. He systematically uses the sequence of colors in the spectrum and different patterns within each color to express vegetational and ecological information. The system has been criticized by Sochava, and indeed, some modifications may be desirable. But the fact remains that so far, and as a method of using colors on vegetation maps, Gaussen's work is unique.

If you agree with me that vegetation maps should be made of the entire Pacific Region, then we should ask ourselves whether or not colors should be used uniformly throughout the region in order to tie the area together and integrate the individual maps into a larger whole. Question 1 is therefore: should a color scheme be prepared for the vegetation of the Pacific Region, or should the use of color be left to the discretion of each author? If a more or less uniform system seems desirable, then there follows question 2: should the use of colors be restricted to vegetational information, or may colors refer to ecological data as well? The more systematic the use of color, the more readily can the reader distinguish the major groups of features at a glance.

Finally, there is the use of symbols which may be employed to enrich the vegetational and/or ecological information. And again, as in the case of colors, should symbols be used indiscriminately or should they be restricted to any one type of features? Uniformity of approach certainly facilitates the appreciation of vegetation maps, but whether such a form of coordination can or should be achieved is a matter for discussion here and now.

Certainly the present state of vegetation mapping in the Pacific Region leaves much to be desired. Certainly, enough vegetation maps have been published all over the world that the basic ideas can be grasped and developed. I want to urge you to clarify the thinking of all of us who are interested in preparing vegetation maps of the Pacific Region.

THE PROBLEM OF THE ORIGIN OF THE "SAVANNAHS" OF THE ISLANDS OF THE PACIFIC†

R. PORTERES

Muséum National d'Histoire Naturelle, Paris, France.

People who deal with the subject of the vegetation of the islands of the Pacific always emphasize the youthful nature and the ubiquitous and more or less ruderal flora of the savannahs of these islands.

The "savannahs" are qualified as "secondary" and as being the outcome, in fairly recent times, of the clearing of forests for cultivation and the subsequent abandonment of the cultivated areas.

The floristic lists given are convincing in this respect, apart from some reservations which should be made.

Virot (1957) considers that the "savannahs" of New Caledonia are of secondary origin and the direct outcome of the deforestation of the island. The first explorers already pointed out the presence of vast "savannahs." However, they represented only "a degraded and secondary aspect of the vegetation and... they are made up almost entirely of the species introduced, particularly the graminaceous species." (Virot, p. 62). "The secondary "savannahs," existing at the time when France took possession of New Caledonia, were, from the beginning, used in part as natural pasture land. Generally speaking, they consisted of stretches of dry grasses, among which the ubiquitous pan-tropical plant predominated, the graminaceous species for the most part, of which the principal ones are *Heteropogon contortus* Roem., *Aristida pilosa* Labill., *Eleusine indica* Gaertn., *Dactyloctenium aegyptiacum* Willd., etc..." (Virot, pp. 65 and 66). "First of all, it is all but certain that almost all the grassy stretches of New Caledonia have no other origin than that of the destruction of virgin forest by fire." (Virot, p. 68). "Among the graminaceous species may be mentioned, among others: *Heteropogon contortus* Roem. and Schult; pan-tropical pyrophytic plant, typical of "secondary savannahs", and *Themeda triandra* Forsk; which are, further, widely prevalent in the interior herbaceous formations of a large part of Africa and tropical Asia." (Virot, pp. 128-129).

The examination of the lists of species reveals, in addition, a deficiency in leguminous plants. Papy (1954) also points out the absence of prairial leguminous plants, endemic species as well as those introduced in ancient times, in the group known as the Society Islands.

Thus, what the authors here call "secondary savannahs" would be nothing but anthropic herbaceous clearings.

Are there no "primary savannahs" in existence in the Pacific islands? Have they, incidentally, ever existed?

We will try to give here both an analysis of this question and a possible interpretation with the help of elements of isolated value.

Two hemicryptophytic graminaceous plants to be found to a certain extent everywhere in the Pacific Region should have our attention: *Themeda triandra* Forsk and *Heteropogon contortus* Roem. and Sch., two andropogoneous plants.

Themeda triandra is exclusively paleo-tropical in its distribution; *Heteropogon contortus* is pan-tropical, present in the old and the new tropical world.

J. Lebrun (1947) proposed the setting-apart of a superior group in the phyto-sociologicous African hierarchy, the *Themedetalia triandrae* order. This order, of paleo-tropical value, would in East Africa include an alliance, the *Themedion triandrae afro-orientale*. (Lebrun). Among the vegetable associations included herein, Lebrun has studied and defined an association with *Themeda triandra* Forsk. and *Heteropogon contortus*, distinguished as *Themedeto-Heteropogonetum*, in accordance with the appellative rules of nomenclature in phyto-sociologicous subjects.

The extension of the genus *Themeda* in the whole of the inter-tropical and sub-tropical zone of the old world contrasts with its total absence in America.

Very generally speaking, all the species of *Themeda* are orophileous or sub-orophileous, at least on approach to the equator. In relatively high latitudes, they become "planitiary" (habitat in plains).

The "prairies" of *Themeda triandra* or of *T. quadrivalvis* Kunth characterize a prairial

† Presented by R. Heim.

pyrophytic type of humid estival tropical climate. This type, as we shall see later, seems to be very ancient in the world. The discontinuity in the area of distribution of two of these species is a partial proof of this antiquity.

The existence of a *Themedion triandrae afro-orientale* does not however presume the existence of an exclusively West African alliance, at least in the sense of a *Themedion triandrae afro-occidentale*. Lebrun (1947) gave an explanation on this subject, suggesting for this latter region a vicarious order in relation to *Themedetalia* and based on another Andropogon *Hyparrhenia diplandra* Stapf.

We have shown (R. Porteres 1951) that, if traces could be found in West Africa of the *Themedetalia* order, of the *Themedion* alliance and even of a *Themedeto-heteropogonetum* association, this has now all collapsed and is relictual. The *Hyparrhenietalia* partially took its place, not as a floristic vicariant, but as an eco-vicariant. We have clearly indicated the ecological contrast between these two orders and have demonstrated the relictual state of the *Themedetalia* in West Africa.

Taken generally, the prairial formations of *Th. triandra* can be defined as "pyro-climatic" and those of *Hyparrhenia diplandra* as "anthropo-pyro-edaphic" (R. Porteres, 1951).

In East Africa, the floristic individuality of the *Th. triandra* and *H. contortus* grouping had already been recognised by R. Staples (1926) in his pastoral experiments on the cultivation of the South African Veld. For Staples and Lebrun, the grouping tends towards a seasonal contrast which results in a marked periodicity of the vegetation of this prairial type and thus favours its maintenance. The periodical spreading natural fires facilitate the extension of the establishment of *Th. triandra* and maintain, in particular, the association with *H. contortus*.

At Dahomey it is said that a residue of this association exists (Porteres, 1951).

Certain differences in the ecological behaviour of the two species could dislocate the association. *Th. triandra* tends towards lighter and better porous soils than *H. contortus*. The latter species at present pan-tropical, appears to be more aggressive, probably on account of its facilities for the scattering of the seeds by man and animals (spikelets which catch on with their awns). *Th. triandra* is less aggressive, and this perhaps explains its absence in America.

In certain countries of the Old World, *Th. triandra* is replaced by *T. australis* (South Africa), *T. quadrivalvis* (Madagascar, part of India). Life associated with *Heteropogon contortus* is also to be noted.

The presence in the Pacific lands, either of *H. contortus* alone, or of *Th. Triandra* alone, or of the two species together, raises in our opinion the problem of the existence or the non-existence of primeval herbaceous groups, of "primary savannahs."

If these species are of recent introduction, the problem does not arise; they would indicate a tendency towards the regression of the potential vegetation of the "present secondary savannahs" which would thus be approaching a pyrophile stage.

If these species are present since very remote ages, this means that pyrophytic prairies existed and formed part of the natural landscape of the Pacific islands.

The fact that certain isolated islands or groups of islands in the Pacific, such as the Society Islands, possess only *Heteropogon contortus* and do not possess *Th. triandra* give us the impression that the pyrophytic conditions of these islands are recent and that primary savannahs have never existed there.

However, the establishment of the vegetation of all these islands is of recent origin, by the covering of uplifts (or volcanic lava stretches) with vegetation, dating from the Pliocene age, or even the Pleistocene or the Holocene age. It is thus impossible to deduce anything much, except perhaps that it was man who destroyed forest vegetation and who favoured the herbaceous clearings which fires were beginning to ravage.

Quite different is the problem of New Caledonia where we ascertain the presence, together with *H. contortus*, of *Th. triandra*. Other species of *Themeda* exist in New Caledonia: *Th. ciliata* which is known to be annual and of recent introduction; *Th. gigantea*, an annual para-littoral species which does not interest us here and which was probably brought in anthropically from India over Melanesia.

Is the *Th. triandra* in New Caledonia a species which is the outcome of natural ancient distribution? Was it part of the normal surface of this island in archaic times?

The genus *Themeda* covers a total paleo-tropical area reaching from one extremity of Africa over India and Australia and into New Zealand (?). *Themeda triandra*, we may say, is to be found in the whole of the area covered by the genus. The species includes numerous variations, certain of which have been established as independent species, and the surviving varieties of which are apparently well isolated morphologically; this isolation is also, correlatively, of a geographic order and reaches as far as the low systematic levels, so that it has been possible to use it for various interpretations in Africa (Stapf 1919, Portères 1951).

Incidentally, the genus *Themeda* (and in particular the species *Th. triandra* in the wide sense) particularly merits a very thorough study at various levels: systematic, geographic, caryologic, cytogenetic, physiological, ecological, sociological, and pastoral.

CONCLUSIONS

It is not possible to know whether the Pacific lands carried balanced herbaceous formations of primeval origin in ancient times. One now finds herbaceous clearings which have been introduced historically. None the less, the existence of the pan-tropical species *Heteropogon contortus* Roem and of the paleo-tropical species *Themeda triandra* Forsk in these meadow lands permit us to assume either a prairial advance towards a pyrophytic stage or a relictual state of pyrophytic prairial conditions.

To know whether primary prairies ever existed in the Pacific lands is a problem which is far from being solved.

In the case of the Central Pacific islands which are geologically young, one should perhaps put forward the view that they have never existed; but the case of certain outer, geologically ancient, chains of islands which belong to the Tertiary Age of Indo-melanesian Asia or of the Australian continent, or of an antarctic continent, may be different.

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THE STRUCTURE OF SOME BIOCOENOSES OF NEW CALEDONIA

J.H. HÜRLIMANN

Ciba, Basle, Switzerland.

Attempts to describe thoroughly and classify the New Caledonian vegetation were started only about 30 years ago. Last year, an important study by R. Virot was published, giving for the first time a synopsis of the vegetation groups of the whole island. Together with the studies by Daeniker, Sarlin and other authors, we now have substantial data regarding the composition of several groups of plant species. However, precise observations of documentary nature are partly lacking with regards to frequency, arrangement and development of species within the biocoenoses. The works of Dansereau, Richards and Schmid set out the lines along which such studies should be conducted, which are of fundamental importance to the knowledge of the ecology of the species and its application in forestry, agriculture and livestock.

By adopting the method described by Schmid, we endeavoured to get an idea of the structure of parts of some biocoenoses. Unfortunately, due to limited time, all generalized study was impossible. On another occasion, we described this method, making certain changes that appeared useful, for the determination of the structural features and their illustration.

The purpose of this paper is to give an idea of the structural facts which are recognizable through these biocoenological surveys.

Sarlin mentions the classification of the New Caledonian vegetation into 7 distinct formations established by previous authors:

1. Coastal zone with oceanian flora;
2. from 0 to 3-400 m the Niaouli Savannah *(Melaleuca leucadendron);*
3. from 400 to 1,000 m medium altitude forest;
4. from 1,000 to 1,500 m dry coniferous forest;
5. the forest galleries;
6. lower serpentine scrub;
7. summit scrub.

Those who know New Caledonia well realize that this classification is superficial, incomplete and even erroneous (for example the definition of the formation under item 4 as "dry forest."

Virot has chosen the following system to give a comprehensive view:

1. Halophilous formations, including:
   a) mangrove,
   b) herbaceous vegetation of beaches,
   c) belt of so-called "Seaside" trees;
2. Non-halophilous formations, divided into:
   A forest series, including:
   a) coastal climatic forests (coastal hillside wood),
   b) hydrophilous forests of the river banks,
   c) photophilous forests of the marshes,
   d) mesophilous forests of the valleys,
   e) shade-tolerant forests (insufficiently specified),
   f) oro-nephepiphilous forests,
   g) photo-xerophilous forests;
   A series of shrubs, including:
   h) edaphic sclerophilous-xerophilous scrub,
   i) orophilous scrub;
   A herbaceous series, including only:
   k) paludal groups.

Of course, this classification will only be provisional since it does not take into account the mixed floristic features which constitute the vegetation of different regions of the island. Despite this defect, Virot's classification shows considerable progress when compared with previous classifications.

Our structural studies were carried out mostly in the formations which Virot calls vallicol-mesophilous and oro-nepheliphilous, which are obviously very mixed formations. By way of comparison, we will also discuss a survey made in a secondary coastal forest. On the other hand we will not talk about shrub vegetation of serpentine areas which we have not been able to study in detail.

The forests in which we were most interested because of their aspect are those with a predominance of Neo-caledonean Fagaceae, of *Trisyngyne* spp. They are distinct from other types of forests by the fact that only one species forms, nearly exclusively, the dominant tree stratum.

Our surveys Nos. 6, 9 and 10 were made in *Trisyngyne codonandra* Baill. forests; survey No. 7 in a *Tr. Balansae* Baill. forest. All the fragments studied are located on peridotitic mountains quite near to one another: the farthest apart are separated by less than 30 km. In spite of this, relatively important differences are apparent, even between the three *Tr. codonandra* biocoenoses.

Due to lack of time, it will not be possible to reproduce here the complete lists of species.

Their study shows that the floristic composition is very variable in *Tr. codonandra* forests. Among all the species found in the 3 surveys, there are only two species, *Tr. codonandra* itself and *Symplocos cf. Pancheri*, found in all three surveys. Five species are common to surveys 6 and 9, eight to surveys 9 and 10, while surveys 6 and 10 have no particular species in common.

It is interesting to see that survey No. 7, in spite of the dominance of another species of *Trisyngyne*, seems to connect the other fragments of vegetation. In fact, surveys No. 7, 9 and 10 have 3 species in common, and surveys 6, 7 and 9 two species. The total of the plants approximately identified in the 4 fragments studied is about 150 phanerogamic species. The coincidences found are therefore rather poor, and it will be admitted that the floristic-statistics method is not of very great use in these circumstances.

Now let us proceed to the information received on biocoenological structure. By grouping the plants together, forming provisional ecological types, the following frequency of the different types in the biocoenoses fragments occurs:

Table 1.
Frequency of provisional ecological types in the vegetation according to the surveys (in per cent of small squares of the surveys):

		6	9	10	7
a	= trees more than 12 m high (number)	3	0	2	4
	shade produced per crown	no data	0	96	67
b	= trees more than 8 to 12 m high (number)	8	9	3	8
	shade produced per crown	no data	47	23	32
c	= trees less than 8 m high	9	45	37	43
e	= trees with tufts of leaves, 2 to 8 m high, few branchings	18	9	2	1
f	= trees with tufts of leaves, less than 2 m high, few branchings	0	0	0	1
g	= prostrate trees	0	1	0	2
i	= shrubs more than 2 m high	4	7	1	13
k	= shrubs less than 2 m high	5	5	0	1
n	= woody lianes or lianes with stiff stems	6	6	5	2
o	= prostrate shrubs	1	4	0	0
p	= erect herbs	13	50	11	46
ph	= herbs forming dense clumps	—	30	10	0
pr	= herbs forming rosettes	—	7	2	—
pst	= herbs forming stems	—	4	9	15
pep	= epiphytic herbs	22	38	6	11
v_E	= bryophytes on the ground	10	1	1	0
v_B	= bryophytes on wood (dead or living)	60	85	73	53
w	= lichens	21	85	77	57
x	= saprotic mushrooms	0	9	1	3
y	= algae	0	3	0	1

To these figures must be added those of young plants which, according to their state of growth, participate in the composition of the various biocoenoses strata:

	6	9	10	7
Young plants more than 1 m high	21	42	4	16
Young plants, 20 -100 cm high	71	72	48	74
Young plants less than 20 cm high	54	45	17	95

The most noticeable differences are found in the density of class c trees (including class e and the young trees over 1 meter high) and in that of non-epiphytic undergrowth (including young plants of less than 20 cm high). The total percentage of participation of these 2 categories in the 4 surveys are as follows:

	6	9	10	7
Class c etc.	48	97	43	63
Class p etc.	67	136	49	156

Therefore, surveys Nos. 7 and 9 present a much more developed undergrowth than Nos. 6 and 10. This fact is also a result of the number of small squares entirely without any vascular plants (in % of the total of squares):

6	9	10	7
10	1	17	0

These differences are due to the growth of the dominant tree strata, producing more or less intense shade according to the density of the foliage.

The frequency of the shrubs follows the same lines, but their absolute number is very small, so that they only play a minor part in the structure of the vegetation as a whole.

The proportion of lianes is almost similar in the 3 surveys Nos. 6, 9 and 10, but there is an abundant presence of young creepers (*Freycinetia* sp., *Smilax* sp. and *Alyxia* sp.) in survey No. 6.

In the participation of young plants, it is advisable to compare the number of adult and young subjects of various species. These observations give valuable information on the probable development of the biocoenoses in question. The lack of young plants of dominant species can induce a change in the structure of the whole vegetation, whilst an abundance of young plants is a certain guarantee for the maintenance of population. Below are the most striking examples of both statements, found in our surveys:

a) Very abundant young plants, compared to adult plants:

	young	adult
Survey No. 6		
Trisyngyne codonandra	139	3
Tree No. 40	22	1
Survey No. 9		
Araucaria muelleri	108	0
Palm tree No. 24	31	1
Survey No. 10		
Trisyngyne codonandra	46	3
Rubiaceae No. 29	23	1
Survey No. 7		
Trisyngyne balansae	652	8
Sapindaceae No. 11	42	10
Guttiferae No. 32	33	0

b) Abundant adult plants, few young plants:

	young	adult
Survey No. 9		
Trisyngyne codonandra	4	7
Cunoniaceae No. 9	2	14
Myrtaceae No. 3019	3	17
Survey No. 10		
Sapindaceae No. 34	0	8
Survey No. 7		
Hibbertia sp. No. 14	0	8
Montrouziera sp. No. 4	1	17
Leucopogon dammarifolius	6	14

In surveys Nos. 6, 10 and 7, seed reproduction of the dominant species is well favoured. On the other hand, its future is uncertain in survey No. 9. Here, the young *Araucaria muelleri* plants occupy a very important place in the vegetation of the lower strata although there are no adult trees of this species in the square of the survey or in its immediate neighbourhood.

However, the abundant seed production and germination are still not sufficient to guarantee the stability of the stock of plants. Furthermore, development must also take place without any particular hindrance, whilst allowing for a successive elimination of young plants by competition. In surveys Nos. 6 and 10, this phenomenon is apparently present since there are young plants of all sizes. The case of survey No. 7 is different: beside 8 adult trees, we find 543 young plants of 10 cm or less, 105 of 11-20 cm, only 4 plants between 21-30 cm and no taller plants. Beside an irregular seed production from year to year which seems likely, it is probable that further growth of the young plants is hindered when they have reached a certain age, although we cannot indicate the factors responsible for this.

We should like to mention here a study made by Mr. Letouzey, Conservateur des Eaux et Forêts in French Camerons, on the *Lophira alata* forest of the coastal zone of the Camerons. There, the *Lophira alata* has the same symptoms of competitive insufficiency in its youth, and the author presumes that without protected artificial regeneration, the forest composition would change.

The interpretation of survey No. 9 is rather delicate. The four young plants of the dominant species are 20, 30, 40 and 40 cm high respectively. An adult plant of 6 meters only has not yet attained its optimal growth. However, the massive growth of young *Araucarias* between 20 to 160 cm high seems to show that this forest will be changed as and when the old *Trisyngyne* die. This transformation is apparently favoured by a rather weak shade produced by the adult *Trisyngyne*, as their crowns are not contiguous, and by the fact that other species participate in the formation of the dominant stratum (*Agathis ovata*, *Salauopris sparsiflora* and *Rhodamnia andromedoides*). In fact, at this high altitude, *Trisyngyne* does not seem to be at its best, and its position seems to be endangered by the strong competition of other plants. Changes of secondary order in ecological conditions may consequently easily provoke structural changes and accelerate the dynamic tendencies of the biocoenose.

One last structural component on which we would like to draw attention is the distribution of the species in the area surveyed. Beside plants like *Phelline lucida* and *Myodocarpus fraxinifolius* of survey No. 6, or *Leucopogon dammarifolius* of survey No. 7, which are all quite regularly distributed over the whole area, there are others such as Rubiaceae No. 29 of survey No. 10, or *Lophoschoenus montisfontium* of survey No. 9, the former located in one corner only, the latter separated in three distinct groups.

These irregularities can be caused by two completely independent factors: 1.—the characteristics of the biological system of dispersion of fruits or seeds, as well as the possibilities of a vegetative reproduction, or, 2.—conditions of the biocoenological medium allowing the development of plants in one area, and hindering it in another.

The first factor is apparently responsible for the grouping of the plants of Rubiaceae No. 29 mentioned: all the young plants are grouped around an adult tree. To a certain extent, tree No. 40 of survey No. 6 and *Spiraeanthemum* sp. No. 2 of survey 10 show similar phenomena. On the contrary, with regards to *Lophoschoenus montisfontium*, their relation to the medium seems more important: it is apparent that it is found mostly under the spaces left open by the crowns of dominant trees. The contrary could be said regarding *Phelline lucida* of the same survey (No. 9) which seems to follow the shade of the trees. Therefore, this species shows that the group forming tendency is subject to the influence of the vegetation itself, having a homogenous distribution in a forest of regular shade, forming groups in a forest of irregular shade.

The presence of groups of certain species, in relation to other plants, is very interesting for the classification of vegetations. However, care should be exercised in order to avoid overestimation of the value of the groups. Daeniker has always insisted on the necessity of considering groups within a wider framework, to look at them as fragments of a mosaic. Temporary dominant or subdominant conditions caused or suffered during certain states of individual growth of a species can be very important, without justifying however a classification of biocoenoses into smaller defined units. In this respect, we recall the lively discussions which took place during the last International Congress of Botany in Paris concerning the existence of tropical associations.

Taking our structural analysis into account, we will not hesitate to put surveys 6 and 10 together as having both the same type of biocoenoses, despite the absence of common species in the under-growth and herbaceous stratum. This type is characterized by one dominant stratum of trees of equal height, reaching 12-15 m. The lower strata are not very developed. There seem to be minor differences only in the composition of the stratum of small trees (presence of many trees of provisional ecological type c) as well as in the frequency of young plants.

Survey No. 9 is clearly different in its structure. Dominant adult trees do not reach the dimensions of the *Trisyngyne* of the two afore-mentioned surveys. The crowns do not form a contiguous cover and consequently, the undergrowth and the herbaceous stratum are much more developed. This structure is emphasized by the abundance of young plants. Analysis of the fragments of neighbouring vegetations will doubtless show that this is a mosaic stone forming a transition to distinct biocoenoses of higher altitudes.

Survey No. 7 belongs to a third type of biocoenoses. The dominant trees reach 12-15 m in height, but without forming a complete cover at crown level. The foliage of *Tr. balansae* produces less shade than that of *Tr. codonandra.* Therefore the undergrowth and the herbaceous stratum are well represented and heliophilous shrubs such as *Leucopogon*, *Dracophyllum* and *Hibbertia*, as well as the heliophilous orchid *Eriaxis rigida*, can be found. Contrarily to what we find in survey No. 9, there is a lot of herbs with a tendency to form aerial stems without leaves *(Lophoschoenus* sp.*)*, while rosette herbs are lacking.

The common characteristics existing between the four surveys cannot fail to be noticed: the dominant stratum reaching a certain height above the ground and formed essentially by one species alone, with, at most, 2 to 4 species reaching the same level, but isolated between the *Trisyngyne*. The most frequent families by number of individuals are the following: Fagaceae, Polypodiaceae, Orchideae, Cyperaceae, Sapindaceae, Rutaceae, Aquifoliaceae and Guttiferae (thus, three families comprising mostly herbs).

Now let us compare briefly another survey with the four fragments discussed: No. 8, situated near No. 7, on a steep slope of a peridotite mountain. Even at a superficial glance a complete difference from the afore-mentioned biocoenoses is apparent.

Above a tree stratum forming a continuous dome but unequal as to its level above the ground (between 10-15 m in general) a few isolated trees grown up to a height of 20-40 m (*Agathis lanceolata*, *Araucaria bernieri*, *Albizza* sp. and other species). Their ecological influence is unimportant compared to the trees forming the dome. Despite the dense shade produced by the latter, the stratum of trees of less than 8 m high (types c and e) is represented in abundance, and small shrubs (type k) are more frequent than in any *Trisyngyne* forest surveys. Herbs are also found in greater abundance than in fragments of shaded biocoenose of *Tr. codonandra* Nos. 6 and 10. Finally the very high number of young plants (33% of the square are young plants higher than 1 m, 91% young plants of 20 to 100 cm, 77% young plants smaller than 20 cm) indicates that this biocoenose is well balanced and that its participants are well adapted to the given conditions.

This is explained by the very different floristic composition of this forest, compared to previous surveys. The most represented families by number of individuals are in this case: Rubiaceae, Pandanaceae, Arabiaceae, Guttiferae, Euphobiaceae, Myrtaceae, Laureaceae and Myrsinaceae, i.e., families of trees found in all dense tropical forests of the world. The undergrowth includes a rather large number of sciaphilous species, specially a *Phyllanthus* and two *Psychotria*. The *Freycinetta* genus is also well represented, specially among young plants. Amongst the genera encountered in the *Trisyngyne* biocoenoses, only *Phelline* and *Myodocarpus fraxinifolius* are found in greater number, hence, trees which are also found under shade in survey No. 6.

Finally, on 100m², we have found 14-16 species in the strata of trees of over 8 m high, and it is certain that this number would increase if the area observed was extended.

Therefore the structure of the biocoenose fragment of survey No. 8 is that of a *tropical forest*. By its complexity and the great amount of species it contains, it is clearly distinct from *Trisyngyne* forests. Of course, it does not correspond to dense forests of the type of equatorial rain forest of the big continents, but it is noticeable that the general idea, if I may call it so, is similar. Besides, we have seen very similar forests from the structural point of view in Central America, in East Cuba and on the Eastern slope of the Drakensberg, South Africa.

Trisyngyne forests, with their simpler structure and predominance of one species only in the higher tree strata, are more reminiscent of forests of temperate regions. However, it would be unwise to use this term in defining any vegetation of New Caledonia. In fact, the geological evolution of this island, the phylogeny and epi-ontology of its vegetation are so different from what is found in temperate countries that we would prefer to create a new expression: "paratropical forest" next to tropical vegetation properly speaking.

To add another type of structure, we would like to mention briefly the study of a fragment of a secondary forest, greatly influenced by man, located on the slopes of Ouen Toro near Noumea. The ground is of sedimentary origin, and the vegetation varies from very impoverished grasslands to regenerated forests, as described by Sarlin in his work.

In the fragment studied, we again find a dominant tree stratum, only reaching 8 m in general, composed nearly exclusively of *Acacia spirorbis*. A few trees of other species are mixed therein: *Casuarina cunninghamiana* and *Melaleuca leuc adendron*. Under the shade of these trees, the crowns of which are close enough together —without producing however a too intense shade, —the small trees and shrubs are few. On the contrary, the herbaceous stratum is very developed (specially *Bidens pilosus*, *Plectranthus parviflorus*, *Rynchelytrum roseum* and other Graminaceae and Composites), and the ground is abundantly covered by young *Passiflora suberosa* plants, Observing the distribution of herbs throughout the survey, it is apparent that the structure is not firmly established, because the herbs are generally limited into groups, with small interference of species. Therefore, we are dealing with initial stages rather than with a normal vegetation competition.

As I said in the beginning, this summary of our biocoenological studies of New Caledonia is not sufficiently complete to give you a general view of the types of structures found on this island. We have spoken neither of swamp forests on sedimentary grounds which are distinct from those found on peridotitic grounds, nor of the Niaouli savannah *(Melaleuca leucadendron)*, which has its own many difficult problems as to its original genesis, problems which perhaps only a detailed analysis of the structure could solve. We have not discussed the following points: the shrubby "bush" and the serpentine vegetations, with their various strata and types;—to what extent are they natural, are they caused by fire or by cutting? We were unable to compare the vegetation of the peridotitic, schistose and gneissic mountains, and we have not established the characteristics of various altitude zones. All this would require much more time for field work than we had, and the only thing we seek to accomplish by this paper is to show the way in which one can attempt to solve these questions.

THE FOG BELT RAIN FOREST OF THE PACIFIC NORTHWEST (U.S.A.)†

RUDY W. BECKING

The Pennsylvania State University, University Park, Pennsylvania, U.S.A.

Coastal forest types in western Washington and Oregon resembling tropical forests by their luxuriant epiphytic growth on trees, have been called "rain forests." Generally these rain forest types are confined to the Fog Belt Subregion.

PHYSIOGRAPHY

The unique physiography of the Fog Belt Subregion consists of high mountain ranges directly parallel to the Pacific Coast blocking the path for southwesterly ocean winds. These mountain masses (Coast Range and the Olympics) form a barrier of 3,000 to 8,000 feet elevation forcing these moisture-laden storms to rise and condense, resulting in the highest orographic precipitation for the whole North American continent. Several large rivers have cut through the Coast Range creating wide valleys open to these ocean winds. Glaciers advancing down from the Olympics have scoured other deep, steep-sided, U-shapped valleys, in places sometimes more than a mile wide.

These glacial valleys are essentially level with a gradient of about 1%. The highest precipitation occurs at the end of the 2-30 mile long and broad valleys around 1,500-2,000 feet elevation, sometimes resulting in an annual precipitation of more than 300 inches.

CLIMATE

The proximity of 2-20 airline miles to the Pacific Ocean creates an ideal marine climate in this narrow Fog Belt Subregion, extending some 500 miles along the Pacific Coast, from California into Alaska.

General characteristics of this marine climate are:

(1) A very narrow fluctuation of temperature extremes hardly exceeding 20°F annually with an average annual temperature of 49° - 50°F.

(2) The longest recorded frost free period extending well over 200 days, ranging from 180-310 days which is exceptional for the 44-49 parallel northern latitude.

(3) Consequently, it has no snowfall directly near the ocean. Six miles further inland in the valley bottoms snow depth increases from a few inches to two feet and at a distance of 15 miles inland from 2 to 4 feet. Above 1,000 feet elevation, annual precipitation in the form of snow can even amount to 300 inches at high elevations.

(4) No appreciable drought period in the summer. During the early morning hours incoming ocean fog will create considerable fog drip within the rain forest preventing these forest types to dry out. Forest fires which commonly ravage more inland forest types have never been able to penetrate into these rain forest types.

VEGETATION PATTERN

Rain forest types cover river flats and the foot hills up to about, 1,000 feet elevation constituting of two, possibly more, alliances of coniferous forest types dominated by the Sitka spruce and western hemlock, and of deciduous forest types dominated by the big-leaf maple and red alder.

The American rain forest types are characterized by:

(1) Unusual tree heights and sizes. The largest and highest individuals of Douglas fir, Sitka spruce, red cedar, and hemlock are all found within the rain forest. Tree heights of 300 feet and more are not uncommon in virgin stands of sheltered valleys with tree ages of about 2,500 years.

(2) Buttressed tree bases and collonades. Sitka spruce and hemlock regeneration usually starts upon rotting logs and stumps. Seedling growth is very slow on these substates until its roots strike mineral soil. Roots become heavier and fuse in order to support the increasing tree size. Gradually, the nurse-log decomposes, leaving a collonade of trees with buttressed bases and exposed root collars.

(3) Luxuriant epiphytic growth on stems and branches of trees. In temperate forests, epiphytic vegetation is rarely encountered. Low temperature and occasional dessication in the summer have limited the epiphytic flora to a few cryptogams, lichens, bryophytes, and pteridophytes. No profusion of vascular epiphytic plants, so

† Presented by F.E. Egler.

typical of tropical rain forest, exist. Trees may become sometimes so heavily laden with an upholstering of rain-soaked bryophytes that they are susceptible for windthrow.

The coniferous forest alliances can be divided into four main forest types:

The Sitka Spruce - Hemlock forest type. This is the most common rain forest type covering river flats, slopes, and ridges. Its tree layer is dominated by *Picea sitcheniss* and *Tsuga heterophylla* usually in an intensive mixture, however locally pure stands of one of these dominant trees are also found. Its shrub layer is dominated by *Acer circinatum* or *Rubus spectabilis* particularly in river flats and on lower slopes. Its herb layer is characterized by the dominance of *Polystichum munitum*, *Oxalis oregana*, and occasionally *Tiarella trifoliata*.

The characteristic species composition includes:

the group of character species of this forest type:

Arceuthobium tsugense
Clintonia uniflora
Cornus canadensis
Disporum smithii
Menziesia ferruginea
Moneses uniflora
Picea sitchensis
Rubus pedatus
Tsuga heterophylla
Vaccinium alaskaense
Vaccinium ovalifolium

Particularly the stands on river flats, lower and middle slopes are characterized by the common moisture indicators:

Acer circinatum
Athyrium felix-femina
Blechum spicant
Disporum oreganum
Dryopteris dilatata
Festuca subuliflora
Luzula parviflora
Maianthemum dilatatum
Melica subulata
Montia sibirica
Oxalis oregana
Polystichum munitum
Rubus spectabilis
Sambucus callicarpa
Stachys ciliata
Tiarella trifoliata

Stands on upper slopes are generally characterized by the lack of moisture indicators and by the abundance of:

Gaultheria shallon
Linnaea borealis

The Coastal Sitka Spruce forest type. This forest type is limited to bluffs and west slopes directly facing the Pacific Ocean. Dominant trees of Sitka spruce, hemlock, and red alder are stunted by wind. Its shrub layer is usually dominated by *Gualtheria shallon*, sometimes on the lower slopes by *Rubus spectabilis.*

The characteristic species composition consists of.

Alnus rubra
Arceuthobium tsugense
Lonicera involucrata
Picea sitchensis
Thuja plicata
Tsuga heterophylla
Vaccinium ovatum

together with most of the common moisture indicators.

The Sitka Spruce - Lodgepole Pine forest type. This forest type is confined to areas with sandy soils and dune formations in the vicinity.

Its characteristic species composition consists of:

Gaultheria shallon
Lonicera involucrata
Malus rivularis
Picea sitchensis
Pinus contorta
Rhododendron californicum
Thuja plicata
Tsuga heterophylla
Umbellaria californica
Vaccinium ovatum

with hardly any of the common moisture indicators.

The Sitka Spruce Swamp forest type. Meandering rivers create extensive swamp forest areas in their deltas. Trees are situated on humps within the swamp. Its tree layer is rather open, characterized by the dominance of Sitka spruce and red alder mixed with an occasional hemlock; its shrub layer is dominated by Rubus spectabilis.

Its characteristic species composition consists of:

Alnus rubra
Cardamine angulata
Carex obnupta
Chrysoplenium glechomaefolium
Lonicera involucrata
Lysichitum camtschatcence
Oenanthe sarmentosa

together with the character species of the Sitka Spruce - Hemlock forest type:

Menziesia ferruginea
Moneses uniflora
Vaccinium alaskaense
Vaccinium ovalifolium

with the common moisture indicators:

Athyrium felix-femina
Blechnum spicant
Dryopteris dilatata
Luzula parviflora
Maianthemum dilatatum
Polystichum munitum
Rubus spectabilis
Sambucus callicarpa
Stachys ciliata
Tiarella trifoliata

In the deciduous rain forests, the Riverflat Maple and the Red Alder forest types are distinguished. The Riverflat Maple forest type is noted for its luxuriant epiphytic cover, being considered usually the veritable rain forest. In virgin stands the dominant bigleaf maple is mixed with Sitka spruce, red alder, cottonwood, hemlock, and grand fir, but in second growth stands usually only the maple is present. A luxuriant cover of bryophytes and vascular plants cover the soil, rotting logs and tree trunks while a dense herb and shrub layer will add to its jungle-like appearance.

However, on the Olympic Peninsula these Riverflat Maple forests have a rather open and park-like character, lacking chiefly the dense layer of high herbs and shrubs. The reason for this is the presence of some 4,000 Roosevelt elk (*Cervus canadensis* var: *roosevelti*) wintering in these rain-forest valleys inside the Olympic National Park. As the Roosevelt elk is gregarious, frequently banding in herds from 20 to 100 animals, the effects of elk herds' browsing and trampling are significant. The lack of high herbs and shrubs and the introduction and abundance of grasses and grazing indicators have given this forest type an overbrowsed appearance. Since 1935, elk exclosure plots have been established within the Olympic National Park. At the present the vegetation inside these fenced plots is characterized by a tall herb layer and a dense shrub layer of *Acer circinatum*, *Sambucus callicarpa*, and *Rubus spectabilis* indicating its natural appearance without the overbrowsing effects of the Roosevelt elk. In other parts of the Fog Belt Subregion where no Roosevelt elks are present, deer will frequently graze in the Riverflat Maple and Red Alder forest types, so that grazing indicators and grasses form a characteristic component of these deciduous rain forest types.

The Riverflat Maple forest type. The characteristic species composition of this forest type is comprised of:

in its tree layer:

Abies grandis	*Pseudotsuga taxifolia*
Acer macrophyllum (dom.)	*Selaginella oregana* (epiphytic)
Alnus rubra	*Thuja plicata*
Picea sitchensis	*Tsuga heterophylla*
Populus trichocapra	

in its shrub layer:

Acer circinatum (dom.)	*Holodiscus discolor*
Corylus californica	*Oplopanax horridus*
Osmaronia cerasiforis	*Sambucus callicarpa*
Rubus spectabilis	*Taxus brevifolia*

in its herb layer:

the group of common moisture indicators:

Acer circinatum	*Melica subulata*
Athyrium feliz-femina	*Montia sibirica*
Blechnum spicant	*Oxalis oregana*
Dentaria tenella	*Rubus spectabilis*
Disporum oreganum	*Sambucus callicarpa*
Dryopteris dilatata	*Stachys ciliata*
Festuca subuliflora	*Tierella trifoliata*
Luzula parviflora	*Trientalis latifolia*
Maianthemum dilatatum	

the group of riverflat moisture indicators:

Asarum caudatum	*Symphoricarpos albus*
Circaea pacifica	*Tellima grandiflora*
Dicentra formosa	*Tolmiea menziesii*
Hydrophyllum tenuipes	*Urtica lyallii*
Mitella caulescens	*Viola glabella*
Nemophila parviflora	
Rosa nutkana	

the group of grazing indicators:

Adenocaulon bicolor	*Galium trifidum*
Agrostis stolonifera/exarata	*Osmorhiza nuda*
Bromus sitchensis/vulgaris	*Poa kelloggii*
Cardamine oligosperma	*Ranunculus bongardii*
Carex leptopoda	
Deschampsia elongata	*Stellaria crispa*
Galium aparine	*Trisetum cernuum*

the group of Riverflat Maple forest character species:

Carex hendersoni	*Elymus glaucus*
Carex mertensii	*Galium oreganum*

Epiphytes on trees are comprised of a large group of bryophytes and lichens of which the most common ones are:

Antitrichia curtipendula	*Mnium punctatum*
Camptothecium lutescens	*Mnium venustum*
Claopodium crispifolium	*Neckera douglasii*
Eurhynchium oreganum	*Neckera menziesii*
Frullania nisquallensis	*Porella navicularis*
Homalothecium nuttallii	*Pseudoisothecium stoloniferum*
Hylocomium proliferum	
Hypnum subimponens	*Rhytidiadelphus loreus*
Lobaria oregona	
Metzgeria conjugata	*Rhytidiadelphus triquetrus*
Metzgeria pubescens	
Mnium menziesii	

A few plants are also characteristic epiphytes:

Montia heterophylla	*Selaginella oregana*
Polypodium vulgare	

The Red Alder forest type. It occupies similar habitats as the former forest type and is usually in a successional transition towards it. Characteristic for this forest type is a dense, even-aged stand of *Alnus rubra*, the almost complete lack of any shrub layer in its typical form and the lack of a dense epiphytic upholstering of the tree trunks. Mostly, the red alder is densely covered by crustaceous and foliose lichens with some bryophytes, comprised of:

the group of common epiphytes:

Antitrichia curtipendula	*Parmelia physodes*
Cetraria glauca	*Pertusaria multipuncta*
Frullania nisquallensis	*Porella navicularis*
Neckera douglasii	*Pseudoisothecium stoloniferum*
Parmelia enteromorpha	

and the group of epiphytes typical for red alder trees:

Cetraria scutata	*Orthotrichum lyellii*
Dicranoweisia cirrhata	*Parmelia pertusa*
Evernia prunastri	*Parmelia saxatilis*
Graphis scripta	*Radula bolanderi*
Lecanora subfusca	*Radula complanata*
Ochrolechia tartarea	
Orthotrichum consimile	

The characteristic species composition of this Red Alder forest type is comprised of:

the group common moisture indicators:

Acer circinatum	*Rhamnus purshiana*
Athyrium felix-femina	*Rubus spectabilis*
Dryopteris dilatata	*Sambucus callicarpa*
Luzula parviflora	*Stachys ciliata*
Oxalis oregana	*Tiarella trifoliata*
Polystichum munitum	

the group of riverflat moisture indicators:

Circaea pacifica	*Osmaronia cerasiformis*
Dicentra formosa	*Tolmiea menziesii*
Hydrophyllum tenuipes	*Viola glabella*
Mitella caulescens	

the group of swamp indicators:

Cardamine angulata	*Lysichitum camtschatcense*
Chrysoplenium glechomaefolium	*Oenanthe sarmentosa*
Corydalis scouleri	

the group of grazing indicators with the following additional grazing indicators typical for this forest type:

Cirsium lanceolatum	*Rumex obtusifolia*
Equisetum arvense	*Stellaria graminea*
Rumex acetosella	

and the group of character species of the Red Alder forest type:

Epilobium adenocaulon	*Pleuropogon refractus*
Glyceria elata	*Ribes petiolare*
Mimulus guttatus	*Senecio triangularis*
Mitella ovalis	*Valeriana sitchensis*
Petasites speciosus	

The deciduous rain forest types are strictly confined to valley bottoms and coves along streamlets below 1,000 feet elevation. They are not completely restricted to the Fog Belt Subregion but may be found locally in the foot hills of the Cascades where the annual precipitation is unusually high. Both forest types occur on alluvial deposits close to the river. The open river bars are first colonized by red alder and cottonwood.

Successional trends of the Red Alder forest type towards the climax Riverflat Maple forest type can be frequently encountered, but no observations have led to the belief that eventually the deciduous Riverflat Maple forest will evolve into a coniferous rain forest type. When the river alters its course, it may disrupt forest vegetation and occasionally Douglas fir may get established in pure even-aged stand patches. The forest communities in such Douglas fir stands are closely allied to the Sword Fern-Douglas Fir alliance. As fire is not the tool for opening up the forest canopy for future Douglas fir regeneration, only clearing of forested land by river erosion and redeposition of new land will perpetuate the Douglas fir forest community. Otherwise, it will evolve into the climax of the Riverflat Maple forest type.

THE ICONOGRAPHY OF THE VEGETATION OF THE NATURAL FOREST IN JAPAN†

MISAO TATEWAKI

Hokkaido University, Sapporo, Japan.

The present project is a research into the forest vegetation of Japan. The writer wished to obtain a phytosociological description of the various forest vegetations, once the tremendous treasure of Japan. The primeval forests in Japan have been largely destroyed, and this destruction will continue until public pressure halts the abuse. The writer selected carefully the experimental plots represented by the fine forests in the present Japan where the excellent physiognomies of the natural forest have been fortunately preserved.

To analyse the construction of the forest vegetation, the writer used "the sociation" as the synecological unit. He treated it as the species in the systematic botany. This idea results from the field surveys of the complicated forest vegetation of Japan in these twenty-five years. For the description of the sociation, the bisect method accompanied by the map, the sketch, the photograph, and the analytical table was used. It is the shortest and the wisest method to express the composition of the forest vegetation in the natural stand. The writer has attempted to describe the vegetation accurately and to analyse precisely and carefully the construction of the forest layers.

Generally speaking, Japan ranges from the zone of southern temperate forest to that of the northern temperate, each represented by the evergreen broad-leaved forest and the summer-green one. The former includes the subtropical rain forests in its southern points and the latter sometimes accompanied by the subarctic forests in the northern part. The latter in Hokkaido except the southwestern part shows the intermediate feature between the temperate and the subarctic forest, expressing the stronger influence of the temperate character.

From the viewpoint of the vertical vegetation, the pure thicket of the Siberian dwarf pine is well developed in the alpine belt of the mountain ranges in the north from Central Honshû (the main island) through the *Betula Ermani* forest. The subarctic or needle-leaved forest represented by *Abies* and *Picea* follows the *Erman*'s birch forest or directly contact the dwarf pine thickets. But it is very characteristic to render the forest vegetation in the Japan Sea side by the absence of the *Picea-Abies* forest.

The climax forests are as follows in the different forest zones:

Subtropical rain	
forest	*Ficus Wightiana*
Salt marsh	*Kandela Candel*
Coast	*Livistona subglobosa*
Warm temperate	
forest	*Shii-Kashi*
Sandy shore	*Pinus Thunbergii*
Coastal district	*Machilus Thunbergii*
Mountain district	*Abies firma-Tsuga Sieboldii*
Cold temperate forest	
Seashore	*Quercus dentata*
Light soil	*Quercus crispula*
Valley	*Pterocarya rhoifolia-Aesculus turbina-Cercidiphyllum Japonicum*
Needle-leaved	
forest	*Picea-Abies*
Hokkaido	*Picea jezoensis-Abies sachalinensis*
Bog	*Picea Glehni*
Honshû	*Picea jezoensis* var. *hondoensis-Abies Veitchii*
Northern mixed forest	
Sandy shore	*Quercus dentata*
Plain	*Ulmus propinqua-Acer mono*
Swany	*Alnus japonica*
Hill	*Acer mono-Tilia japonica*
Valley	*Cercidiphyllum japonicum-Fraxinus mandshurica-Juglans ailanthifolia*

Up to the present, the following three volumes (I-III) have been published. The last two volumes (IV-V) are already prepared and will be published in June of 1958.

I. THE CENTRAL SANYU DISTRICT, HONSHÛ

By M. TATEWAKI and T. TSUJII
Res. Bull. Coll. Exp. For. Coll. Agr. Hokkaido Univ. 18-1. 1 54. (1956)

† Presented by F.E. Egler.

Hiroshima, famous following the first dropping of the atomic bomb, was the center of the research. It is facing the Inland Sea (Setonaikai) and is situated 34°24′N., 132°27′E. We studied a belt which extended from the seaside at Hiroshima to the inland mountains that form the backbone of the Chûgoku Region. The distance is about 42 km, and the rise in vertical elevation from sea level to the mountains is 1,346 m. Along the transects under consideration, five experimental localities were studied as follows:

Name of locality	Transect number	Elevation (m)	Name of forest
Ujina	1.a	20	*Castanopsis cuspidata*
,,	1.b	40	*Cinamomum Camphora*
Iwakuni	2.a	60	*Castanopsis caspidata*
,,	2.b	80	,, ,,
Minochi	3.a	1,000	*Abies firma-Tsuga Sieboldii*
Nakanokô	4.a	1,000	*Fagus crenata*
,,	4.b	950	*Quercus crispula*
Miyajima	5.a	460	*Tsuga Sieboldii*
,,	5.b	500	,, ,,
,,	5.c	470	,, ,,
,,	5.d	460	,, ,,
,,	5.e	460	,, ,,
,,	5.f	420	,, ,,
,,	5.g	200	,, ,,
,,	5.h	40	*Abies firma*
,,	5.i	50	,, ,,

II. ISLAND OF YAKUSHIMA

By M. TATEWAKI

ibid. 18-2. 53 148. (1957)

Geobotanically, the Island of Yakushima is one of the most important localities in Japan. It is extremely interesting, with many endemic and rare elements. Yakushima is roughly orbicular in shape, about 27.1 km long and 26.7 km wide, with an area of approximately 544 sq km, lying between 130°23′-40′ East Longitude and 30°13′-28′ North Latitute. In the central part of the island, there are high mountains, such as Mt. Miyanoura (1,935 m), Mt. Nagata (1,890 m) and Mt. Kuromi (1,836 m). All rivers extend toward the sea from these central highlands, and enroute they often form deep gorges.

In 1916, the American botanist Dr. H. Wilson visited Yakushima and spoke admiringly of the beautiful primeval forests of *Cryptomeria japonica.* Both before and after him, many Japanese botanists have turned their attention to floristic and vegetational studies of the region, among them, Profs. G. Koizumi, G. Masamune, S. Hatsushima, Drs. M. Kawada, K. Imanishi, Mr. Z. Tashiro and so forth. The results of their important researches were cited briefly in the paper. The studies of Prof. G. Masamune are especially important, for he described the flora in excellent and precise terms.

The two islands Yakushima and Tanegashima form a special phytogeographical district of the East Asiatic Warm Temperate Zone. Tokara Strait, lying just to the south of Yakushima island, acts as a line of demarcation between this zone and the elements at the northern limit of their distribution, which perhaps is only natural, considering the unique geographical position of the islands.

But it is quite remarkable that certain Japanese elements, which make up a prominent part of the flora also have their northern limit of distribution in this region, namely: *Cephalotaxus drupacea*, *Torreya nucifera*, *Abies firma*, *Chamaecyparis obtusa*, *Castanea crenata*, etc.

The causes of this peculiar and somewhat confined distribution have been attributed to the presence of high mountains on Yakushima and deep sea separating the islands from the southern areas. These geographical barriers may be considered to be the primary ecological factors operating against a more widespread occurrence of the Japanese elements named above. Along the transects under consideration, nine localities were studied as follows:

Name of locality	Transect number	Elevation (m)	Name of forest
Kurio	1.a	0	*Kandelia Candel*
,,	1.b	0	,, ,,
,,	1.c	0	,, ,,
Mugio	2.a	40	*Ficus Wightiana-Ficus retusa*
Nabeyama	3.a	20	*Machlus Thunbergii*
,,	3.b	20	*Quercus Wrightii*
Near Kosugidani	4.a	800	*Distylium racemosum*
,, ,,	5.a	1,000	*Cryptomeria japonica*
,, ,,	5.b	1,000	,, ,,
,, ,,	5.c	1,000	,, ,,
,, ,,	6.a	1,100	,, ,,
,, ,,	6.b	1,100	,, ,,

Name of locality	Transect number	Elevation (m)	Name of forest
Near Kosugidani	7.a	960	*Abies firma*
,, ,,	7.b	960	*Tsuga Sieboldii-Cryptomeria japonica*
,, ,,	7.c	960	*Tsuga Sieboldii*
Mt. Ishizuka	8.a	1,200	*Tsuga Sieboldii*
,, ,,	8.b	1,440	*Cryptomeria japonica-Trochodendron aralioides*
Mt. Miyanoura	9.a	1,760	*Cryptomeria japonica*

III. FOREST VEGETATION OF SOUTHERN KYÛSHÛ

By M. TATEWAKI and T. MISUMI

ibid. 18-2. 149 208. (1957)

In some limited localities in Southern Kyûshû, the forests are characterized by subtropical vegetation. Pure forest of *Kandelia Candel*, *Cycas revoluta*, and *Livistona subglobosa*, respectively, are representative. The latter two forests, occurring in rather small areas, are found at the points of the peninsula protruding into the Pacific Ocean washed by warm currents or on the islets surrounded by warm current. The forest vegetation in the low lands of the district under consideration predominantly consists of evergreen broad-leaved trees. The present study was carried out from the seaside to the mountain to heights of about 1,000 m., ranging from the subtropical forests to the temperate needle-leaved forest through the evergreen broad-leaved forests. Along the transects laid out for study, eight experimental localities were situated as follows:

Name of locality	Transect number	Elevation (m)	Name of forest
Kiire	1.a	0	*Kandelia Candel*
Kôyama	2.a	520	*Distylium racemosum*
,,	2.b	540	,, ,,
Birô-jima	3.a	20	*Livistona subglobosa*
,,	3.b	20	,, ,,
Hosaki	4.a	20	*Cycas revoluta*
,,	4.b	20	,, ,,
Toisaki	5.a	20	,, ,,
Magaya	6.a	140	*Cinnamonum Camphora*
Aoshima	7.a	5	*Livistona subglobosa*
Mt. Kirishima	8.a	990	*Abies firma-Tsuga Sieboldii*
,, ,,	8.b	1,050	*Tsuga Sieboldii*
,, ,,	8.c	960	*Abies firma*

IV. THE SOUTHERN SHIKOKU DISTRICT

By M. TATEWAKI and T. TSUJI

ibid. 18-2. 149 208. (1957)

The dominant feature of the forest vegetation of Southern Shikoku is represented by "pluviisilvae." In several places of the district under consideration, the natural physiognomy of the forests has fortunately been kept and poses an important problem for geobotany in spite of the comparatively small areas in question.

The general arrangement of the forests will be explained first. Along the shore, the *Pinus Thunbergii* forest is commonly developed on sandy beaches. On flat terraces, the *Pittosporum Tobira* forest mixed with *Eurya emarginata* forms the front zone against the sea. It attains a height ranging 1-3-5 m influenced by the wind. The *Camellia japonica* forest succeeds it and is then followed by the *Machilus Thunbergii* forest inward.

In the *Machilus* forest belt, *Distylum racemosum*, *Podocarpus Nagi*, and *Elaeocarpus sylvestris* are sometimes found, forming groves in some areas. The pure *Quercus phillyraeoides* forests are generally found on the rocky slope along the shore. *Nephrolepis cordifolia* and *Pyrosia Lingua* are commonly found in the underlayer. The *Castanopsis cuspidata* forest is also found inland, but it has lost its primeval physiognomy. Only one place in Ikku, near Kôchi, a rather young natural forest, was selected for ecological analysis.

The elements of the subtropical forests are well represented by *Ficus Wightiana* and *Livistona subglobosa*. Their areas are very limited. The former forest is found in Cape Muroto and Cape Ashizuri. The latter is found only in Ashizuri, but the question whether it is an invader from the south or a remnant is still unsettled. We consider it as a vestige.

Along the transects under consideration, six experimental localities were situated as follows:

Name of locality	Transect number	Elevation (m)	Name of forest
Cape Muroto	1.a	5	*Ficus Wightiana*
,, ,,	1.b	20	*Quercus phillyraeoides*
,, ,,	1.c	100	*Distylium racemosum*
Tosa Ikku	2.a	80	*Castanopsis cuspidata*
Kashima	3.a	5	,, ,,
Cape Ashizuri	4.a	20	*Livistona subglobosa*
,, ,,	4.b	40	*Pittosporum Tobira*
,, ,,	4.c	40	,, ,,
,, ,,	4.d	100	*Camellia japonica*
,, ,,	4.e	100	,, ,,
,, ,,	4.f	40	,, ,,
,, ,,	4.g	40	*Machilus Thunbergii*
,, ,,	4.h	40	,, ,,
,, ,,	4.i	40	,, ,,
,, ,,	4.j	80	,, ,,
,, ,,	4.k	80	,, ,,
,, ,,	4.l	130	*Quercus phillyraeoides*
Yotate-yama	5.a	30	,, ,,
,, ,,	5.b	30	,, ,,
Misaki sample plot		20	*Livistona subglobosa*

V. GEOBOTANICAL STUDY ON THE *FAGUS CRENATA* FOREST IN THE DISTRICT OF ITS NORTHERN LIMIT

By M. TATEWAKI, etc.

The Japanese beech, *Fagus crenata*, is the representive tree of the cold temperate forests in Japan. Up to the present, the precise study of its distribution within the northern limit was carried out by Tatewaki in 1948. The geobotanical study of the Japanese beech forest of the district under consideration is a most important and interesting problem not only from the viewpoint of geobotany, but also from that of forestry. During these ten years, especially during the last five years, Tatewaki accompanied by the members of his institute, T. Misumi, T. Igarashi, S. Watanabe, and S. Kawano, have devoted themselves to the study of this question under the auspices of the Hakodate Regional Forest Office. Along the transects under consideration, seven localities were studied, as follows:

Name of locality	Transect number	Elevation (m)	Name of forest
Utasai	1.a	60	*Fagus crenata*
,,	1.b	100	,, ,,
Tsubame-no-sawa	1.c	560	,, ,,
,, ,,	1.d	560	,, ,,
Shirai-gawa	1.e	280	,, ,,
Yamato-no-sawa	1.f	180	,, ,,
Mt. Kariba	2.a	740	*Betula Ermani*
,, ,,	2.b	680	*Fagus crenata*
,, ,,	2.c	540	,, ,,
,, ,,	2.d	420	,, ,,
,, ,,	2.e	420	,, ,,
Mt. Oshamanbe	3.a	860	*Betula Ermani*
,, ,,	3.b	700	,, ,,
,, ,,	3.c	720	*Fagus crenata -Betula ermani*
,, ,,	3.d	640	*Betula Ermani -Fagus crenata*
Mt. Oshamanbe	3.e	620	*Fagus crenata*
,, ,,	3.f	620	,, ,,
,, ,,	3.g	660	,, ,,
,, ,,	3.h	580	,, ,,
Mt. Ohira	4.a	800	,, ,,
,, ,,	4.b	340	,, ,,
,, ,,	4.c	340	,, ,,
,, ,,	4.d	320	,, ,,
,, ,,	4.e	360	,, ,,
,, ,,	4.f	280	,, ,,
,, ,,	4.g	220	,, ,,
,, ,,	4.h	280	,, ,,
,, ,,	4.i	100	,, ,,
,, ,,	4.j	200	,, ,,
,, ,,	4.k	540	,, ,,
,, ,,	4.l	360	,, ,,
,, ,,	4.m	920	,, ,,
,, ,,	4.n	260	,, ,,
,, ,,	4.o	320	,, ,,
,, ,,	4.p	500	,, ,,
,, ,,	4.q	700	,, ,,
,, ,,	4.r	600	,, ,,
,, ,,	4.s	460	,, ,,
,, ,,	4.t	420	,, ,,
,, ,,	4.u	300	,, ,,
,, ,,	4.v	700	,, ,,
,, ,,	4.z	240	,, ,,

THE DEVELOPMENT OF FOREST COMMUNITIES IN EASTERN ASIA†

CHI-WU WANG

University of Florida, Gainesville, Florida, U.S.A.

INTRODUCTION

Over the land mass of continental eastern Asia, forest communities once flourished in an almost unbroken expanse of over 30 degrees of latitude, from the tropics to eastern Siberia. Throughout the immense geographic range there is a gradual displacement of forest components, with resultant intergradations and segregations of forest types.

The forest vegetation of continental eastern Asia comprises the following main types[1]:

(1) The montane coniferous forest formation: spruce-fir forest, larch forest;
(2) The broad-leaved deciduous forest formation: the mixed mesophytic forest, the mixed northern hardwood forest, the deciduous oak forest, birch forest;
(3) The broad-leaved evergreen forest formation: the evergreen oak forest, the rain forest, the littoral forest.

The main types of forest vegetation are arranged in approximately the latitudinal and altitudinal sequence as presented in the vegetation map.

Throughout the long geologic past, since the advent of angiospermous plants in the late Mesozoic Era, there were always areal and compositional differentiations in the vegetation. The author assumes that all the natural phenomena in geologic time were governed by laws that govern the Universe today. The plants of the existing vegetation, as were plants throughout the ages, are the direct descendants of pre-existing ones with which they are genetically most closely related. Upon this premise, the developmental concept of plant communities used in this paper is based. The phylogenetic relationships of the components of the plant communities offer the most reliable clue in interpretations of development, differentiation and relationship among the different forest communities, their present pattern of geographic distribution, and their vicissitudes during geologic time.

Evidence afforded by the existing vegetation and that of the geologic past suggests that the existing forest communities originated from a type that resembled the modern rain forest. The differentiated, usually simpler and specialized types of forest communities, different as they are, are linked with the ancestral type represented in the modern rain forest by a continuum of variation among phyletic stocks. The modern rainforest has been changed through contraction and speciation among its components, as have other forest communities. It still retains the multitude of phyletic stocks of which the other forest communities are composed and to which they are linked by a close phylogenetic bond.

The ancestral community, as exemplified by the existing rain forest, is generally represented by primitive forms and usually by far more sections, genera, and even sub-families. In other words, the rain forest is composed of descendants from a higher level of plant evolution, and hence an older one in time sequence, while the other forest communities are composed of later-differentiated and often specialized forms of the same phyletic stocks.

The compositional and areal differentiations of the forest communities are primarily the results of two basic processes: historic contraction and regional speciation. They are the manifestation of the innate potentialities of all the phyletic stocks of forest trees ever evolved on the earth's surface. The extreme paucity of components in certain simple forests of wide extent, e.g., birch forest, larch forest, and the multitude of monotypic groups and ogliotopic genera in the polyphyletic communities, e.g., mixed mesophytic forest, furnish evidence of the extent of contraction. On the other hand, the clusters of numerous closely related species, in both the polyphyletic and the monophyletic communities, and the geographic varieties, races, and forms recognized within population of extensive range bear witness to the active process of regional speciation.

Through contraction, which widened the gaps of discontinuity both in character and in range, distinct species (such as *Populus tremuloides*) and subgenera (such as the black oak group, *Erythrobalanus*, of North America) and genera (such as the evergreen beech group, *Nothofagus*, of the Southern Hemisphere) likewise have

† Presented by F.E. Egler.

1 The Forest Types of Continental Eastern Asia I, II. 8th Pacific Science Congress, Manila, Philippines.

resulted from the species clusters. The differentiation of subfamilies and families is only the prolongation of the process, which in turn transforms simple types of forest communities into polyphyletic types in time to come.

In the present treatise the segregation and development of two main forest types, the mixed mesophytic forest and the mixed northern hardwood forest, are traced. The closest living representatives of these two forest types are found in eastern North America. Frequent references are made to the forests of eastern North America. The author believes that the segregation and development of forest communities, as visualized above, is an universal phenomenon and has been contemporaneous in time sequence throughout the world. But it is more fully expressed in the existing vegetation of eastern Asia which extends from the tropics to the Arctic and which is the greatest repository of Tertiary relics. The main types of forest vegetation are not only spatially and compositionally differentiated entities, but each of them reflects a common level of plant evolution. They are linked by a strong bond of descent upon which the interpretation proposed in this paper is based.

THE MIXED MESOPHYTIC FOREST

Composition

The mixed mesophytic forest of eastern Asia is floristically the richest in composition of all the deciduous broad-leaved forests, and is surpassed in complexity only by the rain forest. Not only does it include a multitude of tree species, but the trees represent a large number of remotely related phyletic stocks. It includes also numerous relics of an "arcto-Tertiary flora" whose most closely related modern species are found in the mixed mesophytic forest of North America. The tree components of the mixed mesophytic forest of eastern Asia include more than 10 genera of conifers and over 50 genera of hardwoods (*evergreen broad-leaved trees):

Conifers

Cephalotaxus	*Nothotaxus*	*Taxus*
Cryptomeria	*Pinus*	*Torreya*
Cunninghamia	*Pseudotsuga*	*Tsuga*
Cupressus	*Pseudolarix*	

Broad-leaved trees

Acanthopanax	*Acer*	*Aesculus*		
Aphananthe	*Fagus*	*Nyssa*		
Betula	*Fraxinus*	*Paulownia*		
Camptotheca	*Gymnocladus*	*Phellodendron*		
Carya	*Halesia*	**Photinia*		
**Castanea*	*Hovenia*	*Pistacia*		
**Castanopsis*	*Idesia*	*Platycarya*		
Celtis	**Illicium*	*Prunus*		
Cercidiphyllum	*Juglans*	*Pterocarya*		
Cladrastis	*Kalopanax*	*Pterostyrax*		
Daphniphyllum	*Koelreuteria*	**Quercus*		
Davidia	*Liquidambar*	*Sassafras*		
Diospyros	*Liriodendron*	*Sorbus*		
Ehretia	**Lithocarpus*	*Tetracentron*		
Elaeocarpus	*Maackia*	*Tilia*		
Emmenopteris	*Magnolia*	*Trema*		
Eucommia	**Manglietia*	*Ulmus*		
Euptelea	*Meliosma*	*Zelkova*		
Evodia	*Morus*			

The "mixed mesophytic forest climax" of eastern North America, as defined by Braun (*5*, 40-41), includes 25 species and varieties of dominant trees in the aboreal layer. They represent the following genera:

Acer	*Fraxinus*	*Prunus*
Aesculus	*Halesia*	*Quercus*
Betula	*Juglans*	*Tilia*
Carya	*Liriodendron*	*Tsuga*
Castanea	*Magnolia*	
Fagus	*Nyssa*	

The following genera, which sometimes appear in the climax stands, can be added to the above list:

Celtis	*Liquidambar*	*Robinia*
Cladrastis	*Morus*	*Sassafras*
Cornus	*Oxydendron*	*Taxus*
Gymnocladus	*Pinus*	*Ulmus*
Ilex	*Platanus*	

All these 30 genera are represented in the mixed mesophytic forest of the Yangtze Valley, except for *Oxydendron*, *Platanus*, and *Robinia*.

Braun *(4, 5)* maintains that the mixed mesophytic association of eastern North America is the "lineal descendant" and persisting remnant of the "undifferentiated forest of the Tertiary," and the most complex and oldest association of the deciduous forest formation. It occupies a central position in the deciduous forest as a whole; and from it or its ancestral progenitor (the mixed Tertiary forest) all other climaxes of the deciduous forest have arisen.

How satisfactory this center of radiation theory for the mixed mesophytic forest is, will be verified by further studies of my American colleagues. It is known, however, that the Tertiary forest of the middle latitudes of eastern North America was far richer in tree components than the existing mixed mesophytic forest. It included the following genera that do not exist in the present forest (Wilcox flora, Eocene):

**Acacia*	**Combretum*	**Pistia*
**Anona*	**Cordia*	**Pithecolobium*
Artocarpus	**Cryptocarya*	*Psychotria*
**Avicennia*	**Dalbergia*	**Sapindus*
**Berchemia*	**Diospyros*	*Schefflera*
**Buttneria*	**Engelhardtia*	**Sideroxylon*
**Caesalpinia*	**Eugenia*	**Staphylea*
**Canavalia*	**Ficus*	**Sterculia*
**Canna*	*Glyptostrobus*	**Terminalia*
**Cassis*	**Oreodaphne*	*Zygophyllum*
**Cedrela*	**Osmanthus*	
**Cinnamomum*	*Paliurus*	

The fossils assigned to "*Dryophyllum*" *(3)* are, according to Sharp *(18)*, more closely related to modern Mexican oaks. Representatives of these genera now exist in the broad-leaved evergreen forest region of eastern Asia, and the majority of them (*) still can be found in the southern part of eastern North America south of the mixed mesophytic forest region, mostly in Florida and Mexico *(18)*.

The present mixed mesophytic forest of eastern North America is primarily a deciduous community. If it is the lineal descendant of the Tertiary forest, as suggested by Braun, the evidence indicates that the existing forest has been changed considerably from its progenitor.

Historic Contraction

The most obvious change in the composition of the mixed mesophytic forest has been the nearly total (as in eastern North America) or partial (as in eastern Asia) elimination of evergreen broad-leaved trees. This change resulted in a transformation into an essentially deciduous community, such as the mixed mesophytic forest of today, from a forest community that was dominated by, or at least, included a considerable portion of evergreen broad-leaved trees in the arboreal layer. The modern equivalents of these Tertiary evergreen broad-leaved trees are mostly associated with the rain forest of today.

This trend, as indicated by fossil evidence, is also suggested by the components of the existing forest. The fact that the greatest concentration of epibiotics is in the mixed mesophytic forest is of special significance as a clue to the historic contraction of this community.

Most of the epibiotics of the mixed mesophytic community are represented by monotypic genera, or by monotypic family, such as:

Amentotaxus	*Metasequoia*
Bretschneidera	*Nothotaxus*
Cephalotaxus	*Pseudolarix*
Cercidiphyllum	*Rhoiptelea*
Davidia	*Sargentodoxa*
Decaisnea	*Sinofranchetia*
Dipteronia	*Sinojackia*
Euptelea	*Sinowilsonia*
Emmenopterys	*Taiwania*
Halesia	*Tetracentron*
Huodendron	*Torricellia*
Melliodendron	

The above-mentioned plants include only those epibiotics of regional distribution which characterize the geographic intergradations within the mixed mesophytic community. The epibiotics are not all necessarily restricted in range, however. The following include those that are distributed in the entire region of the mixed mesophytic forest and beyond. They are either monotypic groups or oligotypic "polytopic genera," i.e., small genera composed of only a few geographically disjunctive species, usually isolated in the remote parts of the world.

(1) Monotypic families: In addition to Amentotaxaceae, Bretschneideraceae, Cercidiphyllaceae, Metasequoiaceae, and Rhoipteleaceae mentioned above, are: Ginkgoaceae *(Ginkgo)*, endemic to the mixed mesophytic region of the Yangtze Valley, and Eucommiaceae *(Eucommia)*, Yangtze Valley and the transitional zone of the Northern Provinces.

(2) Monotypic genera: In addition to those mentioned in the last section *(Davidia, Nothotaxus, Pseudolarix, Taiwania, Tetracentron)*, are the following:

Bishchofia	*Idesia*
Camptotheca	*Platycarya*
Cryptomeria	*Poliothyrsis*
Euscaphis	*Pteroceltis*
Fokienia	*Tapiscia*
Fortunearia	

(3) Polytopic genera: The following include those polytopic genera that now occur in more or less the entire range of the mixed mesophytic community. Those genera that have persisted only in certain parts of this region were discussed in the preceding section.

Aphananthe	Eastern Asia and Australia 3-4 species, China 1
Buckleya	Continental eastern Asia 3, eastern North America 1
Chionanthus	Continental eastern Asia 1, eastern North America 1
Cladrastis	Continental eastern Asia 2, Japan 1, eastern North America 1
Cunninghamia	Yangtze Valley and farther south 1, Taiwan 1
Gymnocladus	Continental eastern Asia 1, eastern North America 1
Liquidambar	Eastern Asia 1, western Asia 1, North and Central America 1
Liriodendron	Continental eastern Asia 1, eastern North America 1
Nyssa	Continental eastern Asia 1, eastern North America 4, Himalaya to Java 1
Pseudotsuga	Continental eastern Asia 2, western North America 3-4
Sassafras	Continental eastern Asia 1, Taiwan 1, eastern North America 1

The multitude of relics in the mixed mesophytic forest is in sharp contrast to their extreme paucity in the areas just to the north, which are occupied by plant communities developed over a new land surface and in a new habitat resulting from climatic changes in relatively recent geologic history. This fact seems to indicate that the mixed mesophytic forest is situated at the periphery of the selective pressure which has been effective enough to decimate part of the population, and yet favorable enough for the survival of the rest— a fact which possibly explains the preservation of the numerous ancient relics and the extremely rich floristic composition of the mixed mesophytic forest.

Braun *(5)* aptly observed that the comparable community of North America is "the most complex and the oldest association of the Deciduous Forest Formation." The complexity of this type of forest, however, is not due simply to the multiplicity of tree species. Strikingly indeed, it is composed of many "one-of-a-kind" elements. The 60 species of crown trees that are found throughout the entire range of the mixed mesophytic community represent no less than 50 genera. This fact and the presence of the numerous monotypic groups and polytopic genera suggest that the mixed mesophytic type, complex as it seems to be, is but an impoverished relic of a floristically much richer community.

Tropical Origin

The original composition before the impoverishment included more genera that are related to the trees of the rain forest, as suggested by the history of the mixed mesophytic forest of eastern North America. In the present forest of eastern Asia the rare occurrence of such genera as *Podocarpus*, *Torreya*, *Illicium*, *Phoebe*, *Manglietia*, and evergreen oaks *(Quercus, Castanopsis, Pasania)* suggests similar conditions.

The comparative morphology of angiosperms *(19, 1)* suggests that the deciduous trees in general are derived from evergreen stocks which are close to the more primitive forms. The major components of the mixed mesophytic forest, which are naturally all deciduous trees, are nearly all represented in the rain forest by evergreen trees of closely related genera or species. In fact, most of the trees of the mixed mesophytic forest as listed below are deciduous representatives of phyletic stocks which are predominantly evergreen, viz:

Ebenaceae	*(Diospyros)*
Elaeocarpaceae	*(Elaeocarpus)*
Euphorbiaceae	*(Daphniphyllum, Mallotus)*
Flacourtiaceae	*(Poliothyrsis, Idesia)*
Hamamelidaceae	*(Liquidambar, Fortunearia, Sinowilsonia)*
Lauraceae	*(Sassafras, Lindera, Litsea)*
Magnoliaceae	*(Liriodendron, Tetracentron)*
Moraceae	*(Morus)*
Nyssaceae	*(Davidia)*
Oleaceae	*(Chionanthus, Fraxinus)*
Rubiaceae	*(Emmenopterys)*
Rutaceae	*(Evodia, Phyllodendron)*
Santalaceae	*(Buckleya)*
Sapindaceae	*(Koelreuteria)*
Staphyleaceae	*(Tapiscia, Euscaphis)*
Styracaceae	*(Halesia, Sinojackia, Huodendron, Rehderodendron, Alniphyllum)*

Two species of the genus *Castanea* in the mixed mesophytic forest are evergreen. Even *Acer*, which is represented by over 50 species of deciduous trees in eastern Asia, and the Boraginaceae, which is essentially a family of herbaceous plants of the arid regions, are both represented by deciduous trees (deciduous *Acer* and *Ehretia*) in the mixed mesophytic forest, but by evergreen trees in the tropics (section of entire leaved maples, *Cordia Ehretia*, and *Tournefortia*). The woody boraginaceous plants represent the primitive section of the family *(9)*.

The closest kin of the deciduous trees of the mixed mesophytic forest can nearly all be traced to the rain forests of the tropics, which usually include more tribes, genera, and sections of the phyletic stocks to which the deciduous trees of the mixed mesophytic forest are related in a continuum of variation. The weight of evidence indicates that the mixed mesophytic forest has emerged from the northern fringe of a type of evergreen broad-leaved forest similar to the present rain forest. The evergreen components were gradually eliminated, probably in late Tertiary. Through further contraction and speciation the multitude of relics and numerous closely allied species of certain large genera of deciduous trees which characterize the present mixed mesophytic forest were differentiated.

THE MIXED NORTHERN HARDWOOD FOREST

The mixed northern hardwoods forest, in continental eastern Asia is situated between the boreal coniferous forest farther to the north and the deciduous oak forest of the relatively arid Northern Provinces, which in turn separates the mixed northern hardwoods from the mixed mesophytic forest of the Yangtze Valley. Despite the discontinuity, the mixed northern hardwood forest is closely related to the mixed mesophytic forest in composition. It appears to be a severely depauperized form of the mixed mesophytic forest.

Depauperized Mixed Mesophytic Forest

The primary components of the mixed northern hardwoods are *Acer* (8 species), *Tilia* (5 species), and *Betula* (9 species), intermixed with considerable proportions of white pine *(Pinus koraiensis)*, *Quercus*, *Fraxinus*, *Juglans*, *Maackia*, *Phellodendron*, and *Ulmus*. This forest also includes, as minor components, trees of the following genera:

Alnus	*Malus*	*Pyrus*
Carpinus	*Morus*	*Salix*
Celtis	*Populus*	*Sorbus*
Kalopanax	*Prunus*	*Zelkova*

Taxus, *Magnolia*, and shrubby *Cornus* and *Lindera* also occur as rare accessories.

In comparison with all the other types of deciduous broad-leaved forests, the mixed northern hardwoods is, next to the mixed mesophytic, the richest in composition. All the above mentioned 26 genera are common to both types. However, the specific representative of these genera usually are not the same. Furthermore, there are many more genera (over 40) of evergreen and deciduous trees among the primary and minor components of the mixed mesophytic forest that are not represented now in any other type of deciduous forest. But some of them are known to have occurred in the northern regions in the Upper Tertiary. This fact shows the gradual retraction of the range of certain "southern" genera and the depauperization in components of the northern lobe of a more extensive mixed mesophytic forest which once flourished in the northern region. This process resulted in the simpler type of forest community of deciduous broad-leaved trees now designated as the mixed northern hardwood forest. All the genera of the forest components, without exception, are included in the present mixed mesophytic forest, and some of the eliminated components are preserved in the Tertiary fossils of this region.

With the exception of *Tsuga* and *Fagus*, all the genera of the primary forest components of this community in North America are represented in the mixed northern hardwood forest of eastern Asia, which is somewhat richer in composition than its North American counterpart. Common forest components such as *Phellodendron*, *Maackia*, and *Zelkova* and a common climber, *Actinidia*, are not known in North America. *Schizandra* is represented in North America only in the South. Recent interspecific hybridization *(8)* between the white pine of the Northeastern Provinces of China *(Pinus koraiensis)* and the eastern white pine of North America *(Pinus strobus)*, both of which are important components of the respective mixed northern hardwoods, gives almost 100% fertility. The striking compatibility of the two vicarious species furnishes genetic evidence for the close affinity of the two similar but widely disjunct forest communities.

Post-Pleistocene Expansion

An entirely different interpretation of the formation and the present distribution has been proposed for the mixed northern hardwood forest of eastern North America. According to Braun (5, p. 533), the vegetation of the mixed northern hardwoods is "the result of post-Wisconsin migrations, which brought about an expansion from the unglaciated Allegheny Plateau and northern Allegheny mountains (physiographic sections of Appalachian Plateaus) without pronounced modification of type. The climax elements are almost entirely a result of these expanding migrations."

In the interpretation of the present distribution of the deciduous forests of eastern North America, great pains were taken to correlate the physiographic history with forest development, particularly the Pleistocene glacial boundary. The ice advanced across the Appalachian Plateau, the late Tertiary haven of the mixed forest. From fossil evidence, Braun (*5*, pp. 512-513) deduced that "nowhere far beyond the glacial boundary was climate during the glacial stages sufficiently severe to displace occupying vegetation," and this ensured continuous occupancy by the late Tertiary mixed forest, the progenitor of the present mixed mesophytic forest, on the unglaciated part of the Appalachian Plateau and a small isolated unglaciated area (the Reading Prong and the New Jersey Highlands) farther east. Braun (*5*, p. 529) maintains "Continuity of occupation since early Tertiary time accounts for the antiquity of its vegetation; lack of extreme changes, for the continuance of one climax type; and a consistently humid climate (with rare lapse to subhumid) for the prevalence of this climax." The explanation of the present forest distribution as the result of post-Pleistocene expansion and segregation of the vegetation from the unglaciated areas to the glaciated areas where the former vegetation was removed by the advancing ice, is plausible enough.

Migration and Survival

However, it does not necessitate the continuous occupancy of the late Tertiary mixed forest not far from the front of the continental ice sheet, an assumption that is still open to debate. Periglacial phenomena such as block-fields and thick surficial deposits moved by soli-fluction probably of Wisconsin age are found in the higher parts of the Appalachian Highlands as far south as the Great Smoky Mountains (6,600 ft, circ. Lat. 35° N.) where the cove hardwoods type (circ. 3,000 - 3,500 ft) is considered as the most typical of the mixed mesophytic communities. At the present time, areas in the subarctic or in high mountains where similar periglacial phenomena are actively forming are all essentially treeless. By analogy, Denny reasons that the Appalachian Highlands were likewise essentially devoid of forest when such periglacial phenomena were in action *(1)*.

This inference does not entirely preclude the continuous occupancy of the late Tertiary mixed forest in the unglaciated areas still farther away from the glacial boundaries. It does indicate, however, that the Tertiary mixed forest of eastern North America, like the similar type of eastern Asia, has undergone severe displacement, especially in regions close to glaciations. It also suggests that to a considerable extent the present mixed mesophytic forest is the result of post-Pleistocene migrations from areas farther to the south.

There are indisputable evidences of Quaternary glaciations in the mixed mesophytic forest region of eastern Asia *(13, 14, 15, 2, 21)*. Glaciated areas include: Lushan (1,480 m, Lat. 29°30′ N.), Chiuhuashan (900 m, Lat. 30°32′ N.), Tienmushan (Tienmongshan, 1,547 m, Lat. 30°25′ N.), and Huangshan (1,700 m, Lat. 30° 10′N.). These mountains are situated in the southern part of the Lower Yangtze Valley, not too far from the coast.

The Lower Yangtze Valley, which is now occupied by mixed mesophytic forest, was glaciated not once but three times. In the Poyang glaciation (the oldest and also the largest) and the next, the Taku glaciation, piedmont glaciers were formed. The third, the Lushan glaciation, produced only small glaciers in the higher mountains. These glaciations were separated by interglacial periods of genial or even subtropical climate, resulting in the high oxidation of the ferruginous soil and incipient lateritization of the boulder-clay-like deposit and the Red Loam (*16*, chapter on Pleistocene climate).

Despite the successive glaciations, the existing vegetation of the above-mentioned glaciated mountains, as evidenced by the preserved natural forests, is of the mixed mesophytic type which includes not only nearly all the tree genera of the mixed mesophytic forest of the unglaciated Appalachian Plateau, but also survivals from those genera that are known to have occurred in the late Tertiary mixed forest of eastern North America and to have perished subsequently.

There are distinctions between forest types and forest regions. The mixed forest of the Miocene whose components were almost identical with those of the present mixed mesophytic forest but which occurred more than 500 kilometers north of the northern limit of the present type, has been replaced by the present deciduous oak forest. It is then reasonable to infer that in the Quaternary glaciations the areas that are now occupied by mixed mesophytic forest, but were at that time glaciated or at least exposed to periglacial conditions, could not possibly have been occupied by a type that was similar to the present mixed mesophytic forest. The presence of the mixed mesophytic forest, no matter how complex or ancient the flora may be, does not imply that the area has never been glaciated nor does it necessitate the continuous occupancy of this type in that particular area.

Pre-Pleistocene Continuity and Regional Speciation

Nor is it necessary to assume the total elimination of forest communities and to preclude the possible persistence of a depauperized form of the late Tertiary mixed forest farther to the north, particularly in the maritime regions where the influence of warm currents prevailed. The mixed northern hardwoods forest, Braun maintains, was almost entirely a result of post-Wisconsin migration so far as the climax elements are concerned. To her disadvantage, the forest flora of the deciduous forests of eastern North America with which she was dealing, rich as it is, is relatively simple in comparison with that of eastern Asia. The geographic intergradations in the whole range of the American deciduous forests are not well expressed by the regional speciation of their components. Of the 25 species and varieties listed as "dominant trees of the arboreal layer" of the mixed mesophytic forest of eastern North America, all are represented in other "climaxes of deciduous forest." *Gymnocladus*, *Halesia*, *Liquidambar*, and *Oxydendron* are perhaps the only tree genera of the mixed mesophytic forest that are not represented in the deciduous forests of the North. Not only are most of the genera in common, but their representatives in the primary components of both the northern hardwoods and the mixed mesophytic forest are of the same species, which extends in a continuous range. This fact seems to have led Braun to the conclusion that all the other deciduous forest climaxes have arisen from the centrally located "undifferentiated mixed mesophytic forest," supposedly the oldest association of the deciduous forest formation preserved in the Appalachian Plateau.

In a forest flora like this, evidence of geographic differentiations could be found at the subspecific level, e.g., the local races and ecotypes. Recent studies of the American beech *(6)*, ash *(22, 23)* walnut *(24)*, maple *(10)*, hemlock *(17)* demonstrate that forest trees are made up of a number of more or less distinct types with well-differentiated ranges.

In the deciduous forest communities of eastern Asia, on the other hand, geographic differentiations are well expressed on the species level. The mixed mesophytic forest and the mixed northern hardwoods in particular, are not only richer in components, but the tree genera of the mixed northern hardwoods that are in common with the mixed mesophytic forest are represented mostly by different species. In other words, distinct regional speciation has taken place along with the differentiation of forest types. The interpretation advanced by Braun of the mixed northern hardwoods of eastern North America cannot satisfactorily explain this phenomenon. The mixed northern hardwoods forest of eastern Asia cannot possibly be entirely the result of post-Pleistocene expanding migrations from unglaciated areas south of the ice front:

(1) There are only a few species of trees in the mixed northern hardwoods that are connected with the mixed mesophytic forest in a more or less continuous range. Most of the other non-endemic species of the primary components are generally restricted to the north and rarely occur south of the deciduous oak forest region. These few wide-ranging trees occur both in the mixed mesophytic forest of the south (MM), the deciduous oak forest of the northern Provinces (N), and the mixed northern hardwoods of the Northeastern Provinces (NE). Some of them extend as far as Japan (J), Korea (K), eastern Siberia (S), and Sakhalin (SK). This group of wide-ranging trees includes the following:

Acer mono (A. pictum var. *parviflorum)* (MM, N, NE, K, J)
Betula japonica (*B. mandshurica*) (MM, N, K, J, S, SK)
Carpinus cordata (MM, N, NE, K, J, S)
Fraxinus chinensis (MM, N, NE)
Populus tremula var. *davidiana* (MM, N, NE)
Ulmus japonica (MM, N, NE, K, J)
U. pumila (MM, N, NE, S)

A number of lesser plants can be added to this list, e.g., *Schizandra chinensis* (MM, N, NE, K, J, S) and *Actinidia arguta* (MM, N, NE, K, J, S). The true mistletoe, *Viscum album*, unlike the American form, *Phoradendron Flavescans*, extends from the mesophytic forest to the boreal regions (Siberia) with a total disregard for glacial boundaries.

(2) The majority of the primary components of the mixed northern hardwoods are tree species of a northern range which rarely if ever appear in the mixed mesophytic forest region. A number of these northern trees are endemic to the Northeastern Provinces and the adjacent part of Korea where this type of forest is extensive, or restricted to the general region of the Northeastern Provinces (NE), Korea (K), Japan (J), and eastern Siberia (S). Some of them extend even to Sakhalin (SK). This group of trees includes the following:

Acer barbinerve (NE, K)
A. Mandshurica (NE, K)
A. pseudo-sieboldianum (NE, K)

A. tegmentosum (NE, K)
A. triflorum (NE, K)
Alnus hirsuta (NE, K, J, S)
Betula costata (NE, K, S)
B. ermanni (NE, K, J, S)
B. platyphylla (NE, K, S)
B. Schmidtii (NE, K, J, S)
Fraxinus mandshurica (NE, K, J)
Maackia amurensis (NE, K, J)
Phellodendron amurensis (NE, K, S, SK)
Sorbus amurensis (NE, K, S)
Tilia amurensis (NE, K, S)
T. megaphylla (NE)
Pinus koraiensis (NE, K, J)
Taxus cuspidata (NE, K, J, S, SK)

Magnolia sieboldii (NE, J, K, S), *Cornus alba* (NE, K, S), *Vitis amurensis* (NE, K, S), and a number of shrubs and lesser plants can be added to this list. None of them extends to the mixed mesophytic forest region from which the mixed northern hardwoods is separated by the deciduous oak forest region.

(3) The discontinuity of the two allied forest types, the mixed northern hardwoods and the mixed mesophytic, is paralleled by the similar disjunct occurrence of the following genera:

Alnus (MM, NE, K, J, S)
Lindera (MM, NE, K, J)
Maackia (MM, NE, K, J)
Phellodendron (MM, NE, K, J)
Taxus (MM, NE, K, J, S)

The following plants occur in both the mixed northern hardwoods and the mixed mesophytic forest, but not in the intervening area:

Acer caudatum (Himalaya, MM)
A. Caudatum var. *ukurunduense (A. ukurunduense)* (NE, K, J)
A. ginnala (MM, NE, K, J)
Actinidia kolomicta (MM, NE, J, K, S)
A. polygama (MM, NE, K, J)
Lindera mollis (MM, NE)
Kalopanax pictum (MM, NE, K, J)
Phellodendron sachalinense (MM, K, J, SK)
Samplocos paniculata (MM, NE, J)

The distribution patterns of these three groups indicate progressive contraction in an extensive mixed mesophytic type of forest which once extended in a continuous range to the present mixed northern hardwoods region of the Northeastern Provinces and the adjacent maritime areas of eastern Siberia. This disjunction of some of the components probably is due to the increased continentality in the intervening area. Tertiary fossil deposits show the actual existence of the pre-Quaternary continuity of this type of mixed forest. Trees almost identical with living ones in the present mixed northern hardwoods and the mixed mesophytic forest once occupied the intervening area.

In addition to the compositional affinities, the pre-Pleistocene continuity of a mixed hardwood forest community, and the present disjunct range of those components that are common to both the mixed northern hardwoods and the mixed mesophytic forest, favor the explanation that the present mixed northern hardwood forest is a depauperized form of a pre-Pleistocene mixed hardwood forest community that was similar to the present mixed mesophytic forest. The pre-Pleistocene community extended over a continuous wide range with an essentially homogeneous composition but with well-developed geographic differentiations of tree species. Regional speciation perhaps resulted in the numerous endemic species in the subsequently disconnected and depauperized forest communities, although all the genera of these endemic species and, in fact, all the genera, without exception, of the primary components of the present mixed northern hardwoods are represented in the present mixed mesophytic forest.

The presence of the endemic species, particularly those that are restricted to this region and the adjacent Korea-Japan-eastern Siberia-Sakhalin areas, precludes a post-Pleistocene origin of the mixed northern hardwood forest. If the present mixed northern hardwoods forest were the result of post-Pleistocene expanding migration from unglaciated areas, as proposed by Braun for the mixed northern hardwood forest of eastern North America, then the amelioration of climate should be such that the entire region, including the intervening area, would be sufficiently favorable for the continuous extension of a type of mixed hardwood community that connected both the mixed northern hardwoods and the mixed mesophytic forest in gradual intergradations.

The establishment of a forest community including such disjunct plants as *Lindera*, *Symplocos*, *Taxus*, *Maackia*, *Phellodendron*, and a few species of maples in the intervening area—a condition which the theory of post-Pleistocene expanding migration requires—would necessitate a substantial increase in precipitation and a milder climate than the prevailing one.

If it is assumed that the mixed northern hardwood forest of the entire range is of post-Pleistocene origin, then the implication is that the components common to this region have not only migrated to Siberia but have also crossed a land-bridge to Japan and Sakhalin. A direct land connection between the mainland and Japan and Sakhalin Island was possible at the height of the Ice Age when the sea level was sufficiently lowered. However, such a land connection could not have been in existence when the climate became sufficiently warm and humid to effect the supposedly post-Pleistocene expanding migration.

On the other hand, if it is assumed that only the mixed northern hardwood forest of the mainland, i.e., the Northeastern Provinces (Manchuria) and eastern Siberia, is the result of post-Pleistocene expanding migration, and that similar forests in Japan and Sakhalin are relics of the Tertiary, then the persistence of these forests in Japan, and particularly in Sakhalin which is situated farther north and is more rigorus in climate, serves only to prove the possible survival of the mixed northern hardwood forest. This forest includes a number of the same species of trees in at least the maritime regions of the continent just across the sea.

Pleistocene fossils also indicate that the present mixed northern hardwood forest is the depauperized form of a Tertiary mixed hardwood forest rather than that it is of post-Pleistocene origin. *Zelkova* (MM, N, NE, K, J), now extinct in Siberia, was growing with *Ginkgo* in the early Pleistocene on the Amur River, the frontier between the Northeastern Provinces and Siberia *(11)*. *Juglans mandshurica* (N, NE, K, S) now occurs on the mainland only, but was found in the Pleistocene deposits of Japan *(12)*. The fossil record shows that a progressive reduction in components and shrinkage in their range had taken place. The continuous occurrence of a mixed deciduous hardward community which was slightly richer in composition and which had a more northerly limit than the present mixed northern hardwood forest is evidenced by fossil remains to have occurred as late as the early part of Quaternary.

Complementary Evidence in Lower Plants

So far, the evidence used in the discussion of forest development has been limited as much as possible to the primary forest constituents, with only occasional excursions into the lesser growth, so that the main thesis can be presented with clarity and effect, without unnecessary reference to long lists of plants which have already been a burden to the reader. In the mixed northern hardwoods forest now under discussion, certain lower plants offer complementary evidence for the continuous persistence of the type during the Pleistocene in this general region. The rare occurrence of *Hymenophyllum* and *Trichomanes* in the present mixed northern hardwoods and coniferous forests on the frontier between Siberia and the Northeastern Provinces is of special significance.

Hymenophyllum and *Trichomanes*, are two genera (sen. Lat.) of Hymenophyllaceae which include 400-500 species of filmy ferns, mostly in shaded habitats of the humid parts of the tropics. In North America, one species *(Trichomanes boschianum)* reaches as far north as Kentucky and Illinois. Three species occur in Europe. The numerous species of *Hymenophyllum* and *Trichomanes* of eastern Asia are concentrated in the evergreen forest region. They occur only occasionally in the mixed mesophytic forest, and have been observed in the exceedingly wet valleys of western Yunnan in *Abies-Picea-* deciduous hardwood forests. Over the great distance between the Yangtze Valley and the Siberian frontier, the Hymenophyllaceae have never been observed nor are they likely to be found. They sometimes reach high latitudes in both hemispheres, but only under the conditions of maritime climate, e.g., *Hymenophyllum tunbridgense* on the Faroe Islands (Lat. 63° N.) in the North Atlantic.

Kryshtofovich *(11, 12)* and Vorobiov *(20)* reported the discovery of *Trichomanes parvulum* and *Hymenophyllum wrightii* in the Suchan River basin of eastern Siberia (Ussuri), close to the Northeastern Provinces, a considerable distance from the coast. *Hymenophyllum wrightii* was previously known from Sakhalin and Japan (as far north as Hokkaido), but not from Korea proper except on Quelpart Island.

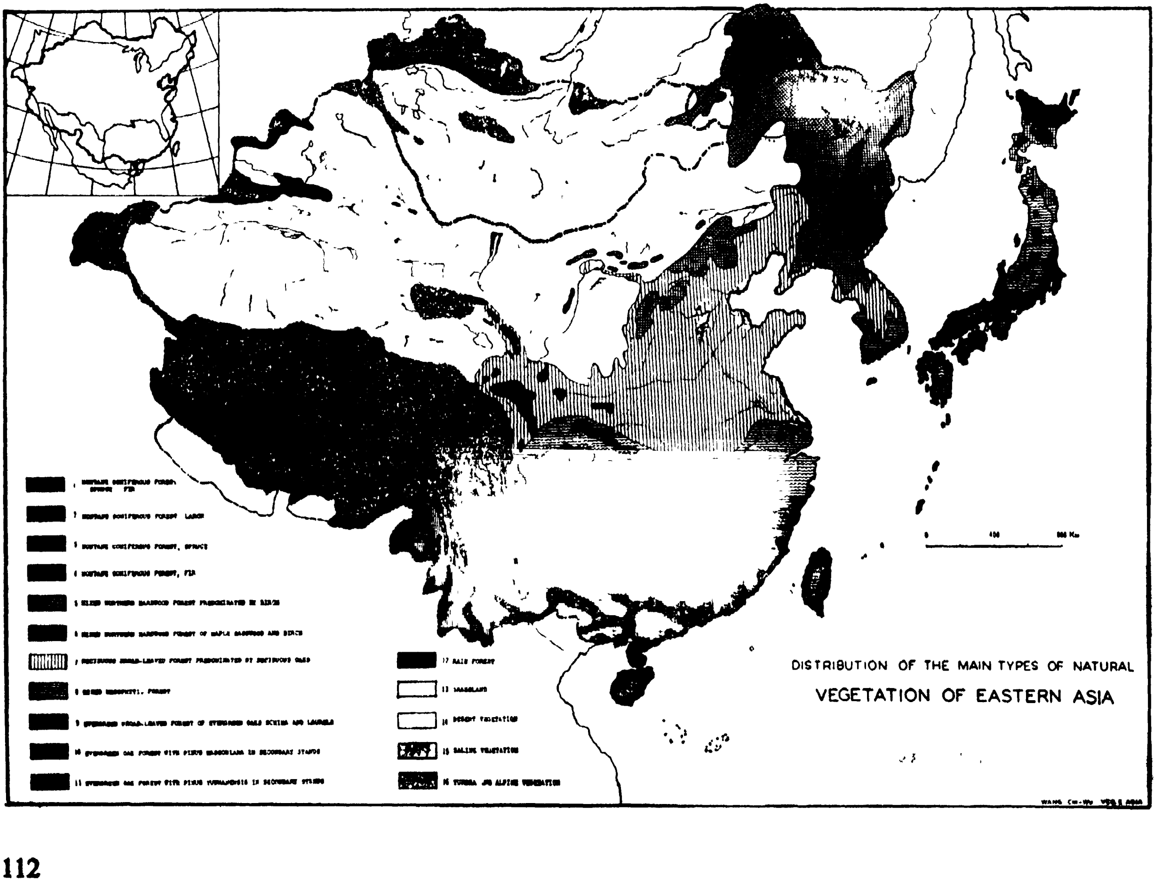
In eastern Siberia, *Hymenophyllum* and *Trichomanes* grow together on a cliff within a virgin forest of *Picea ajanesis*, *Abies nephorlepis*, and *Taxus cuspidata*. A rare fern, *Pleurosoriopsis makinoi*, is found nearby. In this general region, *Vitis amurensis*, *Schizandra chinensis*, *Actinidia* spp., *Phellodendron amurense*, and *Juglans mandshurica* may still be found. Kryshtofovich concluded that they were survivals of the Tertiary forest.

The forest around the growth of *Hymenophyllum* on Sakhalin consists mainly of *Picea ajanensis*, and *Abies sachalinensis*, with admixtures of *Betula japonica*, *Taxus cuspidata*, and *Euonymus sachalinensis*. The soil is thickly covered with *Osmunda cinnamomea* and *Athyrium pterorhachis*. In places, *Ilex rugosa* covers the soils with a thick layer.

The forests of western Yunnan in which hymenophyllaceous ferns occur are thousands of kilometers away from the Siberian coast; nevertheless, the composition is essentially the same, including *Abies delavayi*, *Picea complanata*, *Taxus chinensis*, *Betula caudate*, *B. albosinensis*, *Sorbus* spp., and *Magnolia globosa*. A variety of *Betula japonica* (var. *szechuanica*) is known to this region. The consistency of the composition of the kind of forest in which hymenophyllaceous ferns are associated in such widely disjunct areas suggests the probable conditions of the relic forest that survived the Pleistocene Epoch in the maritime regions of eastern Siberia and adjacent regions.

In the above discussions on the segregation and development of forest communities in continental eastern Asia, frequent references have been made to the similar type of forests in eastern North America. This comparison deserves critical examination because two diametrically different conclusions were reached from observations of two forests that are exceedingly alike in composition, developed under essentially similar habitat conditions, and situated in approximately the same latitudinal ranges.

The differences in opinion do not imply the author's approval or disapproval of the theory advanced by his American colleague. The author realizes that the forest communities of the two land masses are similar but not the same. However, the author does believe that the basic processes that shaped the existing vegetation, as revealed by available evidence and presented in this treatise, are universal and contemporaneous in the general time sequence, but the extent of contraction and speciation has involved regional differences.



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DYNAMICS OF ATOLL VEGETATION

F.R. FOSBERG

Pacific Vegetation Project, Care of National Research Council, Washington, D.C., U.S.A.

Coral atolls are flat islands and reefs of limestone of organic origin lying only slightly above sea level and not in immediate proximity to higher land. They are in the form of groups of small islands or islets on reefs that enclose shallow bodies of sea water called lagoons. Atolls are very common in tropical seas, especially the central and western Pacific, central and western Indian Ocean, and in the Caribbean region. They are almost lacking in the eastern Pacific, the Atlantic, and the eastern Indian Ocean.

Because of the relative uniformity of their substratum, topography, and temperature, their vegetation is rather simple, though by no means uniform. Their wide diversity of rainfall and geographical position contributes to a degree of variation in vegetation that would perhaps not otherwise be expected.

The atoll habitat seems to be a very young one, geologically speaking, though it may well have existed in something like its present form many times in the past. The occurrence after the last glaciation of a warm dry period or "climatic optimum" would logically have brought about a restriction of the glaciers and ice-caps to less than their present extent and a corresponding rise in sea level. Geological evidence suggests that this rise may have been in the neighborhood of either 2 or 3.5 m above present level. At that time, most of the atolls would have been submerged and have existed only as reefs awash with little or no dry land. With the gradual fall of sea level that started perhaps 3,500 years ago, platforms of reef limestone were exposed to erosional processes and to the deposition of the loose sediments produced by this erosion. The resulting land habitats were a mosaic of area of sand and gravel bars, beaches, dunes, and flats, as well as reef breccia platforms variously eroded by action of rainwater. The material of this diverse substratum was limestone, pure except for possible minute amounts of drifted pumice.

Weathering of this substratum by the solvent action of rainwater commenced, of course, immediately when it was exposed above the waves. This process was augmented by the development of vegetation even in its earliest stages, when very soon after coral limestone is exposed to air it is colonized by microscopic blue-green algae. Some forms that grow on solid surfaces have the ability to bore into the limestone. Others inhabit the interstices in the surface layers of sand-textured deposits, causing the particles to cohere and form a crust that is friable when dry and gelatinous when moist. The boring types speed the weathering of the limestone by breaking down the outer layers. Both types are suspected of contributing fixed nitrogen to the resulting soil, though this has not yet been demonstrated for the species involved. Certainly some humus is added as the plants die and decompose.

The soil that forms in such situations is at best a poor one, fit only to support plants of the most absolute pioneer types. With the exception of calcium, the essential elements for plant nutrition are either scarce or chemically almost unavailable. Especially characteristic of these soils are high pH and deficiencies of nitrogen and iron, as well as of certain trace elements such as manganese and zinc. Phosphorus is initially low but may be increased very early by excrement from sea-and shore-birds. Nitrogen may be added in the same way. Extremely high salinity makes these soils even more unsuitable for most plants, as does the almost complete absence of organic matter.

As noted above, the development of microscopic blue-green algal vegetation, indicated by a darkening of the white or pinkish limestone, may tend to ameliorate the deficiency of organic matter and nitrogen. Even so, the number of plants fitted to colonize such a habitat is at best very low. This number is further restricted by the difficulties of dispersal over wide expanses of sea. The natural dispersal agents are practically limited to water, wind, and sea-birds.

Almost the only members of the available floras that are adapted to colonize such essentially strand habitats are strand species, found everywhere along the shores of islands and continents. These species are mostly adapted to dispersal by water, through various floating mechanisms, and by birds, through sticky or burr-like fruits that adhere to feathers or feet or through fleshy fruits that may be eaten and carried for some distance in birds' digestive tracts. A few species, such as some grasses, with very small fruits, and some plants with winged fruits, may be carried by winds, especially typhoon or hurricane winds.

Recorded observations on the original composition of the vascular vegetation on new coral atoll habitats are few. *Pemphis acidula* seedlings are known to become established in tiny pockets of sand caught on otherwise bare limestone rock. On coral sand and gravel banks, bars, or flats *Portulaca lutea*, *Lepturus repens*, *Boerhavia* spp., *Guettarda speciosa*, *Tournefortia argentea*, *Scaevola sericea*, *Suriana maritima*, *Heliotropium anomalum*, *Ipomoea pes-caprae*, *Vigna marina*, *Pandanus tectorius*, *Cocos nucifera*, *Barringtonia asiatica*, and *Thuarea involuta* seedlings have been observed in absolutely unprotected apparently unmodified habitats. Of these, *Cocos*, *Ipomoea*, and *Barringtonia* have been seen in such circumstances only very rarely. Certain other species, though not observed as primary colonists on new areas, undoubtedly are able to fulfill this function.

The simplest types of atoll vegetation are essentially aggregations of these pioneer species. In the driest atolls as well as in a few very remote ones that few species have reached, succession seems not to have progressed much beyond this stage where the original composition still characterizes the vegetation; the actual composition and local variations may result from chance or from local differences in substratum, position in relation to prevailing wind, distance from sea, or altitude. Characteristic types on such atolls are *Scaevola* scrub, scrub forest of *Tournefortia*, *Guettarda* and *Scaevola; Lepturus* grassland or *Lepturus-Tournefortia* savanna; mosaics of thicket and grassland; or dwarf scrub of *Sida fallax* or of *Sida* with *Heliotropium.* It is uncertain whether the *Pisonia grandis* forest, the *Pisonia-Cordia* forests, and the *Pandanus* forests in some of these extreme habitats represent pioneer stages or have developed after some slight alteration of the habitat and resulting succession. Mention should be made here of extreme halophytic types, such as mats of *Sesuvium portulacastrum* on lagoon margins and in saline depressions, stands of *Pemphis* where the roots are flooded by sea water at high tide, and scrub of *Scaevola* or *Suriana* bathed continuously by salt spray.

The establishment of vegetation of any kind tends to bring about change and amelioration of the habitat in a number of ways. The simplest of these, of course, is shading. Even a slight protection from the heat of the sun, from the drying effect of the wind, and from salt spray may make possible the establishment of additional species or create more favorable conditions for some already present. Addition of humus to the soil tends to lower its alkalinity and to increase its water-holding and base exchange capacities. Phosphorus and nitrogen are increased by accumulation of bird excrement which, however, tends to be washed down through the porous soil. Nitrogen may also be contributed by the activity of bacteria on the roots of *Vigna*, of *Azotobacter*, and probably of blue-green algae. *Nostoc* is at times abundant on semi-shaded soil. A further effect may be the concentration of minor nutrient elements in humus. Rain tends to reduce salinity as well as to leach out nutrients, and to build up a body of fresh ground water at a slight depth in the soil.

These processes are, of course, continuous and simultaneous, and usually make possible an increase in the flora and in the complexity of the vegetation. In submesic atolls, those with less than 2.5 m of precipitation, a mixed forest results which, in the Northern Marshalls, for example, may have all or any combination of about 16 species of trees and shrubs: *Guettarda speciosa*, *Tournefortia argentea*, *Terminalia samoensis*, *Morinda citrifolia*, *Pandanus tectorius*, *Pisonia grandis*, *Soulamea amara*, *Cordia subcordata*, *Pemphis acidula*, *Ochrosia oppositifolia*, *Allophylus timorensis*, *Hernandia sonora*, *Intsia bijuga*, *Pipturus argentea*, *Scaevola sericea*, and *Suriana maritima*. These may occur in any arrangement or combination—with chance, distance from the sea, and wetness of climate the principal factors involved. Such forests tend to be more luxuriant with greater rainfall. Substratum may be a factor in the pattern, though the solution is not clear except in a few cases such as where a pure or almost pure stand of *Pemphis* is found on bare rock. Many of the species listed may be dependent on shade for the establishment of their seedlings.

In this mixed forest, ferns appear and mosses become more prominent. The ferns are principally terrestrial, and very few species occur. Certain successional phenomena may be observed, as the gradual dropping out of *Tournefortia* from the more dense forests, the assuming of dominance, in places, by single species, such as *Pisonia*, *Ochrosia*, *Cordia*, *Intsia*, or *Pandanus*. Forests made up exclusively of *Pisonia* are especially frequent and occur under a wide range of moisture conditions. Almost no other species are found established under a thick stand of *Pisonia*. The factors involved in these changes are not usually obvious, and the matter needs much more careful study. With fairly abundant moisture, *Ochrosia* seems able to succeed any of the other species, even *Pisonia*, once it gains a foothold. Under *Ochrosia* its own seedlings usually form a veritable carpet, growing not more than a few cm high unless a break occurs in the dense canopy, when they shoot up rapidly to fill it.

It is of interest that the most stable, or most nearly "climax" types here seem to be composed of single species.

In these submesic atolls, also, man has been able to establish an apparently permanent foothold. He has brought great alteration to much of the vegetation within his influence. Native forests have been cleared and replaced by coconut groves and plantations, and locally by mixed coconut and breadfruit, or by *Calophyllum*. In wet places he has planted taro, or rarely, mangroves. He has excavated pits down to ground water for raising taro and other crops. Later he has abandoned most of these in the submesic atolls. Increasing wetness of climate is reflected strikingly in greater luxuriance of coconut plantations and greater abundance of breadfruit trees.

On the wetter atolls, the limitation on the development of vegetation seems to be much more the lack of available flora than the severity of the environment. The far greater richness of the vegetation of atolls in the western Carolines and especially in and near the Malaysian Archipelago, where a large flora is available, seems to support this idea.

It is not clear whether the much greater prominence of mangroves in wet atolls is a function of climate or of their proximity to the rich mangrove swamps of Malaysia.

Succession to a truly mesophytic vegetation, even to what might be termed rain forest, is in these wet atolls unimpeded either by dryness or by salinity.

Studies of the vegetation of reasonably undisturbed atolls of this character are as yet lacking. Those that have been accessible for investigation have been profoundly altered by man. The anthropogenic vegetation is correspondingly richer there than in drier atolls. In fact it is difficult at times to tell what species have been brought by man. The most striking major aspects are solid, dense forests of giant breadfruit trees and extensive taro-pits or marsh gardens in which many food plants in addition to taro are grown. The weedy vegetation and the undergrowth in coconut plantations are both more luxuriant and richer in species.

Generally speaking, after the earlier stages of colonization and development of vegetation have been passed, the differences in atoll vegetation in the Pacific may be interpreted in terms of three major gradients—that from dry and seasonal to wet climates, that from saline to fresh sites, and that from the east, with a very small available flora, to the west and southwest with the rich Malaysian and Melanesian floras.

All three of these gradients, as expressed, exhibit increasing richness of composition of vegetation. Toward their extreme ends of dryness, salinity, and remoteness, the tendency to complete dominance by single species is marked. Such types dominated by single species, are rare in mesic atolls excepting the forests of *Pisonia grandis*.

The effects of decreasing salinity are reflected in the increased luxuriance and richer composition of vegetation in the interior of fairly wide islets, and, very strikingly, by the great increase in number of species on even slightly elevated atolls over those lying at sea level. The increase on the latter type, however, may also be interpreted as a result of greater age of the land surface in raised atolls.

From dry to wet atolls, both luxuriance and number of species increase in a striking fashion, whether we are considering only native vegetation and flora or including that established by man. The two driest atolls of the northern Marshalls have vascular floras of nine species each, while some of the wet southern atolls of the same group have as many as a hundred or more species.

Accurate figures to show the effect of remoteness are not available for atolls at the ends of the gradient; but it is possible that Clipperton Atoll had no native plants, and only two are recorded from Ducie Atoll. Vostok and Johnston Islands, not so far to the east, but very remote, had respectively two and three species of native vascular plants. However, the floras of other atolls in southeastern and central Polynesia are more diverse than these, but nothing to compare with the large numbers on various East Indian Atolls, or even the Caroline ones. Accurate floristic figures are much to be desired for atolls in the Malaysian area.

It is thought that in very few atolls has vegetation developed or succession reached its maximum possible development under present climatic conditions, as the soils are very immature and oversea migration of plants is sporadic and uncertain. Where atolls have been left undisturbed, though, the climatic conditions have tended to arrest development at different points, corresponding to degrees of wetness. However, owing to the disturbances caused by hurricanes and by man's activities, most atoll vegetation may be regarded as being in a more or less active dynamic status.

TROPICAL PACIFIC GRASSLANDS AND SAVANNAS

F.R. FOSBERG

Pacific Vegetation Project, Care of National Research Council, Washington, D.C., U.S.A.

Grassland vegetation, a collective term for plant communities in which grasses and grasslike plants are the dominant growth form, is fairly widely distributed in the tropical Pacific Basin but in aggregate makes up only a small part of the vegetation. Natural, as compared with man-made, grassland covers an even smaller area. In some instances it is difficult to be certain of the history of a given area.

The classification of grassland may be based on any of several features—composition, physiognomy, structure, habitat, or economic considerations. Because no adequate study has been made of the region as a whole on any of these bases, and because the required information is not available on any of these features for all Pacific grasslands, it seems logical to base a tentative arrangement on such data as are available on all features. Many tropical grasslands, including some Pacific ones, contain scattered trees and are then generally called "savanna." Every stage exists between grassland without trees through savanna and woodland to forest, depending on the spacing of the trees. A savanna may be arbitrarily defined as grassland with trees that are spaced, on the average, farther apart than twice the diameter of their crowns, or with trees covering less than 20 per cent of the ground. The significance of trees in grassland varies, depending on the kinds of trees. In some cases they may represent invasion leading to re-establishment of forest; in others they may belong to species that are able to resist burning when well grown, but which fire will kill when young. Still other savanna trees, usually small ones, belong to species that are found nowhere else than scattered in grassland. Considerable work has been done on savannas in other parts of the tropics but rather little on those of the Pacific. Here they will be treated mostly as variants of grassland types and discussed individually in the above framework.

The Pacific grasslands may be conveniently separated into those of high altitudes and those of medium to low altitudes. Fixed altitude limits may not easily be assigned to these two categories, but the high-altitude types either are mostly natural or are moderate expansions of natural grassland, while many, if not most, of the middle and low altitude types seem to result from or to have been vastly extended by the activities of man.

Montane grasslands are extensively developed in the Pacific Basin principally in the Andes where they occupy the area between timber line and perpetual snow. Timber line ranges from about 10,500 to 11,000 feet in Colombia to nearly 13,000 feet in Bolivia, and there is a corresponding variation in snow line from perhaps 15,000 to 18,000 feet. The Andean montane grassland is a bunch-grass or tussock formation with *Stipa*, *Calamagrostis*, *Poa*, *Agrostis*, and some other genera as the principal grasses and with abundant cushion plants and a rich herb and shrub flora. This grassland belt stretches from Patagonia to northernmost Colombia and, in poorly developed form, to Costa Rica. It is continuous in the south, but is broken into isolated patches in the lower northern Andes. Still, even in Colombia, the aggregate area is large *(3, 4, 5)*.

In addition to much local variation, correlated with altitude, topography, hydrology, exposure, and human interference, there is a large-scale regional variation from north to south, related to climate. This variation expresses itself in three major grassland regions or formations, designated conveniently by the local names—"páramo," "jalca," and "puna." They occur in that order from north to south and are characterized by increasing aridity southward.

The páramo is the most remarkable of the three, marked by features that might well lead to the argument that it is not a grassland at all. The most striking feature is the remarkable composite genus *Espeletia*. The grotesque gray rosettes of this group, called "frailejones" by the local people, are an almost constant feature of the landscape above timber line from the Venezuelan Andes to the Páramo del Angel in northern Ecuador, where they may be seen in great abundance, but where their occurrence stops abruptly. South of the Rio de los Charcos they are completely unknown. Although usually forming only a small part of the cover, *Espelatia* gives a unique aspect to the landscape that amply warrants separation of the páramo from the jalca to the south. In addition, there is a very considerable flora of herbaceous and shrubby plants with striking local endemism which sets off this wetter northern páramo region. Giant bromeliads (*Puya* spp.), *Rumex tolimensis*, *Lupinus alopecuroides*, *Aragoa* spp., *Blechnum arboreum*, and other strange plants add to the unreality of this landscape.

On level or more gently sloping ground, the soil is usually black and highly organic. Rainfall is high, fog is frequent, and mosses, ferns, and other hygrophytes are in places very abundant. The arrangement of the mountains somewhat parallel to the direction of the trade winds lessens possible rain-shadow effects.

The páramo vegetation thins out upward to the level of perpetual snow. The upper part, or super-páramo is more strictly grassland, though sparse. Downward, the shrubby sub-páramo vegetation gradually replaces the grassland in a transition to the "sotobosque" or "elfin forest" and the mossy forest.

Disturbance by man in the region just below the páramo has had the interesting effect of causing at least some elements of the páramo vegetation to spread downward in places, producing, what might be called quasi-páramo, very similar to the páramo in aspect down to elevations as low as 3,000 m. But many páramo species are lacking, and there are many introduced weedy species, including grasses, not normally found in the páramo. Active human utilization of the páramo does not extend much above 3,500 m.

From the Charcos River in northern Ecuador to north-central Peru, the jalca (often also called páramo or even "wet puna") occupies a broadening belt, similarly placed with regard to the forest belts below and perpetual snow above. It is a grassland of bunch-grass or tussock species, with, again, many non-graminoid herbs and shrubs, but lacking the *Espeletia* and thus presenting a far more conventional mountain meadow appearance. This is varied, however, by such oddities as *Puya*, *Azorella*, and *Distichium*.

The jalca, though mostly somewhat drier than the páramo, is still a mesophytic grassland, and the ground cover is complete. Fog is still an important factor in the climate. Human occupation extends locally to 4,000 m elevation. A limiting factor seems to be the cold, resulting from the high degree of cloudiness.

Southward, where the climate becomes significantly drier, the grass clumps become more discrete; *Stipa* becomes the dominant genus; and bare ground becomes apparent, at least locally between the clumps. This is the beginning of the "puna" or high altitude "steppe."

Here timber line, on the east slopes, is higher. Woodland of *Polylepis* reaches 4,200 m. The associated herbs and shrubs in the grassland are mostly more xeromorphic. Such genera as *Tetraglochin*, *Pycnophyllum*, *Lepidophyllum*, and *Opuntia* are found. Large woody species of the cushion plant, *Azorella*, are common and locally, along with the shrub *Lepidophyllum*, provide fuel for the inhabitants.

Here human activity normally extends to 5,000 m, and a road crosses a pass in Bolivia at over 6,100 m. This increase in the altitude limits of effective human occupation seems due to the higher insolation and lower degree of cloudiness.

Enormous areas of puna occupy the broad part of the high Andes, the "altiplano" of southern Peru, Bolivia, and Chile. On the east slope it merges with the "ceja de la montana" or elfin forest of the Yungas, on the west into the desert western slopes of the Andes in Peru and Atacama, Chile. Southward it extends, at lower and lower altitudes, to the south temperate zone and even, in modified form, to Patagonia.

Elsewhere in the tropical Pacific the only equivalent of Andean high-altitude grassland is a weakly developed belt in Hawaii. This is characterized by sparse stands of densely tufted species, up to 1 m tall, mainly *Trisetum glomeratum*, *Agrostis sandwicensis*, and *Aira nubigena*, at timber line on the high volcanoes above 2,600 m. The belt merges downward with the upper forest and upward into bare lava, cinder, and clinker slopes.

In the saddle between Mauna Loa and Mauna Kea on Hawaii, similar grassland is dominated by tufted perennial species of *Eragrostis*. Excessive grazing by sheep and wild goats has damaged and altered these grasslands.

Mention may also be made here of extensive pastures existing at middle altitudes on the northern part of the island of Hawaii. These are artificial and are made up of numerous species of forage grasses deliberately introduced for the raising of beef cattle.

Alpine grassland, in the mountains of Papua, dominated by *Aulacolepis*, *Poa*, and *Danthonia*, are mentioned by Brass (*2*, p. 177), but no description has been found.

At low and middle altitudes in the Pacific tropics, there are of course large expanses of such cultivated grasslands as sugar cane and rice fields. Various minor grassy communities, such as marshes, old fields, salt-grass flats and other strand types, and pastures are of reasonably general distribution. Worthy of special mention are the *Lepturus repens* grassland of coral atolls and other strand situations and the reed marshes composed of *Phragmites karka.* Stands of *Lepturus* are widespread in small patches on dry coral sands and cover substantial areas on Christmas Island and other dry atolls of the Central Pacific and on Pokak Atoll, the driest of the Marshalls, but are strangely missing in Hawaii.

Lepturus repens, in spite of its name, is a bunch grass, and occurs in discrete rather small tufts of fine but hard culms, and narrow but harsh leaves. Frequently these tufts will send out long wiry runners which root at the nodes and send up smaller tufts. Eventually a loose mat may be formed. Usually one or more of several broad-leafed herbs and dwarf shrubs occur mixed with the grass, in varying proportions. These are *Portulaca lutea*, *Boerhavia* sp., *Sida fallax*, and *Heliotropium anomalum*. The last is lacking in the Marshalls but found in Wake and the Line islands. Scattered low, rounded trees of *Tournefortia argentea* may be found, making a savanna of very characteristic appearance.

Reed marshes are widely distributed on higher islands, usually, but by no means always, near sea level just back of the coasts. Fairly extensive marshes are found on Saipan, Guam, and Truk islands. They are usually almost pure stands of the large tropical reed, *Phragmites karka*. It forms hollow canes about 1 to 1.5 cm thick, with broad leaves above, and with panicles bronze-colored at flowering. *Pandanus* trees and *Hibiscus tiliaceus* may occur scattered through these marshes to form savannas.

Much more extensive are several upland types of grassland or savanna. Most widely distributed of these, though possibly not largest in area, is that dominated by the genus *Miscanthus*, principally by *Miscanthus floridulus*, commonly called "sword-grass" because of the scabrous cutting edges of its leaves.

In its simplest form, *Miscanthus* grassland is a pure stand of sword-grass, crowded large tufts of reed-like culms with harsh leaves, up to 3 and even 4 m tall. It is found thus on relatively fresh ash slopes, as on the volcanoes of the northern Marianas. Reasonably pure stands are also widespread in denuded areas on the older volcanic islands of southeastern Polynesia, especially Mangareva. Generally, however, there is a varied accompanying flora of sedges, other grasses, and several broad-leafed species of herbs and shrubs. Most of these grow on erosion scars and other bare spots, which are an almost constant feature of the habitat of *Miscanthus*. In Guam, the *Miscanthus* grassland forms a mosaic with a low, soft grassland composed mainly of *Dimeria chloridiformis*. In this mosaic, *Dimeria* occupies principally the more level or gently sloping situations, fine clay soil that dries out fairly well in dry weather. The steeper, more rocky sites, as well as those with more permanent moisture, are covered predominantly by *Miscanthus*.

Fire is a frequent feature of *Miscanthus* grassland and the associated *Dimeria*. In burned areas, an aggregation of weeds appears, to be gradually crowded out by the grasses. If erosion starts, an erosion scar community of ferns, small shrubs, and various herbs tends to establish itself on the bare soil. As time goes on, this community is replaced by the grasses. Most of the plants peculiar to these grasslands are members of this erosion scar community. Members of the genera *Myrtella*, *Melastoma*, *Geniostoma*, *Hedyotis*, *Timonius*, *Dianella*, *Euphorbia*, *Phyllanthus*, *Glochidion*, *Machaerina*, *Rhynchospora*, *Fimbristylis*, *Cantharospermum*, *Chrysopogon*, and *Ischaemum*, as well as the ferns *Gleichenia*, *Sphenomeris*, *Lindsaya*, and *Cheilanthes*, plus *Lycopodium*, make up the community. They are mostly either very wide-ranging species or very restricted endemics.

The bottoms of permanently or usually wet ravines in the mosaic are occupied by brakes of reeds *(Phragmites karka)* which show up as a deeper green or, at flowering time, a rich bronze against the pale green or buff of the *Miscanthus*. These reeds are very tall, often filling ravines up to the level of the grass tops on the terraces along the ravine margins. Only the difference in color betrays the existence of the ravine to the casual observer.

In this mosaic, seedlings of *Casuarina equisetifolia* tend to appear; and an area not burned for a few years may assume the character of a savanna, or even of a sparse forest. *Pandanus* also form limited savanna.

Westward in the Pacific, other grasslands tend to replace *Miscanthus* as the important types. In Yap and Palau, savannas of ferns, *Nepenthes*, and sedges with some grasses and many secondary herbs and scattered trees and shrubs of various kinds occupy the places where *Miscanthus* would be expected.

In the Philippines and northward, *Miscanthus floridulus* tends to be replaced in certain situations by *Miscanthus sinensis*. The exact environmental relations of these two species are not always clear, nor is it easy to distinguish them under some conditions. In the Ryukyus where *Miscan-*

thus may be unusually abundant on limestone, in contrast to its behavior farther east, the species involved may often be *Miscanthus sinensis* though this has not been determined with certainty. No information is available on the *Miscanthus* (?) grasslands found in western Papua between 1,000 and 2,000 meters of elevation and mentioned by Brass (*2*, p. 176).

In places in the Philippines, Caroline Islands, and probably elsewhere, *Saccharum spontaneum*, a large bunch grass with the aspect of *Miscanthus*, may form considerable stands. Not too much is known of the distribution of this type of grassland. Since the war, *Saccharum spontaneum* has appeared in Saipan and spread with great vigor. It is suspected that the plants involved may really be seedlings from cultivated sugar cane. True *Saccharum spontaneum*,of course, may well have been introduced accidentally with war supplies, or perhaps after the war. The species seems native and not excessively abundant in the high Caroline Islands from Kusaie to Palau, where it is frequently mistaken for *Miscanthus*. The latter is known with certainty in the Caroline Islands only from Ponape.

In the Fly River area in New Guinea and westward are large areas of savanna *(2)*, dominated by *Ophiurus exaltatus*, a coarse grass reaching 2 m in height, but also characterized by *Themeda triandria*, *Imperata cylindrica*, and *Ischaemum* sp., and scattered trees of *Eucalyptus*, *Melaleuca*, and *Tristania*. *Tristania* dominates or shares low, wet places with *Eriocaulon* and many other herbs. In places, *Ophiurus*, *Imperata*, and *Sorghum nitidum* form a grassland on well-drained soils. Elsewhere, *Germainia capitata* forms savannas with *Banksia*. Low, ill-drained soils have a ground cover of sedges with numerous other flowering herbs and small trees of *Melaleuca* and *Banksia*. These savannas fade imperceptibly into "savanna forests" or woodlands. Brass considers these savannas to be natural and to be extensions into New Guinea of the "open forests" of Australia.

From Guadalcanal to the Philippines, and undoubtedly westward in Indonesia in such islands as Celebes, Timor, and the lesser Sunda group, occurs a rather coarse grassland dominated by *Themeda triandria*, the "kunai" grass of New Guinea. In Guadalcanal, Florida, and probably Buka in the Solomons, an almost pure stand of *Themeda*, with wet places dominated by *Phragmites karka* (*9*, pp. 90-91) occurs on the coastal plain and runs up onto low mountain ridges several miles inland, where it changes to savanna and gradually to forest upward. *Themeda triandria* is a stiffish grass 1 to 2 meters in height, with drooping flower clusters.

In the Philippines, the *Themeda* type of grassland is the matrix of many of the pine savannas of Benguet, Luzon. *Themeda triandria*, *Themeda gigantea*, *Chrysopogon aciculatum*, species of *Ischaemum*, *Panicum*, *Andropogon*, and *Fimbristylis*, as well as various other grasses, sedges, and broad-leafed plants make up this grass cover. Merrill *(8)* mentions large areas of *Themeda*-dominated grassland throughout the Archipelago and lists a large number of species as common in open grasslands. There are obviously many variants of this type as well as of the *Imperata* grassland to be described next.

Although *Themeda* and its associates are maintained by burning, if the burning is carried to an extreme, this type of grassland may give way to *Imperata cylindrica* and associated species.

Imperata grassland covers vast acreages in the New Guinea-Indonesia-Southeast Asia region, and is usually, if not always, associated with man. Its altitudinal range is enormous—from sea level to as much as 2,500 m (in New Guinea, according to *6*). *Imperata* is the "lalang" of Malaya, the "alang-alang" of Indo China, the "cogon" of the Philippines. It may be thought of as the true "climax" of the *man-shifting-cultivation-burning complex* in this part of the world. *Imperata*, with the tough matted wiry buried rhizomes, is about as near as nature comes to producing a really fire-proof plant. When the shoots are burned off, the rhizomes remain uninjured and immediately respond by sending up flowering culms, followed by a new crop of leafy shoots.

Though *Imperata* is a harsh, unpleasant grass in texture, it is not large. It forms a tough hard sod, is not bunchy, and seldom exceeds 1 meter in height. Its bright green color gives a deceptive appearance of succulence, but animals do not care much for it. It is commonly associated with a rather characteristic lot of widespread plants belonging to such genera as *Melastoma*, *Pteridium*, *Lygodium*, *Eurya*, *Gleichenia*, *Rhynchospora*, *Fimbristylis*, and *Andropogon*.

Although this type of grassland is easily invaded by woody species, such as pine, such invasion seldom leads to anything, as the invaders are generally susceptible to fire. And fire, the factor that brings about dominance by *Imperata*, is seldom long absent where *Imperata* has achieved such dominance.

Much study has been devoted to the origins of the grasslands and savannas of tropical America and Africa. A paper by Beard *(1)* provides a convincing set of generalizations about at least the tropical American savannas. The grasslands of the western tropical Pacific have received little attention, as it has generally been assumed that they are of secondary origin, due to man's activities. At least one student *(9)* has vigorously contested this view as applied to the grassy areas of Guadalcanal, withal not too convincingly. His conclusions are largely based on low rainfall, as shown by a very short period of record; on absence of evidence of burning at the present time; on the existence of strips of forest along streams; on the existence of two peculiar animals, an endemic subspecies of button quail—an obligate grassland bird—and a fish adapted to intermittent streams; and especially on a curious argument that, because the climate cannot support *rain forest* the grassland must be "climatic." No mention is made of the possibility of other types of tropical forest. From the data he presents, there is no doubt whatever that these grasslands depend for their *existence* on the rain shadow cast by the high Guadalcanal mountains. Whether they are climatic in *origin* is another matter. They may very well be so, but it is not established to complete satisfaction in his paper that man in earlier times did not have a hand in their origin or spread. The fact that he describes them as an almost pure stand of *Themeda triandria* and mentions almost no accompanying flora makes their natural origin at least open to question.

Similar views concerning the *Miscanthus* grasslands of Fiji and Guam have been expressed orally by a number of casual observers. In the case of Fiji, these views were based on the low rainfall, and in that of Guam on edaphic considerations.

Some study has been devoted to the origin of the Guam grasslands. Here, on historical evidence, there was much more forest even within historical times. The introduction of deer and of the custom of driving them by fire caused a great reduction of this forest during Spanish times. Many of the plants characteristic of the present grassland were clearly introduced from America and elsewhere during the Spanish period. These facts favor the idea that this grassland is of secondary nature. However, as in tropical America, there are some native, even endemic species, restricted to the grasslands. Such are *Phyllanthus saffordii*, *Ischaemum longisetum*, *Machaerina aromatica*, *Hedyotis grandiflora*, *Wikstroemia elliptica*, and *Spathoglottis micronesiaca*. *Glochidion marianum* is found on both Guam and Ponape; *Myrtella benningseniana*, *Timonius albus*, *Hedyotis fruticulosa* on Guam and Yap; and *Dimeria chloridiformis* on Guam and Palau.

In addition there are certain widespread plants of similar habitats that are not obviously introduced, such as *Miscanthus floridulus* and *Dianella ensifolia* (both known as fossils from Pagan, northern Marianas), *Curculigo orchioides*, *Fimbristylis tristachya*, *Fimbristylis annua*, *Melastoma malabathricum*, *Lindsaya ensifolia*, *Cheilanthes tenuifolia*, and *Lygodium scandens*.

This assemblage of plants could not likely have developed or lived in forest, as it is made up of shade-intolerant species which do not now inhabit nearby forest. The obvious possible habitats were considered. Fresh ash slopes, such as those covered by *Miscanthus* in the northern Marianas, were ruled out, as such have apparently never existed in Guam. Open ridge crests do not seem likely, as in a climate such as that of Guam and at such low altitudes the ridges are likely to have been wooded. Also many of the species concerned do not elsewhere inhabit such ridge crests. Landslide and erosion scars would be a possibility for some of the species, if there ever had been an abundance of landslides, but this does not seem a sufficient possibility, in the absence of humans and grazing animals to cause large numbers of landslides and aggravated erosion. The late Josaiah Bridge suggested a correlation with bauxite deposits. This would be a possibility, as many of the same plants are associated with bauxite elsewhere. However, extensive deposits of bauxite are lacking in the areas concerned. In any event, even with bauxite, open habitats would have been required.

In attacking the same problem in the tropical American savannas, Beard *(1)* noted a constant association of what he regarded as natural savanna with areas of mature topography—flat or gently undulating country, on plains, terraces or plateaus, having soil with impeded drainage, generally a permeable layer lying on an impermeable one.

It seemed pertinent to look for such an association of savanna and topography on Guam, past or present. When asked about this, J.I. Tracey suggested that certain flat-topped erosion remnants scattered over southern Guam might represent the remains of an ancient flat erosion surface. These "mesitas" present precisely the flat surface and permeable surface layer overlying a clay subsoil that are required by Beard's theory. The general geological reconstruction of southern Guam indicates that this flat surface may have been in existence for a long period, possibly since some time in the Miocene. If this is so, a proper habitat would have been available for the development of the native part of the floristic assemblage now characteristic of the Guam grasslands.

It is suggested that the history of these grasslands is about as follows:

1. The gradual appearance of grasslands and their flora, and their encroachment on the forest as the topography matured during the erosion cycle following the most recent emergence of most of the area from the middle Miocene Alifan submergence.

2. The gradual restriction of these grasslands and encroachment of forest as the flat surface was dissected during elevation and rejuvenation.

3. The persistence of grassland only in small patches, mostly on the "mesitas" or erosion remnants during the time of the Chamorro inhabitants of Guam.

4. The rapid and extensive expansion of the grasslands onto the denuded eroded hills, with addition of numerous introduced species from the time of the Spanish occupation to the present day.

Similarity in situation on other Micronesian islands, such as Palau and Yap, suggests that possibilities of a similar history might be investigated when the necessary geological information is available. Until floristic, geologic, and soils data can be assembled for other Pacific grasslands, little more can be said about their origin beyond the statement that in most regions they have at least been greatly extended, if not actually brought into being, by human agencies.

Merrill *(7, 8)* categorically considers the Philippine grasslands to be the result of human activity. The fact that some of the plants found in these grasslands are endemic to the Philippines suggests that this may be an extreme interpretation and needs more study. However, it is easy enough to see that the pine savannas of Luzon are increasing their area very conspicuously at the present time. Certainly it is safe to assume that at least most of the Philippine grasslands are secondary.

Descriptions of the New Guinea savannas *(2)* suggest that at least some of them may be natural, with the same characteristics of alternate extreme desiccation and waterlogging described by Beard for tropical America. These areas would amply repay further study.

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SOME UNSOLVED PROBLEMS IN TROPICAL FOREST ECOLOGY

TATUO KIRA, HUSATO OGAWA, and KYOJI YODA

Laboratory of Plant Ecology, Institute of Polytechnics, Osaka City University, Osaka, Japan.

SITUATION OF TROPICAL FORESTS IN THE WORLD VEGETATION

In the ordinary sequence of climatic zones on the earth, the moist climates of temperate and tropical regions are separated from each other by the intervening dry climate which prevails over middle latitudes. So that the two major forest areas on the continents, temperate and tropical, rarely come into contact in their geographical distribution. This geographical isolation has made plant ecologists overestimate the contrast between temperate and tropical forest vegetation in physiognomy, community structure and floristic diversity. Indeed the luxuriant growth of huge trees as well as the immense richness of plant species in tropical forests is a wonder to those who are acquainted with temperate vegetation, but nevertheless it is not right to lay too much stress upon this first impression.

Along the western fringe of the Pacific Basin, a long chain of islands stretches from north to south along the continent, starting from Sakhalin through Japanese Archipelago, the Ryukyus and Formosa to the Philippines, where both summer and winter monsoon bring abundant rainfall throughout the year. It should be emphasized that this part of the western Pacific is perhaps the sole example in the world that represents the uninterrupted series of moist forest climates from the subarctic to the tropical zone. According to the researches of Japanese ecologists *(1,2,3)*, no less than six forest zones are discriminated along the western coast of the Pacific. The parallel nomenclature of climatic and vegetation zones are as follows.

Climatic Zone	Approximate Range of Warmth Index*	Vegetation Zone	Dominant or Characteristic Trees
0. Polar zone	0 month-degrees	Barrens, snow and ice	
1. Arctic zone	0 - 15	Tundra	
2. Subarctic zone	15 - 45 ∧ 55	Evergreen conifer forest	*Abies*, *Picea*, *Larix*, *Betula*, etc.
3. Cool temperate zone	45 ∧ 55 - 85	Deciduous broad-leaf forest	*Fagus*, *Quercus*, *Acer*, etc.
4. Temperate zone	85 - 140	Lucidophyllous or laurel forest	*Cyclobalanopsis*, *Shiia*, *Machilus*, etc.
4[1]. Warm temperate zone	140 - 180	,,	*Castanopsis*, *Lithocarpus*, *Cinnamomum*, etc.
5. Subtropical zone	180 - 240	Subtropical rain forest	*Ficus*, *Machilus*, *Lagerstroemia*, and many other genera
6. Tropical zone	240 -	Tropical rain forest	Floristic composition extremely diverse. Genera of Dipterocarpaceae are most remarkable

* Warmth index is a convenient geographical index of thermal climate proposed by Kira *(1)*. It is given by summing the mean monthly temperature *(t)* above 5°C or by $\Sigma\,(t - 5)$. Winter months in which $t < 5$°C are excluded.

These systems also proved applicable to the altitudinal zones on high mountains of Formosa, continental China, Himalaya *(4,5)*, and Malaysia *(2)*, with slight modifications. The zones presented here seem more in number than those in any other systems hitherto proposed. This is not strange because the differentiation of vegetation zones along thermal gradient is expected to be most complete under moist climates. Where the subhumid or arid climate interferes with the normal sequence, the thermal zones may reduce in number or even be discontinued as is usually the case in other parts of the world, on which most other systems of zonal classification have been based.

These zones are more or less physiognomical. They do not represent the discrete units of vegetation, but are no more than the vague patterns joined together by gradual transition. As stressed by Imanishi since 1937 *(6,7,8)* and recently by Curtis *(9,10)* and Whittaker *(11,12)*, one zone gradually and continuously gives way to another, when the vegetation is analysed in terms of the distribution of each component species along an environmental gradient, e.g., thermal, moisture, etc. Fig. 1 illustrates an example of the distribution of some twenty conifer species in central Japan along the thermal gradient, including both horizontal and altitudinal. As seen in the figure, all distribution curves are bell-shaped and neither the ends nor the modes of curves tend to concentrate into definite groups, although the area

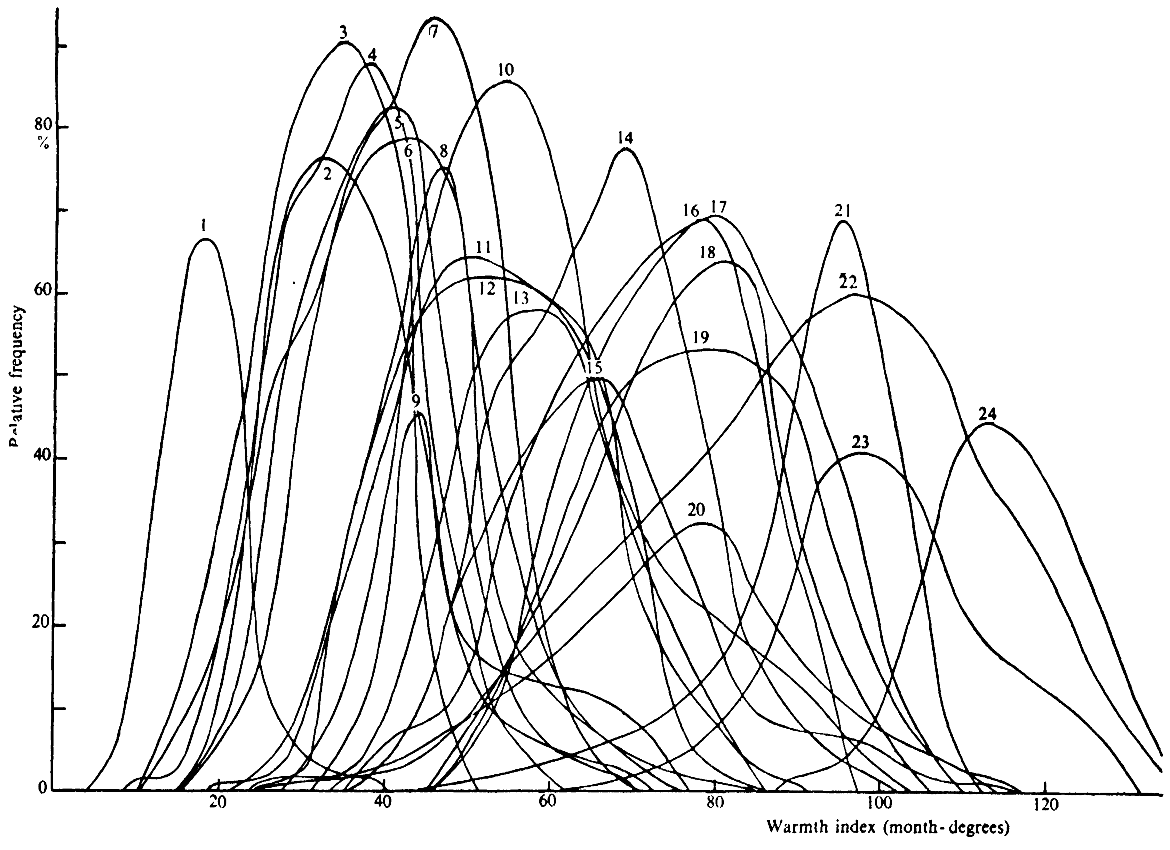

Fig. 1. —Distribution of 24 conifer species along thermal gradient in the Central District, Japan. 1 : *Pinus pumila.* 2 : *Pinus koraiensis.* 3 : *Abies Mariesii.* 4 : *Abies Veitchii.* 5 : *Picea jezoensis* var. *hondoensis.* 6 : *Larix Kaempferi.* 7 : *Tsuga diversifolia.* 8 : *Picea bicolor.* 9: *Taxus cuspidata.* 10 : *Abies homolepis.* 11 : *Pinus pentaphylla.* 12 : *Thuja Standishii.* 13 : *Chamaecyparis pisifera.* 14 : *Picea polita.* 15 : *Chamaecyparis obtusa.* 16 : *Thujopsis dolabrata.* 17 : *Tsuga Sieboldii.* 18 : *Sciadopitys verticillata.* 19 : *Abies firma.* 20 : *Cryptomeria japonica.* 21 : *Pinus Himekomatsu.* 22 : *Pinus densiflora.* 23 : *Torreya nucifera.* 24 : *Pinus Thunbergii.*

surveyed includes four zones from arctic (alpine) to temperate.

In the similar way, as we travel southwards from the subarctic conifer forest of Sakhalin and Hokkaido, the nature of forest community gradually but steadily changes towards the tropical rain forest of the Philippines. No discontinuous, sudden change is found except where the flora is impoverished due to the small size of the islet as on the Tokara Group at the southern end of Japan, or where the thermal gradient is extraordinary sharp as in the narrow straight between Formosa and Botel Tobago. Thus we are inclined to consider that the aforementioned difference between temperate and tropical forest is nothing but the contrast between both ends of a continuous series.

As an instance, the floristic diversity of the tropical rain forest, so often spoken of in ecological literatures, will be considered from this viewpoint. In recent years, plant and animal ecologists have recognized that the number of species and the number of individuals per species in a community are subject to certain statistical regularities. Let us now adopt Fisher's law of logarithmic series *(13)*. Denoting by s the number of species which is represented by n individuals in the sample randomly collected from a certain community, Fisher's law is given by

$$s = \alpha \frac{x^n}{n}$$

where x $(0 < x < 1)$ is the value that represents the completeness of sample and the more complete is the sample the nearer it approaches unity. α, on the other hand, is independent to sample size and means the number of species represented by a single individual when the community is completely sampled. The latter value or *the index of diversity* offers an exact measure of estimating the floristic diversity of a community.

As shown in Figs. 2 and 3, the law is fairly well satisfied by forest samples of utterly different nature and from different climatic zones. Especially noteworthy is the fact that a single dominant forest in the temperate zone (Fig. 2) and a tropical rain forest that contains nearly 100 tree species per hectare (Fig. 3) equally well fit the law. Apparent correlation is found when the values of α obtained from different climatic zones are plotted against thermal gradient (Fig. 4). These evidences suggest the continuous decline of floristic diversity from tropics to high latitudes and do not support the view that the tropical forest is essentially different in its character from the temperate forest.

In his monograph on the tropical rain forest, P.W. Richards *(4)* has recently stated that the tropical rain forest is *not* a highly specialized plant community as usually believed, but represents *the most original type* from which more impoverished vegetation of temperate regions have been derived through evolutional history. With regard to floristic diversity, he found that the diversity was most pronounced in the mixed forest on mesic sites, and that, even under the same rain forest climate, forests on perhumid or subhumid sites tended to be poorer in tree species and to have a few more or less apparent dominants. A similar principle might also be applied to the changes due to the fall in temperature.

PRODUCTIVITY OF TROPICAL FOREST ECOSYSTEM

In view of the continuous concept of the world's vegetation as stated above, the study of tropical forests, especially of the mixed rain forests, is doubtlessly one of the most important subjects for plant ecologists, as it may justly be called the starting point of all kinds of vegetation study. Owing to the unfavorable climate and inaccessibility from civillized areas, however, researches on tropical forest ecology in the past were mostly confined to community floristics and morphology. Among the problems left for future study, we are especially interested in the productivity of forest ecosystems under rain forest climate.

As early as in 1930, Vageler *(15)* estimated the annual organic matter production by tropical rain forest to be 100-200 tons per hectare. There is little doubt about the widespread conception that tropical rain forest is by far the most productive of all terrestrial ecosystems. Vast accumulations or standing crop of living plant body on unit forest area is mainly responsible for the conception. But the amount of standing crop is not always proportional to the true productivity or the velocity of organic matter production, usually given by the amount produced per year and per unit area. As a considerable portion of annual production is accumulated as wood year after year, and leaves as well as small branches and roots are continuously shed off day by day, the productivity of a forest can not be estimated from the standing crop alone.

The difficulty in determining the true productivity caused considerable variation in the estimates by different authors even for temperate forests. Filzer *(16)*, for instance, estimated the dry matter production of German forests to be ca. 4.6 t/ha/year. This figure was largely common, he stated, to pine, spruce, and beech forest, and also to the productivity of pastures. This seems, however, somewhat underestimated. From the growth analysis of a 12 year old stock of ash in Denmark, Boysen Jensen *(17)* estimated the annual production of dry matter per hectare as follows:

1. Wood	4.09	tons
2. Leaf	2.72	,,
3. Branches shed off	0.57	,,
4. Respiration loss	3.10	,,
5. Total	10.48	,,

Underground parts were excluded from the estimation. Assuming the Top/Root ratio to be 5.0, annual net production (1 + 2 + 3) and gross production (5) may amount to 8.9 and 12.6 t/ha respectively. Møller's comprehensive work *(18)* clarified the age-productivity relationship in Danish beech forest. The net productivity reaches its maximum (ca. 16 t/ha/year) at 30-40 years, whereas the maximum gross production (ca. 28 t/ha/year) is found at 60-90 years when increased ratio of respiration loss results in the decrease of net production by 2-4 t/ha.

In 1956, Satoo *(19)* published the result of his growth analysis on a regenerated stand of aspen in central Hokkaido about 40 years in age, and estimated the net productivity of aerial organs to be 8.7 t/ha/year. With the assumption that ca. 30% of gross production is lost by respiration and T/R ratio is equal to 5.0, the estimated annual gross production becomes 14.9 t/ha. If the undergrowth of bamboo grass is included in the calculation, it would rise to as much as 20 t/ha.

Both Japanese and Danish estimates are on the same order of magnitude. Because Denmark and Hokkaido belong to the cool temperate zone

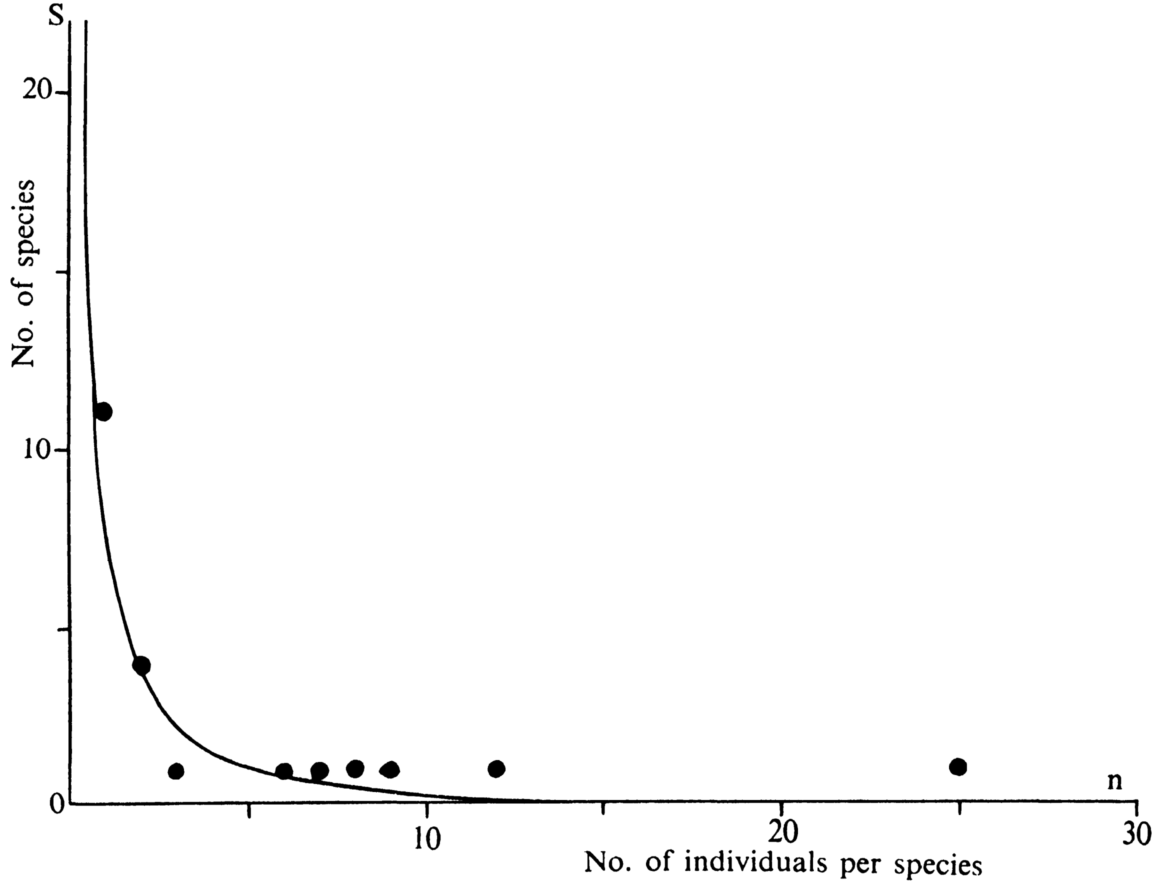

Fig. 7.—Species number-individual number relation in a lucidophyllous forest of central Japan, dominated by *Shiia cuspidata*. The curve indicates Fisher's logarithmic series fitted to the data. Sampled area 0.16 ha. Data after Miki, 1932.

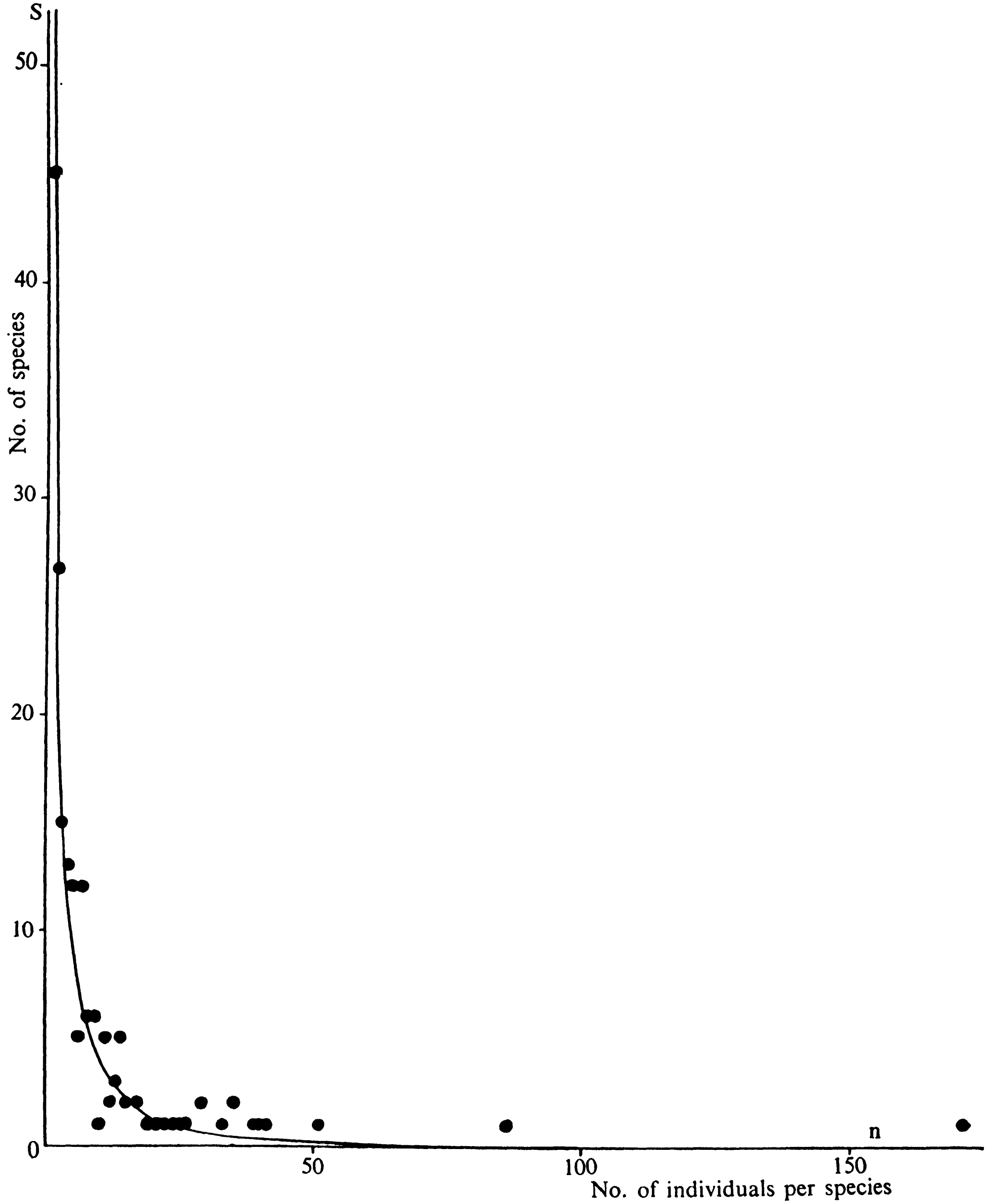

Fig. 3.—Species number-individual number relation in a tropical rain forest, Para, Brazil. Sampled area 3.5 ha. Data after Pires *et al.*, 1953.

(warmth index approximately 50 and 65 month-degrees respectively), we may tentatively conclude that cool temperate forests produce 15-25 tons of dry organic matter per hectare and per year under moderate edaphic conditions.

No exact estimates are now available for warmer climates, but the production of some temperate grasslands may be worth mentioning. Although the standing crop of living plant of forest ecosystem greatly exceeds that of grassland, there is little evidence that the productivity of the latter is much lower than that of the former when they thrive under the same climate. In hilly pastures of Japan belonging to the temperate zone, where the natural grasslands, of *Miscanthus sinensis* are maintained for thatching materials, a standing crop of summer foliage of more than 60 tons per hectare (fresh weight) is common. The approximate equivalent of this in total dry matter including root is 27 tons. As the annual increment of living rhizomes seems negligibly small in a well-developed grassland, this amount of summer crop may roughly equal the net production of the year. Thus the gross productivity would amount to 39 t/ha/year.

In this connection, the relation of agricultural productivity to thermal gradient is very suggestive. Kawakita *(20)* compared the agricultural productivity of eight districts of the Japanese Archipelago in terms of the average yields in calories of edible parts of main food crops. When the productivity is correlated with the average

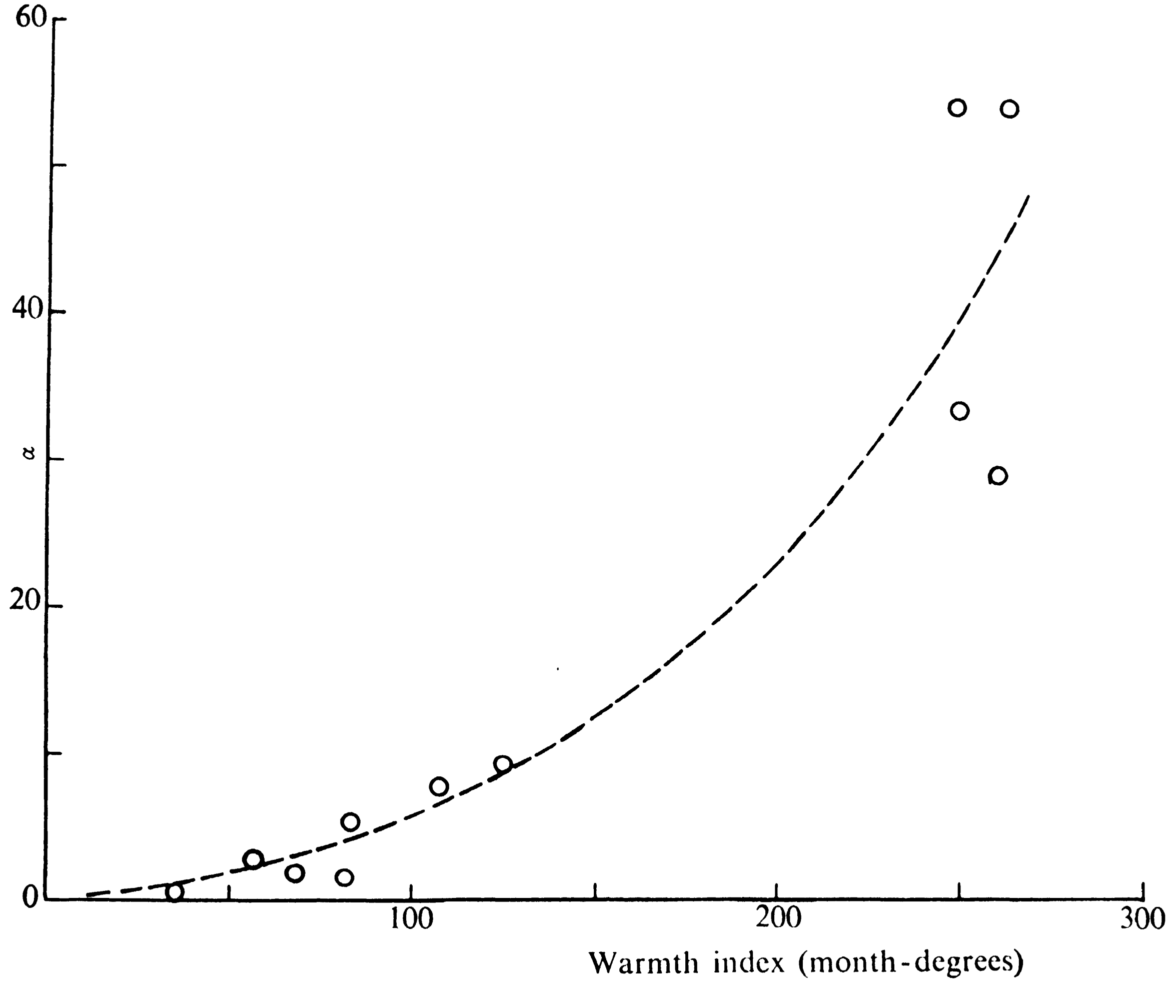

Fig. 4.—Fisher's index of diversity (α) increases with temperature.

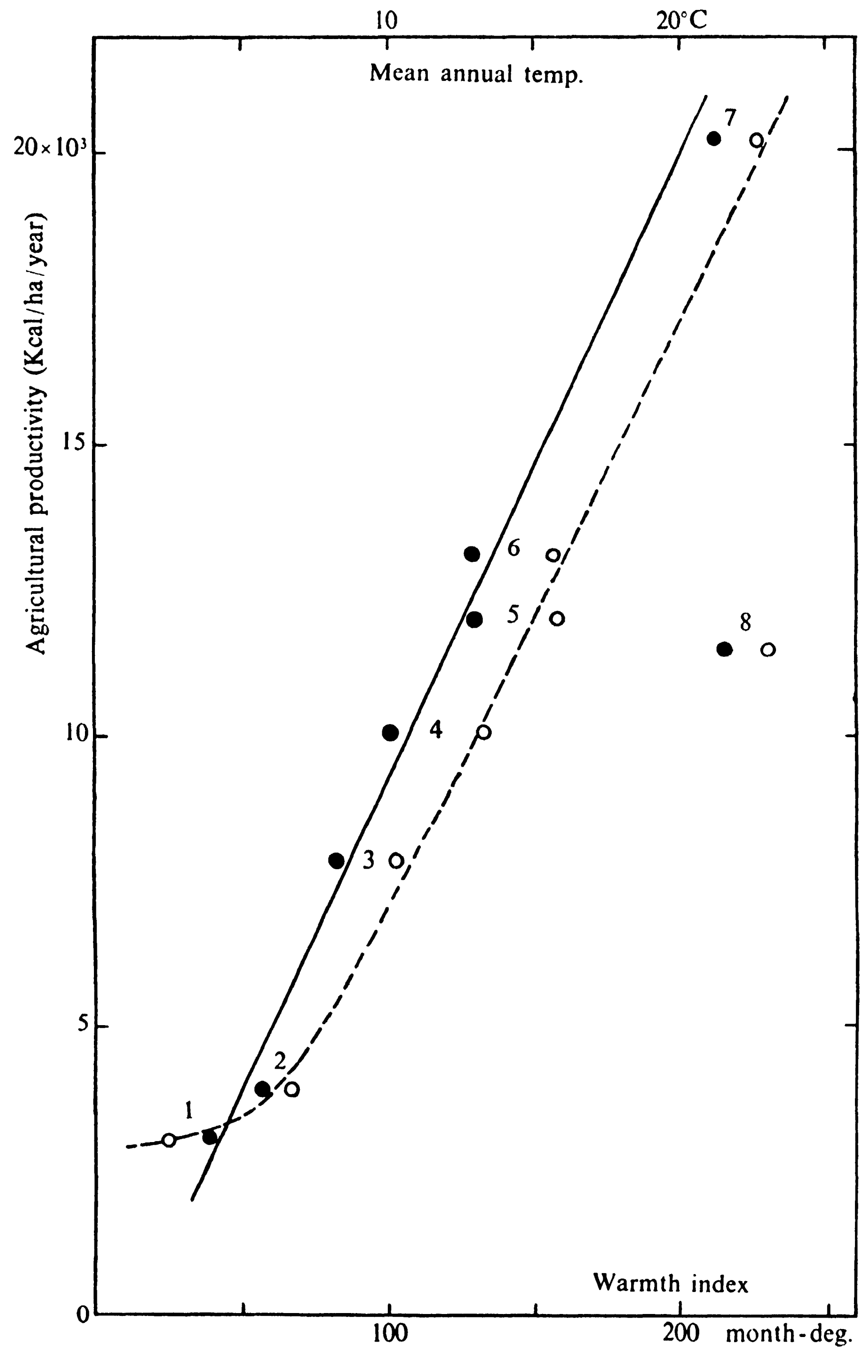

Fig. 5.—The relation of agricultural productivity to thermal climate. 1: Sakhalin. 2: Hokkaido. 3: Northeastern Hondo. 4: Central and southwestern Hondo. 5: Sikoku. 6: Kyusyu. 7: Ryukyus. 8: Formosa. Data after Kawakita, 1949.

thermal data, approximately linear regression is obtained (Fig. 5). It is to be noted that the warmth index appears more linearly correlated to the productivity than the mean annual temperature. If similar linear regression be expected between the warmth index and the productivity of natural ecosystems and the gradient of the regression line remains as it is, we could estimate the productivity of tropical forests by extrapolation. According to the regression of Fig. 5, the productivity at 260 month-degrees of warmth index which is the standard value for humid equatorial climate is about 5.26 times as great as that at 55 month-degrees. Assuming the gross productivity of a forest at 55 month-degrees to be 15-25 t/ha/year, the expected value in the tropics would be 79-132 t/ha/year, falling on the same order with that of Vageler's estimation. It is also of interest to note that the gross productivity of marine algae in a coral reef community of tropical Pacific water was 24g/cm^2/day in glucose *(21)*. Equivalent dry matter of this as ordinary plant materials is about 80 t/ha/year.

A most reasonable representation of productivity is found in the photosynthetic energy efficiency or the ratio of radient energy utilized for the organic matter synthesis to the total radient energy available. The efficiency or Lindeman's ratio has been studied mostly with aquatic ecosystems, and it is now widely recognized that eutrophic lakes and ocean waters in the temperate zone having phytoplankton as principle producer have the annual efficiency of 0.3-0.4%. Higher efficiencies were recently observed by Odum *(21, 22)* in the tropical coral reef and the water-grass community of a freshwater thermostatic spring in Florida, the ratio to the total available radiation at the water surface being 2.9% and 2.6% respectively. One author *(23)* has stated that the energy efficiency in natural ecosystems hardly exceeds 1% and that forests are in general even lower than aquatic ecosystems in their efficiency. However, our calculations on the aspen forest of Hokkaido mentioned above resulted in a considerably higher percentage. Annual gross production of 20 t/ha in this forest corresponds to the annual efficiency of 0.8%; and, if only the radiation during 5.5 months' growing period is considered, the ratio increases to 1.4%. As for the more productive beech forest of Denmark, where the available radiation becomes less owing to higher latitude (56°N.), a still higher percentage is to be expected. For *Miscanthus* grassland of central Japan, the estimated efficiency is 1.9%. We might therefore conclude from these evidences that the forest ecosystem could reach a much higher level of energy efficiency than formerly believed, presumably as high as 2.5%.

Average annual amount of solar radiation on the equator is 0.339 cal/cm^2/min according to Simpson *(24)*. This is equivalent to 1782 × 10^{10} cal/ha/year. Similar estimates by Fukui *(25)* give almost the same value. If the tropical forest is assumed to produce photosynthetic assimilates with the efficiency of 2.5%, 44.5 × 10^{10} calories are expected to be utilized for organic matter synthesis, or 117 tons of glucose are produced per hectare and per year. One hundred and seventeen tons of glucose roughly correspond to 106 tons of dry plant materials. This estimate again agrees well with the result obtained by the extrapolation of the productivity-temperature regression in Fig. 5.

FALL IN PRODUCTIVITY CAUSED BY FOREST DESTRUCTION

One of the greatest difficulties confronting tropical agriculture is the catastrophic decline of productivity that occurs when the forests have been cleared and converted into such artificial ecosystems as farmland or plantation. This is especially the case with humid rain forest areas. In general the agricultural exploitation of these areas is as yet far from success. Only the shifting agriculture on upland slopes and the paddy rice cultivation on irrigated plains, both of which have presumably originated among the inhabitants of humid tropics, are well adapted to this climate.

In temperate regions, the agricultural production is no less efficient than the production of natural ecosystems. Transeau *(26)* estimated, for example, the energy efficiency of gross organic matter production for a heavy crop of maize in Ohio to be 1.6%. Similar efficiency for average rice crop in Japan (ca. 4.6 tons of unhulled grains per hectare in air-dry weight) is about 1.1%. The highest yield of rice hitherto recorded from Japan amounts to 15.3 t/ha, and the gross productivity equivalent to this grain yield means the energy efficiency of about 3.3%. Such high productivity of temperate agriculture is of course maintained by the addition of chemical and organic fertilizers, which not only compensates the amount of minerals removed from the soil as crops and through leaching, but also enriches the soil beyond the level of mineral content under natural conditions. Natural ecosystems, especially the forest with its stratified structure, seem more efficient in utilizing the available space as well as the radiant energy that falls upon it, as compared with singled-layered, widely spaced crop communities. It is perhaps the effect of enriched soil minerals that enables agricultural ecosystems to overcome this handicap.

In the tropics, however, the return of minerals to the soil is so large in amount that to replace it with manuring under cultivated conditions is a hard task. On the other hand, high temperature accelerates the decomposition of litter to such an extent and the leaching of soil minerals is so rapid owing to heavy rainfall that the soil of cleared forest land is quickly devastated. We have seen in Fig. 5 that the agricultural productivity is nearly proportional to the warmth index throughout the long stretch of Japanese Archipelago, from Sakhalin to the Ryukyus, where the way of agricultural land utilization is essentially the same. Turning to Formosa, however, the productivity suddenly falls below the expected value. Although the change in the traditional system of land utilization may be responsible for the fact to a certain extent, this appears to suggest an unavoidable limitation imposed upon the temperate way of agriculture under tropical climates.

Extremely low mineral content of tropical forest soils must be mentioned here. In regions of nearly equal climatic humidity, the organic matter or the nitrogen content in the soil can be represented as the function of temperature, decreasing exponentially with rising temperature *(27)*. In contrast to temperate forest soils containing an average of 0.1-0.3% total nitrogen, the percentage for tropical forest soils hardly exceeds 0.05%. Similar relations may well be expected for other mineral nutrients. The layer of undercomposed organic materials is also poorly developed on the floor of tropical rain forest. But the minor standing crop of minerals stored in the soil does not always indicate the lower productivity of a whole ecosystem, as the standing crop is nothing but the balance in the budget of minerals which at every moment are set free from the litter and absorbed by the roots again. Several authors have reached the same conclusion *(14)* that there is an almost closed cycle of plant nutrients in the tropical rain forest ecosystem and that the minerals are at once reabsorbed by plants as soon as they are released from the decomposing plant materials.

The dynamics of soil mineral budget is quite different in temperate forests. To cite an example from the study of Ovington *(28)*, average distribution of nitrogen in several pure stands of different tree species, artificially established at Abbotswood, England, were as follows:

In canopy	274 kg/ha
Tree boles	132 ,,
Ground flora	32 ,,
Forest floor	235 ,,
Mineral soil	7,041 ,,

(Underground parts are omitted)

Considering the age of stands (mostly 40-45 years), the amount of nitrogen in the annual increment of living plant body as canopy, boles, and ground vegetation may be of the order of 200-250 kg/ha. When compared with the amount present in soil and litter (235 + 7,041 = 7,276 kg/ha), the turnover of soil nitrogen would be only 1/30-1/35 time/year, if the addition due to rainfall and nitrogen-fixers be compensated by the loss through leaching.

As to tropical forests, judging from the productivity and the average nitrogen content of soil, the annual turnover of soil nitrogen might be not far from 1. Namely, the speed of circulation of plant nutrients is 30-35 times more rapid in tropical than in temperate forest. The speed of circulation is most probably the function of temperature, and to establish the turnover-temperature relation as known functions may provide a possible approach to understand the dynamics of the tropical rain forest ecosystem.

What we have said above is little more than common ecological knowledge. Our intention is to point out the importance of the study of ecosystem metabolism in the rain forest and its implications to tropical agriculture. Intensive study in forest areas where shifting cultivation is prevalent may throw new light on the problem.

SUMMARY AND CONCLUSION

1. It is pointed out that the tropical rain forest occupies a terminal situation on a long continuous series of forest vegetation from subarctic to tropical climate. Along the series or the latitudinal thermal gradient on the earth, the floristic diversity, productivity, and other characters of forest ecosystem continuously changes, ending in the tropical rain forest with its extreme richness in flora and organic matter production. The importance of the western Pacific area is stressed which represents the sole example in the world of uninterrupted continuation of humid forest climate from high latitudes to the equator.

2. By the extrapolation of a temperature-productivity curve obtained from temperate regions, the annual gross productivity of tropical

rain forest is estimated to be 105 ± 25 t/ha in dry matter. This agrees well with another estimate based on the energy efficiency of organic matter production by forest combined with the amount of total radiant energy available in the tropics.

3. The cause of the failure of rain forest area as arable land is discussed as related to the ecosystem metabolism. It is suggested that the very rapid circulation of plant nutrients between plant and soil is mainly responsible for the sudden decline of productivity that ensue from the clearance of rain forest. A rough estimation has shown that the turnover of soil minerals may be some 30 times greater in tropical forest than in temperate forest.

4. These results are only tentative, but they may serve as the starting point for intensive field researches on tropical rain forest which are earnestly desired in the near future.

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THE OCCURRENCE OF TROPICAL PLANTS IN THE JAPANESE ARCHIPELAGO AND ITS PHYTOGEOGRAPHICAL SIGNIFICANCE

YOSHIWO HORIKAWA

Botanical Institute, Hiroshima University, Hiroshima, Japan.

(Abstract)

As one of the most characteristic features of the Japanese flora, it is cited that several plants of the tropical origin are growing wild there. This fact was already clarified by me with respect to bryophytes. As to the vascular plants, the following is known about the distribution of some species. According to their northernmost limit of habitat in the Japanese Archipelago, the species are divided into ten types:

Type 1. ranging from Indo-Malaysia north to 44° L.N. in Japan.
Trichomanes parvulum Poir.

Type 2. ——— to 41° L.N.
Vitex rotundifolia Linn. fil., *Albizzia julibrissin* Durazz.

Type 3. ——— to 38° L.N.
Dicranopteris glauca Underw., *Hymenophyllum barbatum* Baker, *Drosera spathulata* LaBill.

Type 4. ——— to 37° L.N.
Psilosum nudum Beauv.

Type 5. ——— to 36° L.N.
Ceratopteris thalictroides Brong., *Mecodium polyanthos* Copel., *Lycopodium cernuum* Linn., *Vittaria flexuosa* Fée. *Anodendron affine* (Hook. et Arn.) Druce.

Type 6. ——— to 35° L.N.
Nephrolepis cordifolia Presl., *Ipomoea indica* (Burm.) Merr.

Type 7. ——— to 34° L.N.
Histiopteris incisa J. Smith, *Humata repens* Diels, *Cocculus laurifolius* DC., *Solanum aculeatissimum* Jacq., *Dichondra repens* Forst., *Ipomoea pes-caprae* (Linn.) Sweet, *Senecio scandens* Hamilt. ex D. Don, *Dianella ensifolia* (Linn.) DC.

Type 8. ——— to 33° L.N.
Alocasia macrorrhiza (Linn.) Schott.

Type 9. ——— to 31° L.N.
Ficus retusa Linn., *Kandelia Candel* (Linn) Merr., *Messerschmidia argentea* (Linn., fil.) Johnston.

Type 10. ——— to 30° L.N.
Blechnopsis orientalis Presl., *Blastus cochinchinensis* Lour., *Melastoma candidum* D. Don., *Spinifex littoreus* (Burm. fil.) Merr.

(The horizontal and vertical ranges of each species are to be discussed with the frequency maps.)

At the present stage of our knowledge, it is hardly possible to form a safe conclusion about the phytogeographical explanation of the occurrence of these tropical plants in the Japanese Archipelago. It is more likely that these species were once distributed much more widely in temperate regions of East Asia, such as China, Korea, and Japan. In later times, through climatic change, they were unable to compete with more aggressive species and have been reduced to their minor role in the vegetation. The coast of the islands of Japan has been warmer under the influence of the warm sea-current of "Kuroshio," and they may have survived here as living fossils.

UNIFYING CONCEPTS IN VEGETATION STUDY AS APPLIED TO THE PACIFIC BASIN

FRANK E. EGLER

Aton Forest, Norfolk, Connecticut, U.S.A.

My role in summarizing this symposium on Vegetation Types of the Pacific Basin is fraught both with customary and uncustomary difficulties. I should state first that my position as Chairman of this program is only as a latter-day substitute for Dr. Pierre Dansereau, to whom should go full credit for organization, and who regrettably was unable to come to Bangkok despite earlier plans to the contrary.

During the course of this symposium we have been presented with several succinct and admirable contributions. At first glance, it may appear that these are totally disconnected and unrelated "islands" in the "sea" of vegetation (plant community) science. Perhaps we should face one fact at once: the terrestrial vegetation of the Pacific Basin, as distinct from that of the rest of the world, has but one element that binds it all together—a vast mass of water called the Pacific Ocean which is not a substratum for terrestrial vegetation, and acts as the best possible agent to prevent the unification of that vegetation. Thus the Pacific Basin is a geographic entity, united more by the common interests of its human populations than by any fundamental vegetational relationships.

The papers presented in this symposium serve to place the spotlight on a few elements of the whole problem, much as if a spotlight were to pass over a crowded stage, temporarily lighting a few personalities, but leaving all the rest in darkness. This momentary lighting however is very important. It serves to add a definite increment to our knowledge of Pacific Basin vegetation, even as does each succeeding Pacific Science Congress. My purpose at this time is no more than to place these papers in the larger framework of such a stage.

There are several "viewpoints" from which vegetation may be approached. No one viewpoint has precedence over any other. In the rest of botany, for example, the morphologist does not vie with the physiologist as to which is most "important," or which comes "first." So it should be with the students of plant communities. The floristic composition of vegetation is one such viewpoint. Within the Pacific Basin, the floras segregate into at least three major groups. There is a circum-Arctic flora on the mountains near the Alaska coast, out across the Aleutians, and down the high elevations of the Kamchatka Peninsula. This flora, giving rise to tundra types of vegetation, has not been represented on this symposium. Progressing southwards, we find temperate floras that have more in common with themselves than with the arctic or tropical floras that bound them on each side. Becking, Tatewaki, and Chi-Wu Wang have each contributed to our knowledge of these areas. The tropics, by comparison, is a relatively unified region, characterized in its vegetation by the relative absence of damaging cold weather (although how that damage is described in purely meteorologic terms is still an ecologic puzzler). Porleres, Hürlimann, Kira, Horikawa, and Fosberg have given us interesting information on vegetations developed from these floras. Of these, Fosberg has handled the atoll problem, where the flora is attenuated to point of poverty, thus greatly simplifying some aspects of vegetation study. The temperate floras of the southern hemisphere, of Australia, New Zealand, and South America are not represented on this symposium, except for Fosberg's comments on the montane grasslands of the Andes.

Passing on to a second viewpoint, interest in the form and structure of vegetation is a major preoccupation of some vegetation scientists. Becking, in handling northwestern United States, is concerned largely with the make-up of vegetation in terms of the plant communities, according to the ideas of Braun-Blanquet. Hürlimann is concerned with structural details of a tropical forest. Thirdly, Dansereau has presented us with an expression of his system of shorthand symbols for recording the structure of communities. Like most systems of shorthand, it is bewildering at first look, particularly this lollipop-oriented one. (Freudian overtones specifically not implied!) Furthermore, Dansereau is very much alive, and I fear there may be revisions to the revisions before the gentleman passes on to a stable end-stage of heavenly climax, revisions that make it difficult for ones of limited mentality like myself to keep up with him. It was questioned from the audience as to whether this system had been or could be used in the floristically more complex tropics. It is my personal opinion that it is in areas of just such complexity where this system might prove most serviceable, in that it describes structure unrelated to details of floristic composition, which details for most tropical regions are not adequately known.

One micro-facet of the morphology of plant communities is that of epiphyte communities, of those aggregations of plants which utilize another plant as a substratum, and which can be studied as a separate element in the total phytosociologic picture. Hosokawa and his colleagues have carried on a great many studies with epiphyte communities, both in Japan and on Pacific islands. Their present contribution is one more in a notable series.

Another aspect of the form and structure of vegetation, related not to the different communities involved, or to the structure of those communities, but to whole mosaics of communities, is the grassland-savanna-forest problem. These types of vegetation are found in close association with each other in many parts of the tropics. Their interpretation as being "natural," or induced by primitive tribes and persisting into the present as "relicts," or induced by contemporary agricultural and pyric factors, is a phase of scientific investigation discussed by Porteres and Fosberg. It is a fascinating field of inquiry not only for the academic mind, but for the Vegetation Manager who wants to manipulate and convert vegetation, sometimes into types markedly different from what now exists.

In the third "viewpoint," that of functions and processes, it is quite interesting that not a single paper is developed along the traditional lines of "plant succession" to "climax," with an orderly diagram showing the origins of the various "seres," culminating by means of arrows, in one final end-stage. Nevertheless, all the speakers have considered adequately and worthily the various dynamic functions that are involved in the life-activities of their various vegetations.

The "ecologic" (environmental) approach, a fourth viewpoint, is coincidentally absent as the major approach in any one contribution to this symposium. This approach, dominant in the thinking of possibly the major part of vegetation research, at least in America, is not omitted from this symposium by intent. Although we have no paper entitled "The influence of climate on the distribution of . . ." or "Soil chemistry as related to the vegetation pattern in . . .," there has been no slight, with any speaker, as to an awareness of the importance of the environment in the behavior and phenomena of vegetation.

The geographical distribution of vegetation types is a fifth viewpoint, and cartography (mapping) is one of its most important aspects. In this branch of knowledge, Kuchler has distinguished himself, particularly in accumulating a world bibliography of vegetation maps. His presentation and views serve excellently to round out this symposium. Aerial photography has enormously enhanced our facilities for vegetation mapping in recent years. It should be pointed out, however, that the vegetation types which are distinguishable from the air are generally the physiognomic types, that is, types distinguished as forest, grassland, savanna, and desert. Equally distinguishable are types dominated by an aerially visible species, such as pine forests in a mixed hardwood region. There are dangers as well as advantages to this facility, for it leads us to overlook the fact that there may be other and even more significant kinds of vegetation types which are not related to these aerially visible differences. Therefore one cannot overemplasize the need for accessory studies on the ground by competent botanists.

A sixth and final viewpoint, that of distribution in time, or history, has also been underplayed, if we view its importance in an ideal vegetation science. Both Porteres and Fosberg have touched the subject in their inquiry on the possibly-human origins of grasslands and savannas, and Chi-Wu Wang has considered the history of the Chinese forests as it extends back into geologic time.

As a postlude in one sense, and as an open door to larger vistas in another sense, the spotlight should be played again on Fosberg's treatment of atoll vegetation. The idea implicit here is developed more extensively by him in another paper delivered elsewhere at this Congress, " . . . Description of the Coral Atoll Ecosystem." Now in all other papers of this Symposium, we have considered "vegetation" as our subject of study. For many years, however, scientists have realized that vegetation is but part of a larger integrated whole, called by such names as ecosystem, microcosm, landscape, and "organism" (*not* the biologic organism). The obvious intellectual advantages of this approach are often offset by the very complexity of the natural phenomena involved, and the fact that adequate scientific knowledge from many disciplines is seldom encountered in one man. The atoll, by its very nature, is a distinctive microcosm, existing at the interface of sea and air, with energy absorbed from and radiated to its environment, with a sort of feed-back mechanism that keeps the system in a relatively steady state. From this view, the vegetation all but loses its separate identity in the structure and behavior of the larger "whole." It is not to be implied that the same conceptual approach is immediately applicable to continental areas, with their enormously greater complexities, and less clearly defined boundaries in space. Fosberg's researches greatly advance our ideas in these conceptual realms, and indicate that the views are both feasible and practicable.

In closing this symposium, which had been planned by Dansereau as Chairman of the subcommittee concerned with Vegetation (plant communities), I wish to say that in my opinion this subcommittee, acting within the framework of these Congresses of the Pacific Science Association, has a brilliant future ahead of it. A unified vegetation science is just beginning to emerge from the various nationalistic disciplines which originated mainly in North America and Europe. There is now no other area in the world than this Pacific Basin where scientists of so many nations can cooperate so advantageously, with the vigor that comes from the interplay and interchange of ideas, of problems, and of research accomplished. I look forward to seeing this vigor translated into a distinct world contribution towards the description and understanding of the world's vegetation.

THE SCHOOL-FLORA AS A MEDIUM FOR BOTANICAL EDUCATION IN THE TROPICS

C.G.G.J. VAN STEENIS

Flora Malesiana Foundation, Oegstgeest, Netherlands.

A proper understanding of plant structure is an absolute necessity for botanical education, without which pupils of the secondary schools—the source from which university students will be recruited—will not be able to understand plant function, plant ecology, flower biology, forestry, and agriculture.

The identification of a living plant by means of keys and a description is still the best means to gain an insight in its structure and its contrasting features with other plants. Plant atlasses may seem to lead to the same result along a more easy way. But this is educationally basically wrong, it leads only to a vague notion of the general habit of a plant and to its name, not to any knowledge of its structure.

Most Floras have a *dualistic character*, they tend to give a *complete* survey of all the species of a country or a more restricted area and must serve simultaneously for *education.*

In tropical countries this dualism is untenable by the wealth of the floras, and would necessitate large and expensive works in which the educative purpose is entirely lost. Such Floras would contain descriptions of plant forms from remote mountains and forests which could never serve for regular class demonstration and which no teacher could be expected to know himself, let alone have available in the living state in sufficient quantity for class teaching.

Complete Floras may be desirable for botanists and advanced amateurs, but for school-children they represent the 'Tables of the Law', they have no educative value and are deterrent rather than awakening interest in plants.

It is compulsory that in the class each pupil has in hand a living specimen and the Flora, with at most a pin or needle as a simple utensil; lens and forceps will generally be not available and are unnecessary for the purpose.

The idea is that the identification of a plant is performed in the class, step by step, and that under guidance of the teacher each pupil can follow the way along which the ultimate goal, the name, is reached with subsequent checking of the description. This simple botanical detective work must give satisfaction.

Such a School-flora must be adapted to the following points:

(a) A selection of plants, hence no completeness whatsoever.

(b) Availability of at least a number of species incorporated in it, as the teacher must be able to collect for one lesson enough material to give a specimen to each pupil. Consequently the choice of selection is restricted to plants available in or near towns and cities.

(c) Extensive use should be made of cultivated plants from school-gardens or nurseries, town parks, roadsides, etc., resulting in inserting in the Flora numerous cultivated and ornamental plants.

(d) To bring pupils into contact with biotopes in his immediate vicinity brings along the inserting in the Flora of some typical plants of beach, mangrove, rice-field, swamps or pools, dry-farming fields, estates, waste ground, secondary growths, etc.

(e) The absence of a lens and forceps and knowledge how to use these necessitates the omission of plants with small flowers which escape easy observation with the naked eye. Besides, there is no educative advantage in dissecting small flowers against using large ones.

(f) There must be no obscurity in the identification keys to the family, genus or species, and when the name of the latter is reached there should be a clear not too elaborate description for checking the identity. Great care should be given to attain a faultless text.

(g) Interest in the plant should be raised in adding where desirable some brief additional notes on uses for mankind, biological topics, or other noteworthy data.

(h) In absence of adequate pre-knowledge technical terms should be avoided and the keys and descriptions should be as much as possible worded in plain language; a plate showing schematic pictures to elucidate necessary technical terms may be handy.

(i) Representatives of the most important tropical families should be inserted by native, introduced or cultivated species.

With such a flora only a *select number of species* can be identified; it serves *merely for educative purposes*; the idea of *completeness is entirely abandoned.*

If we imagine that during the courses in the secondary school not more than about 25-50 species will be identified in the class, the School-flora should contain not more than about 300-400 species in all.

With a few collaborators I have realized such an octavo School-flora for Indonesia, with about 400 species belonging to about 300 genera and 120 families. It covers about 400 printed pages[1].

It is not the intention that pupils will know or learn all these 400 plant species; no more than 10% can be treated in the class. But the number of 400 leaves room to the teacher to make his choice in accordance with available plants in sufficient quantity in his vicinity. Representative species of both the everwet and seasonal regions should be inserted. It further allows pupils who are interested to use the book for their own pleasure.

School-floras, like Alston's 'The Kandy Flora' (1938) and Merrill's 'Flora of Manila' (1912) follow a scheme which is less adapted to practical use as our School-flora for Indonesia. Both contain generic diagnoses which I feel are unnecessary for secondary schools.

My main objection is, however, that they represent a complete flora of the vicinity of a town, Kandy and Manila respectively, without restriction to easily available plants for class teaching and selection on size of flowers. They both still contain a dualistic element (serving education and botany) and are not entirely devoted to the goal of being merely a tool for educative purposes.

In the School-flora for Indonesia we could not avoid mention of such important groups as grasses, sedges, and ferns, and have been compelled to add some simple pictures for a few representatives of these groups.

The insertion of common and widely distributed ornamentals, weeds, fruit trees, wayside plants, etc. is convenient to use the flora in the whole of Indonesia in cities and towns below 1,000 m altitude, the site of most training centres. And I am rather certain that it could for the same reason be used in most parts of tropical southeast Asia, Micronesia, and Melanesia.

I believe that the model of a School-flora of which the principles have been just outlined, is a valuable tool for education purposes and the wakening of the interest of pupils.

I find it desirable to bring these principles to the general notice of teachers and hope it will be a stimulant to the writing of similarly adapted School-floras in other tropical countries.

DISCUSSION

F.R. FOSBERG: E.H. Bryan, of the Bishop Museum is writing the flora of Guam which fills Van Steenis requirement for School-flora. The common species are emphasized so that the ordinary people of Guam can learn. Such books acquaint young students with the nucleus of botany before college time.

C.G.G.J. VAN STEENIS: In Java, education in schools is faced with the problem that knowledge of Java's flora (4,500 species) is impossible. Therefore it is a necessity to have easy tools to instruct people in the morphology of certain plants. One disadvantage is that the teacher must know plants and names himself.

M.L. STEINER: I do not agree with the exclusion of small species of flowers.

C.G.G.J. VAN STEENIS: For secondary classes it is sufficient to study only large flowers.

M.H. SACHET: I disagree.

F.R. FOSBERG: People may learn botany, but not of plants. America has a tendency not toward School-flora but toward picture books which form bad habits.

P. WEATHERWAX: A written examination would find out if students can use the key.

V.A. JIRAWONGSE: Is there an advantage in using just vernacular names?

C.G.G.J. VAN STEENIS: Vernacular names are different in different parts of the world, and Latin names are used.

[1] '*Flora voor de scholen in Indonesië*'. Noordhoff-Kolff, Djakarta, 1st ed. 1949, 2nd ed. 1951.

BOTANICAL EXPLORATION AND EDUCATION IN PRESENT DAY SUMATRA†

W. MEIJER

Faculty of Agriculture, Pajakumbuh, West Sumatra.

SCENERY AND BOTANICAL RICHNESS IN SUMATRA

Sumatra, as compared with Java, is a land of promise for botanical exploration. On the densely populated island of Java, most of the lowland flora is destroyed, and almost the whole country is divided among agriculture, forestry, cattle-breeding, and fishery. Botanical exploration has already been so thorough in Java that only rarely are new plants found. Bogor is still an important botanical centre on Java. In Sumatra we find a quite different situation—though not everywhere. It is not only a land of promise but also of contrasts. Regions like Djambi and Indragiri are still largely covered by primary forests in which are found elephants, rhinos, and tigers. Only 2-5 plant specimens have been collected per 100 sq km in these regions. I read in the newspaper that the tribes of the primitive Kubu-people are still living in these forests. It is told that they walk undressed and are forbidden by their own law to plant.

Quite different situations are found in other places: the Deli-region in the Northeast has been widely cultivated and is still the area of big estates of oil palm and tobacco and rubber. Minangkabau on the West Coast is to be seen from the air like an enclave between the jungles of South Tapanuli, Indragiri, Djambi, and Bengkulu. It was long ago colonized by people who made this a region one of mixed garden agriculture and who still preserve their special customs. The landscape has much the same features as Java, but agriculture is far less intensive than in Java and the flora of the kampongs also shows many differences. Minangkabau people possess, for example, their own races of rice (hundreds!); their own names for and assortment of bamboos; their own names for at least twenty-five different kinds of cultivated bananas; their own way of planting tobacco, cinnamon, sugarcane, clove (tjenkeh), and gambir; their own way of burning grassfields and secondary forests, of plundering the forests, taking no care of silviculture, land and soil protection. It is very difficult to change cultivation customs which cause destruction of the landscape and impede further development. Sumatran students entering the new University Andalas are not selected among the Kubus or among kampongs far from the town; they are largely the sons and daughters of businessmen and government officials—urbanized people who have lost contact with their rural surroundings. They have been strongly influenced by the blessings of modern culture from America and Europe, but are still in search of their own style.

Pajakumbuh, is an ideal spot for botanical exploration and education. Here we find in a region of 10 sq miles (about 14 km square), a flat basin with mixed gardening and marshes (Pajakumbuh means the plain of marshes), surrounded by hills on which tobacco and gambir are planted and forest clad mountains composed of three different types of rocks: sandstone, limestone, and the old volcano Mt. Sago. The lowland forests, rich in Dipterocarpaceae, of the large East Sumatra coastal region are on a distance of about 15 miles. The whole flora of the Pajakumbuh region probably has at least 2,000 species of flowering plants. For Mt. Sago alone, I could list more than 800 species. The whole phanerogamic flora of Sumatra may be estimated as about 10,000 species including, for example, 800 orchids.

When we read in *Flora Malesiana* that the collecting density in W. Sumatra per 100 sq km is 38 (332 in W. Java), we can understand why our recent collections from the Pajakumbuh region contain numerous novelties new to science, or plants hitherto known only in Malaya, or collected only in South or North Sumatra. Several of these plants are really common in special types of vegetation. It is becoming clear now that forest types are strongly correlated with soil types, the so-called climax theory has no scientific basis! The forest vegetation on limestone hills is quite different from that on sandstone hills. Analogous differences are seen in the weed vegetation and the cultivated races of rice. Limestone regions of the plain are very different from sandstone regions. The latter appeared to me in need of phosphate manure which could be

† Presented by J.V. Santos.

found in caves in the limestone hills! We are drawing the attention of the agriculture service to this situation.

We have already more or less compared the flora of Mt. Sago with several other mountains in Central Sumatra. Impressions of the lowland forests were collected in West-Indragiri. The sandstone region was the subject of the most recent expedition. More thorough studies of the limestone flora and of marsh forests remain for the future. We are presently making a thorough inventory of economic plants in the Pajakumbuh region devoting attention to all kinds of fruit trees, vegetables, legumes, races of rice, weeds, and secondary vegetation. We are able to advise and help the population in the rural reconstruction area served by our Faculty to use their waste lands more efficiently and to improve their mixed gardens. The culture region is far less productive as compared with Java. Our hope is that investigation will precede long-run planning in Central Sumatra and that natural resources will be better preserved than at present. Reforestation should become more than incidental planting of *Pinus*, *Acacia auriculaeformis*, and some *Toona sinensis*. Good measures against burning and for forest and soil-protection should be taken. The farmers ought to be educated in this direction.

We are ourselves trying to do this in our reconstruction area. We have succeeded in getting the road improved and have gathered all kinds of informations about economic botany, started a reforestation project and have built a nursery-garden. We are now engaged in project to plant the waste hills which are burned every year and show heavy signs of erosion. Our exploration task cannot be separated from our informations and education. The local population needs much information and education. People are no longer content with their standard of life. Indonesian society is in transition! Descriptive botany and botanical ecology are very useful and practical in tropical agriculture!

THE ROLE OF BOTANICAL EDUCATION IN SUMATRA TODAY

There will be no practical application of our studies in forestry, cattle-breeding, fishery and agriculture because they have no role in the botanical education of the country. Technical assistance for this requires more than three years. The Dean of our Faculty estimates that ten years will be necessary to get Sumatra's own people sufficiently interested and educated in scientific botany.

Are the facilities for such an education already provided at the new University of Andalas? No; after two years of struggle with many kinds of difficulties, a botanical institute is being built, but because of a lack of equipment, it is still impossible for the departments of plantphysiology, microbiology, and cytogenetics to do their work on a modern level. Our Faculty is still without any laboratories for physics, chemistry, and agronomy. For social-economic science we have nobody! In Indonesia it often takes two years before ordered instruments arrive. The education of skilled personnel takes much patience and good-will. Minangkabau people have another discipline of work than Europeans or Americans. Foreign medical doctors feel the same difficulties, but fortunately self-education and self-criticism are also known here. The non-experimental parts of botany can start from the first days of arrival of a field botanist. Old newspapers for drying plants are to be bought on the local market; bamboo sasaks are easily made; and the sun is the great drying oven: Kampong people may be found who know the roads into the forests and many local tree names. The botanist must be able to get the authorities interested in his work; he needs transport, funds, and even soil for experimental gardens. Knowledge of the Indonesian language to educate the students in botany is very helpful. A good exploration of the nearby kampongs and mountains makes it possible to teach botany outside the lecture room in its natural surrounding. Then you have the simple task of showing the new students for the first time in their life what cotyledons really are (the word Dicotyledons they know); opening their eyes to the special structure of flowers of coconut palm, banana, and papaya; teaching them to distinguish fruit trees, legumes, vegetables, curbits, green-manures, and ornamentel plants; teaching them to observe plant forms, to describe them, and to learn how to make use of keys for identification. It is astonishing how little is known about this; a lot of goodwill, patience and perseverance is asked from the teacher. As soon as microscopes arrive—in my case after one year—and the fundamentals of plantmorphology and knowledge of plants in the surroundings are understood, you may start with laboratory courses in plant anatomy and cryptogams. Please do not look for Rhoea discolor to demonstrate plasmolysis; use the red leaved Cannas one meter from your door. As to anatomy, don't look only for the classical examples, but take Portulacca, Sida, and Amaranthus growing along the door. The classical systems of vascular bundles without secondary growth seem to be an exception among tropical plants. Show the students who know only red and white rice, the hundreds of varieties growing in the surroundings. They will be astonished, enjoying the wide range of variation like every taxonomist enjoys seeing how nature plays with forms.

Make the students aware of the fact that their own country should be the real centre for cultivation and breeding of bananas, not Central or South America. Eradicate the theory that bananas were imported from America into Indonesia; eradicate the idea that the clove came from Zanzibar, that the local Rafflesia—the biggest flower of the world—is insectivorous. Demonstrate the wild species of Musa growing on Mt. Sago—how you describe them and document your finds with photographs, how you further investigate the many cultivated varieties. Don't teach them a mass of facts, but methods and synthetic views. What a difference between an ordinary paddy-field seen as a basin with rice or seen as a dynamic whole, a habitat in and around which phanerogams, weeds, algae, bacteria, soil composition, and the origin and breeding of rice-varieties all play a role! What a difference between a kampong as an ordinary collection of fruit trees and vegetables and the same seen through the vision of a botanist who points out the origin of some elements in the forests which grew here during former times; the influence from India, from America; the influence of Dutch agriculture; the richness in varieties, the flower and seed biology and embryology of Manggas, Djeruk, Djambu, and Bananas; the role played by algae and water-plants in small fish ponds fertilised from the primitive houselets above them.

The most clever and interested students may take a part in expeditions to the highest mountain summit of Sumatra (Kerinchi, 3,800 m) or in the lowland forest of Indragiri. They learn the most common forest plants; they learn how to organize an expedition, how to collect plants, how to documentate the collection. They become teachers in secondary schools, discuss with you during evenings in the bivaques the best system for teaching botany there and arrange for you to give popular lectures to the local population, pupils of secondary schools, and their teachers. It might be necessary then to borrow clean trousers from one of your students, but you will find your own improvised lecture in the newspapers, and the radio will broadcast that according to you botanical study is very important for daily life of the people.

When you tell people living along the coast that the brown algae like Sargassum has in principle a method of reproduction analogous to that of human beings, a clever boy may ask you to tell the how and why of this and he hears something about sperms and egg cells. A school teacher living at 1 km distance from the coastal mangrove asks you after your lecture to repeat for him what mangrove forest is and where he can find it. Local authorities want to hear from you about the possibilities of agar industry. Don't fall into this pit.

Kampong People Teaching a Botanist

Is a botanist in tropical regions only explorer and educator? No; he himself learns very much from the simple illiterate kampong people. They know their varieties. Some of them know trees in the forest, only from making a cut into the bark. Why not learn that? Some people may tell you about plants to be used as medicines. You may find drugs which are useful but unknown to the academic doctors, Indonesian or foreign, and you may find a good basis for botanical education of students in medicine and pharmacy.

Coordination between Botanical Work and Local Services and Authorities

Especially growing institutes need a lot of local support and local understanding. At the start in Pajakumbuh, we were without housing and often without our own transport for excursions and expeditions. The behaviour of a botanist looking everywhere in gardens, in paddy fields, and in forests for plants was badly understood by the population. What do you look for? What is the purpose of your work? I was asked these questions everywhere. I made it the subject of a public lecture on the first anniversary of the Faculty. After that popular lecture, I got spontaneous help from the head of the local civil service to build an emergency herbarium, a building of 8 x 14 meters from which several thousand duplicates are already distributed to London (Br. Museum, Nat. History), Kew, Leiden, Amsterdam, Geneva, and Singapore. Officers of the forest service joined several of my expeditions. The trip to the summit of Mt. Kerinchi was simultaneously done by the head of Forestry with several of his officers. Many problems of forest botany, reforestation, and rural reconstruction are often discussed with my forestry friends, semi-academic Indonesians. All projects for nature protection are jointly made with the forestry service.

The head of the service for agriculture is still like a father of the Faculty. He started it locally, and he supports our work in every way. He is as much disappointed as we when we cannot get the money and equipment from the Central government. With the head of the Veterinary service, we started our project for local reconstruction at the base of Mt. Sago. It is not necessary for us to tell the leaders of the Forestry service that their officers rarely enter the forests, to tell the agriculture service that its apparatus has very little practical use for the population, to tell the veterinary doctor that the grasslands on the experimental station are badly treated by burning, etc. They all know this, but they are waiting for our students who shall have to improve the present situation. The country waits for a new, better educated generation. We are clearly confronted with problems in our desa pertjobaan, rural reconstruction area, two kampongs with mixed gardens, surrounded by paddy fields, hills and with above them the forest of Mt. Sago. How are we able to advise, encourage, and educate the population here? Botanical inventories, socio-economic research by the students, practical projects for a cooperative movement including evening courses to be given by students are started here. Thus our work finds roots before modern laboratories and equipment are provided. Of course the illiterate population is not awakened within one year from its apathy, but there is more movement than we anticipated a year ago when this project was started.

International Contacts and Help

When agriculture students after three years of study receive only laboratory courses in botany, not any practical education in physics, chemistry and agriculture we can speak about mismanagement among the authorities who started this Faculty and who have the responsibility for its welfare. We must realize, however, that Indonesia is a land in transition with many financial and economic troubles. As long as these troubles are not resolved, reconstruction of the country remains difficult. It is, of course, disappointing to educate students in agriculture in botanical subjects while other subjects like chemistry and agriculture itself are largely postponed by lack of teachers, equipment, and working rooms. It is very irritating that improvement of this unsatisfactory situation is so long postponed. Visits of several foreign agencies — UNESCO, Ford Foundation, ICA,— always came at the most inappropriate time. Now only some local oil companies are giving support (for chemistry). The best help we received was for the library, especially from America, after the Botanical & Gardens of Bogor gave it a good start.

As to botanical work, it is, of course, almost impossible to collect at new institutes within some years all the old books and journals which are necessary for revision work and monographs. This is another reason to concentrate on exploration, documentation in the field, and to distribute as many duplicates as possible of the valuable collections. The returning namings will help in the work of ecology and plant geography.

The amount of work to be done (Stencilled lecture notes must be prepared for the students as no books in their own language are available, and they cannot read the Dutch language), is so over-whelming that almost no time is left for preparing scientific papers. Work of years ago still remains unpublished. Then we get requests from abroad to send material living or in liquid. We have to go to Java to get the chemicals for fixation; we are not able to obtain glasswork with stops and often cannot fulfill the wishes of foreign colleagues because of lack of time and provisions. The British Museum (Natural History) got a living specimen of Rafflesia by aeroplane. Nobody understands how many bureaucratic barriers had to be broken down for that within some days. I had first to get all kinds of permits from Djakarta and, was not allowed to pay until a Dutch firm took over the responsibility. The Faculty waited two years before the first foreign journals entered the library. A large botanical institution in America, formerly specialising in the flora of Malaysia, writes sour and formal letters to me in reply to enthusiastic proposals which are for mutual benefit. Other institutes like Amsterdam, Leiden, Cambridge, British Museum and Singapore are largely cooperating and stimulating.

THE FUTURE—EAST AND WEST

The work of botanical exploration and education in tropical regions needs the help and support from temperate regions of the globe. There are the books, the old publications, the old centres of botany, the treasures gathered by Blume, Miquel, Hooker, Ridley, De Candolles, and Merrill. There are still many more botanists working than here. Here we have the richest part of flora of the world still to be studied.

What will be the future of the tropical forests? Will they be destroyed before scientific interest is raised among the people of these countries? Must all foreign botanists go away from here? Will it be possible for a botanist from Europe or America to devote his whole life to the richest flora of the world, or will political boundaries and nationalistic movements force him to restrict himself to the scanty flora in his own country or to shift his attention to parts of the tropics which are still under colonical rule? History teaches us that the fate and function of botany in our world cannot be separated from international cooperation.

In my opinion, this is understood by the growing generation of Indonesian scientists, the best of them being further educated in Europe and America. The joint use of natural resources of the world will have its natural equivalent in joint exploration and research.

CONCLUSION

This lecture started like the talk of a circus-artist and ended like a sermon. I hope that you understood that botanical exploration and education has found a good start in Central Sumatra itself, but that this young plant has still many difficulties in growth. The climate is often frustrating and disappointing for it. Much skill, perseverance, and a sense of humour are needed for its growth. Have we to laugh about this undertaking or to pray for it?

PROBLEMS OF PUBLICITY: WITH SPECIAL REFERENCE TO THE NEED FOR POPULAR BOOKS DEALING WITH LOCAL PLANTS†

R.E. HOLTTUM

Kew Gardens, Surrey, England.

In the modern world we are all increasingly dependent on the applications of science, and education for the young must include an introduction to both physical and biological science if they are to have an intelligent understanding of their environment. And it is not only the young who need to have access to such knowledge; there is need for popular publications for adults, to keep them up to date with the changing world.

All life is dependent on the green plant, and though modern technology has greatly changed our ways of living, it has not altered that fact. But the modern habit of living in towns and cities tends to prevent a great many people from realizing the fact, and therefore education in biology is of even greater importance than it was when the majority of people lived in close dependence on their natural surroundings.

Modern political developments have added a new urgency to all aspects of education. Democratic self-government, to be effective, depends on an educated electorate.

Thus the first essential of education in biology is an understanding of the significance of plants as the basis of all life and as a basic natural heritage at the disposal of mankind, and education of this nature must be presented in terms of local plants in their relation to the local climatic environment. Knowledge of this kind is being gradually acquired at the various tropical botanical institutions. Such institutions thus have a duty to contribute knowledge about local plants which may be used in this necessary education in biology. And such institutions will in the future depend for their very existence on a general understanding of their importance by the public and by the politicians elected to power by the public. Publications of this kind become necessary publicity from the point of view of the institutions themselves.

Biological science is not like physical science, the important data of which are independent of environment. Every different tropical country has different plants and animals, and there are many differences of climate which control and limit the activity of those plants and animals, and also of man in exploiting them for his own use. Thus there is need for different presentations of these subjects in different countries; one general text book, or a series of publications from a single source, will not meet the situation.

The great difficulty in preparing such educational and popular presentations of a biological nature lies in the extreme complexity of the subject matter and also in the fact that there has been far less biological study in the tropics than in temperate regions; and studies made in temperate regions are only of limited help because they deal with a different set of organisms in a different environment.

Before anyone can write a simple introduction to a subject for the help of beginners, he must himself be master of the subject, or at least have a wide enough knowledge to be able to select for the beginner those aspects of it which will be most helpful. In order to obtain the necessary wide outlook, one must spend a great deal of time in study; and this involves not merely the study of books already written, but also the local plants themselves, as existing works cover only a fraction of what one needs to know. Original observation and the correlation of such observation are creative processes quite different from the assimilation of knowledge already recorded in books. The ability to carry out such creative work is something that comes only from long practice.

As an example which has come to my personal attention, I will refer to the question of bamboos in Malaya. Bamboos are of great importance to the countryman who uses them every day in many ways, and any student of biology in Malaya should learn something about them. But there is nothing in print about bamboos in Malaya which is of any use to a person who wishes to know how to begin to study the subject, nor even any work which is of direct value to the expert; the only usable taxonomic works have been written in India and in Java, and they leave untouched much of what is in Malaya. Furthermore, nobody has given critical thought to the

† Presented by J.V. Santos.

general classification of this group of plants as a whole (quite apart from Malaya) for nearly a century. Some twenty years ago I began to take an interest in the subject, and after a good deal of casual enquiry I sat down to write a systematic account of what information was available, based on specimens and data accumulated in Singapore. This showed me how inadequate this information was, and during subsequent years I made several journeys with the object of adding to it. Having left Malaya, I cannot add further original observations, and I have written an account of the subject, as far as is possible on present information, so that others may start where I leave off; in particular, I have tried to present an introductory statement which will help a new observer to begin his work.

This work on bamboos is only a small aspect of the study of Malayan plants, and it may be matched in other families of plants and in other parts of the tropics. But unless this kind of work is done, the peoples of the world will not be able to know the scope of their natural heritage of plant life, and they may well, in ignorance, destroy a large part of that heritage before it has been studied. Such primary study of native plants can be accomplished only by experienced workers; it is not something that can be undertaken by a beginner. This is often not understood by administrators and politicians, and even scientists who are not acquainted with the problems of taxonomy sometimes fail to appreciate the great amount of such work which remains to be done in the tropics.

Of course there is a great amount of information already recorded about tropical plants. Much of this information is in taxonomic monographs and formal Floras which can be understood only by a specialist. There is need, as above noted, for specialists to select from this mass of data such parts as are useful as an introduction to the subject. The university student, or the school teacher in training, needs to have such an introductory presentation. When the student in turn becomes a teacher in a school, he will find yet another problem—that of introducing children to the same kind of knowledge. The teachers in their turn must thus review the subject and write books which will serve their particular needs.

From my present standpoint, the work of the tropical botanical institution is, therefore, two-fold: the continued study of natural vegetation and the recording of the results of that study in formal scientific publications and the interpretation of that knowledge in terms useful to the student (especially the student who will be a teacher), and to the adult who wishes to develop an interest in such matters.

The institutions will be able to do this only if there is a sufficient reserve of natural vegetation and if they have sufficient trained and experienced staff to carry out both the fundamental investigation and its interpretation for the student and the common man. In these days, the institutions will not be provided with the staff, equipment, and means of publication unless the general public is aware of the importance of these things. The right kind of publicity is needed, and this can come only from the institutions themselves. It should be a function of this Congress to help to impress on governments and on peoples that the work of tropical botanical institutions, and with it the preservation of natural reserves of plant life, is a matter of fundamental and urgent practical importance.

DISCUSSION

J.V. SANTOS: Mr. Holttum appears to support Van Steenis' idea.

C.G.G.J. VAN STEENIS: Dr. Holttum in his paper intended that there should be more simple, popular knowledge of plants. Dr. Holttum has written papers not intended for secondary schools. Structure must start first.

F.R. FOSBERG: I am pleased to hear this discussion about starting education in secondary school.

FUNCTIONS OF THE ALGAE IN THE CENTRAL PACIFIC†

MAXWELL S. DOTY

Department of Botany, University of Hawaii, Honolulu 14, Hawaii.

The algal roles in nature at sea are those of being the primary producers: primary producers of food and materials in the euphotic zone. The rates of algal production and perhaps the sizes of algal standing crops are a function of the concentrations and rates of addition of otherwise limiting chemicals to this euphotic zone and to light intensity. To an extent these quantitative population features are a function of the abilities of the organisms themselves. The major roles of the algae are related to whether they are planktonic or benthic in nature.

In the open sea the algae are plankters, which in at least some cases must lead a heterotrophic life. As an example, the Coccolithophores dominant in euphotic Mediterranean waters *(3)* have also been found to be abundant at depths of 1,000 to 2,500 meters, far below the euphotic zone. Such organisms may get there initially through sinking or by vertical mixing. In our own work, we have upon occasion found the most chlorophyll-rich waters at the very bottom of the euphotic zone, if not below it. Returned to the surface through upwelling or vertical mixing or rising through changes in density, such organisms may act as the "seed" for normal populations.

The food producers in the sea, the phytoplankton algae, make that 73 per cent of the earth's surface covered by ocean as productive as the land on the average per unit of area. This production may be estimated variously (e.g., *20, 22, 9)* between 0.8 and 15×10^{10} tons of carbon per year.

The rate of primary production varies in different parts of the ocean. At the poleward limits of the temperate seas with seasonal change and the vertical mixing of various kinds that occurs there, the substances normally limiting to phytoplankton production become more readily available. Measurements of phytoplankton productivity have been found *(15)* to increase three-fold as one moved into this productive water from the temperate region. In the divergent current regions of the Central Pacific along the equator, water from the dysphotic zone upwells. In such regions the productivity has been measured *(16)* to be almost ten times that several degrees to the north or south. In these two instances, the rate increases are correlated with areas where the inorganic materials normally limiting to algal growth are being brought upwards into the euphotic zone from below. These areas of major size and consistent presence may be correlated with high fish production: albacore tuna in the first instance cited and yellow-fin tuna in the second.

Phytoplankton productivity rates increase as land is approached. This has been shown *(12)* to be an increase of two or more orders of magnitude. The phenomenon is apparently due to two processes leading to high concentrations of essential minerals near shore. They are (a) contributions from the land brought by water, and (b) substances accumulated in the area from the sea by benthic forms.

General algal productivity in the non-enriched areas of the sea may be supported by recycling of materials derived from the sea or initially from emergent land. Such areas may gradually become poorer in the elements essential for primary productivity through the movement of materials to layers of water below the euphotic zone.

Fixed nitrogen may be exceptional in that supplies of this element in combined form may be derived from rainfall or may dissolve in the sea and be combined there by microorganisms, particularly the blue-green algae. In fact on atolls and in the sea, nitrogen fixation by blue-green algae is expected to be a major as yet non-assessed factor. If the major premises of this and the previous paragraphs are valid, then a relative increase in the ratio of nitrogen to, e.g., phosphorus might be measured in going away from areas where there is enrichment from shore or the depths.

It is of considerable interest to note the trend, even in the study of benthic algae, away from more descriptive aspects and toward more functional aspects. Thus in past years we had oceanic

† The conclusions presented herein without citation were drawn from studies financed largely by contracts between the Botany Department of the University of Hawaii and the U.S. Atomic Energy Commission (AT-(04-3)-15) or the U.S. National Science Foundation (NSF G 1992 and NSF G 3833) or with the U.S. Office of Naval Research (NR 388-001) with the U.S. National Research Council's Pacific Science Board, and by funds from the Graduate Research Committee of the University of Hawaii.

phytoplankton studies concentrating on observing the kinds and numbers of algae. The outstanding example of this is the magnificent series of studies by Lohman *(17)*. Today we have concentration on studies of oceanic phytoplankton such as those of Steemann-Nielsen and Aabye-Jensen *(23)*, using isotopic carbon, and those of Arrhenius (this Congress) on bottom deposits wherein only the algal function or results of algal functions are observed and measured. But very few, an example being the fresh-water lake studies of Rodhe *(21)* have been able to link both observational and functional studies. Marine algal studies of this kind should be encouraged.

The benthic algae are more familiar and are the forms thought of as the marine algae first, even by phycologists themselves. These are the algae normally living attached to the substratum and commonly ranging in size and form from half-ton kelps to solitary diatom cells. In comparison to the plankton algae they are very well known taxonomically and morphologically. For reasons of economic interest, species of some genera, such as *Chondrus*, *Macrocystis*, *Laminaria*, *Gelidium*, *Eucheuma*, *Gracilaria*, and *Porphyra* are rather well known, even in regards to their production (e.g., *28* on *Gelidium*). Their contributions otherwise are conjectured but little assayed as yet. Two roles can be expanded upon here as conspicuous in the more central Pacific: these are essential mineral concentration near shores and material construction of shores and atolls.

The mangrove areas in the Hawaiian Islands are conspicuously clean and devoid of the characteristic faunal and floral populants. In the few years mangroves have been planted there, the well known algal combination of *Caloglossa*, *Bostrychia*, and *Catenella* apparently has not appeared. Surprisingly enough some of the mangrove areas studies on Mindoro (east of Calapan), the Philippines, and in the Thousand Islands (northwest of Djakarta), Indonesia, were similarly devoid of these macroscopic algae. But then, too, these localities were devoid of the intertidal mud characteristic of the areas heavily populated (e.g., Pine River shores in Queensland, Australia) by the above algal triumverate. The theory of causality rears its head at this place: mangroves develop on reef flats and elsewhere where no mud is present, but do the algae appear where there is mud, or, do they cause the mud to be deposited? In the Pandan Nature Reserve in Singapore where there is a magnificent development of these algae on both mud and mangrove roots, the algae were seen to be muddy, covered with a seemingly inseparable coating of mud, while the roots on which they were growing were, otherwise, quite devoid of any regular deposit of mud. In fact the roots except for the algae were as clean as those in Hawaii or the roots of "non-algalated" mangroves in Indonesia or the Philippines.

In Hawaii, in Singapore, and elsewhere, *Vaucheria* forms dense turfs of erect filaments on flat mud areas of deposit, at the edges of drainage channels. It appears, from their mud-choked flat nature, that these turfs act as mud-trapping agents. The presence of this phenomenon far outside the mangrove area (e.g., at Coos Bay, in Oregon, U.S.A. *5*) inclines one to exclude this community from the mangrove community, though it is strongly developed in some mangrove areas.

Reefs and non-igneous islands as we know them in the Pacific are of biological origin and largely rather directly the results of algal activity. Reefs as we are using the term are solid aggregations largely of carbonate, which has usually been deposited by Rhodophyta, Foraminifera, Coelenterata, or Chlorophyta. The order of abundance in a reef is often listed in order as these groups appear above.

This definition of reefs excludes wave cut benches and solution benches, though it is postulated here that some of their common physiognomy is caused by the same effects of algal growth. Both the benches and reefs often have an outer raised margin (rampart or algal ridge) and a higher algae-covered area of reef flat just inshore of the outer margin. Wentworth *(26)* attributes this form in the case of the benches to an algal function: that of reducing erosion. On reef edges such as found in the Tuamotu Archipelago *(11)* in addition to building the reef margin upwards, the algae seem to play the same protective role seaward of the channel area (backridge trough). Thus a common role of the algae, mitigating the results of erosion, is postulated here as a major cause of this similarity in form often seen on all three shore types.

In different places and perhaps at different geological times, the relative importance of the above groups of organisms giving rise to coral has changed. As an example it may very well be that among Chlorophyta, formerly the Dasycladales were more important than now. In atolls seaward reef edges are usually predominantly red algal (Corallinaceae) in composition while those facing lagoons are predominantly coelenterate in composition. Paleontological study of reefs has been of academic interest until recently when certain ore and oil associations with fossil reefs have brought economic reasons to bear on a better understanding of reefs.

Coral islands are common in the Western Atlantic and elsewhere. Here this term is used to denote islands the detrital material of which is of biological origin but islands which are not based on or surrounded by a currently active reef flat. Perhaps those low islands, such as the Bahamas in the Caribbean or the Thousand Islands in Indonesia, are of this general sort. Often they are largely of algal detritus.

The coral islands are of several types including those which are perhaps relics of the normal reef island situation to be discussed below. Johnston and Sand Island at what may be called here Johnston Atoll (south of Hawaii) and some of the smaller islands of the Hawaiian group (e.g., Laysan) are perhaps of this sort. The composition is generally thought of as predominantly algal but is often fine or for other reasons hard to assay as to origin. Some of the Bahama group and Bermuda have been described as consisting largely of *Halimeda* detritus. These are of easily recognizable rather uniform fragmental composition.

Coral islands of animal skeletons, in addition to the two algal types above, are found. The Thousand Islands near Djakarta seem to be at least in part of this sort. It may be that such islands are more frequent in the Eastern Indo-Pacific and, having been investigated first, gave rise to the seemingly false idea of the dominance of coelenterate corals in reefs and islands of biological origin. Such islands, as typified by those near Djakarta, when small, slope gently from at least ten meter depths (as judged by gradual shift in water color) to low tide level and, then, terminate upwards in low (one meter above high tide line) flat island fragments. Larger islands may have reef flats that appear to slope somewhat toward the island. In such cases mangroves, instead of covering the intertidal shore or reef flat, are at times separated from shore by a body of water, which might be termed a lagoon. If one terms the shallowest water at the seaward margin of such a lagoon, a reef, it must be kept in mind that it is different from the reefs dominated by red algae in at least two respects aside from the actual organisms present. First, such reefs seem to be gently rounded in contour, in their shallowest areas or slope steadily into the sea rather than being quite plane or even with a raised margin as in the case of algal reefs. Secondly, it appears that they do not extend upward to such a level that they are exposed to the air as much as are the red algal reefs. It appears that a majority of Central Philippine shore reefs are of this latter type.

Though structurally of coelenterates, this last type of coral island, or reef, is inseparable from the zooxanthellae and filamentous algae which pervade it. Though far from satisfactorily understood, it appears that hermotypic corals, the large and only corals contributing significantly to reef and island substance, are dependent upon these algae. It may be debated whether this dependence is nutritional or functions more in removal of waste products. Recent work *(1, 13)* showing the loss of a large part of the photosynthate from unicells would lead us to expect the nutrient was available, in addition to the older arguments that these endophytes were nutritive; e.g., hermotypic corals develop only in the euphotic region. Undoubtedly the algae untilize the mineral waste products that diffuse away from the coelenterate cells, but it seems less likely that this is essential to the livelihood of the animals. If the hermotypic coelenterates are dependent on the algae, then in turn we can say that even the animal dominated reef structures are quite directly related to algal activity.

A note at this point is to be entered as to the effects of algae on coral island *(19)* intertidally and above high tide line. Their growth on almost all the surfaces of these low oceanic islands is a phenomenon associated with the marine environment. The gastropods in rasping them away as food remove consolidated materials. Their growth on, and in, coral rock must effect its solution. These two phenomena are blue-green algal phenomena and as the major of these algae, *Entophysalis*, is also abundant on much of the non-regularly inundated part of the island, the general phenomenon of nitrogen fixation by such algae should not be overlooked. On these low oceanic islands, the usual nitrogen fixing organisms, such as the *Rhizobium* of legume roots, are essentially absent. In wetter areas, such as Majuro in the Southern Marshall Islands, the island surfaces, where devoid of larger vegetation, may become covered by *Nostoc commune*. Such algae have been shown *(27)* to fix up to 90 per cent of the nitrogen they use even when supplied with what would appear to be adequate supplies of fixed nitrogen.

Coral reefs as found in the Central Pacific and the islands on their reef flats seem to be maintained at the sea surface by algal activity. Characteristically, atolls are formed. There is, as often presented, a variety of reefs in relation to igneous islands or underwater bases. The theoretical origins of atolls and the accumulation of islands on atoll reefs have been elaborated on at length by many authors. Other than to note that these authors have concerned themselves with the formation of "the classical atoll in full bloom" from its beginnings and have given little attention to what may be called their old age or decline, we will restrict ourselves to the postulated algal roles not discussed above.

Let us first consider in brief the distribution of algae across an atoll. As an example let us consider Raroia in the Eastern Tuamotus *(7,11,18)* or Eniwetok in the Northern Marshall Islands *(25,9)*; as the algae can be found in an investigation leading in over the upwind seaward reef, moving downwind, across the lagoon and thence traversing the leeward atoll rim. Upon approaching the atoll coming downwind, the water becomes shallower as the bottom slopes gently toward the surface. Rather abruptly at depths of about six to eight meters, the hermotypic corals become covered or are replaced by coralline algae. In shallow water, there is little else in sight. In deeper water, coelenterate corals are scattered irregularly over the gently undulate surface radiating away from the atoll. In shallower water, radiating rows of individual coelenterate coral organisms give way inshore to grooves and spurs covered with a smooth coating of algal coral.

Spurs extending toward the atoll, at the sea surface, may extend upwards to such levels that the seaward margin of the reef protrudes perhaps a meter between waves even at high tide. The spurs tend to be especially well developed opposite islands and may be fused laterally into a ridge, the famous algal ridge of the literature.

Grooves extending toward the atoll may run through the algal ridge or terminate outside of it. They may extend through the ridge covered by the laterally fused ridge material and reef surface inshore of the algal ridge. They may be open channels throughout or closed over so that the innermost open end is a blow-hole, sometimes enclosed in a low dome, on the inner part of the reef.

Inshore of the algal ridge, the surface is usually plane, horizontal and at low tide level. This surface may be as smooth as a concrete sidewalk. Sometimes it is covered with a turf of jointed coralline or other algae. As Wentworth suggested *(26)* for solution and wave-cut benches the algae here also probably play a role in lowering erosion, as discussed above.

Still further inshore, the reef surface becomes lower and tends to slope so that water coming in over the algal ridge flows to the right or left and back out over the reef margin through grooves or the so-called *(11)* excurrent areas. This area has been termed a back-ridge-trough and termed elsewhere a channel area. This area appears to be one where corrosion and corrasion are dominant over deposition. Indeed from the algal pavement of the outer reef flat to the lagoon, the physical features appear to be largely regulated by mechanical forces though the materials may be predominantly of algal origin, and these latter may in turn regulate the mechanical forces.

The sea reef, phycologically, can be divided into four major zones horizontally in so far as the populations are concerned: (a) *Porolithon onkodes* dominates the surfaces from depths of six to eight meters up onto the outer reef flat; (b) the outer and higher reef flats which may be covered by an algal turf; (c) the channel or reef-pool area; and (d) the shore intertidal and supratidal areas. In designating these we purposely avoid terms used in discussions of vertical distribution.

Porolithon onkodes above its maximum depth comes quickly to cover almost all of the surface. It produces the algal ridge as a series of overlaying overlapping pustules of several centimeters to a few decimeters in lateral extent and from a few millimeters to a centimeter or two thick. Within the cavities resulting reside a host of animal sorts, of which annelids, fishes, crabs, and foraminifera are conspicuous. On the surface patches of small algae, e.g. *Centroceras*, *Microdictyon*, and blue-greens, are scattered about as are such animals as limpets, barnacles, and Cypraeids. *Porolithon onkodes* is a most peculiar coralline alga in that it will live on the most brilliantly illuminated shore areas and stand some exposure to air. This is in contrast to other genera of crustose coralline algae such as *Lithothamnion*[1], which never grows extensively under such circumstances.

The algal turf on higher parts of the reef flat occurs in at least two major forms: as relatively pure stands of jointed corallines on outer reef flats *(7)* underlain by *Porolithon onkodes*; and as mixed stands, on inner reef flats *(24)*, of *Jania*, *Amphiroa*, and relatively small fleshy algae such as *Caulerpa ambigua*, *Polysiphonia*, *Herposiphonia*

[1] Perhaps the confusion regarding *Lithothamnion* and the algal ridge arises from the fact that *Porolithon onkodes* was originally described by Heydrich in the genus *Lithothamnion*.

secunda, *Laurencia*, and *Gelidium* intermixed often with large proportions of blue-green algae. Larger fleshy algae often occur in patches or isolated clumps or sandwiched in crevices or the holes opened by boring animals, i.e., where freed from the browsing of fishes. Two functions must be considered for this turf: first, in providing a direct or indirect source of fish food; second, in reducing erosion of the reef flat.

The channel or pool area is often sandy or floored by shallow pot holes. Algae are few except under the edges of reef boulders, e.g., *Dictyosphaeria*. Often the surface is pinkish from what seems to be incipient growths of *Porolithon onkodes*. Larger algae, such as *Liagora*, *Turbinaria*, and *Padina* sometimes occur. The aspect is that of a shallow but open tidepool. At one time (February), the reef pool area of the eastern end of Ujeland in the Marshalls was strongly pink from the air. Investigation on the ground revealed this to be due to an extensive growth of *Liagora*.

The intertidal and supratidal areas are usually covered by, below, a brown and, above, sun-blackened coatings of *Entophysalis*. As one progresses away from shore and salt, *Anacystis* and finally *Scytonema* or, if very wet, *Nostoc* similarly tends to cover stable surfaces. The roles of these algae in nitrogen fixation and shore processes are taken up above.

Upwind lagoon shores are usually sloping sand beaches. There is little of macroscopic biological nature on such sandy beaches. When not sandy beaches, they are representative of shore types elsewhere in the lagoon. The color of the water changes as one moves out into the lagoon from the shore. As seen from the air, the color is that of the sand beneath, usually a very light buff color, darkening until depths of six to eight feet are reached when the color is definitely green tinged. The water appears greenish and gradually darkening until at perhaps depths of twenty feet when it can be said to be blue. When shallower places in the lagoon are approached, a reverse color sequence shows.

The most shallow places in lagoons are the brown, sometimes pink-edged or light buff-centered reef patches, reaching low tide level. Chunks of rock protruding above low tide level are often blackened with blue-green algal growths. If islands are present, they are likely to be similar to the sandier reef islands. Reef patches have various forms *(4)* which may be arranged in an evolutionary sequence *(11)*; either in the lagoon changing in relation to the bottom, or just growing upwards, or in relation to changes in the shor location with time.

A typical reef patch reaching the low tide sur face of the lagoon is coated on its sides wit *Caulerpa* and, especially on less precipitous area and near the base, with *Halimeda*. The *Caulerp* is reputed by the Tuamotuan natives to be a mos important turtle food. Small fleshy algae occur especially on the uppermost six to eight feet c the rocky column, and serve as fish food. Th classical relationship between the coelenterate and the algae perhaps enables the hermotypi corals to grow and play their role in the produc tion of the reef patches. The brown coloratio of the coelenterate corals on top of the reef patc is probably largely due to the endozoic alga pigments. Occasionally the margins of rec patches will be pink from growths of *Porolithon* especially on their upwind sides, or they ma bear a fur of Rhodomelaceous algae. The center of reef patches are often depressed and san floored with scattered coral fragments. Ther above the sand such algae as *Udotea* and th turf-forming species of shore areas are ofte abundant.

Diving and careful dredging in lagoons hav contributed *(9,14)* considerably to our knowledg of the algae on lagoon bottoms. With the ex ception of *Halimeda*, little in the way of corallin or calcium-depositing algae is found. Contrar to popular opinion, *Halimeda* has not been founc *(11,14)* to occur in dense meadows on the bottom Instead, though lagoon bottom sediments ar often predominantly of *Halimeda* segments, th living thalli are almost always clustered abou the talus bases or occur on the sides of ree patches. Despite this, *Halimeda* is perhaps th agent most responsible for the filling of lagoons.

Reefs are usually found on the downwinc lagoon shores. These have been termed *(11* shore-bound reef patches for both their anatom and components are very similar to what is founc on the lagoon reef patches. The roles of the alga seem to be the same as on lagoon reef patches.

Islands on the downwind reefs are, phycologi cally, very similar to those on windward reefs The islands which occasionally occur on ree patches are also phycologically similar.

Seemingly downwind or lea sea reefs are phy cologically like those of the windward shores anc the algal roles are the same. In some cases, e.g. at Arno Atoll in the Southern Marshall Islands the downwind reef edge may have many more coelenterate corals on it than the sea reef edges elsewhere, and also the algal ridges are often less conspicuous.

As described above, the atoll system seems to persist in equilibrium with the sea as long as changes in the earth's crust are slow. If the crust shifts upward, the reef can be eroded back toward sea level; or if the rate of elevation is sufficiently fast, a raised atoll can result. On the other hand, should the atoll sink, upward growth of the organisms would keep the atoll in contact with the sea's surface, unless the sinking rate were so fast the organisms could not do so. Apparently a sinking rate of over one or two centimeters per year would result in a sunken atoll, at least that is the current estimate for the maximum rate of atoll upgrowth. Examples of atolls where such phenomena have taken place are numerous. The atoll around Johnston Island, south of Hawaii, seems to have sunken on only one side; so a long crescent rim is left at the sea's surface. The atoll of Anaa, east of Tahiti, is an example of an atoll where one edge has been raised, in this case about five meters, while the rest is at normal atoll elevations in respect to the sea surface. Prospective algal roles in both the erosion and upbuilding have been taken up above.

Finally the benthic algae seem to play a most important role in the concentration of the chemical elements essential to life processes. As a result of this process, as one nears shores the biological standing crops as well as the productivity rates increase enormously. Let us consider the events that would lead to this end around a newly created igneous island such as a volcano suddenly rising above the sea's surface. Essentially this condition prevails in Hawaii when new lava flows reach the sea. From a study there of lava surfaces appearing in the sea in 1955 we know it is the algae which appear first and before the animal populations characteristic of older shores in the same general area.

In the open ocean we would assume that when a new igneous mass appeared there would at first be no concentrations around its shores. Leached materials from the newly cooled lava would be diluted and washed away in the passing ocean stream. The first macroscopic organisms to appear would be expected to be such as *Enteromorpha*, *Ectocarpus*, and *Polysiphonia*, as they are in Hawaii, if the new island were in similar waters. These pioneers appear in that order of importance and time in the Central Pacific. Other populants follow. The benthic standing crop increases as the algae convert inorganic materials from the water into organic materials or deposit them as inorganic compounds such as calcium carbonate. This must apply as well to phosphorus and nitrogen and carbon and the other elements essential to protoplasm. Because these populations are benthic forms they do not wash away.

Following the algae, there appear the animals which feed upon the algae: the littorines, limpets, and blennies. A certain amount of the increase in standing crop shifts over to these herbivorous forms and then, theoretically, to carnivores. The detritus and fecal material are undoubtedly degraded to a mineral state, and thus the water near shore becomes enriched in inorganic nutrients. The observed near-shore increases in plankton must be the results of this enrichment.

It is observed that the calcareous organisms appear conspicuously a year or more after the non-calcareous algae are well established. With the very long-term evolution of an atoll, the binding of materials becomes predominantly an activity of the calcareous forms in so far as mass is concerned. This implies a shift to such herbivores as the parrot fish, some species of which live on calcareous algae. The detritus and fecal material they produce contribute to the sediments of the lagoon or island shore as well as to the enrichment of the waters about the high island or atoll.

It is expected that the supply of fertilizer elements and the standing crop of organic material would increase until a new steady state is achieved. Previous to this time, i.e., while the standing crops are increasing, one might expect the water approaching the young atoll to contain more of the fertilizer elements than the water leaving the atoll. This is without taking into account substances from a high island around which the atoll might be developing. In later stages, the amount would be expected to be equal. Perhaps in old age the amount leaving (at least leaving the euphotic zone) would exceed the amounts arriving and being bound by the primary productivity of the algae. It may be that plankton algal productivity near shores, as well as the size of the standing crops of phytoplankton, may serve as an index of the relative age of an atoll.

SUMMARY

The phytoplankton algae are described as having major roles affecting fertilizer concentrations or in primary productivity resulting from variations in fertilizer salt concentrations found (a) in transition or shear zones enriched by vertical mixing or eddies, (b) in divergent current

areas by upwelling, (c) in wind disturbed areas by vertical mixing, and (d) near land by fertilizer increases arising both through concentration by benthic organisms and through addition by fresh-water. The benthic algae are described as having major roles in primary productivity of food, in the fertility of the soil, and in construction and destruction of shores, islands, and reefs, particularly those of atolls.

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DISCUSSION

R.C. MURPHY: Will the mere shallowing of water, as an ocean current approaches an island, cause a concentration of plankton life, and therefore increase the food resources for fish and birds?

M.S. DOTY: In Hawaii, in respect to the circulation in the North Pacific, there is no upwelling along the islands.

G.L. CLARKE: As the contained life is an integral part of the water volume, no such vertical concentration of plankton can occur. I attribute the acknowledged enrichment of life in the coastal waters to more favorable conditions for nutriment and reproduction. If the animals are brought by currents, they will also be carried away by currents that pass around the island unless some mechanism to concentrate them exists. This might be accomplished by the animal's own swimming reactions.

G.F. PAPENFUSS: It is known that in temperate seas the larger algae are very important in providing protection, or a home as it were, for many kinds of animals and thus contribute directly to the concentration of life in shallow waters. Is this also true in tropical regions where the algae are much smaller?

M.S. DOTY: This is true also in the tropics and particularly among the coralline algae which provide many niches and serve for protection of small animals.

H.M. BURKHILL: What species of the mangrove complex has been introduced to Hawaii for purposes of land formation?

M.S. DOTY: It is only the *Rhizophora* spp.

H.M. BURKHILL: The primary pioneer mangrove in Malaya is considered to be *Avicennia* spp., but in the mangrove areas of Singapore a *Dictysta* sp. looks as if it takes an active initiation in the binding of mud found in the intertidal zone and flats below the mangrove limit. Within the tidal prawn ponds of the mangrove belt, *Vaucheria* appears to be an important mud-binder which may critically limit the commercial life of the ponds.

G.F. PAPENFUSS: Can it be that the gradual sloping of the reef on the windward side of an atoll is owing to the scouring action of the waves on that side as compared with the conditions on the leeward side?

F.R. FOSBERG: It should be pointed out that the erosion on the slopes of atoll reefs is of two sorts -- that by ordinary waves and that by typhoon or storm waves. The latter may be much more important; they come from the south, predominantly, and produce different effects than ordinary waves. The function of the other encrusting organisms is to cement the relatively fragile growth-lattice of the reef into a rock capable of resisting ordinary wind waves.

COMPARISON OF THE CALCAREOUS ALGAL FLORAS OF RECENT AND FOSSIL REEFS

J. HARLAN JOHNSON

Department of Geology, Colorado School of Mines, Golden, Colorado, U.S.A.

INTRODUCTION

Reefs ranging in age from the Eocene to the Recent are known from a number of islands of the Western Pacific, and they have been encountered in borings made in several of the islands. It has been the author's good fortune to have spent much of the last ten years studying the fossil algae from these reefs. The fossils consist only of calcareous algae: crustose corallines, articulated corallines, Halimeda, and a few Dasycladaceae. The non-calcareous forms have not been preserved, so any comparisons between Recent and ancient floras will have to be limited to calcareous algae.

Unfortunately Recent calcareous algae have received relatively little study. They are probably the least known of any of the algal groups. Possibly this is because they are more difficult to collect, being commonly firmly attached, and because of the necessity of decalcification, sectioning, and study with a microscope.

THE RECENT ALGAL FLORA

The Recent Calcareous Algae found in the Tropical Pacific appears to form a surprisingly uniform widespread flora consisting of a relatively small number of genera and species. Commonly at a given locality there may be great numbers of individuals of a few species. The magnificent algal ridge at Bikini has been built largely by two species: *Porolithon gardineri* and *Porolithon onkodes*, while the great Lithothamnion bank of Haingsisi near the Southwest point of Timor, so vividly described by Weber Van Bosse (*17*, pp. 4-5), is composed largely of rounded masses of *Lithothamnium erubescens*. Most of the common species are surprisingly widespread, extending from the East Indies over the tropical Pacific and westward across the Indian Ocean. Several species extend from the Red Sea to the Marshall Islands and even to Hawaii. Dawson records some species from both the coasts of Vietnam and western Mexico.

Very few comprehensive listings of the species found in a given area are known to the writer. However, Table 1 will give an idea of the general complexion of the Recent Flora.

FOSSIL FLORAS

The oldest reefs of the Western Pacific for which we have much information are of Eocene age. The author has made detailed studies of large collections of Eocene material from Saipan *(10)* and the Eniwetok cores *(11)*, and is now studying a large collection from Guam. He has also studied small collections from the East Indies and from Ishigaki in the southern Ryukyu Islands. Ishijima has described Eocene species from Taiwan, and adjoining areas.

The Eocene flora is another relatively small homogeneous flora with a wide distribution. A number of species, or very closely related forms, have been found from the western Mediterranean to the Mariannas and even to the Marshall Islands. Data showing the general composition of the Eocene flora of crustose coralline algae is shown on Chart 2.

The known Miocene flora is considerably larger than the Eocene flora, with a greater representation of species belonging to the genera *Lithophyllum* and *Mesophyllum*, fewer species of *Archaeolithothamnium*, and about the same number of *Lithothamnium*. This flora also has a number of links with the Western Mediterranean and even some with the West Indies.

The Pleistocene Flora is not well known. Much more collecting and study is needed. However, it appears to be essentially the same as the Recent. The only difference noted so far is that in some localities it may contain more species than the Recent. This may merely mean incomplete knowledge of the Recent. Most of the Pleaistocene species are still found growing along the present coastlines. The Pleistocene flora is characterized by the presence of large quantities of *Porolithon*, *Goniolithon*, and *Amphiroa*. In some regions (Palau, Saipan, Bikini, and Eniwetok) there is also an abundance of *Halimeda* debris. The *Lithothamnium* and *Lithophyllum* present usually belong to thin encrusting species. *Archaeolithothamnium* occurs, but it is represented by only a few rarely found species.

Too little is known about the Pliocene Flora to merit a discussion here. Charts showing details of the composition and distribution of these floras will be published in the author's forthcoming report on the fossil algae obtained from the deep drillings at Eniwetok, Funafuti, and Kita-Daito-Jima *(11)*, which will probably appear during 1958.

REEFS OLDER THAN TERTIARY

No reefs older than Eocene are known in the Western Pacific region. Reef building corals and rudistids have been dredged from the tops of Guyots in the areas around the Marshall Islands *(1)*, but no algae were described. Permian reef building algae have been found in Timor and

Table 1.
Composition, Recent Floras of Calcareous Algae.

The numbers indicate the number of species of each genus.

Genus \ Region	Bikini & Northern Marshalls (Taylor 1950)	Southern Marshalls (Dawson 1956)	Eniwetok (Dawson 1957)	Nha Trang, Viet Nam (Dawson 1954)	Funafuti (Foslie 1900)	Maylay Archipelego (Weber Van Bosse and Foslie 1904)
Porolithon	5		3		3	1
Goniolithon	1				1	5
Lithophyllum				3	1	5
Lithothamnium	1			1	1	10
Archaeolithothamnium						4
Fosliella	1	1	1	1		
Lithoporella		1		1		1
Heteroderma		2	2			
Jania	4	4	4	4		3
Amphiroa		4		2		8
Corallina						1
Arthrocardia						9
Halimeda	14	7	9	2	6	7
Neomeris	1	3	1	1		1
Bornetella				2		1
Acetabularia	1	2	1	1		1

Japan. However, it is necessary to go to distant continents to learn the character of the algal floras of the Mesozoic and Paleozoic Reefs. The Mesozoic reef floras are almost unknown. The Paleozoic floras have an entirely different complexion consisting largely of calcareous green algae. Calcareous red algae appear to have been rare before the Jurassic. During that period they were represented mainly by members of the extinct family of the Solenoporaceae. The Coralline

Table 2.
Geographical Distribution of Eocene Coralline Algae found in the Western Pacific.

Genus and Species	Eniwetok	Ishigashi	Saipan	India	Egypt	Somali	Algeria	Spain	Italy	Yugoslavia	Panama
Archaeolithothamnium											
A. cf. A. *chamorrosum* Johnson		x	x								
A. *dalloni* Lemoine	x	x					x				
A. cf. A. *hemchandri* Rao	x			x							
A. *nummuliticum* (Gümbel) Rothpletz	x	x		x	x	x	x	x	x	x	
A. *oulianovi* Pfender	x		x				x	x			
A. aff. A. *saipanensum* Johnson	x	x									
A. cf. A. *sociabile* Lemoine	x						x				
Lithophyllum											
L. cf. *lingusticum* Airoldi	x					x					
Lithothamnium											
L. cf. L. *abraidi* Lemoine	x	x	x				x		x		
L. *crisputhallum* Johnson	x		x								
L. *kumbecrustum* Johnson	x		x								
L. cf. *moreti* Lemoine		x					x				
L. *tapachaum* Johnson		x	x								
Mesophyllum											
M. *robustus* Johnson	x	x									
M. *vaughanii* (Howe) Lemoine		x									x
Corallina											
C. *prisca* Johnson	x		x								

algae (Family Corallinaceae) are not common before the beginning of the Tertiary. Most of the genera of today extend back into the Eocene, only a few into the Cretaceous. No representatives of Recent genera have yet been found in rocks older than middle Jurassic. The known geologic range of the common genera of the Corallinaceae is shown in Table 3.

Table 3.
Known Geologic Range of Common Recent Genera of Coralline Algae.

	Recent	Pleistocene	Pliocene	Miocene (Upper)	Miocene (Lower)	Oligocene	Eocene	Cretaceous	Jurassic
Porolithon	x	x	x	x					
Goniolithon	x	x	x	x					
Lithophyllum	x	x	x	x	x	x	x	?	
Mesophyllum	x	x	x	x	x	x	x		
Lithothamnium	x	x	x	x	x	x	x	x	
Archaeolithothamnium	x	x	x	x	x	x	x	x	?
Fosliella	x	x							
Lithoporella	x	x	x	x	x	x	x	x	x
Jania	x	x	x	x	x	x	x		
Amphiroa	x	x	x	x	x	x	x	?	
Corallina	x	x	x	x	x	x	x	x	

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DISCUSSION

M.S. DOTY: Can *Halimeda* be recognized in fossil deposits?

J.H. JOHNSON: Halimeda can be recognized to genus quite readily, but it is not as easy to compare with species because parts used by the taxonomist dealing with modern species may not be preserve in the fossil record. They are quite abundant and contribute a great deal to the shallow water deposits back as far as the Cretaceous.

J.V. SANTOS: Which plays the greater role in the formation of an atoll, the coelenterate corals or the coralline algae?

J.H. JOHNSON: It may vary to some extent, but in general the formation of the atoll is made up basically of coral and then the coralline algae come in, with diatoms and foraminifera finally filling in the spaces.

QUALITATIVE DESCRIPTION OF THE CORAL ATOLL ECOSYSTEM

F.R. FOSBERG

Pacific Vegetation Project, Care of National Research Council, Washington, D.C., U.S.A.

A coral atoll may be described, in the briefest terms, as a cap of limestone of organic origin on a mountain on the floor of the ocean, rising to or only slightly above sea level. Some lie on shallow banks or continental shelves. The cap is a ring-like ridge or reef surrounding a body of water termed a lagoon. Some parts of this reef may emerge above high tide level as islets. These may either be remnants of former higher reef levels or detrital accumulations. Much or all of the reef surface below mean low-tide level and down to depths where sun-light penetration is very attenuated is composed of communities of living plants and animals. In bulk, at least, these are mostly organisms that secrete limy skeletons. Accumulations of these skeletons make up, almost exclusively, the reefs and upper parts of the mountain down to the volcanic (or other) basement rock on which the reefs originally started to grow. The depth of this limestone is known for only a few atolls and may vary from at least 1,400 meters to, probably, very much less.

The concept of the ecosystem, first proposed by Tansley *(9)*, is that of an interacting system composed of an environment and all of the organisms involved with it. It is normally an open system because there is a continuous, though variable, influx and loss of energy and material. Such a system is, of course, an abstraction constructed to facilitate understanding of the complex processes involved in a segment or class of segments of the biosphere. As such, its extent is limited only by selection and definition of the segment or segments under study. Thus it may be varied, in different examples, from the smallest observable unit of environment in which organisms live to the entire world's biosphere as a whole with its total environment *(4)*. As the ecosystem is limited only by the extent of the effective environment, the maximum could be, theoretically, the entire universe. Practically, however, the definition will not ordinarily extend to the ultimate sources of energy, or even of material. It will be restricted to such extent as will best facilitate observation and understanding of the portion of nature under immediate study. This concept, of obvious and increasing utility but not too easy to handle, and never, apparently, used by its creator, has been, in recent years, adopted by a number of ecologists (e.g., *6, 1, 5, 4, 2, 3*). No two have defined or formulated their ecosystems in exactly similar terms, nor is there any critical need, at this stage, to do so.

In this paper, the *coral atoll ecosystem* will be described in terms of processes involving transfer or transformation of energy and material, with only incidental reference to the actual organisms involved in the system or to the physical structures found in the environment. It is recognized that in a complete account of such a system these aspects, also, would be described fully. For present purposes it may suffice to say that the biotic component of the system is composed of phytoplankton and zooplankton; free-living but bottom-dwelling animals and other heterotrophic organisms of many sorts; an enormous aggregation of sessile or fixed organisms representing most classes of algae, a few seed plants, and practically all phyla of invertebrate animals; and a diverse assortment of land animals and plants. Many of the marine organisms secrete skeletons of $CaCO_3$ which are added to the material of the substratum. This process forms a lattice-work of limestone in which free skeletons or loose fragments lodge. By several processes these may become bonded in such a way as to form a rather hard and resistant rock. This is built up in the form of a ridge or reef usually enclosing a shallow body of water or lagoon and rising variously to somewhat below, near, or just above high-tide level. This reef is ordinarily rather flat-topped, of varying width, with irregularities or islets extending above high-tide level. Waves commonly break on the outer margin and water flows from the sea to the lagoon and back to the sea over the flat or gently sloping reef surface or through gaps in it. The flow may be in and out with the tides, or in over the windward and out over the leeward sides. The islets are commonly composed in part or wholly of loose porous limestone debris and are mostly covered by vegetation that includes representatives of all major groups of land plants. The land faunas are made up of a large number of species of insects and other arthropods, worms, land molluscs, a few reptiles, some birds, and a few mammals, including rats and man. Larger islets may contain within their porous structures a body of fresh ground water floating on the underlying salt water and retarded by friction from free diffusion with it.

These atoll structures are found in most regions of the tropical and, more rarely, subtropical seas. Temperatures range generally between 75° and 85°F or in full sun on land, higher, decreasing of course with increasing depth in the sea. General climates range from relatively dry, perhaps 600 mm precipitation, to wet, 5,000 mm or more. The atolls are in trade wind, doldrum, and monsoon belts. Insolation is generally high, cloudiness low to moderate.

Most atolls are inhabited by human beings, some by relatively large populations. These exert a generally appreciable, often profound, influence on the functioning of the ecosystem. Of specific importance in this connection are the economic activities of planting coconuts, harvesting, drying, and exporting coconut meat, and importing in exchange various foods and other materials.

With this description of the general physical and biological situation, we may proceed to describe in more formal terms, the abstraction called the coral atoll ecosystem. This may be outlined as follows in 12 sections, lettered A to L.

A. Media.
B. Nourishment or inflow.
C. Production.
D. Transformation.
E. Decomposition.
F. Excretion.
G. Accumulation.
H. Turnover.
I. Miscellaneous other effects and processes.
J. Losses.
K. Balance.
L. Trends.

A. *Media:* The media in which the system exists are two—a layer of sea water and a superimposed layer of air. These, by the nature of the earth-system itself, are constantly changed by sea and air circulation. Through them or by means of them, all exchange, gain and loss, of matter and energy takes place. These two media are the most universal and pervasive components of the ecosystem and at the same time its environment, influencing in some measure everything in the system.

B. *Nourishment* or *inflow:* As the atoll is an open system, there is a continuous addition of matter and energy in many forms. Fundamental, of course, is the daily increment of solar energy without which the system, in anything like its present form, could not exist. Its functioning is in almost every respect dependent on either photosynthetic or thermodynamic processes, which are dependent on constant addition of energy from the sun. The nourishment of organisms and the circulation of both air and water are important examples.

The energy of wind, mostly indirectly a form of solar energy, also exerts its force in various ways in the system. Most of this energy is received elsewhere and transported to the atoll.

The gravitational energy of both sun and moon contributes importantly to sea-water circulation in the form of tides. The movement of ground water in atoll islets also is influenced by tidal fluctuation.

Essential components of the media, such as O_2, N_2, H_2O, CO_2, as well as dissolved salts and suspended organic matter, and even living propagules and disseminules of organisms are continually renewed or carried into the system by air and ocean currents. Relative concentrations of the various components of the media are maintained at a rather constant level in this manner. The replenishment of the ground-water bodies in islets is dependent on incoming fresh water, mostly evaporated elsewhere and deposited as rain on the islets from wind-borne clouds. Surface currents, upwellings, tradewinds, monsoons, and cyclonic storms are important aspects of the circulation patterns involved. The introduction into the system of phosphorus, on which organic activity is completely dependent, is believed to be controlled to a considerable extent by upwellings of deep-sea water. One important route of transport of phosphorus from areas of upwelling to the atolls is by means of fish-eating birds and their young which deposit phosphates in their excreta within the area of the system. Essential mineral elements, nitrogen, and organic carbon are also brought in by the birds at the same time. Organic matter, in the form of drifting plankton, driftwood, and dead organisms, is brought to the atolls by currents. Currents also bring small amounts of mineral elements in the form of pumice as well as in solution. Volcanic ash arrives by way of winds, especially high altitude winds.

Finally, with changing patterns of human activity on atolls, increasing amounts of imported foods and other materials as well as alien organisms are introduced into the system. These introductions are effecting various rather profound changes in the equilibria and altering greatly the physical appearance of the atolls.

C. *Production:* The elaboration by plants of basic organic materials from elements and simple inorganic compounds is termed production, in an ecological sense. Such elaboration provides the fuel and building materials for all other life processes. The effective capacity of a system for production is called its productivity. (1) The most obvious productive process is photosynthesis, by which carbohydrates are elaborated. Algae and green plants utilize CO_2, H_2O, and energy from sunlight for this purpose. Such algae occur as components of plankton, within the cells of corals and other coelenterates, fixed on the reef surfaces, terrestrially on soil and rocks, and epiphytically on tree trunks. Mosses are found in many terrestrial situations on the islets, as well as on tree trunks, especially where they are shaded. Ferns and psilopsids are common growing on land and epiphytic on trees. Seed plants grow principally on land, but some are epiphytic and a few are marine, growing in shallow lagoon situations on sandy bottoms. All of these groups, together, account for the origin of most of the carbohydrates used in the system. (2) The other essential type of production is the fixation of atmospheric nitrogen—its oxidation and elaboration into simple compounds. It is, well known that this fixation is accomplished by bacteria in the soil and in nodules on the roots of certain leguminous plants. Less well known, but possibly more important in the atoll system, is fixation of nitrogen by blue-green algae. This occurs on the soil surface and possibly in fresh and salt water. Much of the nitrogen available to atoll organisms is probably fixed within the system, but important quantities enter the system by way of birds, rain, and ocean currents.

D. *Transformation: The alteration of primary and fabrication of secondary organic compounds:* This function may be viewed as a succession of processes, mostly involving a break-down of organic compounds and their re-elaboration into more complex ones. Some of these are of an enormous order of complexity (e.g., nucleoproteins).

(1) Autotrophic plants, in the nourishment of their own protoplasm and elaboration of stored material, cellulose, lignin, and other materials, carry out the first major step in a series of turnovers of the products of photosynthesis. Of course, additional inorganic materials are incorporated by this process, and many of the elaborated compounds are infinitely more complex than the original carbohydrates produced by photosynthesis.

(2) Heterotrophic (parasitic and saprophytic) plants carry this process a step farther in utilizing already elaborated complex substances, as well as simpler materials derived from their hosts and organic substrata. Here may be mentioned the utilization of dissolved organic matter in the media by facultatively heterotrophic planktonic algae as discussed by Saunders *(8)*.

(3) Animals, feeding on plants in various ways, convert plant organic matter into animal organic matter. The principal classes of processes by which this is accomplished are as follows:

a. Eating of phytoplankton by zooplankton.
b. Utilization of material produced by zooxanthellae, by their coelenterate hosts.
c. Reef grazing and boring.
d. Eating of land plants by animals.
e. Eating of dead plant parts by animals.
f. Parasitism of plants by animals.

(4) Secondary conversion of animal matter to animal matter is accomplished as a result of three well-known classes of processes, namely:

(a) Predation
(b) Parasitism
(c) Scavenging.

These are carried on in a great number of different ways by a large number of animals. Reef grazing and boring are important here, too.

(5) Reconversion of animal matter to plant matter is not as conspicuous a process, but is important nevertheless. There seem to be no insectivorous plants on atolls, so this reconversion is principally accomplished by bacteria and fungi living mostly on dead, and occasionally on living organic matter. It is an interesting question whether zooxanthellae utilize in any way the materials of their hosts' tissues.

E. *Decomposition* (usually but unfortunately termed "reduction"): The destruction of the elaborated organic compounds and reconversion back to simple inorganic compounds and relatively inert organic residues: Two main categories of processes are involved here. (1) Physiological oxidation (inappropriately termed respiration by many plant physiologists), which is the oxidation of carbohydrate materials within living cells releasing the energy required for other life processes. This process goes on constantly in all living things. (2) Non-biological oxidation, both by burning and by the slow oxidation of dead materials that normally takes place on exposure to atmospheric oxygen, aided or not by hydrolytic and catalytic action.

The principal products of both sorts of processes are CO_2 and H_2O, with, of course, inorganic and inert organic residues. Chemical energy is released and converted into other forms.

F. *Excretion* (within the system): The release of waste products and residues by organisms into the media:

(1) In water, CO_2 and O_2 are released, as well as excreta and soluble metabolic wastes. Calcareous and siliceous skeletons and oily material remain after disintegration of organisms.

(2) On land, likewise CO_2, O_2, and metabolic wastes are released in solution in air or water. Guano and other excreta, as well as deciduous, caducous, or severed plant parts are deposited on the surface of the ground to decompose.

G. *Accumulation*· Storage of materials in unchanging or very slowly changing form, i.e., temporary withdrawal of material (and energy) from free circulation in the system.

(1) In bulk the limestone from calcareous skeletons of plants and animals represents the greatest and most important accumulation, the principal component of the atoll itself.

(2) Phosphatic residues, mainly calcium phosphates, are present as phosphate rock, components of soils, guano, and at least in some atolls (e.g., Washington Island) as a phosphatic mud or sludge on the lagoon bottom.

(3) Humus, both as raw humus in *Pisonia* forests, and as more stable humic residues in A_1 horizons of soils, plays an important part in the functioning of the system. The acid raw humus contributes to the formation of phosphate rock, and the soil humus helps to maintain the soil in condition to support growth or larger plants and micro-organisms. Humus, though relatively inert, is continually undergoing a slow oxidation.

(4) Slight accumulations of charcoal, metal oxides, silica, and silicates occur where human activity is significant. Silica from sponge, radiolarian, and diatom skeletons also occurs in minute amounts, as well as small quantities of silicates from floating pumice.

(5) Finally, fresh water, in the ground-water lens, as well as in the several states of soil water, may be regarded as a temporary accumulation.

The organic matter and other substances in living organisms represent a large total quantity but, as they are in a constant state of turnover, should probably not be classed as an accumulation.

These accumulations, along with the materials in solution in the media, may be regarded as the reservoirs of materials on which the other components may draw for nourishment.

H. *Turnover* of materials and energy: Categories D, E, and F, above are to be classed as turnover. In addition several more processes may be so regarded.

1. Re-use of CO_2 released by oxidation.
2. Re-use of O_2 released by photosynthesis.
3. Re-use of H_2O released by metabolic and external chemical processes.
4. Re-use of fixed nitrogen, both from metabolic wastes and from primary biological oxidation.
5. Re-use of mineral nutrients released by excretion and breakdown of organic materials.
6. Withdrawal from and return of various materials to media.
7. Withdrawal from and return to accumulations.

I. *Miscellaneous other effects and processes taking place within the system.*

1. Inhibition by salt (NaCl). The organic activity in terrestrial situations seems subject to a considerable inhibition by the salinity of the seawater medium. This inhibition results from difference in osmotic pressure, the chemical effects of absorption of excess sodium and chlorine ions and consequent inhibition of absorption of others. The number of land organisms completely adapted to the normal salt concentration of the sea is limited. Hence establishment of immigrant organisms is severely limited, and many of those that become established function at below their optimum levels. Salt water enters the land environment as wind-borne spray, as storm waves, and by diffusion through the ground. The conspicuous nature of the limiting effects of salinity may be a reflection either of the small extent of the land habitat and consequently great exposure to salt or of its probable geologically recent origin that has allowed little time as yet for evolution of a special atoll biota.

2. Effects of sea-air interface: Category 1 is really only one of the consequences of the fact that the land portion of this ecosystem is a thin lens inserted in the general sea-air interface. The distribution of many organisms, marine as well as land, is influenced by the character of this interface. Aeration, principal release of energy from insolation, frequently an abrupt break in temperature gradient, local high salt concentrations resulting from evaporation, solution and other forms of erosion of limestone, and the

shaping of the contours of vegetation and control of its composition are all consequences of the nature of this interface. Many more could be enumerated.

3. Shelter effects. One of the reasons for the diversity of animal life in such an apparently simple environmental complex may be the variety of habitats resulting from the surface irregularity of the several substrata. The vegetation, the deeply pitted rock, the porous soil, and the intricate nature of the reef lattice provide shelter of various types for a large number of species of animals (and plants, too) that have widely differing requirements.

4. Burrowing and turning over of soil by crabs is an important factor in the process of incorporating organic matter into the soil. Crab burrows are very common on many atolls, and fresh mineral soil is often piled or scattered around their entrances. The mechanical tilling of the soil in this manner has been compared to that accomplished by earthworms in other habitats. It doubtless is a process of great importance, though no careful assessment of its extent or effects has been made.

J. *Losses* (or excretion from the system):

a. Of the principal substances lost from the system the first three listed below are present in such constant proportions in the media outside the ecosystem that the losses may be considered as balanced almost exactly by inflow. The others are fluctuating quantities, and there is no exact relation between inflow and loss.

1. CO_2, carried away by winds and currents.
2. O_2, carried away by winds and currents.
3. N_2, carried away by winds and currents.
4. Fresh water dispersed into media and carried away by winds and currents.
5. Nitrates and organic N, carried away by currents.
6. Phosphates, carried away by currents in solution and suspension.
7. Other dissolved mineral substances, carried away by currents.
8. $CaCO_3$, carried away by currents in solution and suspension.
9. Plankton, carried away by currents.
10. Dead animals and plants and detached living fixed organisms, carried away by currents and storms.
11. Birds which migrate.
12. Export of copra.
13. Export of pearl shell, etc.

b. Energy losses:

1. Light, by reflection.
2. Heat, by radiation and convection and carried by winds and currents.
3. Chemical energy lost with elaborated materials.

K. *Balance:* The resultant of all of the factors at work on the segment of the universe (or of nature) occupied by the atoll ecosystem is the atoll itself. It may be thought of as a system in a state of dynamic equilibrium with a positive offset represented by the physical mass of the atoll with its associated biota and its total of organic and mineral matter over and above that of the normal media—air and sea water—that otherwise would occupy the space. All the characteristics described serve to set the system off from the surrounding undifferentiated media.

L. *Trends:* With such complexity, it is hard to estimate trends, though it may be easy to discern them. Over very long periods, the trend is obviously toward greater accumulation of material and probably toward increasing complexity. This trend usually seems directly related to slow subsidence of substratum on which the atoll is built, and may be expected to continue. On a shorter time scale, it is possible to suggest that during periods of general or eustatic rise in sea level mass will increase, by addition of calcareous material in layers. Biotic complexity may at the same time decrease somewhat with tendency toward loss of land habitats. With fall in sea level, the trends may be the opposite—loss of mass by erosion and gain in biota with appearance of land habitats, increased activity of sea birds, and especially the results of occupation by man. Presumably for about the last 3,500 years the latter trend has been generally maintained. Whether or not the last few decades have witnessed a change in this trend is uncertain.

It seems clear that these major trends are controlled by factors external to the system. The ultimate control of sea level is as yet by no means clear. The variation in CO_2 content of the air has been suggested *(7)* as a factor that determines, or at least influences, world temperatures, evaporation of sea water, accumulation of ice, and consequent effects on sea level. It has been suggested that the recent apparent reversal of the fall of sea level may be due to the vastly accelerated industrial activity which pours great quantities of CO_2 into the atmosphere. If this is a valid assumption it seems reasonable to think that the present rise will continue, probably at an increasing rate. Thus a prediction might be made that the presently observed loss of land above water by erosion may be accelerated by a rise in sea level and consequent submergence of much or all of the land area of atolls. Such predictions, however, rest on very insecure bases at present.

On a still shorter time scale are the effects produced by the occupancy of the atolls by man, and especially modern man. These effects tend to be drastic as far as the land portions of the ecosystem are concerned, but trends are as yet hard to isolate. Certainly the replacement of the native vegetation by coconut plantations and the rise of the export of copra are notable and probably involve a complex of related or dependent effects. This change will probably continue but certainly at a decelerated rate, as land for expansion of plantations is becoming scarce. Augmentation of the land biota will probably continue as man's effect on the land environment continues. Pollution of lagoons will undoubtedly increase, with resulting encouragement to some organisms and ill effects on others. Fishing activities have tended to decrease with contact with civilization, but this trend may probably be reversed and with use of such effective methods as dynamiting and poisoning the marine biotas may undergo considerable change. There has as yet been little attempt to measure the results of such factors so that here, as in other aspects of the system, estimation of trends is highly speculative. If such prediction is of interest, attention should be directed toward critical study of the details of the working of the system outlined above, to clarify it and fill in the parts that are at present inferential. It seems possible that if a firm understanding of this ecosystem is achieved it may be used as a model in terms of which to study other ecosystems.

SUMMARY

The general physical and "physiological" framework of the coral atoll ecosystem has been outlined in terms of the media in which the system exists, nine categories of processes taking place within the system, the balance or dynamic equilibrium in the resultant structure brought about by these processes, and suggested trends in the state of this equilibrium. This highly generalized picture rests on a vast accumulation of facts and upon inferences drawn from them and from pertinent facts derived from study of related or analogous situations in other systems. It is hoped that this description may serve, until a better conception is devised, as a framework around which an understanding of this segment of nature may be built and as a guide for future research designed to clarify our knowledge and appreciation of coral atolls.

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DISCUSSION

F.E. EGLER: The approach used by the author and its potential as an approach to land utilization is most valuable. The concept of the ecosystem has been slow to gain recognition, possibly because it is based on the investigations of many fields of knowledge, seldom as the result of one individual's effort. The plant ecologist often comes from the field of taxonomy and may not be fully equipped to handle phytosociological problems. The integration of scientific knowledge by an ecologist requires an unusual breadth of understanding.

M.S. DOTY: It is necessary to distinguish between potential and net productivity.

F.R. FOSBERG: Although potential productivity is something to think about and discuss, the actual productivity is the only tangible aspect of it that could be evaluated.

G.F. PAPENFUSS: Are there atolls that lack a lagoon?

F.R. FOSBERG: There is some question of interpretation regarding when it stops being an atoll and when it becomes a lagoon. With reference to the energy relationships, the constant blowing of wind coming from outside may contribute to the system, but the chief source of energy is from the sun. The wind may build up sand and accumulate energy in the system, but it may also do the opposite and release potential energy from the system.

THE RELATIONSHIPS BETWEEN ATOLLS AND BENTHIC ALGAE†

RALPH F. PALUMBO

School of Fisheries, University of Washington, Seattle, Washington, U.S.A.

In the U.S. Pacific Northwest, one is accustomed to seeing large fronds of such algae as *Macrocystis* and *Nereocystis* floating around in the cold water of Puget Sound. In the Marshall Islands of the warm Central Pacific Ocean, on the other hand, where the species of algae discussed in this paper were collected, the absence of these or any of the large forms of algae is very apparent. There only colonies or individual specimens of tiny filamentous algae or branched species rarely exceeding a few inches in length were found. The striking size difference in the marine flora of the two regions brings up the question as to the nature of the conditions causing this difference, and, at the same time, poses the question as to reasons for the differences in distribution of the algae in the atoll itself. This paper will be confined to the latter problem.

A coral atoll is a relatively small outcropping in the middle of an ocean and contains a diversified environment in which the growth of various organisms is possible. The open ocean surrounding an atoll is a source of the minerals used in the production of organic matter and thus acts as a nutrient solution for the activities of the various photosynthetic organisms present. The principal members of the atoll community engaging in photosynthetic activity, of course, are the benthic and the planktonic algae. The distribution of planktonic algae of the atoll lagoon is primarily dependent on the local currents, and consequently, the problem of this paper is to determine the differences in the environment which might account for the distribution of the benthic algae about the atoll.

Recent studies by Johnson *(5)* and others have confirmed earlier suggestions that the calcareous algae play an extremely vital part in the building of coral atolls. Transects across the reef at Bikini Atoll indicate that 40-90% of the reef is comprised of algal deposits, consisting primarily of the remains of species of the green coralline alga *Halimeda* and of the red coralline algae such as *Porolithon*, *Goniolithon*, *Mesophyllum*, and *Lithothamnion*. Other organisms, such as corals and foraminifera, have contributed to the reef building process, but to a lesser extent. These deposits extend to a depth of over 2,500 feet and date back to the Miocene epoch. They serve as pointers to the equilibrium or relatively stable conditions that exist between the atoll inhabitants and their environment. This theory has also been promulgated by Odum and Odum *(8)* who stated that the productivity of a reef just balances the respiration, suggesting that the reef community is a true ecological climax or open steady state system.

The conditions that have existed, apparently for millions of years, making possible this reef building process, revolve around the activity of these algae and their ability to flourish in this type of environment. The warm temperatures and the abundant radiant energy bathing the exposed reefs combined with the rich supply of oxygen and carbon dioxide form ideal conditions for photosynthesis. The ability of these algae to secrete calcium carbonate as well as other minerals caused these particular species to survive, and their cementing action caused the consolidation of algal and other debris in the formation of the atoll mass.

The calcareous algae mentioned above are found primarily in the regions of pounding surf, where turbulence and oxygen rich waters are at a maximum. Some of the non-encrusting calcareous algae, such as *Codium* and *Udotea*, however, are found in the more protected habitats of the tide pools and along the western leeward reefs where the surf action is less severe. These species apparently cannot survive the rigorous action of the waves impinging upon the northern reefs, but they do require similar conditions of light, temperature, and mineral composition optimum for the growth of the more hardy corallines.

The calcareous algae, however, are not the only algae contributing to the mass of the reef. Odum and Odum *(8)* have shown that the filamentous green algae interwoven in the skeletal material of the coral reef make up a large portion of the mass and consequently increase the overall productivity of the reef.

Of the conditions influencing algal growth in an atoll, temperature is probably the least important. Studies that showed insignificant

† Presented in abstract by M.S. Doty.

temperature differences in the shallow waters on the different sides of the coral reef were made at Rongelap Atoll by Sargent and Austin *(9)*. The temperatures across the three hundred-meter reef varied from 28.3°C on the seaward side to a maximum of 29.4°C on the lagoon side, not sufficient to account for the differences in productivity per unit area on the reef and in the adjacent waters. Munk, Ewing, and Revelle *(7)* found very slight temperature differences with depth in the lagoon at Bikini Atoll. At three feet below the surface, the temperature varied in 24 hours between 27.2°C and 27.1°C and at 165 feet between 27.05 and 27.08°C, indicating a thorough mixing of the top and bottom layers of water. This idea was partially supported by radiological determinations made after the Baker atom test in 1946, by these investigators as well as by W.L. Ford *(3)*. The temperatures in the atoll environment, then, vary only slightly and probably not enough to account for distributional differences of the organisms present. The most significant part that temperature plays undoubtedly occurs during low tides when the tide pools become very warm and the beach rock areas are exposed to the direct sunlight for hours at a time. Here the only algae that survive are the blue-green algae such as *Anacystis* and *Schizothrix*, which possess simple structures and gelatinous sheaths.

Of the factors limiting the growth of photosynthetic organisms, light is often the controlling one. In the murky waters of many northern seashores, the stratification of algal species is well defined. This zonation can be explained at least in part by the amount and quality of the incident light and its effects upon the photosynthetic activity of the various algae. For example, the *Chlorophyta* are found only in shallow water, as the red light from which they obtain energy for photosynthesis cannot penetrate more than a few feet. Some of the *Rhodophyta*, on the other hand, may be found growing at depths up to 300 feet because they can utilize the blue wave lengths which penetrate to this depth. The *Phaeophyta* use both the red and the deeper penetrating orange-yellow light and thus frequent the zone extending from the low tide line to a depth of approximately 50 feet. Whether such an explanation can be used to account for the distribution of the algae in an atoll environment is open to question. Wells *(11)* reported that "light or radiant energy is the principal factor controlling the depth of growth of mutually interdependent reef corals and symbiotic zooxanthellae...temperature is the principal factor controlling their geographic distribution." On the other hand, Sargent and Austin *(9)* stated in Rongelap lagoon, even though the light intensity at 15 meters was only 20% of that just below the surface of the water, it was still adequate for maximum photosynthesis in free-living plants. In the unusually transparent water of Eniwetok lagoon at depths up to 45 meters, the present author and others of this laboratory using self-contained breathing apparatus saw luxuriant "fields" of green algae, especially *Halimeda monile*, *H. gigas*, and *Caulerpa racemosa*, attached to the white bottom sand. Gilmartin *(4)* has also observed these and other green algae at depths of 60 meters. Others have also noted the preponderance of green algae at depths usually restricted to the deeper living red algae *(10)*. This can signify only that sufficient light does penetrate the clear waters of these lagoons to permit maximum growth of the "greens" and possibly to discourage growth of the "reds." It was also noted that some of the same species inhabiting the deeper, relatively calm water were also growing vigorously in shallow turbulent water on the edge of the seaward reefs. Good examples of this type of algae are the green *Halimeda opuntia* and the red *Asparagopsis taxiformis*. In these instances at least, light does not appear to be the controlling factor.

Another factor important in the growth of algae is the mineral content of the medium. Few quantitative studies have been made of the mineral content of the waters in an atoll environment. Sargent and Austin determined the amount of dissolved phosphorous in the water at several localities on one of the reefs at Rongelap Atoll and found that only small differences existed, in fact, the values were so low that the measurements were felt to be uncertain. The total dissolved phosphorous over the reef at a depth of about forty centimeters varied from 0.31 to 0.66 mg atoms/liter. Measurements of Mg^{++}, Ca^{++}, Cl^{-}, and total hardness made by Cloud *(1)* at Onotoa Atoll in the Gilbert Islands showed that even though there were diurnal variations in the values for some of these factors, there were no significant differences in the levels in the shallow water at the four localities studied. Radiological studies to determine the relative uptake of trace minerals by marine organisms have been conducted by this laboratory. These studies have shown that minute amounts of manganese, zirconium, zinc, cobalt, cesium, and iron can be detected in amounts too small to be detected by ordinary chemical techniques *(6)*. The concentration of these minerals by sedentary marine organisms over a long period of time could be useful in the measurement of the different minerals present and could also be useful in evaluating their distribution about the atoll. Until further information of a similar nature encompassing several ecological situations is obtained, no finite conclusions can be drawn regarding the effects of varying mineral composition on algal growth in the environment of an atoll.

A factor which must be considered in the distribution of an alga is its habit or life form. Several classifications of the life forms of marine algae have been outlined, and it has been suggested *(2)* that such classifications could be useful in determining whether certain ecological situations are characterized by the same types of algae. As such an approach has been used with partial success, it might well be expanded to include a wider range of conditions and geographical areas in order to evaluate its dependability.

Unfortunately the information relative to the chemical and physical factors in an atoll environment is far from complete. The information we do have indicates that the quantitative differences in these factors are probably too small to account for distributional patterns among the algae and other organisms present. Radiological studies to aid in determining the relative amounts of minerals about the atoll should be made, and these, in conjunction with mineral nutrition studies using radioactive tracers, might help to clarify the role of minerals in the atoll environment. It has been proposed that the life form of an alga may be the prime factor in determining its distribution, and some studies indicate this to be the case. However, sufficient discrepancies exist to warrant further study of the problem.

In summary it can be stated that the occurrence of an alga in a particular ecological niche is dependent upon many different factors, among which the following must be included: the life form of the alga, the chemical and physical factors of the environment, the dynamic factors of wave action and immersion, and the biological factors imposed by other organisms in the vicinity.

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DISCUSSION

F.R. FOSBERG: One must keep in mind that in the Pleistocene there have been some violent fluctuations with great changes in sea level and that the changes are of such an extent that one would not think in the same terms. The interpretation of a steady state existing since the Miocene cannot be rigidly applied.

THE MICROBIOLOGY OF CORAL REEFS†

E. J. FERGUSON WOOD

Division of Fisheries and Oceanography, Cronulla, Australia.

The microbiology of coral atolls is a sadly neglected field of marine research. We have little information, apart from the studies on the bacterial precipitation of calcium carbonate made by Drew *(6)*, Lipman *(7)*, and Bavendamm *(5)*; some notes on blue-green algae associated with coral reefs by Baas Becking *(1)*; and some conclusions that may be drawn by inference from the work of Baas Becking and Wood *(3)* and Baas Becking, Wood, and Kaplan *(4)*.

Drew came to the conclusion that large-scale precipitation of calcium carbonate was caused in tropical waters by a marine bacterium which he called *Bacterium calcis*. He showed that this bacterium could reduce nitrates to ammonia, which reacted with the bicarbonate in sea water to cuase the precipitation of calcium carbonate, the calcium being derived from calcium sulphate. This is, of course, theoretically possible in a region where the calcium and carbonate equilibria are in delicate balance near the saturation point for calcium carbonate. Lipman questioned Drew's hypothesis and considered the production of ammonia from organic matter was the important factor in calcium precipitation by marine bacteria. He also pointed out that there were so few bacteria in the open sea that extensive precipitation was unlikely. Bavendamm showed that there were enough bacteria in bottom deposits to cause extensive calcium carbonate precipitation, but concluded that there were no specific bacteria concerned.

Zobell *(9)*, reviewing the situation, states that fewer than 5 per cent of bacterial species in the sea are endowed with the ability to liberate free nitrogen from nitrate or nitrite in the presence of abundant organic matter. My own observations show that few marine bacteria can liberate either nitrogen or ammonia from nitrates, and I doubt whether this process is important in calcium carbonate precipitation.

Possibly of greater significance in microbial calcium carbonate precipitation is the utilization of carbon dioxide by autotrophic bacteria and photosynthetic microorganisms. There is no information on the occurrence or abundance of such organisms in the coral reef biocoenosis.

The environmental factors which may affect lime deposition include temperature, pressure, hydrogen ion concentration, and redox potential. In fresh water, salt concentrations also have an effect, but in the sea, these do not vary sufficiently to be important.

The effect of temperature on calcium carbonate precipitation is stressed by Sverdrup *et al. (8)*, who show that, because of the rapid decrease of solubility of carbon dioxide with rise of temperature, extensive deposition is possible only in warmer waters. These authors suggest, too, that, as pressure increases the solubility of carbon dioxide, lime deposition will be confined to relatively shallow waters.

It should be remembered that the carbonate equilibrium is very easily reversible, and that precipitation presupposes re-solution with a slight change of conditions in the right direction. Thus, organisms removing carbonate by photosynthesis or photoreduction may, and do, continue to produce it in the dark by respiration.

Baas Becking and Wood, and Baas Becking, Wood and Kaplan have considered the relation between pH/Eh, along with the microorganisms and the environment for a number of biocoenoses. In the first paper, the limitations of a number of autotrophs by the environment was studied; in the second, the chemical equilibria imposing possible limitations were delineated, and this has been carried still further by Baas Becking (in press). It is unfortunate, but unavoidable, that no observations were made in coral reef areas, so we can get only an approximate and theoretical picture, of these regions. In the estuaries of temperate regions, the pH of the water where measured ranged from 7.0 to 9.4, with a mean of 8.25, while the muds ranged from near 5.0 to near 9.5, with a mean of 7.4.

The estuarine waters had a mean Eh of + 362 mV with a range from + 150 to + 500 mV, while the muds ranged from + 600 to − 350 mV with two means, one at about + 325, and the other at about − 75 mV.

Biologically speaking, all autotrophic processes except sulphate reduction and photoreduction

† Presented in abstract by R.F. Scagel.

could occur in estuarine waters, while sulphate reduction and photoreduction of carbon dioxide, as well as the other autotrophic reactions are possible, and can be shown to occur in the estuarine muds. Baas Becking and Wood consider that the sulphur cycle dominates the muds, and that these in turn dominate the water in shallow estuaries. The lower mean Eh of the muds reflects this dominance.

In fresh-water limestone regions studied by these authors, the pH ranged from 5.5 to 9.0, with a mean of 7.19, while the Eh ranged from +100 to +500 mV with a mean at +333 mV. The pH shows that bicarbonate ion dominated the waters, even those with high concentrations of calcium (at 7.2, there will be little CO_3 ion). In sea water, at a pH over 8, the equilibrium of the CO_2, HCO_3 , $CO_3^{=}$ would move towards the carbonate. At that pH there will be no free CO_2, and 4 parts of bicarbonate to one of carbonate ion. A change in the pH to 9.4 will reverse the bicarbonate-carbonate ratios to 1 part of bicarbonate to about 3 parts of carbonate ion, i.e., carbonate will become the limiting factor in photosynthesis.

In temperate estuaries, a pH of 9.3 - 9.4 is reached on shallow flats with a large plant population, e.g., of *Zostera*, in the middle of the day. Although, theoretically, calcium carbonate should actively precipitate under these conditions, the greater acidity of the muds will limit the amount actually deposited. Another limit is imposed by the short duration of these high pH values, and the counter-effect of respiration at night.

Coral reefs differ from the estuaries studied by Baas Becking and his colleagues in having, on the whole, less photosynthetic plants, and consequently less organic detrital matter in the muds. This should lead to a lower activity of the organisms of the sulphur cycle, which depend on heterotrophic bacteria to produce the low Eh required for starting sulphate reduction. The green and purple sulphur bacteria also require low Eh values to initiate the oxidation of sulphydryl. These regions will also differ from the fresh-water limestone regions in having a considerable amount of calcium sulphate which was absent in the areas studied by Baas Becking, Wood and Kaplan.

It can be safely predicted that the alkaline limit of the coral reef environment will be controlled by carbonate, and the lower Eh limit by the amount of organic matter, i.e., reducing material. The other limits cannot be estimated except by actual observation.

In temperate estuaries, and in mangrove swamps, phosphate is largely controlled by the sulphur cycle in the mud *(2)*. The insolubility of the sulphides of iron cause the release of phosphoric acid from ferric phosphate in the presence of hydrogen sulphide. An alternative method for the collection and storage of phosphate by microorganisms is the chelation of phosphate in the pectic sheaths, also described by Baas Becking and Mackay. I have noticed that encrusting growths of blue-green algae usually have a zone of sulphate reduction immediately below them, and could thus use the sulphur cycle to obtain their phosphate. However, one would expect the pectic chelation mechanism to be of greater importance in the phosphorus cycle on coral reefs. Nitrogen fixation may also be an important function of the Nostocaceae on coral reefs.

It will be realized from the account that I have given that we are largely in a field of pure speculation when we consider the microbiology of coral reefs, but that we have *a priori* some means of approach to the problem. This approach should include (1) the study of the microbial components of the coral ecosystem, (2) their interaction and cumulative effect on the environment, and (3) the actual biological mechanism of lime deposition especially as skeletal material.

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THE MARINE BIOGEOGRAPHICAL PROVINCES OF THE SOUTH PACIFIC†

V.J. CHAPMAN

Auckland University College, Auckland, New Zealand.

Our present knowledge of the biogeography of the South Pacific stems from contributions spread over a number of years dealing with algal zonation and ecology in South America *(23,24,25,26)*, Australia *(9,1,12,20,31,32)*, and New Zealand *(21,8,4,5,2,3,10,11,15)*. The subantarctic islands have also been examined, the first records being those of Hooker *(14)* and Harvey *(13)*, but there are recent ones for the New Zealand subantarctic islands *(6)*, for the Crozet Is. *(17)* and for the subantarctic islands generally *(18)*. Another island flora that is relevant to any discussion on biogeographical provinces is that of Juan Fernandez *(16)*.

The present author believes that proper appreciation and understanding of the provinces is most readily secured by using as a basis the major categories recognized by Stephenson *(27,28,29)* in his work on the marine fauna and flora of South Africa. The three major categories were:

(a) A warm water component, predominant at Durban and gradually decreasing to Port Nolloth. This can be regarded as essentially a *subtropical* province.

(b) A cold water component associated with the cold upwelling on the S.W. African coast, and gradually disappearing towards Cape Town. This can be regarded as forming essentially a *cool temperate* province.

(c) A southern intermediate flora of the Cape district which can be regarded as a *warm temperate* province.

These major groups were correlated with changes in mean sea temperature, and Stephenson *(29)* related them to the main southern littoral faunas as described by Eckman based upon intervals of 10°C. These are as follows:

(1) Tropical and sub-tropical faunas: minimum temperature not below 20°C.
(2) Warm temperate faunas: minimum temperature 10-20°C.
(3) Cool temperate faunas: minimum temperature 0-10°C.
(4) Antarctic faunas: minimum temperature 0°C or lower.

A similar ten degree temperature barrier has been proposed by Setchell *(22)* as operative for marine algal zones. Recent work by Bennett and Pope *(1)* on Australian faunas suggests that the minimum sea temperature boundary of 10°C between warm and cold temperature faunas may need to be raised to 11.5°C. In Australia, the principal marine faunal and floral provinces were first proposed by Hedley but they have been amended since then. At the present time the following can be recognized:

(a) The Banksian from Cape York southwards.
(b) The Solanderian in the Coral Sea area.
(c) The Peronian in Southern Queensland and Northern New South Wales.
(d) The Maugean in Bass St. and around Tasmania.
(e) The Flindersian in Victoria and South Australia.
(f) The Damperian in Western Australia and up to the Northern Territories and the Gulf of Carpentaria.

Recent work on the littoral faunas and floras has served to substantiate these provinces *(1)*, and they have also been shown to be valid for the pelagic Dinoflagellates *(33)*. Of these Australian provinces, the Maugean must be regarded as cool temperate, being associated with cold antarctic waters. The Peronian and Flindersian provinces are both warm temperate, whilst the Solanderian and Damperian are tropical. Further work on those parts of Australia just north of the Peronian and Flindersian provinces will probably show that there are two small subtropical provinces characterized by a mixture of tropical and warm temperate species.

In New Zealand, Moore *(19)* has summarized the distribution of some 200 marine algae, and as a result she recognized seven distinct provinces which can be compared with those of Powell for the marine fauna and of Cockayne for the terrestrial plants. The present writer, whilst agreeing generally with the provinces of Moore and Powell is of the opinion that some modification is desirable on the basis that has been outlined above. The Kermadec algal flora are

† Presented in abstract by M.S. Doty.

based on old lists *(1)*, and a recent collection clearly contains tropical, e.g., *Caulerpa racemosa*, *C. webbiana*, *Pocockiella nigrescens*, and warm temperate species, and can therefore be regarded as a sub-tropical province. Such information as is at present available indicates that Norfolk Is. falls into the same province. Off the shores of South America, the flora of Juan Fernandez suggests affinities with Australia and New Zealand, but there is a distinct warm water element (e.g., *Hydroclathrus*, *Padina*, *Microdictyon japonicum*, *Chaetomorpha antennina*) which justifies treating it as subtropical. The Aupourian or Auckland province is definitely warm temperate *(11)*, the proportion of warm temperate species gradually decreasing towards Cook Strait. The subtropical convergence crosses New Zealand in Cook Strait and, as the minimum sea temperature of the convergence is around 10°C, it forms the logical boundary between the warm temperate province of the northern island and the cool temperate province of the South Island. The Chatham Islands lie very close to the sub-tropical convergence, and they possess a flora with warm and cool temperate elements. There appears, however, to be a slightly higher proportion of warm temperate elements, and it may therefore be placed in the warm temperate Auckland province, or as a sub-province of the Auckland province.

The marine algal flora of most of the South Island of New Zealand must be regarded as cool temperate, and it would seem to have a relationship with the Maugean province of Bass Strait and Tasmania. It is to be noted that although Tasmania lies just north of the sub-tropical convergence nevertheless the waters of the cold antarctic current maintain a cool temperate flora and fauna. The present writer considers that the central and intermediate provinces of New Zealand should be merged into a single province, the Zealandian.

The Forsterian (Stewart Is.) and Antipodean (= Rossian of Moore) provinces of New Zealand comprise the subantarctic islands. Both provinces contain a large proportion of southern species, so much so that it seems desirable to recognize a sub-antarctic province which would also include Kerguelen, Crozet, and Heard Islands. In this case, therefore, the minimum sea temperature boundary would be less than 10°C. It may be suggested that further work in and around Magellan Straits, Tierra del Fuego, and the Faukland Islands may show that they also represent a sub-antarctic province with a flora differing from that of the cool temperate province to the north and the extreme antarctic province of the Antarctic continent and adjacent Islands.

There remain the coral reefs and atolls of the South Pacific. Our knowledge of the marine algal floras of these islands is at present very meagre, but it can be suggested that they represent essentially a tropical province which can conveniently be called the Central Pacific province. It remains to be seen whether New Caledonia, the New Hebrides, and the Solomon Islands group, now placed in the Solanderian province have a flora sufficiently similar to that of the Central Pacific to justify the extension eastwards of the Solanderian province.

Some further confirmation of the conclusions that have been reached above can be derived from a comparative study of the basic zonations in the South Pacific, especially those of Australia and New Zealand. Guiler *(12)* has compared (Table 1) the basic (i.e., not greatly exposed nor greatly protected) zonation of Tasmania with that of New Zealand, Chile, Victoria, and S.W. Africa; and he considers that ecologically the zonation in Tasmania indicates a greater affinity with that found in New Zealand than with that of southern Australia. In making the comparative study, the basis used is that proposed by the Stephensons *(30)*.

In Table 2 a comparison is given of the basic zonation of exposed and protected shores in the Auckland province of New Zealand with the zonation reported from the Zealandian province of the S. Island (Banks Peninsula).

Finally a comparison may be made of the basic zonation from three of the Australian provinces (Table 3).

The distinction between the tropical flora and the other two is very evident. The similarity between the Peronian and the Aucklandian provinces is also brought out. In New Zealand, Pyura is more frequent in the South Island, and it evidently is a representative of the cool temperate zone. A fuller comparison of the varied zonations that have been described from the different provinces is really essential to bring out the finer points that demonstrate the differences.

Whilst our knowledge of the algae and the algal zonations in many parts of the South Pacific is as yet lacking or very inadequate, nevertheless from the data available it would appear that the picture that has been drawn represents the situation as it is at present. It may also serve to highlight those areas from which further information would be very valuable.

Table 1.

	Tasmania	New Zealand	Victoria	S.W. Africa	Chile
Supra-littoral fringe	Littorinids	Littorinids Myxophyceae	Littorinids	Littorinids	Littorinids
	Chamaesipho-Chthalamus	Chamaesipho-Chthalamus	Chamaesipho-Chthalamus	Bolanus	Chamaesipho-Bolanus
Mid-littoral	Galeolaria	Hermella Volsella Elminius or Saxostrea	Algae or Galeolaria	Pomatoceros	Serpulid worms
	Corallines	Corallines-Hormosira or Mytilus	Pyura	Corallines	Corallines
Sub-littoral fringe	Lessonia Xiphophora or Durvillea	Ecklonia Carpophyllum Lessonia or Durvillea	Cystophora Durvillea	Laminaria Ecklonia Macrocystis	Lessonia Durvillea

Table 2.

	Hauraki Gulf (Protected)	Piha (Exposed)	Poor Knights Is. (Exposed)	Banks Peninsula (Exposed)
Supra-littoral fringe	Littorinids (Melaraphe) Myxophyceae	Melaraphe Bostrychia	Melaraphe Myxophyceae	Melaraphe Bostrychia
Mid-littoral	Chamaesipho spp. Elminius Volsella Saxostrea Corallina-Hormosira	Chamaesipho Modiolus Gigartina alveata Pachymenia Mytilus	Chthalamus Elminius Apophloea Corallina-Novastoa	Chamaesipho Serpulid worm Elminius Mediolus Mytilus Corallina-Halopteris
Sublittoral fringe	Carpophyllum Ecklonia	Durvillea (1 sp.)	Xiphophora Carpophyllum	Durvillea (2 sp.) Carpophyllum

Table 3.

	S. Australia	New South Wales	Queensland
Supra-littoral fringe	(Flindersian) Melaraphe Myxophyceae	(Peronian) Melaraphe Tetraclita (exposed)	(Solanderian) Tectarius Melaraphe
Mid-littoral	Barnacles	Barnacles (Chthalamus-Tetraclita)	Barnacles (Chthalamus-Tetraclita)
	Galeolaria	Chamaesipho Galeolaria Pyura	Ostrea
	Corallines	Corallines Hormosira	Coral
Sub-littoral fringe	Ecklonia Cystophora	Pyura Ecklonia Phyllospora	Sargassum

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COASTAL MARINE PLANTS AROUND CAUDA HARBOUR (NEAR NHATRANG)†

PHAM-HOANG-HO

Deputy Director, l'Institut Oceanographique, Nhatrang, Vietnam.

The Nhatrang bay, and the sea coast of Central Vietnam in general have a physiognomy which distinguishes them from the rest of the whole coast from the ecological point of view.

The "Annamitic Cordillera" ends there with rocky outgrowths delimiting sandy bays while alluvial deposits brought in by large rivers continue to build elsewhere muddy and sandy coasts. Climatologically, the coast of Central Vietnam owes the Cordillera a climate diametrically opposed to that of the rest of the country. When in the North and the South the summer monsoon brings in the rain, the dry season (from February to August) prevails in the Centre. The yearly average of rains amounts to 1,441 mm against 1,979 in Saigon.

At Nhatrang, the thermic regime is also the same as in Saigon, with a small temperature difference (4°) between the warmest and the coolest month.

Finally, oceanographically the central coast is distinct. There, in fact, diurnal and semi-diurnal tides manifest themselves on an equal basis. The tide regime is a mixed one as compared with a semi-diurnal regime in the South and a diurnal regime in the North. (We are awaiting details about the harbour establishment along the Vietnam coast).

Thus the physical, climatological, and oceanographical data put emphasis on the interest of a comparative study of the ecology of the central sea-coast and that of the rest of Vietnam.

We began with the study of the submarine vegetation at Nhatrang, mainly on rocky spots. We took, for example, the rhyolitic point of Câuda. We could distinguish the three general bionomical zones of Stephenson (1949), viz. a Littorine zone, a Cirripede zone, and the sublittoral fringe. But the zones which can be easily evidenced are from top to bottom:

(a) the *Calothrix pilosa* Born. and Flash girdle, 30 cm wide, watered by high sea spray (embruns) and submerged under the biggest spring tides (lunar tropic). This is a discontinued girdle, confined to rough substrata.

Upward accessories: *Littorina scabra* Lin., *Tectarus granularis* Gray, *Lygia* sp., ubiquists: *Grapsus grapsus.*

(b) the *Brachytrichia maculans* Gom. girdle, covering 80% to 90% of the area. Another typical growth, *Littorina scraba* Lin., has a maximum thickness which changes according to the tide.

In the anfractuosities are the *Isognomon* sp. and *Pollicipes mittellae* ("mode battu"). And at the lower limit are the patella: *Cellana amussilata* Reev., *Acmaea saccharina* Linn. *A. granostriata* Sch *Patella aster* Reev., etc.

(c) the *Ostrea cucullata* girdle, situated at the mid-tide level with *Ectocarpus braeviarticulatus* J.Ag., *Chnoospora pacifica* J.Ag., *Gelidium pusillum* Le Jolis ("mode battu"), *Acrocystis nana* Zan. On the walls, eurytopics colonies of *Palythao* sp.

(d) the *Gelidiella acerosa* girdle at the low water levels is the large Phaophyceae zone: *Sargassum* ssp. *Turbinaria ornata* and *Turbinaria* sp. ("mode battu") *Padina commersoni* Bory., *Chnoospora implexa* J. Ag. ("mode peu battu à calme"). The great phaeophyceae shelter abundant epiphytic flora. On *padina commersoni* Bory, for example, we found *Griffithsia metcalfii* Tseng, *G. tenuis* C. Ag., *Acrochaetum gracile*, *Centroceras clavatum* Mont., *Ceramium mazatlanense* Daws., *Polysiphonia* sp. Great acorn-shells (*Balanus tintinnabulum*) were covered with Melobeseae or *Ralfsia* sp. at the beaten spots; on the less beaten rocks were *Gastrochaena cymbium* Sprengl. On the scattered rocks you find *Enteromorpha intestinalis* Link. On the small grounds where the waves are not sharp are the tufts of *Ectocarpus mitchellae* mixed with *Enteromorpha clatharata* J. Ag. and *E. Kyllini* Blid.

Inside the beach rock blocks we found *Lithodomus lima* Jouss., *L. Malaccarnus* Reev., *Pholadidea farroti* Jouss., *Arca turella*, several crustaceous: *Gonodactylus*, *Alpheideae*, *Isopoda; Spongiaires* and *Polychaeta.*

(e) the infra-littoral level begins with *Thalassia Hemprichii* Asch., *Halophila ovalis* Hook, *Diplauthera Uninervis* Asch. that is found only at the low spring waters. You find there *Colpomenia sinuosa* Derb & Sol., *Padina commersoni*, *Gracilaria*

† Presented by M.S. Doty.

crassa Harv., *Bornetella oligospora*, *Neomeris annulata* Dick, *Halimeda gracilis* Harv., *Struvea anastomasans* Picc., *Galaxaura fastigiata* Dec., etc.... At the lower part, you see between rocks: *Ceratodictyon spongiosum* Zan., *Halymenia dilatata* Zan., *Liagora ceranoides* Lam., *Liagora farinosa* Lam., *G. filamentosa* Chou, etc..., *Diadema setosa* and other sea-urchins, *Mulleria* sp., the Crinoids. It is also the coral zone whose study is being conducted by M.M.G. Ranson and Nguyen-Thanh-Tri.

We do not yet have data about the deep lower infra-littoral zone. Dawson (1954) found *Galaxaura Vietnamiensis* Daws. at 30 m deep.

DISCUSSION

M.S. DOTY: Is the 4°C. temperature difference referred to for air or water?

P.H. HO: The temperatures given are for air.

BENTHIC ALGAL PRODUCTIVITY IN THE NORTH PACIFIC WITH PARTICULAR REFERENCE TO THE COAST OF BRITISH COLUMBIA

ROBERT F. SCAGEL

University of British Columbia, Vancouver, Canada.

In comparison with the progress in our knowledge of most groups of plants — especially concerning their life-histories and distributions — the advances made in marine phycology have been relatively slow. The limited access to living material or to the facilities to maintain the larger marine algae in the living condition for a prolonged period of time, the difficulties of collection — particularly in the subtidal zone — and the lack of any extensive direct economic value until recent years have all contributed to this slow progress. However, in spite of these difficulties, there has been a considerable amount of interest in the marine algae, including many studies of their ecology. Although this interest has been fairly widespread in a number of countries of the world, until recently there has been little activity in the field of marine benthic algal ecology on the Pacific Coast of North America and nothing of a comprehensive nature has been published for this area. It is an anachronism that this should be so in a region which received such prominence some fifty years ago through the efforts of a pioneer in the field, the late William Albert Setchell.

Although the knowledge of the effect of temperature on the world-wide distribution of plants both horizontally and vertically had developed gradually over a period of many years, it was only during the last hundred years that the attention of phycologists was brought to a consideration of the reasons for the observed distributions of the marine algae. The historical development of this trend of thought and investigation during this early period has been reviewed by Setchell *(30)*. Starting over fifty years ago and extending through a series of papers from 1893 to 1935, Setchell made a noteworthy attempt to explain the world-wide distribution of marine algae, and especially members of the Laminariales on the Pacific Coast of North America, on the basis of latitudinal and seasonal temperature distributions. The physical data available during this early period were limited, but many of the principles set forth by Setchell concerning the distributions of marine algae are as sound now as when they were first proposed. Except for more precise knowledge of the physical and chemical factors of the environment and the distributions of the algae concerned, much of Setchell's ecological work can still be used as a good foundation for further study. Although it was largely a two-dimensional approach to the marine environment, Setchell's work made a significant contribution to the development of marine algal ecology.

Lamouroux *(23, 24)* had suggested the possibility that temperature stratification in the sea might account for the vertical distribution of the marine algae and had considered the effect of tides on intertidal zonations, but this trend to analyze the vertical distribution of the marine algae was not taken up in detail until much later. Coleman *(12)* was one of the first to emphasize the use of tide levels to account for the vertical distribution of the marine algae in the intertidal zone. In a study in Oregon, on the Pacific Coast of the United States, Doty *(15)* has given further evidence for the relationship between the vertical distributions of marine algae and critical tide levels.

There have been a number of lists of marine algae published, and attempts have been made not only to relate the floras of one area to another, such as that by Okamura *(25, 26)* in the North Pacific, but also to account in a general way for distributions on the basis of ocean currents, such as that by Isaac *(22)* in the area around South Africa. However, there soon followed a decided shift to intertidal studies of regional areas, such as that by Feldmann *(17)* in the Mediterranean and Chapman *(11)* and his students in New Zealand. Some attempts have also been made to describe universal features of intertidal zonation throughout the world *(32)*. At the same time, there has been a tendency to place greater emphasis on the interrelationships between the various organisms.

Many of these intertidal studies have been of great value as an initial descriptive stage of investigation, and there is a need for further descriptive studies of this type in new and undescribed regions. However, the variety of systems of nomenclature and terms that have been proposed by marine ecologists to describe zonation, associations, and other ecological concepts have frequently only complicated the descriptive study rather than succeeded in explaining the observed phenomena. This has led to some confusion in terminology. It is a debatable point whether there can be such a thing as a universal system of classification beyond a generalized scheme, such as that proposed by Ekman *(16)*, and it is questionable whether some of the systems proposed can contribute further to progress in marine algal ecology even in regional studies without simplification or clarification.

Although the shift in emphasis to the interrelationship of organisms was an important one, in some instances this approach has been responsible for excluding adequate concurrent studies of the physical and chemical aspects of the environment. It is for this reason that a case may be made for reassessing our position in marine algal ecology, and a critical evaluation of the next steps to be taken to further our progress is timely. Perhaps what may be called a three-dimensional or an oceanographic approach can be used to analyze more precisely various factors in the marine environment and the relationship of these factors to benthic algal productivity. A step in this direction has been considered recently with some measure of success by Dawson *(13, 14)* in Baja California, Doty *(15)* in Oregon and Womersley *(34)* in Australia.

To the oceanographer, the most complicated physical or chemical situation to explain may be the smallest unit of the environment with which he is faced. This is partly a problem of instrumentation. However, it is usually much easier not only to recognize significant discontinuity in properties, such as temperature, salinity—even plankton distributions—over extensive areas of the ocean than in restricted or local regions, but also to use such information in describing dynamic processes. Hence, it is suggested that more attention should be given to studies of the general distribution of various physical and chemical properties in the marine environment in an attempt to set up some workable hypotheses to account for observed distributions of marine algae. In this way we may hope to explain and account for biological phenomena rather than be satisfied by a description of the phenomena or by terms to describe them which do nothing more than give names to dynamic aspects of marine ecology much in need of logical explanation. With increased activity recently in oceanography in the Pacific, we may now hope for more abundant and usable data on some of the more general oceanographic properties of the North Pacific. In specific cases, and particularly in more restricted areas, the ecologist will be forced to turn more attention to obtaining *in situ* physical and chemical data before further progress can be made.

One can arbitrarily start by summarizing all the factors in the marine environment as geological, physical, chemical, and biological. The way in which these are considered may be somewhat a matter of interpretation. Salinity, for example, may be considered directly, as a chemical factor, or indirectly as a physical factor responsible for changes in density and thus contributing to the pattern of circulation. Likewise, the nature of the substratum may be considered indirectly as a geological factor, or directly as a physical or mechanical factor restricting or permitting establishment of benthonic organisms because of particle size. There has been much written on many of these aspects of ecological study in special cases, but it is suggested that, in a general overall reassessment of the environment, an attempt be made to proceed from this more general position to the particulate. This approach may initially lead only to the erection of further hypotheses, as the indirect or direct nature of the action of any particular factor in the environment may ultimately be established only by further experimental work either in the field or in the laboratory. This is the approach that is being promoted in the studies on marine algae being carried out on the Coast of British Columbia, Canada, some aspects of which will be mentioned briefly in this review.

Although on occasion in the past the position of the taxonomist has been questioned in the scientific field, it is apparent that the need for fundamentally sound taxonomic studies of the marine algae is almost as great now as it has ever been, particularly since the recent progress in knowledge of the fields of biochemistry, cytology, and genetics. However, in the sense implied here, the work of taxonomist has reached a logical conclusion only when it is applied, and it is this application that is frequently left for the ecologist. As a step in the direction of increasing our knowledge of the taxa which comprise the tools of the algal ecologist and of completing this descriptive phase of the study of the marine benthonic algae, an annotated check list has just been completed for the Coast of British Columbia and Northern Washington *(28)*. Based on this list, further studies are now in progress to augment the existing data on the marine flora of British Columbia, not only insofar as distributions are concerned, but also relating to life-histories, growth, reproduction, and seasonal aspects.

These problems are now being tackled in marine laboratories which have running seawater available, as well as in the controlled-environment tanks and rooms on the campus of the University of British Columbia. These fundamental studies are basic to all other aspects of ecological research, and more especially when an attempt is made to use specific organisms as indicators of oceanographic conditions.

Not only does this descriptive phase require an adequate consideration of the taxonomic aspects, but a more complete description of the other factors in the environment is needed. With increased activity recently and currently in general oceanographic studies of the North Pacific by a number of institutions on the Pacific Coast of Canada, in Japan, and in the United States, there has resulted a considerable body of knowledge, but it is still far from adequate for the ecologist, particularly for one interested in coastal dynamics. Circulation problems, temperature, salinity, oxygen, and in some areas, phosphate and nitrate distributions are fairly well known in a broad and general sense, but at the present time very few restricted areas are known oceanographically in sufficient detail. More precise physical and chemical data, even in these more restricted areas, are also inadequate. The distribution of other chemical constituents, and to a large extent even a knowledge of the plankton composition, distribution, and activity, is almost completely lacking. It is obvious that the more data that become available the more clearly one can tackle problems relating to specific distributions and set up field and laboratory studies to test hypotheses.

It is already apparent that much can be done experimentally both in the field and in the laboratory with benthonic marine algae. Many of the problems encountered by the ecologist dealing with the larger marine algae present unique culture problems and require an entirely different approach, both in the field as well as in the laboratory. Some studies on growth and reproduction, particularly of some of the larger Laminariales, have been done in this region, both in the field *(27)* as well as in the laboratory. Although the size of many of the cold-water marine algae add new problems, at least some of the stages can be carried out to the point where transplants can be made from the laboratory into the sea for further study. Transplant experiments of natural populations of these larger marine algae, even in the case of *Macrocystis*, are quite feasible.

The successful use of the experimental approach in the laboratory is primarily dependent on having facilities for maintaining temperature and light control, although the size of plants may again present certain special problems. Cultures of Laminariales have been maintained in controlled-environment tanks at the University of British Columbia for as long as a year, during which the complete sexual generations were cultured and the young sporophytes reached a length of fourteen inches, well past the stage where secondary morphological characteristics had developed. These studies have permitted indisputable identification of the sporophytes to genus and in some cases to species. The study of cultures in this group suggests that much of the early work on gametophytes in the Laminariales, and in fact even on the early sporophytes, may be in some question. In most of the early studies, reported plants were not grown long enough to establish beyond doubt the characteristic secondary morphological features of the sporophytes of the genera from which zoospores were initially obtained. In the presence of contaminating zoospores of other species, there is not other way of establishing that the same species or even the same genus in the Laminariales was obtained in the sporophyte generation succeeding the gametophyte generations in culture.

It would be remiss not to mention much of the worthwhile physiological work that has been done on marine algae. However, there is a need for a great deal more physiological work, particularly of the type done by Gail *(18, 19, 20)* in an attempt to related physiological processes more specifically and directly to the environment and ecological problems encountered in the field. In physiological studies, there is frequently a tendency to proceed more and more deeply into special aspects of the physiological behaviour or biochemistry of an organism under artificial conditions, rather than to project back to the field and attempt to explain behaviour under the conditions existing in the natural environment.

Almost all of the quantitative aspects of benthic algal productivity in this area have related to species of economic interest *(27, 21)*. These studies have dealt largely with quantities and distribution and have contributed little to an evaluation or an explanation, in terms of oceanographic factors, of the causes for this production.

Obviously the ideal of a functional interpretation is dependent on an adequate and balanced knowledge of all of the foregoing aspects—of the qualitative and quantitative features of both the organisms and the environment. Many, much-needed, data are still lacking. An attempt to follow this line of investigation has been started on the Coast of British Columbia, and in a somewhat more restricted area at the north end of Vancouver Island in Queen Charlotte Strait. Further detailed work is in progress in the Strait of Juan de Fuca at the south end of Vancouver Island between Vancouver Island and Northern Washington.

The Pacific Coast of Canada is ideally suited to a study of benthonic organisms and the effect of oceanographic factors on their distribution both in the intertidal and the subtidal zones. Although the coast of British Columbia is only about 600 miles long, proceeding directly from the Strait of Juan de Fuca to Dixon Entrance, if all its various ramifications are included, there is a coastline estimated at about 25,000 miles in length. The tidal amplitude in this region is great, ranging from about 11 feet at the southern boundary to nearly 26 feet at the northern boundary. As a result of thorough mixing in the coastal region, the upper zone in this area, except for a few local anomalies, is characteristically rather uniform in temperature at any one period and fluctuations occur within narrow limits. The annual range in temperature of the sea water near the surface is from about 6 degrees C to 18 degrees C. On the other hand, because of the excessive run-off from large rivers, especially through the long mainland inlets, there are conditions ranging from practically fresh water at one extreme to full ocean salinity of about 34% at the other extreme. The oceanographic conditions characteristic of the Coast thus provide a particularly ideal area in which to study the distribution of marine benthonic organisms in relation to salinity over a rather extensive geographic area.

Throughout the Coast, the physical nature of the substratum—ranging from mud and sand at one extreme to solid rock at the other—determines to a large extent the organisms which are found in a specific area. However, a comparison of the flora and fauna on various types of bottom is possible in a number of regions which are otherwise oceanographically rather similar. This permits a correlation of the distribution of a wide variety of plants and animals with other physical and chemical factors of the environment.

Biological observations, extending over the whole length of coastline, indicate that there is a high degree of uniformity in the populations of many benthonic plants and animals extending from the Strait of Juan de Fuca to Dixon Entrance. This would be expected under the relatively uniform conditions of temperature indicated. In attempting to correlate the distribution of some of these organisms with salinity characteristics, as well as other oceanographic factors, there are several areas on the Coast which could be used for purposes of this study. Although some supporting observations have been made in the Strait of Juan de Fuca and Dixon Entrance, and further work is being done in the former area at the present time, the present review is restricted largely to a consideration of the vicinity of Queen Charlotte Strait near the north end of Vancouver Island.

Although soundings are still somewhat incomplete for the area, a general study of the bottom topography in Queen Charlotte Strait indicates extensive shallows, particularly along the Vancouver Island side of the Strait and around Malcolm Island. In this region an abundant and varied intertidal and subtidal flora and fauna are supported. In the central part of the Strait, and between Nigei and Vancouver Islands, there are deeper channels exceeding 100 fathoms in depth. These channels are not continuous, however, with the deeper waters of the mainland inlets and Johnstone Strait, and exhibit physical and chemical properties quite distinct from the latter.

The salinity distribution near the surface in Queen Charlotte Strait indicates a general circulation in a counter-clockwise fashion. The run-off from the mainland inlets along the north shore and at the east end of the Strait, particularly from Knight Inlet at the east end of the Strait, contributes large volumes of fresh water which tends to move seaward at the surface mixing as it progresses along the north shore into Queen Charlotte Sound with the deeper more saline water below. The more saline water from the open ocean and Queen Charlotte Sound moves into the Strait centrally as well as along the north side of Malcolm Island. The intrusion of high salinity water along the deep channels in the central part of the Strait is also apparent. This general pattern of salinity distribution, with fluctuations to varying degrees near the surface, is pronounced in the upper zone to a depth of at least 20 meters.

An analysis of surface salinity data over a ten-year period from Pine Island Lighthouse (*1* through *10*), which is near the entrance to Queen Charlotte Strait, indicates a salinity maximum of about 34% and a minimum of about 28% with an annual mean of 31.75%. Although this station is not fully characteristic of the whole of Queen Charlotte Strait, the data available give a close approximation of the annual salinity fluctuations in the more oceanic part of the Strait. Insufficient data are available from Pulteney Point on Malcolm Island as yet to analyze the seasonal fluctuations in the central region of the Strait, but, for the period available, a range of about 28% to 32% with an annual mean of 28.95% is indicated.

A comparison of the temperature-salinity characteristics of various parts of the Strait and the connecting bodies of water by means of T-S diagrams indicates the discreteness of the water masses typical of Johnstone Strait, Knight Inlet, and Queen Charlotte Sound. The T-S diagrams for Queen Charlotte Strait indicate a characteristically intermediate condition between these extremes in properties of temperature and salinity for the greater part of the Strait.

An analysis of surface temperature data over a ten-year period from Pine Island Lighthouse (*1* through *10*) indicates a temperature maximum of about 12 degrees C and a minimum of about 5 degrees C, with an annual mean of 8.6 degrees C. Although this station, as already indicated, is not characteristic of the Strait in all regions, it probably gives a reasonable approximation of the annual temperature fluctuations for the outer part of the Strait. As is true in regard to salinity, insufficient data are available from Pulteney Point on Malcolm Island as yet to analyze the seasonal fluctuations in the central region of the Strait, but for the period available a range of from about 5 degrees C to 11 degrees C with an annual mean of 8.25 degrees C is indicated.

The tidal amplitude in this area is about 17 feet, so that there is exposed an extensive intertidal flora and fauna during lowtide periods. Although no attempt will be made to analyze the vertical distribution of the organisms of the intertidal zone here, it may be pointed out that many of them can be related to certain tide levels.

Biological observations have been made throughout Queen Charlotte Strait, although a more intensive study has been undertaken at Hope, Deer, and Malcolm Islands. The observations have been restricted so far to the more conspicuous algae and invertebrate animals in the intertidal and immediately accessible subtidal zones. These localities present a transition from Hope Island, where the highest salinities are encountered, to the north and east sides of the Strait where the lowest salinities are found. Deer Island and Malcolm Island are intermediate between these extremes.

Some organisms in the area are more cosmopolitan in their distribution, particularly in their tolerance to extreme dilution. Extending throughout the Strait are forms such as *Alaria tenuifolia* Setchell f. *tenuifolia*, *Cymathere triplicata* (P. and R.) J.Ag., *Costaria costata* (Turn.) Saunders, *Costaria mertensii* J.Ag., *Laminaria saccharina* (Linnaeus) Lamouroux f. *saccharina*, *Nereocystis luetkeana* P. and R., *Porphyra perforata* J. Ag. f. *perforata*, *Rhodomela larix* (Turn.) C. Ag., *Odonthalia floccosa* (Esper) Falk., *Mytilus edulis* Linnaeus, *Littorina planaxis* Philippi and *Strongylocentrotus drobachiensis* (Müller).

Restricted to the region of highest salinity, as at Hope Island, are *Postelsia palmaeformis* Rupr., *Lessoniopsis littoralis* (Farl. and Setch.) Reinke, *Laminaria setchellii* Silva, *Pelvetiopsis limitata* (Setchell) Gardner f. *limitata*, *Dilsea californica* (J.Ag.) O. Kuntze, *Erythrophyllum delesserioides* J.Ag., *Iridaea lineare* (S. and G.) Kylin, *Hymenena setchellii* Gardner, *Ptilota asplenioides* (Esper) C.Ag., *Ptilota californica* Rupr., *Ptilota hypnoides* Harvey, *Mitella polymerus* (Sowerby) and *Flustrella corniculata* (Smitt). *Pleurophycus gardneri* Setch. and Saund., *Pterygophora californica* Rupr., two forms of *Hedophyllum sessile* (C.Ag.) Setch. and *Styela montereyensis* Dall are also present in the regions of highest salinity but are somewhat less restricted in their distribution and extend into the Strait almost as far as Deer Island.

A few organisms extend still further into the Strait but only slightly beyond Deer Island. Among these are *Alaria nana* Schrader and *Alaria marginata* P. and R. Still others extend from Hope Island past Deer Island down into the Strait as far as Malcolm Island, but not as far as the east and north sides of the Strait. Among these are *Macrocystis integrifolia* Bory, *Egregia menziesii* (Turner) Aresch. subsp. *menziesii*, *Alaria valida* (Kjell. and Setch.) f. *valida*, the bullate form of *Hedophyllum sessile* (C.Ag.) Setch., *Constantinea simplex* Setch., *Mytilus californianus* Conrad, *Strongylocentrotus purpuratus* (Stimpson) and *Haliotis kamtchatica* Jones. Isolated populations of the abalone *(Haliotis kamtchatica)*, which have been noted further eastward in Johnstone Strait, and which may be related to local oceanographic features, such as upwelling, present somewhat of an anomaly to the general distribution. A further exception to the distribution described in this group is that of *Macrocystis integrifolia*. Although *Macrocystis* occurs in regions of high or relatively high salinities and extends as far down the Strait as

Malcolm Island and over to Numas Island, it does not occur in the most exposed areas on the open coast where *Postelsia* and *Mitella* are encountered.

There is a distribution of organisms here which follows closely the pattern of salinity distribution in the Strait, which in turn reflects the circulation within the area. It would be premature to say that salinity is directly responsible for the observed distributions of all the organisms encountered. But one may say that the distribution reflects the dependence on waters characteristic of the open ocean and exposure. In some instances, it may be directly salinity that is a causal factor. The open coast, on the other hand, has organisms associated with surf conditions. It has been suggested that the high oxygen requirement of certain organisms is met only in such an exposed environment. However, the measurement of oxygen values in the sea in this area, does not directly support this argument, as the oxygen content of the waters within the sheltered Strait is as high or higher than in the surf in the exposed regions. This is particularly true in the central part of the Strait when there is a heavy bloom of phytoplankton in the area, at which time the water may be supersaturated to as much as 175 per cent. Likewise, although it is known that many marine algae have a high inorganic phosphate requirement, there is no evidence that this nutrient is ever limiting in this area within the zone occupied by the benthonic marine algae. There is a great need for further knowledge of the presence, distribution, amounts, and availability of many more dissolved inorganic and particulate organic substances. The evidence so far points also to the need for a study of quantitative removal and the rate of removal of such substances and precise requirements for growth and reproduction of the benthonic marine algae.

The restriction of certain organisms to surf conditions suggests that constant movement of water is required to provide nutrients and gases which may be rapidly exhausted from the immediate micro-environment of the individual alga, or in the case of the sessile marine invertebrate, such as *Mitella polymerus*, to provide particulate food. It may be that lowering the concentration or removal by dilution or water movement of some substances which accumulate above a certain level of concentration in the micro-environment is just as significant as the availability of others.

In summary, a detailed study of the distribution of marine benthonic organisms in Queen Charlotte Strait has been limited so far to the more conspicuous algae and invertebrates encountered. The relationship of these distributions to the salinity distribution indicates that more intensive study of the flora and fauna in this area, as well as elsewhere on the Coast, will provide further supporting evidence of the effect of oceanographic variables on the distribution of marine benthonic organisms and the possibility of using such organisms as indicators of oceanographic conditions both in time and space. It is hoped that this oceanographic approach—both qualitatively and quantitatively—may then lead not only to a clearer understanding and explanation of the fundamental relationships between the organisms and their environment, but also to an understanding of the interrelationships and interaction among the organisms themselves.

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DISCUSSION

G.F. PAPENFUSS: Is anything known concerning growth rates of the larger brown algae in the North Pacific?

F.R. SCAGEL: In *Nereoaptis* during July and August, the blades can increase in length by 2 to 3 inches per day. Small sporophytes a few inches in height in April can develop into mature, reproducing plants of over 100 feet in length by late June of the same year.

ON THE EFFICIENCY OF PRIMARY PRODUCTION IN THE OCEANS

JOHN H. RYTHER

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

INTRODUCTION

What is the maximum possible rate of organic production in nature? Is this maximum ever attained in the ocean? What are the limiting factors of the marine environment which normally prevent this potential from being realized or even approached?

These fundamental questions may be attacked in either of two ways. First, through extensive and repeated oceanographic surveys we may accumulate a body of data pertaining to the magnitude of primary production in the sea. Eventually these data should include the approximate range of this process, and through correlation with chemical and physical characteristics of the water, one should be able to extrapolate or predict production values for similar oceanic areas.

Second, we may consider the efficiency of utilization of radient energy in the photosynthetic process and in the organic yeild of mass algal cultures, the environmental conditions which influence and control this efficiency, and the existence and relative importance of these factors in the sea. In this way, too, it should be possible to predict the potential and, if sufficient information is available, the actual magnitude of primary production in the various parts of the ocean as a function of its physical and chemical characteristics.

Both of these methods have obvious disadvantages and limitations, so an attempt will be made to use a combination of the two in the following discussion. First the magnitude and efficiency of photosynthesis will be reviewed throughout its entire measured range starting with carefully controlled quantum yield experiments in the laboratory, through mass algal culture experiments, both indoors and out, to measurements of primary production in the sea, from the highest known values to the lowest. This will be followed by a consideration of the factors which affect photosynthetic efficiencies, treating these quantitatively as far as is possible. Finally an attempt will be made to evaluate the relative importance of these factors in the various parts of the ocean and to relate them to the observed values of primary production.

THE QUANTUM REQUIREMENT OF PHOTOSYNTHESIS

The quantum requirement or quantum efficiency of photosynthesis (the reciprocal of the quantum yield) may be defined as the number of quanta of light energy required to reduce one mole of CO_2 to CH_2O. Although a minority of investigators, mainly Warburg and Burk *(28)*, have reported extremely low quantum requirements (4 or less approaching 100% efficiency of utilization of the absorbed light), it is the opinion of most plant physiologists that a maximum sustained photosyntetic yield requires 8-12 quanta of red light for the reduction of one mole of CO_2. (See *3*, *30*, *5*, *6*, *2*.) Values within this range have been observed in a wide variety of plant species, the literature on which is extensively reviewed by Rabinowitch (*17*, chapter 29) and Daniels *(2)*.

As a quantum of red light contains 41 k cal and one CH_2O group has a heat of combustion of 112 k cal, an average quantum requirement of 10 corresponds to an efficiency of

$$(112 \times 100)/(10 \times 41) = 27\%.$$

Efficiencies of this general order are obtained only at very low intensities of light and when the physiological condition of the plants and their external environment are considered to be optimal for photosynthesis. Presumably, then, this (approximate) value represents the maximum biological potential of plants in converting light into chemical energy, a maximum which is imposed by the limitations of the physical-biochemical process of photosynthesis.

THE EFFICIENCY OF MASS ALGAL CULTURE YIELDS

Experiments in mass algal culture by the Solar Energy Research Group at Agricultural College, Wageningen, Netherlands, have demonstrated that the maximum sustained efficiency observed in photosynthesis experiments is closely approached in terms of the organic yield of relatively long-term growth experiments. (See *11*, *30*, *29*, *27*.) Mass cultures of *Chlorella* were grown by this group under artificial illumination with yield efficiencies, calculated on the basis of the heat of combustions of the cells produced, frequently ranging from 10-15% and occasionally greater than 20%. As the organic yield in such experiments does not take into consideration respiratory losses which are automatically corrected for in manometric photosynthesis measurements, the proximity of some of their efficiency values to that observed in quantum yield studies is truly remarkable.

However, when these cultures were grown out of doors under natural illumination, efficiencies declined markedly to values of 1-3% under full sunlight, as high as 6% in shaded cultures (22% in sunlight)[1].

Somewhat greater yields were obtained by a group of Japanese workers *(13)* who grew *Chlorella* (and other unicellular algae) throughout the year in outdoor bubbling cultures. Their yields, in grams dry weight of organic matter produced per square meter per day, averaged 16.5 in summer, about 2.4 in winter when temperatures were apparently unfavorable. If we may assume that their *Chlorella* were similar in composition to the "normal" cells of Ketchum and Redfield *(9)* its heat of combustion calculated by indirect colorimetry would be 5.4 k cal/gram, which is comparable to the values reported by Kok *(11)*. Using this figure, their yield data, and the average radiation values for each experiment, a wide range of efficiencies were obtained from 0.06% to 14.0%, averaging about 4%. To the author's knowledge, the maximum yields obtained by this group represent the most efficient photosynthetic utilization of natural illumination which has been reported.

THE MAGNITUDE AND EFFICIENCY OF PRIMARY PRODUCTION IN THE OCEAN

We may now turn to the ocean and present a brief and partial review of primary production values in various coastal and deep sea areas. No attempt will be made to review the literature completely, and all earlier values of uncertain validity are omitted. In general an attempt has been made to represent as many different types of marine environments and as wide a range of production values as possible. Many of the data are as yet unpublished.

Several different methods have been used to measure or calculate production by the various authors. These will not be described here, but the reader may refer to the cited references for this infomation. Odum *(14)*, Odum and Odum *(15)*, and Riley *(19)* have based their values on measurements of *in situ* oxygen changes in the water, using quite different techniques in each case. Yentsch used the familiar "light and dark bottle" method of measuring oxygen production in his East Sound, Washington, studies. Steemann Nielsen *(25)* and, in part, the present author employed the C^{14} method *(24)*. The remainder of the values were calculated from radiation, light penetration, and chlorophyll data using the method recently described by Ryther and Yentsch *(23)*.

Radiation values, except where specifically measured with a standard type radiation meter, were taken from Kimball *(10)* who gives mean radiation values at sea level on a world-wide and seasonal basis corrected for average cloud cover.

The use of Kimball's tables many be somewhat unsatisfactory in estimating efficiencies of production measured by the C^{14} method as the latter were obtained on specific days when the radiation may have deviated considerably from the mean. This objection does not apply to values obtained by the chlorophyll-light method which themselves were calculated by using Kimball's tables. All other efficiencies were based on direct measurements of radiation except for Odum *(14)* and Odum and Odum *(15)* who estimated radiation from the equation given by Kennedy *(8)*.

The organic yield (g carbon/m^2/day) has been calculated from oxygen production using an assimilatory quotient of 1.25 (see *22*) which represents organic carbon or approximately 50% of the ash-free dry weight of plant material. This may be converted into comparable energy units by multiplying by 2×5.4, assuming that the heat of combustion of the organic yield is the same as that of normal *Chlorella* cells or 5.4 k cal/g (see above).[2] Efficiency was then calculated by dividing the daily organic production by 50% of the incident radiation, both expressed as gram calories/cm^2/day.

Table 1 gives the seven highest single values for primary production known to the author for the marine environment. Of these, the highest values

[1] Photosynthetic efficiencies of the utilization of solar energy are calculated here and elsewhere in this paper on the basis of the visible spectrum only (400-700 mμ) or roughly 50% of the total incident radiation.

[2] If production is calculated as glucose-carbon (assimilatory quotient = 1), a higher value for carbon assimilation is obtained. This may be multiplied by 2.5 (as glucose is 40% carbon) $\times$ 3.7 (the heat of combustion of glucose) giving nearly the same energy content as of calculated on the basis of the actual composition of the plants.

were found in the benthic populations studied by Odum *(14)* and Odum and Odum *(15)*, 10.3 g carbon/m^2/day for the turtle grass community and 9.8 g carbon /m^2/day for the coral reef, corresponding to efficiencies in the utilization of the radiation reaching the surface of the water of 4.0% and 3.1% respectively.

The other production values in Table 1 range from 2.8 to 5.4 g carbon/m^2/day with less than two-fold variation. The implications of the striking similarity of these values, obtained from widely differing types of environments, will be discussed in the final section of this paper.

In contrast to the high values reported in Table 1, Table 2 shows what may be considered as average or normal production rates for various estuarine, inshore, coastal, and oceanic areas. Again the most striking feature of these is their similarity. The shallow water areas have production values ranging from about 0.1 to 1.5 g carbon/m^2/day, and it is interesting to note that the same range was observed seasonally in the two regions where production was followed throughout the year, Long Island Sound and the continental shelf off New York.

It is perhaps surprising that the productivity of a polluted embayment, Great South Bay, averaged only 0.24 g carbon/m^2/day in midsummer despite the fact that chlorophyll concentrations in the euphotic layer averaged about 10 mg/m^3 or some 10-20 times that of unpolluted coastal areas. This is probably due to the shallow depth of Great South Bay and the high turbidity of its waters, factors which will be discussed in more detail later.

Production measurements in Allen Bay, in the Canadian Arctic made by Mr. Spencer Apollonio almost daily during the brief open-water season (July-August) showed no indication of an initial flowering of any magnitude following the breakup of the ice, though values did decrease throughout the period from 0.69 to 0.02 g carbon/m^2/day, averaging 0.19. One possible explanation for the low production of this area is that much of the euphotic zone was diluted with melt water low in nutrients concentration.

The oceanic values for the North Atlantic were obtained during a passage from Woods Hole, Mass. to Plymouth, England by HMS Discovery III in April, 1957. They are probably higher than average for the year as the cruise apparently coincided with the spring diatom flowering (see the deep water continental shelf values for April in comparison with the rest of the year). The four high values from the Grand Banks were obtained during the same cruise.

However, five measurements from the Sargasso Sea made by Atlantis during the same period showed no evidence of a spring maximum in those

Table 1.
Some maximal values and efficiencies of primary production in coastal and oceanic waters.

Environment	Location	Reference	Date	Radiation	Prod. Method	g C/m^2/day	Eff. (%)
Turtle grass	Long Key, Fla.	Odum (1957)	Aug., 1955	560*	*In situ*	10.3	4.0
Coral reef	Japton Reef, Eniwetok Atoll	Odum & Odum (1955)	July, 1954	660*	*In situ*	9.8	3.1
Spring flowering (upwelling?)	Grand Banks 44°40′N., 48°57′W.	Ryther & Yentsch (unpub.)	Apr., 1957	380***	Chl	5.4	3.1
Polluted estuary	Forge River, Moriches Bay, L. I., N. Y.	Ryther & Yentsch (unpub.)	Aug., 1956	400***	Chl	5.1	2.7
Upwelling	East Sound, Washington	Yentsch (unpub.)	July, 1954	700**	Chl Oxy	5.1 4.8	1.6 1.5
Upwelling	Walvis Bay, Angola	Steemann Nielsen (1954)	Dec., 1950	430***	C^{14}	3.8	1.9
Spring flowering	Cont. Shelf off N. Y.	Ryther & Yentsch (unpub.)	Apr., 1957	402***	Chl C^{14}	3.1 2.8	1.7 1.5

* From Kennedy (1949); ** measured; *** From Kimball (1928).

Table 2.
Magnitude and efficiency of primary production in selected coastal and oceanic waters.

Situation	Location	No. sta.	Reference	Date	Mean total radiation (g cal/ cm²/day)	Prod. method	Prod. (g carbon/ m²/day)	Eff. %
Polluted embayment	Great South Bay, L. I., N. Y.	8	Ryther & Yentsch (unpub.)	Aug., 1956	400	Chl	0.26	0.14
Unpolluted embayment	Long Is. Sd., N.Y.	8	Riley (1956)	Mar.-May, 1952	400	*In situ*	1.06	0.57
				May-Aug., 1952	544		1.73	0.69
				Aug.-Nov., 1952	310		1.22	0.85
				Nov.-Feb., 1952-3	139		0.22	0.35
				Feb.-Mar., 1953	252		1.33	1.12
Arctic embayment	Allen Bay, Cornwallis Is., N.W.T.	1	Apollonio, Ryther & Yentsch (unpub.)	July-Aug., 1956	302	Chl	0.19	0.14
Cont. Shelf (25 m depth)	Off N.Y.	11	Ryther & Yentsch (unpub.)	Sep., 1956	317	Chl	0.17	0.12
				Dec., 1956	120		0.61	1.10
				Feb., 1957	223		0.60	0.58
				Mar., 1957	327		0.96	0.64
				Apr., 1957	402		1.25	0.68
Cont. Shelf (500 m depth)	Off N.Y.	5	Ryther & Yentsch (unpub.)	Sep., 1956	317	Chl	0.14	0.10
				Dec., 1956	120		0.17	0.30
				Feb., 1957	223		0.09	0.09
				Mar., 1957	327		0.53	0.35
				Apr., 1957	402		1.10	0.59
Cont. Shelf	N.Atlantic	4	Ryther & Yentsch (unpub.)	Apr., 1957	380	Chl	4.63	2.65
	S. Atlantic (Benguella Current)	2	Steemann Nielsen (1954)	Dec., 1950	476	C^{14}	1.37	0.63
Oceanic	N.Atlantic	36	Ryther & Yentsch (unpub.)	Apr., 1957	380	Chl	0.47	0.27
	Sargasso Sea	5	Turner, Ryther & Yentsch (unpub.)	Apr., 1957	477	Chl	0.044	0.02
	Sargasso Sea	1	Steemann Nielsen (1954)	June, 1952	440	C^{14}	0.048	0.02
	Caribbean	3	Ryther (unpub.)	Feb., 1955	387	C^{14}	0.43	0.24
	Pacific (11°05′S., 171°07′W.)	1	Steemann Nielsen (1954)	Mar., 1952	454	C^{14}	0.15	0.07
	(6°30′S., 16°42′W.)	1	,, ,,	,, ,,	410	C^{14}	0.14	0.07
	(19°57′N., 158°10′W.)	1	,, ,,	,, ,,	460	C^{14}	0.10	0.04
	(4°23′N., 164°44′W.)	1	,, ,,	,, ,,	410	C^{14}	0.26	0.14

waters, the mean of 0.044 g carbon/m²/day agreeing almost exactly with Steemann Nielsen's values for the Sargasso Sea (0.048) obtained by the C^{14} value during June, 1952. Actually these values varied by almost ten-fold from a minimum of 0.009 to a maximum of 0.081.

The remaining oceanic values, from Ryther and Steemann Nielsen, were obtained by the C^{14} method and hence are probably somewhat lower than would have been given by other methods. In spite of this, these data indicate (as do the majority of Steemann Nielsen's values not included here) that oceanic production is considerably lower than that of coastal and inshore waters. However, this cannot be considered as a final conclusion until substantiated by one or more studies of the annual cycle of primary production in a truly oceanic area.

Efficiencies of primary production of inshore waters range from about 0.1 to 1.0 per cent, again showing this range seasonally as well as regionally. Efficiencies for oceanic production are less certain. They appear to be lower, but also vary by at least an order of magnitude, ranging from 0.02 to 0.27% in the few data presented here.

We may now summarize the rough averages of photosynthetic efficiencies from all sources discussed above, from quantum-yield laboratory experiments to the Sargasso Sea. Listed in decreasing order of magnitude, they appear as follows:

Quantum yield of photosynthesis	27.0
Indoor algal culture yields	15.0
Outdoor algal culture yields	3.0
Maximal marine values	2.2
Average coastal and inshore waters	0.5
Average oceanic waters	0.1

In the following discussion an attempt will be made to review and evaluate the environmental factors responsible for the decline of efficiency from the top to the bottom of this list.

FACTORS AFFECTING PRIMARY PRODUCTION AND ITS EFFICIENCY

Respiratory Loss

In quantum efficiency experiments, photosynthesis is corrected for the effects of respiration. However, in the mass algal culture work described above, the yield of organic matter represents the net effect of both photosynthesis and respiration. Similarly the C^{14} method for estimating primary production in the sea appears to measure photosynthesis minus respiration (see *20*). The C^{14} values given in Tables 1 and 2 which were obtained by the author have not been corrected for respiration while those of Steemann Nielsen *(25)* have been increased by 4% to allow for respiratory loss. The other values reported above were obtained by methods which correct for respiration, and this section does not apply to them.

Respiration is probably never less than 5-10% of maximum sustained photosynthesis with light and all other factors optimal. In an earlier paper, the author showed the relationship between total daily photosynthesis within the entire euphotic layer and the incident radiation falling on the surface of the water *(21)*. This curve is reproduced in Fig. 1. If one assumes that respiration is 7.5% of optimal photosynthesis (taking the middle of the range suggested above), the curve for total daily respiration within the euphotic layer relative to photosynthesis may be shown as a straight line (i.e., independent of radiation), as in Fig. 1. The ratio of respiration to photosynthesis, given as a percentage, then represents the respiratory loss.

It may be seen that with an incident total radiation of 100 g cal/cm²/day or less the plants are at or below compensation. With the highest radiation values reaching the surface of the earth, respiratory losses are barely less than 30%, and within the range normally encountered over most of the earh (250-500 g cal/cm²/day), the respiratory loss lies between about 30% and 50%.

These losses apply only to plants within the euphotic layer (the depth of penetration of approximately 1% of full sunlight). If part of the plant population under consideration (whether an algal culture, a phytoplankton population, or a bed or attached algae of rooted plants) extends below this depth, these plants will impose an additional respiratory loss to the system. Thus in an unstable water column with a phytoplankton population which is wind-mixed to twice the depth of the euphotic zone, net growth of the population cannot occur if the incident radiation is less than about 275 g cal/cm²/day.

Similarly a dense culture of *Chlorella*, although brightly illuminated at its surface and supplied with an excess of nutrients and CO_2, may cease to grow not because photosynthesis is stopped, but because the light cannot penetrate to sufficient depth to permit photosynthesis to compensate for the respiratory loss of the culture as a whole.

The relationship between photosynthesis and respiration shown in Fig. 1 is based upon natural daylight conditions and therefore does not apply

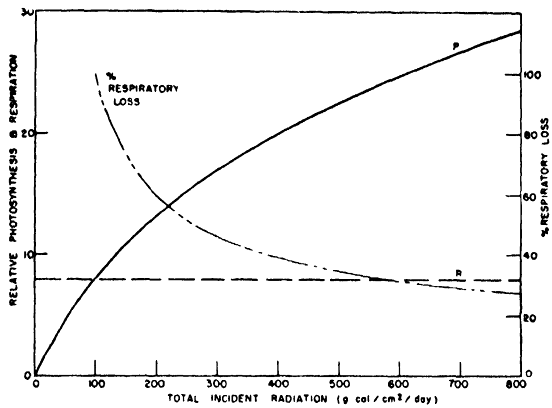

Fig. 1.—Total daily photosynthesis (P), respiration (R), and the ratio of respiration to photosynthesis (% respiratory loss) of phytoplankton within the euphotic zone as a function of total daily incident radiation.

to cultures constantly illuminated by artificial lights. Nevertheless it is clear that a large portion of the cells of these cultures are always in sub-optimal light if not in darkness, and it seems reasonable to assume that the discrepancy between the efficiency of yields of algal cultures grown under artificial illumination (15%) and the quantum efficiency of photosynthesis (27%) may be due to this factor alone.

Similarly the C^{14} values reported by the author are only 1/2 to 3/4 as high as the true values for total photosynthesis, and Steemann Nielsen's values including a 4% correction for respiration are probably also low.

Reflection Loss

In quantum yield experiments, care is taken to consider the utilization of only that light which is actually absorbed by the plants. This cannot be easily determined in culture yield experiments or in measurements of natural photosynthetic rates, and it has sufficed for most workers to base efficiencies on the utilization of the light falling on a square unit of water surface. This introduces a rather small but significant error in that a fraction of the incident radiation is lost through reflection from the surface or from back scattering out of the water.

Powell and Clarke *(16)* measured these losses from the sea surface. At solar angles greater than 30° they found that about 4% of the incident light was lost through the combined effects of reflection and back scattering on clear days, about 6.5% on cloudy days. This appears to be independent of the sea state, from flat calm to winds strong enough to produce white caps.

Reflection losses increase greatly at solar angles below 30°, as predicted by theory, but as relatively little absolute radiation reaches the earth's surface at such low solar altitudes, these higher reflection values may be discounted. It would appear, therefore, that 5% is a reasonable average value to assign to this loss.

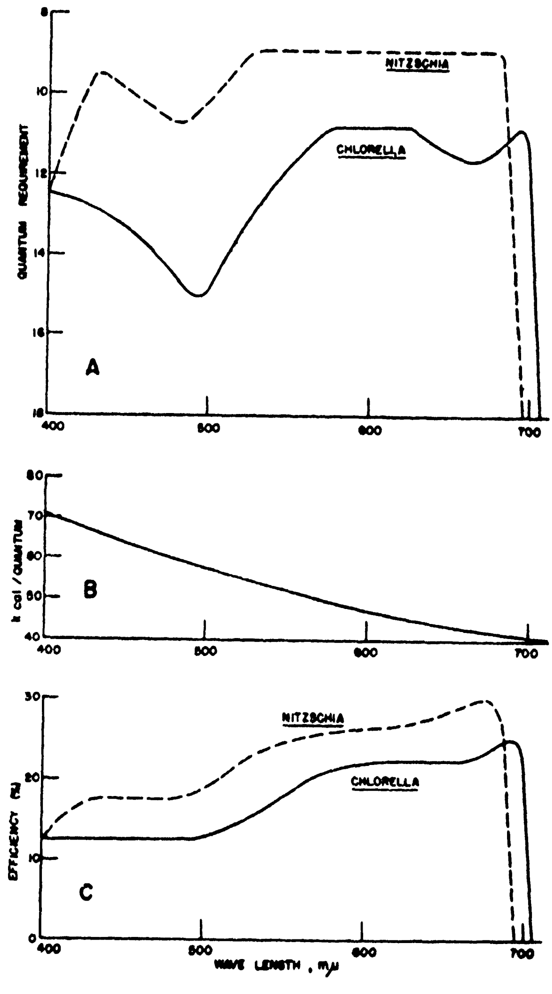

Fig. 2.

A) The quantum requirement of photosynthesis as a function of wave length for *Chlorella* (after Emerson and Lewis, 1943) and for *Nitzschia* (after Tanada 1951).

B) Energy per mole Quantum of light as a function of wave length.

C) The efficiency of photosynthesis as a function of wave length.

WAVE LENGTH EFFECT

It was pointed out that sustained photosynthesis under carefully controlled laboratory conditions requires 8-12 quanta of red light to reduce one mole of CO_2, corresponding to a mean efficiency of 27%. These experiments are usually carried out at or near a wave length of 680 mμ, the maximum absorption peak for chlorophyll.

Emerson and Lewis *(4)* and Tanada *(26)* have studied the quantum requirement of photosynthesis at different wave lengths using *Chlorella* and *Nitzschia* respectively. Their curves are reproduced in Fig. 2A. The differences between the two species may not be significant as techniques may have differed somewhat, but in each case the minimum requirement falls within the range given above, remains relatively constant between about 680 and 550 mμ, increases to a maximum at 490 mμ, and then partially recovers between 490 and 400 mμ. Above 685 mμ, the quantum requirement increases markedly for both species.

Figure 2B shows the energy per quantum of light between 400 and 700 mμ illustrating the fact that this drops from a maximum of 71 k cal per mole of quanta at the blue end to a minimum of 41 k cal at the red end of the visible spectrum.

As red light is most efficient in terms of its energy content per quantum and as the quantum requirement of photosynthesis increases in blue light, the efficiency of photosynthesis decreases from its maximum (25-30%) in red light to a minimum of 12.5% in blue light, as shown in Fig. 2C.

The spectral distribution of daylight varies with solar altitude and with the water vapor, carbon dioxide, and dust content of the atmosphere. Fig. 3 shows the spectral distribution of daylight under average atmospheric conditions with an air mass of 2 (solar angle=60°) as given by Moon *(12)*. If the curves for the two organisms shown in Fig. 2C are averaged and the mean efficiency calculated for the entire visible spectrum, weighted for the spectral distribution of sunlight as given in Fig. 3, this value turns out to be 18.4%. Thus average solar radiation is only about 68% as efficient for photosynthesis as red light of 680 mμ.

In extremely turbid waters, particularly those containing dissolved pigmented organic matter (the so-called "yellow substance" of Kalle, 7) blue and green light may be selectively absorbed which would result in somewhat higher efficiencies

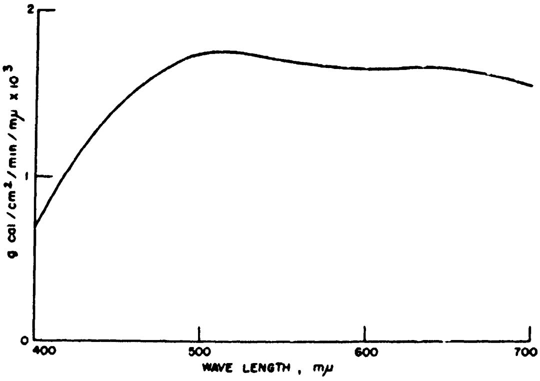

Fig. 3.—The spectral distribution of daylight under average atmospheric conditions with air mass=2 (solar angle=60°).

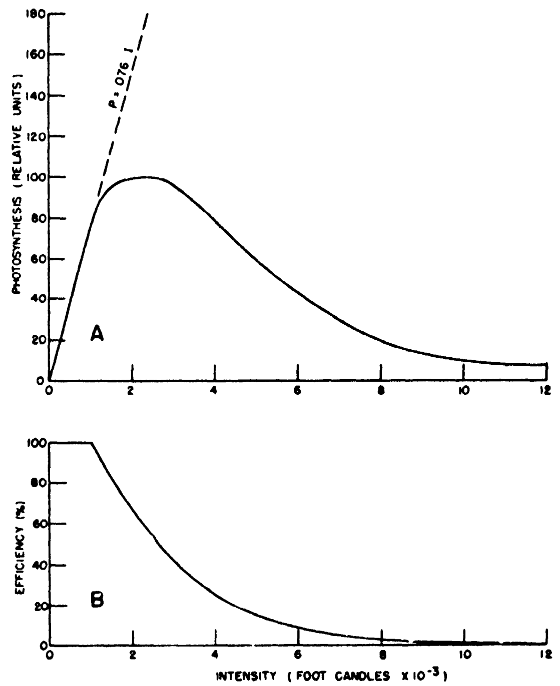

Fig. 4.

A) Photosynthesis of marine phytoplankton as a function of light intensity (after Ryther, 1956a). Broken line is the extrapolation of the linear portion of the solid line, representing hypothetical sustained maximum photosynthetic efficiency.

B) Efficiency of photosynthesis as a function of light intensity, as culculated from Figure 4 A, assuming a maximum efficiency of 100%.

in the utilization of the light which penetrates to greater depths. However, in normal, clear coastal and oceanic waters, red light is selectively absorbed and scattered by the water, and the blue and green penetrate to the greatest depths where they would be used still less efficiently than the incident daylight discussed above.

The Intensity Effect

The exact mathematical relationship between light intensity and photosynthesis is rather controversial (see *27*), but an examination of many intensity-photosynthesis curves (as in *17*, chapter 28) leaves little doubt that the relationship closely approximates linearity up to the saturation intensity. Above this, photosynthesis does not increase further, and at intensities 1/4 to 1/3 of full sunlight and above it may become severely depressed (see *21*).

As soon as the intensity-photosynthesis curve departs from linearity, efficiency begins to decrease. This may occur at intensities as low as 1/20 of full sunlight.

The laboratory experiments described above giving an 8-12 quantum requirement were all carried out at low intensities on the linear portion of the curve. If this linear portion is extrapolated, one may then calculate efficiencies at any intensity by comparing the extrapolated line with the actual photosynthesis curve. This has been done in Fig. 4A using the photosynthesis-intensity curve for marine phytoplankton given by Ryther *(21)*. The broken line obtained by extrapolating the linear portion of the curve, represents the hypothetical sustained maximum rate of photosynthesis. The efficiency, obtained from the ratio of corresponding points on the two curves, is shown in Fig. 4B, with the maximum efficiency arbitrarily given a value of 100%.

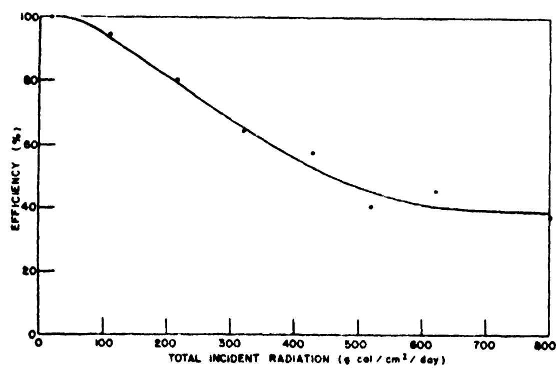

Fig. 5.—Daily efficiency of photosynthesis by phytoplankton within the euphotic zone as a function of total daily radiation, assuming a maximum efficiency of 100%.

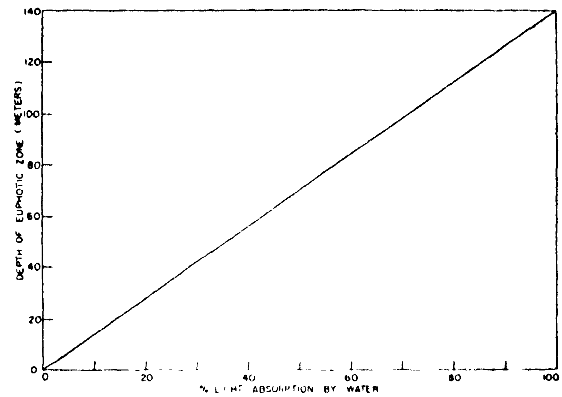

Fig. 6.—The fraction of light absorbed by water as a function of the depth of the euphotic zone, defined as the depth of penetration of 1% of maximum sunlight incident to the surface.

From Fig. 4B and instantaneous values for total incident radiation (corrected for reflection loss), one may calculate photosynthetic efficiencies throughout the day, and these may be averaged to give the mean daily efficiency. This, however, will characterize only those organisms at the surface of the water. The deeper, shaded plants will operate at higher efficiencies. But as light is absorbed exponentially, the greater part of the incident radiation is absorbed at the higher, less efficient intensities. To evaluate this quantitatively it is necessary to calculate mean daily efficiencies at several depths where the surface intensity is decreased by known amounts, weight each depth interval according to the amount of radiation absorbed within that interval, and integrate over the entire illuminated water column.

This was done for eight days, each characterized by a different incident radiation ranging from about 30 to 800 g cal/cm^2/day. The resulting curve showing the relationship between total incident radiation and daily photosynthetic efficiency for the antire phytoplankton population is given in Fig. 5, assuming a maximum efficiency of 100%.

According to these calculations, photosynthetic efficiencies begin to decrease when the incident radiation exceeds about 50 g cal/cm^2/day, and falls to 40% of its maximum on days of highest radiation. Under normal conditions in tropical and temperate regions, where average radiation values fall between 250 and 500 g cal/cm²/day, efficiencies are reduced to 70-50% of their biological potential from the effects of light intensity. Although these calculations are based upon the photosynthesis-light intensity relationships of marine phytoplankton, they probably apply reasonably well to marine plants in general.

Nutrient Deficiency

The availability of plant nutrients has a pronounced effect upon the rate and efficiency of photosynthesis, a fact with which plant physiologists and ecologists are equally well acquainted. A single example is perhaps sufficient to illustrate this point. In an earlier paper *(20)*, an experiment was described in which the marine flagellate, *Dunaliella euchlora*, was grown in a culture medium with a limiting supply of nitrogen and phosphorus, the two elements which are probably most frequently limiting to photosynthesis in the sea. The results of this experiment are reproduced in Table 3. Exponential growth of the flagellate occurred for the first five days after which essentially the same cell concentration persisted for the next twenty three days. Photosynthesis per cell decreased twenty-fold from its maximum on the second day to its minimum on the twenty-eighth day. Respiration decreased to one-half its maximum during the same period. The two processes were equal and the culture at compensation level by the end of the experiments.

In nutrient deficient plants, particularly those limited by nitrogen, the chlorophyll content of the cells decreases markedly. If these cells absorbed less light and the latter could thereby penetrate to greater depths, photosynthetic efficiency per unit of surface area would not be reduced to the same extent as when calculated per unit volume. The following section will have some bearing on this question. Actually, however, this is not the case because the concentration of the carotenoid pigments decreases very slowly in starved cells and their light absorptive characteristics do not differ greatly from that of healthy plants. This was determined by measuring the light absorption of a suspension of *Dunaliella* in the 10 cm light path of a Beckman DU Spectrophotometer, averaging the percent transmission at all wave lengths between 400 and 700 mμ. This varied from 84% in a healthy, growing culture to 88% in a nitrogen-starved culture which had not grown for fourteen days.

Thus under the conditions of this experiment, the efficiency of photosynthesis decreased to 5% of its maximum from the effects of nutrient deficiency. If photosynthesis were measured by a method which does not correct for respiration, this effect would be still more striking as the organisms at the end of the experiment, which were at compensation level, would indicate no photosynthesis whatever.

While it is perhaps doubtful that plants in this extremely impoverished condition normally exist in the ocean, nutrient deficiency is still probably the most important single factor limiting the efficiency of photosynthesis over most of the marine environment as will be discussed later.

Table 3.
Photosynthesis (P) and respiration (R) in a nutrient-deficient pure culture of *Dunaliella euchlora* expressed in ml O_2/24 hrs. (From Ryther, 1954.)

Days	Mean cell count (10^6 cells/liter)	P/cell ($\times 10^9$)	R/cell ($\times 10^9$)
0	26		
1– 2	61	113.0	13.4
2– 3	135	121.0	10.0
3– 4	290	18.3	8.6
4– 5	390	10.5	5.9
5– 6	470	10.1	5.7
6– 7	427	9.5	6.3
14–15	410	7.5	5.9
28–29	415	6.0	6.1

ABSORPTION OF LIGHT BY WATER AND PARTICULATE MATTER OTHER THAN PLANTS

Plants living in an aqueous medium are at some disadvantage over terrestrial forms as some of the incident radiation must be absorbed by the water itself. According to Jerlov, the extinction coefficient of pure sea water is .033. This loss is negligible if the plants are located near the surface and sufficiently concentrated so that the light is all absorbed within a few meters. In a sparse plankton population, however, as is typical of the open sea, light may penetrate to much greater depths and a considerable fraction of it is then absorbed by the water rather than the plants. Fig. 6 shows the percentage of the incident light which is absorbed by the water as a function of its transparency. From this curve it is obvious that in such a place as the Sargasso Sea, where the euphotic zone may exceed 100 meters, over 80% of the light is absorbed by the water, and the efficiency of the photosynthetic utilization of the radiation incident to the sea surface is correspondingly lowered.

This, however, cannot be considered as a direct cause of decreased photosynthetic efficiency, as a sparse plankton population itself merely reflects the decrease or absence of photosynthesis and plant growth which in turn must ultimately result from a deficiency of plant nutrients or light. It is mentioned here to point out the fallacy in the concept that production per unit of surface area should be comparable in dense and sparse plankton populations, an idea based on the assumption that the lower rate of photosynthesis per unit volume in the latter case may be compensated for by a deeper euphotic zone. This obviously does not take into consideration absorption by the water as Steemann Nielsen *(25)* has pointed out.

However, there is some justification for this concept because in coastal or inshore waters with a shallow euphotic layer, a large fraction of the light may be absorbed by non-planktonic particulate matter, either organic or inorganic in nature and probably often associated with the bottoms. Thus Riley, *(19)* taking the relationship between the extinction coefficient and the chlorophyll content of offshore waters and plankton blooms where light absorption by non-planktonic particulate matter was assumed to be minimal, calculated that an average of only 1/3 of the light incident to Long Island Sound is absorbed by plants, the remainder being attributed to absorption by other particulate matter.

Additional light may be absorbed in coastal waters by dissolved pigmented material (i.e., the "yellow substance" of Kalle, 7) which probably consists of organic compounds of terrigenous origin and are of relatively little significance on the open sea. Finally in extremely shallow areas, such as Great South Bay with a mean depth of about 2 meters, light may penetrate to and be absorbed by the bottom.

These various factors probably explain why production and efficiency values are so similar in Great South Bay, Long Island Sound, and the continental shelf area, regions where light absorption by the water, non-planktonic particulate and dissolved matter, and the bottom, although of different relative importance in each case, may add up to nearly the same total effect.

While light absorption by water was mentioned above as an indirect cause of lowered efficiency, symptomatic of other deficiencies, such is not the case in the absorption of light by particulate and dissolved matter which are quite independent of and in competition with the plants for the available light.

DISCUSSION

This discussion is based upon the premise, described in the first section of this paper, that the maximum sustained efficiency of photosynthesis is represented by the conversion of about 27% of the light absorbed by the plants, this light being at or near 680 mμ and at an intensity well below the saturation level. Turning from these ideal laboratory conditions to those existing in nature, and considering the utilization of sunlight falling on the sea surface by the underlying plants, we have seen that wave lengths and intensities are no longer optimal, that light is lost by reflection and back scattering, by absorption by the water itself, by dissolved or particulate matter other than plants, or by the bottom. Some of these factors are relatively constant, others may vary greatly, but all combine to lower efficiencies of natural photosynthesis to a small fraction of the "normal quantum yield" as it is known to the plant physiologist.

Let us consider, for instance, the maximum possible efficiency in nature by marine plants. Under the best of conditions, there is still a 5% loss of light by reflection and back scattering, a wave length effect resulting in efficiencies some 32% below that observed in red light, and an intensity effect, depending upon the length and brightness of the day, reducing efficiencies 30-50% below that possible in sub-saturation intensities. The accumulated effect of these factors is to decrease efficiencies 67-87% of the maximum potential of 27% or to a level ranging from 3.5% to 9.0%.

Are these low values reasonable? They may be checked by re-examining the organic yields of carefully conducted outdoor mass algal culture experiments. Here efficiencies were found to average about 2% by the Netherlands group, about 4% by the Japaness investigators. These yields, however, were not corrected for respiratory losses which, we find, could hardly be less than 30% and may reach 100% in extremely dense cultures. If we take 50% as an average respiratory loss, the efficiency of photosynthesis in these mass cultures would be 4-6%, or roughly the same as that calculated above.

Are these efficiencies encountered in the sea? The data presented in Table 1 shows that they may be attained, or at least closely approached in a wide variety of different marine environments.

These, however, all have one feature in common, a sufficiency of nutrients. The flowing-water, benthic population appear to live under the most optimal conditions, and the reasons for this are obvious—they live at the bottom of a shallow, clear column of water which removes very little of the light, and they are bathed in a constantly replenished medium from which the nutrients can never become exhausted.

Similarly polluted regions are characterized by the constant addition of nutrients from an external source. Here, however, the existence of dissolved or particulate substances competing with the plants for light is almost a certainty, as pollution by definition is of terrestrial origin and highly productive polluted areas are virtually confined to harbors, estuaries, etc., which normally contain considerable amounts of such substances. Furthermore, most sources of pollution also contribute substantial quantities of light absorbing material (i.e., organic detritus, bacteria, silt, dyes, etc.) to the water in addition to the essential plant nutrients. Therefore it is unlikely that such an environment would sustain production at efficiencies as high as those possible in the flowing-water benthic communities.

More favorable conditions for photosynthesis may exist in coastal and offshore areas where the nutrients originate through upwelling or mixing processes from the rich, deep ocean waters which are relatively free of light absorbing substances. However, high production rates under such circumstances are, for the most part, brief and transitory, either in time or space. Although high production occurs at or near an area of upwelling, it quickly diminishes as the upwelled water spreads over the ocean surface. Production may remain high at a given geographical area, but it is not sustained in a given volume of water or by a given population of plants. Similarly, most plankton blooms or flowerings are temporary, usually representing the culmination of mixing or regeneration processes during a period when plant growth can not occur (e.g., during temperate or polar winters). With the return of favorable conditions for photosynthesis, the temporarily enriched waters may support a brief and dramatic period of extremely high production.

According to Redfield *(18)*, the relative proportion of carbon, nitrogen, and phosphorus in plankton is 100:15:1 by atoms. A production rate of 5 grams of carbon per day within a 10 meter water column (such high production rates result in and are therefore restricted to an extremely shallow euphotic zone) would therefore require 6 μgA of nitrogen and 0.4 μgA of phosphorus per liter per day. There is no deep water in the ocean rich enough to meet this demand for more than a few days.

Thus efficiencies of 3-9%, representing the maximum photosynthetic potential under natural illumination, are rarely encountered in the ocean. The average efficiencies reported in Table 2 for coastal and offshore waters are, for the most part, one to two orders of magnitude below this.

Two variable environmental factors have been discussed, both of which decrease efficiencies below this maximum potential. These are (1) light absorption by dissolved and particulate matter other than plants, and (2) nutrient deficiencies. The former undoubtedly plays an important part in reducing efficiencies in coastal waters. As mentioned earlier, Riley *(19)* has estimated that only one-third of the light entering Long Island Sound is absorbed by plants. Similar calculations by the author have indicated that anywhere from 27% to 66% of the light penetrating the waters of the continental shelf is utilized by the phytoplankton, the remainder being about equally divided between other particulate matter and the water itself.

It seems doubtful, however, that this factor can be important in the clear waters of the open sea, and the conclusion seems inevitable that the greater part of the oceans is normally nutrients deficient. Unfortunately relatively little is known about the concentrations of all the essential plant nutrients in the surface water of the ocean; their rates of uptake by the phytoplankton, limiting concentrations for photosynthesis, and rates of regeneration by mixing and decomposition. Consequently the relative importance of this factor cannot be quantitatively assessed. However, the conclusion that nutrient deficiencies are responsible for the low efficiencies (compared to the potential efficiency of 3% or more) normally found in the sea is based upon the following bits of indirect evidence or reasoning: (1) such nutrient concentrations as have been measured in the surface waters of the open sea, mainly N and P compounds, are normally extremely low, often undetectable. (2) Sustained maximum efficiencies such as are possible under natural illumination would require the constant replenishment of nutrients whose only source is the ocean depths. This water cannot be mixed upward into the surface layers without, at the same time, carrying the plants down out of the euphotic zone. In most of the oceans, thermal stratification is an effective barrier against such mixing. (3) The only marine areas where this maximum potential efficiency is approached, temporarily or permanently, are those situations in which some mechanism exists for the enrichment or continued replenishment of nutrients. (4) No other environmental factor appears to exist which could decrease photosynthetic efficiencies to a comparable degree.

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COMPARISON OF ALGAL FLORISTIC PATTERNS IN THE PACIFIC WITH THOSE IN THE ATLANTIC AND INDIAN OCEANS, WITH SPECIAL REFERENCE TO *CODIUM*

PAUL C. SILVA

Department of Botany, University of Illinois, Urbana, Illinois, U.S.A.

Codium (order Codiales or Siphonales of the green algae) is a relatively large genus (that is, compared with other genera of marine algae), comprising about eighty species. It is exceedingly widely distributed, growing on all tropical and temperate shores with the notable exception of the Atlantic coast of North America north of Beaufort, North Carolina[1]. With the cooperation of scores of workers throughout the world, during the past eight years, I have been able to assemble about 2,000 fixed and dried collections. In attempting to work out a taxonomic treatment of *Codium*, I began to perceive certain geographical distributional patterns. It then became important to determine whether a standard of reasonableness could be established against which to judge geographical distributions as a test of taxonomic soundness. It was of interest to see whether there was justification for being suspicious about the alleged occurrence of the same species, for example, in the Irish Sea and on the California coast. The first step was to become aware of previously described distributional patterns for seaweeds; the second step was to compare these patterns with those that are exhibited by *Codium*.

The field of phytogeography is vast, the literature inexhaustible, its data capable of a variety of interpretation, extraordinary manipulation, and distortion. It has the fascination of a chess game. It is a valid, though treacherous, field of investigation. While making no claim to competency as a phytogeographer, I believe that information divulged by my studies of *Codium* warrants evaluation in general phytogeographic terms.

CURRENT PATTERNS

It has long been recognized that along most coasts temperature is probably the most important factor determining the latitudinal distribution of marine algae a view particularly expressed by Setchell *(2, 3, 4)*, who believed that the effect of temperature on reproductive processes was critical. Ideally, ocean surface temperatures could be expected to vary linearly from the equator toward the poles; however, it is well known that the major oceanic currents profoundly alter this gradient. Zones of algal distribution thus do not coincide with latitudinal zones.

Figure 1 is a schematic representation (modified Mercator projection) of an idealized current system, wherein it is assumed that both sides of the ocean are delimited by continuous land masses bearing due north/south. The pattern of currents coincides in many regions with the pattern of prevailing winds, but it depends not only upon the prevailing winds but upon the rotation of the earth and density differences in the surface layers. The pattern in the northern hemisphere has a mirror image in the southern hemisphere. The following features may be noted: northern and southern equatorial currents, equatorial countercurrent, northern and southern high-latitude currents, northern and southern high-latitude minor gyrals. Whether a current as it bathes a particular shore should be designated "warm" or "cold" depends upon the temperature that might be expected in the absence of a current system. Under the idealized conditions of Fig. 1, the western shores of the ocean would be warmed by the equatorial currents while the eastern shores would be cooled by the returning high-latitude currents. Actually, this idealized pattern is significantly altered by at least three factors: (1) the configuration of major land masses, affecting the major current system; (2) the configuration of minor land masses, affecting local gyrals; and (3) upwelling, causing local temperature disturbances.

Figure 2 shows the patterns of currents in the Pacific. Because of the funnel formed between Asia and North America, the North Equatorial Current warms the Japanese coast (as the Kuroshio Current) and its high-latitude extension retains enough warmth, despite the admixture of cold subarctic water south of the Aleutian Islands, to be regarded as a warm current when it

[1] Bouck and Morgan *(1)* report the discovery at East Marion, Long Island, New York, of *Codium fragile* ssp. *tomentosoides* (van Goor) Silva, a weed presumably introduced from Europe, where it is becoming increasingly widespread.

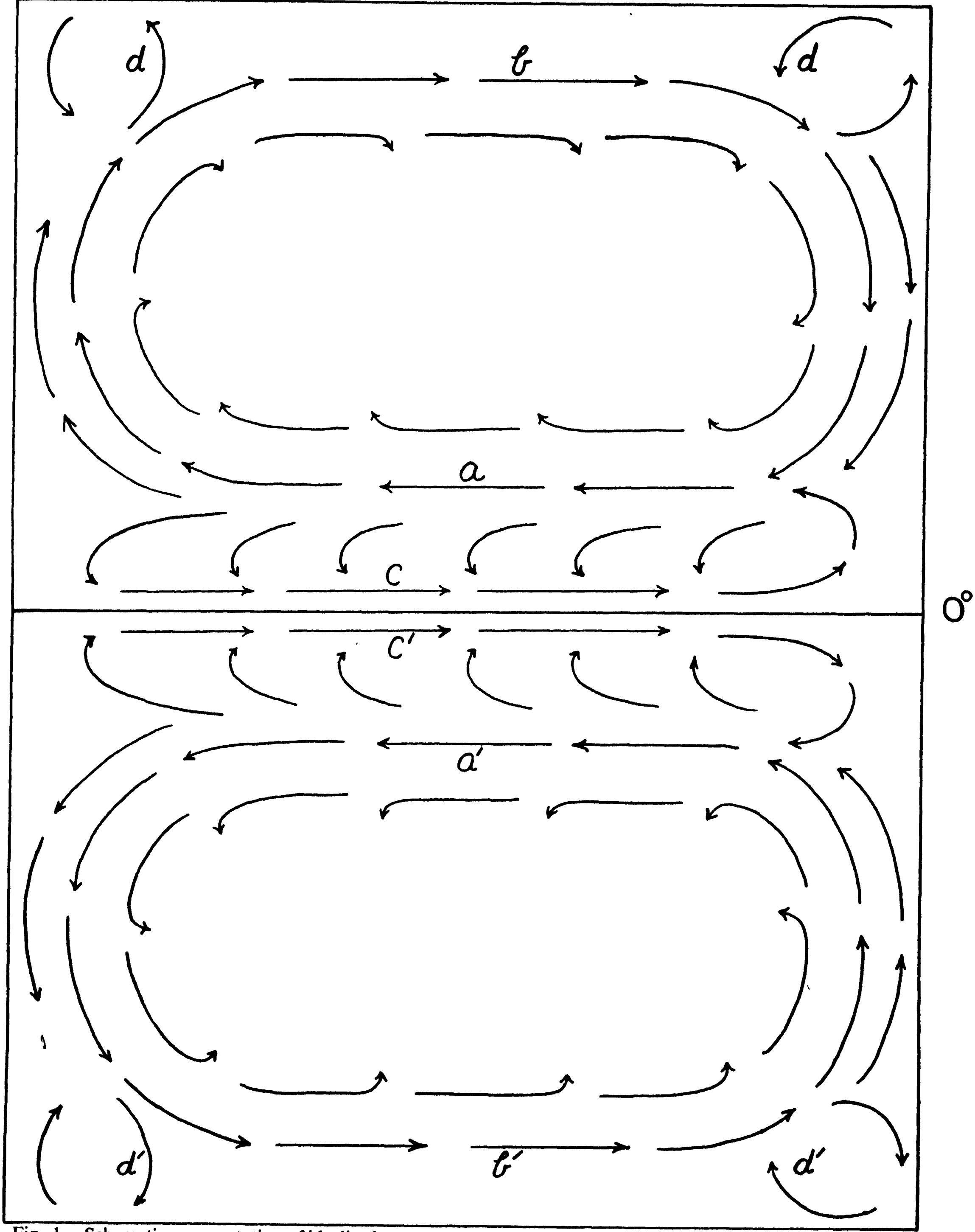

Fig. 1.—Schematic representation of idealized current system (modified Mercator projection). *a*, *a*′, equatorial currents; *b*, *b*′, high-latitude currents; *c*, *c*′, equatorial countercurrent; *d*, *d*′, high-latitude minor gyrals.

reaches the coast of North America. The northward moving minor branch, the Alaska Current, is definitely warming; the southward moving major branch, the California Current, largely because of the upwelling of cold water soon reaches a point where it no longer has the effect of warming, but of cooling. To the northeast of Japan, temperatures are depressed by the western part of the Bering Sea gyral (the Oyashio Current). In the southern hemisphere, the circumpolar current of the antarctic region sets the stage for a very different pattern. The continent of South America extends far south and deflects a part of the eastward moving cold subantarctic circumpolar current northward. The resulting Peru (or Humboldt) Current is further affected by upwelling, so that it has a chilling effect nearly to the equator. In the western part of the South Pacific, there is no current system as well defined as the Kuroshio system. This may be related to the great distance separating South America and Australia. According to Sverdrup, Johnson, and Fleming (*6*, p. 706), "in the western South Pacific annual variations are so great that in many regions the direction of flow becomes reversed, as is the case off the east coast of Australia."

Figure 3 shows the current patterns in the Atlantic. In the North Atlantic the Gulf Stream system, a counterpart of the Kuroshio system in the Pacific, is well known for its role in warming the shores of both North America (the southeastern part of the United States) and Europe (the British Isles and Scandinavia). Among the major terminal branches of this system, the Irminger Current flows westward to the south of Iceland while the Norwegian Current can be traced through two further branches into the Polar Sea. To the east of Labrador and Newfoundland, the western part of a counter-clockwise gyral, the cold Labrador Current, is a counterpart of the Oyashio Current in the Pacific. Part of the North Atlantic Current returns southward off the Iberian and North African coasts and

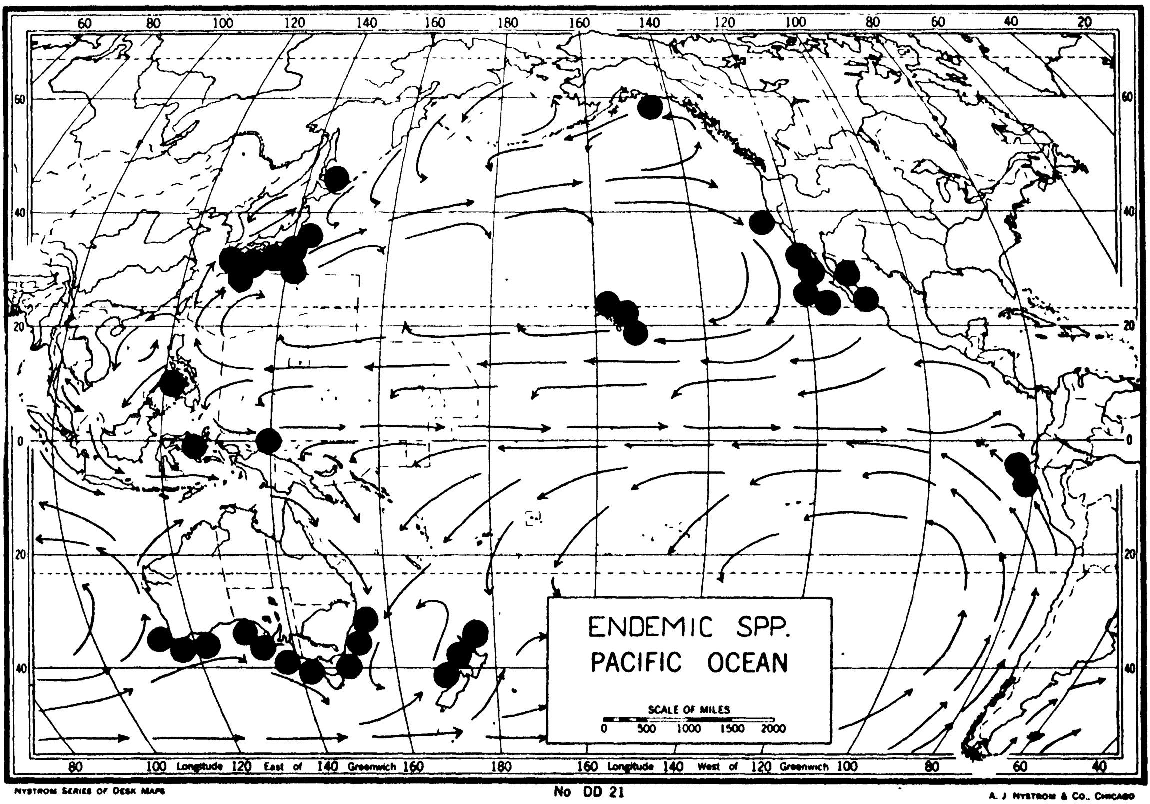

Fig. 2.—Current system and centers of distribution of endemic species of *Codium* in Pacific Ocean. Each circle represents one species.

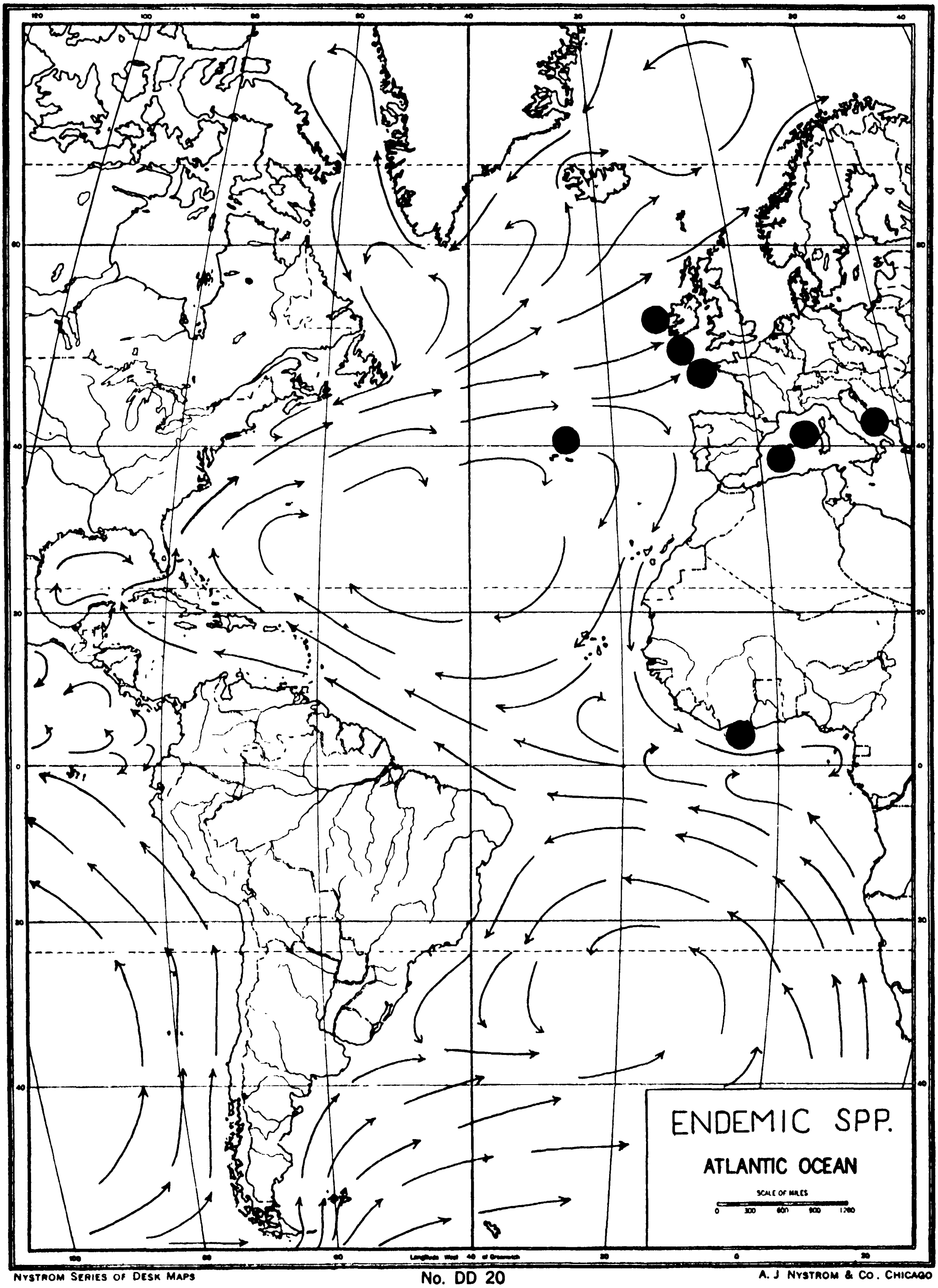

Fig. 3.—Current system and centers of distribution of endemic species of *Codium* in Atlantic Ocean. Each circle represents one species.

contributes in part to the North Equatorial Current and in part to the Guinea Current, which flows along the coast of Africa as far as the equator. In the southern hemisphere, the shape and position of South America profoundly affects the current pattern: the northeastern shoulder of Brazil deflects part of the South Equatorial Current northward across the equator where it flows northwest along the northern coast of South America and ultimately contributes to the Florida Current (the first part of the Gulf Stream system). In the Atlantic, unlike the Pacific, the surface circulation of the two hemispheres is thus interconnected. The southern tip of South America deflects the cold subantarctic circumpolar current not only along the west coast, but also along the east coast. The resulting Falkland Current meets the southward moving branch of the South Equatorial Current (the warm Brazil Current) in the latitude of Uruguay, where a sharp temperature gradient is thus established. Along the west coast of South Africa, the Benguela Current flows northward; and being affected by upwelling, it depresses inshore temperatures until it gradually leaves the coast and continues westward as the South Equatorial Current.

Much less is known about the current patterns of the Indian Ocean (Fig. 4) than of the Pacific or Atlantic. A major counter-clockwise gyral in the southern part of the Indian Ocean prevails, subject to considerable annual variation. The South Equatorial Current flows southward around Madagascar and along the east coast of South Africa as the warm Agulhas Current. There is a well-defined eastward moving current between South Africa and Australia, representing the returning high-latitude component of the gyral.

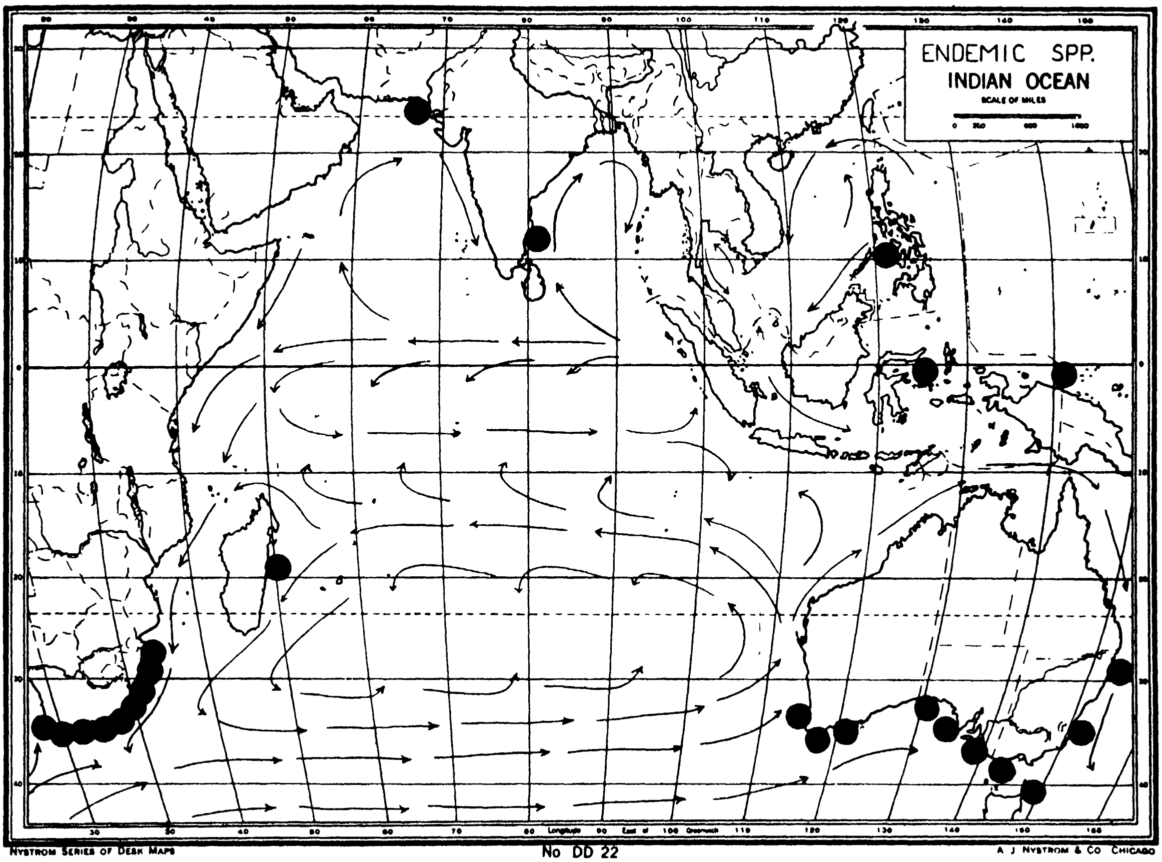

Fig. 4.—Current system and centers of distribution of endemic species of *Codium* in Indian Ocean. Each circle represents one species.

FLORISTIC PATTERNS

On the basis of considerations that temperature controls the establishment of populations of particular genotypes and that currents provide a means of dispersal, we can make predictions concerning the expected distribution of marine algae. In seeking explanations of existing floristic patterns, however, we must also consider the historical factor, despite the difficulty of assessing its role. A more recent origin is suggested by taxa whose distribution can be explained without recourse to the historical factor, while such problems as bipolar distribution imply greater antiquity.

In the Pacific, on the basis of the Kuroshio system, we can predict similarities between the flora of Japan and that of California. In the Atlantic, on the basis of the Gulf Stream system, we can predict similarities between the flora of the northeastern United States and Atlantic Europe. Considering the interconnected surface circulation between the northern and southern hemispheres of the Atlantic, we might also predict similarities between the flora of Brazil and that of the Caribbean region. On the basis of the Antarctic Circumpolar Current we can predict the existence of a circumpolar antarctic or subantarctic marine algal province. As we shall see, each of the four predictions is borne out by data from marine algae in general.

The temperate flora of Japan, although it comprises endemic species for the greater part and includes a sizable arctic element, is clearly related to the California flora. This relationship is expressed in similarity of general appearance and in the sharing of many genera and even some species (including *Heterochordaria abietina*, *Endarachne binghamiae*, *Costaria costata*, *Cymathaere triplicata*, *Pikea californica*, *Baylesia plumosa*, *Rhodymenia pertusa*, *Coeloseira pacifica*, *Binghamia californica* and *Pterosiphonia dipinnata*).

The similarities between the flora of the northeastern United States and that of Atlantic Europe have long been recognized. Among common species shared by the two floras, the following may be cited: *Ulothrix flacca*, *Prasiola stipitata*, *Cladophora albida*, *C. flexilis* and *C. gracilis*, *Bryopsis plumosa*, *Ectocarpus confervoides*, *E. fasciculatus* and *E. tomentosus*, *Giffordia granulosa* *Cladostephus verticillatus*, *Sphacelaria cirrhosa*, *Elachista fucicola*, *Chordaria flagelliformis*, *Eudesme virescens*, *Sphaerotrichia divaricata*, *Stilophora rhizodes*, *Arthrocladia villosa*, *Desmarestia aculeata* and *D. viridis*, *Stictyosiphon tortilis*, *Asperococcus echinatus*, *Desmotrichum undulatum*, *Punctaria plantaginea*, *Dictyosiphon foeniculaceus*, *Alaria esculenta*, *Chorda filum* and *C. tomentosa*, *Laminaria digitata* and *L. saccharina*, *Ascophyllum nodosum*, *Fucus serratus*, *F. spiralis* and *F. vesiculosus*, *Nemalion multifidum*, *Gelidium crinale*, *Dumontia incrassata*, *Polyides caprinus*, *Corallina officinalis*, *Gloiosiphonia capillaris*, *Cystoclonium purpureum*, *Furcellaria fastigiata*, *Gymnogongrus griffithsiae* and *G. norvegicus*, *Phyllophora brodiaei* and *P. membranifolia*, *Chondrus crispus*, *Gigartina stellata*, *Rhodymenia palmata*, *Champia parvula*, *Antithamnion cruciatum*, *Callithamnion byssoides*, *C. corymbosum* and *C. roseum*, *Ceramium diaphanum*, *C. rubrum* and *C. strictum*, *Plumaria elegans*, *Ptilota plumosa*, *Seirospora griffithsiana*, *Spermothamnion turneri*, *Spyridia filamentosa*, *Membranoptera alata*, *Pantoneura angustissima*, *Phycodrys rubens*, *Dasya pedicellata*, *Chondria dasyphylla*, *Odonthalia dentata*, *Polysiphonia elongata*, *P. lanosa*, *P. nigrescens* and *P. urceolata*, *Rhodomela confervoides* and *R. lycopodioides*.

In searching for similarities between the flora of Brazil and that of the Caribbean region, we encounter a distributional pattern that is remarkable in that it encompasses portions of both northern and southern hemispheres. This vast, rather homogeneous algal province extends from the Caribbean (with some northward extensions to Florida, the Carolinas, and Bermuda) to southern Brazil and shows certain affinities with the flora of the Cape Verde Islands and the adjacent African coast and weaker affinities with the flora of the Canary Islands and of the western Mediterranean. Taylor *(8)* in a study of 317 species common in the Caribbean region, found that 28.4% were restricted to the Caribbean, 11.0% extended northward at least to Beaufort, North Carolina, 33.1% extended southward along the coast of Brazil, and 27.5% extended both northward and southward. Taylor concludes that "the Caribbean flora deserves this name only because the Caribbean Sea is the area of its greatest known luxuriance and diversity .... [It] is actually a west or American Atlantic tropical flora which, in spite of the Brazil current and the North Equatorial current, extends down the Brazilian coast to Rio de Janeiro, with few replacements." While the direction of the North Equatorial Current would indeed seem to prevent or at least to impede the southward spread of a Caribbean flora, if the possibility of an eastern Atlantic origin be granted, the existence of this vast algal province would not be in disagreement with hydrographic facts.

The circumpolar marine algal province encompassing the Antarctic Continent and the

Subantarctic region (including the southern tip of South America and such islands as the South Orkneys, South Georgia, South Sandwich, Kerguelen, Heard, Macquarie, Auckland, Campbell, and Stewart) has been summarized by Skottsberg *(5)*. Characteristic species include *Cladophora pacifica*, *Adenocystis utricularis*, *Caepidium antarcticum*, *Desmarestia rossii* and *D. willii*, *Durvillea antarctica*, *Geminocarpus geminatus*, *Halopteris funicularis*, *Macrocystis pyrifera*, *Scytothamnus australis* and *S. fasciculatus*, *Utriculidium durvillei*, *Ballia callitricha*, *Callophyllis tenera*, *Chaetangium fastigiatum*, *Delisea pulchra*, *Lithothamnium antarcticum*, *Lophurella hookeriana*, *Phycodrys quercifolia*, *Plocamium hookeri* and *P. secundatum*, and *Polysiphonia microcarpa*.

DISTRIBUTIONAL PATTERNS OF *CODIUM*

To what extent does the distribution of *Codium* agree with previously recognized floristic patterns? First, it should be pointed out that most species of *Codium* are restricted to continuous shores or closely spaced islands; only a few species occur on two or more widely separated land masses. Figs. 2, 3, and 4, indicate the centers of distribution of endemic species in each of the three oceans. The Pacific with 30 endemic species leads the Indian with 19 and the Atlantic with 8. These numbers undoubtedly will be adjusted upward with further study of certain perplexing material, as yet unidentified.

Let us look more closely at the Pacific Ocean. Fig. 5 shows the distribution of four closely related adherent species. The occurrence of *C. hubbsii* Dawson both in Japan and in California, although separate subspecies probably are involved, should be noted. *Codium convolutum* (Dellow) Silva[2] comb. nov. is an example of a local endemic. On the other hand, *C. lucasii* Setchell occurs in South Africa as well as in Australia. *Codium arabicum* Kuetzing is interpreted here as a complex series of microspecies or subspecies

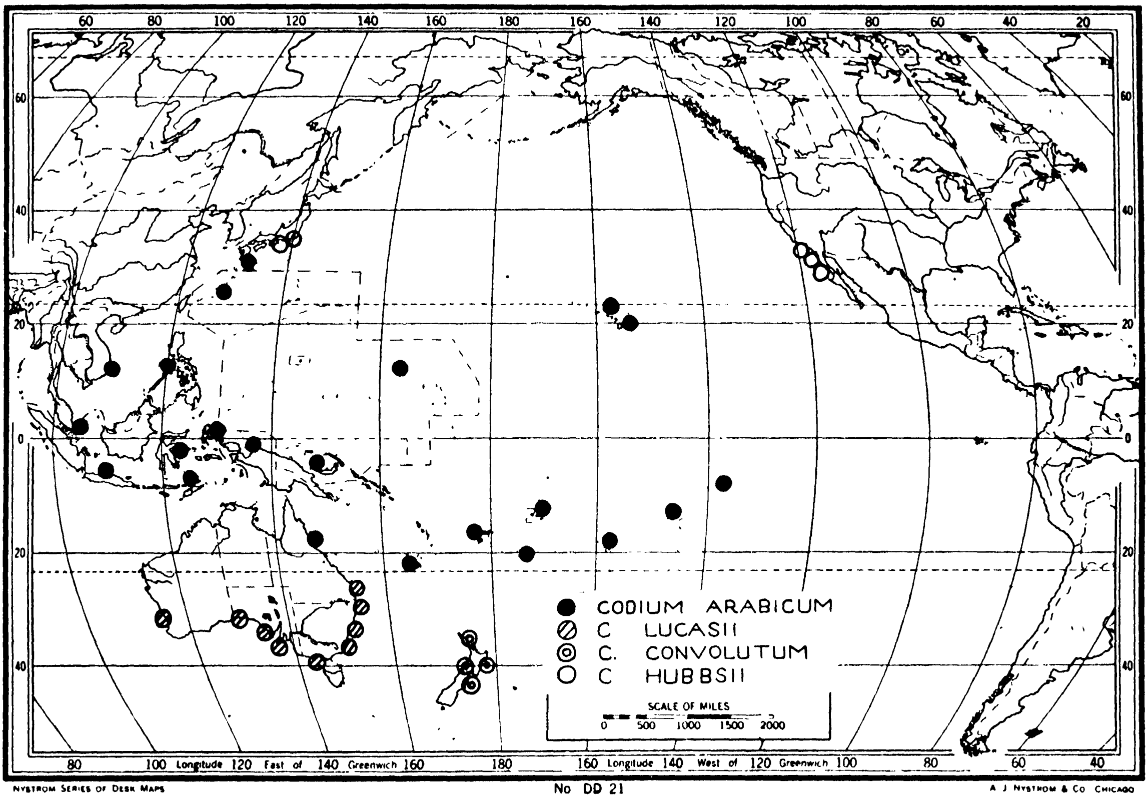

Fig. 5.—Distribution of four closely related adherent species of *Codium*.

2 *Codium adhaerens* C.Ag. var. *convulotum* Dellow, *Trans. R. Soc. N.Z.* **80**: 122. 1952.

extensively distributed throughout the Indo-Pacific region, reaching its northeastern limit in the Hawaiian Islands. Several interesting patterns are shown in Fig. 6. *Codium spongiosum* occurs in South Africa and Mauritius in addition to the localities indicated in Fig. 6 and is thus Indo-Pacific in distribution. The distribution of each of the three members of the highly specialized section *Digitaliformia* is shown: *Codium johnstonei* Silva occurs in California and adjacent Mexico, but lacks a Japanese counterpart; *C. pomoides* J. Ag. is restricted to Australia; *C. dimorphum* Svedelius occurs in New Zealand and southern Chile. The distribution of each of five species of the section *Mamillosa* is also shown: *C. minus* (Schmidt) Silva[3] comb. nov. occurs in Japan; its nearest relative, *C. mamillosum* Harvey, occurs in Australia and Hawaii; *C. ritteri* S. and G. occurs in Alaska; the remaining two species are distinct from the other members of the section and from each other; yet are very closely related and are extremely local in distribution, *C. globosum* Lucas occurring in Queensland and *C. cranwelliae* Setchell in New Zealand. Fig. 7 shows the distribution of several dichotomous species. *Codium contractum* Kjellman in Japan and its very close relative *C. macdougalii* Dawson in the Gulf of California, Mexico, are excellent examples of vicarious species. The distribution of the three members of the section *Lata* is interesting: *Codium latum* Suringar, described from Japan, is represented by a subspecies, *C. latum* ssp. *palmeri* (Dawson) Silva[4] comb. nov., on Guadalupe Island, Mexico; *C. laminarioides* Harvey is endemic to Western Australia; while *C. platylobium* J.E. Areschoug (not shown in Fig. 7) is endemic to South Africa. Fig. 8 shows the distribution of various repent *Codium*, representing several species or complexes of microspecies and subspecies. This group of taxa together with the populations of *C. arabicum* indicated in Fig. 5 and *C. intertextum* Collins and

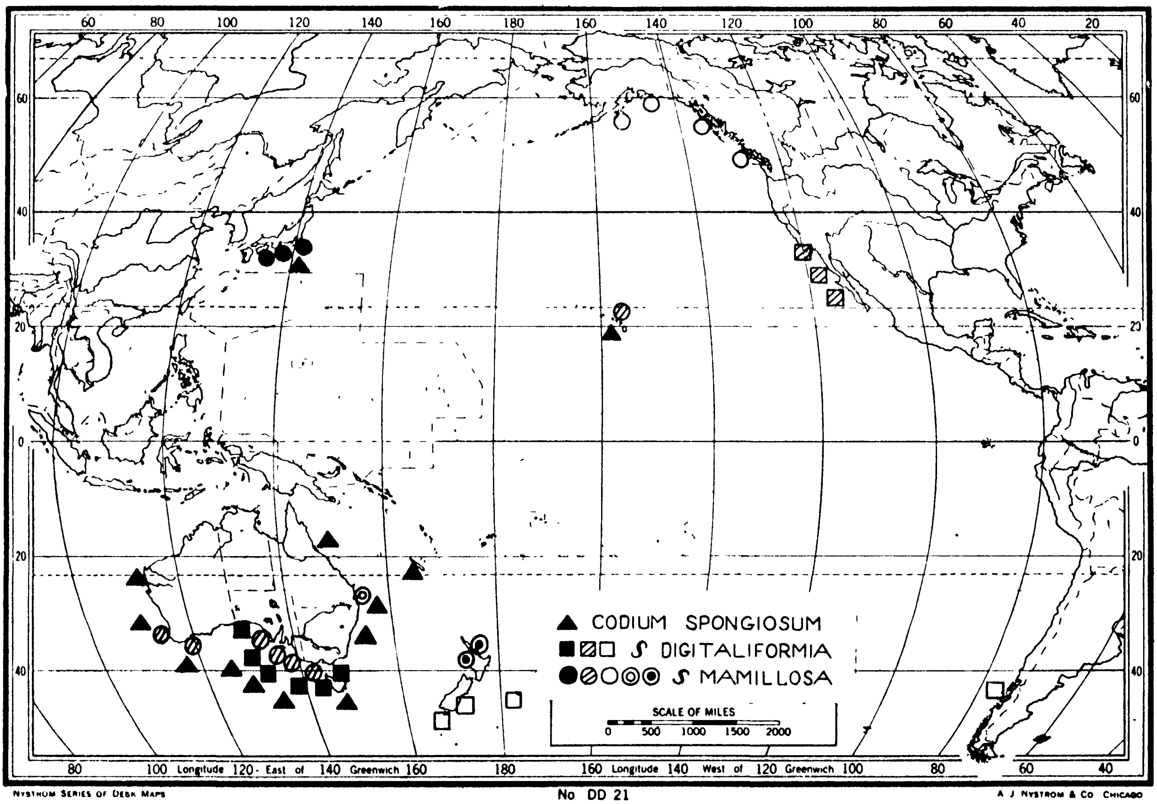

Fig. 6.—Distribution of *Codium spongiosum*, of Section *Digitaliformia*, and of Section *Mamillosa*.

[3] *Codium mamillosum* Harvey var. *minus* O.C. Schmidt, *Bibl. Bot.*, **23**(91): 37, 1923.

[4] *Codium palmeri* Dawson, *Bull. So. Calif. Acad. Sc.*, **44**: 23, 1945.

Hervey indicated in Fig. 9 form an integral part of the biocoenosis of coral reefs. The anatomical variability of these plants from reef to reef is perplexing.

Despite the high degree of endemism exhibited by *Codium*, a study of the distribution of closely related species is thus seen to support the recognition of both the Japanese-Californian floristic pattern and the circumpolar subantarctic pattern. Moreover, data are provided which support the recognition of an Indo-Pacific province, the existence of which has already been indicated by studies of other algae. This floristic pattern, while not strongly suggested by current patterns, is not unreasonable if migration through the Indonesian region is considered possible. Finally, an affinity between the floras of eastern South Africa and southwestern Australia is suggested.

Now let us turn to the Atlantic Ocean. Fig. 9 shows the distribution of two closely related adherent species, *C. adhaerens* C. Ag. and *C. intertextum* Coll. and Herv. The populations of *C. intertextum* in the Canary Islands probably should be accorded subspecific recognition. Fig. 10 shows the distribution of another pair of closely related adherent species, *C. effusum* (Raf.) Delle Chiaje and an undescribed species from Tierra del Fuego and the Falkland Islands (*C. antarcticum* Silva). This remarkable distribution suggests the divergence of a widespread ancestral stock into a warm-water and a cold-water species. The absence of a closely related species in the Caribbean region is notable. Fig. 11 shows the distribution of a pair of very closely related globose species, *C. bursa* (L.) C. Ag. and *C. elisabethae* Schmidt, known only from the Azores. Again it is interesting to speculate on the absence of *C. bursa* or a closely related species in the Caribbean flora. Fig. 12 shows the distribution of three fairly closely related dichotomous species, *C. vermilara* (Olivi) Delle Chiaje, *C. isthmocladum* Vickers, and an undescribed species from the Guinea Coast (already in literature as *C. guineënse* Silva). The last two species are seen to occupy mutually exclusive parts of the tropical

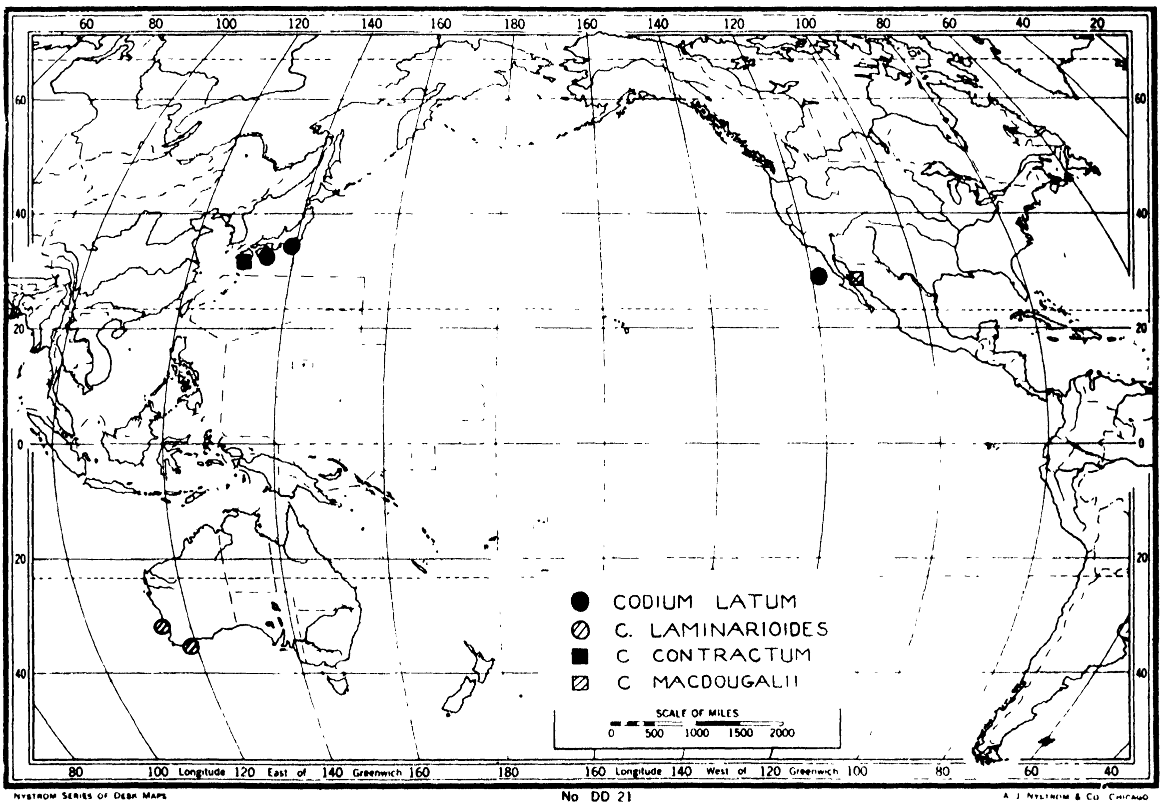

Fig. 7.—Distribution of two pairs of closely related dichotomous species of *Codium*.

Atlantic province. The bipolar distribution of *C. vermilara* is unique and suggests a more extensive distribution in former times. Its absence in North America is notable. Fig. 13 shows the distribution of three distantly related dichotomous species. Both *C. taylori* Silva and *C. decorticatum* (Woodw.) Howe occur throughout the tropical Atlantic province, although the former is absent in the western Mediterranean. Lastly, *C. tomentosum* Stackh., a name at one time applied to almost any dichotomous *Codium*, is seen to have a highly restricted distribution.

It thus can be seen that the temperate North Atlantic province is not supported by data from *Codium* because of the absence of this genus on the northeastern coast of North America. On the other hand, full support is given to the recognition of the tropical Atlantic province. The bipolar distribution of *C. vermilara* is notable.

CONCLUSIONS

In comparing algal floristic patterns in the Pacific with those in the Atlantic and Indian oceans, we find that the Japanese-Californian alliance is the counterpart of the North Atlantic province, but the degree of similarity between the Japanese and Californian floras does not warrant their recognition as a province. The Japanese-Californian alliance is supported by data from *Codium*; the North Atlantic province, while lacking such support, is nonetheless well documented by distributional data from other algae. The tropical Atlantic province has as its Pacific counterpart the Indo-Pacific region, which not only spans the equator but extends over two oceans. Unlike its Atlantic counterpart, it does not have affinities with eastern shores; its boundaries seem to coincide with the limits of coral reefs, and its flora may be an integral part of the coral reef biocoenosis. While the components of the flora of this vast region are not known sufficiently to warrant its designation as a province, it seems likely that even after various subregions with clusters of endemic species have been removed, there will remain a large area with a fairly homogeneous flora. Recognition of both the tropical

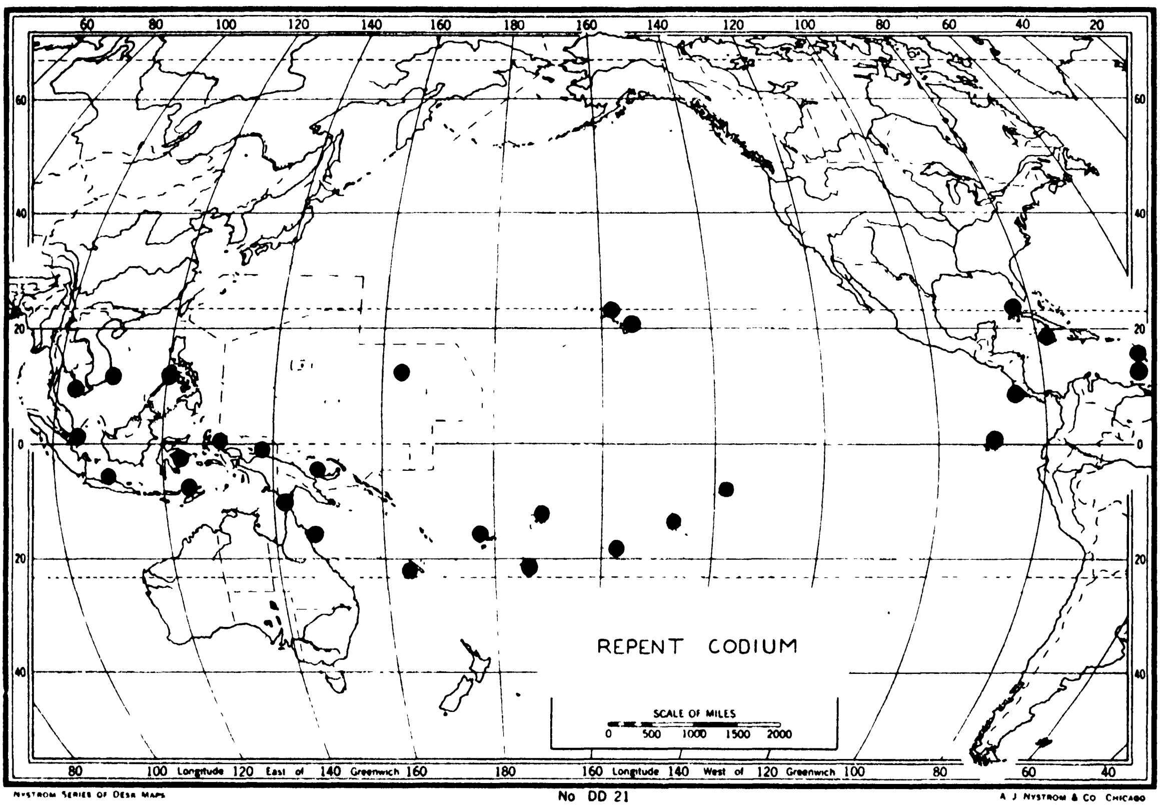

Fig. 8.—Distribution of repent *Codium*.

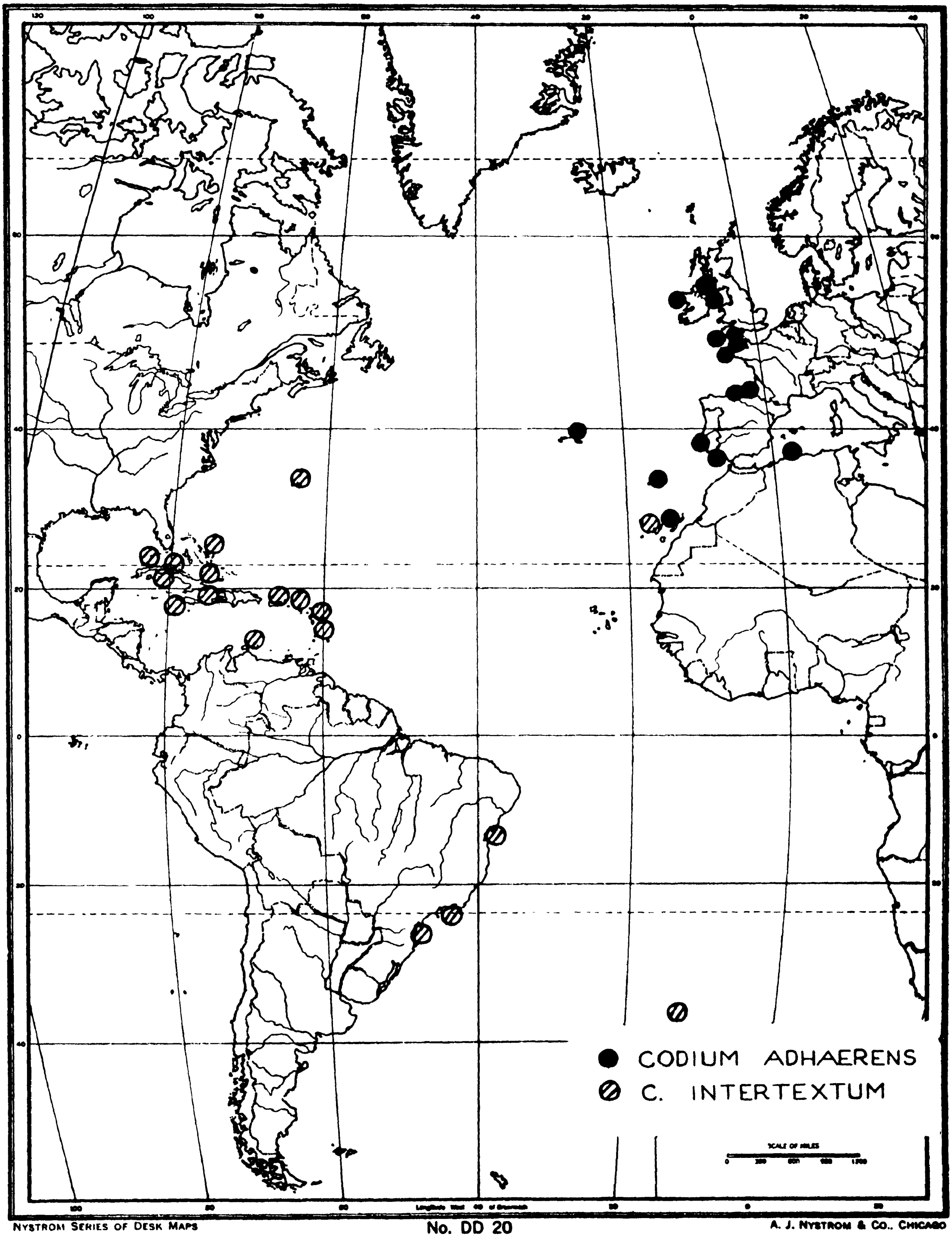

Fig. 9.—Distribution of two closely related adherent species of *Codium*.

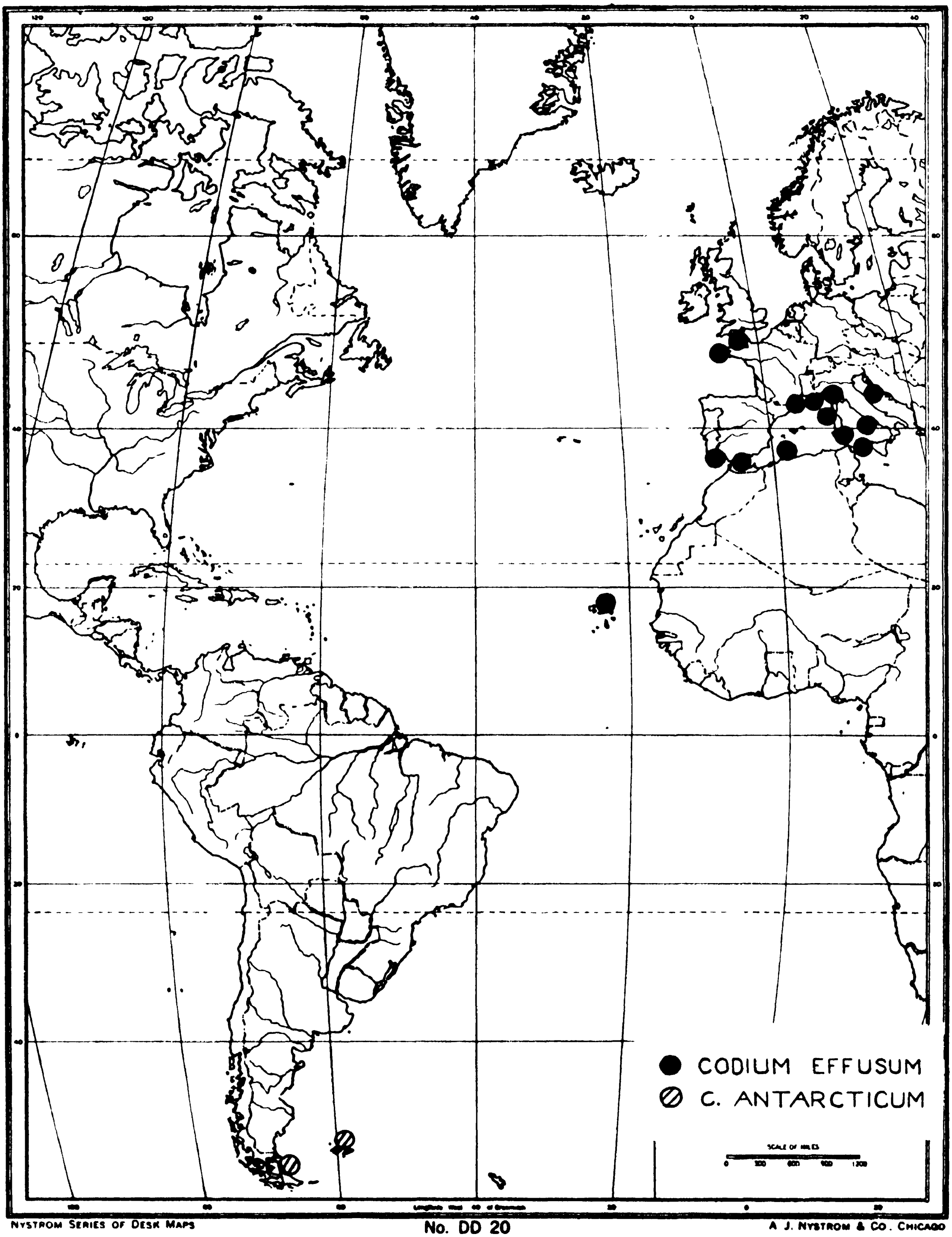

Fig. 10.—Distribution of two closely related adherent species of *Codium*.

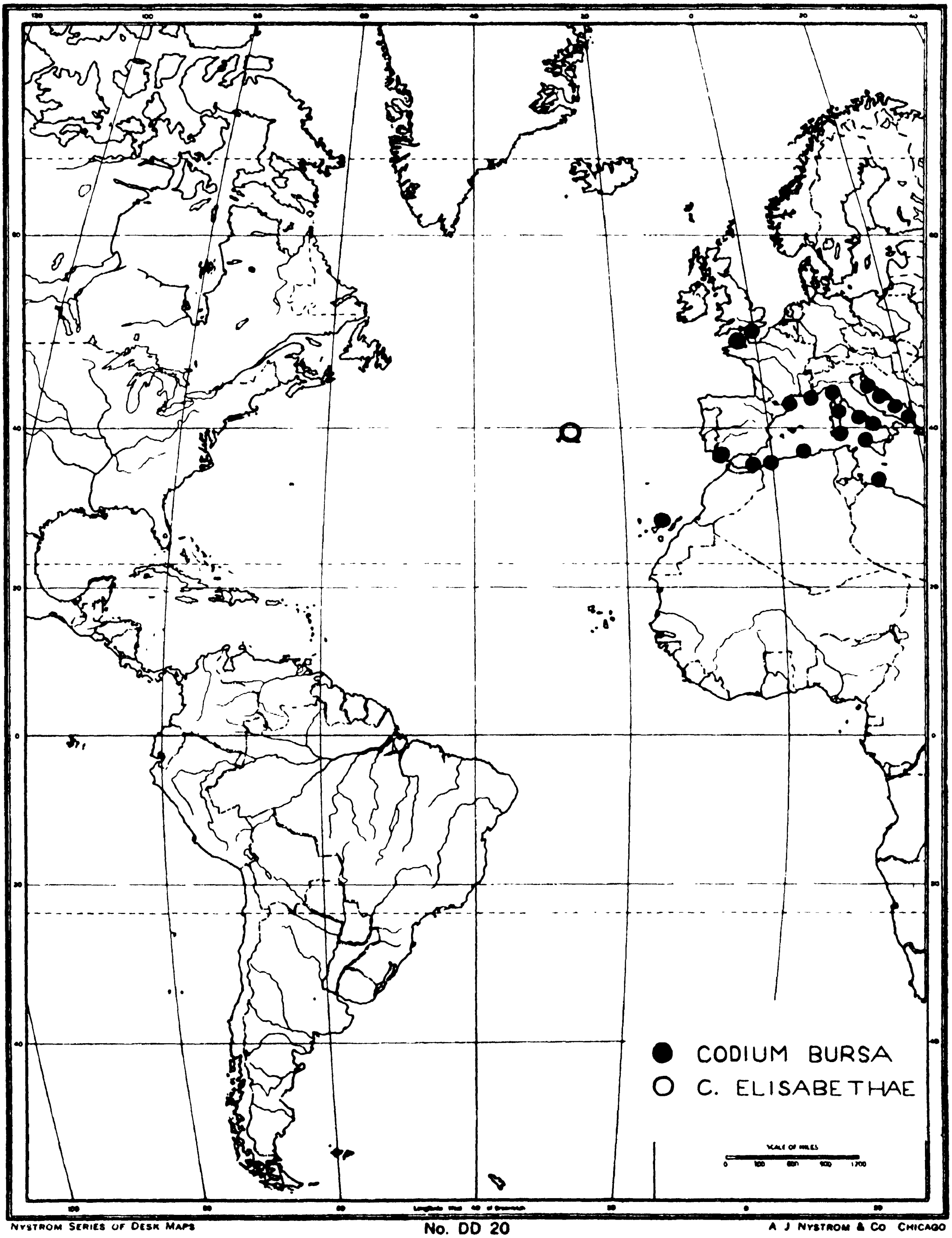

Fig. 11.—Distribution of two very closely related globose species of *Codium*.

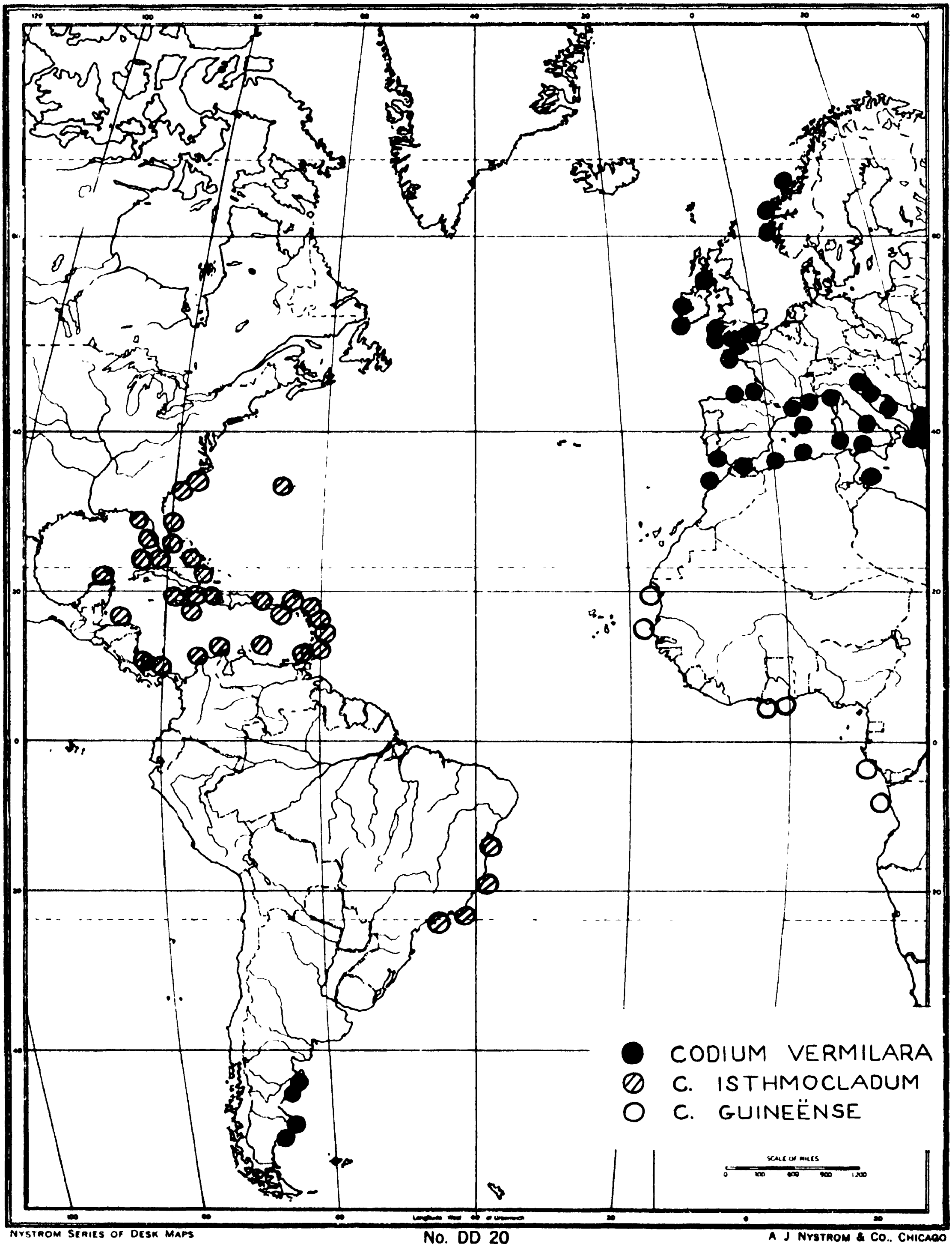

Fig. 12.—Distribution of three fairly closely related dichotomous species of *Codium*.

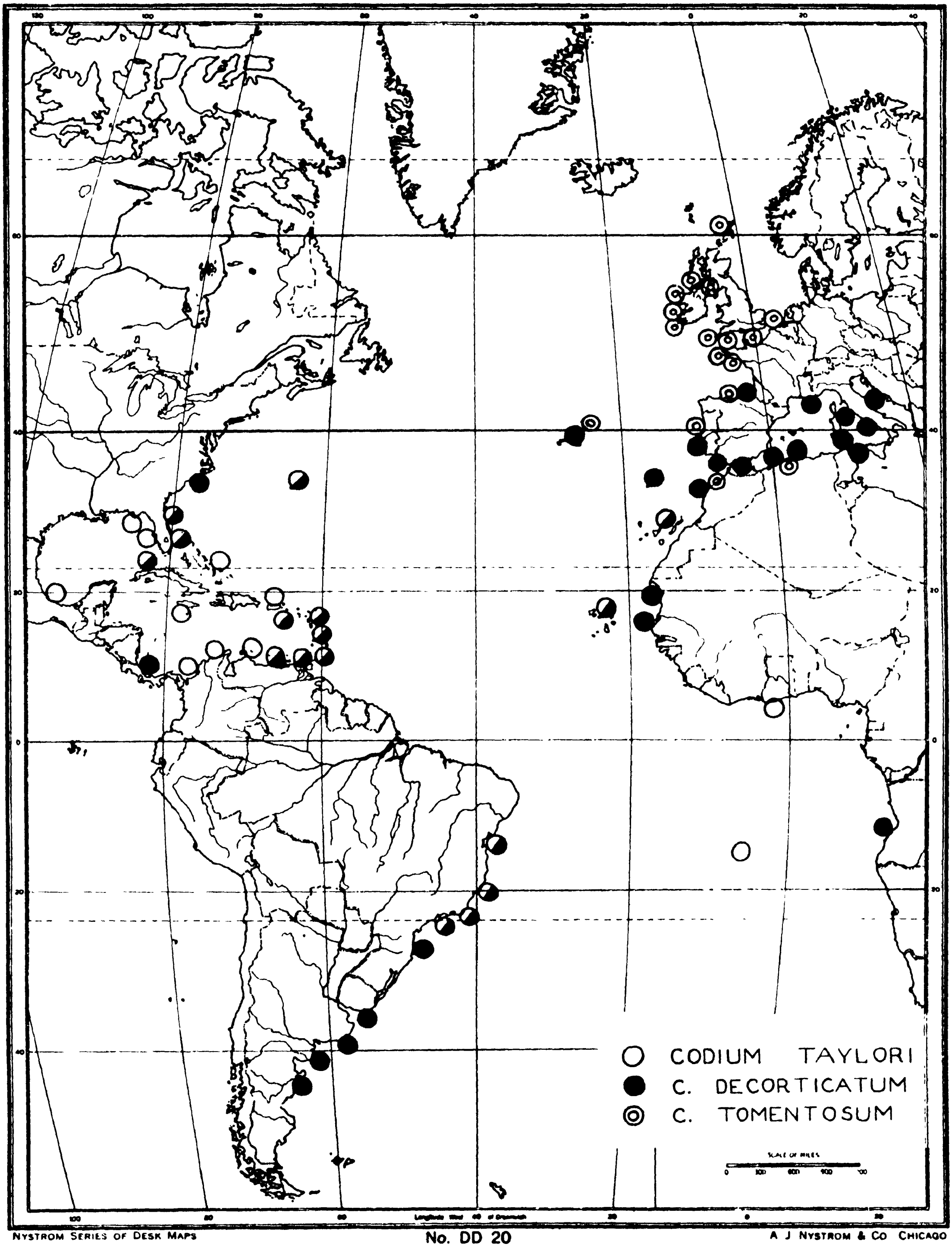

Fig. 13.—Distribution of three distantly related dichotomous species of *Codium*.

Atlantic province and the Indo Pacific region is strongly supported by distributional data from *Codium*. There are no southern hemisphere counterparts of the North Atlantic province and the Japanese-Californian alliance. The circumpolar subantarctic province is well documented, including support from *Codium*. Its northern counterpart, the arctic province, although fully documented *(7)* has not been considered in this paper because of the absence of *Codium* in that part of the world and because the existence of this province is dependent upon climatic and geographic isolation of a mediterranean-type sea rather than upon general oceanic circulation.

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DISCUSSION

M.S. DOTY: Does *Codium arabicum* occur in southern Japan?

P.C. SILVA: Quite possibly.

G.F. PAPENFUSS: Very few algae are common to Northwest Africa and the Caribbean. West Indian species are more likely to be found on the east coast of Africa.

P.C. SILVA: There are marked temperature differences between the coast of Northwest Africa and the Caribbean.

F.R. FOSBERG: Does Dr. Silva think of these distributional patterns of algae as related to currents? Do they indicate historical patterns of plant geography, or are they related to physiological requirements of the plants?

P.C. SILVA: The historical factor is very important but difficult to assess. A large part of the genus *Codium* seems to be actively speciating although many species are widely separated morphologically and would appear to be relicts. The distribution of recent species at least can be related to present-day current patterns.

DISTRIBUTIONAL RELATIONSHIPS OF MALAYAN FRESHWATER ALGAE

G.A. PROWSE

Fish Culture Research Station, Batu Berendam, Malacca, Federation of Malaya.

One of the difficulties encountered when reading past papers on the algae of this part of the world is that the areas concerned are not clearly defined. Political boundaries rarely coincide with biological ones, and the term Malaya has been used to cover anything from the whole of the Indonesian islands to the Federation of Malaya itself. I propose to use it to cover the Federation and Singapore, not through any wish to ignore the surrounding areas, but because the very location of the research station makes it necessary that I should confine my main attentions within those boundaries.

Looking through the literature on fresh-water algae, one finds that while there are many papers dealing with Malay territories generally, very few of them deal with the Federation of Malaya and Singapore. We have papers by West and West, Bernard, Lemmermann, Biswas, and Ruth Patrick, but very little else. This is partly because in the past botanists in this part of the world have been more concerned with the flowering plants and ferns, and it is only recently that any serious phycological studies have been undertaken. With the active interest taken in fresh-water biology by departments of the University of Malaya, and with the opening of the Fish Culture Research Station in Malacca, phycological knowledge in this area has been considerably advanced, although still very inadequate. It is noteworthy that the present Acting-Director of the Botanic Gardens, Singapore is deeply interested in phycology, admittedly marine, but still very encouraging to fresh-water phycologists.

In a survey of the fresh-water algae of Malaya, one might expect certain things, simply by virtue of its geography. Firstly it would occasion no surprise to find those species which are world-wide in distribution, ranging from arctic to tropic climates. Superimposed on these distributional elements would be found those species which are strictly tropical in range, but still circumglobal in distribution. Of greater interest, however, are those species of much more restricted range. The Malay peninsula forms an integral part of a geographical system which stretches from Burma and Thailand in the north right down through the Indonesian islands to Australia. This Indo-Malaysian-Australian system was evidently almost a continuous land mass at one time. One would expect algal species common to the whole area, with perhaps minor geographical variations. In addition, in Malaya one would expect species having greater affinity with those from countries in the north, such as India, Burma, and Thailand, and other species showing greater similarity to those from Java and Sumatra. Finally it is likely that a few species may be even more restricted in range, being confined almost entirely to Malaya.

Such distributional patterns will inevitably be complicated by the nature of the terrian of the country concerned, for the various habitats may differ widely in character. Much of the lowland of Malaya is lateritic, with swamps and padi fields. The water is decidedly acid and desmids abound, whilst the common flagellates are various species of Chrysophyceae. In many places fish ponds have been made, with consequent liming and heavy manuring. Euglenineae are dominant, or with less heavy manuring, Chlorococcales and sometimes *Microcystis aeruginosa.* On the other hand, in the fast flowing streams of the high mountains, such as the Cameron Highlands, diatoms predominate. The limestone peaks of the north have not yet been explored phycologically, and should prove to have an interesting algal flora. In addition, Malaya is divided centrally by the main mountain range, and it would be interesting to see if those algal species on the west side differ in any way from those on the east.

Despite these distributional complications, it should be possible to trace the broad lines due to geological and evolutionary history, particularly if individual groups are studied. Taking the very characteristic desmid genus *Micrasterias*, we find those species of known world-wide distribution — *M, pinnatifida*, *americana* (only once recorded in Malaya so far), *alata*, *crux-melitensis*, *thomasiana* var. *notata* and *jenneri.* Typical circumglobal tropical species or varieties are *M. mahabuleshwarensis* and *M. foliacea* var. *ornata.* In the Indo-Malaysian-Australian group we have *M. ceylanica* and *M. moebii*, although the Malayan form of the latter species is intermediate between those from Thailand and Java. *M. thomasiana* var. *evoluta* and *M. apiculata* var. *tjitjeroekensis* show greater affinity for forms from Java, while *M. mahabuleshwarensis* var. *bengalica*, *M. lux* and *M. anomala* are similar to those from India and Burma. So far, *M. torreyi* var. *crameri* and *M. torreyi* var. *doveri* appear to be confined to Malaya itself. Further investigations may show that some of these species are more widespread than at first apparent, but the list illustrates the fact that Malaya partakes of elements from both northwards and southwards, as well as possessing tropical and worldwide elements. Other desmid genera show a similar picture, often just as clearly.

The diatoms of Malaya are not fully worked out, and we have insufficient representative collections. For that reason, the picture is less clear, particularly as so many diatoms are worldwide in distribution. Examples of these latter to be found in Malaya are *Cyclotella meneghiniana*, *Melosira granulata*, *Synedra ulna*, *Eunotia pectinalis*, *Frustulia vulgaris* and *Pinnularia braunii*. So far I have found none which I would call purely tropical species, but of much more limited distribution are *Stenopterobia pelagica* and *Achnanthes crenulata*, found also in Indonesia, and *Navicula voigtii* occurring also in Thailand and S. China. Ruth Patrick mentions one or two species which she found only in Malaya, and I have found some as yet unnamed ones which apparently have not been reported elsewhere, but on such limited collections it would be unwise to suggest that they are confined to Malaya.

When we turn to the various flagellate groups, we find a wealth of forms of world-wide distribution also found in Malaya, or else species which are recorded for Malaya and for places like Germany and France, which suggests they are really more widespread. Of the purely tropical forms, *Phacus pyrum* is the most typical, but I would not like to be certain about this species, for with the flagellates it is often easier to say which are the species which will not tolerate tropical conditions rather than vice versa. Of more limited distribution are *Chlamydomonas lismorensis*, *Trachelomonas lismorensis*, *Trachelomonas volzii* var. *cylindracea*, and *Peridinium gatunense* var. *zonatum*, all found in both Malaya and Australia, while *Strombomonas australica* is reported from Australia and S. China as well as Malaya. It is to be expected that these species will be reported from Indonesia as well, *Trachelomonas similis* var. *hyalina*, a very characteristic species was described from Burma and has proved quite common in Malaya. No doubt as more work on the flagellates is done in the various countries, the picture will become clearer. There are several species reported from Indonesia and Venezuela, and now from Malaya, and it seems possible that they may occur in other tropical freshwaters.

It will be noticed that most of the examples I have chosen have well-marked external features, so that any differences become obvious. No doubt if such groups as the Myxophyceae and the Chlorococcales were examined closely, it would be found that they show similar distributional patterns.

To sum up, the algal species of Malaya exhibit an interaction of worldwide distributional range, circumglobal tropical distribution, and a much more limited distribution within the Indo-Malaysian-Australian area.

DISCUSSION

R.L. CROCKER: You have mentioned geological and historical evolutionary trends. Have you any theories on this?

G.A. PROWSE: With the limited amount of information available, it would be unwise to formulate any theories.

G.F. PAPENFUSS: What literary sources are used in your work and would Skufa's paper on Burmese algae be useful to you?

G.A. PROWSE: I have consulted the various libraries in Britain and have had photostats made. Good papers are available on Indonesia, Burma, and elsewhere, but very little on Malaya itself. I have a photostats copy of Skufa's paper.

G.F. PAPENFUSS: Looking at canals near Bangkok, I would suggest that the Volvocales are common. Is that so in Malaya?

G.A. PROWSE: So far they have been comparatively scarce, but possibly may be more frequent in the limestone areas.

THE RHODOPHYTA ORDER ACROCHAETIALES AND ITS CLASSIFICATION

JEAN FELDMANN

Laboratoire de Biologie Végétale Marine, Faculté de Sciences de Paris, Paris, France.

The *Acrochaetium-Rhodochorton* complex, as Papenfuss has termed it *(11)*, groups many little, mostly epiphytic red algae, distributed in all the oceans. These algae are generally included in the order Nemalionales, among which they show a more simple structure than the typical forms such as *Nemalion* and *Liagora*. The vegetative fronds consist only of branched filaments with heterotrichous habit.

As I pointed out some years ago *(3)*, this complex may be distinguished from all other Florideae (except perhaps from Gelidiales) because it lacks a true carpogonial branch. In all the Acrochaetiaceae where sexual organs are known, the carpogonium is borne directly on the side of a normal cell of the filament or at the top of a few-celled lateral vegetative branch; sometimes, as in *Grania*, the carpogonium may be intercalary by differentiation of a vegetative cell from the erect filaments.

The lack of a carpogonial branch and the extreme simplicity of the vegetative frond seem to me sufficient reasons to put these algae in a separate order, the Acrochaetiales. Should this order be considered as the more primitive of the Florideae or as a reduced group? I am unable to settle this definitely.

The generic classification of the Acrochaetiales has for a long time puzzled the phycologists. The late Mrs. Drew-Baker *(1)* united all the species in only one genus, the genus *Rhodochorton*. More recently Papenfuss *(11)* proposed a new and much more natural classification. He chose, as the main distinctive character, the structure of the chromatophore and its situation in the cell. Unfortunately, shortly before the paper of Papenfuss appeared, Kylin *(5)* had proposed another classification of the Acrochaetiaceae based upon morphological characters not as good for a systematic classification as those used by Papenfuss.

Kylin proposed, namely, to place into the genus *Kylinia*, created by Rosenvinge *(13)* for a microscopic species epiphytic on *Sporochnus* in Denmark, all the *Acrochaetium* species with a single basal cell. This character does not seem to me a good one. It would be best, perhaps, to take into consideration the heterotrichy of these plants and, if one would use morphological characters for the distinction of genera, to separate plants truly heterotrichous from those with only erect system originating from a single basal cell and those with only creeping filaments. But I agree with Papenfuss in considering the type of chromatophore as a more important criterion for separating genera.

Kylinia rosulata, type of genus, was described by Kylin as having a stellate chromatophore with a central pyrenoid, consequently Papenfuss *(12)* put into this genus all the species previously placed by him in his genus *Chromastrum* characterised by its stellate chromatophore. In fact, the plant studied by Kylin as *Kylinia rosulata* is quite different from the species described by Rosenvinge. Both species exist on the coast of France in the Channel. The species of Kylin is an *Acrochaetium* (*Acrochaetium kylinioides* nov. sp.) with stellate chromatophore and with only asexual monospores. The true *Kylinia rosulata* possesses a parietal chromatophore without pyrenoid and its sexual organs are quite different from those of *Acrochaetium*. The male cells (spermatocysta) are borne at the top of a very long hyaline cell that looks like a hair; and Kylin thought that Rosenvinge made a mistake, interpreting a normal hair with accidentally attached spermatium at the top for the male organs of *Kylinia*. In fact Rosenvinge was right, as I have ascertained by the study of living material.

The carpogonium of *Kylinia* arises generally directly from the spore; and it is, like the vegetative cells, appressed on the filament of the host, but the trichogyne is bent upwards. The plant is monoecious; and after the fecondation, the carpogonium produces directly three carpospores at its top. *Kylinia rosulata* is thus the simplest and probably the most reduced type of Florideae one can imagine.

It is particularly noteworthy to recall the observations of Levring *(7)* about a new *Kylinia* he described from Australia, the structure and reproduction of which closely recall those of the European species.

The carposporophyte of the other Acrochaetiales is not so reduced, and there are some differences in its development according to the different genera. In *Acrochaethium (A. borneti, A. subtilissimum)*, the carpogonium is divided, after the fecondation, into three or four cells; each of them produces lateral branches bearing terminal solitary carpospores. In *Grania (G. efflorescens)*, the development is the same but the carpospores are in chains.

On the contrary, in *Audouinella*, as studied by Drew *(2)*, the carpogonium does not divide after the fecondation but produces directly lateral filaments with the carpospores terminal. By this character, the fresh-water genus *Audouinella* can be distinguished from the marine genus *Grania*.

As to the characters of the chromatophores, we can distinguish different types among Acrochaetiales:

(1) Only one chromatophore per cell; with a central pyrenoid. The shape and the situation of the chromatophore may be variable.

  a) The chromatophore may be axial in the cell with the branches of the chromatophore radiating towards the inner surface of the cell in all directions (stellate chromatophore of the genus *Chromastrum* of Papenfuss).

  b) The chromatophore may be parietal against the cell wall (genus *Acrochaetium* s. str. of Papenfuss). This parietal chromatophore may be rounded or irregularly lobed, sometimes stellate, but only in one plane.

  In fact, there are intermediate forms between (a) and (b), and it is difficult, I think, to use this character for a generic distinction. There will be some species, the place of which among *Acrochaetium* or *Chromastrum* of Papenfuss, will be difficult to settle.

  In some species of this group with only parietal chromatophore per cell, the pyrenoid is lacking as in *Kylinia rosulata*.

(2) More than one (few to many) parietal chromatophores in each cell.

  a) Chromatophores stellate with pyrenoid. This is the case for *Rhodochorton floridulum* but also for plants up to now included in the genus *Acrochaetium*. (*A. caespitosum*, *A.codii*, etc.)

  b) Chromatophores without pyrenoid, disc-shaped or more or less spirally twisted. This is the case for *Rhodochorton rothii (=R. purpureum)* and for the genera *Audouinella* and *Grania*.

Considering the mode of development of the gonimoblast and the characters of the chromatophores as well as the probably haplobiontic or diplobiontic nature of the life-cycle, one can divide the Acrochaetiales into two families and eight genera according to the following key:

ACROCHAETIACEAE

Haplobiontic. Only one chromatophore with a pyrenoid in each cell. In some species the pyrenoid is lacking; in others, there are more than one chromatophore per cell, but each is provided with a pyrenoid.

A. Only one chromatophore (central or parietal) per cell.

  a) Spermatocysta borne on vegetative undifferentiated cells, gonimoblast with sporogenous filaments bearing terminal carpospores.

    (1) Carpogonium transversally divided after fertilization. . . . *Acrochaetium* Naeg. (incl. *Colaconema* Batt.)

    (2) Carpogonium longitudinally divided after fertilization . . . . *Liagoraphila* Yamada.

  b) Spermatocysta borne at the top of differentiated elongated and hyaline cells.

    (1) Carpogonium transversally divided after fertilization and producing sporogenous filaments with terminal carpospores . . . . *Balbiania* Sirodot.

    (2) Carpogonium undivided after fertilization directly producing few carpospores . . . . *Kylinia* Rosenvinge.

B. More than one parietal chromatophore per cell, each provided with a pyrenoid . . . . *Rhodothamniella* nov. gen.

AUDOUINELLACEAE nov.fam.

Probably diplobiontic (or without sexual reproduction). More than one chromatophore, always without pyrenoid, in each cell.

A. Sexual organs present. Chromatophores ribbon-shaped and more or less spirally twisted.

  a) Marine Algae. Carpogonium tranversely divided after fertilization. Carpospores in chains . . . . *Grania* Kylin.

b) Fresh-water algae. Carpogonium undivided after the fertilization. Terminal carpospores . . . . *Audouinella* Bory.

B. Sexual organs unknown. Chromatophores disc-shaped . . . . *Rhodochorton* Naeg. char. mut.

From a morphological point of view, the two families I propose to distinguish among Acrochaetiales, are very alike as to their vegetative structure. But they may not be so closely allied as they seem. Cytologically, Acrochaetiaceae have a less evolved (more primitive) type of chromatophore than the Audouinellaceae. Some species of this family *(Audouinella)* recall the *Chantransia*-stage of *Batrachospermum* or *Lemanea* and may be reduced forms.

Most of our knowledge about Acrochaetiales rests upon researches performed on the coasts of the Atlantic Ocean. In the Pacific Ocean, important work was done upon the species from North America by K.M. Drew *(1)* and upon the species from Japan by Nakamura *(9,10)*. More recently, some very interesting new species were described from Australia and New Zealand by Levring *(7,8)*, but Acrochaetiales of large areas still remain unknown.

It is hoped that in the future, accurate studies on the morphology as well as the cytology, reproduction, and life-cycle of Pacific species will afford new light upon this most interesting group of red algae.

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SOME OBSERVATIONS ON LAMINARIA GAMETOPHYTES AND SPOROPHYTES†

JUN TOKIDA and HIROSHI YABU

Faculty of Fisheries, Hokkaido University, Japan.

The northwestern part of the Pacific Ocean, especially around the northernmost island of the Japan Archipelago, or Hokkaido, and the Kurile Islands, has been known to be remarkably rich in number of genera and species of Laminariales since Dr. K. Miyabe, teacher of Tokida, published in 1902 a comprehensive enumeration of the kelps in Hokkaido *(3)*. An English edition of this paper has recently been prepared by Tokida and published by Hokkaido University as one volume of the Journal of Faculty of Agriculture, Hokkaido University *(4)*. In this paper, Dr. Miyabe enumerated eight genera, of which the genus *Laminaria* was the largest containing as many as twelve species. However, these species are not always considered clearly distinguishable from one another by some researchers such as Dr. K. Okamura and Dr. S. Ueda, who have sometimes expressed their views on the basis of their field observations. Nevertheless, Miyabe's species have an important practical meaning in Hokkaido where most *Laminaria* species are very highly estimated for their economic value. Their market value and the scope of their use differ remarkably from one another, each species representing usually one specific locality or habitat. Their local distinctions are well reflected in Miyabe's species.

In recent years, an attempt to transplant a *Laminaria* of superior quality from its home locality to other places has been practiced experimentally in Hokkaido. In connection with this, there arose a question whether such a transplanted *Laminaria* was really quite distinct or not from other related species of inferior quality. If they were nothing but local or ecological forms of one and the same species, the transplanted *Laminaria* would not be expected to retain its superior quality long enough. On the contrary, if it was really a distinct species peculiar to one district, its characters would be expected to persist to some extent. This question may possibly be solved not only by the transplanting experiment itself, but also by a crossing experiment between certain two species.

Since 1952, cultural experiments of five species of *Laminaria*, viz., *L. japonica* Aresch., *L. ochotensis* Miyabe, *L. religiosa* Miyabe, *L. diabolica* Miyabe, and *L. angustata* Kjellm., and one species of *Alaria*, viz., *A. crassifolia* Kjellm., have been carried out as follows by us with the object of knowing the results of crossing in either couple of these species, following the method and principle of the study reported by Schreiber about twenty years ago, in 1930 *(5)*.

Zoospores were liberated in autumn or early winter. A dilute zoospore suspension was pipetted into small Petri dishes containing filtered sea water. These dishes were placed on the table in the room of our laboratory which was heated in the daytime by steam from the middle of November through the middle of April. The gametophytes developed from those zoospores remained sterile in such a condition and grew within one to two months to minute filamentous thalli visible to the naked eye. The growth of gametophytes was more rapid in those floating on the water surface than in those attached to the bottom of the dish.

Such a filamentous thallus was then picked up with a fine platinum needle or a pointed pincette, and, after determining under the microscope its sex by the size of cells, it was placed in a small dish or tube containing Schreiber's culture solution.

A preliminary cultural experiment of *Laminaria religiosa* under various conditions of temperature was carried out from early December, 1952 to early February, 1953. The cultural tubes were placed in the flasks filled with water and the water of each flask was kept respectively at 8°C, 12°C, 16°C, and 20°C constantly all day long, and at 20°C in the daytime only. Other tubes were placed on the table of the room heated in the daytime as mentioned above. The growth of gametophytes was best of all in the tubes kept at 20°C only in the daytime and in those at room temperature, whereas it was worst in those at constant 20°C. The isolated gametophytes cultured in the tubes at room temperature have survived already more than three and one-half years and have proved invariably sterile. They usually have a minute spherical thallus consisting

† Presented in abstract by G.F. Parpenfuss.

of monosiphonous branched filaments. A piece of filament taken from these thalli can be used at any time as material for a culture experiment, and it can grow to a new spherical thallus. On the other hand, the gametophytes became fertile only when cultured at 8°C and 12°C, bearing sexual organs about 25 days and 30 days after the start of culture, respectively, (cf. Fig. 1).

The eggs thus formed on isolated female gametophytes of all the species studied by us could germinate and develop parthenogenetically. The development of those parthenosporophytes was in general more or less irregular and resulted in the production of variously shaped malformed thalli as illustrated in Figs. 2 and 3. Malformed sporophytes of similar structure were once reported by Kanda *(2)* to occur in a mixed culture of *Laminaria ochotensis* Miyabe *(2*, Fig. 4, 9-10), *L. cichorioides* Miyabe (Fig. 7, 2-11) and *L. sachalinensis* Miyabe (Fig. 10, 4). In view of the very common occurrence of parthenogenesis in our culture experiments, resulting in the production of malformed thalli and the occasional production of malformed sporophytes in Kanda's mixed culture, the presence in nature of parthenogenetically developed malformed haploid embryos of kelps are supposed to be not improbable. However, malformed adult thalli of kelps, such as lately reported from Hokkaido and vicinity (cf. *1*, *6*, *7*, *8*) are not only of very rare occurrence but also are considered not to have been derived from such embryos as mentioned above. Such haploid embryos of kelps may possibly be of a limited life span.

Crossing experiments were carried out by putting in a tube a female or male gametophyte of one species together with a male or female of another which had been cultured in isolation. From twenty to twenty-two tubes were prepared

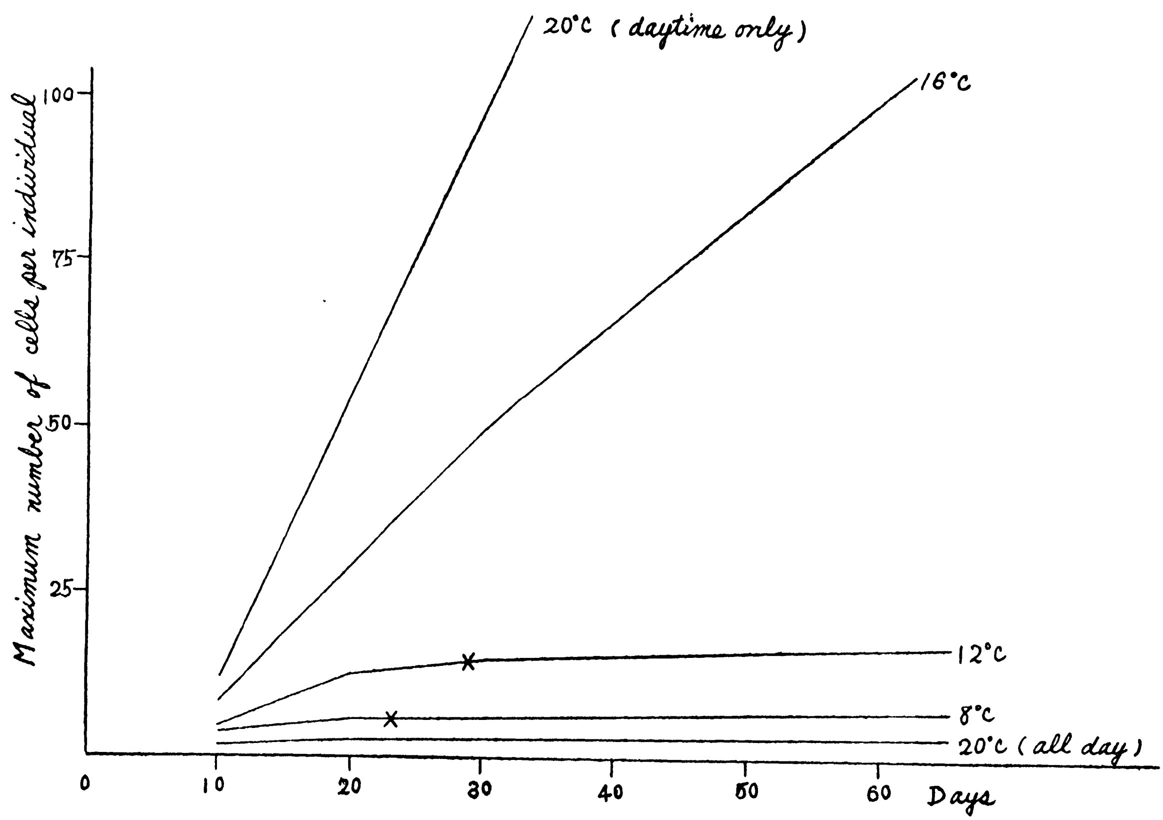


Fig. 1.—Growth rate of gametophytes of *Laminaria religiosa* as indicated by the number of body cells and time of the first appearance of reproductive organs (denoted by ×) in relation to the water temperature.

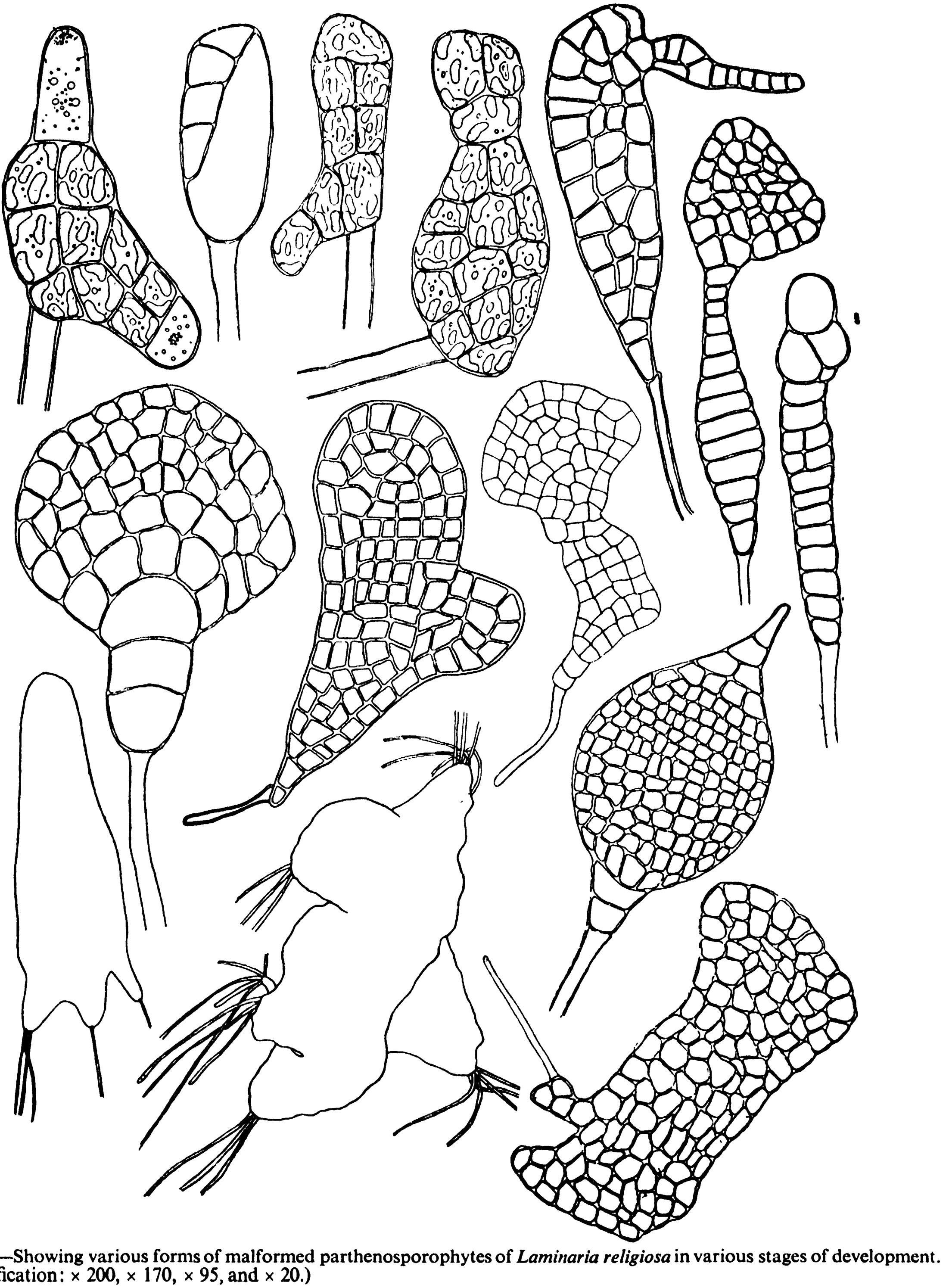


Fig. 2.—Showing various forms of malformed parthenosporophytes of *Laminaria religiosa* in various stages of development. (Magnification: × 200, × 170, × 95, and × 20.)

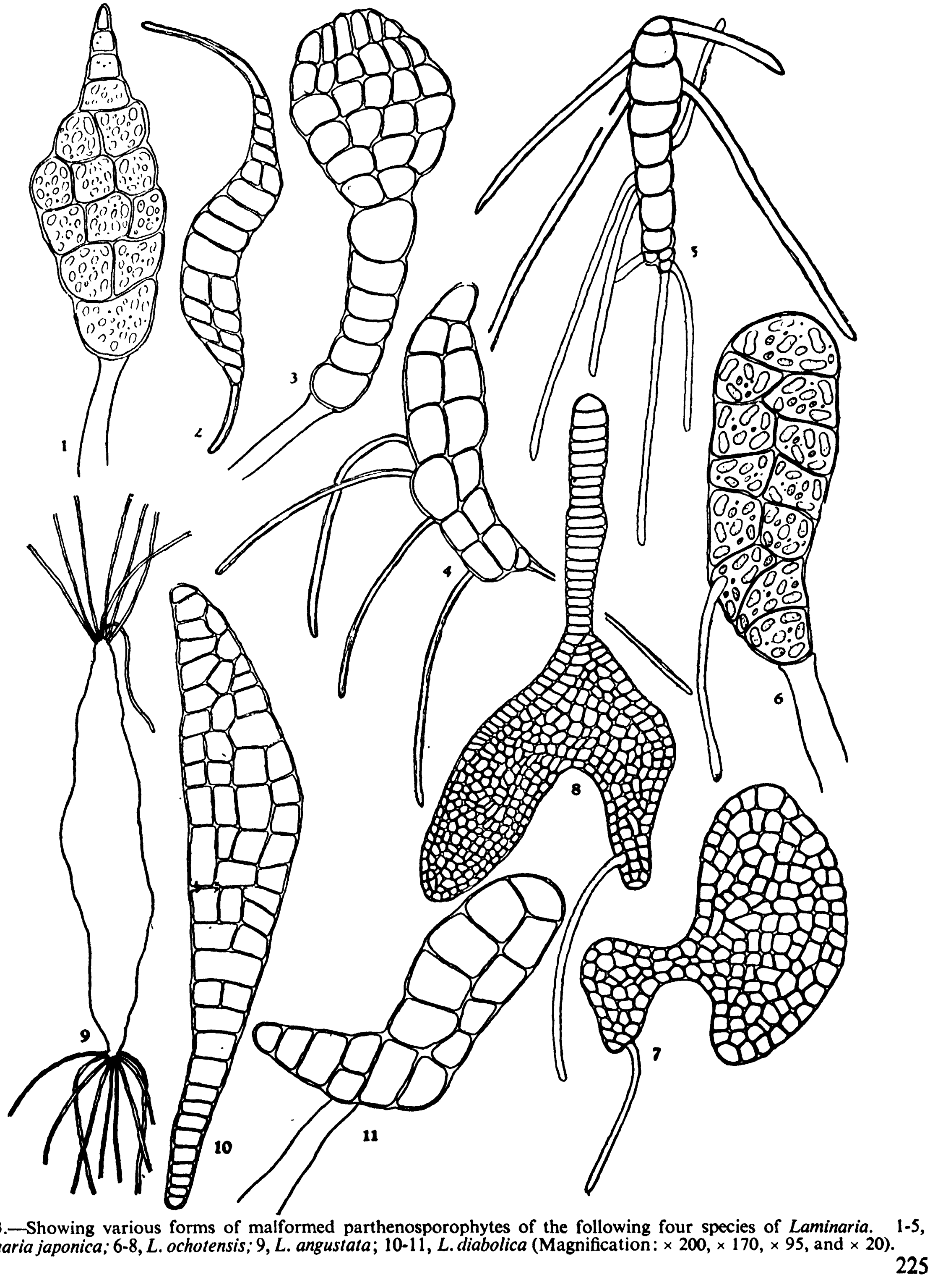
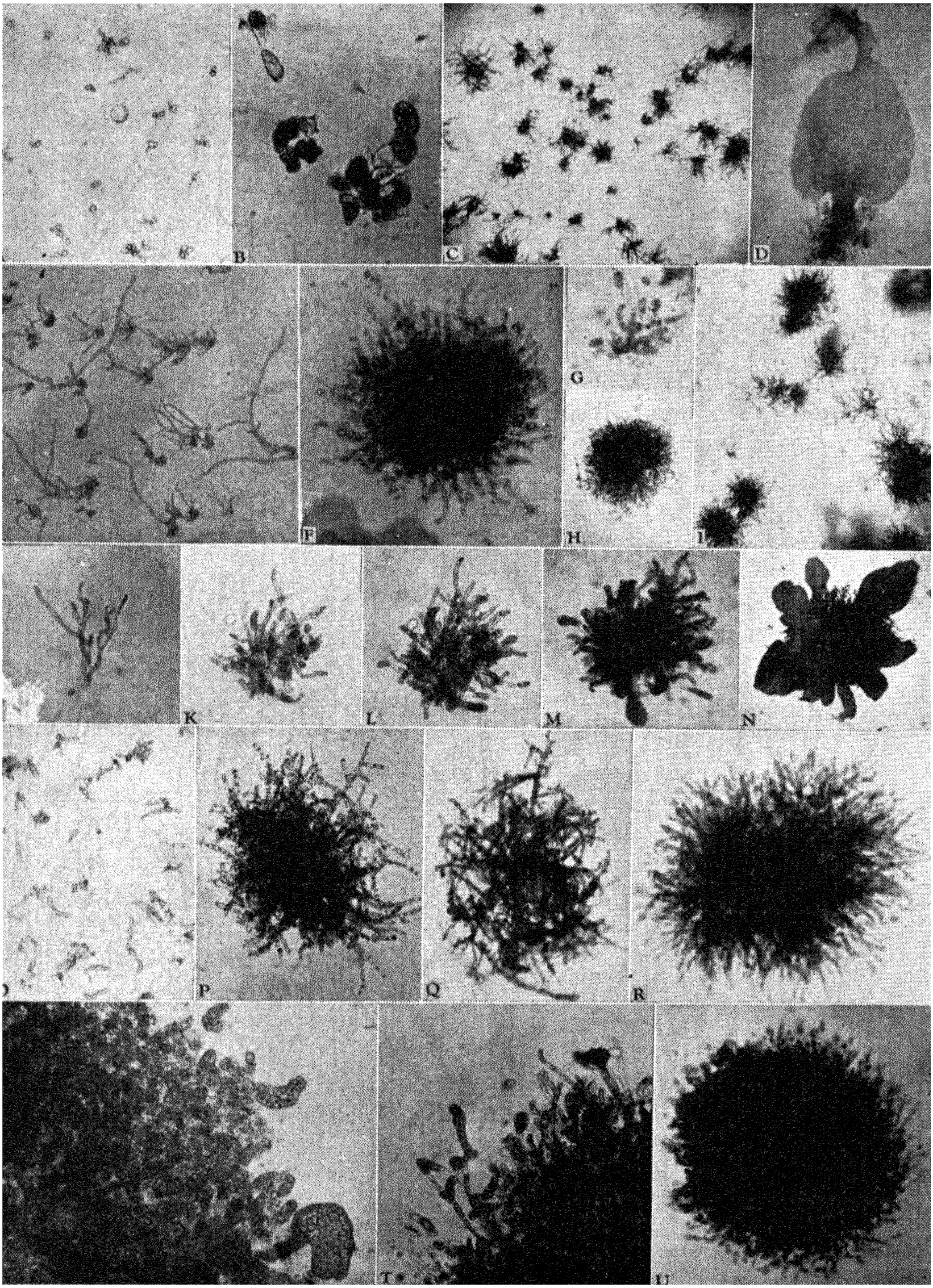


Fig. 3.—Showing various forms of malformed parthenosporophytes of the following four species of *Laminaria*. 1-5, *Laminaria japonica;* 6-8, *L. ochotensis;* 9, *L. angustata*; 10-11, *L. diabolica* (Magnification: × 200, × 170, × 95, and × 20).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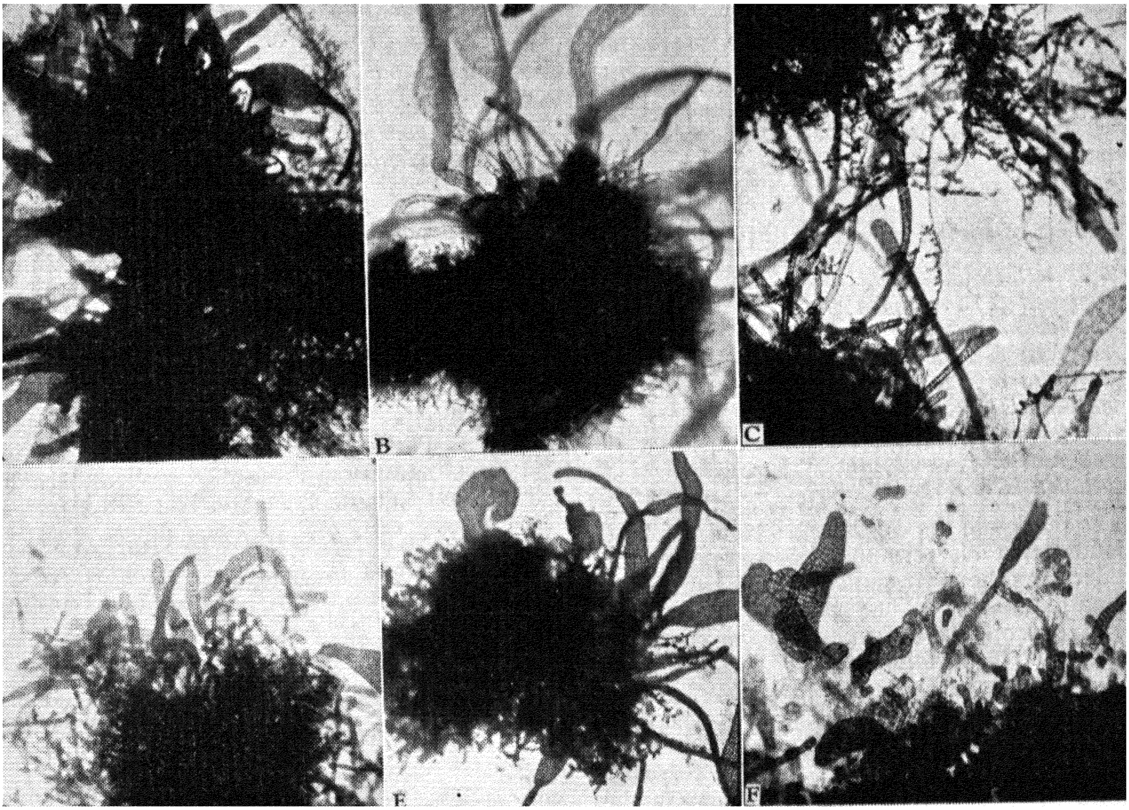

Fig. 5.—Microphotographs of embryonal *Laminaria* sporophytes produced in the following six crossing experiments. A, *Laminaria japonica* ♀ X *L. ochotensis* ♂, × 50; B, *Laminaria religiosa* ♀ X *L. japonica* ♂, × 50; C, *Laminaria ochotensis* ♀ X *L. religiosa* ♂, × 80; D, *Laminaria religiosa* ♀ X *L. ochotensis* ♂, × 80; E, *Laminaria angustata* ♀ X *L. religiosa* ♂, × 50; F, *Laminaria ochotensis* ♀ X *Alaria crassifolia* ♂, × 120.

←

Fig. 4.—Microphotographs of *Laminaria* gametophytes in various stages of development. A-H, J-N, R, U, *Laminaria religiosa*; A, one month old gametophytes cultured at constant 20°C; B, twenty-five days old female gametophytes bearing eggs in a culture kept at constant 8°C; C, sixty days old gametophytes in a culture kept at 20°C only in the daytime; D, seventy-seven days old female gametophyte bearing a parthenosporophyte, floating on the surface of cultural solution; E, thirty days old gametophytes cultured at constant 16°C; F, seventy-seven days old female gametophyte floating on the surface; G, seventy-seven days old female gametophyte attached to the bottom of the cultural dish; H, seven months old male gametophyte floating on the surface; J-N, five stages of development of one and the same piece of filament which was first taken at the stage shown in J from an immature female gametophyte floating on the surface; K, two months old; L, two and one half months old; M, three months old; N, four and one half months old; R, an immature female gametophyte cultured in isolation, 3.7 months old; U, a mature female gametophyte grown from a thallus similar to that which is illustrated in R after placed in a newly prepared Schreiber's solution three weeks before. I, *Laminaria japonica*, three months old gametophyte floating on the surface. O-P, *Laminaria angustata*; O, female and male gametophytes in a nine days old culture, at this stage of growth, isolation of gametophytes was done; P, a female gametophyte isolated 121 days before. Q,T, *Laminaria diabolica*; Q, a female gametophyte bearing parthenosporophytes, isolated 78 days before; T, a female gametophyte bearing parthenosporophytes, 68 days after isolation. S, *Laminaria ochotensis*, a female gametophyte 3.5 months old, bearing abundant parthenosporophytes. (Magnification: A, E-H, J-M, O-R, U × 80; B × 320; C-D, I, N × 40; S-T × 120).

for each crossing pair. The result of the experiments are summarized in Table 1.

Table 1.

Result of crossing experiments, showing the combination of species crossed and the structure, whether normal or abnormal, of sporophytes produced.

Couple of species crossed	Structure of sporophytes produced	
	Normal	Abnormal
L. japonica & *L. religiosa*	+	—
L. japonica & *L. ochotensis*	+	—
L. religiosa & *L. ochotensis*	+	—
L. religiosa & *L. angustata*	—	+
L. ochotensis & *L. angustata*	—	+
L. japonica & *A. crassifolia*	—	+
L. religiosa & *A. crassifolia*	—	+
L. ochotensis & *A. crassifolia*	—	+

The mark + in the Column "Normal" of Table 1 denotes that a larger number of the sporophytes produced in the corresponding couple of species are normal in shape. The parent species of these normal sporophytes are supposed to have achieved interspecific fertilization. Such a positive result of a crossing experiment in *Laminaria* is believed to be new to science, provided that the three species concerned are all valid. Or, this result may be taken rather as an evidence of specific identity of the three species. However, in our present state of knowledge, any conclusive remark is to be reserved until more decisive data, cytological and ecological, are acquired.

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DISCUSSION

G.F. PAPENFUSS apologized for summarizing the paper in the author's absence, and regretted that the illustrations had not arrived.

R.F. SCAGEL: How were the cultures started?

G.F. PAPENFUSS (consulting original script): In petri dishes, the floating gametophytes being isolated to flasks and maintained at room temperature. Sub-culturing was carried out from these gametophytes.

R.F. SCAGEL: Care must be taken when drawing conclusions from such techniques. All gametophytes look alike (apart from the cell differences in male and female), and the sporophyte must show secondary morphological features before the species can be identified.

In reply to Dr. Papenfuss' enquiry, Dr. Scagel said that his laboratory isolated sporangia to start their cultures.

CLEARING OLD TRAILS IN SYSTEMATIC PHYCOLOGY†

GEORGE F. PAPENFUSS

Department of Botany, University of California, Berkeley, California, U.S.A.

There is ample reason to believe that the current interest in the algae as research material for many kinds of problems in biology and biochemistry and as possible sources of food and fuel will continue. This interest has had and will continue to have a stimulating effect on those aspects of phycology that are primarily concerned with the acquisition of basic knowledge about the algae for its own sake. We may look forward, therefore, to expanded opportunities for fundamental work on these plants and to an increase in the number of phycologists in the world.

Because of its large size and the countless variety of habitats that it provides, no other ocean possesses such a rich and diversified flora as the Pacific. Our knowledge of the algae of large parts of the Pacific is still extremely meager, however. Many of the genera and species have been collected only once and are known only from the brief and often inadequate original descriptions. The flora of the Pacific thus provides us with unlimited possibilities for the pursuit of basic problems in all branches of phycology.

In anticipation of the development of opportunities for work on the algae of areas away from the present centers of activity in the Pacific, I have selected for discussion certain problems relating to the taxonomy of green, brown, and red algae occurring in some of the more remote parts of this ocean. The problems chosen are of interest because their solution not only will advance our knowledge of a number of little-known genera, some of which are also represented in the floras of other parts of the world, but the information gained will be useful in the interpretation of natural relationships within the groups concerned.

CHLOROPHYCEAE

Information is needed on the life history, the morphology of the flagella of the motile cells, the kinds of pigments present in the plastids, and the nature of the food reserves of *Pseudodichotomosiphon* in order to determine whether this genus belongs to the chlorophycean family Dichotomosiphonaceae, which was established by Feldmann *(12)* for the fresh-water genus *Dichotomosiphon*, or whether it is a member of the Vaucheriaceae, and hence representative of the class Xanthophyceae of the phylum Chrysophycophyta. *Pseudodichotomosiphon* is a monotypic genus that was established by Yamada in 1934 upon material from the Ryukyu Islands. Tseng *(33)* has obtained it also on the Island of Hainan. Luther (*20*, p. 36) is of the opinion that *P. constricta* (Yamada) Yamada had best be retained in *Vaucheria.*

On the basis of material from Taiwan, Heydrich in 1894 erected the genus *Rhipidiphyllon.* He regarded the type material as representative of the species which Askenasy in 1888 described under the name *Anadyomene reticulata* upon material from Western Australia. More recently Børgesen *(4)* and Taylor *(31)* have reported *R. reticulatum* from Easter Island and the Marshall Islands, respectively. Two problems relating to this genus are: (1) Is the type material actually representative of the plant from Western Australia? (2) Is *Rhipidiphyllon* an autonomous genus or should it be merged in *Microdictyon*, with which it appears to agree in all essential details?

Rhipidodesmis A. et E.S. Gepp *(13)*, *Boodleopsis* A. et E.S. Gepp *(13)* and *Pseudochlorodesmis* Børgesen *(4)* are three genera accredited to the Codiaceae that perhaps are merely the filamentous, unconsolidated juvenile stages of other genera of the Codiaceae, such as *Udotea* or *Avrainvillea*, which are well represented in the Pacific, or *Penicillus*, which has not yet been reported from the Pacific. In this connection, I might remark that I obtained in South Africa filamentous, unconsolidated mats of *Codium* that are easily mistaken for a filamentous genus of the Codiaceae; in fact, they were so mistaken by Dr. Egerod and me until Dr. Silva assured us that they were only the juvenile stages of some species of *Codium.*

Rhipidodesmis is based upon a species from Ceylon, *R. caespitosa* (J. Agardh) A. et E.S. Gepp, which has also been obtained on the Island of Hainan by Tseng *(33). Boodleopsis* was erected for a species from the Malayan Archipelago, *B. siphonacea* A. et E.S. Gepp, and *Pseudochlorodesmis* is based upon a plant from the Canary Islands, *P. furcellata* (Zanardini)

† The preparation of this paper was aided by a Grant-in-aid from the National Science Foundation.

Bøgesen. This species was recently reported from Vietnam and the Marshall Islands by Dawson *(7, 9)*.

In the paper that I gave at the Seventh Pacific Science Congress in New Zealand *(23)*, I have already remarked upon the uncertain status of *Rudicularia* (? Codiaceae), which was described by Heydrich *(16)* from material obtained in the Ryukyu Islands, and of *Bryobesia* (? Derbesiaceae) which Weber-van Bosse *(34)* founded for a plant from Java.

PHAEOPHYCEAE

Troll in 1931 *(32)* described under the generic name *Dictyotopsis* a peculiar monostromatic plant which grows by means of wedge-shaped apical cells that cut off segments alternately on two sides. The plant forms dense growths on the aerial roots of mangroves in river mouths in Sumatra and Amboina. Reproductive organs, other than propagules, were not observed in any of the material. In a general way, *Dictyotopsis* bears some resemblance to the liverwort genus *Metzgeria*, but it differs from this genus in a number of important features. *Dictyotopsis* is provisionally placed in the order Dictyotales, but the type of apical cell in its thallus is quite unlike that characteristic of the thalli of the Dictyotales. Pigment analysis and the discovery of reproductive organs will probably settle the question of the systematic position of this interesting genus.

RHODOPHYCEAE

At the generic level, the red algae of the Pacific present more problems than any of the other large groups of marine algae. The following are some of the genera that would especially repay study.

Gracilariocolax Weber-van Bosse *(38)*, which is based on a species that occurs as a parasite on *Gracilaria* in Java, is considered a genus of doubtful systematic position by Kylin *(17)*. It would be instructive to make a comparative study of *Gracilariocolax*, *Gracilariophila* Setchell et Wilson *(39)*, which is a parasite on *Gracilaria* along the Pacific coast of North America, and *Holmsella* Sturch *(28)*, which is a parasite on *Gracilaria* in England, to see whether there is a relationship between these three genera. None of them has been thoroughly studied, and it is conceivable that they will be found to be closely related, if not congeneric.

The genus *Weberella* (Rhodymeniales: Rhodymeniaceae) was described by Schmitz *(25)* upon material from Flores Island in the Malayan Archipelago. The type and only species, *W. micans*, has also been reported from Timor and Java by Weber-van Bosse *(38)* and from Taiwan by Yamada *(40)*. A study of the structure and reproduction of this genus is highly desirable. To judge from the original description by Schmitz and the observations of Yamada, it appears likely that *Weberella* and *Herpophyllon* Farlow[1] *(11)*, which is based upon a type from the Galapagos Islands, are congeneric. Kylin *(17)* has placed *Herpophyllon* in the Squamariaceae (Cryptonemiales), but the structure of the thallus and especially the habit of these two genera (both have a dorsiventral organization and produce hapteroid protuberances on the lower surface of the thallus whereby the lobes of the thallus become secondarily attached to one another or to the substratum) suggest that they belong in the Rhodymeniales. In connection with these two genera, attention should also be drawn to *Halichrysis* (J. Agardh) Schmitz *(24)*, which is based upon a type from Morocco, and *Sciadophycus* Dawson *(6)*, which was founded for a plant from Cerros Island (off the west coast of Baja California), both of which appear to belong to the same complex as *Weberella* and *Herpophyllon*.

On the basis of material from the Malayan Archipelago, Weber-van Bosse *(34)* established the genus *Exophyllum*. This plant has been referred, with doubt, to the Rhodymeniaceae. One of its characteristic features is the production of tetrasporangia in stichidia, a character which, as Kylin (*17*, p. 558) has remarked, is entirely foreign to the Rhodymeniaceae or for that matter to the order Rhodymeniales. The determination of the systematic position of this plant must await a study of its reproductive organs. Recently the genus was discovered in southern Japan by Tanaka *(30)*.

Zellera and *Opephyllum* are two of the little-known genera of the Delesseriaceae. *Zellera* was described by Martens in 1866 upon a plant from the Island of Tawalli in the Moluccas and was later reported from the same region by Weber-van Bosse *(36)*. The genus appears to be related to the reticulate genera *Claudea* and *Vanvoorstia*, but its true affinities will remain uncertain until well-preserved material of the type species, *Z. tawallina*, has been studied. Martens stated that the blades tend to fuse with others to form a reticulum; but this is not the

[1] De Toni fil. *(10)* has proposed the substitute name *Drouetia* for this genus.

case, according to Sluiter *(27)* and Weber-van Bosse *(36)*. Knowledge of the structure and reproduction of *Z. tawallina* may also assist in the solution of a problem relating to the algae of the West Indies. Sluiter *(27)* has referred a species from that region to *Zellera*, but her figure of its habit gives the impression that the plant is misplaced in *Zellera*.

Opephyllum was erected by Schmitz *(25)* for a species collected by Martens at Zamboanga on the Island of Mindanao. This plant has never again been collected. The genus has not been illustrated; but to judge from Schmitz's description, it seems likely that *Opephyllum* will be found to be congeneric with *Martensia* Hering.

As is well known, Madame Weber-van Bosse described a relatively large number of new genera and species from the East Indies. Unfortunately, she did not always furnish the detailed information that is necessary for the correct placement of her taxa. The following are genera of red algae established by Weber-van Bosse, in addition to some of those already referred to, whose systematic position is uncertain: *Dorella* (1921), *Catenellocolax* (1928), *Microphyllum* (1928), *Corallophila* (1923), *Mortensenia* (1926), *Chalicostroma* (1911), and *Perinema* (1911).

To illustrate the benefits for systematic phycology to be derived from a study of the old taxa, I might review briefly a few of the recent contributions that have materially advanced our knowledge of certain genera.

In the paper that I gave at the Seventh Pacific Science Congress *(23)*, I remarked that the occurrence of the reproductive organs on filaments in the New Zealand genus *Microzonia* is different from the condition in all other Dictyotales, to which order this genus had been assigned. A study by Miss O'Donnell *(22)* of material of this genus given me by Lindauer has shown not only that the reproductive organs (unilocular sporangia) actually are produced on filaments but that the thallus shows trichothallic growth. It is evident, therefore, that *Microzonia* does not belong to the Dictyotales but to the Cutleriales, which order previously comprised only the genera *Cutleria* and *Zanardinia*.

Levring (*18,19*, and in Svedelius, *29*) studied newly-collected material as well as the type of the type species of *Gloiophloea*, *G. scinaioides* J. Agardh *(2)*, and found that our concept of this genus is wrong. The previous concept was that developed by Setchell *(26)* in his monograph on the *Scinaia* complex and was based on a plant from New Zealand which Setchell believed to be representative of *G. scinaioides*, whose type (not seen by Setchell) was obtained in Australia. Levring established that the species from New Zealand (and also the other species of *Gloiophloea* described by Setchell) is representative of a new genus for which he proposed the name *Pseudogloiophloea*.

The genus *Corallopsis* was erected by Greville in 1830 for *Sphaerococcus salicornia* C. Agardh *(1)*, whose type was collected by Chamisso during the voyage of the Russian exploration ship *Rurik*, allegedly in Unalaska. Several authors have doubted that Unalaska actually was the source of Chamisso's material. Dawson *(8)* recently collected a plant in the Philippines that agrees in all essential details with C. Agardh's *(1)* illustration of the type of *C. salicornia*. Examination of the log of the *Rurik* revealed, furthermore, that the ship had stopped for six weeks at Manila, which circumstance suggests with a good deal of certainty that the type of *C. salicornia* was obtained in the Philippines. Dawson's study of the material that he collected in the Philippines has shown that *C. salicornia* is a species of *Gracilaria*. Thus Dawson in a most satisfactory way cleared up the question about the source of the type of *C. salicornia* and at the same time showed that *Corallopsis* Greville *(14)* is congeneric with *Gracilaria* Greville *(14)*.

From the examples that have been discussed of problems awaiting investigation and of problems solved, it is evident that the flora of the Pacific offers challenging opportunities for fundamental work in systematic phycology.

I have confined my discussion to problems relating to the type species of genera occurring in more or less remote parts of the Pacific. In addition, many taxa from such regions have been described as new species of old genera and others have been identified with species based on types from other parts of the world. Detailed study of these species will reveal that a large number of the putative new species actually are not new and that many of the others have been misidentified. Therefore, on the basis of present knowledge of the algae of the Pacific, little can be concluded with any degree of certainty about the geographic distribution of the majority of the species in this large ocean.

I do not wish to convey the impression that in my opinion nothing is to be gained from the cataloguing of the floras of unexplored areas. It is true, however, that in such works further confusion will be created through the inevitable description of new taxa, many of which will have to be reduced when the old taxa have been carefully studied.

I should thus like to recommend to the phycologist for whom an opportunity has developed to work in remote parts of the Pacific, that he selects as territory of operation one or more of the regions where previous collecting has been done rather than an area that has remained unexplored. The unexplored parts can be taken care of much more profitably after the forest of confusion has been removed from the old trails.

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DISCUSSION

M.S. DOTY: I suggest that the algal subcommittee compile a list of problematic species and their localities.

G.F. PAPENFUSS: It is vital to clear up the confusion in old species before erecting new ones.

J. FELDMANN: Few species are completely well-known. More cytological studies should be carried out on genera such as *Vaucheria*.

G.F. PAPENFUSS: The problem becomes simpler if there is a plentiful supply of material.

G.A. PROWSE: In the desmids, the frequent occurrence of dichotypical cells has made the re-assessment of the concept of species vitally essential.

M.S. DOTY: Have the pigments of *Dichotomosiphan* been investigated?

J. FELDMANN: On the basis of the plastids, there is no doubt that it is a green alga.

G.F. PAPENFUSS: Dr. Feldmann is fully justified in erecting the family Dichotomosiphonaceae.

ON THE STATE OF PHYCOLOGICAL KNOWLEDGE IN THE PHILIPPINES†

GREGORIO T. VELASQUEZ‡

Department of Botany, University of the Philippines, Quezon City, Philippines.

One finds the first general attempt to identify the algae of the Philippines in Blanco's *Flora de Filipinas*, of which there were three editions, in 1837, 1845, and in 1877 to 1883, the latter edition posthumous. Blanco's identifications of Philippine species with those of older authors were of necessity unreliable as he worked in botanical isolation and with very little available literature. He proposed a few names for new species himself in his first edition, of 1837, which are no more indefinite that some of those of his contemporaries in other parts of the world. These names were later changed (in one instant by himself) or were considered by other botanists as synonyms of older ones. In his second edition, Blanco himself replaced the name *Fucus Gulaman* Blanco by *Fucus edulis*, which was considered by Georg von Martens to be *Sphaerococcus gelatinus* Agardh. The latter name was based upon *Eucheuma gelatinae* and *Fucus gelatinus*.[1]

Von Martens made a serious attempt to synonymize Blanco's algae and proposed the following equivalents:

Fucus prolifer = *Halimeda discoidea* Decaisne

Fucus denticulatus = *Sargassum* (spp.)

Fucus Gulaman = *Sphaerococcus gelatinus* Ag.

An unnamed species similar to last = *Sphaerocarpus lichenoides* Ag.

Ulva umbilicalis = *Zonaria gymnospora* Kützing

Ulva compressa = *Enteromorpha complanata*, var. *crinita Kützing*

Ulva intestinalis = *Enteromorpha intestinalis* Link.

It must be noted that some of Blanco's names are apparently older than the synonyms, and if sufficiently definite in application to be synonymized, should probably replace the later names. This is particularly true as Blanco was rather precise in indicating localities, where new collections at the places he indicated might enable his species to be interpreted. This is a matter that may rest for the present, but it is definitely indicated that new and ample collections should be made at all localities from which species were described by the older authors, not only Blanco, but also others. Interpretation of old species by careful study of the florulas of type localities is perfectly proper if specimens of the older authors have not survived.

Not only did Georg von Martens look into the identity of Blanco's species, he likewise compiled an elaborate table showing the known geographical distribution in 1866 of all the Algae that had been described or reported from tropical Asia and the tropical Pacific. This table surely affords a key to most of the literature bearing on Philippine algae that appeared prior to 1866, but also accounted for the collections of his son Dr. Eduard von Martens who accompanied the Prussian East Asia Expedition as zoologist. On account of his father's special interest in the algae, Eduard von Martens collected them whenever he had the opportunity.

Only two Philippine fresh-water species were described as new by Georg von Martens, namely *Cladophora diluta* and *Cladophora luzoniensis*. The seaweeds were all considered to have been previously known, but there are among them first records from various localities.

A few of the scanty early records of Philippine algae were based upon collections of the American Exploring Expedition under the command of Charles Wilkes. The botanical collections of the Wilkes Expedition were made by Charles Pickering, general naturalist and ethnobotanist, author of *The Chronological History of Plants: Man's Record of his own Existence illustrated through their Names, Uses, and Companionship*, William D. Brackenridge, who wrote a volume on the ferns, and William Rich, who was primarily interested in collecting flowering plants. Because there was no especialist in the lower cryptogams among the naturalists of the

† Made possible through the Guggenheim fellowship and the University of the Philippines special detail fellowship during 1956-1957.
Presented by G.F. Papenfuss.

‡ Secretary of the Graduate School and Associate Professor in Botany, University of the Philippines.

[1] See J.G. Agardh, 1851, in *Species Genera et Ordines Floridearum*, **2**: 268.

Expedition (and such were few at that early date), the collections of algae were meagre. They were determined by Bailey and Harvey[2], in whose report there are two lists, one of the large forms containing numbers of Philippine reds and browns, only one of them new, namely *Dictyota dichotoma*, and a second longer list containing several new species of diatoms, namely *Amphitetras favosa*, *Campylodiscus Kutzingii*, *Lagena Williamsonii*, and *Triceratium orientale*.

All of the diatoms were listed as having come from the Sula Sea, without designation of place, but are fairly considered as part of the Philippine flora, as they were obtained as epiphytes on the larger algae. There is to be found in the general report of the Expedition, which was written by Wilkes himself, a clear indication that shore collecting was done at only one Philippine locality. That was at Marongas Island, indicated on Wilkes' map of Jolo (Sooloo) Island as lying across a narrow strait of the northeast coast of Jolo.

An English resident of Manila during the Spanish regime was Hugh Cuming, who made the most extensive collections down to the time of the American occupation. His algal collections were described by C. Montagne. They were widely distributed from Kew, and it was possible even as late as the early years of the present century for Dr. E.D. Merrill to secure some of the duplicates for the herbarium of the Bureau of Science, which had been built up vigorously during the period prior to World War II. The Philippine algae of the famous British "Challenger Expedition" were enumerated by Dickie in 1876 and 1877. The specimens were presumably in English herbaria. A good many algae were accumulated by the Bureau of Science collectors and by botanists connected with the University of the Philippines. This included Walter Shaw, especially interested in the Volvocaceae, who wrote on that group and published new Philippine genera, namely: *Campbellosphaeria*, *Janetosphaeria*, *Merrillosphaeria*, and *Copelandosphaeria*. It was fortunate for the beginning of phycological study that some of the algae of the Bureau of Science and University herbaria had been sent out as exchanges or on loan prior to World War II and are still to be found in various herbaria abroad.

During the early part of the American period the most extensive collecting of Philippine algae was carried out by the Dutch Siboga Expedition. There was a general report by Mme. Weber van Bosse on all of the collections, and monographs of special groups, the Codiaceae by A. and E.S. Gepp, the genus Halimeda by E.S. Barton, and the remarkably well represented corallines by A. Weber van Bosse and M. Foslie. The Siboga Expedition dredged very extensively at charted stations throughout the Sulu Sea, and the Foslie contributions to our knowledge of the group are basic. The specimens are presumably in Holland and elsewhere in Europe. They were never represented in the Philippine herbaria.

The algae of the voyage of the Italian Vettor Pisani were described by A. Piccone in 1886. Later in 1889, three more species were added in the record of Philippine algae. That ended the period of visits of oceanographic expeditions, so far as reports on algae were concerned.

During the incumbency of an exchange professorship at the University of the Philippines in 1935, H.H. Bartlett began a systematic effort to collect the algae. Many localities were visited by him, his colleagues, and students. The collections have so far been studied only partially, the Chlorophyceae by Dr. W.J. Gilbert, the genus *Galaxaura* by Dr. Ruth Chou, and various Myxophyceae by the present writer. Fortunately, duplicates of almost everything went to the University of Michigan, and therefore remain as a basis for further study. A collection of minute epiphytes had been picked off of larger algae and mounted on slides. These only were lost, but they can doubtless be replaced from the larger herbarium specimens. A series of plankton collections were also lost. The localities represented have been listed by Gilbert in his doctoral dissertation. Most of the Myxophyceae were collected by the present writer. He was induced by the urgency of the nuisance caused in fish ponds by blue-green algae to concentrate on that group. Hundreds of collections were made, which were largely studied taxonomically by Drouet, and which appeared in numerous papers prepared by the writer. But the more extensive is Drouet and Daily's "Revision of the coccoid Myxophyceae" *(12)* which cited all myxophycean unicellular forms so far known from the Philippines. Thanks to the circumstances of duplicates having gone abroad, the vouchers for Philippine collecting in this group down to 1941 have not been lost.

[2] Summary of the life of J.W. Bailey and W.H. Harvey, each a pioneer in his chosen botanical career at the time, may be found respectively in *Appleton's Cyclopaedia of American Biography*, V. 1, 1888 and *Dictionary of National Biography*, V. 25, 1891.

Bartlett was again in the Philippines in 1940-41, and although engaged in agronomic work, he arranged for a pearl diver (Balhani, Moro of Siasi) to make bulk collections at various places in the Sulu Sea that could be reached by native *vinta* from Zamboanga. The collecting was supervised in large part by Professor Jose S. Domantay of the Bureau of Fisheries. All of these collections were preserved in formaldehyde in 55 five-gallon cans. The huge task of making them into herbarium specimens was undertaken by the University of Michigan under the supervision of Dr. Wm. Randolph Taylor. They have not yet been studied, but sets will be returned eventually to the Philippines for the University and the National Herbarium.

In spite of the discouraging loss of all of the botanical collections and the libraries of the Bureau of Science and the University of the Philippines during the war for liberation of Manila, an immediate effort was made in 1945 to make a new start. This was greatly aided by a grant-in-aid to the present writer from the American Philosophical Society, which enabled him to continue his own researches on the Myxophyceae. Several of his students developed a sufficiently strong interest so that they were able to publish contributions or deposit unpublished master's theses, notably J.D. Soriano, M. Cantoria, V. Aligaen, E. Medina, M. Valero, and V.G. Viola. Needless to say, the publications and theses of these immediate post-war workers could not have been prepared in the absence of all reference materials without the friendly and much appreciated collaboration of authorities abroad, among whom should be especially mentioned Dr. Francis Drouet at the Cryptogamic Herbarium of the Chicago Natural History Museum and Dr. Wm. Randolph Taylor of the University of Michigan.

In order to maintain impetus, the Algological Society of the Philippines was organized in June 1956, with sixteen initial members. Later the names were added of several persons who were interested in algae as sources of food, in their uses in pharmacy and various fertilizer analyses in chemistry, or in other economic aspects of the group such as their cultivation in fishponds. Dean Patrocinio Valenzuela, Executive Secretary of the National Research Council of the Philippines, and Dr. Deogracias Villadolid, former Director of the Bureau of Fisheries and presently engaged in fish culture, were made honorary members to furnish moral support and necessary encouragement to the new organization. Among the enthusiastic members are Professor Domantay who collaborated with Bartlett in organizing and supervising the Sula Sea collecting in 1940-41, Mr. I.A. Ronquillo of the Bureau of Fisheries, Mr. M. Palo of the Institute of Science and Technology, Mr. Z.R. Torres of the University of the East, and Dr. J.V. Santos of the Department of Botany, University of the Philippines.

As the members of this Society could do little at the start, except to collect and to make ecological and economic observations, they have conceived the idea of building up a "bank" of well duplicated numbered specimens, only roughly identified as to family or genus, from which specialists abroad may receive material for use in monographic or regional studies. It is hoped that there will be requests from members of the Subcommittee on Algae of the Committee on Botany of Pacific Science Council for material to be used in their various researches. As fast as material from this "bank" is identified, remaining specimens will be incorporated with the organized herbaria of the Philippine National Museum, the University of the Philippines, and any other institutions that participate in the project. The preparation of "Algae Philippinae Exsiccatae" is soon to be started with the cooperation of Dr. Mason Hale, Associate Curator of the Division of Cryptogams, U.S. National Herbarium of the Smithsonian Institution.

There is every reason why there should be immediate cooperation with other countries of Southeastern Asia and the Pacific. There is so large a widely distributed element in the algal floras of the tropical countries that are neighbors to the Philippines that an understanding of geographical and ecological relationships requires the most extended study possible. Furthermore, there are various new political entities in the Old-World tropics with newly established scientific institutions which might like to cooperate closely with the Philippines, or to organize regional survey work independently in a similar manner.

In the rebuilding of Philippine references and research collections an effort is being made to secure for Manila institutions as much duplicate prewar material as can be found abroad. The fortunate circumstance that much still remains for distribution from the University of Michigan has already been mentioned. The greatest possible cooperation has been realized from Dr. Drouet of the Cryptogamic Herbarium, Chicago Natural History Museum, who has sent to Manila whatever could be spared of duplicates sent him prior to the destruction of the Philippine institutions. Dr. Tiffany of Northwestern University turned over to the writer all his accumulated articles on the Myxophyceae for library references. There could be no greater proof of the value of collecting abundant material and distributing it widely. What is destroyed in one place is preserved in another. As a result of inter-institutional cooperation between the Philippines and the United States, for example, the voucher specimens for 183 Philippine records of Myxophyceae, including types, have been preserved.

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DISCUSSION

G.F. PAPENFUSS: Perhaps Dr. Santos can tell us what has happened to Blanco's material.

J.V. SANTOS: It was destroyed by fire in Manila during the war.

I should explain that the algal society mentioned by Dr. Velasquez has been formed from members from zoology, medical, and fisheries departments. The algal collection is increasing from time to time, and Dr. Velasquez is organizing the identifications.

PHYLOGENETIC RELATIONSHIPS OF CERTAIN DORSIVENTRAL RHODOMELACEAE

ROBERT F. SCAGEL

University of British Columbia, Vancouver, Canada.

Although Schmitz *(14)* and Schmitz and Falkenberg *(15)*, as well as earlier authors, had subdivided the family Rhodomelaceae into a number of subfamilies, Falkenberg's *(2)* monograph on the Rhodomelaceae was the first noteworthy attempt at a broad phylogenetic study of this largest family of Rhodophycophyta in which there are some 1,200 species now recognized. Oltmanns *(8, 9)*, Rosenberg *(11)*, Kylin *(6, 7)*, Fritsch *(3)*, and Scagel *(12)* have attempted to bring the group in line with more modern concepts of classification in the Florideophycidae, but each, with some modification, has essentially followed Falkenberg's division of the family into subfamilies. Rosenberg *(11)* removed the Dasyaceae from the Rhodomelaceae and established this group as an autonomous family, the Dasyaceae, and Scagel *(12)* has attempted, on the basis of a study of certain of the dorsiventral Rhodomelaceae, to further assess phylogenetic relationships in the family. Kylin *(7)* has departed to the greatest extent from the system of classification proposed by Falkenberg *(2)*. It has been possible by further study of some of the genera in this large group to place a number of entities formerly of uncertain position. However, there still exists in this family a broad field for research on a generic level before a satisfactory approach can be made to the solution of the many specific problems and before the merits of the phylogenetic relationships can be adequately weighed. As Oltmanns *(8, 9)* has stressed, one must have a detailed knowledge of the family as a whole before a reassessment of such a large group can be made. Many of the genera, even as they have now been rearranged or subdivided by Kylin *(7)*, still include obscure and little-known plants which have never been adequately studied. There seems little doubt that further rearrangements and subdivisions of this large family will be warranted, but until more of the entities have been studied in greater detail and in all stages of development there seems little justification in proceeding further at this time in an attempt to regroup genera into subfamilies.

The position of the Rhodomelaceae in the classification system, as for the majority of the groups in the Florideophycidae, is based essentially on embryological characters proposed by Schmitz *(13)*. More recent studies, particularly on the female reproductive apparatus, have further emphasized the importance of using these structures for the interpretation of phylogenetic relationships on both ordinal and family levels. The studies of Kylin *(4, 5)* and Papenfuss *(10)* have particularly stressed the importance of the use of the female reproductive system in the delimitation and interrelationships of the families of algae now included in the Order Ceramiales. It is apparent from these studies that the Ceramiales is a highly evolved group. In the members of this order the carpogonial branch, auxiliary cell, supporting cell, and often the central cell, the sterile cells, and in some instances even the inner cells of the pericarpic layer, all contribute in varying degree to the nutrition of the carposporophyte. Of the four families in this order, however, this phylogenetic trend in the nourishment and protection of the developing carposporophyte is most clearly evident in the Rhodomelaceae. In this family, the direct fertilization of an auxiliary cell, which is formed only after fertilization of the carpogonium, and the early formation and high degree of development of the pericarp are well-established features. With respect to both reproductive and vegetative structures, not only the Order Ceramiales, but also the Family Rhodomelaceae is the most clearly defined and most highly developed of all groups of Florideophycidae.

Chief among the distinguishing characteristics of the life-histories of the Rhodomelaceae, as well as for the majority of the Florideophycidae, is the succession of somatic phases, different from that of most other algal groups. This is due to the development of the carposporophyte, following the fertilization of the carpogonium. The gametophyte, which bears the sex organs, is haploid, and the fertilized carpogonium gives rise indirectly to a carposporophyte with diploid sporogenous tissue. No reduction division accompanies the production of the carpospores, which germinate to give rise to the diploid tetrasporophyte. This tetrasporophyte bears the tetrasporangia in which reduction division occurs and the haploid tetraspores give rise to male and female gametophytes. Thus there are four somatic phases, two haploid and two diploid. The carposporophyte, which is almost like a parasitic generation, is much reduced in vegetative development and remains attached to the female gametophyte. Although the tetrasporophyte and the male and female gametophytes are quite separate phases in the life history, they cannot generally be identified morphologically as such, or even anatomically until the reproductive cells are formed. For this reason, there is an even greater opportunity in such a group for studying vegetative characteristics—both in the haploid and diploid phases.

In spite of the large size of the family Rhodomelaceae, there is probably no group of algae which shows such a remarkable degree of uniformity in the female reproductive organs and in the post-fertilization development. Although the uniformity of the female reproductive system is an outstanding feature of the Rhodomelaceae, on the other hand the family shows a diversity in vegetative organization not met elsewhere in a family of multicellular algae. The strictly apical development of the thallus can be traced in the young plant by means of the primary pit-connections between cell lineages, although in older stages secondary pit-connections may be formed between adjacent pericentral cell derivatives and result in a pseudoparenchymatous thallus whose development and organization may soon be obscured. Although the development of the mature thallus may be completely evident from a study of its apices, there are instances, as in *Placophora*, in which the evanescent juvenile stages have been found to exhibit an organization quite different from that of the mature thallus. For this reason it is instructive to study not only the mature plants but also the juvenile plants and their development before completing a phylogenetic arrangement of genera in this group. Although the range in construction of the thalli varies from comparatively simple, radially symmetrical plants to elaborate and complex types with bilateral symmetry or dorsiventral organization, through a study of the apex of the mature plants the polysiphonous theme on which these variations are superimposed is readily ascertained even in the most highly modified types.

The family can be subdivided into a number of subfamilies which can be arranged in several lines of evolution based primarily on symmetry. Accumulated evidence supports the theory that the subfamily Polysiphonieae is the basic group from which all other subfamilies have been derived. The ancestral type was probably a simple, radially symmetrical, *Polysiphonia*-like alga with five pericentral cells in the polysiphonous segments. On this basis the evolutionary lines are: the *Polysiphonia*-series, the basic group from which all Rhodomelaceae are probably derived, the *Lophothalia*-, *Chondria*-, *Pterosiphonia*-, *Herposiphonia*-, and *Amansia*-series. The *Polysiphonia*-, *Lophothalia*-, and *Chondria*-series include chiefly radial forms, whereas the *Pterosiphonia*-series includes primarily bilateral forms. The *Herposiphonia*- and *Amansia*-series include primarily dorsiventral forms. It is a part of the *Herposiphonia*-series which I shall use particularly to illustrate the emphasis which may be placed on vegetative characteristics in the group.

According to Falkenberg *(2)* this series comprises two subfamilies—the Herposiphonieae and the Polyzonieae. However, Kylin *(7)* has further split up the Herposiphonieae into three groups which may be referred to as the Herposiphonieae, Placophoreae, and the Streblocladieae. The genera included in this series are chiefly dorsiventrally organized. In some, as in *Metamorphe* (Herposiphonieae), the axes are simple, more or less erect, and *Polysiphonia*-like with dorsiventrality very slightly developed. In more advanced genera, as *Placophora* and *Amplisiphonia* (Placophoreae), dorsiventrality is very pronounced and the mature thalli, which are almost entirely prostrate, show extensive congenital coalescence of the axes. The Polyzonieae includes genera which show strongly pronounced dorsiventrality. Many of the latter have acquired the form of jungermanniaceous liverworts as the result of various types of wing-development *(Leveillea)*, the coalescence of determinate laterals (species of the "cuneifoliate" group of *Dasyclonium* (=*Euzoniella)* or a combination of both.

The initial stages of the prostrate phase of many of these dorsiventral forms arise from the basal part of an erect, radially or bilaterally symmetrical, determinate and evanescent juvenile or primary axis. But even where there is pronounced dorsiventrality, as in *Placophora*, when reproductive branches are produced, the latter may revert to an erect radial habit. If we interpret these juvenile stages as evidence of ontogeny repeating phylogeny, then we have additional features supporting the theory that the erect, radial, *Polysiphonia*-type represents the prototype of the group. One might postulate that in time the erect form lost its ability to produce exogenous indeterminate laterals. The production of a prostrate indeterminate lateral from the lower part of the juvenile axis consequently has survival value, and the plant is able to produce an extensive thallus despite the fact that it may have lost the capacity of producing exogenous indeterminate laterals at the apex of an erect primary axis. As a result of the development of holdfasts and a prostrate habit, this successful, basal, indeterminate branch has gained a still better chance of survival.

To illustrate how one can carry the analysis of the vegetative characteristics to the specific level I should like to consider in somewhat greater detail the genus *Dasyclonium* (=*Euzoniella*). As far as is known, the dorsiventral phase of the thallus of the species of this genus is initiated by a primary lateral which arises from the basal part of a diminutive, comparatively evanescent, radially or bilaterally symmetrical primary axis. The two groups within this genus, which have been designated *(12)* as the "incisate" and "cuneifoliate" groups, are characterized primarily on the basis of the structure of the determinate branches. The "incisate" group includes those species in which the secondary and subsequent orders of branches formed by the determinate axes are more or less free from one another at maturity. The "cuneifoliate" group includes those species in which the secondary and higher orders of branches formed on the determinate axes are congenitally fused to varying degrees at maturity. Kylin *(7)* has chosen to split up the group of species formerly included in the genus *Euzoniella* Falk. 1901 (in the broad sense as the name was proposed for conservation as against *Dasyclonium* J.Ag.,*1*; by Silva,*16*,*17*) into two groups (*Dasyclonium* J.Ag., *sensu* Kylin, 7 and *Euzonia* Kylin, 7). These two groups are those which have already been designated as the "incisate" and "cuneifoliate" groups. I do not believe that the separation of this group of species into two genera is justified. Further confusion results in properly assigning certain entities, one of which Kylin apparently overlooked, [*Dasyclonium palmatifidum* (Grun.) *n. comb.* (= *Euzoniella palmatifida* (Grun.) Cuoghi-Cost.), *D. harveyanum* (Decne ex Harv.) Kylin (= *Euzoniella harveyana* (Decne ex Harv.) Falk.) and *D. ocellatum* (Yendo) *n. comb.* (= *Euzonia ocellata* (Yendo) Kylin)] to *Dasyclonium sensu* Kylin and his new genus *Euzonia*. Although a good case may be made for conserving *Euzoniella* as proposed by Silva *(16)*, as this proposal was subsequently rejected in favour of *Dasyclonium*, it would now seem best to reject Kylin's division of the group and refer all species to the one genus *Dasyclonium* J.Ag. (= *Euzoniella* Falk.). On the basis of the structure and coalescence of the determinate branches, the species of this genus can be arranged in an evolutionary series whose equal for completeness is probably not encountered elsewhere in the family *(12)*. Any attempt to separate these two groups serves only to obscure their natural relationships. It should be noted that in the "incisate" group, which Kylin *(7)* refers to *Dasyclonium*, he has included *D. harveyanum* (Decne ex Harv.) Kylin. However, the lowermost lateral of the determinate branch of this species is further branched, a feature which is characteristic of the species of the "cuneifoliate" group and, although *Dasyclonium harveyanum* might be regarded as a transitional species, it should more properly have been placed by Kylin in the genus *Euzonia*. On the other hand he has placed *Dasyclonium ocellatum* (Yendo) *n. comb.* (= *Euzoniella ocellata* Yendo; = *Euzonia ocellata* (Yendo) Kylin), in which there is no coalescence of monosiphonous laterals, with the "cuneifoliate" group, whereas this species is most closely related to *D. incisum* (J.Ag.) Kylin (= *Euzoniella incisa* (J.Ag.) Falk.). Furthermore, Kylin has omitted any mention of *D. palmatifidum* (Grun.) *n. comb.* which also forms a natural link between the "incisate" and "cuneifoliate" species. *Dasyclonium palmatifidum* has only incipient stages of coalescence in the laterals on the determinate branch, but it has the branching habit of the lowermost lateral of the determinate branch typical of the "cuneifoliate" group. Thus it can be shown that there are species of the genus *Dasyclonium* which illustrate all stages in transition from the monosiphonous, uncoalesced condition of secondary laterals through to a polysiphonous (or partially polysiphonous) and completely coalesced condition. The development of the spermatangia axes in *Dasyclonium incisum*, *D. palmatifidum*, and *D. cuneifolium* (Mont.) n. comb. (= *Euzonia cuneifolia* (Mont.) Kylin; = *Euzoniella cuneifolia* (Mont.) Falk.) are also identical, as are the number and arrangement of cover cells formed during the development of the tetrasporangium. All of these features further support the argument that these entities are all species of the same genus.

Dasyclonium incisum apparently is one of the most primitive species in the genus, and may have served as the prototype from which *D. flaccidum* (Harv.) Kylin and *D. ocellatum* have been derived by reduction of the polysiphonous laterals on the determinate branches to the monosiphonous unbranched condition. On the other hand, it seems likely that a monosiphonous condition throughout may represent the prototype for the genus as a whole. *Dasyclonium bipartitum*

(Hook. f. et Harv.) Kylin [= *Euzoniella bipartita* (Hook. f. et Harv.) Falk.] may also be considered as having been derived through reduction from *D. incisum*. In this instance it is the number of secondary laterals that has been reduced rather than the polysiphonous character of the laterals that has been lost. In *D. bipartitum* only the two lowermost secondary laterals are initiated.

The next probable step in the evolution of the determinate branch is indicated in *Dasyclonium harveyanum*. In this species several orders of branches, which remain free from one another at maturity, are formed from the lowermost lateral of the determinate appendage. This branching characteristic is also found throughout the "cuneifoliate" group and suggests that *D. harveyanum* forms a connecting link, as has already been suggested, between the "incisate" and "cuneifoliate" groups. In the "cuneifoliate" group, various degrees of congenital coalescence of the secondary laterals have occurred, resulting in the evolution of a monostromatic (for the most part) determinate appendage. The incipient stages of this coalescence and monostromatic character are indicated in *D. palmatifidum*. This congenital coalescence of the laterals is more evident in *D. flabellifera* (J.Ag.) *n. comb.* [=*Euzonia flabellifera* (J.Ag.) Kylin; = *Euzoniella flabellifera* (J.Ag.) Laing] and is even more pronounced in *D. ovalifolium* (Hook. f. et Harv.) *n. comb.* [=*Euzonia ovalifolia* (Hook. f. et Harv.) Kylin; =*Euzoniella ovalifolia* (Hook. f. et Harv.) Falk.], *D. cuneifolium* and *D. adiantiformis* (Decne) *n. comb.* [=*Euzonia adiantiformis* (Decne) Kylin; =*Euzoniella adiantiformis* (Decne) Falk.].

In summary one can say that the female reproductive structures, which are strikingly uniform throughout the family Rhodomelaceae, appear to be of least phylogenetic significance at the subfamily, generic, and specific levels. The diversity in vegetative construction that is associated with this uniformity in the structure of the reproductive organs in the Rhodomelaceae, as well as in the Ceramiales as an order, indicate that the group is a long-established one, whose representatives have undergone pronounced evolutionary development in the vegetative system in comparatively recent times. Of the families constituting this order, the Rhodomelaceae is the most highly evolved.

Symmetry relationship is the most fundamental feature on which a separation of the subfamilies into the various probable lines of evolution can be made. Bilaterality and dorsiventrality appear to have been achieved more than once within the family along entirely different lines of evolution, but in general there appears to have been an advance from simple forms with a radial organization as in the Polysiphonieae to bilateral types as in the Pterosiphonieae, and finally to elaborate forms with dorsiventral organization as in the Polyzonieae.

The method of formation, type, pattern of distribution, and the degree of congenital fusion or subdivision of the laterals are of secondary importance, but are significant at the generic and specific levels in distinguishing taxa.

The genus *Euzonia* Kylin is rejected because the species included in it form only a part of an evolutionary series of closely related entities hitherto referred to the genus *Euzoniella* Falk. Furthermore, because of the additional confusion that has resulted by referring only a part of this same series to *Dasyclonium* J.Ag. (*sensu* Kylin), and because an earlier proposal to conserve *Euzoniella* has been rejected, it would seem best to refer all entities to the one genus *Dasyclonium* J.Ag.

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Symposium: ***Ethnobotany of Thailand and Contiguous Countries***

OPENING REMARKS ON ETHNOBOTANY AND ECOLOGY

THEODORE P. BANK II

Institute for Regional Exploration, Ann Arbor, Michigan, U.S.A.

The subject matter of the current symposium is ethnobotanical. It seems, however, that this is also the subject matter of at least several other sessions of the Congress. I have counted two dozen papers given elsewhere which are directly concerned with ethnobotany, including such topics as the origin of paddy field culture in ancient Japan, the study of variation of taros and kumaras and its possible ethnobotanical significance, a symposium on vernacular names (Botany Division), several papers on the geographical differentiation and origin of barley, banana trees, and other cultivated plants (Agriculture) as well as papers forming a part of the symposium on the humid tropics, sessions on coconut problems and on shifting agriculture.

The dispersion of ethnobotanical reports throughout the Congress is unavoidable, of course, for it is probably the only way of including ethnobotanical data in specialized symposia. In other respects it is unfortunate. It means that many papers will not reach certain persons who are interested in them until after they are published, which may be a matter of years. Furthermore I have noticed in attending sessions that many discussions suffer because they lack authoritative opinions which probably would be present if there were a concentration of ethnobotanical material in a single, jointly-sponsored session or sessions.

Today, I would like to begin our symposium on the ethnobotany of Thailand and contiguous countries by offering a definition of our subject. It is evident, I think, that there is a difference of opinion concerning the nature and scope of ethnobotany—as witnessed, for example, by the diversity of subjects covered in our symposium this morning. For purposes of discussion, I propose a definition of ethnobotany that is largely accepted in America, that is: *ethnobotany is a study of the interrelations of primitive man and plants.*

There is, I believe, a distinction between ethnobotany and economic botany. *Ethnobotany* should deal with verbal traditions only, except for those traditions which have recently found their way into the literature, whereas *economic botany* is more concerned with modern concepts of the science of plants and their uses. The word "primitive" often carries with it unfortunate social implications; it has different meanings for different people. Yet it is nevertheless our best key to the real content of ethnobotanical study. Ethnobotany is primarily concerned with the interrelations of plants and *primitive* man—in the sense that "primitive" denotes only a lack of any written language and therefore the preservation of traditions by verbal means alone. This is, I think, the accepted anthropologicall view.

Chemical analysis of useful plants is not usually considered a part of ethnobotanical work, whereas the following are: the study of plant debris in archaeological deposits, studies of plant patterns in the vicinity of old village sites, pollen analysis, and radiocarbon dating.

The earliest use of the term "ethnobotany" was by J. W. Harshberger in 1895. It was first used narrowly in reference to the use of plants by aborigines. More recently, most authors agree that ethnobotany should deal "not only with plant uses, but with the entire range of relations between primitive man and plants." (V. H. Jones, 1941, p. 219).

It is evident, therefore, that our study must be a broad one, for man and plants are co-existent over a broad spectrum. There is necessarily ecological interaction between them, as Jones points out. Perhaps of even greater significance is the fact that there are *cultural* forces that must be reckoned with, and these make our study uniquely different from animal ecology. It is necessary that we make use not only of bio-ecological concepts in dealing with plants and man in any ethnobotanical work, but also we must bring into our study the various concepts which anthropologists have regarding cultural dynamics.

It goes without saying that ethnobotany is an interdisciplinary study that overlaps a number of established scientific fields. Perhaps, as some have suggested, the real function of ethnobotanical work is to illucidate the interaction of primitive man and plants on a cultural level, not on a biological level, and we should leave the biological interpretations to the plant and animal scientists. To my mind, however, such a restriction on the scope of ethnobotany is a step in the wrong direction. Ethnobotanical study will be of far greater significance if it *seeks* to overlap, if it brings together various approaches of various disciplines for the better understanding of both the cultural and the biological factors involved in the interrelations of plants and primitive man.

The main point I would like to leave from this perhaps overly-long dwelling on already published ideas is that ethnobotany is really an integral part of the newly developing science which various authors have called "human ecology" and "cultural ecology." The content, philosophies, and methods of this new science are yet to be satisfactorily defined. Various authors have their own views of just what "human ecology" is. But from the strides which bioecology has made toward illucidating for us the forces of Nature, and their effects upon biota and environment, I feel certain that the study we are beginning to call human ecology will be able to do the same for a better understanding of the forces of culture. It is significant that the term "ecology" implies that specialists will be involved in the study not only from anthropology but from the biological sciences as well. Ethnobotanists will undoubtedly be called upon to make major contributions to the combined effort.

THE NATURE AND STATUS OF ETHNOBOTANY†

VOLNEY H. JONES

University of Michigan, Ann Arbor, Michigan, U.S.A.

(Abstract)

"The Nature and Status of Ethnobotany" was published by Professor Jones in 1941, when it appeared in *Chronica Botanica*, Volume VI, Number 10, pp. 219-221. Because it contains some pertinent thoughts on the content and status of ethnobotany which are worth repeating for the benefit of this symposium on "The Ethnobotany of Thailand and Contiguous Countries," I have taken the liberty, with Professor Jones' permission, of extracting portions for this paper.

Jones points out in his original article that a large amount of data associated in some manner with the relationships of primitive man and plants has accumulated in the various literatures of such diverse disciplines as botany, anthropology, linguistics, agriculture, horticultural science, and geography. These data are concerned with economic botany, plant lore, properties and value of economic plants, the origins of cultivated plants, plant remains in archaeological sites, and plant names and plant knowledge of primitive peoples. In America these various aspects of the study of the relationship of aboriginal peoples and plants have come to be known under the term "ethnobotany."

Among the students of ethnobotany, the plant scientist is primarily interested in knowing what plants were and are used by primitive man, how they are gathered and utilized, and what effect man has had upon the dispersal of plants. The former distributions of plants as indicated by archaeological deposits should offer the botanist valuable data to supplement his own research in plant geography. The lists of plant names and ethnological and archaeological occurrences of plants have been shown to be of value in the study of the origin and dispersal of cultivated plants. The plant ecologist is interested in the influence of primitive man on the plant environment, especially the effect of man's activities in disturbing the otherwise normal processes of plant succession. The anthropologist, on the other hand, is more interested in the manner in which primitive man adapts himself to his plant environment, what plants he uses, and how his economy, activities, and thoughts are influenced by the plant world. The cultural implications, in other words, are paramount over the botanical. The ethnobotanist, speaking of the professional worker who specializes in ethnobotany, is most useful perhaps in correlating the data on these and similar problems and in presenting his results in a form that is useful to either the plant scientist, the anthropologist, or both.

Few individuals, either in the United States or elsewhere, have given their entire attention to ethnobotany alone. Ethnobotany for its own sake is practiced by perhaps a handful of workers. On the other hand, anthropologists have gone into ethnobotany to solve certain problems, and botanists have become part-time anthropologists for the same reason. Recently there has developed in America a healthy and productive cooperation among botanists, anthropologists, and linguists, and a more concerted attack has been made upon ethnobotanical problems of mutual interest.

Although many ethnobotanical observations were made much earlier, it is only since about 1850 that any great amount of substantial progress has been made in the correlation of ethnobotanical information. In Europe the most notable early work was that of such men as Alphonse de Candolle, Unger, Targioni-Tozzetti, Bretschneider, and Wittmack in applying ethnobotanical data to the solution of problems of the origins and distributions of cultivated plants. More recently, emphasis in Europe has been on the development and application of techniques for the removal and study of archaeological plant materials. Some of the early work in America was done by Europeans; but since about 1875, American ethnobotany has progressed more or less independently. A rather extensive and valuable literature bearing on the relations of the Indians of North America and plants has accumulated. American archaeological plant material has yet to receive the attention which it deserves. Although little has been done on the ethnobotany of South America except in Peru, there would seem to be remarkable opportunities in that continent.

† Presented in abstract by T.P. Bank II.

The results of the intensive surveys of the expeditions of the Soviet Union under the direction of Vavilov seem to indicate that many kinds and varieties of cultivated plants distinct in their genetic constitution, adaptations, and virtues from any now in the agriculture of civilized man may yet be obtained in various parts of the world. In the collecting of such products and particularly in the obtaining and recording of the knowledge of the natives concerning uses, properties, cultural treatment, and other such information, ethnobotanical experience and the ethnobotanical approach should be valuable.

MATERIALS USED FOR THATCHING IN THAILAND

TEM SMITINAND

Chief, Section of Botany and Zoology, Forest Products Research Division, Royal Forest Department, Bangkok, Thailand.

In rural parts of Thailand, thatches are still in use, as they are cheap and easy to procure. The materials used vary in different parts, but fall roughly into three categories:

Tree Leaves

In northern Thailand, people collect mature leaves of young trees of Mai Pluang *(Dipterocarpus tuberculatus)*, abundant in the dry deciduous forests. In thatching, these leaves are arranged in an overlapping row on a thin piece of bamboo, about one metre long, fastened together with bamboo or rattan. This kind of thatch, when properly seasoned, is not susceptible to insect attack and is not inflammable. The thatch lasts for two to three years.

Palm Leaves

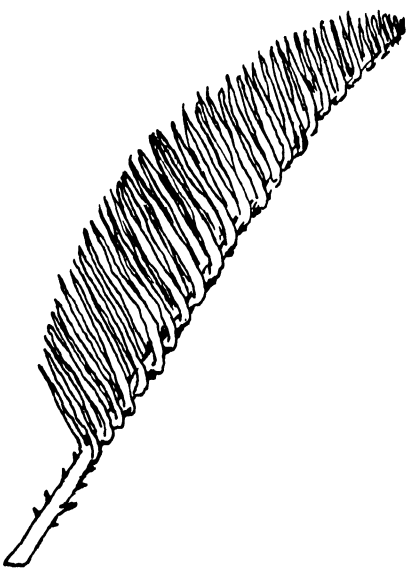
At least four varieties of these leaves are used in thatching:

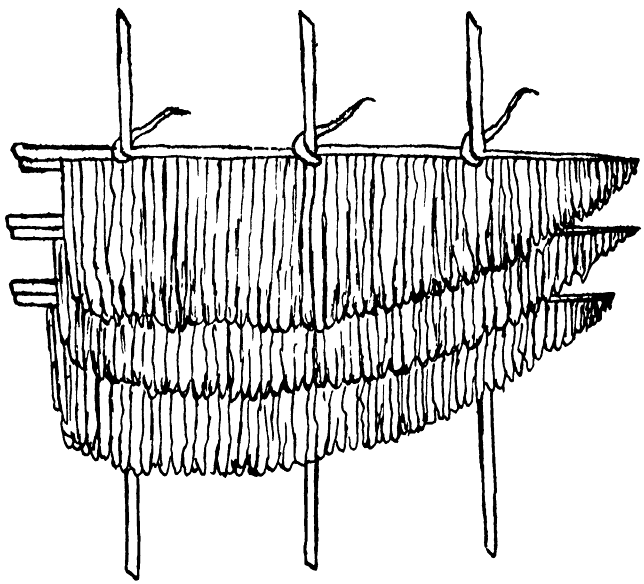
Kaw (*Livistona* sp.) is a tall, erect palm of 15 to 20 metres in height, common in evergreen forest. The leaves are fan-shaped and are much used by hill tribes who fold them in half into a roughly triangular shape which are then arranged to overlap each other, being secured to the building framework with rattan. The thatch does not last long, but as these hill tribes move every three or four years, this does not matter.

Wai (*Daemonorops* sp.) is a kind of rattan, known in certain places as Wai Chak. There are two or three species of this rattan whose leaves are feather-like in shape with thin spines growing on the pinnae and larger spines growing on the petioles. The leaves are folded in half and placed in pairs to three long rattan canes to which they are secured by split rattan binding at intervals of 5 cm as illustrated below.

When a required length has been made, the whole sheet is rolled up, ready for laying upon the building framework to which it is secured by split rattan binding. These thatches last from two to three years.

Chak (Nipa fruticans), a feather-leaved palm with underground stem, grows gregariously in tidal forests and provides material for roofing for people living in the central plain and coastal area. The pinnae of matured leaves are cut from the axis, one-third of their length is then





folded and placed overlapping each other on a bamboo split and bound with Wai nam *(Flagellaria indica)*, a riperian species of scandent shrub.

Sakhu (*Metroxylon* sp.), known commercially as sago palm, is another form of thatching prepared in a like manner to Chak. This is commonly used in the Malay peninsular.

Grass Leaves

Two kinds are used, Kha *(Imperata cylindricata)*, commonly known as Alang-Alang, and Faek *(Vetiveria* sp.*)*.

Kha is extensively used by local people in every part of the country, whereas the use of Faek is limited to central and northeastern parts. The method of preparation is similar. After the grasses are reaped and dried in the sun, they are made up into bundles. Six to eight leaves are folded along one-third of their length on a piece of bamboo about one meter long and are secured by a string of Paw (*Sterculia* sp.). In certain parts, branches of Khon Tha *(Harissonia perforata)* are used instead of bamboo. The thatch lasts for two to three years, and it is interesting to note that after the grasses are reaped the whole area is burned down, as it is thought that this will produce a good crop for the next season.

SOME FOOD PLANTS IN THE FORESTS OF THAILAND†

K. SAMAPUDDHI

Royal Forest Department, Bangkok, Thailand.

Ancient Thai literature often described the forests as abounding in food plants and fruit trees. In the well-known story of Vesandorn Chadok, for instance, the part of the Himapharn forest into which Prince Vesandorn was exiled by his Royal Father, King Son Chai of Siplee, was described as full of fruit trees like wild banana, langsat *(Lansium domesticum)*, Mafai *(Baccaurea sapida)*, Krathon *(Sandoricum koetjape)*, Lamyai *(Euphoria longana)* etc., on which the Prince could manage to survive without much trouble. It is felt that there is some truth in this, for, in the northeastern region of Thailand, especially, villagers more or less depend on the forest for their daily meals. Greens, bamboo shoots, mushrooms, etc., are gathered from the nearby woodland. They are cooked, roasted, or fried with either fish or meat and eaten with rice, the staple food of the teeming millions of the East.

During his tours through the forests of Thailand, the writer has always been interested in food plants, and, in order to give travellers and adventurers an idea of how one could survive when lost in the forest, he has compiled a list of plants from which food material can be obtained. The list is by no means exhaustive, and the common herbs or fruit trees which are already well known and not actually growing wild have been omitted. The edible parts of the plants are either the flowers, fruits, shoots, leaves, stem, roots, bulbs, or tubers.

For practical purposes, the forests of Thailand may be classified into four main types, namely, the evergreen forest, the mixed deciduous forest (including teak forest), the deciduous dipterocarps forest, and the mangrove forest. For the sake of convenience, the plant names listed here have been grouped under the various types of forests in which they are found.

Table 1.
Food plant of the evergreen forest.

No.	Local name	Bot. name	Edible part	How prepared	Taste	Remarks
1.	Kum Nam (กุ่มน้ำ)	*Crataeva nurvala* Ham.	Young leaves	Pickled in vinegar	Almost tasteless	A medium-sized tree
2.	Kluey-pa (กล้วยป่า)	*Musa* spp.	"Stem" as a source of water, also fruit	Taken fresh	—	Wild banana is rather full of seeds
3.	Chamuang (ชะมวง)	*Garcinia cowa* Roxb.	Young shoots and leaves	By boiling with meat or pork to form an appetizing broth	Slightly sour	A medium-sized tree in Southern Thailand
4.	Chaluerd (ช้าเลือด)	*Premna integrifolia* Linn.	Young shoots	To be boiled or baked before being taken with chilli paste	Crispy and almost tasteless	A medium-sized tree
5.	Tao (ต๋าว)	*Arenga pinnata* Merr.	Young shoots	May be taken fresh or boiled	Sweetish	A palm with similar appearance to nipa palm
6.	Book (บุก)	*Amorphophallus* spp.	Young stems	May either be fried or used as an ingredient in the preparation of Thai curry	Sweetish	A herb; must not be washed with coldwater. The contact with cold water creates a reaction that causes a irritable itch in the throat when eaten. Only boiled water must be used.

† Presented by T.P. Bank II.

No.	Local name	Bot. name	Edible part	How prepared	Taste	Remarks
7.	Bua (บัว)	*Nymphaea lotus* L.	Petioles	May be taken fresh or fried or boiled	Almost tasteless	Aquatic; found in ponds or swamps
8.	Phak Koot (ผักกูด)	*Athyrium esculentum* Copel.	Young leaves	To be boiled and prepared as an ordinary vegetable	Almost tasteless	A fern
9.	Mafai-pa (มะไฟป่า)	*Baccaurea sapida* Muell-Arg.	Fruits	Taken fresh	Sweet or acid	A forest fruit tree
10.	Madua-nam (มะเดื่อน้ำ)	*Ficus scandens* Roxb.	Fruits	Taken fresh	Sweetish	Sort of a fig tree
11.	Madua-din (มะเดื่อดิน)	*Aganosma marginata* G. Don	Young shoots and leaves	Taken fresh with chilli paste or pla-ra (fish paste)	Slightly astringent	A scandent climber
12.	Wild Raspberry	*Rubus* spp.	Fruit	Taken fresh	Acidic	A shrub usually found in mountain evergreen forest
13.	Canes (หวาย)	*Calamus* spp.	Young shoots	To be boiled and taken with chilli paste or Pla-ra (sort of salted fish)	Slightly bitter	
14.	Soke (โศรก)	*Saraca indica* Linn.	Young leaves and inflorescence	To be used as an ingredient for preparing a Thai curry	Slightly sour	Small tree growing along stream banks
15.	Hucha-niang or Niang (หูชะเนียง)	*Pithecolobium jiringa* Prain.	Seeds both young and germinated	Slightly astringent	Taken raw with chilli paste and curry	Tree 15-20 m tall
16.	Kariang (กะเหรี่ยง)	*Parkia javanica* Merr.	Germinated seeds	Slightly astringent	Taken raw with chilli paste and curry	Tree 30-40 m tall buttressed
17.	Sataw (สะตอ)	*Parkia speciosa* Hassk.	Seeds	Slightly astringent	Taken raw or pickled, with chilli paste and curry	
18.	Kra (กระ)	*Elateriospermum tapos* Bl.	Mature seeds	Slightly sweet	Pickled and taken with curry or used in salad	Tree 20-30 m tall, lacticiferous

Table 2.
Food plants of the mixed deciduous forest.

No.	Local name	Bot. name	Edible part	How prepared	Taste	Remarks
1.	Kradone or pui (กระโดนหรือปุย)	*Careya arborea* Roxb.	Young leaves	Taken fresh	Slightly sour	A medium-sized tree
2.	Krathon (กระท้อน)	*Sandoricum koetjape* Merr.	Fruit	Taken fresh	Sour and slightly astringent	A big forest tree
3.	Kae-foy (แคฝอย)	*Dolichandrone crispa* Seem.	Flowers	To be boiled or roasted before being taken with sauce or chilli paste	Almost tasteless	
4.	Chakan (ชะค้าน)	*Piper* sp.	Young shoots	To be boiled before being taken with sauce or chilli paste	Aromatic	A vine

No.	Local name	Bot. name	Edible part	How prepared	Taste	Remarks
5.	Matat (มะตาด)	*Dillenia indica* Linn.	Young unripe fruit	Used as an ingredient in preparing a Thai curry	Sour	A large tree
6.	Teiw-klieng (ติ้วเกลี้ยง)	*Cratoxylon polyanthum* Korth.	Young leaves	May be taken fresh	Slightly sour	A medium-sized tree
7.	Bamboo shoots	*Dendrocalamus* spp. *Bambusa* spp. & *Oxytenanthera* spp.	Shoots	Usually boiled before being eaten	Almost tasteless	
8.	Bamboo Seed	,,	Seeds in the form of grains like rice grains	Boiled like rice	Like rice; may be substituted for rice in time of famine	Found scattered about on the forest floor in bamboo flowering areas
9.	Kloy (กลอย)	*Dioscorea hispida* Dennst.	Tuber	Boiled with salt water	Starchy like potato	May cause nasty itch in the throat if not properly prepared
10.	Peka or Marid-Mai (เพกาหรือ มะริดไม้)	*Oroxylum indicum* Vent.	Seed in the young pods	By boiling	Almost tasteless	A shrub
11.	Makok (มะกอก)	*Spondias pinnata* Kurz.	Young leaves and fruits	May be eaten fresh	Slightly sour and astringent	A big tall tree
12.	Tamarind (มะขาม)	*Tamarindus indica* Linn.	Young leaves and fruits	May be eaten fresh	Acidic	Found growing wild in old village sites; a big tree
13.	Leb yeiw (เล็บเหยี่ยว)	*Zizyphus oenoplia* Mill.	Fruits	May be eaten fresh	Acidic	A thorny shrub
14.	Maroom (มะรุม)	*Moringa oleifera* Lamk.	Young pods and flowers	To be boiled before eating; may be eaten fresh with chilli paste	Almost tasteless	Found growing in old village sites
15.	Wan Poh (ว่านเผาะ)	*Kaempferia galanga* Linn.	Tuber	May be eaten fresh with chilli paste	Crispy and almost tasteless	A herb
16.	Wah (หว้า)	*Syzygium cumini* Skeels.	Fruits	Eaten fresh	Sweet	A big tree
17.	Sadao-pa (สะเดาป่า)	*Antelaea azadirachta* Adelb.	Young leaves and inflorescence	By boiling	Rather bitter	A medium sized tree
18.	Samaw-Thai (สมอไทย)	*Terminalia chebula* Retz.	Fruit	Taken fresh	Slightly acid and astringent	A big tree
19.	In-ta-nin (อินทนิล)	*Lagerstroemia macrocapa*	Young shoots	To be boiled before eating with chilli paste or pla-ra (fish paste)	Almost tasteless	
20.	Siew (เสี้ยว)	*Piliostignaa malabasica* Benth.	Young leaves	May be boiled with meat or pork to make a tasty broth	Acid	A large shrub
21.	Cha-om (ชะอม)	*Acacia insuavis* Lace	Young shoots and inflorescence	May be boiled or baked or taken fresh with chilli paste or sauce	Slightly bitter	Large wood and thorny, scandent shrub
22.	Kracheo (กระเจียว)	*Curcuma* sp.	Inflorescence	Taken fresh or steamed with chilli paste	Slightly sweet and aromatic	Herb with bright red bracts

Table 3.
Food plants of the deciduous dipterocarps forest.

No.	Local name	Bot. name	Edible part	How prepared	Taste	Remarks
1.	Kabok or Mameun (กะบกหรือมะมื่น)	*Irvingia malayana* Roxb.	Endorsperm of the seed	By roasting until well cooked	Like melon seed	A big tree
2.	Pak-wan (ผักหวาน)	*Melientha suavis* Pierre	Young leaves	By boiling into a broth or used in a curry	Sweetish, delicious	A shrub. At times, especially in the rainy season, it may turn deadly poisonous — a mystery to both villagers and botanists
3.	Phan-ngu (พันงู)	*Amorphophallus* spp.	Stems	By boiling or frying with meat or pork (if available)	Like lotus stem, almost tasteless	A herb with flowers in the form of spadises
4.	Uang-mai-na (เอื้องหมายนา)	*Costus speciosus* Smith	Young shoots	By boiling until well cooked	Like asparagus	A monocot herb
5.	Phayom (พะยอม)	*Shorea talura* Roxb.	Inflorescence	Used in a curry	Slightly astringent	A big tall tree

Table 4.
Food plants of the mangrove forest.

No.	Local name	Bot. name	Edible part	How prepared	Taste	Remarks
1.	Kong-kang or Panga (โกงกางหรือพังกา)	*Phizophora mucronat* Lamk.	Young shoots	By boiling and taking with sauce or chilli paste	Just crispy and almost tasteless	
2.	Kilek-pa or Samaesarn (ขี้เหล็กป่าหรือแสมสาร)	*Cassia garrettiana* Craib.	Young leaves and flowers	By boiling	Slightly bitter	A small tree
3.	Chik (จิก)	*Barringtonia asiatica* Kurz.	Young shoots	May be eaten fresh	Slightly astringent	Found in swamps
4.	Samet Kao (เสม็ดขาว)	*Melaleuca leucadendron* Linn.	Young shoots	By boiling before taking with chilli paste		

DISCUSSION

T.P. BANK II: Would botanists and ethnobotanists study the ritual and folklore attached to these plants, and not leave it at a list of plant names?

THE USE OF TALIPOT PALM LEAVES AS WRITING MATERIAL IN THAILAND

KASIN SUVATABANDHU

Department of Agriculture, Ministry of Agriculture, Bangkok, Thailand.

Leaves of the palm known in Sanskrit as tala or tal were used in India as writing material for a very long time. The name tala or tal was confined to *Borassus flabellifer*, *Corypha umbraculifera* and *Phoenix sylvestris*. When the Indians brought the custom of writing on the tala leaves to the Malesian area where *Borassus flabellifer* was plentiful, they also introduced that word into the local language. Tala became ron-tal and later, by metathesis, lontar; that is how the common name lontar, or lontar palm for *Borassus flabellifer* was derived.

Whereas in Ceylon the leaves of *Corypha umbraculifera*, the talipat (tali or tal, and pat = leaves), were used, because the Indian who brought the custom of writing on the tala leaves used the Corypha leaves, *Corypha umbraculifera* being plentiful in Ceylon. The word talipat later became talipot and the tree is called by the Anglo-Indian the talipot palm.

The use of the talipot palm leaves as writing material was very likely adopted in Ceylon before B.E. 900, because it was known at that time that the manuscripts of all the teachings of the Lord Buddha had been written on talipot palm leaves.

Thailand had for a long time been connected with Ceylon through religious channel. She accepted Buddhism from Ceylon as national religion. Some Thai monks were sent for training, and on return they were supposed to bring back authentic Buddhism to Thailand. It was recorded that religious manuscripts written on talipot palm leaves were brought into the Thai Kingdom just a little before B.E. 1800. Copies were then made using locally prepared talipot palm leaves vernacularly known as "Bi-larn". The Thai have used "Bi-larn" for writing religious manuscripts from that period up to the present.

Talipot palm *(Corypha umbraculifera)* is found indigenously in Thailand. It forms great groves usually in the mixed, more or less dry and evergreen forests. It is a big tree of erect cylindrical trunk, 2-3 ft in diameter and 30-80 ft in height, clothed throughout with petiole bases. Leaves with stout petioles 5-10 ft long, lamina large 8-16 ft in diameter palmately pinnatifid, plicate, cleft to about the middle into 80-100 linear lanceolate acute or bi-fid lobes. The lobe is web-liked blade in between two small ribs (veins). Flowering and fruiting occur after the age of 30 years. The plant dies after fruiting.

Talipot palm is classified as one of the forest products which is a national treasure. Those who want to exploit this particular palm must apply to the Royal Forest Department for licenses. Under the rules and regulations of the Department, a license is valid for 3 years. After a permission is granted the exploiter may enter the Corypha grove and starts cutting juvenile plicate leaves with a curved and long handled knife. There are 2 or 3 usable leaves in a tree, but 1 or 2 leaves only can be cut near the base of the lamina, leaving the youngest for future growth.

All cut leaves are then recut at both ends. Only the middle part of the leaves which are about 27 inches in length are gathered and dried in open air for 3 days, and then split along the ribs into bi-lobed slips (2 lobes with 1 rib in between). Bundles of one thousand bi-lobed slips tied up near both ends are prepared and shipped to Bangkok for sale.

The Bi-larn makers purchase these raw bi-lobed slips, and grade them according to the width. There are four grades varying from 2.25 inches to 1.75 inches wide. The undersized slips are not used as writing material but are sold as plaiting and weaving fibre for hats and other articles.

After grading, the thin ribs of the bi-lobed slips are removed, so that one raw bi-lobed slip produces 2 sheets. These sheets are again selected in order to eliminate poor specimens.

Each sheet is cut to standard size and two holes, seven inches apart, used for binding purpose, are made along the centre line of the sheet. (The normal standard sizes of the sheets in inches are 1.75 x 20.5, 2.0 x 20.5, 2.0 x 21.0, and 2.25 x 22.5.) Five hundred sheets are bound up into one packet with talipot ribs piercing through the holes for guiding. The packet is then placed in a wooden frame and tightly pressed in order to straighten and flatten the sheets. At the same time the edge are planed for smoothness.

After that, the whole frames (with pressed packets of palm sheets) are placed in a smoking oven to be dried and coloured for about 48 hours. Rice husk or the palm leave waste may be used as fuel. The dried smoked sheets are then ready for writing.

The so prepared talipot palm leaves are called "Bi-larn." In writing, this Bi-larn is placed on a metal table and characters are engraved with an iron stylus. Usually there are only 4 to 5 written lines on a single slip. To render the characters more legible, cow-dung or miller charcoal or soot mixed with coconut oil is smeared on the engraved leaf so that the written lines are blackened.

The written Bi-larn are cleaned with sand and cloth and then bound into a packet by running through the holes two small cords, one for each hole, which are formed into two loops. The number of leaves in a packet depends on the size of the article or story. After binding into a book form, the edges are painted with a red dye-stuff known as "Chard", varnished with lacquer and then plated with gold leaves. These are very useful as a protection against fungi and insects which may occasionally attack Bi-larn.

Nowadays, most of the religious articles or manuscripts are not transcribed, but printed. The use of iron stylus for writing on the palm leaf will be lost from the sight of younger generation in the very near future.

In printing, the prepared Bi-larn must first be roasted over a fire to remove excess oil in the leaf before it can be used by a printer. The characters are printed on both sides of the leaf, using generally 4 to 6 lines, and are arranged in three columns.

The printed Bi-larn are brought together article by article and then bound into books. The edges are again dressed by planing, painting with red dye-stuff, and gold plated.

The preparation of Bi-larn becomes a flourishing home industry in the Thai Kingdom; the palm leaves are used not only for religious and language writings, but also for making into cords, ropes, and plaiting or weaving material.

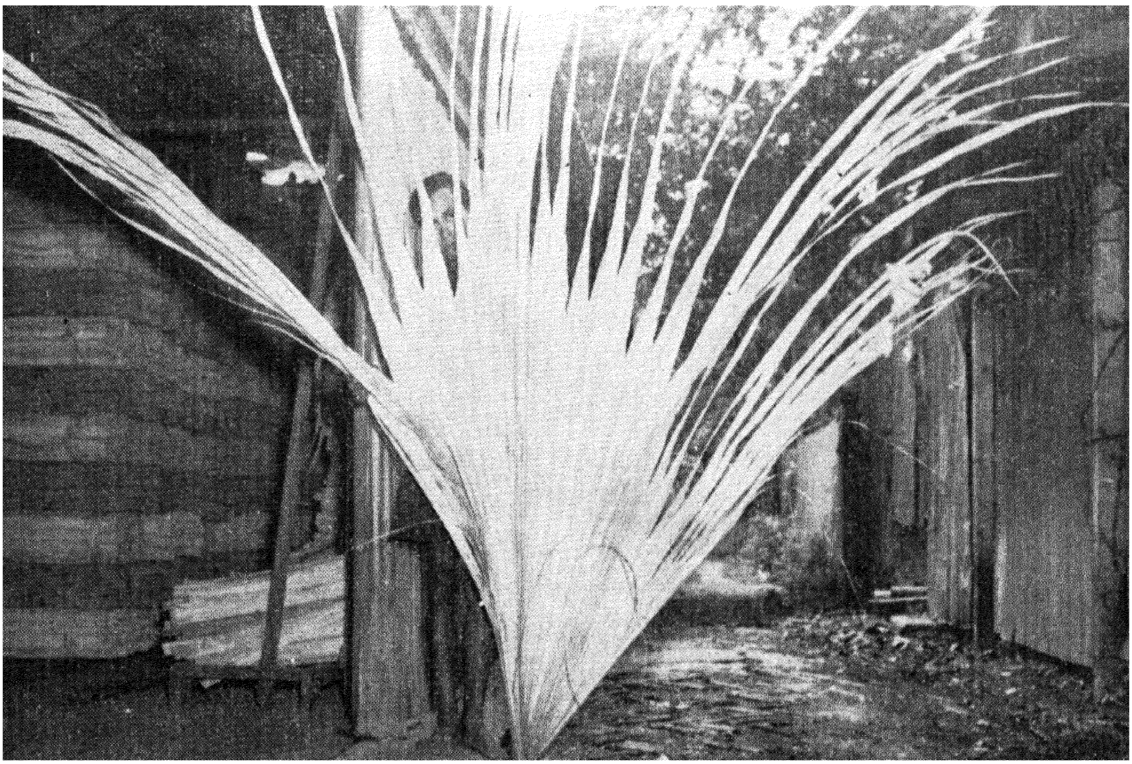


Fig. 1.—Talipot palm leaf.

Fig. 2.—Grading of the bi-lobed slips.

Fig. 3.—Removing of the ribs from the bi-lobed slips.

Fig. 4.—Cutting to standard sizes.

Fig. 5.—Trimming for uniformity.

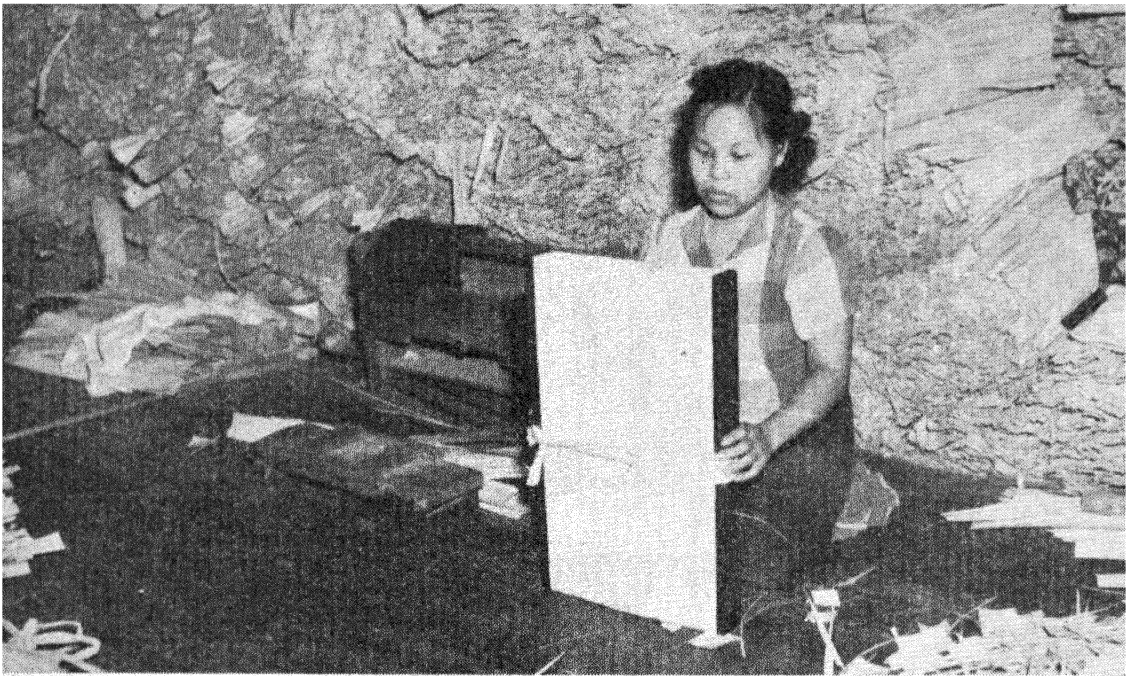


Fig. 6.—Binding in the pressed frame.

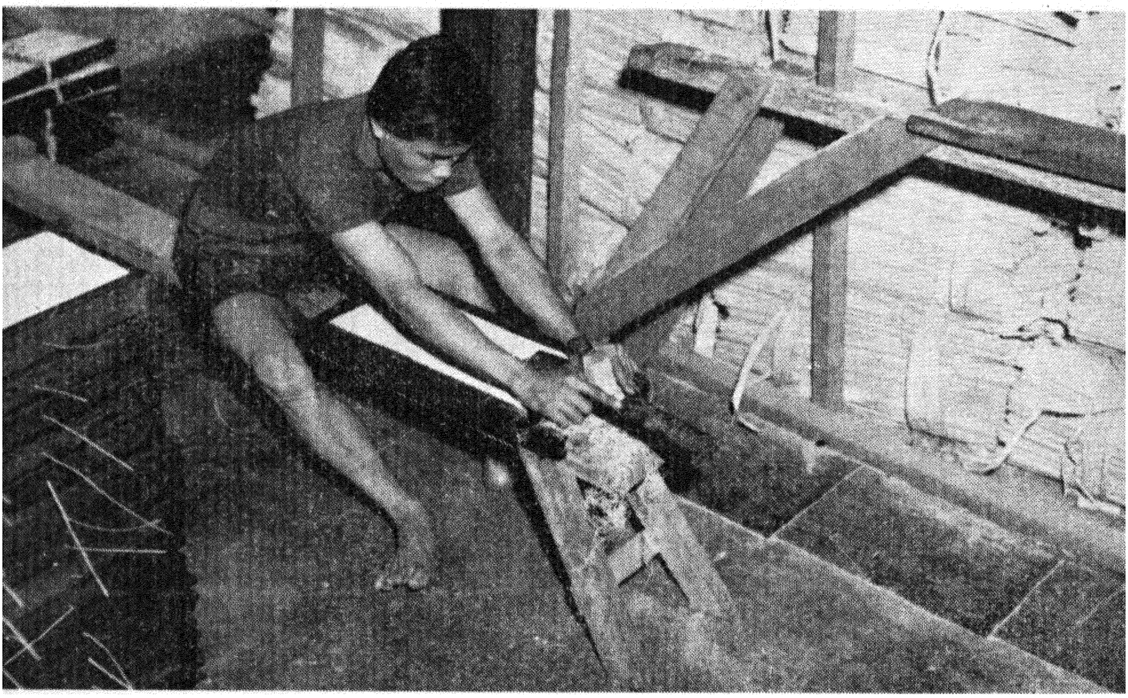


Fig. 7.—Planing for smoothness.

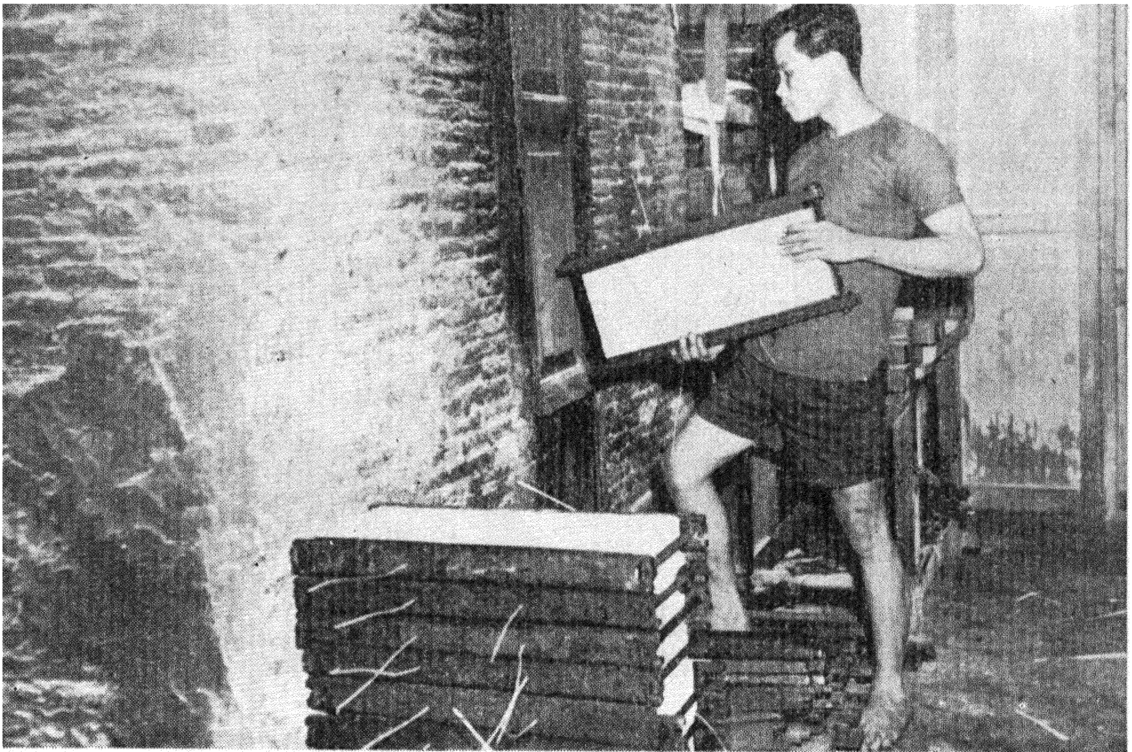


Fig. 8.—Smoking and drying in hot air oven.

Fig. 9.—Removing oil over a fire before printing.

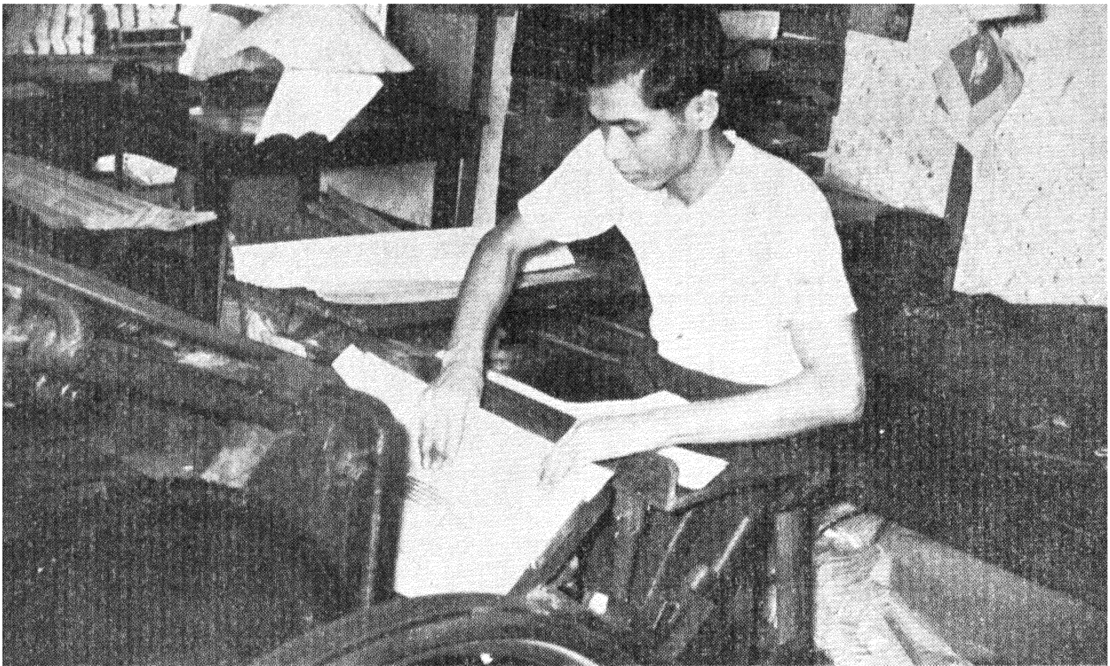


Fig. 10.—Printing.

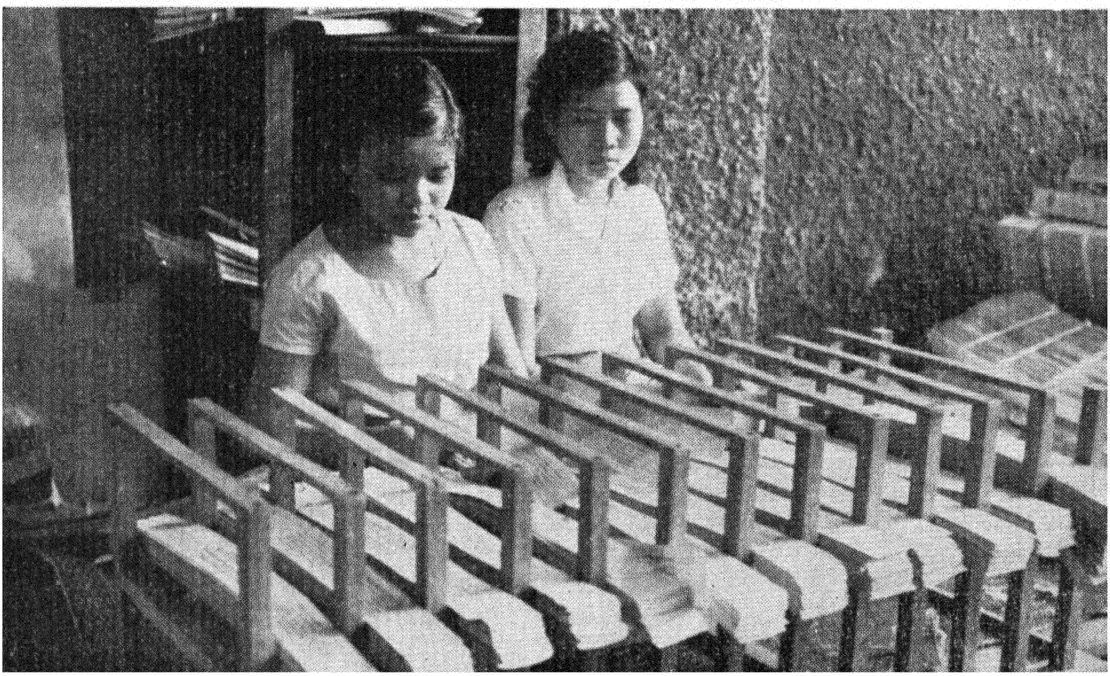


Fig. 11.—Sorting the printed leaves for further binding.

DISCUSSION

F.R. FOSBERG: I would like to ask Mr. Kasin about the geographic range of Talipot palm in Thailand.

K. SUVATABANDHU: So far only in the North and Northeast, but in the South another species occurs, and all species are used for writing.

C.G.G.J. VAN STEENIS: I am glad to have heard the detail on the talipot palm, that its use for writing has been imported to Thailand from Ceylon. I only know it from Bali where, however, the leaves used are derived from the lontar palm *(Borassus flabellifer)* which has been used for it since Hindu times and has been introduced by Hindu culture and wandered together with the invaders. The Bali lontars are mainly on religion, medicinal prescripts, history, art, etc. and thus the old ones contain much written information. They have been a great subject for study by ethnologists."

F.R. FOSBERG: I would ask Prof. Van Steenis if the famous Sumatran manuscripts, such as Prof. Bartlett has collected, are written on this sort of material.

C.G.G.J. VAN STEENIS: As to papers in North Sumatra, I do not know particulars. The palms (Corypha, Borassus) are not growing in the mountains where the Batah live, but they occur on the sub-seasonal northern coastal plains of Atjeh (northernmost Sumatra).

M.L. STEINER: In the Philippines palm leaves and bamboo strips are used.

NOTES MADE FROM LOCAL KNOWLEDGE OF THE USE OF POISONOUS PLANTS BY THE THAI PEOPLE

TEM SMITINAND

Chief, Section of Botany and Zoology, Forest Products Research Division, Royal Forest Department, Bangkok, Thailand.

The Thai people are, by nature, migratory, as can be seen from their history. During their migrations, they learned much from nature around them. At one time, however, they did settle down, but hostile and aggressive neighbours forced them to move. Their migration over a period of thousands of years stretch from the Altai Mountains in Mongolia to the present Thailand.

In their history, the Thai people made much use of poison in both war and peace time. Most of the poisons used came from plants, and in spite of the impact of Western civilization upon the Thais, they are still used today.

The poisons now in use are for poisoning arrow tips, insecticides, and fish-poisoning, as follows:

Local name	Botanical name	Habit	Parts used			Habitat
			arrow	insect	fish	
Khamin kru's	*Anamirta cocculus*	Liane	Fruits & Seeds	—	Fruits & Seeds	Evergreen forest
Nong	*Antiaris toxicaria*	Tree	Latex	—	—	Evergreen forest
Sakae dong	*Cocculus laurifolius*	Liane	Bark	—	Bark	Evergreen and mixed forests
Saba	*Entada phaseoloides*	Liane	—	—	Bark	Evergreen forests
Prik pa	*Ervatamia corymbosa*	Shrub	Bark & Roots	—	—	Evergreen forests
Bua khru'ng sik	*Lobelia chinensis*	Herb	Leaves	—	—	Evergreen forest & cultivated
Makham di khwai	*Sapindus rarak*	Tree	—	Aril	—	Evergreen forest
Tatum bok	*Sapium insigne*	Tree	Latex	—	—	Evergreen and mixed forests
Rak pa	*Semecarpus curtisii*	Tree	Latex	—	—	Evergreen forest
Nawn tai yak	*Stemona tuberosa*	under-shrub	—	Roots	—	Evergreen and mixed forests
Khika daeng	*Trichosanthes bracteata*	Climber	Fruits	Leaves		Mixed forests
Nong khru's	*Strophanthus scandens*	Liane	Latex	—	—	Evergreen forest
Salawt	*Croton tiglium*	Shrub or small tree	Bark	—	Seeds	Mixed forests
Rak	*Melanorrhoea usitata*	Tree	Later	—	—	Mixed forests
Lian	*Melia azedarach*	Tree	—	Fruits & Seeds	Bark & Roots	Mixed forests
Salaeng chai	*Strychnos nuxivomica*	Tree	Seeds	—	—	Mixed forests
Wan nam	*Acorus calamus*	Herb	—	Rhizome	—	Riparian
Thawn	*Albizzia procera*	Tree	—	—	Bark	Mixed forests
Lai nam	*Derris elliptica*	Climber	Stem	Stem	Stem	Riparian
Khao san	*Phyllanthus columnaris*	Tree	—	—	Bark	Riparian

Local name	Botanical name	Habit	Parts used			Habitat
			arrow	insect	fish	
Tatum thale	*Excoecaria agallocha*	Tree	Latex	—	Latex	Mangrove swamps
Man kaew	*Pachyrhizus erosus*	Tuberous climber	—	—	Leaves & seeds	Cultivated

TEA IN THAILAND

PRASIDHI PHUMXUSRI

Mae Malai Farm, Mae Rim, Chiang Mai, Thailand.

The genus *Camellia* was originally thought to be indigenous to China, but later discovered that the location of Nature's original tea-garden is in the monsoon districts of Southeast Asia. The monsoon, one of the most vital producing factors to this part of the world, is called "Morasoom Tawan Tok Xieng Tai" or Southwest monsoon in Thailand, it blows across the Indian Ocean towards eastern Tibet, world's top-most plateau, carries moisture-laden clouds over the northern mountain ranges of Thailand, precipitates along its route as rains to an average of well over sixty inches per annum.

The climate in Chiang Mai, Chiang Rai, Lampang, Mae Hongson, Nan and Phrae may be divided into three distinct seasonal categories; the cool and dry lasting from November to February, the hot and dry from March to early May, and the hot and humid from late May to October. The season in these vicinities is favorably comparable to many tea producing countries.

The topography of northern Thailand may be divided into three regions: (1) The low-land or paddy field region, "Tung Na." (2) The dipterocarpus region, "Pa Daeng." (3) The evergreen region, "Pa Dong Dib," with an altitude ranging from 200 to 300 metres MSL, 300 to 800 metres MSL, and 800 to 1,500 metres MSL respectively. The one that is concerned most in this report is the evergreen mountain region, the soil with a pH value of 4.5 to 5.5 of which has its origin from Gneisses rock and Quartzitic sandstone.

Among these high hill ranges, there are tracks after tracks of Tea-trees growing. Villages after villages sprang up with the sites, people engaged in preparing the tea-leaf into "Miang," this name also implies to Shan, Laos, "Leppetso" to Burmese, and "Pickled-tea" to the English speaking world.

"Miang" is consumed by Thai, Burmese, Lao, Shan, and Singpho (a tribe inhabiting the upper-reach of the Chindwin river in Northwest Burma).

The miang trees have not at all been cultivated, they were allowed to grow in their natural states and some acquired a height of from 3 to 6 metres, when they are found too high for Plucking, the top branches may be broken off or given a light skipping.

In preparing "miang" the leaf is plucked, in halves without stalk after the buds are all opened and not as a bud and two leaves, four times a year. The first plucking is locally called "Miang Hoa Pee," lasting from April to June, the second plucking "Miang Klang" from July to August, the third plucking "Miang Soi" from September to October and the fourth plucking "Miang Moey" (Dew Tea) lasting from November to December.

After plucking and bundled, the leaves are put into a round wooden container "Hai Nueng" with plaited bamboo base and placed over a pan of boiling water for steaming which last from 10 to 15 minutes. When the steaming process is through the content is thrown on to bamboo mat, people, sitting around kneading and retightening the bundles and let cool for 5 to 10 minutes; then the bundles or the day's plucking are placed and stamped down in bamboo silo 5 to 6 feet in diameter and 8 to 10 feet high.

The silo is made of plaited bamboo lined heavily with wild plantain leaves, and kept adding to the content with steamed-leaf throughout the season; at each filling the contents must be pressed down by tramping and planked with heavy stones. Under pressure, no doubt, the juice is oozed out, it is collected, boiled to a very thick consistency called "Nam miang" which is used as one of "Miang" delicacies. The leaf may be left in the silo for a period varying from 15 days to several months or until the commencement of the next season's plucking.

Raw "miang" is very pungent and people prefers longer pickled one that has a sour taste. Miang has the smell of wet humus decomposed in a limited air supply (ensilage). It also has a slight sweet smell of fermented with yeast steamed glutinous rice (Khao mark) or alcoholic fermentation (zymurgy). The colour is bright yellowish green when taken out from the silo and rapidly becomes red when exposed for any length of time, the quality deteriorated since then. For preservation and handyness in packed-bull transport from the producing hills down to the nearest motorized road or bullock-cart track, miang is repacked into bamboo baskets shaping like a mortar in lots of 60 to 80 kilograms. To assure of having proper insulation the basket is both sides smeared with viscid cow-dung, and heavily lined with plantain leaves. Once the basket is packed it never can be inspected in any transaction until retailing to consumers. Quality is guaranteed through honesty, the number of bundles in the basket is recorded by a numerical system engraved on a piece of bamboo stripe in the shape of a multiplication sign, a plus sign, a minus sign and dot sign; each symbol representing the amount is well known to all engaged in the trade.

The marts of the pickled tea are in Mae Rim, Doi Saket, Ban Mae Ai in Chiang Mai district, Cheh Hom, Lampang district and Wieng Papao in Chiang Rai district. The storage for miang in these marts is a very interesting sight, a huge ditch swimming-pool-like is dug within the compound and kept filled with water, all tea baskets are kept submerged under water to keep them from contacting with the open atmosphere.

Miang has a small export through Raheng-Mae Sot land route to South Burma, the rest of which is consumed locally. The common way of consuming "miang" is to wrap the leaf with salt and just hold in the mouth like lozenges, in a deluxe fashion "miang" is wrapped with hog's fat, pickled garlic, cocoa-nut-chips, ground-nuts and salt. The fashion of consuming miang is slowly dying out.

Thailand is undoubtedly a country where tea could be grown in plantations commercially and economically. Hill-tribes labour is plentiful and who when employed to permanent agriculture will be a great asset in minimizing the destruction of forest wealth through "clearing culture" (Kainginining) or "Rai luen loi."

In 1938 a small plantation was started the progress of which is rather slow. At Huey Tart a factory was built postwar time with modern equipment to make black tea with leaf purchased from smallholders. The production in 1952 was nearly 150,000 lbs. The product is sold in Thailand only.

Developments and researches can be carried on and on for further advancement.

THE MANUFACTURE OF SUGAR FROM THE SUGAR PALM IN UPPER MANDAILING, SUMATRA†

ELISE TUGBY

Australian National University, Canberra, A.C.T., Australia.

INTRODUCTION

The sugar palm (Bargot), *Arenga pinnata* (Wurmb) Merr., is found throughout Upper Mandailing, Southern Tapanuli, Sumatra[1]. The area is one of complex mountain ranges bisected by a rift valley. Height varies from 400 to 2,000 metres. The more temperate, wetter mountains contrast with the hotter, drier valley. The Medan-Padang road follows the latter, linking the main market centres and providing the import and export channel for the region. As the major subsistence crop, wet-rice in the major and tributary valleys, contrasts with dry-rice on the hill slopes. Rubber and coffee are the important cash crops.

Table 1 shows the altitude and general soil type of the fifteen villages producing sugar for the extra-village market, throughout the year. The total number of villages in Upper Mandailing is eighty-seven. From the table it can be seen that economically significant palms grow on a clay soil usually of volcanic origin. The first nine villages listed are sited on lava flows originating from the volcano Sorik Merapi. It may be noted that most villages below the 500 metre level occur in valleys on soils derived from sandy sediments.

The highest village in the area, Pagargunung, 1,140 metres, is enclosed by hills rising to 1,310 metres. Here the palm was previously utilised, but although the sap was sweeter than elsewhere, the flow is now considered too little to warrant collection. Here, too, coconuts were grown but did not bear. This situation is concomitant with Burkill's remarks that "the palm can be

Table 1.
Approximate height and general soil type of villages producing for the extra village market.

Name of Village	Approximate height above S.L. in metres	General Soil Type
Si Banggor Djai	760	Heavy clay derived from lava
Si Banggor Djulu	960	,, ,, ,, ,, ,,
Huta Tinggi	800	,, ,, ,, ,, ,,
Huta na Male	950	,, ,, ,, ,, ,,
Pasar Maga	580	,, ,, ,, ,, ,,
Angin Barat	620	,, ,, ,, ,, ,,
Si Antona	600	,, ,, ,, ,, ,,
Pangkat	480	,, ,, ,, ,, ,,
Si Ladang Djulu	430	,, ,, ,, ,, ,,
Simangambat	480	Clay derived from limestone and schist
Torrumbi	950	,, ,, from volcanic breccia
Si Bio Bio	800	,, ,, from volcanic breccia
Batahan Djulu	800	,, ,, from limestone
Simpang Duhu Dolok	930	,, ,, from slate
Simpang Banjak Djulu	1,060	,, ,, ,, ,,

Note: Term used throughout the paper are those current in upper Mandailing.

† Presented by C.S. Christian.

1 Upper Mandailing includes the Ketjamatan Kotanopan and the three villages forming the Si Ladang complex at the foot of the mountain, Tor Sihite.

grown at greater elevations than the coconut..."[2]

During the month of fasting (Ramadan) in at east eight other villages there is a little produc-ion of sugar to supply the extra demand in that period, and output is also increased in villages producing throughout the year.

Formerly, nearly all villages in the area pro-luced some sugar, but, with the introduction of ubber, production has become concentrated in a few. The industry was stimulated during the Japanese occupation, when a ready market existed for sugar, but not for rubber.

In recent years the planting of palms has become are. Distribution depends on wild animals, such as the civet cat, which eat the fruit and void he seeds. It is reported in many villages that he number of palms has increased in the past en years. The highest concentration of palms s found in the Si Ladang villages, the scattered elements of which lie within what is virtually one arge grove. Elsewhere in Upper Mandailing only small groves occur—and these outside the village proper.

TAPPING THE PALM

A palm comes into use when about ten years old. Before tapping commences, the common peduncle of the male inflorescence (Sajatan) is beaten with a wooden mallet ten times in a month, causing the flowers (Apili) to increase in size and darken. This is taken as a sign that the sap (Aek Ni Bargot) is flowing into the inflores-cence and that it is ready for cutting.

On cutting, one flower-spike (Arirang) is left. The heel of the knife blade is struck repeatedly with a mallet to force it through the peduncle. Three days elapse between the first cutting and hanging a bamboo container (Taguk) below to collect the sap. Each morning a slice of the peduncle about two cm thick is cut off. The low is then considerable, and a large container s set to catch the sap at night when the quantity exuded is large, while during the day a smaller container is used.

The sap is collected every twelve hours. Each morning the peduncle is given two taps with the knife handle before a slice is cut off, the size of which may be progressively increased to about hree cm. A leaf is tied round the cut to channel he sap into the container below.

Access to a high peduncle is gained by climb-ng the palm or by means of a notched bamboo pole.

Substances may be placed in the container before it is fixed below the peduncle to retard fermentation, e.g., the fruit of the mangosteen (Manggis) or a pulverised root (probably ginger) from the forest. A further preventative measure is the washing out and smoking of all the bamboo containers before reuse. Clean containers are stored adjacent to the hearth.

The length of time one inflorescence will yield is usually three months; but, where use is irregu-lar, it may extend to nine. The yield is measured in terms of the number of kilogrammes of sugar produced per day. Inflorescences in use (1956) were each yielding from one and a half to three kilogrammes of sugar per day. A very high price was being asked for an inflorescence yield-ing five kilogrammes. The female inflorescence (Alto) is distinguished, but never cut as the flow of sap from it is considered too insignificant.

COOKING THE SAP

The fresh sap is boiled in large open pans in a special out-of-doors cooking place. After about one and a half hours, a thick liquid (Tangguli) is obtained which is returned to a bamboo container. This part of the preparation reduces the volume of liquid (one large pan of sap yields only one kilogramme of sugar) and prevents the sap from souring due to fermentation.

When there is sufficient Tangguli on hand, a second boiling for one to one and a half hours, depending on the strength of the fire, produces a red liquid "free of water." To the boiling liquid a little coconut oil or crushed kernels of the candle nut (*Aleurites moluccana* Willd) or kernels from a bush (Djarat possibly *Jatropha curcas* L.) is added to prevent the liquid boiling over. A spoon with a perforated bowl may be used to remove froth in the early stages of cooking and any foreign materials. As the liquid thickens, a little is tested in the air on the stirring spoon to ascertain its setting properties and when ready it is ladled into moulds.

The plank of wood on which the moulds are placed is washed down to prevent contamination from bacteria resulting from its prior use; this is seen in Mandailing eyes as a sickness of the sugar. The board may also be rubbed over with crushed candle nut kernels. The moulds (Bila) are hoops of bamboo made in three sizes, approximately 7, 14, and 21 cm in diameter and 1, 2.5, and 3.5 cm in height, respectively.

I.H. Burkill: *A Dictionary of the Economic Products of the Malay Peninsula*, 1935, Vol. 1, p. 231.

When set, the cakes (Paske) are pressed from the moulds and allowed to cool and harden. Cakes of like size are wrapped together in the dried fibre of the banana trunk and tied in parcels of a marketable weight. On account of the hygroscopic nature of the sugar the parcels are stored above the hearth until marketed. Type and quantity of paske produced are adjusted to the market aimed at; the first, to the small scale intra-village spending of child and household; the second, to the market town and the largest to the requirements of bulk export. In 1956, the producers' selling price of a parcel of twenty medium sized cakes, was about Rp. 10, at about Rp. 2.50 a kilogramme.

Variations in the process of cooking are mainly the result of differences in aptitude of the producers, in particular, in their ability to judge when the sugar has been sufficiently boiled. In the local markets the quality of the sugar varies considerably and, as a consequence, so does its price. Sugar may be marketed black in colour due to overcooking or smoke, moist and crumbling from undercooking, or adulterated by various foreign bodies such as bees and palm fibre. Or, again, though carefully prepared, it may be held back until the market price rises, and then finally be sold in a deteriorated state.

The site of the cooking place affects the quality of the final product. Cooking takes place in the precincts of the village, at the edge of the rice fields, or in the arboreal gardens. In the former case, unless sheltered by a roof and walls, dust may be carried by wind from the bare village streets into the cooking pans. In the garden and field sites it is usual to build a shelter to house the hearth and implements, but greater care has to be taken to prevent bees and other insects from being trapped in the liquid. But the construction of a cooking place in gardens is considered justified only where a number of palms owned or hired by the tapper are clustered together.

LABOUR FORCE

The care of the palm and the preparation of the sugar are male occupations. Women assist indirectly by providing some of the wood for the cooking and directly in guarding the simmering liquid and tending the fire. Although women never participate in collecting the juice, in the Si Ladang villages women do climb the palms to collect the fibre.

OWNERSHIP OF PALMS

Ownership of the palms is established by inheritance, by planting, and by finding palms on land jointly owned by the village. Where a person desires usufruct of another's palm, several alternative arrangements exist. They are as follows:

1. The hiring of a tree and repayment with approximately a third of the final product.
2. The buying of the usufruct of an inflorescence at a fixed price after it has been established that the palm is yielding.
3. The buying of the right to tap an untried palm. As there are many unproductive palms in the area, this represents a speculation. However, the slightly lower price is attractive, and it is said that some men have acquired the skill of being able to estimate the likelihood of a palm yielding.

ECONOMIC STATUS OF PALM SUGAR

Palm sugar plays an insignificant part in the subsistence economy of the area. As a cash crop, its actual and potential use is severely limited by its storage properties which enforce a delicate adjustment between production and market demands. It has to compete with rubber and coffee for which a market is assured and which can be stored in anticipation of a favourable price. Hence the industry is usually combined with the production of other cash crops. In most of Upper Mandailing it is the preferred occupation of only a few and is irregularly practised. In the Si Ladang villages, on the other hand, tapping is regularly engaged in, and there is a greater standardisation in the quality of the product.

In most areas the investment of labour and capital in the cultivation of the palm is slight as compared with that involved in coffee or rubber. Thus the palm is utilised when the demand is high, e.g., during the fasting month, and otherwise neglected. There is no loss due to idle capital.

Since the introduction of cheap white sugar with its better storage qualities, the use of this commodity has spread with a concomitant decline in the utilisation of the palm for sugar.

OTHER USES OF THE PALM

The multipurpose functions of the palm are appreciated in Mandailing, all parts other than the roots being utilised, e.g., the fibre for roofing, cord, and brooms, the pith of trunk and seeds for food, the trunk for conduits, the fronds for shelters, and the leaves for decorative purposes.

Note: Terms used throughout the paper are those current in Upper Mandailing.

DISCUSSION

T. R. McHALE: Is there any knowledge there concerning the use of earthernware vessels for boiling sugar juices? If sugar as a crystalline product was known before 600 A.D., it was probably extracted from *Arenga pinnata*, not cane. Did sugar techniques evolve from India or from Southeast Asia before Persian techniques were invented?

POSSIBLE SEPARATE ORIGIN AND EVOLUTION OF THE LADANG AND SAWAH TYPES OF TROPICAL AGRICULTURE†

HARLEY HARRIS BARTLETT

University of Michigan, Ann Arbor, Michigan, U.S.A.

In reviewing a vast amount of literature on primitive tropical agriculture, the writer has been impressed by the fact that there are a few chief types which must have been adapted to the early pre-agricultural environments of those tribes who became agriculturists. One finds himself speculating about where agriculture could have originated and what environments would have favored its development in succession to a purely food-gathering economy. It is a certain conclusion that primitive man in the humid tropics was not pastoral. The safest habitat for him would have been the shores of salt water, where he lived largely on molluscs and other marine products, supplemented by what fruits and vegetables he gathered in the forest, as well as by hunting and by fishing. The first horticulture of the seaside dweller might have been the planting of such food-producing trees as coconut and breadfruit; his first vegetable gardening the actual planting of edible plants that first presented the idea to him (or to her!) by springing up as weeds at the home site on rubbish heaps and other accidentally fertilized areas. Permanent or long-continued occupation of a site would result in constant accession of fertilizer derived from the debris of living, and so we might think of household gardening and seaside horticulture as growing out of the sort of a subsistence that prevailed among people who built up shell mounds, inhabiting one place through many generations. It is easy to conceive of their migration along streams and into the forest as soon as they invented or came into possession of even simple tools and weapons for fishing, hunting, and defence.

The fertility of burned-over .places would suggest the clearing of land, and moving the living site into the clearing would start an entirely new cultural evolution and population mobility, in which various forms of agriculture would coexist with the more ancient house-site gardening and horticulture. Early shifting dry-land *(ladang)* agriculture must have developed in areas of the most tropics where no irrigation was necessary, in forest clearings prepared by deadening trees without felling them and by the burning of slash. At first the crops must have been the same species that were gathered in the wild, such things as *Tacca* (in Polynesia) and yams (throughout the eastern tropics), and the tubers of edible aroids. A century ago heavy, edged, blade-like clubs not unlike canoe paddles were reported to be used in Fiji for slashing down the forest undergrowth in making agricultural clearings; and similar implements, still surviving elsewhere, indicate something of the technique of clearing prior to the introduction of metal tools. Trees were deadened by ringing them with stone axes or adzes, or by piling and burning slash about them. The ashes of slash and the superficial organic debris of the forest floor fertilized the soil. Cultivation was abandoned when weeds and sprout growth became too rampant. There was no regular rotation of cropping with forest fallow.

Ladang agriculture extended rapidly when the introduction of metal blades permitted the more complete clearing which is general in shifting agriculture today and which is characteristic of the Malay *ladang*. The greater area that could be cleared with the Malay metal-edged adze *(beliung)* or its equivalent enabled the chief men to have larger than ordinary clearings with more substantial houses, built by the joint labor of the people. In Indonesia, the primitive clearing in which there would have been no tillage may have been called *uma*, and this term was retained in the original sense or as a name for the entire homestead, including clearing and house.

The more gregarious people would retain one permanent house site, and around it the original *ladang* or *uma* would become stocked with fruit trees and little patches of disorderly mixed kitchen garden. Round about the old original inhabited site the repeated clearing of land for shifting cultivation might result in a regular orderly sequence of cropping and forest fallowing—permanent land use of a sort. Over-population might result in the flocking away of a colony, to repeat the same process. In Sumatra such a colony would have been called a *dusun*.

† Presented by T. P. Bank II.

On the contrary, a less socially-minded, less gregarious population with plenty of land to spread over might never develop village life or orderly land use, but remain in a semi-nomadic state, utilizing previously unused forest as long as it lasted, and migrating as the old forest retreated. They would not have practiced tillage, but would merely have sown in the soft ash-covered soil.

Chitemene and *Rab* agriculture grew out of typical shifting agriculture. In remotely separate places there has arisen the technique of increasing productivity of a clearing by burning upon it more slashings and other vegetable debris than it has produced during a period of forest fallow. Thus, in eastern tropical Africa a clearing is made, and in it are strewn branches cut from trees in the surrounding forest. With the debris thus supplemented, the ashes, sometimes dug into the soil with spades or hoes, are sufficient to produce good crops on sadly depleted soils. The technique is called *chitemene*. In India, an essentially similar form of supplementary fertilization by the ash of extra slashings from outside the cultivated area characterizes *rab* agriculture.

The clearest transitions from *ladang* to permanent dry-land agriculture by the introduction of tillage have been observed over the course of years in Java. Here the population has grown so enormously that the typical *ladang* has all but disappeared. Its place has been taken by *gogo* (or *gaga*) agriculture which is characterized by the introduction of tillage. Its counterpart in other parts of the world is generally designated as *hoe* agriculture or, in Africa, Bantu agriculture.

It is unusual to find good descriptions of the primitive tillage of pre-plow agricultural peoples. Too often one runs across the expression "hoe agriculture" as indicating a stage of agriculture higher than the more primitive types of shifting cultivation, in which there is no tillage, but with no description whatever. The hoe agriculture of tropical Africa seems to have developed typically in forest lands marginal to savanna and more readily transformed by fire into grassland than likely to become regenerated forest if abandoned. So hoe agriculture has to have tillage and be able to combat grass as well as brush. It may have various developments before it develops into plow agriculture, one of which has developed both in India and Africa, namely sod-burning for securing ash from grass rhizomes and stubble, where wood is no longer available. The sods, dug by hoe or digging stick, are dried, then piled up and burned. There are enough rhizomes and roots so that the mass burns through, leaving a mixture of ashes and burned-out soil which is spread over the ground and dug in.

So far all of the types of primitive agriculture considered may have evolved from a single point of origin. Two main groupings are on the one hand homestead or village horticulture with vegetable gardening which is more or less continuous, and shifting agriculture, which may likewise give way to a type of permanent land use if population increases to the point where the use of land falls into a regular progressive rotation with alternate cropping and bush or forest fallow.

Still left for consideration is wet-land rice growing, or *sawah* agriculture. What evolutionary sequence could have led to this?

A chief objective of this communication is to point out the possibility that there may not have been any linear or connected sequence in the evolution of dry-land and wet-land types of agriculture which we may call the *ladang* and *sawah* types, respectively, using the convenient and rather familiar Malay terms, but rather, that wet-land rice agriculture may have had a direct origin from a food-gathering phase of human culture. Such a possibility is suggested by the existence in various countries of seasonally inundated grass lands upon which the vegetation is chiefly grass after the water subsides. It is frequently thought that all tropical grasslands, with the most minor exceptions, result from repeated clearing followed by fire, and this is undoubtedly true in general, for many have observed degradation to grassland of originally forested lands. There are, however, extensive tropical areas, seasonally flooded, which show no trace of ever having been forested. Such occur in central Africa, where certain of the lakes are surrounded by great areas of marsh which, depending upon fluctuation in regional rainfall, have the soil surface submerged to a greater or less depth during several months of the year. Such areas are resorted to for the harvesting of grain from wild grasses, including various kinds of wild rice. Extending from the Sudan southward and westward through tropical Africa, there are various instances of such harvesting of a wild grain, and of easy transition to agriculture.

In a state of nature many grass inflorescences have a highly developed mechanism for disarticulating below the spikelets or at other nodes as fast as the grain ripens. They are therefore self-sown so promptly that the birds (and man) are not likely to secure most of the seed. There are occasional mutations, however, to hereditary sorts of which the inflorescence does not shatter.

In order to be harvested economically, a cultivated rice or grass would have to be of this sort. It is impossible that primitive man would not have noticed such mutations and have taken advantage of them. Such mutational types in nature would have been at a definite disadvantage in the struggle for existence, but with man's intervention might have been artificially sown in appropriate places and guarded during the ripening period, just as the cultivated crops are guarded from the rice birds in the tropics.

It must be noted that the habitat of wild rice and other edible subaquatic grass grains would have been open, not requiring the clearing of forest, and that a type of agriculture might readily have evolved on seasonally submerged lands that would have required a minimum of tools and implements, as it would have consisted chiefly in the selection and sowning of especially valuable grass mutations in habitats that already existed.

Some of these habitats in Africa were so deficient in natural vegetation when the seasonal flood water subsided that they were described as expanses of mud that quickly became covered with grass and other herbage, sometimes becoming so dry as to split into hexagons during the rainless months.

Other African habitats had a continually emersed marsh vegetation. Why they did not become forested is perhaps because they were markedly saline during the dry season, but only slightly brackish when the salt was in more dilute solution during high water. At any rate there is no sufficient reason to believe that marsh grasslands with highly varying water level were always man-made, through the agency of fire. The present writer has collected several instances, from the literature on Africa, of types of primitive agriculture on seasonally flooded land that could well have developed directly by tribes at a food-gathering level. Such types of cultivation, hardly removed from the artificial increase of natural products by selection and sowing in unprepared habitats, must have preceded the modification of habitats by diking, elimination of useless vegetation, and soil preparation.

Turning to Asia, we can see how *sawah* cultivation, the growing of subaquatic rice in diked land, seasonally submerged, might have come about in such areas as the Sunderbans at the mouth of the Ganges. From here up into Assam there are reports of wild rices, often harvested, and similar to those generally planted in shallow water, after the partial subsidence of flood water. Needless to say, the management of artificially modified habitats would in time have resulted in the clearing of forest to extend the area of what in Sumatra (East Coast) would be called *bandjir* land into seasonally wet swamp forest, in which flood water could be retained by diking.

Needless to say, after wet-land cultivation had once come about, the techniques of irrigation and diking would be developed to transform dry habitats into wet. It is reasonable to suppose that the terracing of irrigable mountain sides was a relatively late development, carrying *sawah* agriculture upward from the flood plains, where the subaquatic rices would have naturally occurred and would have been first grown, into areas that had to be profoundly modified in order to be suitable for *sawah* rice. All kinds of confusing intermediates have been developed between dry-land *(ladang)* and wet-land *(sawah)* agriculture, such, even, as diking land to retain rainwater, and planting a mixture of *sawah* and *ladang* rices in order to secure a crop regardless of how much or how little rain there might be.

The most extraordinary type of rice cultivation that exists is that of the floating rice which is found throughout flood-land areas from India to Indochina, has attracted especial attention in Thailand and Cambodia, and has not been unknown in Java. (For the literature, see "floating rice" and "wild rice" in the indexes to the writer's *Annotated Bibliography.*) This cultivation takes advantage not of subsiding or of shallow flood water, but of rising flood water, which is eventually many feet deep. The growth of the floating rice keeps pace with the rise of the flood water, and the stems may be several meters long when the grain ripens. It is harvested from boats. This type of grain harvesting closely resembles the grain gathering of the Indians of the Great Lakes region of the United States, who gather the excellent grain of *Zizania aquatica* directly into their canoes from its shallow-lake habitat. These Indians may have extended the range of the useful *Zizania* by artificial seeding of appropriate places where it did not grow. Far from the tropical Orient, we have a suggestion of how a type of aquatic cultivation might well have become important and have had no relation whatever to dry-land maize cultivation. So the *ladang* and *sawah* types of agriculture might have had entirely different beginnings, depending upon the habitats occupied by primitive agriculturists.

DISCUSSION

C.G.G.J. VAN STEENIS: As far as I have understood from the reading of the paper, Prof. Bartlett assumes a continuum of ladang (huma) and irrigated rice-field. I doubt this generality. The irrigated rice culture is agriculturally a complicated thing requiring great skill and a suitable soil. As Prof. Beyer showed in the Philippines, the rice terraces are laid from the Gulf of Lingeyen into the mountains, a process requiring very many centuries; it came from an invading people from Formosa or Indochina, and the culture travelled with the invaders. The same thing holds for Java which was originally called the "Millet Island." I think the original shifting cultivators (Proto-Malays) planted their huma with millets (*Setaria italica*, *Coix*, *Panicum*, etc.) as cereal; later the rice was added or replaced the millet in bulk. There was no continuum between the shifting cultivators and the wet-rice settlers. There was also certainly not an independent (polytopic) origin of the wet-rice culture, but the custom travelled with human migration waves from the Asiatic mainland.

Furthermore, I want to state that huma (ladang) is also employed in the seasonal areas of the tropics, for example, in the Lesser Sunda Islands, where the grassland is worked by overthrowing the sod by means of pointed sticks by the combined village population. This is obviously also done in Africa where the huma is found mostly in the seasonal or sub-seasonal marginal savanna part of the rain forest. Besides, ladangs are more easily made under sub-seasonal conditions which facilitate clearing the land by fire. Ladang is not confined to the ever-wet rainforest area.

T.R. McHALE: Taro was cultivated long before rice in the Philippines and elsewhere in Southeast Asia; rice is a more recent introduction than most people assume. The Philippine terraces may be old and made for wet-taro cultivation.

F.R. FOSBERG: The Mariannas mark the eastern limit of Pacific rice cultivation. There seems to have been little contact with Asia, yet rice may tentatively be estimated to have grown there for 3,000 years.

T.R. McHALE: Is this wet- or dry-rice cultivation?

F.R. FOSBERG: I do not know.

T.R. McHALE: Many of the wet-rices can be grown on dry-land, and vice-versa.

SOME WORDS USED IN CONNECTION WITH PRIMITIVE AGRICULTURE IN SOUTHEAST ASIA†

HARLEY HARRIS BARTLETT

University of Michigan, Ann Arbor, Michigan, U.S.A.

This paper deals with certain words that recur in various languages and dialects and that pertain to shifting agriculture. Sometimes when cognate words are found far apart they show considerable phonetic change. Likewise unrelated words of different origin may converge into deceptive similarity.

The writer has traced the geographical distribution of Common Malayo-Polynesian *uma*, which would appear to have had the basic meaning "forest agricultural clearing." This meaning has persisted in some languages without change, but has changed somewhat in others to mean "clearing and house" (i.e., "homestead"), "home," "household," "persons descended from one household," and "ceremonial center of a local population of related persons." It is a word widely distributed from Madagascar to Samoa and represented in many languages, which must indicate the extent of some ancient cultural drift, and one suspects that it is related to *rumah*, house, another widely dispersed world.

Although *uma* is more widespread than other words for "forest clearing" it is not so generally well known as Malay *ladang*, which would seem to have spread with the Malay language, and to be, in its present wide distribution, comparatively modern in comparison with *uma*.

In Assam, several languages have the word *jhum*, which the writer has vainly sought to equate with *uma* because of the occurrence in the Batak languages of Sumatra of the word *Juma* (*djuma; djoema*). The latter word, however, is considered by students of the Sumatran dialects (such as Joustra and Warneck) as being a condensation of *di uma*, meaning "at the *uma*." Therefore, unless the derived word *juma* spread to the continent from the islands rather than in the other direction, it must be concluded that the similarity to *jhum* probably does not indicate a common origin. The probable correctness of the explanation of Batak *Juma* finds support from the occurrence of a parallel derivative of *uma* in Toba Batak, namely, *hauma*, presumably *ha uma* ("at the *uma*"), for Toba has h instead of the k of Common Malayan *ka*, meaning "at," "towards," or "associated with." Nevertheless, the similarity of *juma* and *jhum* should be kept in mind by philologists, who will find a disturbing recurrence of *jum* for shifting agriculture as far away as Africa.

Another word associated with shifting agriculture is *Kaingin* of the Philippine languages and dialects. Its origin and distribution should be carefully looked into, especially in view of the rare occurrence of startlingly similar words in Indochina, which, if the words of the two areas were found to be cognate, would constitute a bit of new evidence on possible early cultural drift directly from Indochina to the Philippines, rather than round about by way of more southern islands.

Another word of key significance from the standpoint of locating centers of cultural drift is the Indochinese *ray*. Its history and distribution in local languages should be given attention by persons favorably situated to do so, and a point of especial importance would be to find out what languages and dialects have some other and possibly more ancient word for *ray* (*rai*). The latter, like Malay *ladang* and Philippine *kaingin*, may be suspected of having had a relatively recent extension of occurrence because of selective use by administratively or politically dominant groups.

The term *taungya* (*toungyah; yah*) originally meant, in Burma, nothing more than Malay *ladang*, but it has had a very curious dispersal and change of meaning in the course of a century. In Burma, as elsewhere, during the occupation of a forest clearing (*taungya*), a good many fruit trees might be planted, and this might lead to the transformation of the clearing into a permanently occupied site. The transformation of an old clearing, occupied by a chief or important man (who would have a more than ordinarily valuable house and unusually extensive house-site plantings) into a disorderly orchard interspersed with garden spots, may be observed in many places in Southeast Asia. Such a process was observed by Kurz in Burma where (exceptionally, not generally) the interplanting of a clearing with fruit trees was done early, intentionally, and

† Presented by T.P. Bank II.

somewhat systematically. It gave him and others the idea that this procedure, with the planting of forest trees instead of fruit trees, might be adapted to the needs of foresters as a regular silvicultural system. The trials met with considerable success, and the word *taungya*, from the tongues of foresters, quite lost its proper general meaning as a temporary clearing for shifting agriculture (only rarely transformed into a grove of fruit trees) and came to designate a systematic silviculture pro.edure. In the latter sense, the word has spread far and has been especially attractive to British foresters in tropical Africa. The reader who wishes to trace the change of meaning should consult the indexes of Vols. I and II of the writer's *Annotated Bibliography*, and subsequent volumes when they appear.

Although only one term of several which apply to agricultural implements, and to which attention might be called, there is one word that may prove to be of special importance from the standpoint of cultural drift. That is *tuwai* or *tuai* (Malay), the name for a curious little reaping implement consisting of a blade mounted lengthwise in the edge of a flat, thin vertically perforated piece of wood. The hole is for the vertical insertion of a stick of wood or bamboo which enables the implement to be held and operated in one hand, for harvesting the rice straw by straw, cutting shortly below the inflorescence. Its use instead of the sickle often has a ceremonial significance, for it is concealed in the hand and so "does not alarm the soul of the rice." The cult of the rice spirit is widely diffused in the Southeast Asian area and probably was associated with the exceedingly important cultural migration that originally carried rice cultivation with it. So vestigial beliefs and primitive techniques connected with rice cultivation are especially important to the investigator of prehistory, and it is merely significant that the curious little *tuwai*, so familiar in Indonesia and Malaya, extends up into Indochina. It should receive attention from ethnologists and linguists. It is doubtless younger by millenia than the simple digging stick (which should also have more attention); but nevertheless archeologists should be on the lookout for symmetrical shell, stone, and metal blades with a median perforation, which might have preceded the blade mounted in wood. It is, of course, possible that bamboo blades preceded the present *tuwai*.

DISCUSSION

T. HARRISSON: I doubt the value of drawing conclusions from word comparisons in different languages; I believe that "*Umah*" is derived from the Malay "*Rumah*" as also may be the words used by the Kalabits, the Kayans, and the Kenyahs, and the related words used in other languages. The word means not a *ladang*, but a group of people and the place they move to in the three languages mentioned. These people came from the Southeast, and the word is used by a people therefore accustomed to moving through the forest as a community.

ETHNO-ECOLOGICAL RELATIONSHIPS BETWEEN THE MAIZE PLANT AND MAN IN WESTERN ANCIENT AMERICA

PAUL WEATHERWAX

Indiana University, Bloomington, Indiana, U.S.A.

It is generally conceded that the growing of maize was the principal key to civilization in ancient America. Those Indian races which developed the three great cultures centered, respectively, in Mexico, Central America, and Peru, all had well developed systems of agriculture. Their arts, folklore, and religions consistently reflected their dependence on maize.

We ordinarily attribute this close relationship between maize and man's cultural accomplishments to the fact that the use of this superlatively productive plant left to the Indian enough time for the leisurely thought and exercise of the imagination necessary for cultural development. No one would seriously question this point, but this simple statement of cause and effect falls far short of telling the whole story. For many centuries before the discovery of America by Columbus, there had been a complex interplay between man and his principal agricultural plant. Man did something to maize, and it, in turn, did something to him, and this exchange of stimuli had a profound influence on both. At the dawn of modern history, man and maize had traveled the same road so long, and had exchanged influences in so many ways, that, to understand either, we must know a great deal about the other.

As this drama of cultural and biological evolution was enacted mostly near the western shores of the Americas, on the eastern borders of the Pacific, the development of this theme would seem to be an appropriate topic for consideration in this Congress. It is further justified by the fact that we hear from time to time rumors of ancient exchange routes across the Pacific, between the Old World and the New, and even the occasional suggestion that the whole process had its origin in Asia and not in America.

In many ways, maize is unique among the great food plants of the world. It is so prolific that, even under conditions of primitive agriculture, it sometimes has a ratio of increase of almost a thousand fold. Per unit of land occupied and per hour of labor spent on it, it gives enormous yields of food.

More significantly than this, maize is one of the few annual crops in which each plant stands out with sufficient distinctness to attract individual attention. In a field of beans, squashes, or quinua or of the small grains, in which basal branching makes it difficult to determine just how much constitutes one plant, the individual is submerged in the mass. A single maize plant, however, has a discrete individuality. It may produce enough grain to feed a man for a day. It is worth individual care and attention. Moreover, it completes its life cycle in a short time, and anything that is done to it produces quick results. We can imagine the slow steps by which man learned to give it a better environment and even the slower process of giving it a better heredity. If it were longlived like a tree, the lag between cause and effect would obscure their relationships.

The collective accomplishment of the native American races in shaping the maize plant into what European found it to be in 1492 has never been fully appreciated. It will ultimately come to be regarded as one of the half-dozen or so greatest accomplishments of applied genetics of all time. Knowing nothing of genes or chromosomes or of the fertilization process, and usually very little about even the rudiments of reproduction, native Americans employed methods of trial and error which changed the simple wild species into a most complex cereal completely dependent on man for its existence.

At one end of this long process was probably a perennial plant having something of the appearance of modern tripsacum or teosinte, but a plant so handicapped by certain maizoid characteristics that, when it was first taken into custody by the Indian, it was well on the way toward extinction. At the other end we find a highly efficient cultivated species displaying a morphological and genetic complexity probably unequalled in any other crop plant. It grew on a great variety of soils, at altitudes ranging from sea level to 13,000 feet, and in climates from the humid tropics to deserts, from perpetual summer to latitudes and altitudes where the frost-free season was scarcely more than two months in length.

The stature of the plant might be 18 inches, or it might be more than 20 feet. Some ears were less than an inch in length, while others are said to have measured no less than 30 inches. The largest grains weighed at least 60 times as much as the smallest. The endosperm ranged from flinty hardness to a texture so soft that the mature, dry grain could be crushed between the fingers, and its chemical structure showed corresponding variations in protein and starch content, with a few extra features, such as the high sucrose content of the sweet varieties, the side-chain starches of the glutinous forms, or the ability to pop, all thrown in for good measure.

There was a relatively high correlation between these characteristics of the plant and the ways in which it was grown or used. The adjustment of varieties to soil and climate was imperative. The character of the grain dictated methods of popping, parching, boiling, milling, or brewing. The soft, floury grain, for example, was preferred for dry grinding, and the flinty kinds were used mainly in the processes involving treatment with quick-lime or wood ashes. Almost any variety might be parched, but there were special advantages for this method with the sweet corns and pop corns.

The complex pigmentation of the grain merits more consideration than it has ordinarily received. Indeed, some modern investigators speak disparagingly about any interest in this characteristic except insofar as it presents good subject matter for color photography. For the Indian, however, color of the grain was not only a thing of beauty but also often a guide to his practice of genetics, even though he did not know what he was doing. The Hopi maintained one of their favorite varieties through careful attention to its blue color, and the Navajo used an aleurone pattern in maintaining a "sacred" variety. The *sara misa* ears, regarded with much awe by some of the Andean races, displayed a baffling chimera of pericarp colors. The husking games, popular in the South American highlands and many other places, in which prizes went to those who found certain color combinations, undoubtedly had the effect of maintaining hybrid vigor in highly heterozygous seed stocks.

In shaping the environment of the plant, the Indian showed a skill and experienced an evolution similar to those incident to his work on heredity. It was a long road from the first observation that a grain placed in the soil would produce a new plant, or that the plant grew better if the weeds were removed from around it, to the elaborate practices of drainage, irrigation, terracing and fertilizing which were in use at the end of the fifteenth century.

An especially significant progressive trend was initiated when it was discovered that there were good times and bad times for planting corn. This led to observations of the movements of the sun and stars, with the ultimate formulation of permanent systems of counting time.

It is well that at this point we repeat the primary thesis of this discussion: the maize plant had a unique civilizing effect which far surpassed its importance as a mere source of food. As the Indian observed the plant and made decisions about seed selection, planting, and cultivation, he experienced many successes and many failures. As he was dealing with a species in which the individual was taller than a man and economically very important, it was easy for him to test his decisions. In other words, intelligent judgment paid prompt and impressive dividends, and this was conducive to further straight thinking. The cultural value of this was immeasurable. A few illustrations may help to clarify this point.

Maize agriculture was the original germ out of which grew the elaborate mathematical system of the Mayas. In order to know when to plant corn, the Indian observed the movements of the sun and discovered the solstices and the equinox. Numerous sundials scattered among the ruins from Arizona to Peru testify to the accuracy with which these determinations were made. The next step was the discovery that the length of the day and the length of the year were not integrally related. Their leapyear correction for this was unusually accurate for its time. Out of this came the division of the year into months, the recognition of the decimal and duodecimal systems, and the discovery of the 52-year cycle. All this called for a system of notation, which ultimately involved place values and the use of zero. By this time the fascination of abstract mathematics had left the humble agricultural origin of the system far behind.

As the Indian worked in his fields, he came to have a friendly regard and a feeling of awe about this important plant. It could be nothing less than the work of a deity—or even a deity itself. From this, came an emotional expression in pageantry, story, and song, in ornamentation of sculpture, architecture, and ceramics, and in an endless array of religious rites and ceremonies. Even the human sacrifices which shocked the early explorers could often be traced directly to agricultural origins.

To tie this theme more closely to the purposes of this Congress, a word must now be said about the time and place of the origin of the maize plant and maize agriculture. This involves some differences of opinion which arose as the New World first became known to Europe. Because the writer of this article is not primarily an anthropologist, he refuses to be drawn into the controversy between the independent inventionists and the diffusionists, but will limit himself to the problem as presented by maize.

Soon after the discovery of America by Columbus, attempts were made to identify maize with plants mentioned by ancient writers. There were good reasons for this error. The new-born science of western Europe still stood in awe of the authority of the classics and expected to find there the answers to most of their questions. The world was believed to be much smaller than it later proved to be, and the newly discovered lands were regarded as eastern outposts of Asia. And methods of collecting and evaluating data were not yet well standardized.

The idea that maize was known in Asia in ancient times, or even that it originated there, still breaks out in our literature from time to time, but it is our opinion that there is no objective evidence to support it. The varieties of maize recently described from upper Burma and adjacent areas could have reached there by Portuguese trade routes in the early part of the sixteenth century, and the testimony of an illiterate people that they have always had maize is not to be taken seriously when other evidences are against it. The earliest definite mention of maize in western China is late enough to allow plenty of time for it to have come in from eastern India, and it is significantly characterized in these early reports as something new. The report of an early African potsherd ornamented with maize is beset with much doubt both as to its age and as to the identity of its ornamentation. The linguistic arguments of similar import have largely backfired against those who have advanced them. Probably the weakest of all the evidences is the one which points out the sweet potato and possibly one or two other crop plants as having been present in both hemispheres and then asks why not also maize. As far as we know at present, Asia does not hold a single fragment of the maize plant, a single statement about it, or a single artifact connected with it which is definitely dated earlier than almost a century after 1492.

No very near relative of maize was native of the Eastern Hemisphere. In spite of various theories which have been held in the past, it now seems that there is no close relationship between maize and the sorghums or others of that section of the *Andropogoneae*; and, although *Coix* and a few other oriental genera have been placed in the tribe *Maydeae*, this classification is to be regarded as only an artificial one.

In addition to all these things, we note the rapid migration of maize after it reached Asia in the sixteenth century. It filled a great need in countries suffering from a shortage of food, and, if it had been there before that time, why had not its value been recognized?

We are safe in assuming that maize has been cultivated in America for at least the past 4,000 years, and fossil pollens indicate that it and *Tripsacum* and *Euchlaena*, the only plants closely enough related to be able to hybridize with it, have been associated there for many thousands of years. The ancient human cultures based on maize agriculture testify to its having been under domestication for many centuries before the dawn of history. In view of this array of evidences all pointing in one direction, it seems futile to speculate further about the origin of maize in Asia or about its having been there before the early years of the sixteenth century.

ETHNOBOTANY OF NORTHERN PEOPLES AND THE PROBLEM OF CULTURAL DRIFT

THEODORE P. BANK II

Museum of Anthropology, University of Michigan, Ann Arbor, Michigan, U.S.A.

(Abstract)

A few writers, notably de Laguna (1934), Collins (1937), Birket Smith and de Laguna (1938), and Heizer (1943), have suggested that prehistoric Aleut contact with Kamchatka and the Kuriles is indicated by archaeological and ethnographic evidence, including the presence of aconite poison whaling among the Ainu, Kamchadal, Aleut and Koniag. Japanese archaeologists declineate an Okhotsk Sea cultural sphere, more recently a Moyoro phase (Kodama, 1948; Oba, 1955), which shows strong Aleut-Eskimo characteristics, including use of the labret, bone arrow heads, toggle heads, stone lamp, compound fish hook, and needle cases. Further, Kurile and Kamchatkan sites yield artifacts which some (Baba, 1934, 1936; Nakayama, 1933, 1934) believe indicate a definite prehistoric contact with the Aleutian area.

Historical references to Aleut-Koniag voyages are on firmer ground. In 1621 the Japanese Duke of Matsumae described non-Ainu Kurileans who apparently had skin boats and other Eskimoid traits. Following Bering's voyage, Russian fur hunters transported Aleuts to Kamchatka, and the first definite record of Aleuts and Koniags in the Kuriles appears in 1800 (Kondo). They were probably brought by Russians in 1789 (Baba, 1943). In 1826, the Russian-American Fur Company settled about a hundred Kodiak islanders at two villages in the middle Kuriles, and in 1869 another group was taken to Sakhalien (Stejonger). After the Russo-Japanese exhange in 1867, all Aleuts and Koniags were presumably resettled in Kamchatka or the Kommandorskies.

It is well known that the Aleuts undertook long voyages on the American side of the Pacific. Aleut sea mammal hunters, forced by the Russians, undertook voyages in historical times to the Pribilofs, Kodiak, Sitka, and as far south as California. Even in pre-Russian times, they probably traveled at least as far as Kodiak for trading purposes.

Aleut-Koniag voyages, both in America and in Asia, during the Eighteenth Century are of more than mere historical interest; they may account for a few of the cultural similarities found among the Ainu, Kamchadal, Aleut, Koniag, and Northwest Coast American Indian, including the presence of aconite poison whaling in the Aleutian-Kodiak area.

A recent study by the writer shows that there are similarities in method of preparation, actual use, or beliefs surrounding use of plants among Aleuts and Ainu in approximately 55 per cent of the instances where the same plant genera are found in both areas. Some similarities of use are striking, but the body of lore and beliefs surrounding these plant uses is much more highly developed among the Ainu. These correspondences can largely be explained in terms of independent invention and historical contact, and there is no indication of prehistoric cultural drift via the Aleutians.

DISCUSSION

C.G.G.J. VAN STEENIS: Dr. Bank defines ethnobotany as the study of the relationship between plants and primitive man. In Holland there are such relationships that have arisen only within the last few hundred years.

T.P. BANK: But this would come within the realm of economic botany.

C.G.G.J. VAN STEENIS: I disagree. In the instance mentioned, the people of East Holland make a soup with herbs introduced only 300 years ago. This is an ethnobotanical problem, but "primitive" has no meaning here.

T.P. BANK: I agree. The economic botanist may be an anthropologist as well. There is no real distinction between the two terms.

F.R. FOSBERG: In this definition of ethnobotany, I wonder where such studies as of the plant relationships of the Kentucky mountaineers or of the Maldive Islanders, who do have written languages, come in. These studies would scarcely be of interest to economic botany in its modern sense, but are important botanically and ethnologically. Perhaps the way to adapt the definition would be to omit the word "primitive."

C.G.G.J. VAN STEENIS: The definition should be the relations between plants and man, other than where economics comes in.

F.R. FOSBERG: What about the word "primitive"?

P.W. RICHARDS: Would it not be correct to regard economic botany as a specialized branch of ethnobotany—that which deals with the relations of man and plants in our present culture? Our distant descendants may perhaps regard us as "primitive" people.

T.P. BANK: All would agree but the ethnobotanists.

MEDICINAL PLANT LORE OF THE ALEUT

THEODORE P. BANK II

Museum of Anthropology, University of Michigan, Ann Arbor, Michigan, U.S.A.

In the early Russian accounts there are frequent references to "concoctions of bitter plants" and "astringent roots" used by the Aleuts in the treatment of various ailments, but plant names are rarely given, even in later anthropological reports.[1] Knowledge of medicinal uses of local plants and animals was probably well developed among the native doctors, but, as with the use of local plants for food, these uses are now mostly forgotten by the Aleuts. A few of the older villagers still remember and occasionally resort to traditional remedies, however, especially to some of the plant infusions, which are known to be effective tonics and astringents. They still use the aromatic yarrow *(Achillea borealis)*, for example, for treatment of chest and muscular pains. Yarrow is also said to give some aid, when crushed and placed over a bleeding wound, in bringing about clotting. Fox oil, derived from the rendered fatty portions of newly killed foxes, is a favorite cure—all for skin lesions and itches. An infusion made from *Matricaria matricarioides* is frequently used by Aleut elders for gas pains and general stomach disorders. The root of *Geum calthifolium*, the leaves of *Conioselinum Gmelini* and *Angelica lucida*, and the roots of *Plantago macrocarpa* are all employed occasionally in tonics. Leaves of the cow parsnip *(Heracleum lanatum)* and of *Artemisia unalaskensis* are sometimes heated and placed over sore muscles and minor cuts. The leaves of *Geranium erianthum* are boiled in water, which is then used both as a tea and as a gargle. A number of other plants find occasional medicinal use in the Aleut household when the local teacher is not at hand. For the most part these plants grow near the villages and do not necessitate any major trek inland when the need arises for employing them.

A list of the chief ingredients in native medicines formerly or still used by the Aleuts includes:

Yarrow, *Achillea borealis* (Atkan SAMIKAYAX).[2] —An infusion was made from the leaves and taken as a cure for stomach and throat pains, also for colds. In post-Russian times it was thought to be especially good for consumptives. Even today, the leaves are plucked, rolled between the palms, and placed over open cuts as a coagulant. Leaves are also crushed and stuffed into the nostrils, for nose-bleed.

Matricaria matricarioides [all Aleut dialects, RAMASKAN (Russian)]. —This plant was greatly used by Aleuts and Russians alike as a cure-all. It was thought that an infusion of the leaves was good for stomach pains, especially for gas on the stomach. The infusion was also quite beneficial

[1] Waldemar Jochelson, *History, Ethnology and Anthropology of the Aleuts* (Washington, D.C.: Carnegie Institution of Washington, 1933).

[2] The letters in the alphabet adopted for Aleut words (essentially that of R.H. Geoghegan, *The Aleut Language*, Washington: U.S. Dept. Interior, 1944) are pronounced as follows:

A	generally like the a in father
C	like the ch in charm and chew
D	like the hard d in day; sometimes like a softly voiced th
G	usually like the hard g in garden
I	generally like the i in machine; sometimes like the i in kid
K	as in kite and kiss
L	softly, like the first l in bull; sometimes with a suggestion of a y before the vowels a, i, u
M	as in man and moon
N	as in noon and naughty
NG	as a single sound uttered through the nose, nga; somewhat like the ng in sing and ring, with nasal exaggeration (very difficult for non-Aleuts)
Q	like a deep clearing of the throat; often like a ch spoken far back in the throat; at the end of words, hard, like the German ch in ach
S	as in seen and soon; at times like z between vowels
T	as in tune and tea
U	generally like the oo in moon and moo
W	like the w in we and wash
X	like the German ch in noch and auch, but sometimes especially at the end of words, uttered in a more gutteral fashion
Y	like the y in you and young.

as a laxative. Today, the Nikolskians rely upon this plant as a tonic.

Artemisia unalaskensis aleutica (Atkan SISI-KAX). —This plant was heated over hot stones and used as a switch to beat the part of the body where pain was felt. A few older Aleuts, particularly rheumatic individuals, still use the plant as a switch during steam baths. It was also heated and used as a poultice, and sometimes the leaves were boiled in water for a tonic which was thought especially beneficial for dying persons.

Pondweed, *Menyanthes trifoliata* [Nikolskian TRILISKAN (Russian)]. —Modern Nikolskians remember that the roots of this plant were a powerful ingredient in a tonic. They say that it was especially valuable for gas pains, constipation, and rheumatism.

Pond scum (fresh-water algae and oils given off by plants bordering ponds) (Atkan UQUXLUX). —The scum is believed by modern Aleuts to be especially good in the treatment of eye troubles. It is gathered and used for bathing the sore or inflamed parts. The oils are more often used than the actual algae.

Avens, *Geum calthifolium* (Atkan AMIDUXIX or AMIDUGIX). —The roots are boiled, and the infusion is drunk as a tonic for colds and sore throat. The Aleuts once used the leaves on sores that refused to heal naturally, placing the wet or boiled leaves over the wounds and binding them in place. It was thought that the plant helped to dry out the sore and aided scab formation.

Umbelliferae. —Much used in the past in tonics for colds and in soothing drinks for sore throats were: cow parsnip, *Heracleum lanatum* (PUTSCHKE of the Russians); wild parsnip, *Angelica lucida* (SAKUDAX of all Aleut dialects); and hemlock parsley, *Conioselinum Gmelini* (Atkan CIKIGALUX). Wild parsnip leaves were also used as a poultice, and the older natives would slice the roots into two parts, heat the halves, and place them over the area of the body that hurt. If the pain was deep within the body, merely placing the heated roots over the skin in the general region was supposed to bring relief.

Ragwort, *Senecio Pseudo-Arnica* (Atkan UKCUDAX). —The leaves are gathered when the plant is in flower. They are placed directly over cuts and boils to aid in drainage.

Clubmoss, *Lycopodium clavatum* (informant has forgotten local name). —After delivery of a bady, the mother, if she is in pain, is given an infusion of this plant to drink.

Rumex acetosella (Atkan TANGAX UQUX). —The leaves are steamed and placed over a wart, or over bruised skin.

Leptarrhena pyrolifolia (Atkan ALIXSISIX). —The leaves used to be brewed, and the infusion was taken internally in the treatment of sicknesses such as influenza.

Iris, *Iris setosa* (Unalaskan NASANCAGA-DAX). —The root is boiled in water, and the infusion taken as a laxative.

Geranium erianthum (Atkan CUNUSIX). —The leaves are used in a gargle for sore throat.

Anemone, *Anemone narcissiflora* var. *villosissima* (Unalaskan CIXUDANGIX). —The root is boiled until all of the juice is extracted, and the juice is then given to patients suffering from hemorrhage.

Plantago macrocarpa (name not recalled). —The root is boiled in water, and the infusion is used as a tonic.

Reindeer moss, *Gladonia* spp. (Atkan KINA-DAM AIYUKAX). —One informant said that this plant is used as a tea for internal chest pains. It is also said that hunters who are climbing hills eat it in order to maintain their wind.

Raw fish. —One informant at Atka said that her people occasionally eat raw salmon or halibut in the belief that it stops heartburn.

Soap. —Brown laundry soap is shaved, mixed with bread and milk, and made into a paste [Atkan PIPARKIX (Russian)], which is placed on boils to draw out the pus.

MAGICAL AND POISONOUS PLANTS

According to one informant, if the juice of the buttercup *Ranunculus occidentalis* (Atkan KANGLAGIM AMAGI) could be slipped into the food of a well man, he would soon take sick and would "dry up" until he had wasted away into nothing. But the deed was dangerous to the perpetrator, for it was thought that constant plucking of the buttercup would bring on bad rain storms, which would drown the wrongdoer when he was at sea. Another informant mentioned feeding a soup made with mare's-tail, *Equisetum* (Atkan LAGIS KALGADAX), to a guest who was hated. It is also said that fox trappers used to carry a "sparkling sand" and pieces of mare's-tail in their pockets as a special charm to help them catch more animals. One of the red-capped mushrooms *(Russula)* is thought to spring up where human blood has been spilled.

These are the only bits of magical plant lore we gathered concerning poisonous or possibly poisonous plants, except for what relates to monkshood, *Aconitum maximum*, the one actually poisonous plant which we discovered. *Aconitum* has been found in a number of cultures as the primary ingredient of poison for harpoon points, and it was apparently employed at one time by Aleut hunters as a whale poison.[3] We made every effort with living Aleuts to track down this tradition, but, except for one individual, none recalled the use of *Aconitum* as a poison, or otherwise.

Not only do the Aleuts know of no use for the plant, but most of them deny that the monkshood is in any way poisonous. To prove their contention, several of them chewed and swallowed small portions of the plant. As far as we are aware, they suffered no ill effects. One of the Nikolski natives declared that the old harpoon poisons were made from decayed human fat mixed with crushed bodies of small, poisonous worms found in a fresh-water lake near the village. He was, however, not able either to describe or to collect the worm for us. One of the Aleuts at Unalaska vaguely recalled hearing that the monkshood had once been employed as a poison in conjunction with decayed human fat, but he was unable to tell us anything more. It seems obvious that the use was not widespread among the Aleuts and that it was discontinued soon after the arrival of the Russians. Probably, as has been suggested by Heizer,[4] the use was restricted to a few whalers, who kept the secret of the poison to themselves. Interrogation of the oldest living Aleuts near the ancient whaling center of Akutan might yield fuller information regarding this matter, which is of considerable interest in comparative ethnology. Collections of the Aleutian *Aconitum* from various localities are to be made for an alkaloid assay. It is possible that not all races of *Aconitum* have a sufficiently high alkaloid content, or even the right alkaloid, to be particularly poisonous.

The author recently had an opportunity to study Ainu plant uses at first hand during one year of research in northernmost Japan. An extremely comprehensive monograph on the subject of Ainu plant lore has already been written[5] but it is available only in Japanese.

Of the more than one hundred fifty plants used by the Ainu for food, medicine, poison or in handicraft, approximately half of the genera occur in the Aleutian Islands, and of these, a majority found use among the Aleuts in similar fashion to Ainu plant uses. In a few instances, especially among plants used for medicines and poisons, the similarities are striking.

It is impossible, however, to draw from the ethnobotanical evidence at hand any concrete suggestion, certainly no proof, that there were prehistorical cultural contacts between Ainu and Aleut via the Kuriles and the Aleutian Islands. Aleut plant lore can be viewed as having its origin 1) in environmentally determined needs and independent invention among the Aleuts; 2) in cultural exchanges with American aboriginals, primarily with Kodiak Islanders and Southeast Alaskan Indians; and 3) through historical contacts and cultural exchanges after 1741 with Kurile Island Ainu and Kamchadals. Similarities with northern Alaskan Eskimo plant lore are few in number, largely due to cultural differences that are environmentally determined. The Aleuts had access to and an abundance of many kinds of useful plants, whereas the northern Eskimos were much more restricted to a few plant uses which were not highly developed among them because of severe limitations of climate, terrain and a much more nomadic form of life.

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[4] *Ibid.*

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THE PROBLEM OF VERNACULAR NAMES OF PLANTS IN THE PACIFIC AND ITS SOLUTION

MONA LISA STEINER

Pasay City, Philippines.

Scientists are mainly concerned with scientific nomenclature and pay little attention to vernacular names. For teachers, linguists, anthropologists, ethnobotanists, foresters and numerous other researchers vernacular names, on the other hand, are significant. Foodplants, lumber trees, weeds and forage plants, ornamentals and medicinal plants, they all concern a tremendous number of people, and with growing contacts and economic international research those names are often essential to collectors and scientists as well.

In Europe and the United States the problem of common names has been solved to some extent, most European countries, for instance, have produced floras or lists of plants with their corresponding common names. Dictionaries of plant names exist, and particularly economic plants have been well covered. In the Pacific, however, numerous languages exist and these plant names can only be found in regional lists or floras. These lists of plant names are so much in demand, as a rule, that they are frequently out of print and therefore not available to the general public. In many instances collectors or people without proper botanical background are responsible for such enumerations and the scientific equivalents may be outdated or incorrect.

The problem of vernacular names in the Pacific is too complex to be treated by one or a few individuals; results can only be obtained by cooperation, coordinated cooperation, carried on over an extended period. Three phases of this work are to be considered: (a) collecting of unrecorded regional names together with their Latin equivalents and herbarium specimens, (b) inducing individual countries to publish lists of plant names if no other botanical up-to-date references with vernacular names are in print in this region, (c) the coordination of the recorded material, published and unpublished, in the form of a dictionary of economic plant names in the Pacific.

The first attempt of such a vast undertaking was initiated by the Pacific Science Association in the form of a *standing committee on Common Names* of *Economic Plants in the Pacific*, which should work towards the compilation of lists of common names of plants in active use in the Pacific Basin together with their botanical equivalents. Since such a vast task cannot be accomplished uno actu the project was divided into several parts such as: foodplants, medicinal plants, forest trees, weeds and forage plants, and ornamentals. For the Ninth Pacific Science Congress only foodplants were worked on.

A preliminary list of foodplants was prepared by the chairman. This list of scientific names of foodplants, together with their synonyms, was sent to representatives of botanical institutions of the various countries in the Pacific. Numerous responses have been received from all parts of the Pacific, and all the available literature in Manila was scanned for vernacular names of foodplants. Through the facilities of the National Research Council in the Philippines, courtesy of Dr. Patroncinio Valenzuela, 250 copies were mimeographed. One page was reserved for every plant. Next to the known Latin synonyms the vernacular name in the major languages were given: Chinese, Dutch, English, French, German, Japanese, and Spanish. Then the Pacific Basin was divided into various regions such as: Malay Peninsula, Thailand, Indonesia, North Borneo, Philippines, Formosa, East coast of China, Okinawa, Japan, New Guinea, Micronesia, Melanesia, Polynesia, Central America, and North America. The respective vernacular names with their location in parenthesis were then given.

Since this mimeographed compilation was done mainly in 1956, empty spaces indicated that many regions did not send in sufficient material before 1956. After this preliminary compilation was sent to various institutions in the Pacific much new material was collected by the chairman. During her leave in Europe the chairman was also able to gather numerous vernacular names particularly in the major languages. All these materials are going to be incorporated into the *Dictionary* of *Vernacular Names of Foodplants in the Pacific*. Supplied with a cross index it will become a valuable reference work.

Before the final publication all plant names have to be checked and rechecked by residents of that certain region. Only a person familiar with the Thai language, for example, can correct the common names of Thailand, leave out extinct names or those of hybrids. An overall dictionary can naturally not include varieties and hybrids, plants as the banana, rice, etc., would alone fill a book. Regional collaborators are also to select the *preferred names* of a region, and mark them. Although standardization is not planned, the selection of a preferred name will help the readers to pick out the most commonly used name. In the Philippines, for instance, about 80 languages are reported, yet one of them, namely Tagalog is the National Language, and this one name is generally understood in most provinces. The problem of the multiplicity of vernacular names in many countries is thus solved to some extent, the various common names of a plant will be recorded in the dictionary, but the preferred name will be set off by a different type of print.

Although the project was started with phase (c), as previously mentioned, it initiated indirectly also phase (a), namely the listing of hitherto unrecorded common names of economic plants in the Pacific. Various members of the committee, such as Mr. Jacques Barreau, Mr. Jean Huon de Navrancourt, Kamulai, Papua, have sent in valuable lists of sofar unpublished material which have been included. From several communications it became apparent, that the work of the committee on vernacular names has been a stimulus for further recording of lists of common names.

Phase (b) was not yet attempted, namely inducing individual countries to publish lists of plant names, but this work is part of the future program.

Future program: In case this committee should be continued by the Pacific Science Association the following procedure is suggested:

The publication of the *Dictionary of Common Names of Foodplants of the Pacific.* Besides the cross-index of the vernacular names, a bibliography will be included to furnish detailed information too voluminous to be incorporated. The publication must be well printed and properly distributed to be of real value. Much of its usefulness depends on its wide distribution and availability.

Foodplants are, however, only a part of economic plants, and forest trees, medicinal plants, and ornamentals have also to be worked on. The chairman intends to cover foodplants and ornamentals, and has appointed specialists to handle forest trees and medicinal plants. After the individual publications on forest trees, medicinal plants, etc., have been issued, all these information should be fused into *one comprehensive dictionary.*

This is a very far reaching project to be accomplished only by several persons, one scientist alone can not reach its aim, it requires *adequate funds* and most of all *international support.* This is not a work that can be "accomplished" within a few years, but working, recording, listing and improving has to be continued over a long period. Working members have to be supplying the committee in every country, and the expenses of mail alone are sizeable.

One of the main purposes of this committee should be to act as a *clearing center* for common names. They should be recorded and evaluated to some degree. Overall standardization is neither possible nor intended. One common name can not be used by different language groups, and the general usage can naturally not be altered by any group of people-language lives, grows, and changes.

It is quite obvious that vernacular names can never be perfectly under control such as Latin names, but a serious effort nevertheless should be made to bring some order in this most confusing matter of vernacular names, first by recording, and secondly by selecting preferred names for a certain region, if feasible. Standardized names of lumber trees appear on many lists in the Pacific, but they are not circularized sufficiently, maybe the committee could eventually combine these various lists, and lumbermen will be able to survey the various common names and know their scientific equivalents, and can check with the help of the dictionary its validity.

Landscape architects dealing with tropical plant material are frequently faced with lack of common names, eventually each one coins a new one. Standardized Plants Names, prepared by the American Joint Committee on Horticultural Nomenclature has proven very effective, but although numerous tropical plants are listed with their common names, many new ones are not included, and it is felt that tropical material should be treated only after all common names have been recorded, and one can select the common usage for Hawaii, India, etc. One name can eventually be preferred in the English language, and once a dictionary has become available the preferred names will be used in references, in literature and employed by teachers and laymen as well.

From the enthusiastic response of the project on vernacular names from various institutions, and also from the well attended symposium during the 9th Pacific Science Congress and its discussion, it became apparent that this undertaking is of substantial interest to numerous branches of applied and pure science. Continuation and further advances are highly recommended.

SUMMARY

The complex problem of vernacular names is particularly complicated in the Pacific, where numerous language groups meet and tropical plantlife is extremely rich. A Standing Committee on Vernacular Names of Pacific Plants has been established after the 8th Pacific Science Congress and produced a "*Preliminary Compilation of Vernacular Names of Foodplants in the Pacific*," which was sent to various institutions and economic botanists all over the Pacific to be checked and filled in. Published and unpublished references and lists respectively have been used and incorporated. It is to be hoped that a *Dictionary of Vernacular Names of Foodplants in the Pacific* will be published soon, including a cross-index and substantial bibliography.

It is hoped that through the initiative of the committee members and through international cooperation lists of hitherto unpublished common names will be recorded and published. Individual countries should also be induced to publish their own lists of common names.

Besides food plants, *forest trees*, *medicinal plants*, *weeds and forage plants*, and *ornamentals* should be worked on. Specialists in each field should take over each field and publish an individual dictionary. Eventually all special dictionaries can be combined into one complete dictionary of vernacular names of Pacific Plants.

List of members of the Committee on Vernacular Names of Pacific Plants and other who have sent in lists of vernacular names or references:

Mr. H. ANDO Hiroshima University, Sendamachi, Hiroshima, Japan (member, Japan)	checked and corrected Preliminary Compilation
Mr. JACQUES BARRAU Laboratoire d'Agronomie Tropicale, Faculté de Sciences, Marseille, France (member, Melanesia)	sent several published and unpublished lists New Caledonia, Trust Territories
Miss N. BURBIDGE Canberra, Division of Plant Industry (member, North Australia)	sent lists of New Guinea plants, and reference on Australia
Mr. R.E. DWYER Director of Agriculture Papua, Port Moresby (member, New Guinea)	list of Solomon Island, Comparative list of Micronesia, Polynesia, Melanesia
Dr. SHIU-YING HU Arnold Arboretum, Jamaica Plain, Mass. U.S.A.	sent mimeographed copies of a specially prepared extensive enumeration of the food plants of China
Mr. M.C. LAKSNAKARA KASHEMSANTA Department of Agriculture, Bangkok, Thailand (member, Thailand)	sent reference on Thai names
Mr. FAUSTINO MIRANDA Instituto de Bilogia Casa del Lago, Chapultepec, Mexico (member, Mexico)	sent list of Mexican plant names
Mr. H.W. LI Director Academia Sinica, Taiwan, China (member, Formosa)	sent list of Formosan names
Miss M. NEAL Bishop Museum, Honolulu (member, Polynesia)	sent list of Hawaiian names
Mr. JEAN HUON DE NAVRANCOURT Kamulai, Papua	sent unpublished list of names of plants of Papua
Mr. B.E.V. PARHAM Department of Agriculture, Suva, Fiji (member, Fiji)	sent Fijian plant names, published
Mr. HAROLD ST. JOHN University of Hawaii, Honolulu	sent several publications with vernacular names on Micronesia
Dr. MONA LISA STEINER 2833 Park Avenue, Pasay, Philippines (chairman)	checked Philippine names
Mr. TEM SMITINAND Royal Forest Department, Thailand	checked and filled in Preliminary Compilation.

DISCUSSION

F.R. FOSBERG: The fact that lists of vernacular names are generally out of print seems a significant fact in indicating a need for such lists. This situation may be very useful when the dictionary is ready for publication in persuading a publisher to accept it.

Attention should be called to the existence of a card file said to contain one and one half million vernacular names. This was compiled by a man named Williams and is deposited at the Los Angeles Museum Herbarium. It should prove to be a valuable source of information.

E.H. WALKER: In connection with compilation of vernacular names, there should be compiled a bibliography of sources of these names. These entries should be well annotated with special stress on comments and interpretations of the works.

Preliminary treatments such as Dr. Steiner's list are valuable by their unavoidable omissions and errors in stimulating others to cooperate in correcting them.

In compiling lists of vernacular names, careful consideration must be made to document their origins. The source of each name must be given. It is important to start this now on an understanding basis because the project will undoubtedly snowball to unexpected proportions.

T. TUYAMA: Concerning Dr. Steiner's "A Preliminary Compilation of Vernacular Names of Food Plants in the Pacific" I wish to indicate that Japan has a large number of vernacular names that are still unrecorded. I also suggest that Okinawan names be included in Japanese when they are so used.

P.S. ASHTON: In my opinion, to get this work

(1) representative of the whole area under study,

(2) to get it in some form of completion in the near future, all those at present concerned with the project should use all the opportunities at their disposal to:

a. Contact and appoint willing people in all areas under study, who are more or less permanently living in these areas, to take on the duties of regional investigation. Short-term investigators rarely get valuable material for this type of study as, through ignorance of the language and the people, they do not get their full cooperation.

b. To find people in Europe and America who can find time to spend in the herbaria and libraries in order to:

(i) gather information concerning early European names of Pacific plants and

(ii) gather information of Pacific vernacular names already recorded — both to help this present work and also to compare with the field work being done by the regional representative that recorded mistakes may be eliminated.

c. We need one person or one more or less centralized committee (as we have at present) to goad on the regional and herbarium library representatives.

F.R. FOSBERG: Obsolete or archaic names would be of much more use to me than modern names. It is probable in special instances that we will not get any one botanist to handle this, perhaps not a botanist at all. It may be desirable to bring in people with historical interests, linguists, etc. and to help them to correlate the vernacular names with Latin binomials.

J.H. HÜRLIMANN: Recording of Portuguese vernacular names seems important, especially for etymologic understanding of alterations in indigenous languages, as Portuguese were amongst the first Europeans to come to the Western Pacific area.

T.P. BANK: Dr. Fosberg's remarks are pertinent to what I'd like to say. Why don't we use this excellent work of Mrs. Steiner and her group to enlarge the scope to include not only vernacular names of current usage, and names of obsolete usage (*very* important to linguists and ethnobotanists), but also an *ethnobotanical dictionary*? This is something which we have been planning for some time, and now we have in this compilation of vernacular names a focus to give us a start.

We might do this by forming a sub-subcommittee — a group of interested botanists, linguists and anthropologists — to obtain local traditional uses for these plants. This would make the compilation much more useful to those working at a cultural level. Much of the necessary data is already available but hidden away in numerous field reports and publications by anthropologists and others. The result of their combined effort would be an ethnobotanical dictionary for the Pacific area.

J.V. SANTOS: The introductory remarks of Dr. Steiner presents a problem on the vernacular names of many plants introduced into the Philippines. There are instances when the vernacular names of plants in the country from which they were believed to have been introduced, were also "imported" and adopted in the Philippines. We have, for example, the following plants which are known in the Philippines in their Spanish-Mexican names: *Antrogonon legtopus* (Cadena de amor), *Delonix regia* (Caballero).

At the same time we have also a large number of introduced plants without vernacular names in the Philippines. If these plants should be given vernacular names, then the problem will be how to go about it.

AN ENUMERATION OF THE FOOD PLANTS OF CHINA WITH VERNACULAR NAMES

SHIU-YING HU

Arnold Arboretum, Harvard University, Cambridge, Massachusetts, U.S.A.

This enumeration is prepared in response to a request of Dr. Mona Lisa Steiner, Chairman of the Committee for the Vernacular Names of Pacific Plants, who has asked me to join the committee and to participate in its activities by supplying Chinese plant names for the forthcoming dictionary of Pacific plants of economic importance. It contains over five hundred species of edible plants. Each entry covers the scientific name and the vernacular name or names in Chinese and their transliterations both in sound and in meaning.

The distribution of the enumerated species in the plant kingdom is as follows: 15 algae, 11 fungi, 7 ferns and fern-allies, 8 gymnosperms, 86 monocota and the rest are dicots. The arrangement of the species follows the Engler and Prantl System of classification. It seems that the relatively small number of the non-vascular plants does not call for subdivisions down to the families to insure clarity. Only higher hierarchical categories are adopted for the algae and the fungi. For example, all the red algae are arranged alphabetically under the Rhodophyceae, and all the mushrooms and their allies are alphabetically arranged under the Basidiomycetes.

The Chinese plant names are generally composed of two or three, and rarely more monosyllabic words with one or two representing a noun and the others being modifiers. As China has many dialects, these names can be pronounced differently by different people. In this enumeration the sound of each Chinese character is transliterated in accordance to the pronunciation given in the Revised American Edition of Mathew's *Chinese-English Dictionary*. The sounds of a name with several characters are connected by hyphens.

China is vast both in space and time. A plant of some economic importance is often widely distributed and generally has several vernacular names which are used simultaneously in various parts of the country. For example, "*maize* or *corn*" is called *yu-shu-shu* in East China, *pao-ku* in West China, and *pang-tzu* in North China. Moreover, a name used once in historical time may have been changed and the current name for the same species are different from the book names. For example, *la-la-yang* and *chu-chu-t'ung* are both current vernacular names for *Humulus japonica*. In books *lu-ts'ao* is always given for this species. In this enumeration the names which to my knowledge are the most widely used in this generation have priority while the other follow. The names which appear in print only are marked "book-name."

In regard to the food plants of China, there are several words which appear repeatedly in this enumeration. They are often seen in other references, and are worthy of remembering. These are *kua* for melon or squash, *kuo* for fruit, *li* for pear, *mei* for wheat, *mi* for grains—especially for rice, *t'ao* for peach, *ts'ai* for vegetable, *ts'ao* for herb, and *tzu* for seed. Wild form of edible plants are often designated as *yeh* by the northern people and as *shan* (which means mountain) by the southern people. For example, *yeh-fen-t' wan-erh* is the northern name of *Aster brinervius* while *shan-po-chu* is the southern term for the same. Both refer to the white flower. Introduced plants are designated as *hu* if they entered China overland by the ancient silk route, as *yang* if they have come to China by the sea route and reached the Yangtze area, and as *fan*, if they have come to China through Hong Kong, Macao, and Canton. For example, *hu-t'ao* for walnut, *hu-tou* for broad bean, and *hu-kua* for cucumber, are all ancient introductions. *Yang-szu-tzu* and *fan-ch'ieh* are synonymous for tomato and *Yang-yu* and *fan-shu* are synonymous for Irish potato. These are more recent introductions which entered China through the seaports like Shanghai, Foochow, or Canton.

The Chinese language is an old and complicated but living language. Various combinations can be made to meet the need of the people. It has been proved to be quite sufficient to convey the idea of the Chinese people from the ancient historical time to the present atomic age. Nevertheless, there are certain limitations. The words are monosyllabic. As the number of sounds are limited and the number of combination of parts to make new words unlimited, every sound covers many characters. Take Mathew's *Chinese-English Dictionary* as an example, this book gives 366 variations of sounds and 7,773 words.

Thus each would average more or less 20 characters. When the first persons recorded the plant names in writing, they were usually people without much education. They may have given the correct character or they may have put in any character that sounded like what the illiterate people pronounced. This often happened and consequently the written names of certain plants are far from expressing the meaning of the people who used them. For a long time I could not understand why the pokeweed was called "*shang-lu.* 商陸." Finally on a collecting trip with a medicine digger, he casually called the plant the mountain radish in Chinese, and I began to realize that *shang-lu* was derived as a corruption of *shan-lo-pu.* In this enumeration there are several such names. In these cases no translation for the meaning of the name is attempted.

Many of the species in this enumeration appear for the first time in the English language as edible plants. To these species a short note concerning the parts of the plant used and also as to whether they are eaten raw or cooked is given. Wild edible plants are specially marked with E, meaning emergency food. The more expensive food plants are marked "delicacy" for this may avoid embarrassment or shock when the bills are received. It is worthy of note that the most expensive item in this enumeration is *Tremella fuciformis*, a Basidiomyctes. It is sold by dollars per ounce.

There are quite a number of plants which have recently been introduced in the tropical regions of China such as Taiwan and Canton. Their distribution is limited to experimental stations and their names are usually straight translations of the scientific or the common English names. These species are marked by NI, meaning newly introduced, and now translation of the meaning of the names are necessary.

yu-shu-shu	玉蜀黍	*shan-po-chu*	山白菊
la-la-yang	拉拉央	*hu*	胡
chu-chu-t'ung	鋸鋸籐	*yang*	洋
lu-ts'ao	葎草	*fan*	番
kua	爪	*hu-t'ao*	胡桃
kuo	果	*hu-tou*	胡豆
mei	麥	*hu-kua*	胡瓜
mi	米	*yang-szu-tzu*	洋柿子
t'ao	桃	*fan-ch'ieh*	番茄
ts'ai	菜	*yang-yu*	洋芋
ts'ao	草	*fan-shu*	番藷
tzu	子	*shang-lu*	商陸
yeh	野	*shan-lo-pu*	山萊菔
shan	山	*tremella fuciformis*	銀耳
yeh-fen-t'wan-erh	野粉團兒		

THE PROBLEM ON THE VERNACULAR PLANT NAMES IN JAPANESE

TAKASI TUYAMA

Ochanomizu University, Otsuka, Tokyo, Japan.

The first appearance of plant names in the Japanese literature can be traced back to about 100 A.D. These names are essentially on plants of economic importance. At that time, the Japanese alphabets had not been invented. These names were written in Chinese characters. Among them there were many names pertaining to plants introduced from abroad, principally from or through China. For example, *Prunus mune* from China, *Cannabis sativa* from Central Asia through China were all mentioned.

About 700 A.D., the first Japanese poetical collection as well as an encyclopedia was published in Japanese alphabets. One section of it was devoted to plants. For the first time the Japanese pronunciation of plants were recorded. Of these plant names, some remain unaltered while others have been more or less changed in pronunciation and spelling. So that the plant names in Japan, as in the other countries, reflex the culture and history of the country. For example, "Cotton" or "Wata" in older Japanese literature means the kapok-like product, while in later usage (about 1600 A.D.) "cotton" refers to the newly imported *Gossypium*. Similarly, "Potato" or "Imo" in the older records refers to *Dioscorea nipponica* which is wild in Japan. But in later years, after the introduction of *Colocasia antiquorum* from the south, the name of the wild *Dioscorea nipponica* was distinguished by the addition of "Yamatsu," meaning mountain. Thus we have "mountain Potato" or "Yamatsu Imo" for *D. nipponica* and "House Potato" or "Iëtsu Imo" for *C. antiquorum*. Still later, after the introduction of *Ipomoea batatas* and *Solanum tuberosum* into Japan in the fifteenth century, there are four kinds of plants bearing the name "Imo." They are as the follows:

Dioscorea nipponica with the addition of new yams introduced thereafter... "Yama-no Imo
Colocasia antiquorum........ "Sato Imo"
Ipomoea batatas........ "Satsuma Imo"
Solanum tuberosum...... "Jaga Imo".

At the present *Ipomoea batatas* is the most commonly cultivated species. It is often simply called as "Imo".

This is a brief history of the changes in "Imo." However the actual courses of development are more complicated.

Of course, there are local differences in the vernacular names at the present as well as in the past. Some old names are remaining occasionally in certain places and are used with the recently and sporadically developed names. Some compilation of such vernacular names has been undertaken by herbalists. Today we have many outstanding works compiled by botanists and ethnologists. The present day Japanese vernacular names of plants can roughly be classified as the follows:

1. Standard Japanese names: These names are used for educational and scientific purposes. There are occasionally several standard names used in accordance to the opinions of different botanists.
2. Commercial names: These names are used principally by dealers of horticural plants such as floriculturists, nursery men, etc.
3. Local names and names used only by children: These are names used by people in different localities and those by children in their plays.

In fact, there are collective names of different species or genera used in popular periodicals or in general conversation. For example, "Sakura" means the flowering cherry of any kind when it is not accompanied by any modifiers.

There are also special problems concerning the name represented by Chinese characters. Even after the establishment of Japanese alphabets, the Chinese characters have been used in mixture with the Japanese. Chinese characters were used exclusively and extensively in Pharmacognostics because this subject has been developed in China very greatly since the ancient days. It has been a difficult task for the Japanese herbalists to find the identities of the Chinese plant names and the actual plants wild or cultivated in Japan or imported from China.

Owing to the extensive development of general education in Japan, standard names of plants are gradually taking the place of the local ones. In some cases the vernacular names are accepted as standard ones. For example, in the islands of Ryukyu and Izu archipelago, there are local names used generally by the natives. Many of these have been authorized by the modern botanists as standard names.

In the Bonin islands the vernacular names of plants are strongly influenced by the introduction of Polynesian language, especially that of the Hawaiian.

I must add here that there are some researches on the Micronesian vernacular plant names by Japanese botanists, some of which are not yet published.

DISCUSSION

F.R. FOSBERG: I would like to call attention to the fact that vernacular names are a part of everyday language. Creation of pseudo-vernacular names has no significance and is worse than useless. True vernacular names belong to folk language and are useful in studying languages and in getting clues to other things, such as presence of species in a flora, tracing relationships of peoples, languages, etc. Botanical precision is served by Latin binomials, not by vernacular names. The study of vernacular names is a part of linguistics more than of botany.

T.P. BANK: I would like to suggest that workers with vernacular names in Japan attempt to determine whether or not the common names for plants are derived in any way from *Ainu* words. Place names, for example, Fuji yama — mountain of fire god — throughout most of Honshu are often Ainu words. I believe we would find this to be true, also, for many plant names.

COMMON VERNACULAR NAMES OF PLANTS OF THE PACIFIC BASIN

J.W. PURSEGLOVE

Professor of Botany, Imperial College of Tropical Agriculture, Trinidad.†

The compilation of vernacular names with their scientific equivalents for the whole of the Pacific Basin would be a formidable undertaking, and if done with any completeness would run into many hundreds of thousands of names. With an unlimited staff available, this would be an interesting and instructive exercise and would undoubtedly be of use to those interested in the plants of the area, more especially if it could be printed under the various vernacular languages, rather than all the languages printed together in an alphabetical list.

To be authentic, however, it would be essential that the work of collecting and compiling the names should be done by competent botanists with access to herbarium material and who are also competent linguists in the language in which the names are recorded. Quite frankly, unless this is done critically, the mere compiling and printing of vernacular names, as recorded in the literature and on herbarium specimens would be very time consuming and of comparatively little use. It might well lead to increased confusion. With so few capable taxonomists working in the area, I doubt very much whether they can spare the time to undertake the task; they would in fact be more profitably employed on other work, unless the lists were limited to a few economic plants (names of which are likely to be given in the dictionaries any way), a few ornamental or other restricted groups of plants.

This does not mean that I believe vernacular names to be of no use. On the contrary I believe that they can be of great value, provided they are critically recorded. They may even help the taxonomist in his work and often provide information as to the local uses of the plants. They may sometimes provide the key, if correctly interpreted, to the movement and spread of cultivated and other introduced plants in an area. Undoubtedly, they can be of great value to the forester, as he can inflict upon the small number of his local indigenous staff vernacular names, which his department has standardised for the commoner timber trees and timbers of an area, more especially when such staff would have much greater difficulty with the scientific names of the trees concerned. It does not follow, however, that the standardised names provided by a Forest Department will be in general use by the mass of the population of an area.

What I think is essential is that every effort should be made to collect reliable vernacular names for as many as possible of the plants of an area, as it is likely that with the spread of education and sophistication that many of these names will be lost in the future. I would emphasize, however, that these vernacular names should be very carefully checked by those who are recording them, and it is desirable that they should have some knowledge of the language in which the names are given.

Nevertheless, there are innumerable snags in this work, as I have found from past experience, when I recorded several thousands of vernacular plant names in various Bantu and Nilotic languages in Uganda during my 16 years there. I can only presume that some of the difficulties encountered there must also arise in the Pacific Basin and from the perusal of the literature it would appear that they do. It is worthwhile, I think, to list some of them.

1. Unreliable Information

It frequently happens in collecting vernacular names, and in approaching the people who live in the area about them, that they will not admit that they do not know and will either make up a name for the satisfaction of the person recording them or will give a wrong name. Unless the names are carefully checked and rechecked, a large percentage of them may be completely useless and in fact misleading. Usually the older members of the community have a better and more reliable knowledge of such names and will usually give reliable information when they know well the person who is recording them, more especially when this person can point out information which has been wrongly given. An unsuspecting person with no knowledge of the local language will often record such names as "I don't know,"

† Formerly, Director of Botanic Gardens, Singapore.

"It is a plant," etc., and these appear on herbarium sheets.

2. Spelling

The person recording the names usually writes them down phonetically and it is not surprising to find that quite reliable recorders will spell the same name in different ways. It seems to me that the person recording them should have a reasonable knowledge of the vernacular language before he attempts to record this type of information. Often the names have been misheard by the European and great care must be taken not to confuse names that sound alike to Western ears, but which are quite distinct to the local person who is giving the names. It is also likely that there would be divergent spelling according to the nationality of the person recording the names. Thus it often happens that different spelling is given by the British, Dutch and French authorities, etc., even when the name recorded is in the same vernacular language. In some cases, certainly in Africa, the orthography of the language has not been fixed. Committees are formed from time to time to try to reach a finalised orthography, which invariably results in changes of spelling of the language and, of course, of plant names, so that one has constantly to be revising the method of writing these names, thus leading in some cases to confusion.

3. Prefixes, etc.

In Bantu languages, and I understand in Malay, names are frequently changed by changing the prefixes, which if recorded incorrectly is often a cause of confusion. Care must be taken to record the singular of the vernacular names.

4. Names of Various Parts of the Plant

It sometimes happens that parts of a plant are given quite distinctive names, and one man will record the name of the fruit, another of the leaves and another of the complete plant, etc. It is obvious for any list of vernacular names that the name of the complete plant should be recorded.

5. Multiplicity of Names for the Same Plant

Very often the same plant has several quite distinct names even within one area and certainly the names change as one moves to other parts of the country, although the inhabitants may be of the same race. This can add greatly to the confusion and mitigates against the value of vernacular names. If it is proposed to standardise them and have only one vernacular language all over the country for the one plant, who is to do the standardisation? Even if this is done by a committee such as yours, it is unlikely to be accepted by the inhabitants themselves, who will continue to use the names to which they are already accustomed. I have come across cases in Africa in which the witch-doctor will use his own peculiar names for the commonest plants, in order that the mass of the population should not know to which plant he is referring.

6. Generic of Family Names

Indigenous peoples often recognise closely allied species and will use a general generic name for a number of similar species. Sometimes the grouping is even bigger and the name will be given to a number of genera or even to a family. This becomes very confusing when very different species belonging to different families are given the same vernacular name. Corner (1951) quotes the name of *Tangisong Burong*—"It is given to any tree, shrub, climber or epiphyte the fruit of which is yellow or red and has large, often pulpy seeds so that it is attracted to birds, yet because it is poisonous or unpalatable, the birds weep with disappointment."

7. Degeneration of Foreign Words

When a new plant or crop is introduced into an area, the English or scientific name of the plants may be changed considerably to form the basis of the new vernacular names for these plants. Thus, in one area in Uganda, Black Wattle became in the vernacular *Buli Koti*, while *Eucalyptus* became *Kalitunsi*. The variety of sweet potato was known in one area as *Disi*, which is how the people of those parts describe the D.C. or to give him his full title—District Commissioner. This variety gets its name because the D.C.'s on tour tried to persuade the people to plant this particular variety, because of its superiority to those which they were already growing. I well remember introducing a certain grass for soil conservation into a district and which spread widely over the area; this grass became known as *Pulesigulufu*, which was how the people of that area attempted to pronounce my name. Thus unless the historic aspect is considered it is often difficult to see how some vernacular names have been derived and the final result bears little resemblance to the original name.

8. Vulgar Names

Quite a number of plants in any area are given vulgar names, which are often a source of amusement to a certain section of the community but are a source of embarassment to others. As one dictionary put it when asterisking such words "they are not used in polite conversation."

9. English Plant Names

Attempts have been made from time to time in popular works on the plants of a tropical area to give each plant a common English name, in the hope that this may prove to be of use to the non-botanist. This was done by Henderson in "Malayan Wild Flowers" and by Corner in "Wayside Trees of Malaya." Sometimes the name given is a direct translation of the scientific name of the plant. Thus *Lettsomia maingayi* is called Maingay's Lettsomia. Surely this is a little unnecessary. Sometimes common English plant names are taken and given to a tropical plant which bear no relationship whatsoever to the plant so named in Britain. Thus *Passiflora foetida* is called "Love-in-a-mist." Both these examples were taken at random from Henderson. To me this merely adds to confusion. Similarly, common cultivated trees and shrubs are given completely different English names in various parts of the world, which was a great cause to confusion to me, coming as I do from Africa to Malaya. Thus *Delonix regia* is known as Flame of the Forest in Malaya. In Africa it was known as Flamboyante, while in Africa *Spathodea campanulata* (syn. *S. nilotica*) is known as Flame of the Forest, but in Singapore as Tulip tree. Even if your Committee decided which plant should be called the Tulip tree, I cannot see that this will be accepted by other countries, where a completely different plant is currently known by that name, e.g. *Liriodendron Thespesia*, etc.

10. Different Language Groups

A further difficulty is that in a cosmopolitan region such as Singapore with a total area of just over 200 sq. miles, it would be necessary to list vernacular names in several languages—Chinese (several dialects), Malay (often several names for the same plant), Tamil, Javanese, English and other European languages, etc. Furthermore, the flora of Singapore includes a great number of introduced species, which have now become naturalised, in addition to many introduced crops and variety of crops. A list for this small area would be formidable and difficult to finalise and to use.

11. Varietal Names

The number of local vernacular names for the many varieties of cultivated groups is legion and the work of collecting them would be prodigious. It is very easy to record the name of an obscure variety instead of the general name for the species as a whole.

12. Sources of Information

A very great number of vernacular names have been recorded and published for Malayan Plants. The mere physical effort of extracting these names into an alphabetical list with the scientific equivalents would take many months.

The principal sources are as follows:

Burkill, I.H., 1935, *Dictionary of the Economic Products of the Malay Peninsula*, 2 vols., London.

Corner, E.J.H., 1952, *Wayside Trees of Malaya*, 2 vols., Singapore.

Henderson, M.R., 1949-54, *Malayan Wild Flowers*, 4 parts, Kuala Lumpur.

Holttum, R.E., 1953, *Gardening in the Lowlands of Malaya.*

Ridley, H.N., 1922-24, *Flora of the Malay Peninsula*, 4 vols., London.

Watson, J.G., 1928, *Malayan Plant Names, Mal. For. Rec. 5.*

A list of Botanical and Vernacular Equivalents.

Govt. Gazette, F.M.S. XXIX, 5884, 1937.

Numerous articles in *Gardens' Bulletins, Agricultural Bulletins. F.M.S. Malayan Forester*, etc.

NOTES ON THE SIGNIFICANCE OF SOME VERNACULAR NAMES OF FOOD PLANTS IN THE SOUTH PACIFIC ISLANDS

JACQUES BARRAU

South Pacific Commission, Noumea, New Caledonia.

Our knowledge of the vernacular names of food plants in the South Pacific Islands is far from complete. The Polynesian and Micronesian names are rather well known, but a lot remains to be done where Melanesia is concerned. There the multiplicity of language and dialects makes it sometimes difficult to record plant names.

Even in this preliminary stage, it may be useful, in these notes, to study very briefly the meanings of those names already known. Besides, a comparison between lists of South Pacific vernacular names shows apparent similarities between names in different Melanesian, Micronesian and Polynesian territories. A study of these resemblances could lead to better understanding of the significance of vernacular names.

It may be of interest to consider first the vernacular names of food plants introduced into the South Pacific Islands since their discovery by Europeans. Their meaning could help understand how the plants used by the islanders in old times were named. It seems that the vernacular names of the more recently introduced food plants can be classified as follows:

I. Plants completely unknown by the islanders in the pre-European era:

a. The name adopted is the vernacular name used in the territory from which the plant was first introduced.

Examples: The sweet potato, *Ipomoea batatas* (L.) Lam. was most probably introduced into Guam Island during the 17th century from Mexico. The vernacular name in this island is CAMOTE (or KAMOTE) a name derived from CAMOTLI (or CAMOTL) as the Mexican Nahuatl Indians called the sweet potato. CAMOTE is also used in the Philippines where *I. batatas* was probably introduced from the same area. The first European discoverers who visited Guam (cf. PIGAFETTA) mentioned sweet potato tubers among the local food. I think that there was a confusion with the tubers of *Dioscorea esculenta* (Lour.) Burk. one of the main subsistence crops in ancient Guam. Le Gobien's book, "Histoire des iles Mariannes nouvellement converties a la religion chretienne" published in Paris in 1700 does not mention the sweet potato among the Guamanian subsistence plants but says that the bases of the vegetable food pattern were tubers of NIKA, *Dioscorea esculenta*, and SUNI, *Colocasia esculenta* (L.) Schott.

Another example: *Xanthosoma brasiliense* (Desf.) Engl., an aroid grown for its edible leaves was introduced into Tahiti from the West Indies probably at the beginning of the present century. Today, its vernacular name in French Oceania is CALALUO, which in the Caribbean area is the name of a popular dish, a kind of soup, of which the leaves of *X. brasiliense* are the basic ingredient.

b. The South Pacific Islanders found that the new plant had some resemblance with one of their traditional food plants, and used the latter's vernacular name for the new comer.

Examples: *Xanthosoma sagittifolium* (L.) Schott is called TARUA in the Cook Islands and French Polynesia. This name originally designated a local pre-European variety of the banana *Musa sapientum* L. The cooked lateral tubers of *X. sagittifolium*, according to the islanders, tasted and looked like the cooked bananas of the variety MEIKA TARUA. The aroid still bears this last varietal name.

Another example: The sweet potato, *I. batatas*, is called KAV by the Marind Papuans of the Southern coast of Netherlands New Guinea. KAV as a matter of fact is the local name of *Dioscorea esculenta* the tubers of which, according to the Marind, look like those of the sweet potato. Similarly in some dialects in Indonesia, the sweet potato is called GUMBILI or KUMBILI, which is the name of *D. esculenta*. This emphasizes the frequent confusion between the tubers of the two plants already indicated in the case of the Guam name of *I. batatas*.

2. *Plants belonging to a species (or a variety) of a genus (or species) already present in the area before European times.*
   a. The vernacular name includes the name used for the genus (or species) plus one or several words indicating that the new comer was introduced by Europeans.

   Example: The bananas introduced in Samoa by Europeans, particularly *Musa nana* Lour., are called FA'I-PAPALAGI (VUDI-NI-PAPALAGI in Fiji), meaning banana (FA'I) of the European (PAPALAGI). The same is the case in the Loyalty Islands where introduced bananas are called WA-WIWI meaning bananas (WA) of the WIWI (OUI-OUI), a nickname given to Frenchmen because the Loyalty Islanders were apparently much amused by the exaggerated use of the affirmative OUI in French speech.

   b. The vernacular name of the new plant includes the name used for the species (or genus), plus the name, more or less transformed, of the territory where the plant was thought to have come from.

   Example: *Xanthosoma sagittifolium* is called in Ponape SAWA-N'AWAI, literally, the *Colocasia* taro (SAWA) of Hawaii (N'AWAI). The same aroid is called BISECH-LARUK in Palau, meaning apparently the *Colocasia* (BISECH) from Truk (LARUK), whence the Palau Islanders said it was originally introduced.

When the islanders had to name a cultivar of an already known food plant, the vernacular name was, of course, more complex. In such a case, in addition to the name for the species, one or more words indicate:

—Either the place where the cultivar was originally found or grown, or whence it was originally introduced. Thus one very common variety of *Dioscorea alata* L. in New Caledonia is called KU (or KUK, WUKUK, WU, etc. according to the name of *D. alata* in the dialect) PAPUA. A New Caledonian teacher of the London Missionary Society brought it back from New Guinea during the last century.

—Or the name of the islander who first used, grew or introduced the cultivar. Thus a taro, *Colocasia esculenta*, grown in Ateu, a highland village of New Caledonia is called WA (Colocasia) ENEILOKAPU. The meaning of this last word is that a New Caledonian woman named KAPU used to eat only the tubers of this cultivar.

—Or, more frequently, a particular characteristic (shape, size, color) of a part of the plant. As an example, a variety of the yam *Dioscorea alata* is called THAMBWA in Wunjo, a coastal village of New Caledonia. Among the THAMBWA yams, the islanders distinguish:

—THAMBWA TANA BWALI: red-fleshed (TANA), long (BWALI) tubers.

—THAMBWA TANA XUMAT: red-fleshed, short (XUMAT) tubers.

—THAMBWA FWAT BWALI: white-fleshed (FWAT), long tubers.

—THAMBWA FWAT XUMAT: white-fleshed, short tubers.

—Or, a word reminiscent of a particular circumstance associated with the discovery or introduction of the cultivar: Thus a cultivar of *Colocasia esculenta* grown in the vicinity of Canala in New Caledonia is called ENLA-POCHE. This seems to be an alteration of the French "DANS LA POCHE," literally, IN THE POCKET. The islanders said that the first propagating material of this cultivar was stolen in another village by a man who brought it to the Canala area concealed in his pocket.

Sometimes the vernacular name of a cultivar is even more complex and combines several of the ways of naming a plant listed above.

Several of the names used in the South Pacific Islands for subsistence plants grown for their tubers or as a source of edible starch show some likeness. Many of them seem to be related to the BIAH or PIAH of Malaya. Thus *Alocasia macrorrhiza* Schott is called in Malaya BIAH, BIRAH or BRAK. Apparently BIAH is also used for the same plant by the Semang negritos of Malaya. In Indonesia, we found among other names, BIRA and WIRE. In Melanesia, this aroid is called:

—In some dialects of New Guinea: ABIR and WERIAK.

—In one dialect of the New Hebrides: BARU.

—In New Caledonia: AWERE, PERA, PIA, PIRA, VIA, VIE.

—In Fiji: VIA.

In the latter island group, VIA is also used for *Cyrtosperma chamissonis* (Schott) Merr., VIA KANA. The same aroid is called BRAK in the Palau Is., this name being used for *Alocasia macrorrhiza* in Malaya. In Micronesia, we found as names for *Cyrtosperma* PURA, PUNA, and PULA (Truk), PWOLOK (Ulithi), LOK (Yap). The PURA series may well be related to the

BIRA, BRAK, and BIAH series used in Malaya for *Alocasia macrorrhiza*. Finally the names of *Cyrtosperma chamissonis* in Polynesia, BROKKA (Ellice Is.), PULA'A, PULAKA or PURAKA (from Samoa to the Cook Islands) apparently have also the same origin.

East of the Cook Islands, the names for *Cyrtosperma chamissonis* are different: thus we find in the Leeward Islands the name APE-VEO, literally *Alocasia* (APE) yellow (VEO) and a similar case in the Marquesas Islands where the name for *Cyrtosperma* is TAO-KAPE, literally *Colocasia* (TAO) *Alocasia* (KAPE).

Returning to the vernacular names apparently related to the Malayan PIAH, BIAH, and BIRAH, there is, according to H.B. Guppy (1897, the Polynesians and Their Plant Names, *Jour. Trans. Vict. Inst.*, **29**: 135-170, London) some resemblance between some of the Indonesian names of the sago palm, *Metroxylon* spp. (LAPIA, PIHIR, RAMBIA), the Melanesian names of the same palms (ABI, BIA, IABIA, RABIA) and some of those used for *Tacca leontopetaloides* (L.) OK in Melanesia and Polynesia (PIA, RABIA, YABIA). Both *Metroxylon* and *Tacca* are the source of edible starch. In the case of *Tacca*, it may be further significant that its Polynesian name PIA has been given to the introduced Cassava which has replaced *Tacca* as a source of starch in many Polynesian islands.

The vernacular names of *Tacca* are different in Micronesia where we find the following series of names from the Marianas to the Gilberts: GAOGAO, GABGAB, SOBOSOB, MOGMOG, MOKMOK, MOKIMOK, MUGAMUK, TE-MAKAMAKA. In the Philippines, *Tacca* is known, among other names, as GAUGAU and YABYABAN. This last name may possibly be related to the YABIA of the Fiji Is. In the British Solomon Islands, there is one name for *Tacca* related to this series: MAMAGO.

PIA is not the only name of *Tacca* in Polynesia where, in the Samoa-Tonga-Rotuma area names such as MASOA, MAAENA, and MARA are found, MASOA being used also in Tikopia. However, it seems that PIA was also used in Samoa in ancient times.

Not being a linguist, I am unable to draw any conclusion from all these names. However, it seems that the apparent common origin of vernacular names used for some different basic sustenance plants of ancient Oceania could profitably be the subject of further investigation. Listing the vernacular names of plants is useful, but a better knowledge of their significance seems necessary. In this respect, a more careful study of the ways used at present in the islands to name recently introduced plants could help us understand the meaning and origin of some of the ancient names.

DISCUSSION

C.G.G.J. VAN STEENIS: It does not follow from the existence of a field vernacular name that the plant is native or of ancient introduction. I observed with a plant which I introduced myself. Use is now made of it as a mild laxative, and has acquired a fixed vernacular name *(Enphorbia geniculata)*.

J.H. HÜRLIMANN: In the Tougan Islands, the name of the country is sometimes added to a plant name, in order to characterize a species or variety as the best available, not for indicating the true origin. One must, therefore, be careful with conclusions from this type of names.

ETHNOBOTANICAL PROBLEMS IN THE COMPARATIVE STUDY OF FOLK TAXONOMY

HAROLD C. CONKLIN

Department of Anthropology, Columbia University, New York, New York, U.S.A.

With specific reference to Malaysian ethnobotany I would like to discuss briefly six general problems faced by the ethnographer when analyzing and comparing cultural systems of categorizing diverse forms of natural phenomena.

1. The nature of folk taxa (cf. scientific taxa). Several important differences distinguish folk taxa from scientific taxonomic categories. The former are concerned only with locally observable phenomena. They are based on criteria which may differ greatly from culture to culture. In folk taxonomy there are no formal rules for the recognition or rejection of taxa, though new categories can be added with considerable ease. In respect to any particular flora, there is no reason to expect the local folk categories to equal those of systematic botany—either in number or in size. The Hanunóo of Mindoro, whose system of folk botany I have studied recently in the field, classify their local plant world into more than 1,600 categories while botanists catalogue the same flora—species-wise—into less than 1,200 groups.

2. Translation and semantic structure. At least at the level of obligatory categories, native names for folk taxa always comprise a segment of the everyday vocabulary of a particular language. The associated semantic structure of such a set of lexical items is something to be discovered for each language, not to be prescribed through familiarity, in another system, with the concrete designata of the set. In ethnobotanical terms, this means that a local system of plant classification cannot be described accurately by merely trying to obtain vernacular "equivalents" for recognized botanical species. Translation labels are frequently necessary, but in a strict sense they can serve neither as definitions nor as exact equivalents. This well-established, and perhaps almost obvious, semantic principle is sometimes forgotten where the assumed absolute nature of "scientific" names is involved.

3. Hierarchies of generalization. Folk systems vary in the number and position of their levels of contrastive usage, and in their methods of increasing or decreasing specification. Without the conventions of taxonomic nomenclature, the investigator of such systems must discover these levels and the rules determining their use by internal means, i.e., by intracultural analysis of varying contexts. The kind of data involved can be illustrated easily. A Hanunóo, for instance, may answer correctly a question about the identity of a particular yam vine with any one of at least seven answers depending on the context in which the question is asked, and upon the degree of specificity required:

(1) *kāyu*	a plant, i.e., not a rock, etc.
(2) *halāman*	a domesticated plant
(3) *wākat*	a plant having a vinelike stem
(4) *tanum*	a plant propagated horticulturally
(5) *'ūbi*	a yam
(6) *'ūbi dungun*	a *dūngun* yam
(7) *dūngun*	a *dūngun* (meaning dark-colored, of certain root crops).

In this case, two crosscutting systems of plant categorization are exemplified, one based on treatment (2 levels: 2,4), and the other based on morphological type (3 levels: 1, 3, 5-6).

4. Partial vs. unit concepts. In folk taxonomies, growth stages or parts of individual biotic units are often classified in much the same way as unit concepts of distinct animal or plant types. Confusion can result when these categories differ widely from the investigator's own folk or scientific concepts, yet it is in these very differences that clues to the significant features of folk classification may be found. A few examples may help to illustrate this point. One form of *Diospyros discolor* is known to the Hanunóo as *kamagung mabīru*. When this tree matures fully its heart wood is much sought after for spear handles, and canes because it becomes exceedingly tough and hard. Conceptually, the plant then becomes a new entity, *baluntīnaw*. When the low cattle sedge *pādang (Cyperus kyllinga)* sends up tall slender stems to fruit, it becomes *pāray-māya* 'sparrow rice.' These and numerous other instances reflect the primary categorization of plants by the Hanunóo according to contrastive habits of stem growth.

5. Linguistic structure. The shape and combinatorial structure of the linguistic forms which designate folk taxa are irrelevant, in a strict sense, to the analysis of the system of classification itself, i.e., to the semantic structure. Labels and categories can change independently and, therefore, must be analyzed separately. On the other hand, a knowledge of the linguistic structure involved is essential for understanding folk *nomenclature*, and in working out this structure, clues for isolating folk *taxa* and eliciting information about them may be found. In the comparative use of native names, however, particular care should be exercised to avoid confusing forms with meanings. In many Philippine and Indonesian languages, for example, *bágo*—or some similar form—refers to the bast-providing vine *Gnetum indicum*. The expected Hanunóo cognate *bāgu* occurs, but not as the name for *Gnetum indicum* which the Hanunóo call *sandarí*. Instead *bāgu* refers specifically only to the inner bark of another species *Gnetum gnemon*, known as *lungud*, and is the probable root of the plant name *malibāgu* which designates a bast-providing shrub *(Wikstroemia polyantha)* of another family (Thymaceae not Gnetaceae). Numerous similar examples can be expected in comparing the plant names and associated vocabularies of such related languages. Malay *pinang* and Hanunóo *pīnang*, for example, are cognate forms, but the first is a unit name for the areca palm, the second a name for only one type of fallen areca fruit. In Tagalog *kawāyan* is a general term for bamboo, while in Hanunóo *kawāyan* refers specifically to only one type of bamboo *(Bambusa spinosa)*, etc. In short, plant names are subject to the same processes of historical change as other linguistic forms.

6. *Synonomy*. In a narrow sense, there are no true synonyms, but terms with overlapping areas of associated meaning are common in all languages. At lower levels of generalization, vernacular names for folk taxa often include such "partial" synonyms, which must be distinguished from terms for separate ontogenetic stages on one hand and from those indicating greater or lesser specification on the other. While such alternative labels may not modify the basic system of classification involved, they may suggest historical connections or associated behavior patterns of interest to the comparativist or to the ethnographer in other contexts. Over 200 specific plant name synonyms have been recorded in Hanunóo. In part, they indicate religious taboos, ritual and literary usage, metaphoric extensions, and the degree of contact with neighboring speech communities.

Some of the implications of the preceding remarks for the use of vernacular plant names in reference to, or as a substitute for, scientific botanical nomenclature (with particular reference to the Indo-Malaysian area), are as follows:

(a) Without other evidence, one cannot assume that similar vernacular names, in different local languages, refer to the same scientific taxa. The chances for error in this type of guess work are very great especially where names are short, traditional orthographic transcriptions are highly simplified (ignoring many phonemic distinctions), and many closely related languages are involved.

(b) Most vernacular terminologies include numerous loans, the shapes of which have been modified to adjust to the phonological requirements of borrowing languages. In quoting or referring to these forms *as vernacular names*, they should be treated like the other forms in the languages concerned. No advantage is achieved in trying to represent such labels in the form of the supposed etymons.

(c) When a local name is used as an *equivalent* of a scientific binomial, it ceases to be a vernacular lable as such, in that it no longer designates a segment of a folk botanical classification. In other words, when a local term is selected as an "official name," it becomes a synonym in the language of systematic botany and thus it cannot be considered a native plant name, except historically. Scientific vocabulary can be prescribed, standardized, and—at least relatively—stabilized; vernacular usage can only be described. Folk botanical terminology is subject to the same kinds of modification that affect other parts of the lexicon of any spoken language.

For the culture historian or phytogeographer the vernacular names for plants and plant products in the Pacific-Indo-Malaysian area comprise a very rich, and as yet almost untapped, source of indirect evidence of the pre-European spread of cultigens, weeds, and agricultural practices. Watt, Heyne, Merrill, Burkill, and other workers have furnished excellent compilations of local plant names in restricted parts of this vast and luxuriant botanical province, but many areas remain completely undocumented, and very little use has yet been made of the available materials. Those of us who are particularly concerned with the relation of plants and man in the Pacific hope that recent interest in vernacular terminology will stimulate further descriptive and comparative research in this field.

DISCUSSION

A. CAPELL: The term *tona* is applied in some Polynesian languages to *imported* plants, *tona* being a compass point as well as of a specific island. This usage is noticeable, especially about Futuna-Aniwa in New Hebrides, and is borrowed in some neighboring Melanesian languages.

Newcomers often name local plants after one of their homeland to which it bears physical resemblance, though there may be little or no botanical relationship. This fact must be taken into consideration in any subsequent study.

A LINGUISTIC APPROACH TO THE ETHNOBOTANY OF SOUTH-SAHALIN

ROBERT AUSTERLITZ

Columbia University, New York, New York, U.S.A.

(Abstract)

The area discussed is the southern half of the island of Sahalin (Japanese: Karahuto), specifically, the area along the Gulf of Taraika. The ethnic groups involved are the Gilyaks *(G)*, the Oroks *(O)*, and the Ainus *(A)*. The *G* language is not known to be genetically related to any other language. *O* forms part of the large Manchu-Tungus stock which occupies many areas from the Enisei eastwards to Sahalin. No genetic affiliations have as yet been found for *A*. Population data:— *G*: total 4,000 (mostly around the mouth of the Amur), of which 100 in South-Sahalin. *O*: total 420 (probably all on Sahalin), of which 250 in South-Sahalin. *A*: 15,000 in Hokkaidô and 1,000 in Sahalin. (Figures are approximate and based on pre-war Japanese and Soviet sources; geographical distribution is pre-war.)

The material adduced consists of (1) about 170 plant names in *G*, *O* and *A*, accompanied by *(a)* a discussion of the linguistic aspects of each plant-name and *(b)* ethnological data concerning each plant; (2) a list of about 60 terms concerning plant anatomy, folk-botanical notions, and plant-artefacts; (3) a list of about 30 topographic terms, and (4) nine names of plant-commodities (tobacco, rice, etc.). The investigation has a Gilyak bias: information concerning *O* and *A* cultures and languages is considered ancillary although the optimum, namely, complete information concerning all three cultures, has been striven for. The information has been mainly collected from one *G*, one *O*, and one *A* informant, but other informants, when available, have also been consulted. All work was carried out in Hokkaidô, Japan. Reference to earlier sources has been made. The information was elicited by letting the informants associate freely (singly and in groups), by asking them to procure specimens from nature, by reference to older sources (*G* and *A*), and by showing them illustrations in Japanese and Western books on northern flora. The entire collection of plant names was finally identified (from descriptions and specimens) and provided with scientific binomials by Prof. M. Tatewaki (Sapporo).

The following points are especially noteworthy from the viewpoint of ethnobiology: (1) Plant uses: nutritional, industrial, medicinal, ritualistic; (2) The folk-botanical distinctions made in the cultures in questions; (3) The etymologies of plant names and flora terminology in *G*, *O*, and *A*.

Accordingly, the preliminary conclusions of the investigation reveal the following: (1) *G*, *O*, and *A* plant uses in South-Sahalin overlap to a great extent. Since we assume a different geographical and cultural origin for each of the three groups we must here reckon with cultural borrowing. In the case of drugs, especially, we assume that the lending party has been the *A*. In the case of ritualistic uses, *G* and *O* show similarities, whereas *A* stands apart. Industrial uses are highly developed among the *A* (weaving, dyeing), much less developed among the *O*, and primitive among the *G*. (2) *G* culture shows a predilection for sophisticated terminology for mosses, lychens and conifers; this points to a tundra-origin. The same distinctions are primitive among the *A*. The *O*, who form a part of the large reindeer-culture complex (Tungus) have the terminology to be expected under these circumstances. Hunting and trapping are equally represented everywhere, but it seems that the *G* terminology concerning topology is the most developed. (This conclusion may result from the above-mentioned *G* bias.) (3) The etymological investigation of plant names shows that much borrowing in all directions has taken place, perhaps mostly from *A* to *G*/*O*.[1]

The overall picture gained confirms and strengthens previous hypotheses reached by other means: (1) The *G* and *O* moved to Sahalin from the Amur area. (2) The *O*, being reindeer-breeders came from an originally more temperate zone than the *G* (whose reindeer terminology is Tungus/ but not *O*!/) (3) The *A* moved from Hokkaidô to Sahalin and are the most plant-conscious group. (4) The *O* seem to have borrowed many cultural features from the *G*; this implies a relatively remote separation from the main Tungus stock. (5) *G* plant names are very often analytic, i.e., names can be analyzed into components which are not basically botanical: this would indicate a relatively recent "awakening of a folk botanical consciousness."—Reindeer-culture terminology

and sea-mammal distinctions should be scrutinized together with plant-terminology.—On a larger scale, the evaluation of the data in terms of the broader area of Northeast Asia's flora remains to be carried out.

DISCUSSION

T.P. BANK: When last I saw Austerlitz's manuscript (in November, 1957) it had already grown to enormous proportions. He is a linguist who has developed a recent interest in ethnobotany and he is doing an excellent job of his project. Not only is he working with Gilyak, Ovok and Ainu informants, but he is collecting the plants wherever possible, recording his data on the plant collection sheets, and working closely with Professor Misao Tatewaki of Hokkaido University (professor of botany) to obtain authoritative plant identifications. When finished (this winter, I think) his volume will form a most useful and valuable contribution to the botany and anthropology of the North Pacific region and Northeast Asia. It definitely should be published and I hope Dr. Austerlitz can be encouraged to continue his interest in ethnobotanical linguistics.

[1]It is very difficult to reach definite conclusions about the direction in which a loan travelled without disposing over a greater body of data than we have at present. For the time being, we employ the following methodology which is based on four foci:

		Dialects:
cG	sG	cG -continental (Amur) Gilyak
		sG -Sahalin Gilyak
		hA -Hokkaidô Ainu
hA	sA	sA -Sahalin Ainu

If a term in *sG* and *sA* contains features which lead us to believe that we are dealing with a loanword and if this term also exists in *cG* we conclude that the loan travelled from *G* to *A*. If the term exists in *sA* and *sG* as well as in *hA*, we assume that, it travelled from *A* to *G*. If the term exists in all four (*sG*, *cG*, *sA*, *hA*) we are faced with a larger problem. This method can, of course also be carried out in respect to *A* and *O* (employing Tungus cognates for *O* terms). There are, of course, also other indices, by which loans can be determined. The most useful of these is the evaluation of the structure of the word within the framework of the structure of the respective language as a whole. Thus, anyone familiar with the structure of *G* will conclude that a term like **orarif** "*rosa rugosa* **Thunb.**" is not originally *G* in structure and must be considered a loan. Another index is the analytic structure of certain plant names: if a term can be decomposed into such meaningful terms as have a relevance to the plant in question and if the same term reappears in another language, we may assume that the language in which the analytic term appears is the lending party, e.g., A **otárup** "*rosa rugosa* **Thunb.**", decomposable into **otá** "sand" and **ru-p** "round (thing)". In such cases, however, there is always an imminent danger of folk-etymology on the part of the borrowing party. Still another index is the number of names per plant: if a language has three or four names for the same plant (in one dialect), at least one of these is certainly a loan. Etc.

The large collection of *A* plant names by M. Tiri is now available. For *G*, however, we only have the century-old collection of Grube (Schrenck and Glehn). A source on *cG* plant names would be a most welcome aid.

VERNACULAR OR COMMON NAMES OF PLANTS

R.E.P. DWYER

Department of Agriculture, Stock and Fisheries, Port Moresby, Papua.

It is considered a great honour to be asked to present a paper even so limited as this one to the members of this Ninth Pacific Science Conference, especially to that Sub-Committee or section, dealing with vernacular names of Pacific plants. At the request of Dr. Mona Lisa Steiner of the Philippines, Convenor of the Symposium on Vernacular Names of Pacific plants, lists of common names of, mainly, Papua and New Guinea plants have been compiled. These have been done from a number of sources, by Departmental officers of the Department of Forests, particularly the Forest Botanist, and the Department of Agriculture, Stock and Fisheries, and the author (see acknowledgments). The actual compilation and collation of the plant lists for this submission is definitely the main purpose envisaged.

The attached nomenclature lists[1] are presented in three phases:

(1) A list of native, or vernacular names of plants, from Papua and New Guinea, including the out-lying islands.

(2) A shorter, comparable list from the neighbouring British Solomon Islands and other South Sea Islands showing some common names which were collated while compiling the above list. This list is supplementary and most incomplete.

(3) A list of some comparative names, chiefly of food plants, from Micronesia, Polynesia, Melanesia, Indonesia and Malaya is also included. See Barrau *(1 and 2)* Merrill *(7)* Ochse *(9)*. This is a limited attempt at comparative nomenclature to try and find out whether any affinity in the common names used exists for specific plants for the various territories and districts represented. Refer to the more comprehensive list by Dr. Steiner, Philippines, 1957 *(11)*.

The lists of plants submitted herewith are generally presented under the following headings:

(a) Scientific name.
(b) Native name.
(c) Dialect and locality.
(d) District.

It will be seen that widely-used, ordinary, common names such as bananas, coconuts, breadfruits etc. have been omitted as these are readily available.

The present author was formerly working as an economic botanist, up to 1942, in the old, New Guinea Department of Agriculture, so that the assembled scientists will realise that the comparable data deals with food and important economic plants, but not purely in timber, or forest trees, as such, or with plants of mainly botanical interest.

The lists of plant common names, although comprising an extensive collection, can only be regarded as being most incomplete. From the experience presently gained in these compilations, it would appear that it would take months, or longer to collect and present the data in such a way as to be of maximum use to the working botanist. The immensity of the task involved in collecting vernacular names of Papua and New Guinea plants is highlighted by the following considerations:

(1) The very diverse physiography present over the Territory of Papua and New Guinea as briefly there are dry savannah areas, such as in East Papua and very wet areas, up to nearly 300″ per annum, in some districts. The average rainfall for the whole Territory would probably exceed 80″ per annum. The Territory can therefore be generally regarded as wet, except in the south east coast of Papua, in the dry belt.

(2) Variations in altitude ranging from sea level to mountains of 15,400 ft in height, with immense, highland valleys of around 6,000 ft. It is estimated that more than one-third of the Territory is above medium to high-altitude terrain.

(3) The hundreds of islands present, including coral atolls, archipelagoes, etc. Thus diverse genera and species of plants are found in some islands in this Territory which are not present in others, due to different ages of geological separation, difficulties and types of dispersal etc.

[1] These lists are not published in the Proceedings but will form part of the dictionary of vernacular names being compiled by the sub-committee on Vernacular Names of Pacific Plants, Standing Committee on Botany, Pacific Science Association.

(4) The great diversity of peoples and languages represented in the Territory's population, presents a great difficulty in compiling reliable data on plant names. This is perhaps the most difficult obstacle to getting anything like a complete survey of all the local names used by the indigenous inhabitants. It is necessary to point out that the, approximately, 1¾ million inhabitants here speak several hundred major group languages, many of which include a number of different dialects as well as "lingua franca" languages such as Motu, Tolai, Kote, Yabim, Pidgin English etc.

The peoples here are roughly classed as Melanesians by anthropologists, yet there are true Micronesians in the Western islands, Polynesians in the outer islands (in the far Eastern part of the Bougainville District), also Negrito people in the hinterland, and also mixtures of these types in Papua and New Guinea. The present data are presented with some trepidation, therefore, especially as lack of time has prevented the listing of the plants under their botanical orders, or generally the names of describing authorities. There has been no presentation of brief descriptions as has been so well done by Record dealing with Waterhouses Collection *(10)* 1932-36. Lane Poole *(4)*, Barrau *(1, 2)* and many other authors see *(3, 4, 5, 6, 7, 8, 9)*.

The native peoples of the Territory are particularly adept at recognising and naming plants, in the field, as they are so important for their subsistence. They can even recognise and name various fungi, both those which can be used for food and those which are poisonous. Even luminous fungi are recognised and used in games. It would be valuable to know how far they go in recognising sea-weeds, marine plants etc. It is known that some coastal natives do use sea-weed as food and also in their totems.

Professional botanists are well aware of the various main Flora, far too extensive to be quoted in the present bibliography, which describes the Flora of the South Pacific and Indo-Malaysian region, e.g., Flora Malesiana; Flora Papuasian, Flora Kaiser Wilhelmsland, etc. Few of these flora or the numerous, separate, botanical monographs in this region present vernacular names. However, a limited bibliography of books and articles, where common names are quoted, is presented.

There is also a wide field not touched on here, where widely-used common names are given in the main languages to represent plant life, or groups of flora, as a whole, so just a few examples are given:

"KUMU" or "KUMUL"	A Pidgin term for all green vegetables
"PICUS"	Pidgin for all species of *Ficus*
"KAPIAK"	Pidgin for *Artocarpus* Spp.
"BIN"	Pidgin for Legumes
"KUNDA"	Pidgin for all rattans, *Calamus* Spp.
"REI"	Motu for all grasses, Gramineae
"MULIS"	Pidgin for all limes and lemons *Citrus* Spp. generally
"SEPORA"	Motu corresponds with above-all *Citrus* Spp.
cf. "DJERUK"	for all Citrus in Indonesia.

Where important food and economic plants are widely used for a number of purposes, as with the coconut, *Cocos nucifera* all parts of the plants receive vernacular names which fact, in itself, can be very confusing, as can be the practice that food products made from the fruit, or plant, itself, also receive separate names, see Massal and Barrau *(6)*. It is the author's considered opinion that a properly-conducted survey of the range and usage of common names and their implication and comparisons would yield much valuable data as to plant origins and plant migrations in the South Pacific area. The indications are very strong, though not definitely proved, that where plants have been introduced and are not widely used, only a few common names, often similar in sound and derivation, are used and even where the variations occur, they are readily traceable. However, even with introduced plants such as sweet potato, when they are spread over a wide area range of Territories, many common names may be applied, especially as numerous varieties of sweet potato *Ipomoea batatus* are cultivated. Even in such cases, according to Barrau (loc. cit.) and other authors, it is possible to trace a similarity in common names between those used in Micronesia, Melanesia and Polynesia. It is an interesting fact that the sweet potato has no known representative in the wild plant sector. It would appear that, historically, it is not many centuries ago this plant was introduced to the South Pacific region.

There are numerous introduced plants in this Territory which are so ubiquitous that they are practically accepted as indigenous. Examples are well known, such as the pawpaw, *Carica Papaya*, the betel nut, *Areca catechu*, pineapple, *Ananus cosmosus*, tobacco, *Nicotiana tabacum*, which was probably brought here not long after it was introduced to Malaya and the Philippines, about 1610, and there are many other examples too numerous to mention. In the reverse direction, the position exists where various types of taros have been distributed from this region to other parts of the world, particularly the South Pacific Region, bread fruits *Artocarpus* spp., sugar canes *Saccharum* spp., okari nuts *Terminalia* spp. which have similar common names even as far afield as Malaya and Indonesia. Again, these only present a suggestion of the movements which have taken place and would need more investigation as in fact has been tried by Merill *(7)* and Barrau (loc. cit.) and others.

There is some evidence from the study of common names of coconuts and from local folk-lore that they have been introduced into the Pacific Islands and particularly to New Guinea within the last two or three centuries and enquiries from the inland people here seem to denote this. The common name "Niu" (New) is very commonly used throughout the area. This may, or may not, be very significant. The original introduction of the ordinary, tall coconut should not be confused with the spread of the Malayan and dwarf types from the East which can be traced to within a relatively few years ago.

The study of the common names of plants used in the Territory indicates that often where the names seem to vary very much, they have relatively the same meaning though expressed in different languages. Examples are: in Bougainville a number of different names which all mean "possum's ear" as applied to the peculiar shape of the small flower of *Aporosa papuana* and there is no douht about the similarity which has been noticed. In some cases, the names have magic, or taboo meanings, e.g. *Codiaeum variegatum* has the Siwai name, "tatovo" which refers to the use of the live plants to define prohibited areas; *Entada phaseoloides*, the Siwai name, "aija" means crooked, also for *Boehmeria platyphylla*, "Omoro" equals tail of a fish, and numerous examples could be used to show the derivation of the common names which have reference to their appearance, their usage, their ceremonial importance, economic importance, and so on. In some cases, the inhabitants use common names to separate large divisions in the one genus; e.g. the use of the derivations "moi" and "pii" to separate the large divisions of the Genus *Canarium*.

One interesting feature is that a large number of villages and plantations and, in a few instances, districts and subdistricts have been named after the common names used for wellknown plants. It is possible that the plants are named after the place names, or naming occurs in both directions. This subject would warrant further study though, of course, there are examples of where this has been done deliberately, as in one suburb of Port Moresby, where common names of trees are used to denote the streets and avenues, e.g. Okari Avenue, Hohabu Avenue etc.

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In addition, Mr. W.L. Conroy, Chief of the Division of Agricultural Extension and Mr. F.J. Broekhals, A/Plant Introduction Officer, both of the Department of Agriculture, Stock and Fisheries, Papua and New Guinea; have greatly assisted.

The idea of these compilations, however, originated from Dr. Mona Lisa Steiner as stated in the text and, last of all my thanks to Dr. J.J. Szent-Ivany, who is to present the brief, introductory article.

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DISCUSSION

F.R. FOSBERG: The author has pointed out the matter of collective names for groups of plants with some general resemblance, some point of utility in common, or some other feature. This idea should be emphasized. It seems to be a general feature of all languages, at least those with which I am familiar to have both general and specific names. This situation may often mislead the botanist or collector, who may put on his label a name which only indicates a grass-like plant, an edible fruit, a potherb, or some similar term, not knowing that it is not a specific vernacular name for the plant in hand.

P. WEATHERWAX: I have found this a most interesting and stimulating symposium, and it is to be hoped that it may provide an incentive and a pattern for further work.

One interesting study might consider what we are to do about vernacular names which are obviously incorrect in application. Example: the yam — sweet potato — potato complex.

Despite the fact that studies of this sort can never be completed and that they often arouse feelings of disgust or at least impatience in workers in experimental botany, they certainly fill a great need and merit consideration.

A warning against "forcing" vernacular names. Many species, many grasses for example, are not clearly recognized as separate entities, and it is foolish to try to find common names for them. It is even worse to create common names for such plants when none exist.

Another warning about the informant who, wishing to please you or feeling that it is necessary to save face, "manufactures" information for you.

ORIGIN OF THE SUSTENANCE PLANTS OF POLYNESIA, AND LINGUISTIC EVIDENCE FOR THE MIGRATION ROUTE OF THE POLYNESIANS INTO THE PACIFIC

HAROLD ST. JOHN

Senior Professor of Botany, University of Hawaii, Honolulu, Hawaii.

(Abstract)

One of the riddles of the Pacific is the origin of the Polynesians and how they crossed the Pacific to discover and colonize the distant isles of the tropic sea. It happened more than a thousand years ago. They were a people of a stone age culture and without a written language, so there is no record in written history of their maritime explorations. Yet, in the central, and especially in the eastern Pacific they found and settled all fertile islands of the tropics and even some down into the south temperate zone. In the many earlier attempts to unravel the history of the Polynesian migrations, much evidence has been studied, most of it of an ethnological nature. The writer has approached the problem from a botanical angle, attempting to solve the riddle by a study of the crops that the Polynesians cultivated and ate.

The Polynesians had a highly developed agriculture based upon the growing of 27 species of crop plants. One, *Piper methysticum*, was a beverage plant, the others were food plants. By the known source and by phylogeny, the home land of these crops can be determined. One, *Ipomoea batatas*, is demonstrably of American origin, but in aboriginal times was carried by native people as far west as New Guinea. One was domesticated in Polynesia; three in Polynesia and adjacent Melanesia, two in Melanesia, and one in Micronesia. These central Pacific ones make 25 per cent. The great majority of them came from farther west, 7 from Malaysia, 6 from Malaysia and southeast Asia, 3 from the shores of the southwest Pacific and the Indian Oceans, and 3 from India or Ceylon. These Oriental ones total 70.4 per cent. Hence, the geographic origin of their crops implies that the people brought them from Southeast Asia.

Evidence of origin can also be found in the vernacular names used by the many tribes of aborigines. It was pointed out by S.H. Ray (1912) that the coconut, *Cocos nucifera*, was known by the name "niu," in that same or in a cognate form of the word, all the way from Madagascar to Hawaii. The same wide usage is true of the name "taro" for *Colocasia esculenta*. Others of the 27 crops have names with a wide use, but over area of less size than the whole tropical Indo-Pacific.

Since all but one of these crops are of Asiatic or Pacific origin, it would be of interest to find the route over which they were imported, that is, either through Micronesia direct to Polynesia, or through Indonesia and Melanesia to Polynesia. The aboriginal occurrence and use of the crop plants gives the best evidence. In aboriginal times, in all Micronesia 4 of the crops were missing, while in the Marshall, Gilbert, and Ellice Islands, all of which are atolls or cora islands, 11 were missing. On the other hand, all 27 were in use by the natives in all or in several parts of the East Indies. This supports the theory that Polynesians, emigrating from Southeast Asia, followed the chain of islands of the East Indies or skirted and touched them while migrating through Malaysia and Melanesia to Polynesia.

EDIBLE YAMS OF THE SOUTH SEA ISLANDS, SPECIES PRESENT, VERNACULAR NAMES AND DISTRIBUTION

JACQUES BARRAU

Muséum National d'Histoire Naturelle, Laboratoire d'Agronomie Tropicale, Paris, France.

Yams are important food-producing plants to be found in all the high Pacific islands. It may be of interest to give here a list of the species together with the vernacular names known and the distribution of the plants. A more complete study has been given elsewhere (*Journal of Tropical Agriculture and Applied Botany*, III, 7-8, 1956). The enumeration which follows is based, from the botanical point of view, on Burkill's monography, "Dioscoreaceae" (in *Flora Malesiana*, I, 4, 3- 1951).

I. Section *Combilium*

Dioscorea esculenta (Lour.) Burk. [*D. sativa* Linné, *D. aculeata* Linné, *D. fasciculata* Roxb., *D. spinosa* (Roxb. ex) Hooker, *D. papuana* Warb.]

Two botanical varieties of these are present in the South Sea Islands:

—*spinosa* var. (Roxb.) Prain and Burkill, corresponding to the very prickly yams of the species abundantly found in the wild state in the island of Guam in the Marianas archipelago.

—*fasciculata* var. (Roxb.) Prain and Burkill, which groups together all the less prickly horticultural varieties common from New Guinea to the Samoa islands inclusive.

Vernacular names:

1. Melanesia:
   New Guinea: *Diba, Kav, Kava, Nale, Nar, Nemu, Taitu, Taitukava*
   Trobriand islands: *Taitu*
   New Caledonia: *Diwada, Kudik, Kudim, Ku din, Si, Ubin, Wale, Walei, Ware, Warei*
2. Micronesia:
   Yap: *Dai*
   Marianas islands: *Nika*
3. Polynesia: *Ofa lei, Ufi lei, Uhlei.*

The species is only found plentifully as far as the islands of Samoa included. Further eastwards it is rare and its introduction perhaps recent.

II. Section *Paramenocarpa*

According to Sasuke, "Breadfruit, yams and taros of Ponape island," *Proceedings of the Seventh Pacific Science Congress*, **VI**, 1953, one of the yams of Ponape is *D. flabellifolia* Prain and Burkill, the presence of this yam in the Palau islands having already been pointed out by Burkill.

III. Section *Opsophyton*

Dioscorea bulbifera [*D. sativa* (non Linné sp. pl.) Thunb., *D. sercidea*? mentioned by Langley in the "Report of the 1947 New Guinea nutrition survey expedition," 1951].

Four varieties are present in the South Sea Islands:

(a) Wild tuberculous and bulbous plants which are bitter and poisonous,

— *bulbifera* Burk. var. with cordate leaves,

— *heterophylla* Burk. var. with more elongated leaves.

These two varieties are present in almost all the Upper Pacific Islands.

(b) tuberculous and bulbous plants with a less bitter taste and only slightly or non-poisonous, probably the outcome of empiric selections in ancient times,

—*suavior* Burk. var. bulbils with greyish and uneven epidermis, present in almost all the Upper South Sea Islands,

—*sativa* Burk. var. bulbils with smooth and light coloured epidermis, to be found in New Guinea.

Vernacular names:

I. Melanesia:
   Trobriand islands: *Kasiena*
   New Caledonia: *Ae, Ave, Dema, Dimoa, Dimwe, Eja, Niwa, Nua, Numwe, Soa, Sua, Samoa, Waeki, Wasuma*
   Fiji islands: *kaile*
II. Micronesia:
   Palau: *Belloi*
   Yap: *Rok, Yoi*
   Truk: *Apuereka*
   Ponape: *Palai*

III. Polynesia: *Hoi, Soi, Oi.*

IV. Section *Lasiophyton*

1) *Dioscorea pentaphylla* Linné

Two varieties are present in the South Sea Islands:

—*papuana* Burk. var. for hardy plants with prickly stems and tubers carrying numerous roots,

—*palmata* Burk. var. for the plants with short, pyriform tubers which are sometimes flattened and lobed and which have a smooth epidermis. The "cultivar Piia" described by St. John, "The Hawaiian variety of *D. pentaphylla*, an edible yam," (Journal of the Polynesian Society, 63, 1, 1954), seems to correspond to this latter variety.

The former variety is found principally in New Guinea, the latter is common as far as Eastern Polynesia.

Vernacular names:

I. Melanesia:
New Caledonia: *Tue, Wahneor, Xota*
Fiji islands: *Bulou, Kaile, Tokatolu*

II. Micronesia:
Yap: *Duol*

III. Polynesia:
Samoa island to the Cook islands at Rarotonga: *Pirita*
Cook islands to the East of Rarotonga: *Pakatiro*
Society islands: *Parauara*
Marquesas islands: *Utau.*

2) *Dioscorea hispida* Dennst. (*D. triphylla* L., *D. hirsuta* Dennst.)

This variety is to be found only in New Guinea and at Ponape, Caroline islands. I have found it in the cultivated state in the latter island.

V. Section *Enantiophyllum*

1) *Dioscorea alata* L.

The most important species with multiple clones in the South Sea Islands.

Vernacular names:

I. Melanesia:
New Guinea: *Ambi, Dari, Kav, Krenup, Nar*
Trobriand islands: *Kuvi*
New Hebrides: *Dem, Ngaka, Pae, Taufi*
New Caledonia: *Ko, Koko, Ku, Kuik, Kuk, Kuvik, Nuvuk, U, Ufi, Uvi, Uvuk, Wakoko, Wu, Wukuk, Wuvuk*

II. Micronesia:
Palau : *Telngot*
Yap : *Duok*
Marianas islands: *Dago*
Caroline islands a) Truk: *Ep*
b) Ponape to Pingelap: *Kap, Kep*

III. Polynesia: *Puauhi, Ufi, Uhi.*

D. alata is present and cultivated in all the high South Sea Islands. This yam is a basic food plant in certain territories of Melanesia only (Trobriand islands and New Caledonia, for example) and at Ponape in Micronesia. Elsewhere, in eastern Polynesia in particular, it is a subsidiary food plant.

2) *D. Nummularia* Lamk. (*D. pirita* Nadeaud, *D. glabra* (non Roxb.) Koorders, *D. seemanii* Prain and Burkill, *D. hebridensis* Knuth, *D. palauensis* Knuth, *D. angulata* Knuth, *D. lufensis* Knuth, etc.)

This yam was identified by Brown, "Flora of southeastern Polynesia, 1931," who gathered it in the Marquesas as *D. cayenensis* Lamk. His conclusion was that its presence indicated ancient contacts with America, an argument which was taken up by Heyerdahl "American indians in the Pacific, 1952."

Vernacular names:

I. Melanesia:
New Guinea: *Boku, Sinngo*
Salomon islands: *Karausu, Pu'uitiko*
New Hebrides: *Loopitiko, Telewo*
Fiji islands: *Rauva, Rauvadua, Tivoli, Tikau*

II. Micronesia:
Yap: *Sep*
Ponape: *Kapnair*

III. Polynesia:
from Niue to Rarotonga: *Uhi Palai, Ufi Parai, Ufi Palai*
from Atiu to, and including, the Society islands: *Pirita*
Marquesas islands: *Puauhi-Peahi.*

D. nummularia has, so far, never been found in New Caledonia. Although this species is present in almost all the high South Sea Islands, it has never been extensively cultivated. Just a few plants are to be found growing often in the villages, sometimes in gardens, more by tradition it seems than by necessary. It may be a case, as suggested by Guppy, "Observations of a naturalist in the Pacific 1906," of a food plant of more importance at one time but the usage of which almost completely disappeared on the introduction of food crops easier to produce and prepare. Guppy classed *D. nummularia* among what he called "pre-polynesian" food plants.

Symposium: *Vernacular Name of Plants*

GENERAL DISCUSSION

F.R. FOSBERG: Dr. Carter of Johns Hopkins University, on seeing the preliminary compilation of names of food plants, brought up the desirability of extending this work to include meanings and derivations of these names. This would provide additional clues to the origins of the plants, migration of peoples, development of languages, etc. This extension might also secure for us the cooperation of able people in these fields who might not otherwise be interested.

J.H. HÜRLIMANN: A joint botanic, linguistic, and anthropologic study of the plants of Tonga seems to be feasible, because materials have been gathered in the three fields of approach in 1951-1952.

A. CAPELL: Linguists are in the process of organizing symposia for the next Congress. I suggest that arrangements may be made for a joint session between Botany and Linguistics on ethnobotany. There is still time to arrange this through the relevant sub-committees.

T. TAKESI: I wish to call attention to the problem of Pandanus. There are many edible species of rather limited distribution. As an entry in Dr. Steiner's project, I suggest that the generic name is enough, after the vernacular names of different localities, specific names may be better recorded in parenthesis.

F.R. FOSBERG: The matter of vernacular names of Pandanus will not be straightened out to everyone's satisfaction. The Pandanus tectonics group includes a myriad of cultivated and wild forms comparable to those of the domestic apple. These have vernacular names just as do apple varieties. No one agrees on which are to be regarded as species. Edibility is no criterion. When seeds of some of the large edible varieties are planted, the resulting plant may be the small fruited with plant. There are reasons for the diversity of names, in that the fruits are of different quality. It is desirable to record these things, but we should not delude ourselves about getting anywhere with it.

T.P. BANK: I don't wish to take sides in this argument except to point out again that from an anthropological point of view some of these periphereal names, these synonyms for the same species, are *most* significant. For example, among the Ainu there are many names for the same tree, depending upon whether or not it is scared (and the spirits have escaped). The Ainu have a whole complex of ritual associated with tree spirits, and the accompanying names are *most* important in gaining an insight—for anthropologists.

J.V. SANTOS: With regards to the accuracy of vernacular names of plants, I have the impression that there may be an occasion when there is danger of considering seriously some names furnished by the informers. Based on my little experience on collecting trips in the Philippines, I gathered the information that there were times when a guide did not know the name of a plant presented to him and in his desire to satisfy the inquisitiveness of the collector, he (the guide) supplied any vernacular name which came to his fancy.

ACETO-CARMINE STAIN IN THE CYTOGENETICAL INVESTIGATION OF SOME MARINE ALGAE OF THE PACIFIC COAST†

KATHLEEN COLE

Department of Biology and Botany, The University of British Columbia, Vancouver, Canada.

There exist many problems concerning the speciation of marine algae on the Pacific Coast of North America. A cytogenetical study is fundamental to an understanding of speciation and, in conjunction with culturing, helps to correlate the presence or absence of morphological alternation of generations with cytological phenomena.

Information pertaining to the life histories of the green, brown and red marine algae has been obtained by improved culturing techniques and has assisted in the interpretation of phylogenetic relationships within these groups. Investigations within the Chlorophyta have proved that, in the order Ulvales, the genus *Monostroma* lacks an alternation of generations, thus differing from the genera *Ulva* and *Enteromorpha* (Kunieda, 1934; Moewus, 1938; Yamada and Saito, 1938). Kornmann (1938) claimed that *Halicystis* and *Derbesia*, genera of two distinct families, Halicystidaceae and Derbesiaceae, of the order Siphonales, are phases in the life history of one and the same alga. Others, including Hollenberg (1935), have shown that they are distinct genera. It is evident that Kornmann's work is in need of repetition since the conclusions regarding the life histories differ so greatly. Cultural studies have also made it apparent that the algae offer possibilities for genetical studies such as the heritability of sex determination already demonstrated in *Dictyota* and *Laminaria saccharina* (L.) Lamour. (Schreiber, 1930, 1935), two members of the Phaephyta.

There is a notable lack of algal cytological literature dealing with problems such as the nature of cell division and the nature and function of the pyrenoids, centrioles and nucleolus. This is understandable when it is realized that technical difficulties arise in dealing with many of the algae and especially those having gelatinous wall layers, large vacuoles and very small nuclei. This small size of the nuclei mitigates against critical observation of certain important phases of cell division. In spite of this, more or less typical mitotic divisions similar to those of higher plants have been reported for representatives of all the algal groups.

A cytogenetical investigation of some marine algae of the Pacific Coast was begun recently at the University of British Columbia. This study includes the culturing of several forms in an attempt to obtain complete life cycles. The iron-aceto-carmine squash technique (Belling, 1926) which has been used successfully with many different animals and plants, including certain fresh water algae (Cave and Pocock, 1951), was selected for the cytological observation of all species. Squash preparations have the advantage over sections in that they permit rapid fixation and handling of materials and the examination of single layers of cells in totality. The combined stain-fixative is the simplest of all chromosomal treatments since cells are directly mounted and studied in the fixative. The mounts may be readily prepared in the field and the stain applied to living material or to material which has been previously fixed. Prefixation of the material reduces the staining of the cytoplasm and allows more rapid absorption of the stain by the chromatin.

A general survey of the Chlorophyta, Phaeophyta and Rhodophyta, with emphasis on the benthonic marine algae, was conducted first and it was soon evident that the iron-aceto-carmine effectively stained the nuclei in all examples studied. Certain modifications of the technique were required in some instances. There follows an account of the techniques found most suitable for genera of the three major algal divisions.

I. Chlorophyta. Species of the following genera were studied: *Chaetomorpha*, *Cladophora*, *Codium*, *Derbesia*, *Dunaliella*, *Haematococcus*, *Halicystis*, *Rhizoclonium*, *Spongomorpha* and *Urospora*. Prefixation in 1-and-3 acetic alcohol for a period of 12 to 24 hours facilitated nuclear staining. A small portion of the material was placed on a slide with several drops of iron-aceto-carmine stain and a cover slip applied. The slide was heated gently over a spirit lamp

† Presented by R.F. Scagel.

for several minutes to flatten the cells, stick them to the slide and speed up penetration of the stain. Slight pressure was exerted on the cover slip with the thumb or the end of a pencil. Temporary slides were made permanent rapidly and easily by means of the quick-freeze technique (Conger and Fairchild, 1953). Following this treatment most cytological features such as flagellae, cell walls, cytoplasmic inclusions, pyrenoids, nuclear membranes, nucleoli and chromosomes were readily observed.

II. Phaeophyta. Species of the following genera were studied: *Nereocystis*, *Pleurophycus*, *Soranthera* and *Sphacelaria*. Slides were prepared as for the Chlorophyta with the exception that when the iron-aceto-carmine was applied to living material it was necessary to add one drop of iron alum solution (23 ml of 3 per cent aqueous iron alum in 77 ml of 90 per cent alcohol) to the slide in order to speed up absorption of the stain. Nuclei and mitotic figures were observable when this procedure was followed.

III. Rhodophyta. Species of the following genera were studied: *Antithamnion*, *Bangia*, *Callithamnion*, *Ceramium*, *Corallina*, *Cryptopleura*, *Dasyopsis*, *Euthora*, *Fryeela*, *Gonimophyllum*, *Herposiphonia*, *Nitophyllum*, *Platythamnion*, *Polycoryne*, *Polyneura*, *Polysiphonia*, *Porphyra*, *Pterosiphonia*, *Sarcodiotheca*, and *Weeksia*. Certain of the red algae studied required more modification of the staining technique than the greens and browns. Slides of *Antithamnion*, *Callithamnion*, *Herposiphonia*, *Platythamnion*, *Polysiphonia*, *Pterosiphonia* and *Dasyopsis* were prepared as for the Phaeophyta. Species of the other genera listed above were fixed in either alcohol-formalin or Karpechenko's chrom-acetic-formalin, since decolorization of the tissues was necessary. Before staining, treatment with 50 per cent HCl softened the calcified thallus of the corallines and facilitated separation of the cells of others whose tissue had hardened during fixation. *Porphyra* and *Bangia* required pre-mordanting in the iron alum solution. A small portion of the material was placed on a slide together with a drop of iron-aceto-carmine stain, a drop of iron alum solution and a drop of liquid detergent. Portions of the thalli of the genera studied required vigorous heating before pressure was applied to the cover slip. The use of this technique allowed the clear observation of nuclei and mitotic figures.

In conclusion, it has been demonstrated that the iron-aceto-carmine squash technique, with modifications, may be used as a nuclear stain on marine forms of the Pacific Northwest. It is particularly suitable for a cytogenetical survey because it is simple, rapid, stains the nuclei effectively and may be used in the field if necessary. The survey is being continued and the study intensified in order to obtain chromosome counts and a more detailed knowledge of the cytological aspects of the life cycles of many of the marine algae of this region.

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DISCUSSION

J.V. SANTOS: Has the method been used to examine the chromosome figures in the algae?

R.F. SCAGEL: There are numerous problems in the stages of division, since some cells are multinucleate and the nuclei small. Some nuclear divisions have been seen with chromosome figures, other without. In addition there was a lack of well-developed nuclear membrane.

G.F. PAPENFUSS: Columbia is lucky in having two algologists and a cytologist interested in algae. Valuable work should result from this team.

THE 1956 TYPHOON SEASON ON OKINAWA†

JACK C. ELLIOTT

Natural Science Consultant, Michigan State University's Mission to the University of the Ryukyus, Naha, Okinawa.

(Abstract)

Between 31 July and 25 September, 1956, five typhoons visited the Ryukyu Islands. Four of these (Table 1) hit Okinawa, the largest island of the archipelago.

Although damage to man-made objects was considerable, time will not permit an accounting, excepting as damage had effect on vegetation, i.e., destruction of sea-walls permitting flooded paddy lands.

Crops were considerably retarded in their maturing (sugar cane, tea, banana) or the normal growing season was a loss (sweet potato and other vine crops, papaya).

Windbreaks of Australian Pine *(Casuarina equisetifolia)*, Pandanus, Hibiscus *(Hibiscus rosa-sinensis)*, Garcinia *(Garcinia spicata)* withstood the typhoons and salt-spray with a varying degree of success. Most resistant was Garcinia. Pandanus withstood the assualt well, however, by the last typhoon much of its effectiveness had been lost because of wind and salt spray damage. Both Australian Pine and Hibiscus suffered intensely, being severely burned and broken with the first, Wanda. Australian Pine, an introduced species, was much used. However, because the majority of them, which were approximately six years old, were broken-off in the top half or third, some other materials will have to be used. Garcinia is best, but slow growing. Perhaps a combination of Pandanus and Garcinia may be workable.

Sprout forests in northern Okinawa were affected by both wind damage and salt burn. The co-dominant trees of the area, *Castanopsis cuspidata* and *Schima liukiuensis* did not produce a seed crop because of salt burning. Ryukyuan Pine, *(Pinus luchuensis)* was badly burned. Life cycles, especially those in woody vegetation, were completely upset. Many were the species which started anew after each typhoon, never to realize their destiny.

Following a typhoon season such as that of 1956 all Okinawa was brown, bleak and in some cases barren. It was not until seven months later, April 1957, that again the countryside took on the healthy green look which characterizes the island when no typhoons have rent it so.

Table 1.

Typhoon Name	Period Typhoon in Area of circle Approx. 240 miles radius with center at Naha				Wind Velocity Recorded at Naha		Approx. Total Precipitation at Naha during Typhoon period
	Entered		Departed		Average	Maximum (Gusts)	
	Date	Time	Date	Time			
Wanda	July 31	0200	Aug. 1	1900	73	111	8.0
Babs	Aug. 14	1000	Aug. 16	1400	64	94	7.4
Diana	Sept. 1	1100	—	—	35	52	0.32
Emma	Sept. 7	1200	Sept. 9	1100	97	165	15.2
Harriet	Sept. 25	2400	Sept. 26	1800	87	129	3.96

† Presented by R.F. Carlson.

DISCUSSION

Egbert W. Walker and P.R. Wycherley referred to typhoons as one of the limiting factors in the Ryukyus vegetation, due in part to the damaging wind, but perhaps more to the injury from salt spray, especially in dry typhoons. More extensive investigations are needed to determine the distribution of the salt spray in respect to altitude and windbreaks. There is room for more investigation of windbreaks, especially as to their materials, construction and penetrability as well as the exact nature of damage in their lee due to special swirling action from non-penetrable windbreaks. The reported highly effective use of *Casuarina equisetifolia* in windbreaks seems as yet not to have been fully realized and needs further study.

F.R. Fosberg referred to observations elsewhere on breakage in this species from wind. It is noticeable that trees in areas not affected by typhoons have a very different growth form. There is need of further observations on plants whose blooming seems dependent on or stimulated by typhoons.

THE EVOLUTION OF THE GERMINATIVE POWER OF RICE SEEDS

TRAN-NGOC-TIENG

Department of Botany, Faculty of Sciences, University of Saigon, Saigon, Vietnam.

Although rice seeds appear to be mature at time of harvest, when left to germinate, even in best conditions, only a few of them can grow immediately, while others fail to do. The former are physiologically mature, the latter have to undergo a post-maturation after which they become mature. Even so, they do not remain always viable, their longevity varies with the ways of conservation, age, humidity, temperature.

In South Vietnam, rice seeds kept without any precaution, lose all their germinative power in a year.

In this paper, we study the Evolution of the germinative power as related with time, so as the influence of ways of conservation, humidity, temperature, amylase activity of seeds on it.

We used two local, purified varieties of Rice: Nang-Phet-Muon and Nang-Quat respectively harvested at the beginning of the dry and rainy seasons.

Experiments were conducted at once after the harvest as follow:

Rice seeds were divided into four series;

The first series was left in the open-air but sheltered from sun-light.

The second was exposed to the sun 3 hours daily. Its mass was mixed after every exposure and its temperature was taken. It varied between 28° and 30°C.

The third series was composed of lots of 10 g of seeds put in test-tubes sealed with paraffin. They were conserved at different temperatures: 28°, 15°, at alternate temperatures of 28° - 40°C. Each tube was used once.

The fourth series was made with a mass of 250 g of seeds kept in a dessicator with sulfuric acid.

The germinative power, the rate of humidity, the amylase activity of seeds were determined every week on these lots.

Fifty seeds apparently identical were put to soak during 24 hours, to germinate during 48 hours on Petri dishes fitted with a ring of cotton covered by two rings of filter-paper and moistened with 15 ml of water from a tap. The value of germinative power is given by the number of germinated seeds reported to 100.

The rate of humidity in seeds was calculated on 5 g of every lot which had been dried until constant weight (about 16 hours) in a drying-stove of 110° - 115° C. The difference between fresh and dry weights reported to 100 expresses the rate of humidity of each lot.

As rice seeds are rich in starch, we thought to compare their germinative power to their amylase activity. We used Wogelhmuth's method which consists in determining the minimum quantity of malt extract necessary to provoke a complete decoloration of 5 ml of a 2% starch solution after 30 minutes in the presence of Iodine 1/1200.

From the results we can see that the evolution of the germinative power of rice seeds is divided into two periods: an acquisition of maturity which lasted 7 weeks for Nang-Phet-Muon and 10 weeks for Nang-Quat, a second period the duration of which was variable.

The germinative power of Nang-Phet-Muon harvested in wet season became null after 20 weeks of conservation in the open-air in the shadow, that of the same variety dried in the sun was 3 weeks longer; time did not affect seeds kept in sealed tubes or in the dessicator.

Nang-Quat harvested in dry season, left in the shadow, maintained its power much longer than Nang-Phet-Muon kept in the same way.

With regard to the rate of humidity we notice that when it decreased from 14.50% to 11.40% germinative power increased from 12% to 100% for seeds in the open-air.

So, when seeds are in contact with air, the atmosphere humidity, the rate of humidity of seeds have an important influence on their germinative power. Humidity favors the coagulation of proteins, the diffusion and hydrolysis of albumen substances. It makes the seed coat more permeable and accelerates respiration rhythm.

But, seeds kept in sealed tubes and in dessicator could maintain their germinative power to a maximum even when the rate of humidity reached 14%. In confined atmosphere, gazeous exchanges are quickly limited by the accumulation of carbon dioxide and the rarefaction of oxygen. In the dessicator, we must add the effect of dessication which makes the seed coat more impermeable and stop respiration.

Experiments on the influence of temperatures were begun on Nang-Phet-Muon at once after harvest when its germinative power was to a minimum, and on Nang-Quat 10 weeks after harvest when its germinative power was to a maximum.

Results show that alternatives temperatures had a retarding effect on Nang-Phet-Muon and a destructive one on Nang-Quat. The responsible temperature is the higher because seeds kept at 28° C had a normal evolution. It is supposed to strengthen the respiration rhythm and enzyme destruction.

Low temperatures occasion a cooling on the acquisition of seeds maturity as well as on enzyme activity. But the raising of Nang-Quat power to 100% and the slow evolution of Nang-Phet-Muon power to a maximum show that low temperature have the same effect then vernalisation, bringing insoluble glucides and nitrogen compounds to soluble and useful ones.

Seeds possessed two amylases: the α amylase or amylase of activity appearing when germination occurs and the β amylase or amylase of dormancy present in seeds at rest.

Results show that amylases are destroyed by age and by cold. Seeds of Nang-Phet-Muon harvested in 1955 lost all their amylases activities in 1957, amylases activity of seeds kept at 15°C was lessened too. We notice that amylases activities were closely related to germinative power, α amylase was more abundant than β amylase. Seeds which has such an activity that 0.2-0.4 cc of their malt extract could bring a complete decoloration of starch has the highest germinative power.

Besides those experiments we also studied the influence of the date of harvest: None of the seeds collected 8 days before the normal date could germinate. Seeds harvested 15 days later had a higher energy. Insolation, ventilation would provide seeds on plants with favorable condition.

The effect of a long washing was determined too. Seeds were submitted as soon as harvested to a washing of 6 to 96 hours. They had a higher power than those of the same age but not washed; the longer washing lasted the higher their energy was.

We suppose that fresh seeds would keep substances which delay germination, substances which would act as inhibitors or as activators according to their concentration.

So, one variety of Rice seeds can see its germinative power vary with the way of conservation, for instance Nang-Phet-Muon left in the open-air, cannot germinate after three months, but kept in sealed tubes, they are still alive after sixteen months.

Once inhibitors taken away, factors like age, humidity, light, temperature, oxygen rarefaction and carbon dioxide accumulation, act through the medium of biological phenomena, in disturbing the respiration rhythm, intensifying oxydations, degradations, olden in one word the living matter, and thus lessen germinative power and energy.

STIMULATION OF YIELD IN HEVEA BRASILIENSIS†

P. DE JONGE

Botanical Division, Rubber Research Institute of Malaya, Kuala Lumpur, Federation of Malaya.

It is not the intention of this communication to discuss the different theories which have been brought forward in an attempt to explain the high increase in yields obtained after application of a yield stimulant. Much work has been done and still more will have to be done to explain this phenomenon. Here we limit ourselves to discussing results obtained in field experiments carried out at the Experiment Station of the Rubber Research Institute of Malaya, and on cooperating estates.

LONG TERM EXPERIMENTS

I. (a) *Single cut 100% intensity tapping systems*

Our experiments on trees initially 18 years old have shown that periodical applications of a yield stimulant can be continued over a period of five years without inducing any signs of deterioration of the trees. However, young trees should not be treated with a yield stimulant. In an experiment carried out on clonal seedlings six years old, girthing was 30% less after application of a stimulant containing 2,4,5-T. Increased yield was obtained at the expense of growth. After about the 15th year of life, by which time the growth curve has flattened out, carbohydrate in excess of that required for growth can be mobilised for rubber production. On such trees we have not been able to detect any retardation in growth following application of a yield stimulant.

In an experiment carried out on clonal seedlings which were 18 years old at the time of the first application, the stimulant was applied at intervals of six months to a three inch strip of scraped bark below the cut. The mean yields shown in table 1 were obtained in nine half-year periods, the tapping system being alternate-daily half spiral (S/2.d/2.100%) throughout, the figures adjusted for pre-treatment differences. It is clear that the response to successive applications on a given tapping panel falls off progressively while continuous alternate-daily tapping is done. The falling off in response is not observed on budded trees.

Table 1.

The effect of stimulant on the yield of clonal seedling trees.

	Control	Treated with 2,4,5-T	
	g/tree/ tapping	g/tree/ tapping	as % of control
1st 6 months	27.4	48.3	176%
2nd ,,	25.7	44.6	174%
3rd ,,	30.6	42.3	138%
4th ,,	31.4	42.5	135%
5th ,,	34.1	41.7	122%
6th ,,	35.9	41.5	116%
7th ,,	42.5	46.2	109%
8th ,,	30.5	42.0	138%*
9th ,,	33.7	41.4	123%

* New panel in bark of second renewal.

In an experiment carried out on buddings of nine clones, planted in 1929, highly satisfactory yield increases were still obtained after four years of continuous half-yearly treatments (table 2). Throughout this experiment tapping was once again alternate-daily on a half-spiral cut on bark of first renewal.

A further experiment has been set up to investigate the optimum frequency of application. This experiment is being conducted on clonal seedling trees planted in 1930 and tapped on renewed bark, to determine at what intervals stimulant should be applied on trees tapped alternate-daily on a half-spiral cut. The results covering the first experimental year of tapping are summarised in table 3, in which the figures have been adjusted for pre-treatment differences. We have already completed another 10 months of tapping, but the data can only be validly compared over yearly periods. The figures show that, during the first year, treatment 4 has produced the highest yield; but the extra yield obtained is not large when compared with treatment 6. Treatment 5 would have yielded less than treatment 6 if no accidental scraping had been done.

This incomplete experiment suggests that half-yearly applications may prove more profitable in the long run than more frequent applications.

† Presented by P.R. Wycherley.

Table 2.
The effect of stimulant on the yield of budded trees.

	Control	Treated Trees	
	Yield in g/tree/ tapping	g/tree/ tapping	as % of control
Pretreatment	32.6	35.2	108%
1st 6 months	32.2	46.7	148%
2nd ,,	31.4	43.6	139%
3rd ,,	26.8	35.4	132%
4th ,,	27.3	40.3	148%
5th ,,	30.5	43.1	141%
6th ,,	33.7	49.1	146%
7th ,,	30.7	40.6	132%

I. (b) *Double cut 200% intensity tapping systems*

Our experiments on the tapping of high cuts (ladder tapping) of unselected seedling trees and budded trees, combined with the use of yield stimulants and later intensive tapping, have been very successful. The recommendations based on these experiments are now applied on a large scale all over Malaya. Indeed, the high yields obtained from old unselected seedling trees tapped at 200% intensity (often exceeding 1,000 lb/acre) has led to the replanting programme being postponed on several estates.

The results of an experiment carried out on unselected seedling trees planted in 1929 are summarised in table 4 as adjusted mean yields over a period of 20 months. The experiment is a tree plot design, in which each tree is considered as a treatment plot. There are 50 replications, hence fifty trees are tapped on each of the systems listed in table 4. The treatments are randomised over the field. A result of this is that the control trees yield more than usual, it is believed because small amounts of the stimulant are transferred on the tapping knife to trees not treated. The effect of a yield stimulant is therefore, if anything, better than is shown by an experiment of this design.

The trees are tapped alternate-daily on a high V/2 cut on virgin bark and a low S/2 cut on bark of second renewal 2C/2.d/2.200% both on the same day. Yields of the high and low cuts have been recorded separately by coagulation of the latex in the cup on each tapping day. The following conclusions can be drawn from table 4.

1. Trees tapped S/2.d/2.100% in bark of second renewal show a significant but small response to the yield stimulant. If it is applied below the tapping cut, a high increase is noted during the first month but the yield sometimes drops below control level during later months.

2. Ladder tapping V/2.d/2.100% results in slightly lower yield than low cut tapping. This is partly caused by the shorter length of the high cut on seedling trees, partly by the high cut moving towards the junction of virgin bark and bark of second renewal where yields are always low. The yield on high cuts shows a continuous downwards trend. Applying a stimulant below a high cut gives a clearly better response than below a low cut. We therefore consider that old unselected seedling trees with poor renewed bark should be tapped on high cuts and that a stimulant should be applied at half-yearly intervals as an ordinary estate practice.

3. The yield of the high and low cuts of unstimulated trees tapped at 200% intensity (treatment 7) is practically identical with the yield

Table 3.
The effects of frequency of application of stimulant treatment.

Treatment	Mean yield in lb/acre/ month	as % of control
1. Control (S/2.d/2.100%)	69.2	100%
2. as 1. plus monthly stimulation *above* the cut	96.2	139%
3. as 1. plus bi-monthly stimulation *above* the cut	94.2	136%
4. as 1. plus stimulation *below* the cut at 3 months intervals	117.7	170%
5. as 1. plus stimulation *below* the cut at 4 months intervals	105.1*	152%
6. as 1. plus stimulation *below* the cut at 6 months intervals	105.7	153%
7. as 1. plus stimulation *below* the cut at 12 months intervals	86.9*	126%

* All trees belonging to these treatments were accidentally scraped when treatments 3 and 6 were due for application. This has resulted in a temporary highly increased yield level.

of trees tapped on a high cut only (treatment 4) and of trees tapped on a low cut only (treatment 1). There is no interference between cuts on these low yielding trees if they are kept 4 feet or more apart. A further considerable boost in yield can be obtained when tapping at 200% intensity by applying a stimulant and, as might be expected, the highest yields are recorded when both cuts are treated. Even under these treatments, no cases of brown bast have yet been recorded. A stimulant should not be applied above the low cut on trees tapped on two cuts (treatment 11) for this greatly reduces the yield of the high cut.

The 200% double cut tapping system requires double the number of tappers employed on normal tapping. If labour or tapping costs are the limiting factors, periodic double cut systems with stimulant application should be considered, with tapping to be done during the periods of flush yields after stimulant application.

Another experiment on intensive tapping is being conducted on the site of an old clone trial. Nine clones are being compared, in four replications. Before the experiment started the trees, which had been planted in 1929, were tapped on bark of second renewal. The figures given in table 5 show that high level tapping of budded trees results in a greatly increased yield which, however, falls off as the cut moves towards renewed bark. There are large clonal differences. Those clones which were considered high yielding before the war have generally responded outstandingly to high level tapping, whereas the moderate and low yielding clones yielded only slightly more on high cuts, as is shown in table 6. The progressive fall in yield on high cut tapping is pronounced for the high yielders, but in both classes the high cuts yielded less than the low cuts after two years of tapping.

An inter-action between cuts on trees tapped at 200% intensity, depressing the combined yield, is suggested more strongly for the high than for the low yielding class, as might have been expected, but in neither group has there been an increase in brown bast incidence. Though it might reduce the inter-action to tap the cuts on different days, this is difficult in practice because tasks tapped on high cuts are only about 70% as large as those tapped on low cuts.

On this budded material, the worst of which still yields appreciably more than the unselected seedling trees discussed earlier, it might be desired to separate the tapping cuts by more than four feet, but this is not feasible.

The experiment has not been sub-divided, in part the tapping treatments being combined with application of a stimulant, but the results are not complete.

Table 4.
The effect of stimulant treatment and tapping systems on old unselected seedlings.

Tapping system	Yield in lb/acre/month			% of control
1. S/2.d/2.100% in bark of second renewal	46			100%
2. as 1. plus half yearly application of stimulant *below* the cut	55			117%
3. as 1. plus monthly application of stimulant *above* the cut	55			117%
4. V/2.d/2.100% in virgin bark opened at 90 inches from the ground	40			87%
5. as 4. plus half yearly application of stimulant *below* the cut	63			137%
6. as 4. plus monthly application of stimulant *above* the cut	51			111%
	Low cut	*High cut*	*Total*	
7. 2C/2.d/2.200% — one high V/2. cut in virgin bark — one low S/2. cut in renewed bark	44	41	85	185%
8. as 7. plus half yearly application of stimulant *below* high cut	44	54	98	213%
9. as 7. plus monthly application of stimulant *above* high cut	46	55	101	219%
10. as 7. plus half yearly application of stimulant *below* low cut	57	40	97	211%
11. as 7. plus monthly application of stimulant *above* low cut	47	32	79	172%
12. as 7. plus half yearly application of stimulant *below* both cuts	54	61	115	250%
13. as 7. plus monthly application of stimulant *above* both cuts	49	49	98	213%
14. as 7. plus application of a stimulant to alternating high and low cuts at three months intervals.	54	54	108	235%

Table 5.
The effects of tapping systems on older clones.

Tapping system	Mean yield in lb/month/acre				
	1st 6 months	2nd 6 months	3rd 6 months	4th 6 months	5th 6 months
Trees tapped on high cut (V/2.d/2. 100%)	105	95	90	82	70
Trees tapped on low cut (S/2.d/2. 100%)	62	70	80	85	85
Trees tapped (2C/2.d/2. 200%)	155	150	147	150	131

Table 6.
The effect of tapping of high and low yielding clones.

"Low and Moderate" Yielders
Clones AVROS 152, AVROS 49, AVROS 50, PB 23, and BD 5.

Tapping system	Mean yield in lb/acre/month				
	1st 6 months	2nd 6 months	3rd 6 months	4th 6 months	5th 6 months
Trees tapped on high cut (V/2.d/2. 100%)	60	71	76	70	57
Trees tapped on low cut (S/2.d/2. 100%)	58	63	72	78	77
Trees tapped 2C/2.d/2. 200%)	117	129	129	134	121

"High" Yielders
Clones PB 186, Tjir 1, Pil A 44, and Pil B 84

Trees tapped on high cuts (V/2.d/2. 100%)	153	125	109	96	86
Trees tapped on low cuts (S/2.d/2. 100%)	68	79	89	94	95
Trees tapped (2C/2.d/2. 200%)	203	173	169	170	143

The major conclusion from these experiments with double cut tapping systems is that fully mature rubber trees can stand up to more intensive tapping than has been practised for a long period in the past. A more intensive tapping policy is now practised on a large scale in Malaya in areas due for replanting in the foreseeable future, and the results obtained are generally highly satisfactory.

SHORT TERM EXPERIMENTS

II. (a) *Optimum concentration of 2,4,5-T in a stimulant*

An experiment has been conducted on low yielding unselected seedling trees tapped on bark of second renewal to find the optimum concentration of 2,4,5-T (normal butyl ester) to be used in a palm oil/petrolatum carrier. Knowing from previous experience that a 1% concentration was about right, we tried the following concentrations: 0.5%, 1%, 1.5%, and 2% acid equivalent of 2,4,5-T. The results of this experiment, covering a period of 16 months, are given in table 7. The figures confirm the soundness of the present composition of the commercial 2,4,5-T yield stimulant, which is made up according to our prescription and contains 1% acid equivalent of 2,4,5-T. Not only did the 2% concentration result in severe burring of the bark, but it did not induce as high a peak yield as the 1 and 1.5% concentrations.

II. (b) *Upward versus downward tapping on seedling trees*

Upward tapping has been carried out in our experiments during the final year before replanting and has proved successful when combined with application of a yield stimulant. Its major disadvantage is that it leads to high bark consumption (a) because thicker shavings are taken and (b) because it is necessary to leave a one-inch strip of bark untapped at intervals of half a year, to guide the latex into the channel.

Upward tapping has been compared with downward tapping on low yielding unselected seedling trees planted in 1930. For downward

Table 7.
The effects of different concentrations of 2,4,5-T.

Mean Yield	Control	0.5% 2,4,5-T	1% 2,4,5-T	1.5% 2,4,5-T	2% 2,4,5-T
in grams/ tree/ tapping	33	44	53	56	50
as % of control	100%	133%	180%	170%	151%

tapping a high V/2 cut was opened in the virgin bark at 90 inches from ground level. For upward tapping a V/2 cut was opened in the virgin bark with the lowest point one inch above the renewed bark. Tapping was done alternate-daily. The results summarised in table 8 show a slight initial advantage for upward tapping without stimulant, when compared with downward tapping especially during the first two months after opening. The difference may prove to be more pronounced on higher yielding material. The advantage of upward tapping becomes clearly apparent when it is combined with application of a stimulant. However, we do not recommend this method for practical application except during the final year of high intensity tapping, because of the high bark consumption, which was 39 inches for upward tapping against 27 inches for downward tapping during a period of 23 months.

Table 8.
The effects of stimulant treatment and upward tapping.

Tapping system	Mean yield in lb/acre/month		
	1st 6 months	2nd 6 months	3rd 6 months
1. V/2.d/2.100%-downward	37	36	37
2. as 1. plus half yearly stimulant application	50	53	50
3. V/2.d/2.100% upward	40	39	33
4. as 3. plus half yearly stimulant application	67	68	55

FLOWERING TREES THAT FAIL TO FLOWER IN ALIEN LANDS

EDWIN A. MENNINGER

Stewart, Florida, U.S.A.

Plantsmen wanting their plants to bloom is scarcely a new aspiration; trying to force them to bloom is a process almost as old. It is significant that to the present day, almost the only success attendant upon this struggle has been achieved by physical means; chemical procedures have scored practically a complete failure.

The author has been introducing to South Florida (where temperatures remain above the freezing point) all the showy flowered trees of the tropics that have been found available, either seeds or plants, and over a period of 25 years he has established there more than 1,000 species, constituting probably the largest collection of "flowering" trees in the world. With plenty of examples to draw from, he is confronted with the fact that a good many of the most beautiful flowering trees in the world do not want to flower when they get moved to this new environment.

Growers have observed that many plants will not flower at all, or will flower only after considerable delay, unless certain environmental conditions are met which simulate conditions that prevailed where the plants previously or normally grew. The two Temperate Zone conditions to which most study have been given are the period of low temperature storage required between growth periods (peony roots, carrots, gladiolus bulbs, etc.) and the photoperiod of length of day (chrysanthemums). These conditions have been studied chiefly in connection with non-woody plants. Similar environmental conditions are the basis of extensive research done by fruit trees physiologists to discover nitrogen-carbohydrate relationships preceding flowering and fruiting. They have learned much. But aside from physical control measures that range from barking to root pruning, they have not come up with any formula to force bloom that is sure fire even for a single species. Nobody, in the history of research in this field, has ever succeeded in making a plant come into bloom by chemical means, i.e., spraying it with a "sex-life-awakener" or adding this to the soil, except in one isolated instance. The pineapple is the only plant ever to be brought into flower as the result of chemical treatment.

Today the plant world is being invaded by new chemical compounds that may change this picture. Chief of these at the moment are gibberellic acid and some of its derivatives, and triiodobenzoic acid (called TIBA in the trade). The uses of these, as well as the several physical methods of inducing bloom will be discussed briefly, but first the author cites some outstanding showy-flowered tropical trees that are being grown successfully in Florida but which so far are worthless as ornamentals because they will not or do not flower normally. No research work has been done in the United States to determine the reasons (environmental or others) that these and other tropical transplants do not bloom, or whether these conditions could be corrected. To remove ancestry and geography as influencing factors, six trees are cited belonging to different natural orders and coming from different countries.

Jacaranda mimosaefolia (Bignoniaceae). This beautiful species is widely planted as a street tree in southern California, blooms for nurserymen there when still 3 feet high in a can, and in the belt across central Florida from Tampa to Daytona Beach it blooms at an early age, often 2 years. However, south of this belt, the trees ordinarily will not bloom at all until they are 25 years old or more. I have a 40-foot tree in my yard that is 27 years old and bloomed last year for the first time. This hesitancy to bloom is being overcome in south Florida by grafting 40-year-old wood onto seedlings and these bloom the second or third year. But this is an expedient rather than a solution. What factor is it that awakens the sex instinct of the Jacaranda tree and makes it want to bloom? There are exceptions. One of my friends has a tree that bloomed beautifully when it was 4 years old but has failed to throw a single blossom the succeeding two years. In my nursery I have a hundred trees and they do not bloom. I am familiar with the theory that, like peaches, the Jacaranda requires a certain number of cold nights to ripen the flowering buds (in contradistinction to the leaf buds) and that it gets sufficient cold for this purpose in Central Florida but does not in South Florida. I doubt the validity of this theory; at least I have seen no evidence of any connection between unseasonably cold winters in south Florida and the vigor of the Jacaranda trees—they still do not bloom. *Jacaranda sagreana*, a Cuban form, bloomed when 5 feet high; now, 6 years later, it is 18 feet high and has not bloomed again. Contrariwise, *Jacaranda chelonia* from Argentina, started blooming when 6 years old and has flowered vigorously every year.

Phyllocarpus septentrionalis (Caesalpiniaceae), a Guatemalan was introduced by Dr. Wilson Popenoe because in bloom it is such a spectacular affair that he hoped to brighten Florida's landscape with it. That was 50 years ago—almost. Trees were planted all over Florida, but although I am familiar with the location of at least 50 of them, only 3 or 4 have ever bloomed. Last year in St. Petersburg I was called on to identify a huge tree spreading over a filling station on a busy corner. It was covered with red flowers, it had a spread of 50 feet or more, and undoubtedly was one of the trees Popenoe sent in so long ago. "Nobody knows what it is," I was told by the park superintendent. Not much wonder, for it was the first time the tree had bloomed, and none of the present generation had ever seen anything like it. Two years ago I was giving an illustrated lecture on flowering trees to perhaps a hundred persons at a home in Coconut Grove, and I made the mistake of showing a kodachrome of the fiery flowers of *Phyllocarpus.* The slightly alcoholic but intensely interested host demanded that I stop the lecture; he turned on the flood lights in the garden and insisted that the entire audience troop out on the grass and look at his 50-foot *Phyllocarpus* that had never bloomed. Now by contrast, consider another leguminous tree that can hardly wait to emerge from the pot before it starts to bloom—*Chamaefistula antillanum.* Dr. Britton's book on Puerto Rico says this is a vine, but in Florida it is a handsome 15-foot tree that blooms wildly from December into April. It is cauliflorous all over the trunk and main branches as well as producing axillary and terminal clusters among the leaves. It just insists on blooming, and it starts when 6 inches high! I call attention to the fact that it blooms all through our coldest season.

Metrosideros tomentosa (Myrtaceae). The New Zealand Christmas tree does exceedingly well in California around Los Angeles, is highly resistant to salt spray and cold wet winds, and there are fine specimens to 35 feet high. In Florida the tree is sparingly grown from Homestead as far north as Winter Haven in the center of the state, but to the best of my knowledge it has never bloomed in Florida. I doubt that temperature has anything to do with flowering inclinations, as the mercury drops to 25° in Winter Haven and Homestead on occasion. I doubt if high humidity is the answer, because we have 5 times the rainfall they have in Los Angeles and it is reasonably well distributed through the year. Occasionally we have prolonged dry spells but we also have month-long wet spells that would awaken the sexual activity if only water were needed. The plants grow well enough in Florida, although mortality without obvious reason is above the average. In contrast, there are a good many Myrtaceous plants that grow and bloom enthusiastically in South Florida, like the *Callistemon* and *Melaleuca*, a score of *Eugenia*, etc.

Triplaris americana (Polygonaceae). This is one of 4 species in cultivation in South Florida, and the female tree is one of the tropics' breathtaking sights when in bloom. Unfortunately Florida is not sharing the enjoyment of this spectacle because, although there are thousands of these trees on the Florida landscape, I have yet to see one of the female trees in bloom, and I have been looking a good many years. Contrast with this the common seagrape *(Coccoloba uvifera)* in the same group, which is native on our shores, blooms and fruits plentifully, and is highly ornamental even if the bloom is not showy.

Millettia (Papilionaceae). There are 8 species of this tree in my garden, one from India *(M. ovalifolia)* which blooms beautifully every March, and 7 from Africa, not one of which has ever bloomed though several of them are old enough and large enough. They grow well, their foliage is handsome, but there are no flowers.

Stenocarpus sinuatus (Proteaceae). Grows splendidly through Florida but does not bloom. In its native Australia blooming is usual at 8 years but is sometimes delayed until 15 years old, which is bad enough. Here in Florida, there are a good many specimens, but the only one in the State that blooms is at Lake Placid. Contrast this with *Grevillea banksi fosteri*, of the same Natural Order, which blooms and fruits most precociously all over Florida and I have had it in flower in a gallon can when 8 inches high from seed.

The dividing line between juvenility in trees and the period in which they have achieved maturity and are ready for flowering and fruiting, is ordinarily not well marked. But in the unique flora of Australia and New Zealand, many trees have this change period or phase in their growth exceedingly well indicated, especially in their leaf structure.

Many *Eucalyptus* trees have leaves in the juvenile stage so entirely different in size, shape and arrangement from the mature tree of the same species, that many observers have fallen into the trap of believing they are different trees. Most New Zealand trees are so markedly different in the juvenile and mature stages as to seem like different plants. It is conceivable that this dividing line between youth and middle age is equally as important in other trees, though not so apparent, and inability to cross that line easily in a new environment might be an explanation for absence of flowering. Is something more than age required to push the tree across the line of maturity?

There are other avenues that should be explored. Several experimenters with the transplanting of the Proteas—an exceedingly difficult operation in most instances—have found a measure of success by transferring soil cultures from the old location to the new, along with the plant. The presumption is that certain microorganisms complement the plant, perhaps are required to make available the food supply in a form the plant can use, perhaps have other functions peculiar to the species. The same reasoning might be applied to the non-flowering of certain trees in an alien environment.

It is conceivable that a change in the degree of acidity from that enjoyed in the original location, might accelerate the growth of leaf buds at the expense of flowering tissue and create an imbalance that might even develop into an antipathy for flowering. The peculiarities of the problems involved might even pose the question whether sex is a physical or a metaphysical demonstration.

Dr. William J. Robbins, director of the New York Botanical Garden, has written me in this connection.

"The question of inducing trees to flower and fruit is one which has received a great deal of attention, and only rule of thumb methods have resulted without too much real basic knowledge. In general, conditions which favor vegetative growth interfere with flowering. Too much nitrogen, too much water, too much of anything which favours the general vegetative growth of a plant may prevent flowering. There seems to be an antagonism between vegetative growth and flowering, but just why is still a mystery.

On this basis various procedures have been followed to induce flowering. Root pruning is one. In some instances actually digging up the tree and exposing its roots for period has been used. Ringing a twig or a branch has been found to be effective sometimes. Limiting applications of nitrogenous fertilizers also works on occasion. Your comment on Jacaranda blooming in California in cans suggests that the slower growth which probably occurs in the dry air of California and in the root bound condition in a can, explains the difference. I note also, how well the trees grow in Florida. I wonder whether they may not grow too well and if you could find some practical method of limiting growth you might make them flower.

For some plants day length is the controlling factor in determining blooming. Though some are indifferent to day length others bloom only when the days are long and some only when the days are short. I don't believe this is of any importance for your problem. Strong sunlight seems to be important in some instances—in shade those plants fail to bloom and in strong light they do. Temperature is important also. In general, the temperature limits for blooming are narrower than for vegetative growth. At one time a good deal of attention was given to the importance of the ratio between carbon and nitrogen in the plant. It was thought that if the relation between these two elements did not fall within certain limits, the plant would not flower. This idea is less popular now than it once was.

There is some evidence for a flowering 'hormone' which plants must produce in sufficient quantity before they flower, but it is still unidentified. It would not surprise me if in the next few years substances were found which, sprayed on a plant, would induce it to flower. As yet, however, we do not have such substances and can only use methods of the sort I mentioned in the beginning of this letter.

Is there any marked difference in soil between the areas where the trees in which you are interested bloom and those where they do not? The amount of minor elements like zinc, manganese, boron, etc., your plants are able to absorb might be important, especially if your soil is calcareous. It might be worth while to see what would happen if you sprayed your plants with one of the leaf sprays now on the market which furnish these minor elements."

Besides the physical measures suggested by Dr. Robbins to induce flowering, several others are noteworthy. Sometimes thinning a fruit tree helps to make it bloom by letting more light into the crown, thus increasing the production of carbohydrates. Bending the branches to a horizontal position often helps. Both these procedures have the same effect as girdling as suggested by Dr. Robbins. Many persons have tried spraying trees with growth-promoting compounds, but there is no evidence that this has induced flowering.

Perhaps the most interesting physical procedure is that suggested by Dr. Karl Sax, professor of botany at Harvard University. In a letter to me, Dr. Sax briefly explained his procedure to induce flowering, thus:

"We do it by inverting a ring of bark on the trunk or branch of a tree. We do this in mid to late June and always get flowers the next year with apple varieties which have been grafted, but not with seedling trees.

The technique is tricky, the bark must fit closely when inverted, it must be bound tightly with a wide rubber band, and all cut seams must be covered to exclude air. Try it on some surplus trees first."

In considering chemical compounds that are or might be useful in inducing flowering, we are confronted immediately with the fact that almost no experimental work has been done to date on woody plants, and the two chief chemicals being tried are still too new to permit any conclusions.

Chief of these are the gibberellins, a group of these closely related compounds derived from a fungus disease of rice. Almost all plants treated with any of the gibberellins, respond with accelerated growth, and there are other effects. The gibberellins have overcome to some extent the two Temperate Zone environmental obstacles to flowering heretofore cited—cold storage delay and photo-periodism. Gibberellic acid has greatly increased certain seed yields. An experimental work done at the University of California has prompted Anton Lang of the Department of Botany to predict: "The flower-promoting effect of gibberellin may prove of practical value . . . raising certain ornamental plants in such climatic regions where they ordinarily do not give reliable results."

The other chemical compound being tried experimentally is TIBA (2, 3, 5-triiodobenzoic acid) in extremely dilute concentrations. Dr. A.C. Leopold and Dr. Frances S. Guernsey of Purdue University, Agricultural Experiment Station, Lafayette, Indiana, are pioneers in this work. One of their papers says: "In view of the fact that treatment of seeds or seedlings with various chemical materials plus low temperatures appears to be promotive of flowering in plants generally, it may be justifiable to designate the treatment with a simple name. We tentatively propose the term *chemical vernalization*." However, the authors have done almost all their work with herbaceous species, and this is true of others who have been experimenting with TIBA.

The foregoing discussion leads back to the original observation that the phenomena of flowering trees that do not flower remains an enigma.

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