1955 PROCEEDINGS

NATIONAL SHELLFISHERIES ASSOCIATION

Volume 46

PROCEEDINGS

of the

NATIONAL SHELLFISHERIES ASSOCIATION

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TABLE OF CONTENTS

EDITOR'S NOTES

Appointment of Editorial Committee. Although this volume of the *Proceedings* contains only Convention papers and comments on Association affairs for the year 1955, acceptance by the Association at its Annual Convention in 1956 of a revised constitution should be announced at this time. The revision establishes an Editorial Committee consisting of three members appointed for staggered terms of three years. The Committee is responsible for the establishment of standards, for editing, and for publishing the *Proceedings of the National Shellfisheries Association* (officially abbreviated *Proc. Natl. Shellfish. Assoc.*). President Francis Beaven appointed the following persons to take office in August, 1956: Editor, Melbourne R. Carriker; Associate Editors, Thurlow C. Nelson and Jay D. Andrews.

Information for Contributors. Scientific papers delivered at the Annual Association Convention and additional papers submitted by members of the Association will be considered for publication, in entirety or in abstract form. Papers appearing in print elsewhere are not acceptable.

Manuscripts will be judged on the basis of the original data, ideas, and interpretations which they contribute. They will be examined by the Editorial Committee and by other competent reviewers. Each paper should be ready for publication before submission to the Editorial Committee.

Manuscripts should be typewritten and double-spaced; carbon copies are not acceptable. Tables and footnotes should appear on separate sheets; most footnote material should be incorporated in the text. Scientific names should be underlined. Use the following style in lists of literature citations: "Galtsoff, P.S. 1955. Recent advances in the studies of the structure and formation of the shell of *Crassostrea virginica*. Proc. Natl. Shellfish. Assoc. 45: 116-135." Reference to literature citations in the text should be made as follows: "Loosanoff (1955)." Abbreviations for the names of serial publications will be patterned after those employed by *Biological Abstracts* (for special list see *Biol. Absts.* 29(5): v-xxxv, 1955). Abbreviations for units of weight and measure, and fundamental rules for the use of these, will be patterned after those given in the *Handbook of Chemistry and* Physics, 36th. Edition, pages 3108-3134.

Illustrations should be reduced to a size to fit on paper 8 x 10½ inches with ample margins; photographic copies of high quality are preferred to originals. Illustrations smaller than page size should be loosely attached to plain white paper with rubber cement, and the legend typed in the proper position under the illustration. More than one illustration may appear on a sheet. If the illustration is page size, the legend, properly spaced, should be typed on a separate sheet of paper.

No illustrations should appear on text pages.

Every paper should be accompanied by an author's summary, complete in itself and understandable without reference to the original article, for submission to Biological Abstracts by the Editors. Address all manuscripts and correspondence concerning editorial matters to the Editor, M. R. Carriker, Department of Zoology, University of North Carolina, Chapel Hill, North Carolina. All manuscripts should reach the Editor prior to October 1 for inclusion in the Proceedings of that year.

Duplimat masters and plates used in the reproduction of the Proceedings will be retained for one year. Reprints can be made at cost, expense to be borne by the author. Authors desiring reprints should communicate directly with Mr. Jesse C. Bowen, Secretarial Service Company, P. O. Box 2313, Durham, North Carolina.

ANNUAL CONVENTION

The 1955 Annual Convention of the National Shellfisheries Association was held jointly with the Oyster Growers and Dealers Association of North America and the Oyster Institute of North America, July 31-August 4, at the Emerson Hotel, Baltimore, Maryland. In addition to the contributed technical papers, the formal program consisted of a special symposium on "Pollution Control in Shellfish Growing Areas."

OFFICERS AND COMMITTEES OF THE NATIONAL SHELLFISHERIES ASSOCIATION FOR THE YEAR 1954-1955:

Officers

President: Alphonse F. Chestnut, Institute of Fisheries Research, Morehead City, North Carolina.

Vice-President: G. Francis Beaven, Maryland Department of Research and Education, Solomons, Maryland.

Secretary-Treasurer and Editor: Melbourne R. Carriker, Department of Zoology, University of North Carolina, Chapel Hill, North Carolina

Executive Committee

Alphonse F. Chestnut
G. Francis Beaven
Melbourne R. Carriker
James B. Engle

Other Committees

Nominating Committee: Victor L. Loosanoff, Chairman; G. Robert Lunz, Jr., and Fred W. Sieling.

Resolutions Committee: J. L. McHugh, Chairman ; William P. Ballard, and Eugene L. Cronin.

Program Committee: J. Francis Beaven, Chairman; Philip A. Butler, James B. Engle, William E. Fahy, Dana E. Wallace, and David H. Wallace.

RESOLUTIONS

The following resolutions submitted by the Resolutions Committee were unanimously adopted by the Convention:

WHEREAS, according to the Constitution of the Oyster Growers and Dealers Association of North America, Inc., the tenure of office of Mr. J. Richards Nelson as President must terminate, and

WHEREAS, under his leadership, particularly by virtue of his success as a commercial oyster grower, his family tradition of experience and high competence in scientific research, and his exceptional personal characteristics, the Oyster Institute of North America has prospered,

THEREFORE BE IT RESOLVED, by the Oyster Growers and Dealers Association of North America, the National Shellfisheries Association, and the Oyster Institute of North America, in Convention assembled, that their appreciation of the contributions of Mr. Nelson to the benefit of the oyster industry as a whole be duly recorded and communicated to him.

WHEREAS, the Congress of the United States of America has seen fit to further the needs of the fishing industry by enacting legislation in the form of the so-called Saltonstall-Kennedy Act, and

WHEREAS, the United States Fish and Wildlife Service, in advising the Committee appointed to allocate these funds, and the Committee itself, in considering the many requests before it, have given due consideration to the problems of the oyster industry by approving research projects designed to alleviate some of its most pressing problems,

THEREFORE BE IT RESOLVED, by the Oyster Growers and Dealers Association of North America, the National Shellfisheries Association, and the Oyster Institute of North America, in Convention assembled, that their appreciation of this consideration be recorded in the convention minutes, and that copies of this resolution be forwarded to the Secretary of the Interior and the Director of the Fish and Wildlife Service.

WHEREAS, during the past year the oyster industry of North America has lost one of its most competent scientific workers in the person of Dr. A. E. Hopkins, and

WHEREAS, the many contributions of Dr. Hopkins to our knowledge of the oyster are duly recognized and appreciated,

THEREFORE BE IT RESOLVED, by the Oyster Growers and Dealers Association of North America, the National Shellfisheries Association, and the Oyster Institute of North America, in Convention assembled, that their appreciation of the contributions of Dr. Hopkins be duly recorded in the convention minutes, and that a copy of this resolution be sent to his immediate family.

WHEREAS, during the past year the oyster industry of North America has lost one of its most influential members, in the person of Mr. William M. McClain, and

WHEREAS, the contributions of Mr. McClain, as second Vice-President of the Oyster Growers and Dealers Association of North America, Inc., and as an untiring supporter of the oyster industry, to the benefit of the industry as a whole, have been numerous and significant,

THEREFORE BE IT RESOLVED, by the Oyster Growers and Dealers Association of North America, the National Shellfisheries Association, and the Oyster Institute of North America, in Convention assembled, that their appreciation of the contributions of Mr. McClain to the betterment of the industry be duly recorded in the convention minutes, and that a copy of this resolution be sent to his immediate family.

WHEREAS, the Bethlehem Steel Company, in planning a television commercial which will feature the oyster can, has shown great consideration for the marketing problems of the oyster industry, and

WHEREAS, the broadcasting of this commercial on the program "Bethlehem Sports Time" will bring to the attention of a wide audience the many virtues of this foremost seafood delicacy, and will introduce the oyster to a great many people heretofore unfamiliar with its virtues,

THEREFORE BE IT RESOLVED, by the Oyster Growers and Dealers Association of North America, the National Shellfisheries Association, and the Oyster Institute of North America, in Convention assembled, that their appreciation of this consideration be recorded in the convention minutes, and that a copy of this resolution be forwarded to Mr. Husted, the Manager of Sales of the Bethlehem Steel Company.

FINANCIAL STATEMENT OF THE NATIONAL SHELLFISHERIES ASSOCIATION
FOR AUGUST 1, 1954, TO AUGUST 1, 1955:

Receipts:

Cash on hand August 1, 1954	$ 440.18	
Annual dues and arrears	325.00	
From the Oyster Institute of North America for typing and mailing the "Proceedings" for 1953	59.75	
Total Income		$ 824.93

Expenditures:

Postage	$ 18.40	
Mimeographing, letters and revised N.S. A. Constitution	9.65	
Bank services	1.28	
Office supplies and expenses	27.51	
Cost of Dr. T.C. Nelson's reprints for distribution to N.S.A. members	10.00	
Typing and mailing "Proceedings" for 1953.	59.75	
Total Expenditures		$ 126.59

NET BALANCE. . . . . $ 698.34

Respectfully submitted,

Melbourne R. Carriker
Secretary-Treasurer

OPENING REMARKS OF THE PRESIDENT OF THE NATIONAL SHELLFISHERIES ASSOCIATION

A. F. Chestnut

Institute of Fisheries Research
Morehead City, North Carolina

As we gather together at another of our annual meetings, it is a pleasure for me to welcome the members and friends of the National Shellfisheries Association. This year we meet in an area that is rich in oyster history, the city of Baltimore.

This city can rightly claim the birth and development of an industry that reached its greatest development in this country--- and later gradually declined. The oyster business first reached maturity in New York and New England where Fair Haven, Connecticut, was reported as the country's first oyster packing center. However, as early as 1811 vessels from Fair Haven and other northern ports were supplementing their local supply with Chesapeake oysters.

Some enterprising men from Connecticut were reported to have established an oyster business in Baltimore in the 1830's. The first oyster packer to can oysters here was Edward Wright, a native son from Kent County, Maryland. From this beginning grew an industry that handled between 9 and 10 million bushels a season. In Baltimore alone more than 800,000 bushels of oysters were consumed a year. Forty-five firms were engaged in oyster packing during the decade 1880-1890.

The development of oyster biology in this country also had its beginning in Baltimore. The foundations of marine ecology in this country were laid by Louis Agassiz who came to America in 1846 from Switzerland. He taught the men that in turn trained the pioneer American ecologists. With the establishment of a summer laboratory on Penikese Island off Woods Hole, Massachusetts, in 1873, Agassiz had a direct or indirect influence on the establishment of the many marine laboratories along our coasts.

The famous Johns Hopkins University was established in Baltimore in 1876. One of the three biologists who became associated with this institution was Dr. William Keith Brooks, a student of Agassiz. Professor Brooks had a great influence on oyster biology and on the development of zoology in this country. It is interesting to read and hear about this stimulating teacher and ardent investigator. Studies on the oyster began in 1879 and were continued for many years. In 1882 the governor of Maryland appointed Professor Brooks chairman of the Oyster Commission of the State of Maryland.

Dr. Thurlow C. Nelson in his introductory remarks at our meeting at Old Point Comfort in 1949 pointed out the legacy that Dr. Brooks has left in his students. Some of these students associated with oyster biology were: James L. Kellogg, Julius Nelson, Caswell Grave, Otto Glaser, Robert E. Coker, Gilman Drew, D. H. Tennett, G. LeFevre, and many others.

The spawning of biologists from the Chesapeake area has been comparable almost to that of the oyster. Over half of the scientists appearing on our program have at one time or another been associated with oyster studies in Chesapeake Bay.

Turning now briefly to matters of the Association, we are gratified to note the continued growth in membership. Although this has reached an all time high, a considerable increase may be expected in the future. Our "Proceedings" have been further improved, and you will note that a volume number has been assigned the forthcoming issue. In past years your secretary has functioned as the unofficial editor. We hope future issues will continue to improve under the direction of an editorial committee whose appointment is included in a proposed revision of the constitution of the Association, a copy of which each member has received. We hope a revised constitution may be adopted in the near future so that the Association can function more efficiently.

Your officers extend a cordial welcome to you all and trust this meeting will be profitable as well as a time of fellowship in renewing acquaintances and meeting new friends.

It has been a distinct privilege to serve as your president for these past two years.

ANNUAL REPORT OF THE PRESIDENT OF THE OYSTER GROWERS AND DEALERS ASSOCIATION OF NORTH AMERICA

J. Richards Nelson

The F. Mansfield & Sons Co., New Haven, Connecticut

Your Association has had an active year. A considerable number of problems have arisen. Most of them have been solved; a few are still being dealt with, but in all cases the position of the oyster industry has been well represented.

Annapolis is an advantageous location for our office in the heart of Maryland's oyster production, yet close enough to Washington so that our director, Mr. Wallace, can readily keep in touch with the officials of the several government departments that deal with our industry. By meeting problems quickly and efficiently he has been able to solve many of them before the situation became troublesome. This is sound execution of trade association policy.

The demand for educational material which our Institute distributes to school teachers increased 13.5 percent. One hundred and twenty-five thousand of these bulletins were sent out in reply to requests and we can assume that most of them are put to good use. Many phases of the oyster industry are covered in the subject matter: culture of our product, harvesting, packing and shipping, food value and recipes. Bringing this information to school children is one effective method of keeping the public informed about our industry -- both the present and future generations.

Our Public Relations Committee, under the chairmanship of Mr. Royal S. Toner, and its Oyster Information Bureau functioning efficiently under Mr. Abel E. Kessler, continued their good work during the year. A tremendous volume of information in the form of newspaper and magazine articles, radio and television time, all helpful to our industry, has resulted. I regret that lack of funds has made a curtailment of the activities of the Committee necessary. Projects have been put in motion that result in continued requests for material and information on oysters. Only this past week I received a request through Mr. Kessler from one of the country's largest television studios for a few dozen oysters in the shell to exhibit on a nation-wide program. The request has been filled. It will be unfortunate if our Association does not take steps to insure the continuation of adequate financial support for the important work of this committee.

This past September the U. S. Public Health Service called a conference of public health officials from all over the country. Most states were represented. The conference was attended also by officials of the Food and Drug Division and the State Department. The subject considered was concerned primarily with the need for certification of foreign shellfish that come into this country. For many years Canada has had a satisfactory reciprocal arrangement with this country under which we accept their sanitary certification and they accept ours. Shellfish have been traded back and forth about as readily as shipments move between our own states. As Canada imports a considerable volume of oysters, this is advantageous to our industry. Within recent years frozen shellfish have appeared on the market from Mexico and from Japan, and our Public Health officials have lacked a basis by which to judge the conditions under which they have been grown and packed. In some cases the Food and Drug Department has confiscated shipments because of high bacterial scores, but there is little or no basis for judging the quality of shipments in which the score is low. Representatives of the U. S. Public Health Service visited Japan and studied their shellfish producing areas for several weeks. It was their conclusion that, while many of the areas are fine, their system and conception of sanitary control are so totally different from ours that there is no practical way at present whereby these shipments could be certified. Mr. Wallace and the writer attended the conference and took the position that no foreign shellfish should be allowed to come into this country unless they are produced and packed under the same rigid sanitary regulations that are required of our domestic producers, and that compliance with these regulations must be established and maintained beyond any reasonable doubt. Since that time the Atlantic States Marine Fisheries Commission and the Gulf Marine Fisheries Commission have both passed resolutions supporting the same position.

Our Government Relations Committee, under the chairmanship of Mr. Joseph B. Glancy, met with the Fish and Wildlife Service to discuss the research projects affecting our industry. Mr. Wallace and the writer also conferred with Director Farley in regard to additional research on the oyster drill. One project set up under the Saltonstall-Kennedy Act funds is a study of the chemical control of drills. Additional drill studies are being carried out in Virginia, North Carolina, and the Gulf.

The Saltonstall-Kennedy Act provides that an amount equal to 30 percent of duties collected on fishery products shall be transferred annually for three years from the Department of Agriculture to the Department of the Interior. Expenditures for any one year may not exceed three million dollars. These funds are used for research to benefit the fishing industry. The Department of the Interior has appointed an Industry Advisory Committee of 19 members to aid it in the allocation of these funds. The writer is a member of this Committee.

The Oyster Institute has contracted with the Fish and Wildlife Service to administer the funds on a project for the utilization of salt water ponds. This is a three year project and the work is currently being carried out by Dr. Melbourne R. Carriker, using the salt water ponds on Gardiners Island, N. Y. The work has been going on since 1953 and was supported for the first two years by private subscription. The results of these early years will be available to the whole industry, together with the later results. Possible utilization of salt water ponds for producing seed and market oysters has wide application and if successful could be used on any of our coasts. Experiments with the freezing of southern oysters is another project that is being carried on with Saltonstall-Kennedy funds.

A new shellfish sanitation manual is in the course of preparation by the U. S. Public Health Service. Our industry has been consulted and suggestions are invited. Progress should be made on this project during the present convention.

During the past year Mr. Wallace appeared before the Tariff Commission opposing a reduction in the tariff on canned oysters. The position of our domestic oyster canners was presented and placed on record and the strongest possible arguments were put forward against a reduction in the tariff.

Mr. Wallace attended the recent Weights and Measures Conference in Washington and opposed the adoption of a resolution which would bring some labelling requirements in conflict with Food and Drug regulations. Resolutions adopted by the Weights and Measures Conference have the force of law in 26 of our states. We are sure that this Conference has no intention of adopting any resolutions that would be unworkable, and it has agreed to send representatives to our convention to discuss the matter. Doubtless a satisfactory solution to the problem can be found.

We have received a suggestion from the Pacific Oyster Growers Association that local and regional oyster associations be affiliated with our group. It would benefit all concerned if such groups as the Pacific Oyster Growers Association, the Louisiana Association and the Maryland Oyster Packers Association could be affiliated with us. It would make us stronger when we represent the industry in Washington, D. C.

Our Finance Committee, under the chairmanship of Mr. William Woodfield, has been actively studying the financial needs of our Association. We need a stable income even though, considering the work accomplished, we have a modest budget. Broad support from the industry is necessary. This will insure the continuation of this good work at a moderate cost to each member. The Finance Committee has been giving a lot of thought to this problem and doubtless has some recommendations to present at this convention.

In behalf of the Association, and personally, I wish to thank the Fish and Wildlife Service, the United States Public Health Service and the Bureau of Food and Drugs for their fine cooperation with our industry.

My thanks go to the committee chairmen and members of the Association and to officers and directors who have taken time from their own busy schedules to work for the welfare of the Association. The death of our beloved Vice President, William McClain, leaves a void that cannot be readily filled. His active support of our Association and his fine personality will be long remembered.

The trade magazines, Fishing Gazette, National Fisherman, and Southern Fisherman, have given our activities excellent coverage. This is much appreciated.

It has been a pleasure to work with our able director, David Wallace, and I reach the end of my term as president happy in the knowledge that my successor will find an active organization that will continue to serve the oyster industry of the whole country in the best traditions of a trade association nearly fifty years old.

ANNUAL REPORT OF THE DIRECTOR OF THE OYSTER INSTITUTE OF NORTH AMERICA

David H. Wallace

Bay Ridge, Annapolis, Maryland

The past year has been devoted to two major activities. First we have been working closely with several government agencies including the Public Health Service, the Fish and Wildlife Service, Food and Drug Administration, and Tariff Commission, and secondly we have been enlarging our membership and expanding our services to cover all segments of the industry. I will not go into detail on the first part of this work since it has already been covered by President Nelson. I believe, however, that a closer working relationship has existed this year than ever before between our organization and the various segments of government which have some interest in oysters.

While I am unable to evaluate conditions before 1951 I know that the oyster industry is now accepted as an equal partner in the Federal-State-Industry Sanitation Program. This was most evident last fall at the National Shellfish Sanitation Conference held in Washington. The industry's advice was sought and their proposals frequently accepted. Under these circumstances we believe that a much greater degree of cooperation can be obtained. It is obvious that the industry should and will be more receptive to observing recommendations particularily when they have had a part in establishing the policy or rule.

The relationship between the industry and the Fish and Wildlife Service has also been close and continuing. The appointment of J. Richards Nelson, our President, as a member of the Advisory Committee was welcomed by all those in the industry. Mr. Nelson has already distinguished himself and will continue to represent the enlightened leadership which should bring prosperity to those in the industry.

Considerable travel has been done to various parts of the country to observe local conditions and discuss oystermens' problems. In August, 1954, I attended the annual meeting of the Pacific Coast Oyster Growers Association. This contact has resulted in increased membership from the state of Washington and a closer working relationship on oyster problems of mutual interest to all sections of the country. For example, our organization represented oystermen and packers on all coasts when we appeared before the U. S. Tariff Commission during the winter. We opposed vigorously a proposal to lower the tariff on imports of hermetically sealed canned oysters. I believe our position was sound even though the tariff was decreased from eight cents to six cents per pound in the negotiations of our government in the spring with Japan and certain other countries.

Action of this kind on the part of our government poses a dilemna for the industry. With an eight cent tariff, canned Japanese oysters were selling at wholesale about 25 percent less than American oysters, while imported smoked oysters were only half the price of the United States pack. With a six cent tariff this spread will be exaggerated further. We are faced with the unpleasant picture of possible destruction of a moderate-sized industry so that ties with Japan will be strengthened. While all of us agree we must counter the inroads of communism on every front, we have a responsibility to our own people which must be met. So far no one has come forward with a practical plan to meet this condition. One possible way would be the use of funds collected from import duties on oysters to promote the American product. This avoids subsidies and gives the industry some chance of competing. The Federal Government has already attempted such a program on New England haddock with considerable success. It is our understanding that a tuna publicity program has also been launched. The need for assistance on canned oysters is just as great.

Some have said that the most efficient businesses will survive in world trade and artificial trade barriers should not be permitted to limit the free flow of commerce. This is dangerous reasoning since industries such as ours still comprise a large segment of the economy of the country.

We must make every effort to have our government work out some solution to this tariff condition, which is creating a real hardship in a part of the industry. It should be one of our major aims during the coming year.

A significant development this year was the restatement of the regulation of the Food and Drug Administration which permitted the total weight of the contents to be placed on the label of canned oysters. This appears to be sound and should bring about a closer working relationship between the Gulf and West Coast Canners. Unfortunately state and municipal weights and measures officials are taking a different view stating that drained weight or count should be on the label. We have only one year to reconcile these differences, before the National Weights and Measures Conference meets late next spring in Washington.

You heard Mr. Eugene Jensen yesterday discuss the revision of the Shellfish Sanitation Manual. Representative members of our organization from all over the country have been reviewing drafts of this document to help make it a practical and yet efficient guide for oyster production. There is every reason for real optimism that a revision will result, which will be beneficial to the industry, and maintain the sanitary level of our oysters.

We have attempted to enlarge the scope of our activities and keep abreast of developments in other fisheries industries. This has required attendance at numerous fishery conferences and conventions. I have met with oystermen and packers in every coastal area. This has enabled us to be aware of many problems and to take action on them before they develop into major catastrophes. While this is the difficult and less spectacular way to serve the industry it has appeared to be the soundest approach.

These contacts, plus the efforts of some of our members, enables us to announce that the membership in the Association is at a new high, with more members coming in regularily. This does not mean we can halt our efforts. We should not slow down until we have practically every packer and grower in the United States and Canada. Only then can we say that the Association is representative of every tiny segment of the industry. Our educational material continues to be a major part of our work. We distributed 125,778 pamphlets to every state, Canada, and some foreign countries.

Limited production has been and will continue to be the plague of the industry. We must make every effort in the various states to utilize our resources in such a way as to attain a maximum sustained yield. Our great hope for the tools and techniques to attain this goal is in the biological research being carried on by the federal government, state laboratories, and at private research stations In some areas these techniques have already been blue printed and we, the industry, must be alert to recognize and adopt them. In others, the solutions have not been found. We must lend our support so that this work will go forward with all speed.

It has been said that the failure to utilize available technical knowledge in oyster cultivation has cost the nation $40,000,000 annually. While one would hesitate to place an evaluation on oysters we did not produce, it is apparent to most people in or associated with the industry that our markets can and will absorb vastly greater quantities of fresh oysters than we have produced in recent years.

Licking the production problem is the great challenge to the industry today. When we correct this weakness, many of the other problems will cure themselves.

THE FISH AND WILDLIFE SERVICE AND THE SHELLFISH INDUSTRY

Arnie J. Suomela, Assistant Director,

Fish and Wildlife Service, U. S.
Department of the Interior, Washington, D.C.

The Service and the oyster and clam industries have an identical interest in our national shellfish resources---their conservation and full utilization in serving this country's food needs. Our shellfish laboratories and research activities exist to provide the knowledge necessary to achieve these goals.

Among the biological problems facing us today, the most critical are lack of satisfactory production in many areas and the destructive action of oyster drills, green crabs, and other predators. These problems cannot, however, be solved quickly and easily. They are tough problems, requiring a lot of money, time, and effort for final or even partial solution.

Fortunately, our efforts during the past year have been given a much-needed "shot in the arm" by the funds made available under the Saltonstall-Kennedy Act. With these funds we have intensified existing programs at Milford, Annapolis, Beaufort, Pensacola, and Boothbay Harbor, and have executed research contracts with several non-government institutions. Much of this increased effort has only recently been started and has, therefore not yet borne fruit. Nevertheless, progress along several lines has been made during the past year and I should like to review this with you briefly.

Our biologists at Milford, Connecticut, continued to study the spawning and setting of oysters in Long Island Sound. Through a special series of bulletins, they accurately predicted beginning dates of spawning and setting of oysters and kept the industry informed about the intensity of setting throughout the season. On the basis of scientific observation, they advised oystermen to plant shells at the most advantageous time for securing the best oyster sets, or not to plant shells at all, if prospects in areas under observation were not promising. The industry was advised to utilize more extensively the inshore, well-protected waters for cultivation of oysters, and with the cooperation of State shellfish authorities and several oyster companies, spawning beds were established in such areas.

Our staff at Milford has demonstrated that oysters of different geographical areas along the Atlantic Coast belong to races having distinctly different physiological requirements. Therefore, importation of southern oysters into the waters of Long Island Sound is an unwise and wasteful procedure because they will never normally propagate under local conditions but will merely compete for food and space with local populations. Eighteen years of studies showed that no relationship exists between intensity of setting of oysters and the intensity of setting of starfish in Long Island Sound.

Other studies showed that the ecological conditions of our North Atlantic shore are well fitted for the existence and propagation of the European flat oyster. In recent years, the Maine Department of Sea and Shore Fisheries have planted some of our stock of this species and report that they have propagated naturally. We will follow with much interest the course of these introduced populations, which are still too small to be commercially valuable.

Laboratory culture of larvae continued, special attention being paid to their physiological requirements and to methods of controlling their diseases. Various antibiotics, fungicides, and ultra-violet treatments are being tried. Methods for hatching larvae and growing juvenile mollusks have advanced so far that several concerns are experimenting with commercial production of clams using these methods.

Our most baffling problem is the control of drills. We may eventually solve this problem by chemical warfare. To develop suitable weapons, we have recently embarked on a large-scale screening program at our Milford Laboratory. Through the National Research Council, we are receiving a constant supply of newly developed organic chemicals, and testing their effect on drills under experimental conditions. What we hope to find is a cheap chemical that will attract drills, or repel them, or poison them. At the same time we are intensifying our studies of the physiology of drills to find weak points in their life cycle where these predatory animals may be most vulnerable to attack.

The staff of the Shellfish Laboratory at Beaufort, North Carolina, is engaged primarily in basic research on the foods and feeding activities of oysters, clams, and scallops; the utilization of food materials ingested; factors concerned with the fattening of oysters; and the role of metals in the metabolism of these shellfish. These researches will yield information which later may explain fluctuations in the fattening of oysters and in conditions affecting their marketability. They may point out possible improvements in oyster cultural methods.

The efficiency of the gills of oysters, clams, and scallops in filtering marine plankton is being measured and many data have been collected on food selectivity in oysters. The use of plankton marked with radioactive chemicals has proven particularly valuable in these studies, and the use of mixtures of various species, each carrying a different tracer, is very useful in noting the removal of certain species from the sea water in the presence of others.

At Pensacola, Florida, seven years of observations of the reproductive cycle of the oyster have been completed and this cycle has been shown to be related to climatic changes.

A comprehensive survey of water currents near Pensacola has been made, and although analysis of the data has not been completed, it is expected to show the degree of tidal flushing and the magnitude and direction of local water currents. With this information, biologists can establish sampling stations and continue their investigation of whether or not waterborne factors are responsible for the better quality of oysters grown in some areas as compared with others. Differences in plankton, as indicated by plant pigments, should measure the relative amounts of food available to the oysters.

Clam biologists at Boothbay Harbor, Maine, have for seven years been following the population level of soft-shell clams in Sagadahoc Bay and keeping records of the commercial catch. The catch has remained low during the entire period and is not believed to be responsible for the observed population changes.

The seventh annual clam census, which was completed in June of this year, shows a decrease in the number of clams over 25 mm. from 11.5 millions in 1954 to 8.3 millions in 1955. This is a continuation of the trend towards a decreasing population in this Bay. A coincident increase in the population of green crabs has been observed in Sagadahoc Bay and is believed to be responsible for the decrease in the clam population. The extent of crab predation is being determined by a comparison of the survival of clams planted in the spring of 1955 in fenced and unfenced plots. An estimate of the present green crab population will be obtained from the results of an intensive trapping program planned for the summer of 1955.

More than 1,600 green crab stomachs have been examined for the purpose of studying their food. Results confirmed that these animals feed largely on shellfish.

As a means of green crab control, low wire-mesh fences, each enclosing 100 square feet, were installed in Sagadahoc Bay during the spring of 1954. While these fences have prevented most crabs from entering the areas, the small clams are sufficiently active to move in and out of the small fenced areas and are eventually destroyed on the open flats. We concluded from this work that natural set cannot be protected in small areas of a large flat while the clams are in the active stage. Biologists are intensifying their efforts to find successful anti-green-crab measures.

Studies of hard clam population levels and commercial catch have been conducted in Greenwich Bay for the past five years to develop methods for managing the resource, and a population census late in 1954 revealed the lowest density in five years of sampling. This decline in abundance was accompanied by a drop in the average number of boats fishing.

Oyster production on the Gulf Coast for the 1954-55 season to date is ahead of the preceding two seasons in spite of the many predators, and frequently unfavorable environmental conditions of too high or too low salinity, and the pollution of many good growing areas. This increase is due to increased cannery production for which there is a well-established market both for domestic consumption and for export. Meanwhile, the industry for fresh shucked oysters in the South has remained less significant.

Undoubtedly many factors are involved in this poor marketing position of the fresh Gulf oyster as compared with its biologically identical brother from the Chesapeake Bay and north. These include excessive labor costs in tonging and in shucking due to small size, insufficient return of shell to beds, and other cultural practices related to the general use of public beds as compared to those in use for private beds in other producing areas. Much of the trouble is that there is not enough consumer demand for fresh Gulf oysters when they are at their best to make general improvement of conditions economically feasible. It is a vicious circle in which the southern fresh-shucked oyster industry has been trapped for many years.

The present program of the Service is aimed at improvement of the marketing position. The fresh-shucked-oyster market is now largely limited geographically to a thin strip of the coast not even including the whole of the States in which the oysters are produced. Among the reasons for this may be mentioned the difference in color---browns and black shades rather than the uniform gray of the Chesapeake oyster. There is the tendency to develop free liquor after packing. Directly related to this characteristic of excessive bleeding is the presence of shell and mud due to the very limited washing usually given these oysters. Environmental and physiological reasons for color, its chemical character, and ways to control or eliminate it are being studied. The basic physiology of the tendency to bleed excessively is under study at Tulane University, while other aspects of this problem are being explored along three different lines at Florida State University, at Louisiana State University, and at our Fishery Technological Laboratory, College Park, Maryland. Much of the work will be related to the freezing of oysters and oyster products, since basic knowledge as to how and when Gulf oysters can best be frozen and stored will materially better the industry's economy in two ways: (1) it will permit spreading out the season, and (2) it will permit enlarging the market area greatly.

At present the national oyster marketing season starts to build up in September when the weather in the Gulf is often still warm and the oysters are poor and thin. Until the end of the Christmas holidays, demand is usually good, and continued cool weather and the tourist season keeps some activity in the market through February. In March, the southern oysters are said, by the plant men, to be in the best condition of the season, but the market is stagnant and the fresh-shucked-oyster business shuts down, with the canneries taking over.

If a good frozen package of individual oysters, or a product such as breaded (raw or pre-cooked), smoked, creamed, scalloped, or otherwise prepared, can be developed, southern oysters can be packed when in prime condition and marketed in an orderly manner throughout the year as a high-quality product. These fat, high-quality oysters should meet the demands better in their present market territory. They should be capable of competing throughout a much larger market area as well. Any foreseeable increase in oyster production from the Gulf Coast can thus be absorbed without depressing prices of the raw, fresh, or frozen product. The research program at Louisiana State University, Florida State University, and at the College Park, Maryland, Laboratory, has been developed on this basis.

We hope to develop an acceptable and practical field method for the evaluation of fresh oysters. An improved technique for the bacteriological examination of oysters is also being developed. Such a rapid and positive test, if available, would go far toward establishing the frozen oyster products in our markets.

The summary I have just presented has not attempted to, and in fact, could not cover the details of our scientific investigations. These are being presented in papers at the Technical Sessions of this Convention which many of you are attending. In summary, we have a somewhat discouraging picture this year---declines in abundance of many shellfish stocks and heavy inroads by a variety of predators. As I mentioned earlier, however, the picture has its bright side, too. Our own intensified efforts under the Saltonstall-Kennedy Act, plus those of cooperating universities, State fishery agencies, and the Oyster Institute itself, should, during the next few years, bring us closer than we now are to a solution of our vexing problems. We pledge to you our continuing utmost efforts to that end.

CONVENTION SYMPOSIUM

on

POLLUTION CONTROL IN SHELLFISH GROWING AREAS

Papers by C. B. Kelly, H. F. Udell, M. B. Edwards, M. LeBosquet, Jr., and J. W. Ryland constituted a special symposium arranged for the Convention by Mr. Eugene T. Jensen, Acting Chief, Shellfish Sanitation Section, United States Public Health Service, on the subject of pollution control in shellfish growing areas. Mr. Jensen also presided at the symposium. Only the first four papers are included in this volume of the "Proceedings", since the one by Mr. Ryland was not available for publication.

PUBLIC HEALTH SERVICE RESEARCH ON SHELLFISH BACTERIOLOGY

C. B. Kelly

Public Health Service
Chief, Shellfish Sanitation Laboratory
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The Public Health Service Shellfish Sanitation Laboratory was organized in 1948 to conduct studies, principally bacteriological, in problems relating to the sanitation and sanitary control of shellfish. The laboratory was located at Woods Hole, Mass., until 1953, when its activities were transferred to Pensacola, Florida. The principal objectives of the unit are:

1. To conduct fundamental investigations in the sanitary bacteriology and biology of shellfish and shellfish-bearing waters, with a view to the evaluation and improvement of presently accepted practices in the sanitary control of shellfish as exercised by the individual states under the general guidance of the Public Health Service.

2. In collaboration with federal control agencies---principally the Shellfish Sanitation Section, Milk and Food Program, Division of Sanitary Engineering Services, Public Health Service---to assist and guide the various states in their program of sanitary control of shellfish by rendering technical advice to the pertinent state agencies.

3. In cooperation with these same agencies, to develop and evaluate improvements in current commercial practices in the harvesting, processing and marketing of shellfish.

4. To investigate laboratory methods for the examination of shellfish and shellfish-bearing waters for the purpose of evaluating current methods and developing new techniques.

The first investigations of the unit were conducted in the north-east while the laboratory was located at Woods Hole, Mass. They were directed toward the determination of the above-mentioned factors in the three commercially important species of shellfish in that area: the oyster, the hard clam and the soft clam. The studies were chiefly of a basic nature, investigating such items as the survival of indicator and pathogenic organisms in sea water and shellfish, the principles involved in the purification of shellfish, and the determination of the relationship in bacteria between shellfish and the overlying water.

Survival of Enteric Organisms in Sea Water

Studies on the survival of enteric organisms in sea water involved the determination of the comparative survival of a specific enteric pathogen, Salmonella schottmuelleri, and a selected coliform, Escherichia coli, in natural sea water stored in the laboratory at temperatures similar to those of the source water. Concentrations of test organisms introduced into the sample bottle (10,000 E. coli and 1,000 Salmonella per 100 ml.) approached those probably found in naturally heavily polluted waters. These studies, although conducted under laboratory conditions, indicate the reliability of the indicator organism in demonstrating the probable presence of pathogenic organisms. Although survival time of both organisms varied with temperature, more rapid reduction occurring at warm than at moderate or cold temperatures, a marked similarity in the rate of decline of the coliform and the pathogen was observed. Salmonella organisms survived at temperatures of 2.5 to 6.5°C. for 13 days, at 7.5 to 11°C. for approximately 7 days, and at 21 to 23.5°C. for approximately 2 days.

Survival of Enteric Organisms in Shellfish

Comparative survival of the same two test organisms, E. coli and S. schottmuelleri, in stored shell oysters and soft clams was determined. The shellfish were polluted by exposure to sea water containing known quantities of the test organisms, allowing the shellfish to acquire pollution by natural physiological processes. After the period of pollution, the shellfish were transferred to dry storage at temperatures resembling conditions in the northeast during the harvesting season: oysters at approximately 5°C. and soft clams at approximately 5 and 19°C.

As in the water survival series, a marked similarity in the rate of decline of the test and indicator organisms was observed. Salmonella persisted in oysters stored at refrigerator temperatures with little reduction after 49 days of storage. In soft clams stored at 5°C., concentrations of both organisms declined at similar rates, reducing steadily during 14 days of storage. At the higher temperature, Salmonella and E. coli still reduced at a parallel rate which continued until the animals were no longer in marketable condition.

Little evidence of multiplication of either organism was seen in shellfish that could be considered in marketable condition, although on occasions multiplication of either or both organisms occurred in animals that showed spoilage or were moribund. It could be generally concluded from these investigations that Salmonella persisted for a period of time at least as long as the shellfish might be in transit from the point of harvesting to consumption.

Purification of the Soft Clam

Depletion of the supply of soft clams in the northeast has necessitated exploitation of beds in moderately polluted areas. Since the species does not generally survive transplantation to clean, natural areas, purification by this means is not a feasible process. The method in use in this country consists of submitting the clams to chlorinated sea water in enclosed tanks. Recognizing the potential demand for a suitable method of artificial purification of this species, the Shellfish Sanitation Laboratory undertook studies in a pilot plant to determine some of the factors involved in this method of purification.

The pilot purification plant furnished an abundant supply of clean sea water of a bacteriological quality lower than the Public Health Service recommendations for growing areas. Experimental animals were polluted by exposure to sea water containing suspensions of *E. coli* and *S. schottmeulleri* in a fashion similar to the method used in the experiments on survival of enteric organisms in shellfish. The course of purification was determined for both test organisms by successive sampling of water and shellfish until bacteriological tests demonstrated the absence of *Salmonella* from two successive samples of shellfish. The feature of the use of *Salmonella* organisms as an indicator rather than coliforms was of decided advantage in determining the rate of purification by eliminating the confusion caused by the presence of naturally occurring coliforms in the purifying water.

The clams functioned and purified at water temperatures as low as 3.5°C. and as high as 20°C. Reduction in coliform M.P.N. to the presently accepted limit of 2,400 per 100 ml. was usually attained in 24 hours or less even with concentrations of coliforms at or near the upper limit of acceptability for clams to be submitted to the treatment process. Reduction of *Salmonella* to a low or indeterminate level required 48 hours of purification.

Evaluation of the Membrane Filter Technique

Soon after the announcement and release of the membrane filter in 1951, the Shellfish Sanitation Laboratory inaugurated a series of comparative studies to evaluate the application of this technique to the estimation of coliform organisms in sea water. Simultaneous examinations of sea waters from areas of three levels of pollution were made by the membrane filter and Standard Methods lactose broth M.P.N. The two techniques gave overall results 87.1 percent in agreement. However, higher agreement was obtained from waters with large coliform concentrations than from waters having low coliform counts.

In connection with an investigation to determine the sanitary quality of certain marine areas in the vicinity of Pensacola, membrane filter studies were continued. Incorporated in these studies was a comparison of a modification of the technique involving the use of agents inhibitory to extraneous organisms. These studies are now under evaluation but, as a preliminary report, it might be stated that results obtained on similar technique in both areas have produced a similar degree of correlation.

Shellfish Pollution Studies

Investigations at Woods Hole on the measurement of the relative coliform content of shellfish and overlying water would probably be of most direct interest to those engaged in sanitary surveys of growing areas. It has often been surmised that there is a difference in the rate of accumulation of bacteria by the commercially important species of shellfish. Furthermore, studies of the rate of pumping of oysters and other molluscs have indicated variation due to temperature, and in later investigations the influence on pumping rate of the presence or absence of minute quantities of certain organic compounds has been suggested.

In the Woods Hole studies, the three commercially important species of shellfish---clams, quahaugs, and oysters---were subjected simultaneously to continuous flow of artificially polluted water in laboratory aquaria. The course of pollution and the relative accumulation by the shellfish was determined by periodic examination of the shellfish and water. Experiments were conducted at three levels of pollution and at temperature ranges encountered in the northeast area of the country. The number of replications of these experiments was sufficient to allow an extensive statistical analysis by Dr. E. K. Harris, Analytical Statistician for the Sanitary Engineering Center. From this analysis, the following general conclusions may be drawn:

1. The rate of accumulation of coliform organisms by quahaugs and oysters varies markedly with temperature. Both the relative coliform density and its rate of increase with increasing water pollution were found to be considerably greater at temperatures above 8°C. than at lower temperatures.

2. In soft clams, the influence of temperature on the rate of accumulation was not nearly as great. Clams were found to accumulate coliforms almost to the same degree at temperatures between 0 and 8°C. as at temperatures between 8 and 17°C. Some reduction in the rate of accumulation was observed at temperatures ranging from 20 to 23°C.

3. At cold and moderate water temperatures (5 to 18°C.), the density of coliform organisms was significantly greater in soft clams than in quahaugs or oysters. At water temperatures of 20 to 23°C., clams still showed the highest coliform density at pollution loads equivalent to low or moderate pollution, but under heavy pollution loads (water coliform M.P.N. 700 or more), the coliform density of the oysters equalled or exceeded that of the soft clams.

4. All species contained larger numbers of coliform organisms at water temperatures between 8 and 17°C. than at either higher or lower temperatures.

Summary of Woods Hole Investigations

In June 1953, the Shellfish Sanitation Laboratory completed its tour at the Woods Hole Laboratory. During their stay in that vicinity, the laboratory staff made the following studies:

1. There is no question that shellfish are possible vectors of enteric disease organisms. It was demonstrated that shellfish have the ability quickly to reflect the sanitary condition of their aquatic environment, and, if this is unsatisfactory, they may retain enteric pathogens as well as other bacteria. The rate of accumulation, as well as the coliform level attained, varies not only with temperature and bacterial content of the overlying water, but also with species of shellfish.

2. Salmonella organisms were demonstrated to survive in stored sea water at least as long as the selected coliform indicator. Results of studies on comparative survival indicate that Salmonella may persist in water long enough to influence adversely the sanitary quality of shellfish in natural waters subject to fecal pollution.

3. Artificial purification of soft clams by exposure to an ample supply of running sea water of good bacterial quality is a feasible process. Purfication to a satisfactory level can be accomplished in a practical length of time, usually 48 hours or less.

Pensacola Studies

Following increased activity in shellfish sanitation in the Gulf Coast area, data gathered during the course of sanitary surveys indicated marked differences from those prevailing in the northeast in the rate of natural purification of estuaries, as well as differences in the bacteriological relationships between shellfish and the overlying water. Review of sanitary surveys of the estuaries in the Gulf indicates a prolonged survival of coliform bacteria, resulting in far more extensive opportunity for contamination of shellfish by similar quantities of discharges than is ordinarily observed in the colder climates.

Transfer of activities of the Shellfish Sanitation Laboratory to the Gulf Coast area was made in 1953 to afford an opportunity to investigate these reported differences in the warmer environment. An over-all program of activities for the laboratory was developed in consultation with a group of specialists in the field called together by the Public Health Service as a Shellfish Advisory Panel. The first phases are completely investigative, involving laboratory studies under controlled conditions and to a great degree are a continuation of similar investigations carried on at Woods Hole. Additional factors, however, must be considered, such, for example, as the significance of salinity, because of wider fluctuations in the local shellfish growing areas.

The Advisory Panel considered it desirable during the first two years to conduct basic studies which would give information on such factors as the relationship in coliform content between oysters and the overlying water, the rate of accumulation and removal of coliforms in shellfish exposed to varying degrees of pollution, and the relative survival of the coliform group and selected representative enteric pathogens in sea water. Two main projects are now in progress. These involve studies on the comparative survival of enteric pathogens and indicator organisms in saline waters and the relative coliform content of oysters and water. The studies on survival in water are nearing completion. The oyster pollution studies should be completed by the end of 1955.

We are, therfore, proceeding with preliminary investigations leading to the design of other studies suggested by the Advisory Panel. Selection will be made from the following:

(1) Survival of enteric organisms in shell and shucked oysters,
(2) Survival of coliforms and enteric organisms in bottom muds,
(3) Relative coliform content of oysters and bottom deposits.

It is fully recognized that information obtained from these laboratory scale studies might not always be capable of direct application to conditions prevailing in the natural environment. Laboratory scale experiments have been necessary in order to determine under controlled conditions the relationship between certain factors, but we feel that in many instances there will necessarily be indicated a series of studies under actual commercial and field conditions. For this reason, we have been giving serious consideration to extension of the oyster pollution studies to at least known variations in water quality in a completely natural environment. This concept, we feel, should also be applied to bacteriological studies of oysters and other shellfish during and after harvesting and processing by conducting a series of investigations, carefully followed, on traced lots of shellfish produced in commercial practice in several local environments.

Only after opportunity has been had for a review of the complete cycle of investigations at both the laboratory and commercial level can intelligent application of the facts so obtained be made by control agencies for the formulation of reasonable standards of practice.

SANITARY SURVEYS OF SHELLFISH AREAS

Harold F. Udell

State of New York Conservation Department
Shell Fisheries Management, Freeport, Long Island

I feel certain that all present at this meeting are extremely conscious of the effect pollution has on many of the estuaries and bays along the east coast of this country. The discharge of inadequately treated and completely untreated industrial and domestic wastes into our marine waters continues to be a threat to the shellfish industry. This effect is a matter of degree; thus, small amounts of waste when discharged into correspondently small estuaries may result in an extreme degradation of the waters. Large estuaries or embayments may receive small amounts of untreated or moderate quantities of partially treated sewage with no noticeable change in the chemical or physical characteristics of the waters or bottom, except near the point of discharge. This probably will not hold biologically as the bacterial concentration in the discharged sewage may be of such magnitude that dilution and the effect of natural purification will not reduce the numbers of bacteria for a considerable distance from the point of discharge. Furthermore, the effect of wind, tide and current may be unfavorable for a satisfactory reduction of the sewage bacteria over a large area of the body of water in question.

It might be well to consider the relation of pollution to the shellfish industry in two phases. The first is concerned with the propagation of mulluscan shellfish such as oysters and clams; the second is the effect of pollution on the harvest and distribution of these shellfish.

As the quality of marine waters becomes degraded by the discharge of industrial and domestic wastes, life in these waters becomes adversely affected. Wastes containing excessive amounts of organic material result in a depletion of dissolved oxygen. A critical depletion of dissolved oxygen upsets the normal biological balance necessary for the propagation of such higher forms of marine life as bivalve mollusks. As free oxygen disappears from the water, groups of microorganisms disappear which normally utilize some of the organic waste material as food and, in doing this, the remaining constituents of the waste are converted to food for other organisms which in turn serve as food for the bivalves. As this group of organisms disappears, a new group, which does not need free oxygen for its existence, takes over the task of decomposing the waste material. This process is one of fermentation and is accompanied by production of gas, foul odors, and an unpleasant appearance of the water. Organisms of the type fed upon by oysters and clams cannot survive these conditions. Continual deficiencies of dissolved oxygen cause mortality of adult oysters and clams and interfere with the setting and growth of juveniles.

The organic material in untreated waste may be thought of as occurring in suspension in the liquid waste. In domestic sewage roughly

50 percent of the organic material is in suspension and of this amount 65 percent will settle on the bay or stream bottom. The rate of deposition of this material depends upon the velocity of the stream flow or transport of the bay waters by tidal currents and winds. The actual effect of this material settling on the bottoms is to cover the area with an increasing amount of putrescible fine-textured material in which oysters and clams cannot live.

The discharge of industrial wastes into marine waters produces an additional effect on shellfish. Amounts of organic materials in untreated industrial waste usually greatly exceed that contained in raw domestic sewage, thus the problem of deposition of material (or silting) and dissolved oxygen depletion becomes more complex. In addition industrial wastes, unless given a high degree of treatment, usually contain toxic materials as waste products of industrial processes. These toxic materials are poisonous to shellfish and to the microorganisms upon which they live.

The effect of pollution on production, harvesting, and distribution of shellfish is related primarily to the numbers of sewage type bacteria in shellfish growing waters and in the shellfish. The presence of pathogenic bacteria, whose normal environment is the intestinal tract of man and certain animals, in shellfish or shellfish growing waters, presents a hazard to the public health. It is therefore essential to the entire shellfish industry as well as to the consuming public to have available an up to date official record attesting to the fact that shellfish growing areas from which oysters, clams, or mussels are taken for marketing are free from dangerous concentrations of bacteria capable of producing disease in humans. As long as state shellfish regulatory authorities who are actively concerned with shellfish sanitation are able to certify areas from which shellfish may be taken and dealers who may distribute these shellfish, our industry will continue to enjoy the confidence of a world-wide consuming public.

In order to produce and keep such an official record current, periodic or, if necessary, continual sanitary surveys of shellfish growing areas are necessary. A survey of this type should be carried out objectively and should produce adequate data upon which an area may be certified or condemned for the taking of marketable shellfish. Such action must be based upon scientific fact, as conclusions drawn from incomplete data may result in a potential menace to the public health. On the other hand, use of incomplete data may unduly penalize members of the industry.

Experience gained by conducting numerous studies of shellfish growing areas has led to the conclusion that each area should be treated as a separate study. It is not possible to properly carry out sanitary surveys of estuaries and marine embayments by the "recipe book" method. Each area is characterized by certain factors affecting the hydrography, characteristics of the water and bottom, and biological life which differ from other areas.

In general all sanitary surveys follow the same pattern. However the details of the various parts of the study should be developed according to the factors involved. There are four major considerations in making a sanitary study of inshore marine waters.

1. Sanitary reconnaissance of the shore area and tributaries entering the embayment,

2. Bacteriological study of the waters,

3. Chemical study of the waters,

4. Hydrographic study of the area.

The sanitary reconnaissance is made to determine sources of pollution entering the area. A detailed investigation is made of each source of pollution and its location noted on a map. If a sewage treatment plant is noted as a source of pollution, an investigation is made to determine adequacy of treatment, condition and character of the plant effluent, and any physical or operational conditions which might result in reducing the efficiency of the plant.

The report of the reconnaissance will indicate both active and potential sources of pollution entering the area. It will also indicate remedial measures which may be taken to reduce or eliminate pollution.

The bacteriological phase of the study is designed to give a numerical value to the bacterial concentrations at various points throughout the embayment. Some field groups run samples at random or on irregular lines over an area with sampling stations at or near potential sources of pollution. Such a system although adequate in a small estuary will not give the required coverage in a large embayment. I prefer to cross section all areas to be studied in order that sampling stations may be accurately occupied each time. This may be accomplished by running several parallel lines in the same direction between fixed "sights", and intermediate lines may be run by compass. This system not only produces results by which successive surveys may be correlated, but also lends itself to ease in plotting on charts and maps.

There has been considerable discussion as to the proper methods to be employed in sampling marine waters for bacteriological examination. Without extensive reference to these differences, I will describe the method I favor and justify its use by stating that it produces highly accurate data for evaluating conditions.

Let us consider first that oysters from the time they "set" until they either die or are harvested, remain directly on the bottom. Clams also remain on the bottom after "setting" but burrow into the bottom, the depth of burrowing depending to a great extent upon the temperature of the water. Further, fresh water having a specific gravity less than that of salt water will tend to float. Thus fresh water entering an estuary will remain at the surface until mixed with the salt water beneath. Mixing is dependent upon currents, winds, and temperature. Greatest stratification may occur during the warmer months, which, incidently, is usually the time of year chosen by state agencies to carry out sanitary surveys. In some cases fresh water flowing into sea water will mix slightly with the underlying sea water and remain as a floating pond until carried out to sea. In other cases a definite stratification will occur with sea water distinctly pooled beneath fresh surface water. Needless to say some mixing takes place continuously, but the degree of mixing varies. In shallow areas having little tidal difference, no stratification occurs under normal conditions; in these areas the sampling problem is of no consequence.

Finally it should be recalled that pollution from land areas is discharged in fresh water. Roughly 65 percent of the solids which are in suspension in the liquid waste settle to the marine bottom, the remaining amount becomes dispersed in the receiving waters through mixing. It should also be noted that bacteria from sewage and waste occur in combination with the suspended solids. Thus greatest pollution occurs in the zone where greatest settling occurs. The degree of bacterial pollution diminishes as the material in suspension is dispersed. It follows that stratification and mixing become important factors.

With these points in mind, it is clear why, in sampling, water should be taken at a depth below the surface with due regard to stratification and mixing in order that shellfish not subject to excessive pollution will not be condemned.

The next consideration in the bacteriological phase of the surveys is the frequency of sampling. Here again it is evident that all areas should not be treated in the same manner. As an example I have in mind an area consisting of approximately 50 square miles surveyed a few years ago. On the basis of results of bacteriological examination of water samples collected during the two month period, May and June, it was concluded that a large portion of the area should not be approved for the harvest of shellfish during the period April through November, restrictions to be relaxed from December to March. A recent extensive study of the area covering a 14 month period has demonstrated that bacterial pollution in the area shows a marked increase during the period April to July due to excessive fresh water inflow. These findings were based on bacteriological and chemical examination of shellfish and of bay waters collected at the bottom and at a depth below the surface in order to record the effect of mixing. In carrying out this study several stations were occupied twice a month for a period of 14 months. Samples of water were collected at a predetermined depth below the surface and at the bottom for chemical and biological examination. Samples of clams (Venus mercenaria) were also collected at each station for similar examination. A total of 1,476 biological examinations were made. These indicated that the same concentration of coliform organisms (type of bacteria indicating sewage pollution) found in the waters directly over the shellfish grounds would be found in the shellfish, except at water temperatures below 8°C. In this case an extensive sanitary study of an important hard clam producing area may result in the imposition of restrictions only during a two to three month period rather than during a large part of the active shellfish season.

I have been asked by authorities responsible for the supervision of shellfish sanitation why we should become involved in chemical or hydrographic studies of marine waters when all that is needed is information concerning bacterial densities. My answer to this question is that random sampling of waters for bacteriological analysis only is not adequate to condemn or approve areas for the harvesting of shellfish for the market.

Chemical analyses of marine waters subject to pollution provide important information necessary for an adequate evaluation of an estuary or embayment. Information is also provided for use as a basis in developing a pollution abatement program. Furthermore, data gathered by chemical analyses of the waters give an indication of biological activity and provide information necessary in making predictions concerning reductions in coliform bacteria.

Although a hydrographic study of shellfish growing areas may be of more value in providing information for propagation purposes, a certain amount of this type of information is necessary to complete the sanitary reconnaissance of the tributaries. Data gathered through a study of the hydrography of an area will be of utmost importance in pollution abatement and in depicting the circulation pattern of the shellfish growing area. A knowledge of such circulation patterns is important in evaluating the capacity of the tidal waters to disperse pollutants introduced by fresh water streams. Data thus collected on the distribution and concentration of stream water with its contained pollution may be utilized to compute its rate of seaward movement in various portions of the estuary. The volume of the river water within the area is an indication of the accumulation of fresh-water-borne pollutants. The flushing time, or the average time required for one day's stream flow to move through the area may be derived from these computations. Thus the characteristics of the water movements in an estuary indicate areas of greatest concentration of pollutants and the rapidity of their removal by circulation of the water.

It therefore follows that the circulation pattern of an estuary or embayment is not only important in providing necessary data for the overall sanitary survey but also to an oysterman who is contemplating the expenditure of considerable time and money for the cultivation of oysters or clams.

From this discussion it is evident that a sanitary survey, if carried out with the idea of a collection of complete data concerning biological, chemical, and physical characteristics of marine waters, will provide a satisfactory basis for action in condemning or approving an area for the taking of shellfish for market purposes. Such a survey also will provide the marine biologist and the oysterman with sufficient information for the development of plans for shellfish cultivation.

It seems important to note that shellfish regulatory authorities and the entire shellfish industry all have a definite responsibility in determining that shellfish areas be approved on the basis of an adequate sanitary survey. Such surveys of shellfish growing areas are a necessity in order that all concerned with the production, harvest, and distribution of these molluscan bivalves may proceed intelligently toward increased production of wholesome oysters and clams for market purposes. I believe that the governing factor in the shellfish industry today is not the lack of oyster sets, which greatly concerns this meeting, but rather the confidence the industry enjoys from the consuming public of these United States, Canada, and parts of Latin America.

LOCAL SANITATION PROBLEMS IN SHELLFISH GROWING AREAS

Malcolm B. Edwards

President, Pacific Coast Oyster Growers Association

It is highly important to the shellfish industry that only shellfish grown in waters of assured purity be marketed if we are to hold the present confidence of the buying public. It should be recognized that one facet of pollution control is the control of the discharge of sewage from the rural homes near the shellfish growing areas.

This is especially important in shellfish growing areas where adjacent uplands have recreational or potential home site value. These uplands have had a recent history of rapid development in home construction due to the recreational value of the waterfront property. There has also been the problem of home development along streams, lakes, and other watercourses which discharge into shellfish growing areas.

With the advent of rural electrification, pressure water systems, and modern plumbing the use of sub-surface sewerage disposal systems has increased at a great rate.

The improper location, design, construction, or maintenance of individual sewerage disposal systems can be an important item in the pollution of shellfish growing waters. As such conditions might result in the condemnation of shellfish areas it is important that some means of regulating such systems be employed.

Normally, the most efficient method of such control is by providing by law (to the local regulatory agency responsible for the control of sewage disposal) power to set minimum standards for the installation and maintenance of individual sewerage disposal systems. As such problems are best handled on a local basis, the responsibility for the control of individual sewerage disposal systems is normally delegated to the local health department.

The law should empower the local agency to prohibit the discharge of sewage upon the surface of the ground, directly into the water-table, or into any water course. It should further describe the sub-surface disposal system to be used and require that such systems be installed on a permit basis with agency approval prior to coverage or operation.

As approval of the shellfish growing area is often the responsibility of an agency other than that one responsible for the control of pollution, only through very close cooperation of these agencies can shellfish growing areas be protected from pollution of human origin.

The shellfish industry must assume leadership responsibilities in the prevention of pollution from individual sewerage disposal systems as it does in the control of other pollutants. It is extremely important that the industry properly dispose of the sewage from its own facilities, and should aid the local regulatory agency in the enactment or enforcement of laws relating to the proper disposal of individual sewerage disposal system wastes.

As the industry is dependent upon relative freedom from many pollutants within shellfish growing waters, failure to actively participate in the elimination or control of such pollutants could well result in the eventual loss of more of our shellfish areas.

As an example of how industry can act to help in matters of this kind, I would like to cite the action of a group of Oyster Growers in Mason and in Thurston Counties, in the Shelton-Olympia area, State of Washington. Oystering has been carried on there since the turn of the Century. This is the home of the small Olympia oyster (Ostrea Lurida). Much of the area is highly developed, dike culture of the Olympia oyster being initiated as early as 1890. Commercial plantings of Pacific oysters were introduced in these waters in 1922 and now represent the major commercial oyster culture.

Olympia, the capitol of the State of Washington, is situated on Budd Inlet and is within 50 minutes drive of Oyster and Mud Bay, the principal oyster producing bays. As the population increased in the vicinity of the state capitol, the beautiful wooded upland adjacent to the water area quite naturally became choice home sites. Being a rural area and not subject to city building codes it was quite natural that many of the upland owners followed the line of least resistance when planning their individual sewerage disposal systems. Soon, because of the increased building pace and lack of proper supervision over construction, a situation developed which became a potential hazard not only to the shellfish industry using adjacent waters, but to those who used the waters for recreation.

Something had to be done within the next few years to save the oyster industry. A move was started by the oystermen enlisting the aid of the Federated Women's Clubs of the two counties and the local health authorities. This brought about the passing of a county ordinance setting forth minimum standards for the installation and maintenance of individual sewerage systems.

It took considerable effort on the part of all concerned before the ordinance could be passed. First, a set of specifications had to be framed that would provide the backbone for the ordinance. Local health authorities provided technical information for this phase. The legal department then framed the ordinance. The next step was to petition the County Commissioners to adopt it. Such a petition required the signatures of several thousand free holders within the county before it could be considered. The signatures were eventually secured, there was a public hearing, and the ordinance finally adopted.

In order to point out the need for such an ordinance the oyster industry, working with local health authorities, hired a sanitarian to make a survey of existing rural sewerage disposal systems in the most critical areas. The findings were significant enough to make the public aware of the problem and pointed to the need for immediate action.

A typical report came from the examination of a fine new home owned by a local physician. He was most cooperative when asked to assist with the survey and also very much surprised when the colored dye placed in his residential toilet and flushed through the sanitary system could be seen coloring the adjacent bay water almost immediately. His doctor's training in addition to the fact that the beach was used for swimming by his family, helped him to reach a decision for an immediate revision in the sewer system.

It is significant that the regulations have been in force for more than a year now and the hazard to the oyster growing area from the aforementioned source has been virtually eliminated.

The reaction of the doctor brings to mind another concern to those of us who work with people within the industry. One of the most recent tasks confronting us has been the analysis of the "Review Draft" covering the sanitary control of the harvesting and shucking of shellfish. The Pacific Oyster Growers approach to the study was to provide key grower processors with a copy of the draft asking each to express his opinion in writing and to forward the written statements to the Association Headquarters for study. A committee of grower processors then met together and evaluated the findings. Statements were prepared and forwarded to the U. S. Public Health Service setting forth our position.

To be perfectly frank with you, the following factors were involved in our evaluation.

(1) How does this draft compare with the existing manual and the existing state regulations?

(2) Is the revision necessary? If so, how much will it cost?

(3) Is the regulation necessary from the standpoint of the protection of public health?

(4) Is there sound scientific knowledge for the regulation based on the conditions of our particular growing area and our particular oysters?

Part of the caution expressed by our industry in this matter is due to the fact that present sanitary regulations are based largely on conditions common to the control of the eastern oyster industry. The major research projects for the past several years by Public Health Service agencies and others have been carried on to secure basic knowledge on the eastern oyster. This is a matter which will undoubtedly be corrected as the years go by. It is only natural for us to feel that until such time as basic research has been carried on by the U. S. Public Health Service with the Pacific oyster in our area it will be difficult to write sound minimum standards, especially regarding the regulation of growing areas.

I am sure that at the present time our reactions are somewhat like the doctor's when he saw proof of pollution in the colored dye in the water at the front of his home. If there are substantial indications favoring revisions in the handling of our product to insure adequate protection of public health and to improve our product we will be most anxious to make them.

SEWAGE TREATMENT PROTECTS SHELLFISH GROWING AREAS

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Sewage treatment is an important part of the broad program of water conservation. As population grows and industry expands there is an ever-greater demand on the Nation's available water supply. In 1900 our population was 75 million. In 1950 it had doubled to 150 million, and by 1975 it is expected to reach over 200 million. Industrial activity multiplied seven times from 1900 to 1950, and is expected to double again by 1975. This rapid growth is accompanied by a consequent increase in pollution which impairs water quality for domestic, industrial, agricultural, and recreational use and impairs wildlife habitat and shellfish growing areas.

For the problem of municipal sewage pollution, the answer is the modern sewage treatment works. In the case of industrial pollution, the answer can be treatment works or can be pollution control measures through process changes and recovery practices. My discussion today concerns the municipal sewage treatment plant: the problems encountered and the workings of the individual treatment units.

The benefits derived from adequate sewage treatment are substantial, not the least of which are benefits realized by the shellfish growing industry. Benefits in this case can be real and substantial, and go far in justifying the $35 and $110 per capita construction cost of sewage treatment works, or the daily average figure of about 10 cents per family.

In accordance with presently established policy, the responsibility for abating pollution rests with the city or industry creating the pollution. State water pollution control agencies furnish aid, conduct investigations, and administer enforcement provisions of state laws. The Federal role as presently practiced is in the field of research, support of state programs, and enforcement on interstate problems.

How a Sewage Treatment Plant Works

There are two kinds of sewage treatment: primary and secondary. Primary treatment removes about 35 percent of the pollution load of sewage water. Secondary treatment, following primary treatment, removes much more; it is also, of course, more expensive. Some cities need secondary treatment. For others, primary treatment is enough. It depends mainly on two things: the ability of the natural waterway to purify itself, and the uses to which the water will be put after it re-enters the waterway.

Figure 1 shows the path of sewage water through a sewage treatment plant.

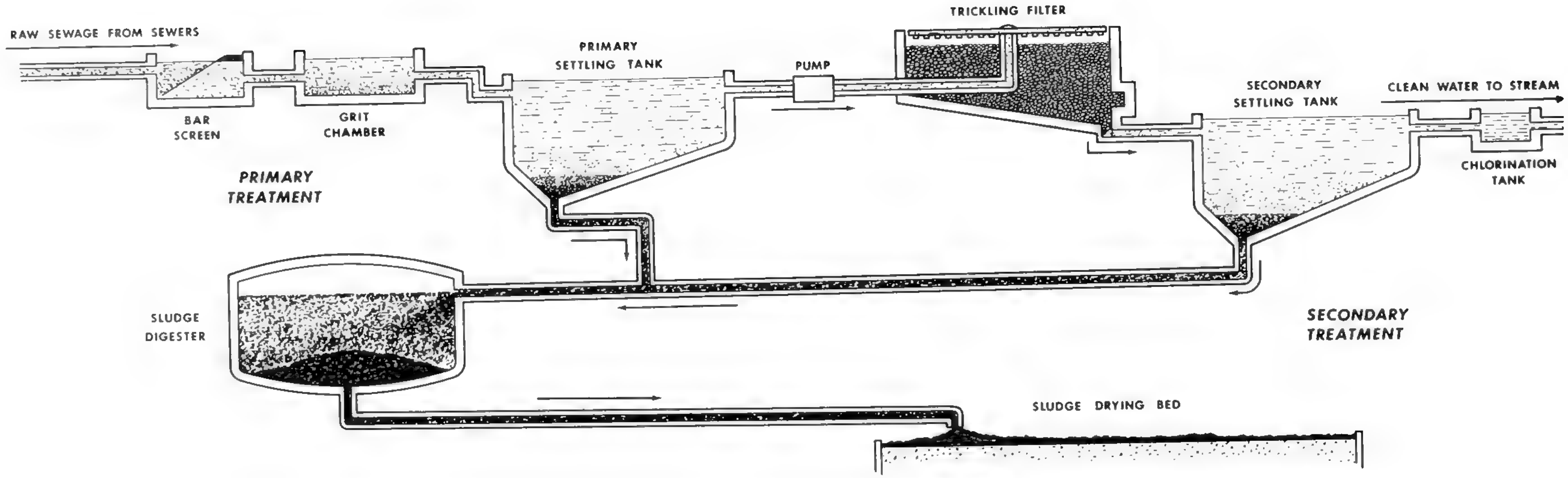

Fig. 1. The path of sewage water through a sewage treatment plant.

Primary Treatment

Step 1. As the sewage water enters the plant, it passes through a screen. The screen catches large objects such as sticks, rags, etc.

Step 2. Next the water flows slowly through a grit chamber. This allows sand, gravel, and other heavy objects to settle.

Step 3. The water then flows into a large settling tank. Here it stands for a considerable time. The solids in the waste matter settle to the bottom as "sludge" or rise to the top as "scum." The water between these two layers is then drained off.

When this matter leaves the primary settling tank, it may be discharged to the waterway in this condition. If more treatment is needed, it passes on to secondary treatment.

Secondary Treatment

Step 4. Secondary treatment depends on the action of bacteria which remove dissolved organic matter from the water. Many plants have a trickling filter for this purpose. A trickling filter is a bed of coarse stones about six feet deep. Bacteria grow on the stones. The sewage water is sprayed over the stones and allowed to trickle down through them. The bacteria do their work as the water trickles down. The water is then drained off at the bottom of the bed.

In some plants the activated sludge process is used instead of the trickling filter. This also depends on the action of bacteria.

Step 5. The sewage water may then be sent into another settling tank. Again it is allowed to stand, while the remaining solids settle.

Step 6. Finally, chlorine gas may be added as a safe-guard. The water is then discharged into the river or lake with 85 percent or more of its organic pollution load removed. To protect shellfish growing areas effective chlorination is practiced with bacterial removals normally in excess of 95 percent.

One more important job is done at a sewage treatment plant. The waste matter which has been removed from the water is made harmless by a sludge digestion tank and drying beds. It may then be used as land fill or as fertilizer.

Storm Overflows

In protecting shellfish growing areas by sewage treatment, it is imperative that there be a minimum of interruption in this protection. Failure of the treatment works even for a few hours could so contaminate the shellfish area that it would be necessary to interrupt harvesting. Benefits to the industry from the sewage treatment process would be greatly reduced. Because of the serious consequences of failure it is necessary that all precautions be taken to prevent interruptions. In many cases this might involve the added expense of duplicate equipment, particularly of the vital chlorination process.

An important possible cause for interruption of the sewage treatment process is the storm water overflow made necessary because it is not economically possible to design a system of combined storm and sanitary sewers to carry away the heaviest rainfall which can be expected. A proper practice in the sewage treatment plant protecting a shellfish growing area is an investigation each time an overflow occurs to see if the overflow could have been prevented. This has turned out to be very rewarding. Overflows often have been found to be unnecessary and preventable by an alert operator taking proper precautions. Overflows during the heaviest storms, however, are almost certain to occur. While overflows are to be expected during the heaviest storms, generous design of intercepting sewers at increased cost plus installation storm water holding tanks can reduce damaging overflows to a minimum.

TECHNICAL PAPERS

ON THE BIOLOGY OF CERTAIN SHELLFISH

SPAWNING AND EGG PRODUCTION OF OYSTERS AND CLAMS

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Probably everyone who has worked with oysters and clams has been impressed by the great number of eggs produced by these animals. To those of us interested in maintaining commercially significant numbers of these mollusks in any given area, the number of eggs produced by a single female is one of the important factors in determining what constitutes a sufficient breeding stock.

The earliest estimate of the number of eggs produced by a female oyster, Crassostrea virginica, was by Brooks in 1880, who made his estimate by determining the volume of eggs washed out of ripe females and calculating the number from the dimensions of the egg. His first estimate was about 9 million eggs but states that "an unusually large oyster" gave an estimated 60 million eggs. It might be noted, that from the volume calculation, Brooks' figures gave 18,750,000 to 125,000,000 eggs but he believed that as much as 50 percent should be allowed for foreign matter washed out with the eggs. Churchill (1920) estimated over 16 million eggs and Nelson (1921) estimated 16 to 60 million eggs per female but both estimates were apparently based largely on those of Brooks. Galtsoff (1930) made an estimate based on experimental data. He found that individual oysters may release from 15 million to 114.8 million eggs at a single spawning, and estimates that the maximum number released by a single female during a season may be close to half a billion. Burkenroad (1947), although highly critical of Galtsoff's estimate, on the basis of calculated volumes, offers no experimental evidence of his own.

The only known estimate of the number of eggs released by a female clam is that of Belding (1912) who merely states in his summary that the average number of eggs for a $2\frac{1}{2}$-inch quahog is about 2 million.

The experiments we are reporting were designed to obtain more information on the total number of eggs produced by individual oysters and clams, and to determine how this total was affected by varying the time interval between spawnings. We also wished to find whether there was any correlation between the size of the female or the number of spawnings and the total number of eggs discharged.

For our first experiment 75 oysters and 75 clams were brought into the laboratory on December 30, 1954, and placed in conditioning trays of running sea water at 10.0°-13.0°C. The temperature of the sea water in the trays was raised to 20.0°-21.0°C. on the 31st of December. In a routine examination on New Year's Day it was discovered that some of the clams in one tray were spawning. On January 4th we attempted to spawn the 50 clams in the two trays that did not spawn on New Year's Day and found that nine of the females and eighteen of the males could be induced to spawn after only four days at 20.0°-21.0°C. One of these females released about 12,000,000 eggs and culturing revealed that approximately 89 percent of them were capable of developing into normal straight-hinged larvae.

Since this was a much shorter conditioning period than we had previously considered necessary (Loosanoff and Davis, 1950), it was assumed that, by error, we had included some clams in this group that had already been used in the laboratory. We discarded all 75 of these clams and started this portion of the experiment again on January 5,1955, with clams freshly dug near the New Haven breakwater. We attempted to spawn 30 of these clams, immediately after they had been brought into the laboratory and found that one male spawned just 16 minutes after opening in the spawning dish. Consequently this group of clams was kept at about 18.0°-19.0°C. instead of 20.0°-21.0°C. as the oysters were.

After approximately two weeks at conditioning temperature we started spawning 25 of the clams and 25 of the oysters at three-day intervals. A second group of 25 oysters was spawned at five-day intervals and a third group of 25 clams was spawned at intervals of 14 days. Since we wanted to determine the number of eggs produced by each female, each individual was placed in a separate spawning dish (Fig. 1.) and males were discarded as soon as identified. The shells of the females were marked with a sex symbol and an individual number. The number of eggs released by each female was determined and recorded each time she spawned.

There are marked differences between clams and oysters in their behavior when subjected to chemical and thermal stimulation in the spawning dishes. It was not unusual for 80 to 100 percent of the oysters to open within 15 to 20 minutes after being placed in the spawning dishes and usually they remained open until after spawning or until they were disturbed. Records available on 183 of the 227 spawnings of female oysters included in the present experiment, showed how long each female was open before starting to spawn. This period ranged from one minute to 219 minutes, with an average of 34.2 minutes. Approximately 80 percent of the spawnings occurred 30 minutes or less after the female opened, about 10 percent of the spawnings occurred within 31 to 60 minutes, and about 10 percent of the spawnings occurred over an hour after the female opened and started pumping.

Clams, on the other hand, are much less predictable. A few may open almost immediately after being put in the spawning dishes, some may open only after several hours, and usually there are a few that remain closed throughout an attempted spawning. Even after opening they frequently close again for variable lengths of time for no apparent reason. The interval between the time the clams first opened and the time they started

Fig. 1. Spawning table showing individually numbered oysters in separate spawning dishes. The table is used as a common water bath for regulating the temperature of the sea water in the spawning dishes.

spawning was recorded for 208 of the 235 spawnings in this experiment. This interval ranged from less than five minutes to 840 minutes with an average of 137 minutes. Moreover, only 35 percent of the spawnings occurred within one hour after the clams first opened. Both male and female clams have been observed to spawn for a short time, then, while still remaining open, cease spawning for periods of an hour or more, and finally spawn even more heavily than at first. Also, on several occasions both male and female clams that have been open and pumping vigorously for 30 minutes or more have started spawning immediately when placed in dishes of fresh, cooler sea water.

The spawning records of the oysters subjected to spawning stimuli every three days are shown in Table I. Within the group the total number of eggs per female ranged from 7.8 million to 59.9 million, while the number released at a single spawning ranged up to 28.3 million. The number of spawnings per female ranged from 2 to 16. Only number 14 failed to spawn on two or more consecutive three-day trials, and number 10 spawned repeatedly at three-day intervals. The highest number of eggs (59.9 million) was produced by a female that spawned nine times. The female that spawned 16 times ranked second, and a female that spawned only five times ranked third. The lowest total number of eggs was released by a female that spawned seven times.

The spawning record of the clams spawned every three days (Table II) shows a range from 17.1 to 37.4 million in the total number of eggs released. The highest number released by any female in this group at a single spawning was 17.7 million. The number of spawnings per female ranged from 3 to 10, and the female producing the highest total number of eggs spawned seven times. Second highest total was by a female spawning nine times, and the third ranking female spawned only three times. The lowest total was by a female that spawned five times.

We were surprised to find that it required about two and a half months or approximately the duration of a normal spawning season, to spawn out completely either oysters or clams, even though they were subjected to spawning stimuli every three days. Moreover, there was almost no difference in the time required at the different spawning intervals used in this experiment.

We compared the oysters of the three groups, spawned at different intervals, after arranging the females according to their rank in egg production (Table III). The range in total number of eggs per female was from 10 thousand to 66.4 million. Despite the relatively great differences between females, however, the range in all three groups is essentially similar, and the mean number of eggs per female in all three groups is approximately the same. The 14th and 15th ranking females, spawned at seven-day intervals, appear to have abnormally low totals. Except that they were the last to spawn, spawned only once, and released exceptionally few eggs, there seems to be no reason to exclude them.

A similar comparison of the three groups of clams spawned at different intervals (Table III) shows that they have even more closely comparable ranges in the total number of eggs per female than do oysters. The mean numbers of eggs per individual in the three groups of clams are also in closer agreement.

An analysis of variance test confirms the conclusion that varying the spawning interval from three to seven days for oysters and from three to 14 days for clams did not affect the total egg production. We believe that the similarity of variances and the agreement of means further indicate each group represented an adequate sample of the populations used.

From Table III we see that the maximum number of eggs released by one female at a single spawning, in either clams or oysters, may be greater than the seasonal total of many other females in the same population. We also note that the average number of eggs per spawning increases progressively in oysters as the interval between spawnings is increased. In clams there is no difference between the groups spawned at three- and seven-day intervals but the number of eggs per spawning increases slightly as the spawning interval is increased to 14 days.

If we compare clams with oysters, we find that clams, although they are, as previously mentioned, more unpredictable and variable in their response to spawning stimuli, are more uniform than oysters in egg production. The average number of eggs per female varied less from group to group (Table III) and the range in total number of eggs released by different female clams was not so great. Moreover, as shown by the frequency distribution (Table IV), the number of female clams producing different total numbers of eggs had a fairly normal distribution with a well-defined modal class at 20 to 24.9 million eggs per female and the arithmetic mean number of eggs per female (24.6) falls within this class. In oysters, by contrast, the distribution is not obviously a normal one and there is no well-defined modal class near the arithmetic mean (28.8 million).

A comparison of the frequencies of individual spawnings in which different numbers of eggs were released (Table V) also illustrates the greater variability of oysters, since again, the clams have a lesser range and a somewhat better-defined modal class. We also see that the number of spawnings in each group of clams was about the same, while in oysters there is a progressive decline in number of spawnings as the time interval between spawnings is increased. This is more clearly indicated in Table VI which shows the frequency distribution of female clams and oysters by spawnings and the average number of spawnings per individual in each group. We find that in oysters the range in number of spawnings per individual varied from a single spawning to 16 spawnings, while in clams it was only from two to eleven spawnings. The average number of spawnings per oyster decreases progressively as the interval between spawnings increases, while with clams there is little difference between the different groups. An analysis of variance confirms our conclusion that varying the spawning interval for oysters significantly affects the number of times a female oyster will spawn, those subjected to spawning stimuli at shorter intervals spawning more frequently. The analysis also shows that varying the spawning interval from three to 14 days had no significant effect on the average number of spawnings per individual clam.

To find whether there was any correlation between the size of the female oyster and the number of eggs produced, we chose the volume of the shell cavity as our best criterion of size. The total number of eggs produced, expressed in millions, was then plotted against the volume of the shell cavity in milliliters for each female (Fig. 2). In plotting, different symbols were used to differentiate the groups spawned at different intervals. The plot shows that, while the three separate correlations would differ, there is no striking reversal of trend. The data were therefore combined and one over-all correlation was computed for all oysters in the experiment considered as a single group. The resulting correlation was reasonably good: r was .54 (significant at the .01 level for 41 degrees of freedom), which means that about 30 percent of the variation in total egg production for oysters could be attributed to the differences in size as denoted by cavity volume. For clams a similar plot of the number of eggs in millions was made against the shell cavity volume in milliliters. Again, we used different symbols for the groups spawned at different intervals, but the data were combined for computing an overall correlation. For clams r was .38 (significant at the .05 level for 36 degrees of freedom), which means that about 15 percent of the variation in total egg production could be attributed to the differences in size of the female clams used in the experiment.

A similar test was made for a correlation between the number of times a female spawned and the total number of eggs produced. The correlation for oysters was .51 (significant at the .05 level). Thus, in general, females that have a large number of eggs to release will spawn at more frequent intervals than females having a lesser total number of eggs. For clams this correlation was only .17, or was not significantly different from zero.

It should be remembered that the oysters and clams used in this experiment were brought into the laboratory in mid-winter and that conditioning in trays of running sea water does not provide optimum feeding conditions. Field observations at Milford have shown that, in some seasons, oysters that go through the winter with relatively little glycogen may increase this reserve by as much as two or three times in the spring before gonad development begins. Moreover, Loosanoff and Nomejko (1951) showed that the <u>average</u> gonad thickness of oysters in Long Island Sound, at the beginning of some spawning seasons, may be almost double that recorded at corresponding periods of other years. Although no measurements of gonad thickness or glycogen content were taken at the beginning

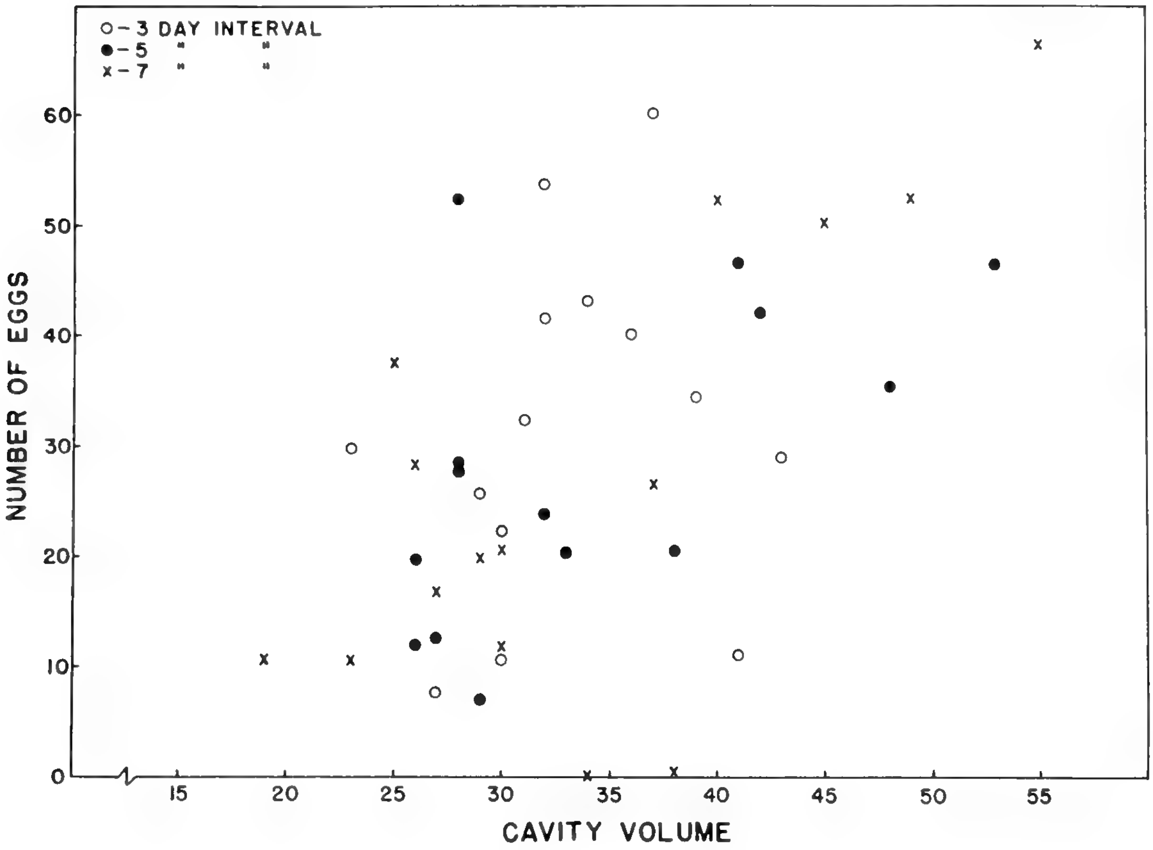

Fig. 2. Scatter diagram showing the total number of eggs produced, in millions, plotted against the volume of the shell cavity, in milliliters, for each female oyster. Different symbols are used to differentiate between oysters spawned at three-, five-, and seven-day intervals.

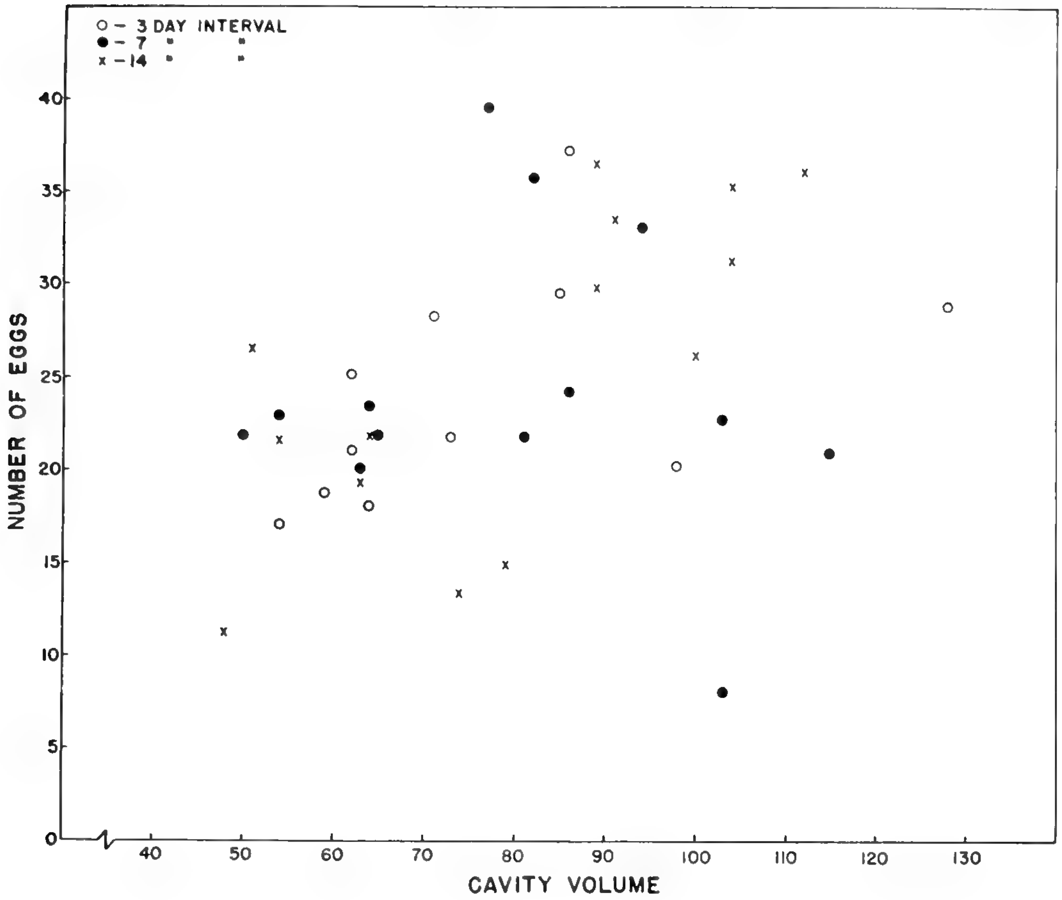

Fig. 3. Scatter diagram showing the total number of eggs produced, in millions, plotted against the volume of the shell cavity, in milliliters, for each female clam. Different symbols are used to differentiate between clams spawned at three-, seven-, and fourteen-day intervals.

of the experiment, from inspection we believe the condition of the oysters used in these experiments was below average for oysters of Long Island Sound.

A similar experiment involving only nine females was started on June 27, 1955, with oysters that had developed gonads under normal conditions in Long Island Sound. The total number of eggs per female ranged from 23.2 million to 85.8 million, and averaged 54.1 million eggs per female. Thus, both the average number of eggs and the maximum number per female were about 20 million higher than in the winter experiment. This was, we believe, at least in part, the result of these oysters having built up additional reserves of glycogen during the spring prior to the initiation of gonad development. Even these oysters, however, gave far fewer eggs than the 1/2 billion per female suggested by Galtsoff (1930).

From the present studies, and from another experiment in which 70,000,000 eggs were released by one female at a single spawning, we are in general agreement with Galtsoff (1930) on the number of eggs a female oyster may release at a single spawning. Galtsoff's estimate of 1/2 billion eggs as about the maximum number a female oyster might release in a single season was based, in part, on the assumption that a female might release approximately 100 million eggs at each of five or six spawnings during a season. Our experiment indicates that this would be unlikely. For example, the female that gave the highest number of eggs at a single spawning, 48.8 million, spawned on only two other occasions during the experiment and on each of these occasions released less than 4 million eggs. Of the 43 female oysters in the experiment only one released in excess of 10 million eggs at as many as three spawnings.

At the conclusion of the experiment all the females were opened and the gonad condition, presence of shell injuries, and degree of _Polydora_ and sponge infestation noted for each female. Statistical analysis does not reveal any effect of shell injuries or of _Polydora_ and sponge infestations on the number of eggs produced by a female oyster. Histology indicated that only one female oyster still contained a few eggs, but that all the female clams still retained a few apparently mature eggs (Loosanoff, 1937).

As noted in Table I, only one of the 14 female oysters failed to spawn two or more consecutive times when subjected to spawning stimuli every third day and female number 10 spawned repeatedly at three-day intervals. This led us to suspect that at least some female oysters might not show the two- to five-day refractory period that Galtsoff found (1938, 1940). An experiment was therefore designed to determine whether some female oysters might spawn at more frequent intervals.

For this experiment 50 oysters were brought into the laboratory April 4, 1955, and placed in conditioning trays at 20.0°-21.0°C.

Twenty-one days later these oysters were placed in individual spawning dishes and both chemical and thermal stimulation were used to induce spawning. Seventeen females and 24 males responded on the first day (Table VI). After spawning, the males and females were washed separately in cold running sea water, and the shell of each was marked with the appropriate sex symbol and an individual number. All males were then returned to one conditioning tray and all the females to another tray. Those oysters that did not spawn on this first trial were returned to a third tray. Each morning for five consecutive days these oysters were subjected to spawning stimuli and a record of the spawning of each individual was kept.

As shown in Table VI, of the 24 females in the experiment, 14 spawned on two or more consecutive days, eight spawned on three or more consecutive days, five spawned on four or more consecutive days, and three spawned on each of the five days of the experiment. As was to be expected, 25 of the 26 males in the experiment spawned on three or more consecutive days, nine spawned on four or more consecutive days, and eight spawned on each of the five days of the experiment. By the fifth day, however, it was difficult to induce spawning and the spawning of both males and females was light. However, when these oysters were again subjected to spawning stimuli after remaining undisturbed in the conditioning trays for an additional week, 22 of the 26 males and 18 of the 24 females responded, releasing approximately average amounts of spawn.

From our experiments, we believe that either there is no refractory period for female oysters, such as Galtsoff described, or it is less than 24 hours in duration. Our results suggest that both male and female oysters can spawn upon proper stimulation any time they have physiologically-ripe sex cells to discharge. Under constant or closely spaced intervals of stimulation we believe they may so deplete their supply of physiologically-ripe sex cells that they are unable to release more until additional sex cells have become physiologically mature. Some females, for example, were observed to give fairly typical spawning motions on the 4th and 5th days of the above experiment without releasing any eggs and yet spawned normally after several additional days of conditioning.

We wish to express our thanks to the Director of the Milford Laboratory, Dr. V. L. Loosanoff, who suggested the problem, for his advice throughout the experiments, and to our colleagues, Mrs. Barbara Myers, for the statistical treatment, and Mr. C.A. Nomejko, for the figures and slides.

Summary

1. The total number of eggs released by individual female oysters, *C. virginica*, ranged from 10 thousand to 66.4 million and averaged 28.8 million.

2. In this experiment the highest number released by a female oyster in a single spawning was 48.8 million but in a previous experiment one female discharged 70.0 million eggs. Thus some females release more eggs at a single spawning than other female oysters do in a season.

3. There was no significant difference in the average number of eggs released in a season whether the oysters were spawned at three-,five- or seven-day intervals.

4. Female oysters that had large numbers of eggs to release tended to spawn more frequently than females with lesser numbers of eggs.

5. The average number of spawnings per female oyster decreased progressively as the interval between spawnings was increased.

6. The total number of eggs produced showed a correlation of .54 (significant at .01 level) with the size of the female oyster, as indicated by shell cavity volume.

7. No correlation could be found between the number of eggs produced and Polydora or sponge infestation, or shell injury.

8. We find no two- to five-day refractory period during which female oysters cannot be induced to spawn, as reported by earlier investigators.

9. The total number of eggs released by individual female clams, V. mercenaria, ranged from 8 million to 39.5 million, and averaged 24.6 million per clam.

10. The highest number released by any female clam at a single spawning was 24.3 million eggs.

11. The correlation for clams between number of eggs produced and volume of shell cavity was .38 (significant at the .05 level).

12. There was no significant difference in the average number of eggs released in a season whether the clams were spawned at three-, seven-, or fourteen-day intervals, nor was there any significant difference in the average number of spawnings per female.

13. The correlation between number of times a female clam spawns and the number of eggs produced was not significantly different from zero.

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TABLE I

Spawning dates and number of eggs (in millions) released by each female oyster induced to spawn at 3-day intervals.

Spawning Date	Oyster Numbers													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1/18/55	9.0	2.0	6.8	7.9	6.3	0.4	0.07							
1/21/55	1.0	0.8		3.8	8.7	0.5	2.0	0.9						
1/24/55	3.1	8.4					6.8	2.9	0.05	0.01				
1/27/55			0.4	6.9	16.3	2.5	3.3	1.3		0.1	1.8	3.3		
1/30/55	2.8	18.7		1.6		1.1	7.7	2.9		4.0	2.7	2.3		
2/ 2/55										9.2				
2/ 5/55	3.9	5.8		4.7		1.5		2.0	7.1	6.5			5.6	
2/ 8/55							9.7			5.6			1.8	
2/11/55	3.8			3.5		1.8		3.6		4.1	28.3	16.5	3.6	
2/14/55	0.9	9.6			10.1	0.02	7.0	2.3		4.0		0.1	3.4	
2/17/55										2.8				
2/20/55	4.0							6.6					6.4	
2/23/55										5.9				
2/26/55	1.0		1.4				3.5			3.6			3.5	
3/ 1/55		9.4	0.5	3.7						2.0	1.2		1.7	8.4
3/ 4/55	0.3								27.3	2.4			1.4	
3/ 7/55														
3/10/55		5.2						3.2		2.7	9.1		1.5	
3/13/55										0.6				
3/16/55										0.2				
3/19/55														
3/22/55		0.03	1.9											2.1
3/25/55			0.05											
Total Eggs	29.8	59.9	11.0	32.1	41.4	7.8	40.0	25.7	34.4	53.7	43.1	22.2	29.0	10.5

TABLE II

Spawning dates and number of eggs (in millions) released by each female clam induced to spawn at 3-day intervals.

Spawning Date	Clam Numbers										
	1	2	3	4	5	6	7	8	9	10	11
1/15/55	0.3	7.7	1.1	9.3	4.9	8.5	13.6	5.7	4.7		
1/18/55											
1/21/55		2.1					6.4			13.5	
1/24/55	6.4			3.5	5.9	3.9			5.4	1.3	11.1
1/27/55											
1/30/55	2.1	4.2	17.7	1.6	2.5	2.6	4.0	6.3	1.6	2.3	2.5
2/ 2/55	1.4								1.0		
2/ 5/55	0.7	3.5			4.0	0.1		1.9		3.1	
2/ 8/55	1.7		10.0	2.4		3.4		0.7		1.1	3.7
2/11/55	1.1			1.0	2.2	1.8	6.3				1.8
2/14/55	1.4										
2/17/55					1.8					1.4	
2/20/55		4.2				5.0			5.0	0.8	1.0
2/23/55								2.5			
2/26/55				3.2	3.7	2.2	0.3				
3/ 1/55					0.5						
3/ 4/55											
3/ 7/55	3.4										
3/10/55					2.4		6.6				
3/13/55											
3/16/55					0.2	1.9					
3/19/55											
3/22/55									0.2		
3/25/55							0.2			1.5	
Total Eggs	18.5	21.7	28.8	21.0	28.1	29.4	37.4	17.1	17.9	25.0	20.1

TABLE III

Total number of eggs discharged by female oysters spawned at 3-, 5-, and 7-day intervals. Number of eggs in millions.				Total number of eggs discharged by female clams spawned at 3-, 7-, and 14-day intervals Number of eggs in millions.			
Rank	3-day Spawning Interval	5-day Spawning Interval	7-day Spawning Interval	Rank	3-day Spawning Interval	7-day Spawning Interval	14-day Spawning Interval
1	59.9	52.2	66.4	1	37.3	39.5	36.5
2	53.6	46.6	52.6	2	29.5	35.7	36.1
3	43.1	46.6	52.2	3	28.8	33.0	35.3
4	41.3	42.0	50.3	4	28.2	24.2	33.5
5	40.0	35.3	37.4	5	25.1	23.4	31.2
6	34.4	28.3	28.3	6	21.7	22.9	29.8
7	32.2	27.7	26.7	7	21.0	22.2	26.5
8	29.8	23.8	20.4	8	20.2	21.9	26.2
9	29.0	20.3	19.9	9	18.7	21.8	21.6
10	25.6	20.1	16.8	10	18.0	21.7	20.8
11	22.2	19.7	11.8	11	17.0	20.9	19.3
12	11.0	12.5	10.8	12		20.0	14.9
13	10.4	11.9	10.5	13		8.0	13.3
14	7.8	7.0	.6	14			11.2
15			.01	15			
Mean	31.4	28.1	27.0	Mean	24.1	24.2	25.4
Average per Spawning	4.4	5.5	7.2	Average per Spawning	3.6	3.6	4.7

Maximum number of eggs from one female at a single spawning 48,780,000.

Maximum number of eggs from one female at a single spawning 24,300,000.

TABLE IV

Frequency distribution of female oysters and clams producing different total number of eggs.

	Clams				Oysters			
Number of eggs (millions)	3 days	7 days	14 days	Total Females	3 days	5 days	7 days	Total Females
Less than 9.9	0	1	0	1	1	1	2	4
10 - 14.9	0	0	3	3	2	2	3	7
15 - 19.9	3	0	1	4	0	1	2	3
20 - 24.9	3	9	2	14	1	3	1	5
25 - 29.9	4	0	3	7	3	2	2	7
30 - 34.9	0	1	2	3	2	0	0	2
35 - 39.9	1	2	3	6	0	1	1	2
40 - 44.9					3	1	0	4
45 - 49.9					0	2	0	2
50 - 54.9					1	1	3	5
55 - 59.9					1		0	1
60 - 64.9							0	0
65 - 69.9							1	1
Total females	11	13	14	38	14	14	15	43

TABLE V

Frequency distribution of spawnings in which different numbers of eggs were released.

	Clams				Oysters			
Number of eggs (millions)	3 days	7 days	14 days	Total Spawnings	3 days	5 days	7 days	Total Spawnings
Less than 0.9	10	30	21	61	19	21	22	62
1 - 4.9	45	40	31	116	49	20	11	80
5 - 9.9	13	6	13	32	25	18	8	51
10 - 14.9	4	7	4	15	1	9	6	16
15 - 19.9	1	4	2	7	3	2	2	7
20 - 24.9			4	4	0	0	4	4
25 - 29.9					2	0	1	3
30 - 34.9						1	0	1
35 - 39.9						1	1	2
40 - 44.9							0	0
45 - 49.9							1	1
Total Spawnings	73	87	75	235	99	72	56	227

TABLE VI

Frequency distribution of clams and oysters by number of spawnings.

	Oysters				Clams			
Number of Spawnings	Number of Females in 3-day group	5-day group	7-day group	All groups	Number of Females in 3-day group	7-day group	14-day group	All groups
1		1	2	3				0
2	1	2	1	4		2		2
3	1	1	5	7	1		2	3
4	2	3	4	9		1	2	3
5	1			1	3	2	2	7
6	1	3	1	5	2	1	6	9
7	2	1	1	4	1	2	2	5
8	1	2	1	4	1	1		2
9	3			3	2			2
10	1			1	1	2		3
11				0		2		2
12		1		1				
13				0				
14				0				
15				0				
16	1			1				
Total Females	14	14	15	43	11	13	14	38
Mean number of Spawnings	7.1	5.2	3.7	5.3	6.6	6.8	5.3	6.2

TABLE VII

Spawning record of male and female oysters subjected to spawning stimuli daily for 5 consecutive days. X indicates spawning.

Females						Males					
Female Number	Days 1st	2nd	3rd	4th	5th	Male Number	Days 1st	2nd	3rd	4th	5th
1	x		x			1	x	x	x	x	x
2	x		x			2	x	x	x		x
3	x	x	x	x		3	x	x	x		x
4	x		x	x	x	4	x	x	x	x	
5	x	x	x	x	x	5	x	x	x		x
6	x		x	x	x	6	x	x	x		
7	x		x		x	7	x	x	x	x	x
8	x	x	x	x	x	8	x	x	x	x	x
9	x			x		9	x	x			x
10	x		x	x		10	x	x	x		x
11	x	x	x	x	x	11	x	x	x	x	x
12	x	x			x	12	x	x	x		x
13	x	x	x	x		13	x	x	x		x
14	x		x	x		14	x	x	x		x
15	x		x	x		15	x	x	x		x
16	x	x				16	x	x	x		x
17	x	x		x		17	x	x	x		x
18		x			x	18	x	x	x	x	x
19		x		x		19	x	x	x	x	x
20			x		x	20	x	x	x		x
21			x			21	x	x	x	x	x
22			x	x		22	x	x	x		x
23			x			23	x	x	x	x	x
24			x			24	x	x	x		x
						25		x	x	x	
						26			x		

EFFECTS OF SOME DISSOLVED SUBSTANCES ON BIVALVE LARVAE

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A number of dissolved substances has been tested in the course of experiments to find methods for improving the rate of growth and controlling mortality in our larval cultures at Milford Laboratory. This report is a summary of our observations of the effects on clam and oyster larvae of vitamins, fungicides, antibiotics, sulfa drugs, and the dissolved substances accompanying a dinoflagellate bloom. The data are incomplete in many respects and some of our present conclusions may later require revision as more information is obtained.

Investigation of the effects of some of the water-soluble vitamins was stimulated by the report of Collier et al (1950) of a substance in sea water that affected the rate of pumping of adult oysters, and Wangersky's (1952) report that this substance was, in part, a vitamin. Wilson (1951) and Davis (1953) have also reported some evidence that growth of invertebrate larvae is affected by unidentified substances in sea water.

In one experiment we tested the effect of a series of vitamins on the growth and survival of larvae of the hard clam, *Venus mercenaria*. Vitamin A, B_{12}, biotin, calcium pantothenate, nicotinic acid, pyridoxine hydrochloride, riboflavin, thiamine hydrochloride, and a combination of calcium pantothenate, pyridoxine hydrochloride, riboflavin, and thiamine hydrochloride were used. The growth rate of clam larvae was not significantly increased under the conditions of this experiment by any of the separate vitamins nor by a combination of the four vitamins. We have plotted the mean length of larvae in the control culture, with the 95 percent fiducial limits of this mean, and superimposed the range of the means of the vitamin-treated cultures (Fig. 1). Only on the eighth day did the mean of the fastest growing vitamin-treated culture fall above the 95 percent fiducial limit of the control. By the tenth day the mean length of larvae in the control culture was higher than that of any of the vitamin-treated cultures.

A similar experiment with larvae of the American oyster, *Crassostrea virginica*, indicated that growth of these larvae was significantly accelerated by riboflavin and that calcium pantothenate, thiamine hydrochloride, and pyridoxine hydrochloride increased the rate of growth slightly. A combination of these four vitamins significantly increased the rate of growth of larvae both when given alone and when given in combination with mixed *Chlorella*. Larvae receiving vitamins but no *Chlorella* actually grew faster for the first six days than larvae receiving *Chlorella* but no vitamins (Fig. 2). In another experiment all cultures received riboflavin throughout the experiment, but the addition of *Chlorella* as food was delayed until

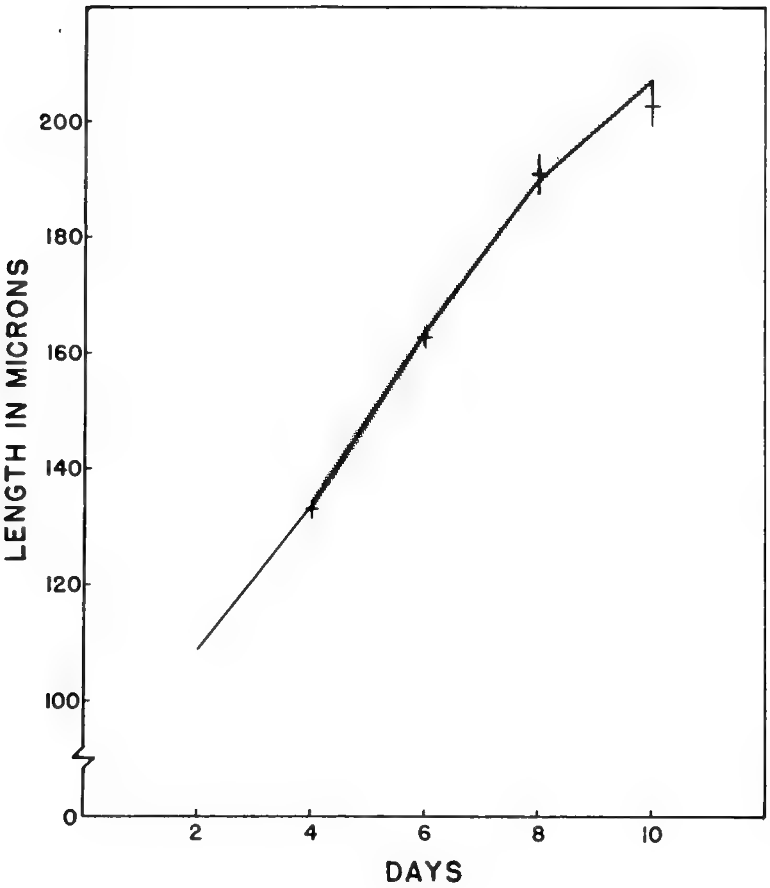

Fig. 1. Growth of vitamin-treated clam larvae compared with growth of untreated larvae. For explanation see text.

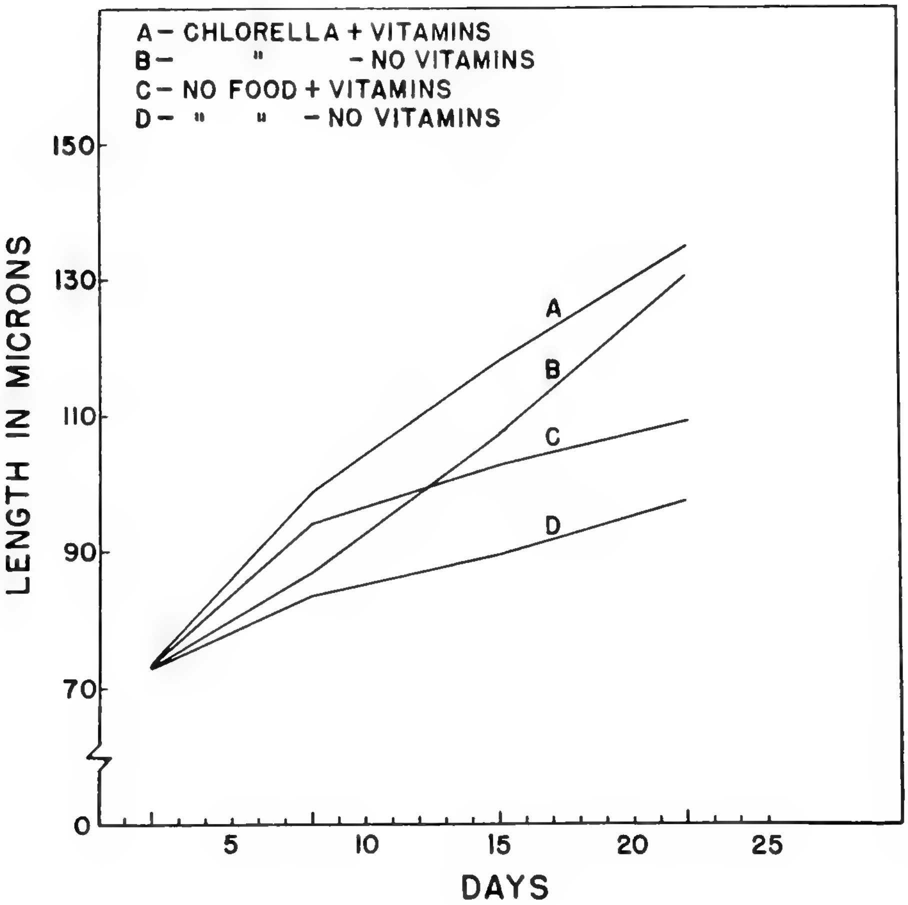

Fig. 2. Effect of vitamin treatment on growth of oyster larvae in the presence, and in the absence, of mixed Chlorella as food. Vitamin-treated cultures received a combination of biotin, calcium pantothenate, pyridoxine hydrochloride, riboflavin, and thiamine hydrochloride.

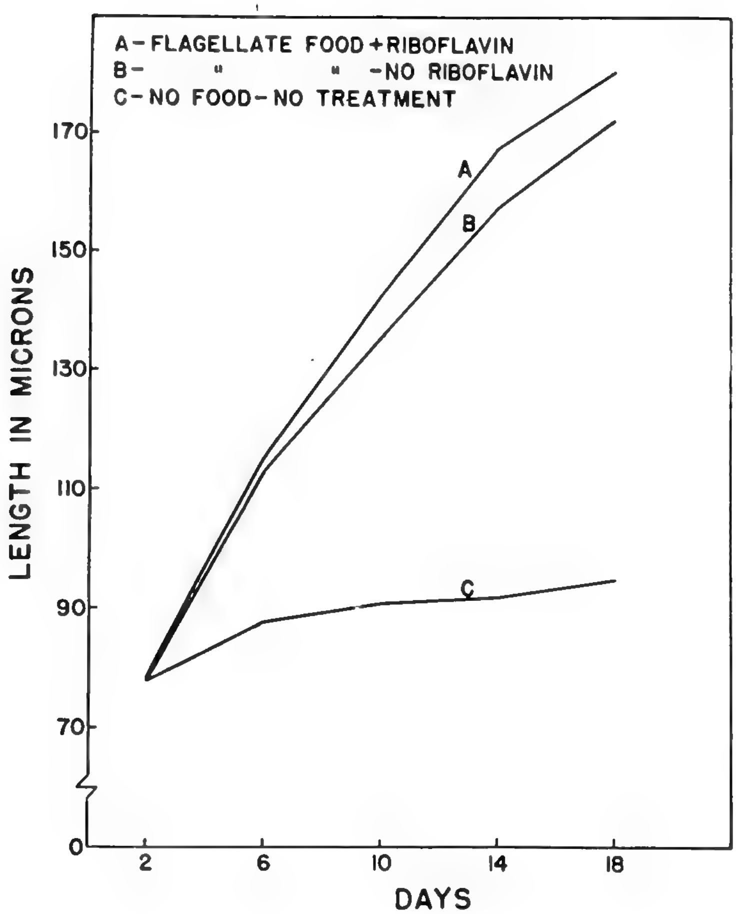

Fig. 3. Growth of oyster larvae receiving riboflavin and mixed flagellates as food, compared with growth of larvae receiving the same food but no vitamins, and with growth of larvae receiving neither the food nor the riboflavin.

the second, fourth, or sixth day. By the 14th day the larvae in the culture that did not receive Chlorella until the sixth day were not only larger but a higher percentage of them had survived (Table I).

When riboflavin was used with a good food, such as mixed flagellates, the growth rate of oyster larvae was still significantly increased but the effect was less pronounced (Fig 3). Although in most cases the rate of growth was increased by the addition of these vitamins, in some experiments the increase was either negligible or non-existent. In no case, however, was growth significantly retarded.

The growth of the larvae of the Olympia oyster, Ostrea lurida, was similarly accelerated by a mixture of riboflavin, thiamine, pyridoxine, calcium pantothenate and biotin (Table II). Again, as with the American oyster, the increase in growth rate was negligible or non-existent in some experiments.

Since there is considerable variation in the effects of these vitamins on oyster larvae in different experiments and at different times, it is possible that they might also have increased the rate of growth of clam larvae under other conditions. It is not known whether this variability of effect is caused by changes in the vitamin content of the food, or of the sea water, or is the result of other factors.

We investigated the effects of certain fungicides on the growth and survival of bivalve larvae and their efficiency in controlling the fungus disease reported by Davis et al (1954). A number of the common fungicides was found ineffective in controlling the fungus but in these early experiments detailed records of their effects on larvae were not kept. We did find that clam larvae survived for at least six days in 1 : 100,000 copper sulfate, while oyster larvae were killed by concentrations of less than one part per million.

Malucidin, a fungicidal antibiotic extracted from Brewer's yeast, prepared by Dr. Parfentjiev of the Yale University Department of Microbiology, has been studied more extensively. This substance, in the presently available unpurified state, is quite toxic to clam larvae at high concentrations. Even at lower concentrations, at which it has no effect on fungus, either the antibiotic or impurities in the present preparations reduced both the rate of growth and the survival of clam larvae (Table III). The purest preparation of malucidin available contained 3.5 percent active antibiotic. Larvae treated with different concentrations of this malucidin averaged five percent to 18 percent smaller than the controls at the end of the experiment. The crude extract, although it contained less of the active principle of the antibiotic, was even more toxic when used in equal concentrations and reduced the average size by 23 percent to 31 percent. Heavier concentrations, of either the crude extract or the more refined product, reduced growth even more drastically and resulted in increasingly heavier mortalities.

Some other antibiotics, known to increase the rate of growth of higher animals, have been investigated to determine whether they have a similar effect on bivalve larvae. It was also hoped that by reducing the numbers of bacteria by the use of these antibiotics, we might improve the percentage of survival in our cultures. Streptomycin has been used in a number of experiments and we have some data on the effects of aureomycin and terramycin.

Both pure streptomycin and commercial grade, containing one gram of active streptomycin per 1.86 grams of the commercial product, have been used with clam larvae. The growth rate of clam larvae was slightly increased even at our lowest concentration of one part per million, and the rate of growth increased progressively, in most experiments, until an optimum concentration of from 10 to 100 parts per million was reached (Table IV). At concentrations above the optimum, the rate of growth of the larvae falls off slowly at first and then very rapidly until at 1000 parts per million, even with pure streptomycin, the larvae averaged only 78 percent as large as those in control cultures.

Any interpretation of the survival data must take into consideration that our method for determining survival is only accurate to about ±10 percent, and therefore differences of less than 20 percent are of dubious significance. With this allowance for inaccuracies in method, the survival of the treated cultures was significantly lower than in the control cultures in only three cases. In one of these, when 1000 parts per million of commercial grade streptomycin was used, the complete mortality almost certainly resulted from impurities in the commercial grade product. A similar concentration of pure streptomycin although greatly decreasing growth, had no effect on survival. In the cultures receiving 100 parts per million of commercial grade streptomycin the poor survival was primarily the result of a fungus epidemic. Although the cause of the lower survival in the culture receiving 10 parts per million of pure streptomycin was not apparent, the mortality was probably the result of some condition other than the treatment. In no single case was survival significantly improved but the number of cases in which survival was slightly improved leads one to suspect that streptomycin generally tended to decrease mortality.

The effect of aureomycin on the growth rate of clam larvae was, in general, similar to the effect of streptomycin. The increase in rate of growth was less pronounced, however, and the threshold concentration, optimum concentration and lethal concentration were all lower. A concentration as low as 0.4 parts per million appeared to increase slightly both the rate of growth and survival, although not significantly (Table V). The increase in growth and survival was somewhat greater at a concentration of 3.2 parts per million and this appears to be near the optimum concentration. Thirty-two parts per million is obviously above the optimum concentration, as indicated by the decreased rate of growth, although survival was still very good. When the concentration was increased to 320 parts per million, mortality was complete. The commercial grade aureomycin, which contained only 25 grams of aureomycin per pound of commercial product, slightly increased the larval rate of growth at the very low concentration of 0.1 part per million. The decreased rate of growth at one part per million, as well as the lowered survival at both the above concentrations, indicates that the impurities in the commercial grade aureomycin exerted a toxic effect. Complete mortality resulted at concentrations of 10 parts per million and higher.

Commercial terramycin was extremely toxic to clam larvae. A concentration as low as one part per million was sufficient to cause 100 percent mortality (Table V). Even at one part per hundred million the larval rate of growth was seriously decreased although there was no significant decrease in survival at this concentration.

Three of the sulfa drugs, sulfamerazine, sulfathiazole and sulfanilamide, have also been tested on clam larvae to a very limited extent. The sulfamerazine was virtually insoluble in water and consequently almost impossible to evaluate. Neither the rate of growth nor the survival of the clam larvae was increased significantly at any concentration of sulfamerazine (Table V). In higher concentrations, growth was slightly decreased but this decrease may well have been the result of mechanical interference by the undissolved material.

Sulfathiazole and sulfanilamide were tested at only two concentrations. Both of these substances reduced the growth rate of clam larvae at both concentrations used. Sulfanilamide also substantially increased the mortality of clam larvae (Table V). Sulfathiazole appears to have reduced mortality but this may be misleading as the control culture developed fungus while fungus was not observed in the culture receiving sulfathiazole.

The effects of a dense bloom of dinoflagellates on our larval cultures were probably also attributable to dissolved substances. Loosanoff (1955) has previously reported that this bloom caused the abortion of embryos and immature larvae by gravid European oysters. It first appeared in our salt water system on the week-end of July 4, 1954, and continued in varying intensity until about July 21. Clams were spawned on several occasions during the 10 days immediately following the appearance of this bloom, but very few of the fertilized eggs obtained developed into normal straight-hinged larvae.

On July 14 an experiment was started that permitted us to contrast the percentage of oyster eggs developing into shelled veligers in sea water from two different sources. Twelve cultures were started by placing fertilized oyster eggs in cotton-filtered sea water that contained dinoglagellates. Two additional cultures were started in sea water that had been passed through a charcoal filter on July 1, before the dinoflagellate bloom appeared. We anticipated that a rather low percentage of the eggs would develop normally in the two latter cultures because of charcoal filtration. After 48 hours it was found that 57 percent of the eggs in these two cultures had developed normally and that an additional 16.3 percent had developed some shell but were not normal. In contrast to this total of 73.3 percent, which showed shell formation, only 13.2 percent of the eggs in the dinoflagellate-infested sea water developed far enough to show any shell formation (Table VI).

Additional attempts to start cultures of clams and oysters in the dinoflagellate-infested Harbor waters pumped into the laboratory from Milford Harbor were made on July 15 and 16, but virtually none of the eggs developed normally. On July 19 sea water that was relatively free of dinoflagellates was brought in from a point in Long Island Sound almost midway between Milford and the Long Island coast. One culture of clams and one of oysters were then started in Harbor water and one culture of each species was started in Sound water. The percentage of eggs developing normally even in this Sound water was comparatively low, only 40.61 percent for oysters and 36.03 percent for clams, perhaps indicating that the effects of the bloom extended some distance offshore. Nevertheless, development in Sound water was considerably better than in Harbor water, in which only 4.59 percent of the oyster eggs and 5.89 percent of the clam eggs developed normally (Table VI).

Finally, on July 20, some abatement in the number of dinoflagellates began and the percentage of eggs developing normally began to increase until within a few days cultures could be started with approximately normal success.

In the summer of 1955 a dinoflagellate bloom appeared on June 30, and continued in varying intensity throughout July. In localized areas concentrations as high as 300,000 per milliliter were recorded. Again we found that the presence of the bloom was correlated with the failure of all but a very small percentage of either clam or oyster eggs to develop into normal straight-hinged larvae. Removal of the dinoflagellates, by filtering the sea water through millipore filters, only slightly increased the percentage of eggs developing normally. We believe, therefore, that the effects noted are attributable to dissolved substances. The abnormal development of clam and oyster eggs may result from the almost complete removal of some substance, necessary for normal development, by the rapid increase in numbers of dinoflagellates, or it may result from the toxicity of certain external metabolites liberated by the dinoflagellates. A third possibility is that some substance, by favoring the rapid growth of dinoflagellates and by preventing the normal development of larvae, is responsible for both phenomena.

Our observations on antifungal agents, antibiotics, and the sulfa drugs indicate that the rate of growth and survival of lamellibranch larvae can be profoundly affected by very minute concentrations of certain substances. Even substances that were beneficial in low concentrations were found to be harmful at only slightly higher concentrations. Moreover, the pattern of the harmful effect on growth and survival of the larvae was remarkably similar for antifungal agents, antibiotics and for the sulfa drugs. The first effect of a slight excess of the dissolved substances was to reduce the rate of growth. This reduction in rate of growth may be very pronounced, as with streptomycin, for example, before the concentration of the dissolved substances becomes high enough to cause appreciable mortality. As the concentration of most dissolved substances was further increased, a point was reached at which mortality of the larvae was 100 percent.

Since the very dilute solutions of some of the substances tested are so extremely toxic, pollution of natural waters may be of more importance than previously thought in determining the success or failure of oyster and clam sets.

We wish to express our thanks to our Laboratory Director, Dr. V. L. Loosanoff, for continued interest and critical advice throughout these experiments, and to our colleague, Mr. C.A. Nomejko, for the preparation of the graphs and slides.

Summary

1. Riboflavin alone, or in combination with calcium pantothenate, thiamine hydrochloride, and pyridoxine hydrochloride, significantly increased the rate of growth of C. virginica and O. lurida larvae.

2. These same vitamins had no effect on the growth rate of V. mercenaria larvae under the conditions of our experiment.

3. Malucidin, an unpurified fungicidal antibiotic, decreased the growth rate of clam larvae at all concentrations tested and was too toxic to be of value in controlling fungus in larval cultures.

4. Pure streptomycin accelerated the growth of clam larvae at lower concentrations but above a concentration of 1 : 1,000 the growth decreased.

5. Commercial streptomycin gave similar results but caused complete mortality at 1 : 1,000, whereas pure streptomycin did not.

6. Pure aureomycin gave results similar to pure streptomycin but the increase in growth rate was less and aureomycin caused 100 percent mortality at a concentration of only 3.2 parts in 10,000.

7. Commercial terramycin decreased the growth rate of larvae at concentrations of 1 : 100,000,000 and caused complete mortality at 1 : 1,000, 000.

8. The sulfa drugs tested generally reduced the growth rate of larvae and increased mortality at the concentrations used in our experiments.

9. Clam larvae reacted in the same manner to overdoses of many of the substances tested, i.e., slight excesses reduced the growth rate, and progressively increasing concentrations correspondingly decreased the growth rate and increased mortality.

10. A dense bloom of dinoflagellates caused clam and oyster embryos to develop abnormally and only a few developed into shelled veligers.

11. The very low tolerance of oyster and clam embryos and larvae to many of the substances tested suggests that dissolved substances may be more important than heretofore recognized in the success or failure of oyster and clam sets.

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TABLE I

Growth and survival of vitamin-treated oyster larvae, as related to the time at which feeding with *Chlorella* is begun. Mean length and survival at 14 days.

Treatment	Mean length in Microns	Number of larvae surviving per jar (original numbers unknown but equal)
Riboflavin throughout *Chlorella* from 2nd day	92.92	15,500
Riboflavin throughout *Chlorella* from 4th day	111.83	29,700
Riboflavin throughout *Chlorella* from 6th day	117.44	43,000

TABLE II

Effect of a mixture of five vitamins (Riboflavin, Thiamine HCl, Biotin, Calcium pentothenate, and Pyridoxine HCl) on the growth of *Ostrea lurida* larvae.

Treatment	Mean Length in Microns						
	2 days	4 days	6 days	8 days	10 days	12 days	14 days
Receiving vitamins	182.93	193.14	202.86	201.03	212.54	228.57	230.30
Control (Not receiving vitamins)	180.55	183.69	188.15	192.10	197.20	201.49	211.52
Superiority of vitamin-treated cultures	2.38	9.45	14.71	8.93	15.34	27.08	18.78

TABLE III

Effects of malucidin on growth and survival of clam larvae. Mean lengths of treated larvae are expressed in percent with the mean length of the control taken as 100%. Survival is expressed in percent with survival in control cultures taken as 100%.

Treatment	Triplicate 800 ml. cultures		
	Dosage parts per million	Mean length	Mean Survival
3.5% Malucidin	27.8	95.57	96
3.5% Malucidin	55.6	90.37	89
3.5% Malucidin	83.4	82.93	70
Crude extract	55.6	76.82	64
Crude extract	83.4	68.74	81

TABLE IV

Effect of streptomycin on growth and survival of clam larvae.
Mean lengths of treated larvae are expressed in percent with the mean length of larvae in the control culture taken as 100%.
Survival is expressed in percent with survival in the control cultures taken as 100%.

DOSAGE	MEAN LENGTH					SURVIVAL				
Parts per million	EXPT. 1. Single 800 ml. cultures	EXPT. 2. Triple 800 ml. cultures	EXPT. 3. Single 18 liter cultures	EXPT. 4. Quintuple 18 liter cultures	AVERAGE ALL EXPTS.	EXPT. 1. Single 800 ml. cultures	EXPT. 2. Triple 800 ml. cultures	EXPT. 3. Single 18 liter cultures	EXPT. 4. Quintuple 18 liter cultures	AVERAGE ALL EXPTS.
1.0	102.69	101.96			102.32	84	104			94.0
10.0	107.07	101.94			104.50	60	101			80.5
13.9			106.23		106.23			109		109.0
27.8			104.33	107.02	105.68			110	109	109.5
100.0	104.52	104.43			104.48	116	44**			80.0
1000.0	77.86	lethal			77.86	106	0			53.0

*Commercial Streptomycin used in EXPT. 2.

**Heavy mortality caused by fungus infection.

TABLE V

Effect of antibiotics and sulfa drugs on growth and survival of clam larvae. Mean lengths of treated larvae are expressed in percent with the mean length of larvae in the control culture taken as 100%. Survival is expressed in percent with survival in the control culture taken as 100%.

Pure Aureomycin Single 800 ml. cultures			Commercial Aureomycin Triple 800 ml. cultures			Commercial Terramycin Triple 800 ml. cultures		
Parts per million	Mean length	Survival	Parts per million	Mean length	Mean survival	Parts per million	Mean length	Mean survival
0.4	101.04	106	0.1	101.96	89	0.01	90.62	94
3.2	102.42	110	1.0	78.50	67	0.10	83.08	53
32.0	86.07	111	10.0	-	0.0	1.00	-	0.0
320.0	-	0.0	100.0	-	0.0	1.00	-	0.0

Sulfamerazine Triple 800 m. cultures			Sulfathiazole Single 18 liter cultures			Sulfanilamide Single 18 liter cultures		
Parts per million	Mean length	Mean survival	Parts per million	Mean length	Survival	Parts per million	Mean length	Survival
1.0	101.42	101	56.0	96.08	109	56	93.54	98
10.0	95.68	90	111.0	91.09	136	111	90.62	42
100.0	97.19	95						

TABLE VI

Percentage of shelled veliger clam and oyster larvae developing from eggs released on different dates and cultured in different waters during July 1954.

Date of Spawning	Sea water used	Percentage of eggs developing into shelled veligers oysters	clams
7/14	Harbor	13.2	-
7/14	Harbor (7/1)	73.3	-
7/15	Harbor	-	1.0
7/16	Harbor	1.0	-
7/19	Harbor	-	Very low
7/19	Sound	-	Fairly good
7/19	Harbor	4.59	5.89
7/19	Sound	40.61	36.03
7/20	Harbor (7/19)	1.78	-
7/20	Harbor	7.55	15.18

REPRODUCTIVE CYCLE IN NATIVE AND TRANSPLANTED OYSTERS

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(Abstract)

This study was undertaken to determine if any changes occurred in the normal reproductive cycle of northern oysters transplanted to Florida waters. Seasonal changes in gonad histology were compared in three groups of oysters: Chesapeake oysters and Pensacola oysters in their native habitats and Chesapeake oysters transferred to Pensacola at the age of six months. The only essential difference found was in the timing of the stages of the reproductive cycle.

After one year of adjustment in Pensacola waters, Chesapeake Bay oysters started spawning at a temperature level 5°C. above that of their parent stock and reached a stage of mass spawning also at a 5° higher temperature level. In addition, the spawning period was extended from the usual three and a half to five months. Their reproductive activity was indistinguishable from that of the native Pensacola oysters. It is significant that the Chesapeake oysters at Pensacola did not show any sign of spawning when water temperatures reached 20°C., their customary initial spawning temperature in Maryland. Such results suggested that the oyster's reproductive activity is regulated by changing temperature levels rather than by an hereditary response to temperature thresholds. Re-examination of our spatfall records at Pensacola for the past seven years showed that the initial set each year had occurred at temperatures ranging from 18° to 27°C. and varying in time from mid-March to mid-May. Significantly, in all years setting first occurred only after there had been a minimum temperature increase of 5°C. in the preceding 30-day period.

These observations indicate that the oyster reproductive system can adjust to different temperature levels just as the oyster can adapt itself to changing salinity levels. There is no suggestion of any hereditary factors controlling the changed pattern of the reproductive cycle. In this case, at least, there is no necessity for postulating physiological speciation in the oyster to account for its different reproductive behavior at two different lattitudes.

SOME ADDITIONAL DIFFERENCES BETWEEN CRASSOSTREA VIRGINICA AND OSTREA EQUESTRIS IN THE GULF OF MEXICO AREA*

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Introduction

Even before the general acceptance of the division of the genus Ostrea into two genera, Ostrea and Crassostrea (Gryphaea), there were several recognized differences between the two types. Most of these differences are given by Gunter (1950). Menzel (1955) found a few additional differences, especially in the stratification of the larval attachment in waters of high salinity and in the feeding behaviour. The differences are given in Table I. The present report deals with differences between the two genera, represented by C. virginica and O. equistris, in the Gulf of Mexico area, in their reactions at low temperatures.

Menzel (1955a,b) devised an apparatus that enabled the observation, at low temperatures, of small oysters attached to glass slides. By use of this apparatus observations were made on the rate of heart beat and the ciliary activity on the gills as well as other physiological functions.

Results

It was found (Menzel, 1955a, b) that ciliary activity becomes progressively slower at low temperatures, especially at temperatures below 10°C. At decreasing temperatures, cilia ceased beating on the posterior filaments before those on the anterior filaments. Also it was observed that cilia continued their activity at the base of the filaments at lower temperatures than at the apex. After all ciliary activity had ceased due to low temperature, the order of commencement of ciliary activity, at increasing temperatures, was the reverse of that during cessation. Thus ciliary beat started first on the anterior filaments and at the base of the filaments.

Some of the differences in ciliary activity at various temperatures for C. virginica and O. equestris are given in Table II. It is seen here that ciliary activity on the gills continued at temperatures as low as 0.9°C. for O. equestris and 4°C. for C. virginica. O. equestris was able to bring carmine particles into the epibranchial chamber (indicating pumping action) at temperatures as low as 6°C. and C. virginica as low as 8°C., although in each species these particles were not moved to the palps until the temperature had risen several degrees. It is possible

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Table I

Differences in the genus *Ostrea* and *Crassostrea*

	OSTREA	CRASSOSTREA
1.	Prodissoconch shell with small, rounded, umbo	Prodissoconch shell with protruding umbo
2.	Average size smaller	Average size larger
3.	Larviparous	Oviparous
4.	Eggs large, number *ca* 1,000,000	Eggs small, number above 50,000,000
5.	Gill ostia large	Gill ostia small
6.	No promyal chamber	Promyal chamber
7.	Muscle centrally located and scar not pigmented	Muscle posteriorly located and scar pigmented
8.	Left valve flatter	Left valve more cupped
9.	Shape subcircular; more constant	Shape elongated; more variable
10.	Inhabitants of sea water, high salinity and clear	Inhabitants of estuaries and brackish waters of high turbidity
11.	Predominantly inhabitants of cold water, but adult unable to withstand freezing (*O. lurida*)	Predominantly inhabitants of warm water, but adult able to withstand freezing (*C. virginica*)
12.	Selectivity of food based on size alone	Discrimination in feeding
13.	Cleansing mechanisms not well-developed	Well-developed cleansing mechanisms
14.	Poor elimination of waste materials, including faeces and pseudofaeces	Efficient elimination of waste materials
15.	Indication that nannoplankton not used extensively as food	Indication that nannoplankton used as food
16.	Spat attach subtidally on or near bottom in waters of high salinity	Spat attach subtidally on or near bottom in low salinity; near surface or intertidally in high salinity

that ciliary action is able to move smaller particles to the palps at these, or even lower, temperatures.

The heart beat was readily seen and the rate per minute was timed with a stop watch. It was seen that there was a difference in the rate of heart beat between the two species at low temperatures and that no heart beat occurred at temperatures below 8°C. in O. equestris and 12°C. in C. virginica. This does not mean that there was no vascular movement because Hopkins (1936) has found that the contraction of the accessory hearts, and Menzel (1955a) has observed that the contraction of the gills and mantle, cause blood movement.

The average rates of heart beat at the various temperatures are given in Table III for the two species. All of the oysters in both species measured below 12 millimeters in length, and the majority measured below about 8 millimeters. Relatively few observations were made, and the figures are not absolute by any means. On the average the heart was inactive one-fifth of the time or more, even when the adductor muscle was relaxed and the animals were actively pumping water. The data do indicate the relation of the heart beat to temperature and serve as a comparison between the two species.

Summary and Discussion

These data give some additional differences between the genera Ostrea and Crassostrea in the subtropical waters of the Gulf of Mexico area.

Some of the published data indicate that Crassostrea exists in several physiological races with respect to temperature. Thus Nelson (1928) found that this species spawns at lower temperatures in the more northern waters than in the South Atlantic States and Gulf of Mexico region. Takatsuki (1929) has found that oysters that normally live in colder waters are less sensitive to low temperatures than those that normally live in warm waters.

Loosanoff (1950) found that C. virginica could pump water at temperatures as low as 2°C. and Galtsoff (1928a, b) found that ciliary activity continued at temperatures as low as freezing of sea water. In the present observations, it was found that the temperature was several degrees higher when ciliary activity ceased. This disparity is probably due to the fact that the other investigators worked with C. virginica from more northern and hence colder water. This supports the observations that C. virginica exists as several physiological races, not only in relation to the temperature threshhold in spawning but also in other physiological reactions.

It was found (Menzel, 1955a) that O. equestris spawns at lower temperatures in the Gulf (Port Aransas, Texas) than does C. virginica. It was suggested that this species retains the generic characteristic of a cold water inhabitant, as Orton (1928) states, despite being a warm-water species of the genus.

Table II

Comparison of ciliary activity on the gills of *Crassostrea virginica* and *Ostrea equestris* at various temperatures

Temp. C°	*C. virginica*	*O. equestris*
0.0-0.8	none	none
0.9-1.9	none	none to very slow at base of anterior filaments
2.0-2.9	none	none to very slow at base of anterior filaments
3.0-3.9	none	none to very slow at base of anterior filaments
4.0-4.9	none to very slow at base of anterior filaments	none to slow at base of anterior one-third of filaments
5.0-5.9	none to very slow at base of anterior filaments	slow at base of anterior one-half of filaments
6.0-6.9	none to very slow at base of anterior filaments	entire at anterior one-third; base at anterior two-thirds; particles brought in
7.0-7.9	none to base at anterior one-third to entire anterior two-thirds	entire at anterior one-third; base at anterior two-thirds; particles brought in
8.0-8.9	entire anterior one-third; base entire gills; particles brought in	entire at anterior two-thirds; base entire gills; particles moved at base
9.0-9.9	entire anterior two-thirds; base entire gills; particles moved at base	entire gill; slowly at posterior; particles moved at base and edge
10.0-10.9	entire gill; slowly at posterior; particles moved at base and edge	entire; slightly slower posterior
11.0-11.9	entire; rapid anterior; slower posterior	entire; rapid anterior; slightly slower posterior
12.0-12.9	entire; rapid anterior; slightly slower posterior	entire; rapid anterior; slightly slower posterior
13.0-13.9	almost normal; slightly slower posterior	almost normal; slightly slower posterior
14.0----	rapid normal activity	rapid normal activity

Table III

Average Rate of Heart Beat Per Minute at Various Temperature Ranges for *Crassostrea virginica* and *Ostrea equestris*

	C. virginica		*O. equestris*	
Temp. C°	Rate per Minute	Number of Observations	Rate per Minute	Number of Observations
4 - 7	0	6	0	6
8 - 11	0	6	5	6
12 - 15	5	4	29	16
16 - 19	38	3	47	19
20 - 23	65	10	60	32
24 - 27	84	4	78	2
28 - 31	112	13	103	6

The fact that O. equestris exhibited heart beat as well as ciliary activity on the gills at lower temperatures than did C. virginica supports the last statement that O. equestris retains the generic characteristic of cold-water inhabitants.

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CULTIVATION OF OYSTERS IN PONDS AT BEARS BLUFF LABORATORIES

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The oyster industry in South Carolina yearly harvests between three-quarters of a million and a million bushels of oysters. The greatest portion, 85 percent, are canned, 13 percent are used in the raw-shuck trade, and two percent are sold in the shell. Practically all of the oysters grow intertidally. In South Carolina the tide ranges from four and a half to eight feet above mean low water. At Bears Bluff Laboratories the range is about six feet. Oyster farming, or cultivation, in the State is extremely simple. Shells are planted in May--- the wild crop is harvested 18 months later.

One of the greatest drawbacks to good quality oyster production is "wrap-up", or the crowding of oysters on cultch. This is due to the long setting season, the intensity of setting, and the low mortality of the young.

To control this intense setting, to practice water farming, and to utilize unproductive lands, cultivation of oysters in ponds was begun in 1944 when a small basin was dug in the marsh near Wappoo Heights, Charleston, South Carolina. The preliminary working of this pond gave sufficient promise to warrant greater effort, and by late 1945 a suitable area was found on Wadmalaw Island, South Carolina on the property of Mr. H. Jermain Slocum. Here finger-like sloughs of marsh extended into the high land. The elevation of this submerged marsh land is about three to three and a half feet above mean low water. With a normal rise and fall of tide of six feet these marsh sloughs were alternately drained and flooded. The construction of ponds was simple. A small dike was extended from high land to high land, enclosing the finger-like sloughs. Flood gates were installed in these dikes. At first three-foot sections of concrete pipe were used and cemented together. These were not practical because of settling and the resulting leaks. Ultimately automatic cast-iron flood gates on twenty-foot culverts were placed in the dikes. These galvanized culverts lasted eight years before they commenced to develop small leaks. The ponds were provided with over-flow spillways placed at about normal high tide elevations. Thus, on spring tides the ponds always received additional water. The dikes were planted with _Spartina patens_ and have held up remarkably well despite being completely inundated several times by hurricane tides (Fig. 1).

Once the ponds were flooded and kept under water, the marsh vegetation, principally _Spartina alterniflora_, died out. The floor of the ponds was shelled to harden the bottoms. Seed oysters were brought in. The seed oysters were collected in the usual spat bags and on cement-dipped egg crates. Oysters grew faster in the ponds than in the nearby creeks and rivers. They were fat and showed good condition. Their flavor was excellent. On hard beds good quality seed produced good quality single oysters (Fig. 2). Marketable single oysters were produced in two years. In soft areas in the ponds, using clutch with a heavy set of young, typical cluster type oysters were produced (Fig. 3).

Figure 1.--One-acre ponds were constructed by diking in the marshlands that extend fingerlike into the highlands at Bears Bluff Laboratories.

Fig. 2. Spat-size seed planted on hard bottom in the ponds rapidly grew into good quality single oysters.

Fig. 3. Crowded seed on soft bottoms in the ponds produced typical cluster oysters.

These too had good flavor, fine quality, and grew fast. Although oysters spawned in the ponds, the oyster set was negligible. There are several theories why this is so. Regardless of the cause, the effect is what is needed in South Carolina oyster cultivation.

The ponds were in their peak of production during the years of normal to excessive rainfall. From 1944 through 1949 the salinity ranged from 20 o/oo downwards. The temperature was usually somewhat higher than that of the nearby creek at times reaching as high as 95°F. during the summer. The ponds were drained every few months to cultivate and study the oysters.

Up to 1950 only small plot plantings within the one-acre experimental ponds were made. In 1950 the ponds were stocked and cultivated to produce 2,000 bushels of oysters to the acre (Fig. 4). Most of these oysters were of the cluster type.

The ponds were not drained and flushed as frequently as before. A series of drought years followed. Salinities began to climb from 20 o/oo to 25 o/oo to 28 o/oo. Some fresh water was available from a fresh-water pond built by damming off one end of one of the original marsh sloughs, but this water was never used to control the oyster pond salinities. Drought conditions became so bad that this lake finally dried up. Food conditions apparently changed in the ponds because the oysters no longer became fat. Polydora infestation became heavier and heavier, and boring sponge made its appearance. A sudden mortality spread outward from one edge of the pond. This was probably due to Dermocystidium. Silting became a problem. Funds for this type of work at Bears Bluff became non-existent with the death of Mr. Slocum and the exhaustion of a grant from the Hughes Foundation and a Guggenheim Fellowship; and, frankly the fish, crabs, and shrimp harvested from the ponds when drained began to look more important economically. Experiments on the growth of shrimp and fish in the experimental ponds indicated that from six to eight percent return can be expected on the financial investment necessary to construct a pond.

By having available a supply of fresh water, and by draining the ponds frequently to discourage the depredation of the usual oyster pests such as boring sponge and Polydora, by the application of hard work and management, good quality oysters can be produced in ponds built in the marshes of South Carolina. However, until the oyster industry can no longer make a success from harvesting the more or less wild crop of oysters in the natural waterways of the State, it seems unlikely that pond cultivation of oysters will be economically practicable.

The cultivation and growing of oysters in ponds experimentally is a wonderful school. Much can be learned from it. Relatively large experimental ponds can, without a doubt, be extremely valuable in solving such problems as to how to control oyster diseases. However, with the amount of funds presently available for fisheries research in the State of South Carolina, this type of experiment will have to be postponed until some later period of time.

Fig. 4. A one-acre experimental pond was planted to produce 2,000 bushels of oysters to the acre.

TEN YEARS OF STUDY ON OYSTER SETTING IN A SEED AREA IN UPPER CHESAPEAKE BAY

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Oyster production in the upper or Maryland portion of Chesapeake Bay declined from 15,000,000 bushels in 1890 to less than 3,000,000 at the present time (Fig. 1). In general, except that quantities vary, this may also be said of most of the other major oyster producing areas of the Atlantic seaboard. In only one major area, the lower or Virginia portion of Chesapeake Bay, has production steadily increased over the latter part of this period.

The cause may be the cumulative effect of many things, but primarily it seems to be a contest of exploitation versus reproduction. The basic problem then, biologically at least, is to increase production and survival of young oysters sufficiently to reverse the unbalance of commercial utilization and seed oyster production.

Generally, on the Atlantic coast, natural replacement becomes less regular as the oyster beds are located farther north. Commerical oyster production is maintained on a small scale in southeast Canada largely through the cultivation procedure of artificial cultch collection of seed oysters. Few oysters are produced commercially in Maine and New Hampshire today although the evidence of former heavy natural production is present in the huge piles of oyster shells, kitchen middens, accumulated on these shores centuries ago by the American Indians. Massachusetts had oysters in abundance when the first white settlers reached these shores in the 17th century. Within a hundred years under the influence of unrestricted utilization, the oyster beds were depleted. Restrictions and cull laws did not bring back the so-called unlimited supply of the past. Connecticut, Rhode Island, and New York produced many oysters and the natural supply withstood the exploitation for a longer period than in the States to the north and east.

New Jersey, Delaware, and the Chesapeake states had a richer natural heritage because each contained areas of prolific regular oyster setting. Many boatloads of young oysters from here found their way northward to bolster the declining productions from the New England oyster grounds. In spite of this natural advantage, reduction also occurred in the Middle Atlantic areas during the 20th century.

The states south of Chesapeake Bay along the coasts of the Atlantic Ocean and Gulf of Mexico produce prodigious numbers of oysters. In many parts of this region, however, the heavy setting of oysters in itself is a problem because the denseness of growth produces misshapen and poor quality oysters. The problem of production in the south is not one of a short seed supply but the need for thinning and conditioning by cultivation.

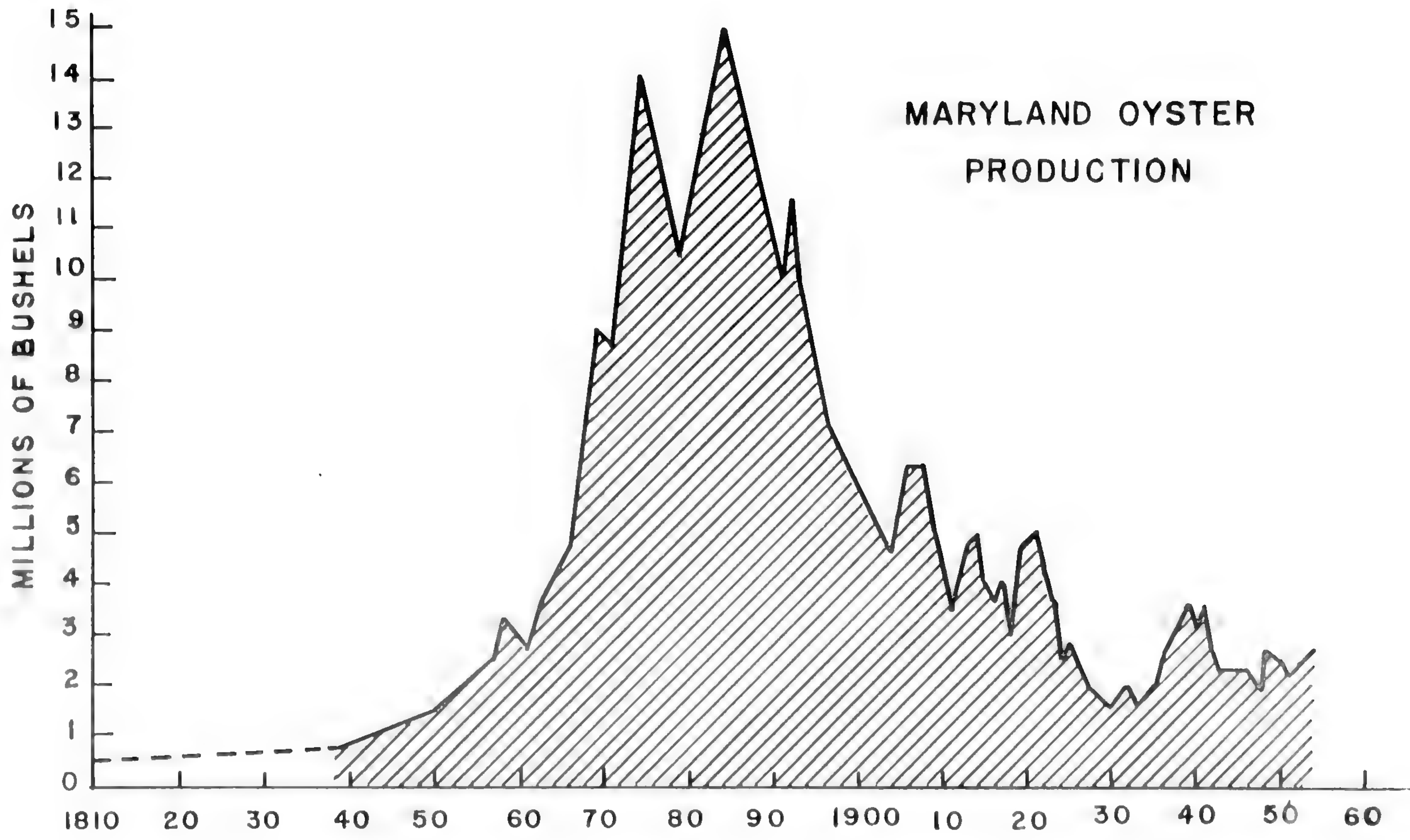

Fig. 1.--Annual producation of market oysters in Maryland. Data from Special Report to the General Assembly of Maryland, The Commercial Fisheries of Maryland, Educ. Ser. No. 30, Department of Research and Education.

Natural replacement in general is not sufficient to maintain most oyster bars under the pressure of commercial exploitation, but there are some areas in every region where a combination of factors in the environment enhances the setting. Perhaps the most significant of these areas are the James River in Virginia and the Delaware River in New Jersey. These states recognized the importance of this phenomenon and regulated the use of their crops as seed for transplanting and redistribution. These areas, representing less than 100,000 acres, produce several million bushels of oyster seed annually which account for a reasonably stabilized production in the states of New Jersey and Virginia. The James and Delaware Rivers are the outstanding examples of areas specialized by nature for oyster seed production.

There are other areas where potentialities exist for the production of oyster seed to fill the ever-increasing demand in all the commercial oyster-producing regions. Biologists, State, Federal, Industry, and other public officials are keenly aware of the need to expand oyster seed production in every area. All have felt the pressure from the perturbed industry and the word has come to us to do something. This, however, is an old problem which plagued our predecessors, too, and for many years most programs of oyster research included as an integral part some phase of the oyster seed production problem. There may be, and probably is, a key not fully revealed to us now that will eventually simplify this problem.

Maryland does not have within her boundaries a large dependable seed area on the scale of the James River of Virginia. It was through this seed source that Virginia was able to produce in 1953, the year of the latest complete figures on harvest, a crop of 3,661,125 bushels of oysters from private planting grounds and 631,517 bushels from public grounds. Maryland in that same year produced 2,514,052 bushels of oysters on public grounds and 828,495 bushels on private grounds. The bulk of the oysters harvested in Virginia came from seed oysters transplanted to growing grounds while the Maryland harvest came mostly from natural bars depending on natural recruitment.

The need in Maryland for a local supply of seed oysters was recognized when the decline in production first caused alarm. Promiscuous shell planting failed to stem the decline especially on the Bay bars which suffered the most. Nevertheless, shell planting has a very important part in rehabilitating oyster bars, and shells are undoubtedly the best natural cultch. However, where and when the shells are placed are very critical parts of a shell-planting program if the limited supply of shells is to be used advantageously.

The first step considered in the Maryland program by both State and Federal research agencies was exploration to establish the oyster setting potential of many areas in upper Chesapeake Bay and tributaries. After several years of field observations and a thorough examination of available records, this became known to us. The information disclosed the degree of variance in setting that existed. There were high setting, moderate setting, and low-setting areas indiscriminately distributed. The rarest of the setting rates, as would be expected, was that of high setting. High setting rates determined the placement of seed areas, some of which were lightly developed within the last fifteen years, or are now in the process of development in this State.

Every year since 1943-44, Maryland raised some seed oysters on several artificially produced seed beds. This seed was far too meager to materially increase production when transplanted to growing beds. The seed areas developed and currently used in Maryland are Millhill in Eastern Bay, Cinder Hill in Holland Straits, Seminary Bar and Gravelly Run in St. Mary's River, and Punch Island in Chesapeake Bay. The majority of these seed areas are in tributaries of Chesapeake Bay. The total area involved does not exceed 500 acres, and under good shelling and setting can produce only about 500,000 to 600,000 bushels of seed annually for transplanting. In 1951-52, seed transplanted from public areas was 627,000 bushels; and of this amount about one-half (321,590 bushels) came from seed beds in Eastern Bay.

Millhill Bar in Eastern Bay was set aside by the State of Maryland for development as a seed area about 13 years ago. The area involved is about 150 acres of originally barren bottom. The State plants shell cultch on these acres annually and the seed, if the set exceeds 500 spat per bushel of shells, is transplanted to growing grounds during the next spring. The figure of 500 spat per bushel of shells, or about one spat per shell, is a minimum spatfall which can be moved economically as seed. On this basis, the seed production is evaluated as good or poor. The spat per bushel of shells is determined from counts on random samples of the planted shells usually taken at the end of the setting season in the fall of the year. By this time, the summer hazards of predators, disease, and environment have extracted their toll on brood stock, larvae and set, and the residual set becomes the seed crop.

Millhill Bar, which has the longest history of observations on setting in Eastern Bay, 1941 to 1954, presents statistics for an analysis of the fluctuations in setting. The set caught on clean shells in spat collectors gives the closest approach to the optimum. The set caught upon shells planted by the State in its seed-producing program shows the realistic return for the State's efforts. On the basis of the latter figure, the advisability of moving or not moving the seed is determined (Table 1).

The figure that is very significant to us is that derived from set on spat bag shells. It represents for the most part the number of larval oysters able to survive to setting the dangers of a two-week free swimming period. Plankton samples taken weekly give a record of the number of larvae and a little of their fate. One step prior to

Table I

Spatfall, Millhill Bar in Eastern Bay

Year	500 spat bag shells	500 planted shells	Percentage survival
1944	25	38	152.0
1945	9075	666*	7.3
1946	525	522*	99.4
1947	3775	1724*	45.7
1948	825	792*	96.0
1949	550	48	8.7
1950	1450	146	10.0
1951	7075	198**	2.7
1952	377,350	1172*	0.3
1953	675	42	6.2
1954	10,725	514*	4.8

* Spatfall commercially significant for transplanting.

** Spatfall of several years accumulation may equal enough to permit transplanting.

taking plankton samples for larval records are observations made on gonad development. All these combine to give a seasonal picture of steps involved in seed production. Each of them should be a measurable factor in the production of seed.

Table 2 presents some evidence to support the suggestion that the magnitude of the set of oysters depends on the number of late-stage larvae per unit volume of water. Weekly plankton samples are collected from June to October. A sample is more of a composite of the water flowing past the screened intake of the collection hose than a spot sampling of a small portion of the general area under observation. The method of pumping samples was used first by this investigation in 1947, and continued for the next eight years as the preferred technique for plankton collection.

The average number of late-stage larvae per 100 liters of water sample was compared with the oyster set found on one bushel of wild or planted shells picked at random from a larger sample of bottom material brought on deck by dredges or tongs. The set showed a positive correlation with the available larvae that survives the rigors of the free swimming life before settlement. This was also true with the set found on spat bags.

There are some factors in operation that work on the destruction of spat from the time of settlement until the time of harvesting. In Eastern Bay the focus has been on the conditions surrounding the survival of the spat for the first few months of existence or the time of growth from spatfall to seed size. A comparison of spat bag or initial set to fall survival of spat on planted shells showed no correlation. This may be the effect of fouling, predation, disease, crowding, silting, and little known adverse environmental conditions. One conclusion, which is drawn from the setting observations on spat bags and planted shells, is that a great loss occurs between initial set and seed-size oysters three to four months later. Survival of less than 10 percent of the spat bag counts indicates a loss of sufficient magnitude to bear investigation.

Some tests were made to see if the period of time shells were on bottom had any effect on setting results. Spat bags full of clean shells were put overboard at the same time and at the same place as bags with old shells. The placement was timed with the period just prior to the estimated beginning of spatfall. These two groups of bags were left on the bottom throughout the period of setting and examined for spat set and survival in October. These results are compared in Table 3 with spat-bag counts and spat survival on planted cultch, to point out that shell cultch broadcast on the bottom is not as effective as cultch held slightly off the bottom, probably because for at least one reason shells in bags offered more surface for spat attachment. The tremendous difference between cumulative spat count on weekly spat bags and total set on seasonal spat bags and planted cultch also suggests that cumulative fouling both by organisms and silt interferes with setting or survival of set.

Table II

Total late oyster larvae and set per bushel on planted and spat bag shells at Millhill Bar, Eastern Bay

Year	Late stage larvae*	Set per bushel planted shells**	Set per bushel spat bag shells***
1947	19.7	1,724	3,775
1948	3.7	792	825
1949	0.7	48	550
1950	0.7	146	1,450
1951	5.3	198	7,075
1952	15.7	1,172	377,350
1953	1.3	42	675
1954	6.0	514	10,725

* Average per hundred liters per season.

** Sample taken by dredge on shell planting near spat bag station. Area covered quite large, which makes this a representative sample.

*** Sample taken from spat bag containing 50 shells and represents total season set per shell x 500.

Table III

Oyster set or spat count per bushel of shells on seasonal shell bags, weekly shell bags and planted shells at Millhill Bar, Eastern Bay

Year	Spat count weekly clean shells in bags	Seasonal new shells in bags	Seasonal old shells in bags	Spat count planted shells broadcast
1952	377,350	3,370	1,095	1,172
1954	10,725	1,175	710	514

An effort to improve setting rates on an experimental level was tried in 1949 and 1950 on Millhill Bar in Eastern Bay. A very poor set occurred on the 1949 shell planting on Millhill seed bar. Three plots were marked out in 1950 on these shells, and each was treated in one of the following ways:

1. Shells planted in 1949 and left untouched in 1950 and still containing the previous year's fouling.

2. Shells planted in 1949 and scoured with a bagless dredge in 1950 to remove fouling before calculated setting time.

3. Clean shucking-house shells planted in 1950 just before the calculated setting time.

4. In addition to these treatments of the bottom, spat bags were maintained on the plots during the whole of the 1950 setting season.

The setting rate on planted shells in the summer of 1950 in Eastern Bay was not of commercial significance, but the difference in setting seen on the shells from each of these plots suggests a differential based on cleanliness that has practical application in oyster culture. The setting results in 1950 were as follows:

1. 1950 spat bag setting:	1450 spat/bushel of shells
2. 1950 clean planted shells:	146 spat/bushel of shells
3. 1949 shells scoured in 1950:	132 spat/bushel of shells
4. 1949 shells unscoured:	80 spat/bushel of shells

The preceeding information was collected from observations on a single oyster bar, Millhill, in Eastern Bay. Other bars in this area were explored and tested for sustained setting possibilities. Specifically, oyster bars at Parsons Island, Bodkin Rock, and Long Point, shown on Figure 2, were the sites of these other observations. These particular bars usually showed higher setting rates on spat bags than those at Millhill with the magnitude of the set usually increasing from east to west. Most of the time the setting rate at Long Point was four times that of Millhill, as shown in Table 4. Such a distribution indicates the seed production possibility of Eastern Bay to be much better per acre than is presently manifested by the use of Millhill for that purpose.

Eastern Bay with tributaries has 15,000 acres of surveyed oyster bar. About 150 acres of this is now used for seed production to produce 150,000 bushels of seed annually or when the set is heavy enough to use. Theoretically, then, Eastern Bay could produce a minimum of 1,500,000 bushels of seed annually if 10 percent of the oyster-bar

Table IV

Total set or spatfall per shell on spat bags at four stations in Eastern Bay*

Year	Millhill	Parsons	Bodkin	Long Point
1946	1.05		10.80	
1947	7.55	46.55	31.00	43.50
1948	1.65	5.30	3.35	4.95
1949	1.10	3.75	2.10	0.90
1950	2.90	2.80	4.05	8.30
1951	14.15	26.40	41.00	69.40
1952	754.70	207.40	150.15	46.30
1953	1.35		2.70	3.05
1954	21.45		98.70	159.70

* Per shell per season.

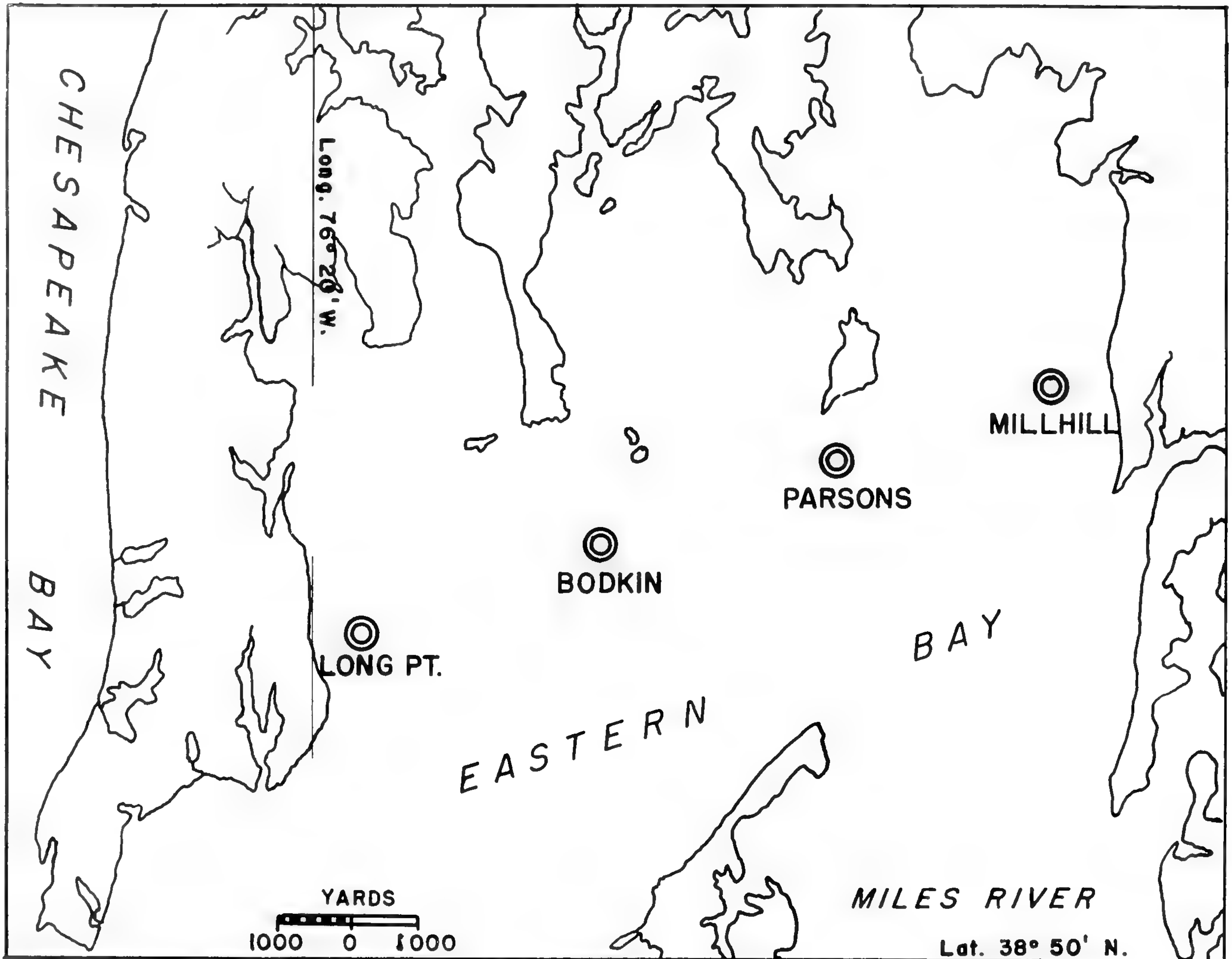

Figure 2.--Eastern Bay, Maryland, showing location of spat-collecting and bar-sampling stations.

acreage that the present crop of shells could cover were utilized for seed production. There are many places in Maryland where growth and condition of oysters are excellent, but the natural replacement rate is too low to be a factor in increasing production. These areas can be made more productive by a management program of seeding them from a seed area such as Eastern Bay.

Eastern Bay, because of its natural high setting potential, maintains an abundant brood stock, a first requirement for a seed area. The Bay does lack enough natural cultch to be self-sustaining so that seed areas would need annual planting of shells or some other cultch to maintain production. The Bay is free of common oyster predators such as oyster drills, starfish, and drum fish. The salinity is stable at 10-15 parts per thousand. Oyster seed transplanted from Eastern Bay to many other areas in Upper Chesapeake Bay and tributaries survives and grows well. It is a good seed producing area that has ample room for expansion to fill a very definite need in Maryland.

We are indebted to the Maryland Departments of Tidewater Fisheries and Research and Education for cooperation in planning and physically carrying out some of this work.

Acknowledgment is made of the help of many people who worked on this project during these ten or more years. Among them are Dr. Philip A. Butler, Mr. H.H. Whaley, Mr. John R. Webster. Mr. Webster is at present associated with me in these studies.

THE MARYLAND SOFT SHELL CLAM FISHERY: A PRELIMINARY INVESTIGATIONAL REPORT*

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During the past five years an important new fishery has developed in Maryland, based on a previously unexploited resource, the soft shell clam (*Mya arenaria* L.). Clam populations are almost entirely subtidal in the upper half of Chesapeake Bay and its tributaries, where tidal range is generally less than two feet. The soft shell clam resource is therefore unavailable to traditional methods of harvesting, and local demand has never been great enough to provide incentive for development of a fishery of commercial proportions.

Depletion of stocks of clams in the New England fishery undoubtedly supplied impetus for development of the Maryland hydraulic clam dredge, which is shown in Figure 1. A centrifugal pump, usually of five- or six-inch intake, supplies water to a transverse row of small downwardly directed pipes just forward of the cutting head, which is 30 to 36 inches wide. The bottom is thus softened immediately in front of the cutting head which moves slowly forward in response to the boat's propeller thrust, the bottom edge traveling about 18 inches below the soil-water interface. Most of the bottom material which will pass the one-inch square mesh of the conveyor belt is washed through at the lower end of the conveyor. The remainder is elevated to deck level where the operator picks off the marketable clams. Most of the sand, gravel, shell, and other relatively heavy bottom material falls back into the trench as it is dug. The more finely divided materials, such as silts and clays, may be carried some distance by currents. The depth of the trench seldom exceeds 10 inches a few minutes after it has been dug; exceptions have been observed where two dredging paths cross or where an operator, for one reason or another, has used abnormally high water pressure. If the outside jets are set parallel to and directly forward of the sides of the cutting head, the width of the trench is only slightly greater than the width of the head. The period required for complete filling of the trench may vary from a few days to several weeks, depending on the type of bottom and exposure of the area to wind and tidal currents.

Sixty hydraulic clam dredges are now licensed in Maryland. Fifteen licensed dealers handle virtually the entire production of soft shell clams, estimated at 110,000 - 120,000 bushels annually, worth about $500,000 to the dredgers.

*Resource Study Report No. 9, Chesapeake Biological Laboratory, Maryland Department of Research and Education, Solomons, Maryland.

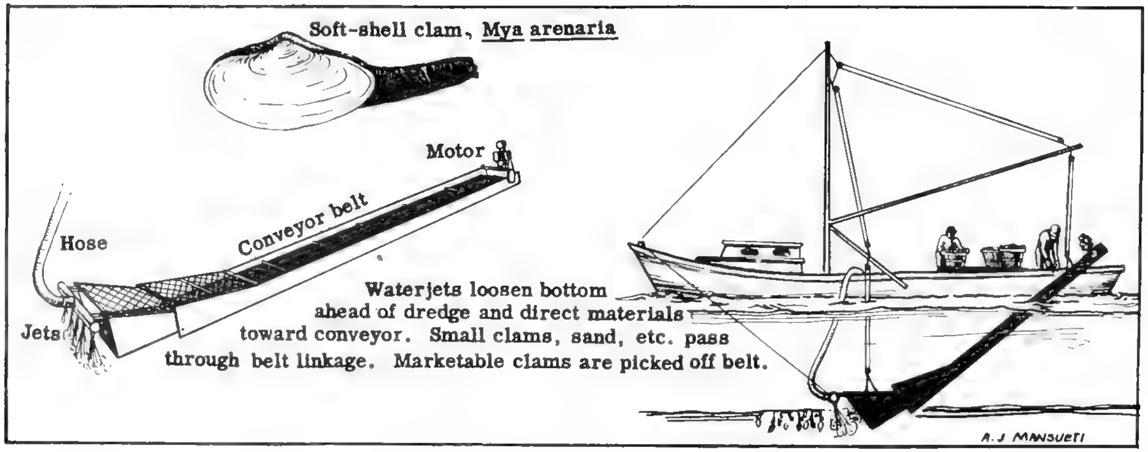

Fig. 1. Maryland Hydraulic Clam Dredge.

A great deal of controversy has accompanied the development of Maryland's soft shell clam fishery. Many extravagant statements have been made concerning the effects of hydraulic clam dredging on estuarine resources--statements ranging from allegations that the use of this gear is "killing all the oysters" to claims that hydraulic dredging has no effect at all on the aquatic environment. The fishery has been termed a "mining operation" based on accumulated and irreplaceable stocks of clams. In 1953 the Department of Research and Education was requested by legislative resolution to obtain factual information relating to the fishery and its problems. Prospects were not altogether encouraging. The gear was unique. Knowledge of the life history of the soft shell clam in Maryland was limited to some observations on the early development and growth of the species reported by John A. Ryder in 1880 and 1884. Funds were not available for needed equipment and personnel. On the brighter side, a great deal of research on the species had been and was being done in other areas, particularly in New England. A search of the literature turned up a considerable amount of useful information. A limited program of investigation, implemented by part-time personnel effort and improvised equipment, was undertaken. Experimental results and observations were summarized in December 1954 for consideration of the Maryland Department of Tidewater Fisheries and the Maryland General Assembly.

In 1955 the General Assembly enacted legislation regulating the fishery in Talbot, Queen Anne's, and Calvert Counties, where the industry was already well established. Concurrent legislation prohibited use of the hydraulic dredge in the waters of six counties representing about 70 percent of the potential clam producing area of the state. Recognizing the need for thorough and continuing study of the soft shell clam resource and the fishery it supports, the legislators established a fund ". . . to be known as the Clam Fund, the monies in which shall be for the use of the Department of Research and Education in the study and research of clamming in the State of Maryland..." A tax of 10 cents per bushel was levied on all soft shell clams caught within the State, all revenue from the tax to be credited to the Clam Fund.

It should be emphasized that a great many of the legislators who supported the measure legalizing hydraulic dredging did so with reservations. Many questions concerning the industry remain unanswered, and this Department, with enabling funds available, recognizes its obligation to find the answers as expeditiously as possible. Before considering what we plan for the future, it may be well to discuss what can be said at this point on the basis of our own and others' observations, even though much of it must be in the nature of generalization and speculation.

There is considerable evidence to indicate that the soft shell clam represents a rapidly renewable resource. Estimates of the growth rate of the species have been obtained through (1) length-frequency distributions in large samples taken from virgin populations in a limited area, and (2) the marking, replanting, recapture, and remeasurement of clams of various lengths above 0.5 inches. In Figure 2 some of the length-frequency distributions in large samples from the lower Patuxent River are plotted. The samples of October and December 1954 and July 1955 were taken entirely with a hydraulic dredge, using a conveyor belt of approximately 0.4-inch mesh. This belt retains almost all clams of 0.6 inch or greater length. In February and April 1955 dredged samples were supplemented with samples taken by screening bottom materials through a sieve of 0.06-inch mesh. Growth of the well defined year class with a modal length of 1.6 inches in October 1954 can be followed through July 1955, when the modal length had reached 2.2 inches. From interpretation of Figure 2 and other similar data, from Ryder's observation that soft shell clam spawning occurred in early autumn in 1880, and our own observations indicating that spawning occurred about the same period in 1954, this age group is designated as year class I. The existence of at least one, and probably two, older year classes is indicated in all the samples except that of February 1955. The complete absence of clams over 2.4 inches long in that sample may be attributable to a very localized failure of set, or more likely to a complete mortality less than one year prior to setting of the oldest extant year class. The appearance of a new year class will be noted in the February 1955 sample, with an apparent modal length of 0.1 inch which may be misleading, inasmuch as the sieve used for screening will pass clams less than about 0.09 inch in length. The modal length of this year class increased from 0.2 inch in early April to 0.9 inch in late July. Table I indicates close agreement between the growth of individually identified clams and the modal length increments of large samples (avg. N = 1100) of the same year class.

Table I Length increments, clams of year class I, 1954-1955.

Period	Modal length increment, virgin populations, in.	Mean length increment, marked clams, in.
Oct. 1954-Feb. 1955	0.2	0.3 (N = 64)
Oct. 1954-Apr. 1955	0.4	0.3 (N = 6)
Oct. 1954-Jul. 1955	0.6	0.6 (N = 2)
Dec. 1954-Apr. 1955	0.3	0.3 (N = 24)

From the data thus far accumulated the tentative growth curve shown in Figure 3 has been constructed. Increase in length apparently averages about 0.15 inch per month during the first year of life, 0.08 inch per month during the second year, and becomes very slow thereafter. It appears that about 50 percent of a year class can be expected to reach the minimum legal length of two inches in 18 months, and that approximately 75 percent of a year class will be available to the fishery 20 months after setting. These estimates are based on data obtained during a period of only nine months, and in a single area, and are offered with full realization of their limitations. It is believed, however, that they are fair approximations of representative growth rates in Maryland.

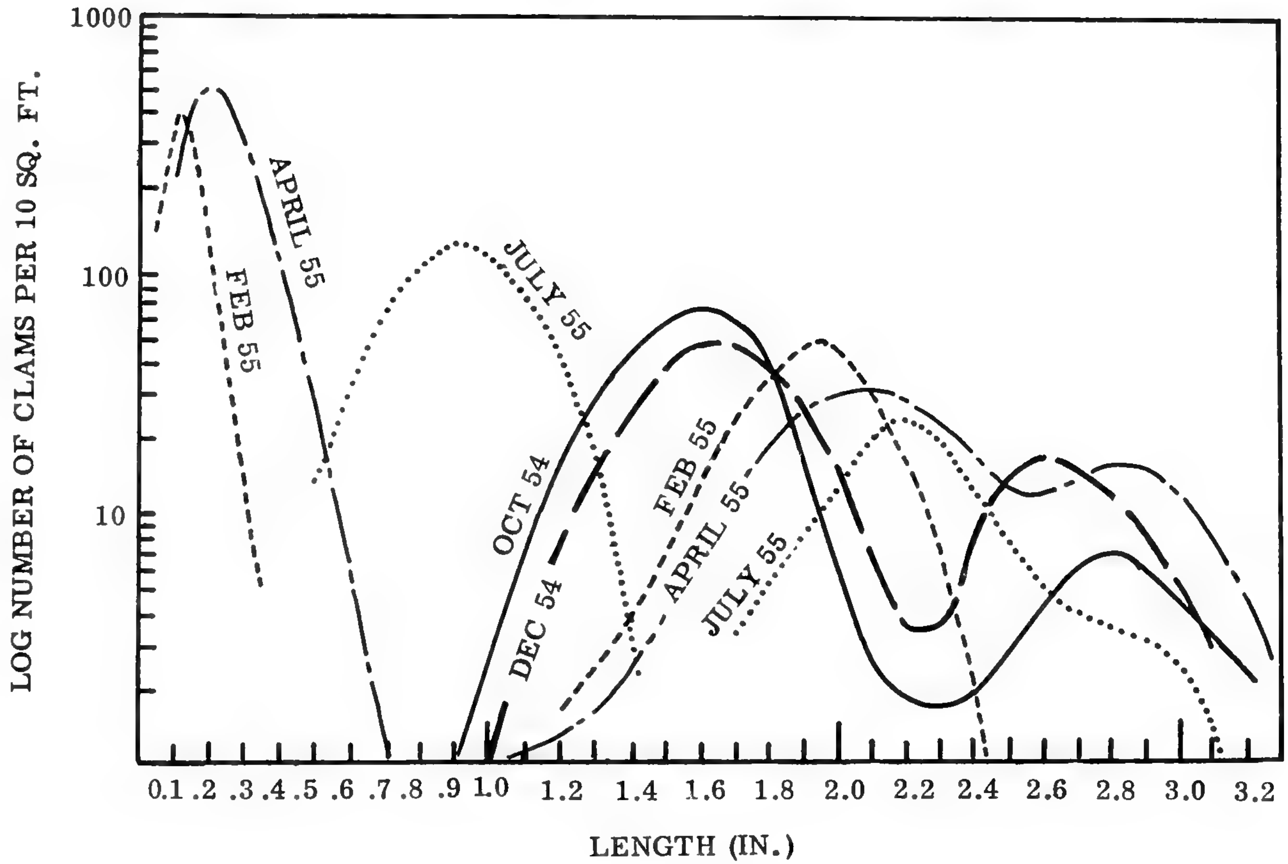

Fig. 2. Length-frequency Distributions of Samples of Mya arenaria from the Lower Patuxent River, 1954-55.

The growth curve for Maine clams shown in Figure 3, based on data of Dow and Wallace, represents the coast-wide average in that state. It will be noted that the mean terminal length is approximately the same in the two areas, but in Maryland it is reached in about one quarter of the time required in Maine. Smith and his associates have reported growth of native clams in Massachusetts to be rapid, the species generally reaching market size (2 inches) after three summers, or just over two years. One year class produced a commerically diggable crop in two summers of growth. There is, apparently, a positive gradient in growth rate of the soft shell clam in a north-south direction along the Atlantic Coast, from Maine to Maryland. This may be attributable to the corresponding gradient in water temperature. Mead has reported observations and experimental results in Rhode Island which strongly suggest that the prevailing subtidal nature of Maryland's clam population favors higher growth rates.

Depletion of spawning stocks does not seem likely in Maryland's soft shell clam fishery. Divers of the Chesapeake Bay Institute have observed extensive beds of clams at depths of 30 to 40 feet, far beyond the maximum depth at which the hydraulic clam dredge can be operated. Present law limits the length of the conveyor to 19 feet between axles, and dredging at depths of more than about 12 feet appears to be impracticable.

There are other factors which operate against depletion. A well-constructed dredge catches almost all the marketable clams in its path. A reasonably careful operator breaks less than five percent of the clams that are caught, often almost none. The materials that are washed through the belt or fall off at the after end of the conveyor are well sorted as they descend to the bottom, and the specific gravity of the clam is relatively low. In Baptist's recently reported experiments about 70 percent of clams in the 2 - 22 mm. length range burrowed within 30 minutes when the current velocity was one-quarter knot or less and the water temperature ranged from 4.0 to 5.6°C. In June 1954 John Glude, using an aqualung, examined bottom in the Miles River about half an hour after it had been dredged. Nearly all of the clams of sub-legal size which he could see had begun to dig in. Along the sides of the trench he observed some legal sized clams, up to three inches in length, many of which had also begun to burrow. The ability of clams to burrow after having been subjected to hydraulic dredging is attested by recovery of almost 300 marked clams in the length range 1.1 - 3.3 inches from three to nine months after relaying. In December 1954, with the water temperature at 8°C., 76 clams in the length range 1.2 - 3.0 inches were relaid on hard clay bottom which was covered by about one-half inch of less compact sediments. The clams were covered by an inverted oyster tray to prevent predation. All but 20 clams burrowed out of sight within 24 hours, and all but 14 had disappeared in 50 hours. After four days two clams were incompletely burrowed and one other had made no progress. After six days only one clam was visible, and it had not completely burrowed at the end of four weeks. In general, the time required for burrowing varied directly with the size of the clams. Observations indicate that clams are able to burrow much more quickly in dredged

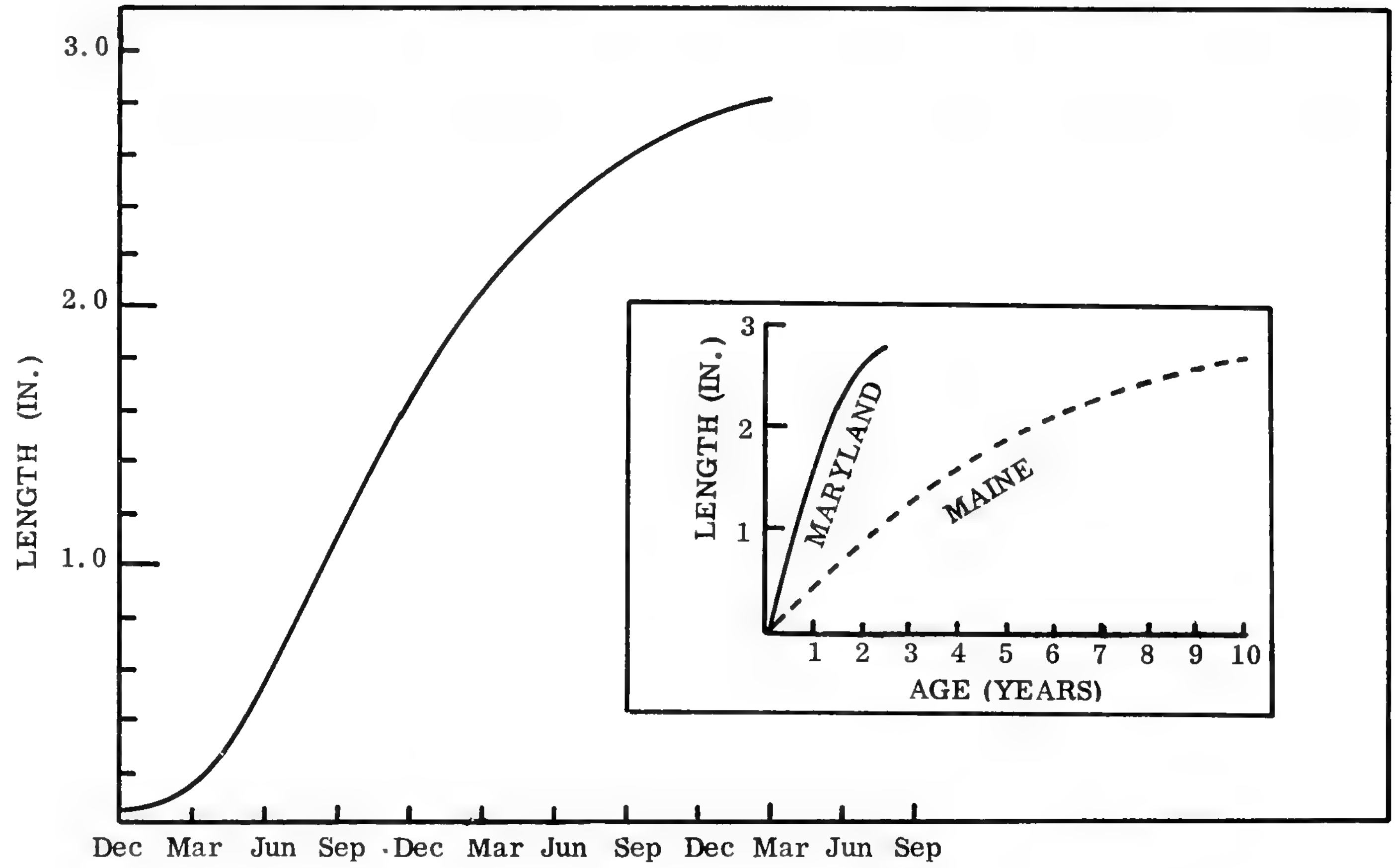

Fig. 3. Growth Curves for Mya arenaria in Maryland (tentative) and Maine.

bottom. The mortality caused by predators such as eels and crabs has not been measured, but observations indicate that it is sometimes heavy during the warmer months. The wisdom of using only well designed dredges which catch a high percentage of the displaced clams is obvious.

Glude points out that he could not, from his observations in the Miles River, evaluate the effect of the dredge fishery on the very small clams, and we have no evidence worth mentioning except the demonstrated capaciy of some areas which have been dredged for several years to produce an annual crop of clams. This does not necessarily mean that any of the very small clams in the path of the dredge survived. Smith has shown that clams up to about one-half inch long are constantly redistributed on the flats in Massachusetts.

Table II provides a basis for estimates of the standing crop of marketable clams on a productive flat, not previously dredged, in the lower Patuxent River. The flat is several acres in extent, and has a maximum depth of about six feet of water at mean low tide. The bottom is a mixture of sand and mud, subject to shifting during southeast storms. Oyster planting has been attempted in this area with disastrous results, and large quantities of shells are in the bottom. Occasional live oysters can be found, and some nippering is done, but the annual crop of oysters certainly does not exceed one or two bushels per acre. All figures given in Table II represent means of two or more 10-square-foot samples, except for October, when a single sample of 30 square feet was taken. Statistical analysis of these and other comparable data indicates that the sampling error is large. An approximation of the number of bushels of marketable clams per acre may be obtained by multiplying the figures in the bottom line by six. Dividing the same figures by 10 gives a rough estimate of the number of bushels that could be dredged in an hour. When this rate exceeds about 10 bushels per hour, however, the rate at which the catch can be culled becomes the limiting factor. The conversion factors used here are only approximate, since their values depend upon type of bottom, age composition of the catch, and other variables.

Table II. Estimates of numbers of marketable soft shell clams on a flat in the lower Patuxent River, 1954-1955

Size	Number of clams per 10 square feet				
(in.)	October	December	April	July	Average
2.0 - 2.4	10	35	131	79	64
2.5 - 2.9	24	59	83	22	47
3.0 - 3.4	9	4	23	4	10
Marketable Clams	43	98	237	105	121

The commercial diggers seldom dredge systematically. Several boats usually work a bed together, and because of the turbidity of the water the operators can not well avoid crossing and recrossing their own or others' courses. Therefore, when half the area of a flat has been covered, the dredges will be operating about half the time in bottom which has been recently dredged, and the rate of harvest will have fallen off to about 50 percent of the initial rate. Assuming that the figures given in Table II applied to a clam bed of one acre area, in October the initial catching rate of a dredge, approximately four bushels an hour, would have fallen to about two bushels an hour after three or four days of dredging. This does not greatly exceed the minimum harvesting rate at which hydraulic dredging is profitable, and the area very likely would have been abandoned for more productive digging elsewhere, leaving about 100 bushels of clams age II or older unharvested. By April a new year class had become dominant numerically, and presumably dredging again would have been profitable. In working newly discovered beds of clams, dredgers have often caught 50 to 75 bushels a day. In the Patuxent River, which was first dredged commercially in August 1954, one operator has averaged 4.3 bushels an hour since April 1955. On the Eastern Shore of Maryland, where the fishery has been in existence for five years, the dredgers are now largely dependent upon an annual crop, and catch per unit effort apparently has become fairly well stabliized at two to three bushels per hour.

Observations thus far seem to indicate that the soft shell clam fishery is based on a highly renewable resource of major proportions. This is not to say that the clam resource can not be over-exploited. Several factors, however, among which the rather high operational and maintenance costs involved in hydraulic dredging are believed to be of great significance, operate against depletion. It is felt that, with intelligent management of the fishery, supplies may be expected to stabilize at a level which will support a continuing and valuable industry. We believe that continued, industry-supported research can pay its way through contributions of factual information necessary to management. Currently research is continuing on reproduction, growth, and mortality of the soft shell clam. The merits of several methods of determining index of condition are being appraised. A study of the effects of temperature and turbidity on the pumping rate of the clam is in progress. As rapidly as funds become available and the necessary equipment and personnel can be acquired, the research program will be directed toward determination of the effects of hydraulic clam dredging on estuarine resources of commercial and recreational value.

First of all, we must evaluate the effects of hydraulic clam dredging on the oyster resource, which is the basis of Maryland's most valuable fishery. Use of the hydraulic dredge is prohibited on the charted natural oyster bars, which comprise about one quarter of the bottoms beneath tidewater. There are, however, many uncharted inshore "nippering grounds" which support relatively small populations of oysters but at times are resorted to by tongers in severe weather. Conflict between oyster and clam interests centers on the use of such bottoms, which often support commercially important clam populations and are more or less intensively worked by the clam dredgers. The clam dredger will point out--and often, though not always correctly, he is right--that the value of the clams he is harvesting greatly exceeds the value of the oysters that could be caught in the same area. To the oyster tonger, however, hydraulic clam dredging on nippering grounds represents infringement of a long-standing right of prior use, regardless of the relative values of clam and oyster crops. The problem obviously goes beyond biology. What we can contribute toward its solution is factual information which will provide a basis for estimates of (1) the mortality rate of oysters caught by the hydraulic dredge, (2) the mortality rate of oysters at finite distances from the dredging operation; (3) the displacement and deposition of bottom materials such as sand, silt, and clays by hydraulic clam dredging, and (4) the productivity of representative nippering grounds in terms of both oysters and clams.

Urgently needed also is an appraisal of the effects of hydraulic clam dredging on the rooted aquatic plants which provide food or cover, or both, for waterfowl, forage fish, crustaceans, and other organisms, and contribute to the stability of the bottom. This is a matter of considerable concern to conservation and sporting interests. Concurrent studies have been planned which should contribute to the knowledge of benthic ecology, and particularly to understanding of the plant and animal successions which may result in areas subjected to hydraulic dredging.

Obviously, definitive results can not be expected from such studies in a few months' time. We believe, however, that with intensive effort we should be able to estimate the effects of hydraulic dredging on the oyster resource within a year. Progress on the research program will be summarized for the information of the General Assembly at its January 1957 session. We sincerely hope that we may be able to fulfill our obligation to the public by providing factual information which will contribute to intelligent management of Maryland's estuarine resources.

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TECHNICAL PAPERS
ON THE BIOLOGY OF CERTAIN SHELLFISH
ENEMIES

THE LIFE CYCLE AND RELATIONSHIPS OF *DERMOCYSTIDIUM MARINUM*

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(Abstract)

A. Reproduction of *D. marinum* in the Host Oyster

Any stage of the cycle apparently may be infective if phagocytized by a host oyster leucocyte. For purposes of convenience description of the cycles in the oyster is begun with a phagocytized aplanospore (Fig. 1: 1), which is ordinarily transferred into the digestive epithelium of the host by amoeboid action of the leucocyte (2). In the host oyster the aplanospore grows to become an immature thallus (3,4) with a diffuse nucleus. From there development may proceed by one of three routes. These are first, a sequence of fission and budding following nuclear fragmentation (5 to 8 and 9) which may produce, by fission, nearly equal cells (5 to 8) or, by budding, unequal cells (9). Growth, formation of the vacuole with its inclusion body and the characteristic nucleus with a compact endosome completes development to the mature thallus (presporangial ? stage (18). The mature thallus may rarely bud or produce a morula-like sorus by formation of supernumerary nuclei around chromidial granules in the cytoplasm (10,11).

In some cases immature thalli divide progressively into 2, 4, 8 or more cells, the cytoplasm appearing to cleave as nuclear division proceeds (12,13). There is some indication that the two-cell stage (12) may be a conjugation stage, but cytologic confirmation is now lacking. The cleavage pattern results in an unconfined clump of small spherical cells which grow and modify to become the mature thallus (18).

The usual method of reproduction in oyster tissue involves nuclear reproduction in the immature thallus to form a multinucleate stage (plasmodium?) (15) without corresponding cytoplasmic cleavage. When the definitive number of nuclei is formed, apparently simultaneously, cleavage furrows develop in the cytoplasm and the structure becomes a small sorus, (16) the elements of which are uninucleate, and correspond exactly with the original aplanospore stage. Successive new infections of host cells produce enormous numbers of fungus cells throughout the oyster tissues. These cells liberated from the sorus by rupture and/or lysis of its own thin wall (17) may develop to the mature thallus stage (18). These remain without further change until liberated from the host, usually by death and fragmentation of the oyster. Further development apparently may take place in sea-water or another host may be infected directly.

B. Saprophytic Reproduction

When liberated in the sea-water, stages in the oyster begin a sapro-

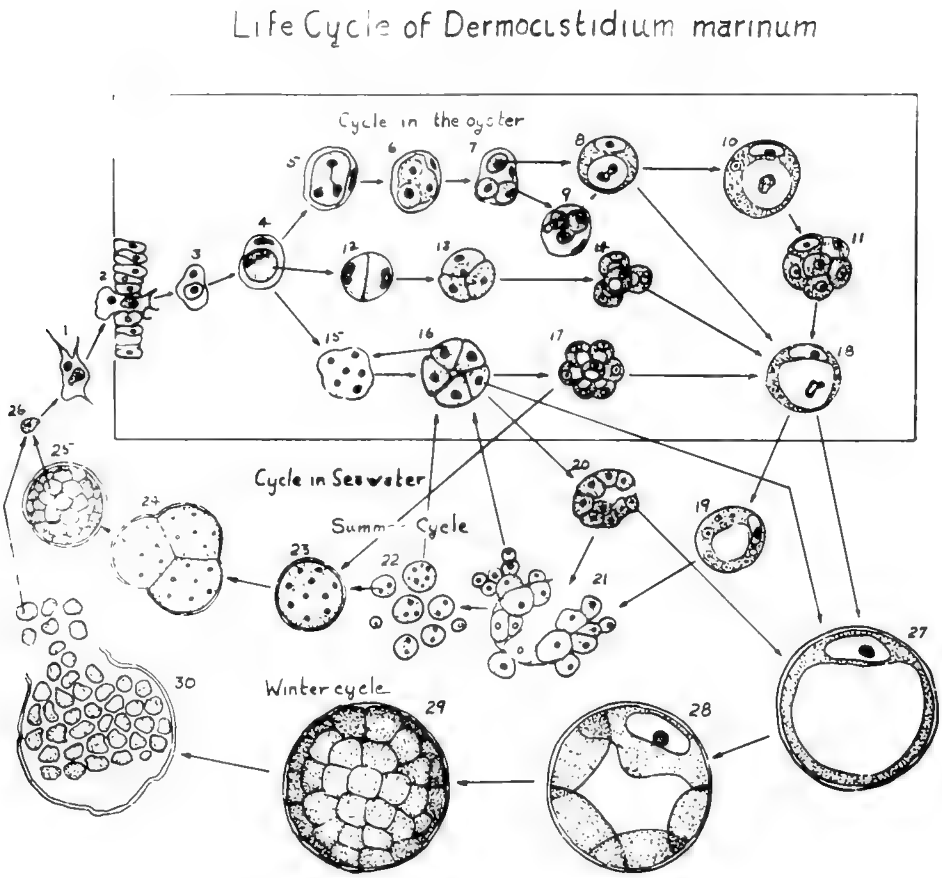

Fig. 1. Diagrammatic representation of the life cycle of Dermocystidium marinum. Explanation is in the text.

phytic reproductive cycle which differs in some respects from that in the oyster. Basically the cycle is the same, involving vegetative reproduction, and soral development. These however, seem to be more regularly progressive and integrated into a well defined succession. Mature thalli (19) or sori (20) initiate a budding-fission sequence (21) which results in enormous numbers of cells. Peculiarly, in a mass of cells predominantly reproducing by fission, some revert to production of sori exactly as in the oyster tissue, these minute sori producing uninucleate aplanospores. For a period, the cells produced by fission are tightly clumped together, the clumps containing thousands of cells, most of which are uninucleate. The clumps are, however, unconfined and correspond to an enormous sorus. Later the units of a sorus separate (22), become multinucleate and grow (23). Growth usually results also in laying down a definite wall which probably is cellulose. However, some remain thin walled. The multinucleate forms may develop directly to thick walled or thin walled sporangia (25) or they may cleave to become large sori, the elements of which are multinucleate (24). These sori may be either thin or thick walled, and the factors governing the development of a thick wall are unknown, since both types may be produced in the same culture. Sporangia (25) from a sorus produce aplanospores (26). It is assumed that under normal conditions in sea-water aplanospores may develop flagella and become zoospores. Zoospores have been observed in culture, but under conditions which lead to doubt as to their origin.

A theoretical cycle involving enlarged forms, morphologically like those produced in thioglycollate culture, has been suggested (27 to 30). Because in oyster serum culture these forms have been observed to go into cleavage stages (28), it is assumed that the enlarged forms are hypnospores or winter sporangia. They may complete their cycle as suggested in the diagram (29,30), by producing aplanospores (or zoospores?). There are insufficient data to substantiate the cycle as shown for enlarged forms (27 to 30) but the data indicate that enlargement and laying down of a resistant wall are normal, and the cells thus produced are morphologically comparable to hypnospores.

Details of the saprophytic cycle have been worked out by culture method. It was found that D. marinum could be cultured in (1) very dilute thioglycollate medium (2) dilute oyster serum, and (3) sea water containing fragments of host oyster tissue. The conditions making culture possible will be presented in another paper.

C. Relationships

The sori and sporangia of D. marinum are nearly identical to the same structures in the Synchytriaceae. Basically the cycle is the same as that of such genera as Synchytrium and Micromyces. D. marinum differs from genera of the Synchytriaceae in (1) lack of a flagellated zoospore stage, and (2) the interpolation of an extensive vegetative reproductive sequence. It is believed that the nature of the animal host is responsible for most of the apparent differences, and the ease of infection via the phagocytic route has obscured the relations of the flagellated zoospore. The apparently highly developed saprophytic cycle is unknown in the Synchytrids, but it should be noted that failure to culture the plant-parasitizing Synchytrids may have led to the erroneous concept that such does not occur, when in actual fact it may occur.

In some species of *Micromyces*, sori may develop either in the host cell or external to it.

It is believed that *D. marinum* is correctly placed as to genus. Species of *Dermocystidium* other than *D. marinum* are parasitic in vertebrate hosts, and much of the descriptions of these species is given over to discussion of the host reactions in formation of a cyst about the parasite. The undue attention to the cyst has obscured the fact that the "plasmodial" stage of some species of *Dermocystidium* is a sporangio-sorus, and the cells produced by these structures are identical to the mature thallus of *D. marinum.* Only fragments of the cycle of other species of *Dermocystidium* are known. But all indications are that, since the mature thallus stage ("spore" of authors) is not infective, there must in fact be a saprophytic cycle in an aquatic medium, the end result of which is an infective spore which may be a zoospore.

DERMOCYSTIDIUM MARINUM AND SALINITY

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Introduction

The control of Dermocystidium marinum must rest partially on management of plantings and engineering of freshwater supplies, so that oysters will be in their own optimum salinity environment. The data indicate that some areas now marginal for oyster production may be reclaimed by proper management of freshwater supplies. The association of high salinity and high mortality of planted oysters has been long known. But the exact methods by which fluctuation in salinity operates to modify incidence and intensity of infection of oysters with D. marinum are only partially known. On the theory that exact knowledge of effect of salinity may make possible better management of oyster plantings it is undertaken in this paper (1) to examine the published data bearing on the subject, (2) add some data as yet unpublished, and (3) analyze and evaluate the facts.

Literature

Mackin et al. (1950) first remarked on the relation of D. marinum to salinity. They stated that low temperature and low salinity retard development of the fungus in oysters. They presented no salinity data in that preliminary paper which was the original description of D. marinum. Mackin (1951) again mentions the apparent association of massive individual infection with high salinity conditions. He later (1953) compared data on mortality, weighted incidence of infection with D. marinum at a low salinity station in Louisiana with the data from several stations at which the salinity was markedly higher. These date showed that incidence of the disease was much lower at the control station, but it was not absent. Salinity data were not given.

Hewatt and Andrews (1954a, 1954b), Andrews and Hewatt (1954), Andrews (1954,1955, 1955a) mentioned the salinity-incidence relationship repeatedly. A study of their data shows that D. marinum occurs in heavy concentration in the lower Virginia Chesapeake and the lower parts of the esturial rivers, while disease incidence decreases up stream in the James, York, Rappanhannock and Potomac rivers. Pritchard (1952) has made available data on the salinity of the Chesapeake Bay estuarine system. His data show that the James river seed area varies in mean salinity from 8 to 19 o/oo (surface, at high water). The greater salinity was about at "the bridge". and the lower salinity at the upper end of the oyster seed production area. At low water the range is about 5 to 15 o/oo. Andrews stated that D. marinum was rare above the bridge of the James river, which bridge crosses just above

Newport News. Where D. marinum infection is in high incidence (Gloucester Point, York River) Hewatt and Andrews (1954a) found the salinity over two years varied from about 9 to 25 o/oo but summer salinities when D. marinum was present in abundance (July, August, September) was in the range from 16 to 23 o/oo. For most of this period salinity was about 20 to 22 o/oo.

At just what point D. marinum disappears altogether in the James river cannot be determined from the literature. In the Potomac river Andrews (1954) says that the Machodoc river is about the upper limit; in the Rappahannock the fungus disappears at about the town of Morattico. In such estuaries it appears certain that there is a salinity below which D. marinum does not exist, but salinity per se is not necessarily the factor of greatest importance in its elimination.

Ray (1954) presented considerable data bearing on the relation of D. marinum to salinity. He contrasted time of development of D. marinum infection to lethal level in oysters in low salinity (10 to 13.5 o/oo) with the time in high salinity aquaria (26 to 28 o/oo). He found that low salinity retarded infection and development of D. marinum to lethal leval, and in those experiments where infective dosages were comparatively small, the effect was marked. He stated that salinities within the range tested did not prohibit development, and did not prevent death of the oysters but only delayed it. He concluded that low salinity was not physiologically unfavorable for D. marinum, and suggested that any small delay in appearance of acute infections might be very valuable. He thought that the present author's theory that the flushing and diluting effects of inflowing freshwater in estuaries might be combined with retarding effect of low salinity to produce the association of low incidence of D. marinum with low salinity.

Owen (1954?)* studied the relation of D. marinum to salinity. He concluded that "(1) Unusual mortalities of oysters occurred in Louisiana waters under the conditions of high temperature and high salinity of the waters. (2) The primary cause of these mortalities is Dermocystidium marinum, a pathogenic fungus". Owen presents considerable data to substantiate his statements. His field data showed that both high salinity and high incidence of D. marinum were associated with high salinity and that those areas with a constant source of river water from the Atchafalaya and Mississippi Rivers had comparatively less mortality and a lower incidence of D. marinum.

Some of Owen's data on field studies are significant. I have taken data on salinity, mortality, and incidence of D. marinum from several of his tables and have presented them here in condensed form (Fig. 1). The plots show that the three are related to each other. The data are not too convincing since the salinity data apparently were taken over a period of years while the incidence data are taken from a few analyses over a short period.

*Unpublished data contained in voluminous report on investigations of causes of oyster mortality in Louisiana. The studies were conducted by Dr. Owen for the State of Louisiana, Department of Wildlife and Fisheries, Division of Waterbottoms, 1947 to 1950.

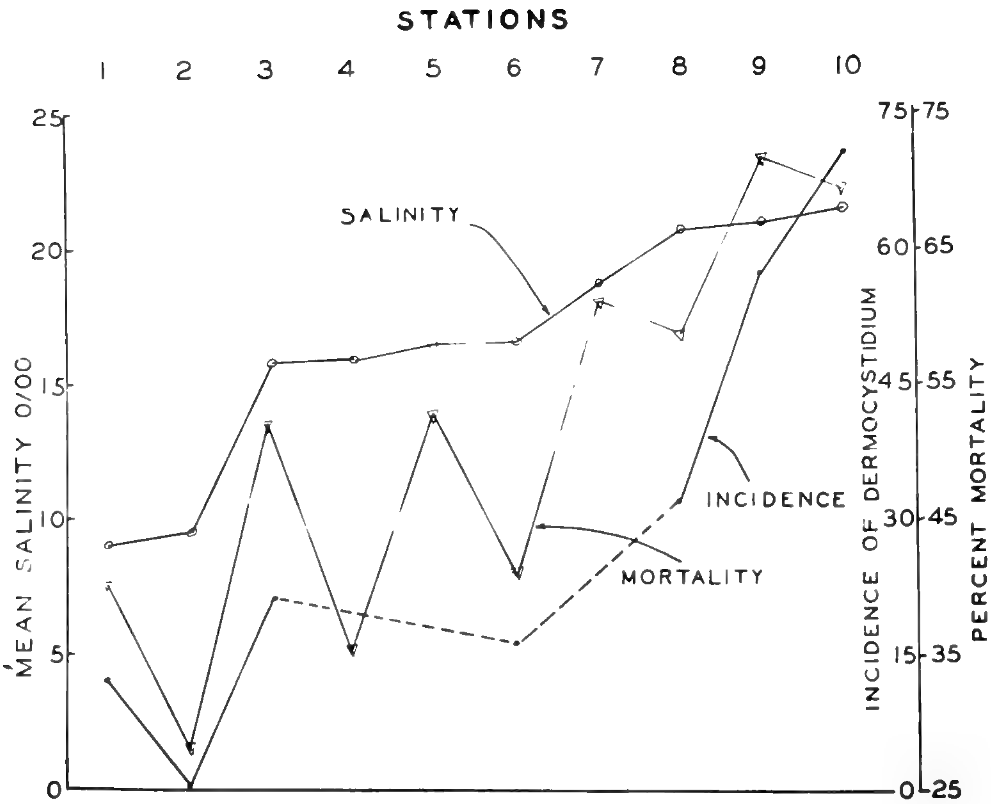

Fig. 1. A comparison of the salinities at 10 stations in Louisiana with index of mortality of oysters and incidence of infection with Dermocystidium marinum at the same stations. Stations are (1) St. Mary's Point, Barataria Bay, (2) Sister Lake, (3) Bayou Pierre, (4) Bassa Bassa Bay, (5) Grand Bay, (6) Lake Felicity, (7) Bay Adam, (8) Scofield Bayou, (9) Lower Barataria Bay, (10) Lake Grande Ecaille. For three stations (4, 5, and 7) there were no data on incidence of disease. Data are from Owen, 1954.

Owen also performed certain controlled experiments to determine the relation of salinity to infection. From these he concludes (1) that oysters may contract the disease irrespective of salinity and (2) that in previously infected oysters salinity does not much affect the development of the disease to lethal termination.

Dawson (1955) after studying the distribution of D. marinum in Apalachicola Bay, Florida, concluded that "massive infections (of individual oysters) occur in Apalachicola oysters under conditions of high temperature and low mean salinity". Dawson's salinity data were extremely meagre, and the data on salinity in the period immediately preceding the analysis for incidence of infection were not given. Instead he presented mean data from salinity spot samples for a year, which included the sampling period, and for six months preceding the week during which he took oyster samples for analysis. Such procedure fails to show what were the salinities in the critical period of the month of June. Sampling for D. marinum was done by Dawson in late June and early July.

A study of the salinity data presented by Ingle and Dawson (1953) indicates that Apalachicola Bay is all polyhaline in nature and it is doubtful whether Dawson's conclusions regarding the relations of D. marinum to low salinity have much meaning. In discussing the salinity conditions Ingle and Dawson state "In dry seasons salty water prevails in the entire region (i.e., Apalachicola Bay) even invading the area surrounding the river mouths". Cat Point, the station closest to the "low salinity" area of Dawson (1955), had a salinity range of 0.0 o/oo to 32.1 o/oo. Other stations in Apalachicola Bay attained salinities of greater than 40 o/oo, showing that evaporation exceeds influx of fresh water at certain times of the year. It is difficult to envision any part of such a bay having anything but a polyhaline environment.

Ray and Chandler (1955) state that in waters of salinity of 15o/oo and less "mortality of oysters and incidence of parasitism (are) comparatively low". After reviewing the data they again suggest that (1) low salinity effects may be caused by dilution by fresh water of the infective cells (the author's theory), (2) low salinity may be effective per se in retarding speed of development of D. marinum but the effect is not sufficiently potent to prevent development of disease to lethal intensities if given sufficient time.

They also believe that some apparent effects of salinity may be due to other environmental factors, such as certain carbohydrates or copper, which are present in greater quantities in river water or marsh drainage water than in oceanic water. Mentioned also is the fact that some very highly saline waters (Port Aransas, Texas) in excess of 35 o/oo may be harmful to D. marinum.

Low Salinity Tolerances of *D. marinum* and *Crassostrea virginica* in Louisiana

To establish the low salinity tolerances of oysters and of *D. marinum* under field conditions, records have been studied where both salinity data and incidence data are available. Redfish Bay, Louisiana, is an area where *D. marinum* periodically exists in low incidence, but is sometimes absent. Also it is an area marginal for oysters, so far as tolerances to low salinity are concerned. In the spring and summer of 1953 data on occurance of oysters and *D. marinum* were obtained in Redfish Bay following a two month period when extensive salinity data were also obtained. These salinity data, collected by Mr. R.A. Guyer of the Humble Oil and Refining Company, were made available to the author. They are presented in Table I in condensed form. The stations listed are identical with oyster sampling stations, and the data on tolerances of oysters and *D. marinum* are contained in the same table. Oysters were collected in the 12 day period directly following the two months of salinity studies.

Table I

Salinity of Redfish Bay, Louisiana,
May 5, 1953 to July 2, 1953.

Shown are salinities at which oysters died, those at which a few lived, and those where survival and growth were excellent. *D. marinum* was found not to be present.

Station	Salinity, o/oo Bottom min.	Bottom max.	Surface min.	Surface max.	Mean bottom	Mean surface	Oyster tolerance
(1) Extreme upper Bay	3.0	6.8	2.6	5.8	3.8	3.5	None
(2) Mid Bay	2.8	15.8	2.4	6.2	4.5	3.5	Few scattered live oysters
(3) Lower Bay 1 mile from Gulf	2.5	21.2	2.1	6.4	7.5	3.7	Survival good Growth poor
(4) Southernmost Point of Bay at Junction with Gulf	2.8	21.7	2.5	16.4	7.2	3.8	Survival and growth excellent

All oyster sampling stations have produced oysters within the preceding year or two, judging from the preservation of shells. However, two of the stations are not now significantly productive. One, that in the extreme upper Bay, was completely barren of live oysters and the near-freshwater snail Neritina was numerous. A few scattered live oysters were found at station 2, just above the middle of the Bay, but mostly there was nothing but a rubble of old shells and boxes. This station was probably on the borderline between the area above which oysters could not survive, and that to the south where they grew prolificially. The mean salinity at both stations 1 and 2 was less than 5 o/oo.

At stations 3 and 4 oysters were surviving well, although at station 3 their size was distinctly small. At station 4 the oysters were growing vigorously but all showed the characteristic thin brittle shells of low salinity oysters. They were free of Polydora, Cliona and Martesia.

The mean salinity at stations 3 and 4 was between 7 and 8 o/oo. The maximum occurred only at times of high spring tide, when a tongue of Gulf water intruded along the bottom.

One hundred and ninety-five oysters from stations 2, 3, and 4 were checked for D. marinum infection using the thioglycollate method (Ray 1952). None of these oysters was infected. Under the conditions in Redfish Bay at that time D. marinum either was not present or could not infect oysters. The collections of oysters were made on July 2, which was the date of the last salinity check, and on July 15, nearly two weeks later.

The southern part of Redfish Bay at the time of this study had minimum salinity requirements for oyster growth. But the conditions were too severe for D. marinum. One should be wary in attributing the elimination of D. marinum to low salinity alone. There were perhaps other factors which paralleled and enhanced the effect of the low salinity. One of these certainly was the diluting effect of the large flow of Mississippi River water which enters the Gulf through numerous "passes" at the Delta tip. Another might be the presence of increased amounts of some trace elements, such as copper, as suggested by Ray (1954).

Nine months after Redfish Bay was found to be free of D. marinum, another check of 25 oysters from station 4 showed that eight percent were infected, with a weighted intensity of 0.25. Unfortunately no salinity data are available for this later date.

To gain further insight into the conditions under which D. marinum can barely exist, the data from two other stations in Louisiana were examined. These data are taken from Owen (1954), and are incorporated in Table II. Low incidences are shown at both stations and the mean salinity at each was very close to 9 o/oo and the maximum was 18 o/oo. At the St. Mary's Point station the maximum would seem to be too low, for our own data at that point indicates a maximum salinity of 29 o/oo. The salinity at some period according to our data stayed between 20 o/oo and 25 o/oo for as much as a week and occasionally dropped to zero. However, Owen's mean seems to be nearly correct, though a little low. The data are somewhat subject to criticism because the salinity data belong to the 1947-48 period while the disease incidences were established in 1949-1950. In the Louisiana area, these salinites probably are about the minimum at which D. marinum ordinarily exists. Too much reliance may not be placed on such figures, because of unknown variables which may exist. It is interesting that Owen never found D. marinum at Sister Lake when examining oysters taken directly from the bottom. His records were obtained from oysters from Sister Lake which had been removed to aquaria and kept there for an unstated period. This may indicate that latent stages, too few in number to be recognized in sections, exist in the oysters. These may accelerate growth under aquarium conditions.

Table II

Incidence of D. marinum and salinity
at two Louisiana stations.
(Data from Owen, 1953, 1954)

Station	Incidence of D. marinum			Salinity, o/oo		
	Oysters sectioned	Infected	%	Mean	Min.	Max.
Sister Lake	60	9	15	9.4	5.0	18.1
St. Mary's Pt.	27	3	11.1	8.8	5.0	18.0

In summary it seems probable that oysters may exist and grow vigorously in salinities slightly lower than the minimum tolerated by D. marinum. However, the margin is so narrow, that for practical purposes it does not exist. If other factors enter into the picture, the apparent effect of low salinity derived from the tolerance data may not exist in fact at all.

Field and Laboratory Experimentation

A field study of the relations of D. marinum to salinity was set up by the author in 1951. A group of oysters was divided into two groups of 400 each. One of these was placed in trays at the Chene Fleur station, the other was similarly kept in trays at the Bayou Rigaud station. Chene Fleur is a "low salinity" station, situated above Barataria Bay in Wilkinson Bayou at the entrance to Chene Fleur Bay. At the lower end of Barataria and near Barataria Pass, the Bayou Rigaud Station is more or less constantly in comparatively high salinity water. Three years of comparison of salinity in lower Barataria with those at Chene Fleur shows that these two stations fluctuate in the same direction so far as salinity is concerned. Influx of water from heavy precipitation in the Barataria Bay watershed arrives at Chene Fleur first and is diluted as it proceeds down bay. There is always a differential of several parts per thousand between the two stations. In lower Barataria Bay tidal fluctuations are more extreme than in stations above the bay. The relations are better expressed by graph than by description (Fig. 2).

Each month from January to September 1951 a random sample of 20 oysters from each station was sectioned, stained slides made, and these were studied to give the incidence and weighted incidence of infection with D. marinum. The "weighted incidence" is an arbitrary scale developed by the author to reflect both incidence and intensity of infection. For example two groups of oysters might both have an incidence of 50 percent but be very unequal so far as intensity of disease is concerned if the infections in one group were all light while in the other the majority were heavy. To give a true picture, each light case is given a value of 1, the moderates, 3, and those with heavy infections, 5. The sum of all values divided by the total number of oysters in the sample gives the weighted incidence, which may not be greater than 5.0.

Mortality records were kept at the two stations. This was to determine whether or not mortality varied with the intensity of disease. These data are included in Figure 2 which shows in histogram form the changes in the weighted incidences and mortality rates through nine months. In an inset are salinity data, in the form of frequency histograms, from September 1947 to August 1948 in the lower Barataria area and at Chene Fleur above the bay. It is regretted that salinity data at Chene Fleur were not available for the exact period of the study. However, the relations of salinity at the two stations had been thoroughly studied in the period from 1947 to 1949, and there can be no doubt from the locations of the stations that the salinity contrast is valid.

The wide difference in intensity of disease between the two stations is apparent at a glance. The effect of the low temperature period (January to May) is shown, but even in winter there is a marked difference in intensity of disease at the two stations. The graph also shows that winter mortalities are held down by the low temperature. Factors other than salinity and temperature were probably influencing the results to a lesser extent.

In the laboratory, results presented a somewhat different picture. Apparatus was set up to allow control of salinity levels in flowing water aquaria. Two studies were carried out. In the first the salinity in one aquarium was held between 8.6 o/oo and 14.8 o/oo, with a mean of 11.1 o/oo. In the other, salinity varied from 17.6 to 25.0 o/oo with a mean of 20.9. Oysters used were 90 percent infected according to a sample check of 20 oysters. Both the high and low salinity aquaria contained 15 oysters each. The study began on June 27, 1951, and terminated on August 24, 1951, an approximate two month period. At the end of the study, all oysters in the low salinity aquarium were dead and all but four died in the high salinity tank. Incidence and weighted incidence of D. marinum in gapers and survivors are shown in Table III.

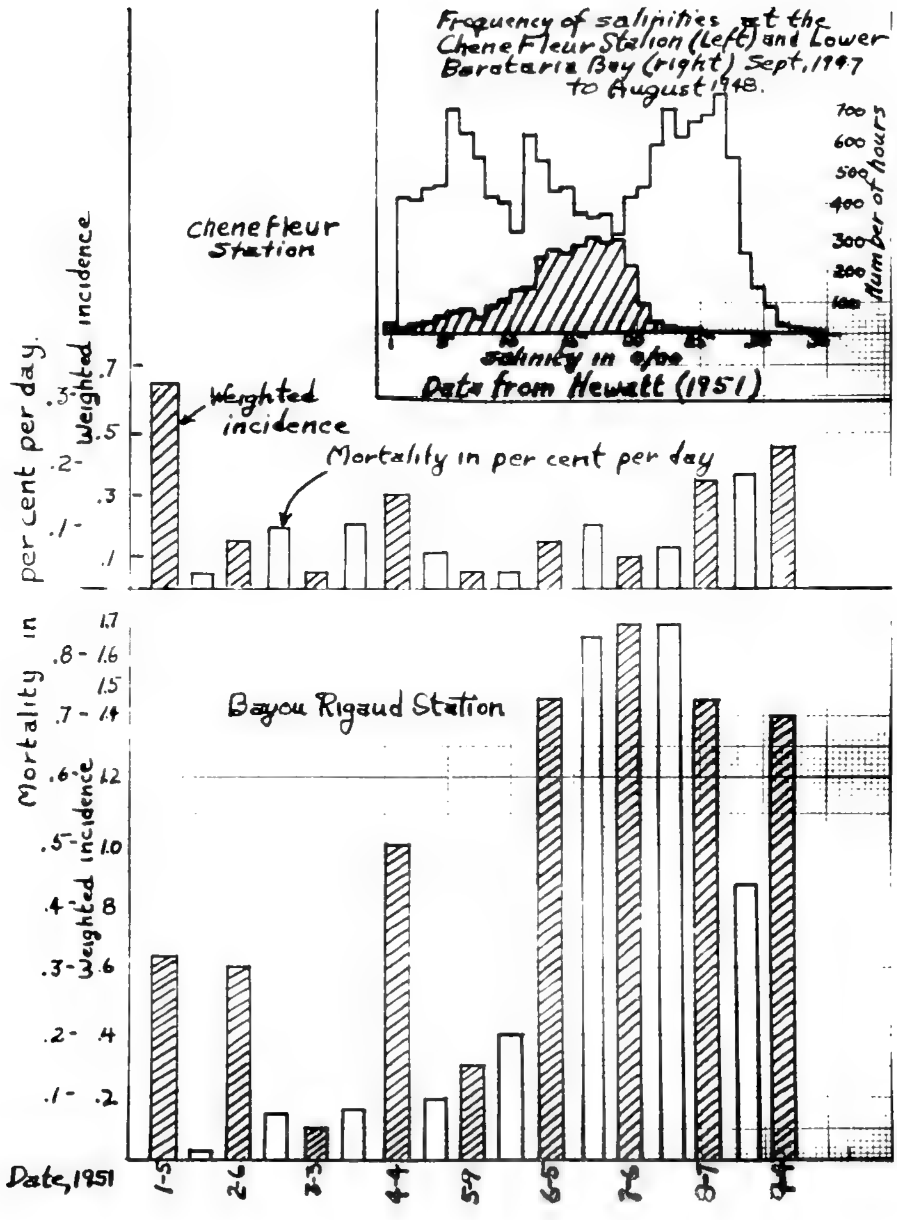

Fig. 2. Incidence of Dermocystidium marinum at Chene Fleur, a low salinity station, and at Bayou Rigaud, a high salinity station. Mortality accruing from disease is also plotted. Inset shows the hourly frequencies of salinities at Chene Fleur and in lower Barataria Bay (corresponding to Bayou Rigaud) for a period of a year.

The repetitive study began on September 6, 1951, and ended October 23, 1951. Oysters used were shown to be 80 percent infected by a sample check of 20 oysters. The salinity in the low salinity aquarium ranged from 13.6 to 20.8 o/oo with a mean of 17.2 o/oo. In the high salinity tank the range was 19.8 to 28.1 o/oo and the mean was 23.7 o/oo. The aim was to have the lower salinity aquarium about two-thirds the salinity of the higher salinity tank. The aim was narrowly missed. Fifteen oysters were used in each tank. The study was brought to an end when eight oysters (about 50 percent) had died in the high salinity tank. Data on incidence and weighted incidence of infection with D. marinum are presented in Table III.

Table III

Summary of data on weighted incidence (WI) of D. marinum in oysters kept in low and high salinity aquaria.

Study No.	High Salinity				Low Salinity			
	gapers		survivors		gapers		survivors	
	No.	W.I.	No.	W.I.	No.	W.I.	No.	W.I.
1	11	4.55	4	0.50	15	4.40	0	---
2	8	5.00	7	2.00	5	5.00	10	2.30
Totals	19	4.74	11	1.27	20	4.55	10	2.30
Combining gapers and survivors	No. 30		W.I. 3.53		No. 30		W.I. 3.80	

These data indicate that there is no significant difference in development of disease in low and high salinity aquaria. The diluting water in the low salinity aquaria was rain water and water from vapor pressure machine for extracting salt from sea water. This was probably different from river water or marsh water in metallic ions and carbohydrate content. These variants were possibly eliminated, and the results modified thereby. Certainly the data contrast oddly with those derived from field studies. The failure to demonstrate a chemical influence of salinity on development of D. marinum must be of some significance. It supports the theory that dilution of number of infective elements and their removal from low salinity areas by the preponderance of ebb over flood currents account for the observed field correlation of high salinity and high incidence of D. marinum.

Because in the two studies just described the oysters used were previously infected in high percentage, the studies reported by Ray (1954) should be closely studied. Beginning with uninfected oysters Ray showed that low salinity has a definite retarding action when the oysters are artificially infected by the "feeding" method. Furthermore, the retardation was accentuated when infective dosages were reduced. These studies by Ray lend support to both the chemical inhibitor theory and to the dilution theory.

The author has projected studies in which oysters in filtered sea water of equal salinity are given carefully graded dosages of infective cells by the injection method. This series of studies is not complete. However, those completed at this time show that death rate from *D. marinum* infection is lowered by reducing the infective dosage. As yet, no threshold has been found below which infection and development of disease does not occur. Speed of development is reduced by lowering the dosage.

Discussion

Study of the references in the literature and of the results of field and laboratory study at Grand Isle indicates that the following are true.

1. In the field there is a general positive correlation of high salinity and high incidence and weighted incidence of *D. marinum*.

2. Although *D. marinum* infection is reduced in low salinity, the salinity tolerance range is nevertheless very wide. In one culture of *Dermocystidium*, salinity mounted by evaporation to more than 50 o/oo without visible effect on reproduction of the fungus. In the field, the fungus is tolerant to a mean salinity of about 8 or 9 o/oo and possibly lower. The effect of the range at these low means has not been determined. In Louisiana, oysters apparently can grow well at slightly lower means than can *D. marinum* but the difference is not impressive.

3. Laboratory experimentation indicates that there may be a retarding effect of low salinity per se, but that the disease may nevertheless develop in oysters in quite low salinities. There is probably no physiological handicap for *D. marinum* produced by low salinity.

4. It is suggested that dilution of infective elements by fresh water inflow coupled with the preponderance of ebb over flood current rate tends to eliminate infective cells in low salinity areas and to concentrate them in high salinity areas. If this is true, continuous, uninterrupted inflow of freshwater into estuaries may be of greatest importance in the epizootiology of the disease.

5. There probably are other factors which modify the incidence of disease. It may be that increased amounts of copper ions in river water or higher concentrations of carbohydrates in marsh drainage may have some effect, direct or indirect, as suggested by Ray.

6. In any event, the matter of the role of salinity variance in the epizootiology of disease caused by D. marinum is far from resolved. Because introduction of fresh water into oyster producing areas is now the principle hope of control, it is hoped that investigators will devise means of further testing the hypotheses advanced.

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TEMPERATURE CONTROL EXPERIMENTS ON THE FUNGUS DISEASE, DERMOCYSTIDIUM MARINUM, OF OYSTERS *1

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In 1950 Mackin, Owen, and Collier described a fungus parasite, Dermocystidium marinum, found in oysters of Louisiana coastal waters. Since that time numerous studies have been conducted on the nature of the fungus and its effects upon the host. It has been definitely established that the pathogen is the main contributor to the causes of mortality of oysters in some areas. Ray and Chandler (1955) have adequately reviewed the literature on the subject.

Among the various observations that have been made on the fungus disease there is very positive evidence that the incidence and intensity of the infection are primarily controlled by the temperature of the water. Mackin (1953) found that mortality rates and intensity of the infection were greatly depressed during the winter months in Barataria Bay, Louisiana. Hewatt and Andrews (1953) reported a high mortality period extending from June through October in the lower York River, Virginia. Ray and Chandler (1955) stated that temperatures exceeding 20°C. favor the development of Dermocystidium marinum in waters of the Gulf of Mexico.

During the summer of 1954 we conducted a series of experiments in an effort to determine the effects of relatively low and high temperatures on the development of the fungus disease. Oysters were collected from two different sources. One group of oysters, estimated to be three years of age, was collected from Wreck Shoal of the James River, where no evidence of the fungus has been found. This group will be referred to as the "Nonendemic Oysters". The other group of oysters came from the Rappahannock River, where fungus infections have been found. This group will be designated "Endemic Oysters".

A total of 300 oysters was used in the experiments. They were held in trays suspended from the Virginia Fisheries Laboratory pier for a period of approximately two weeks. They were then placed in well aerated laboratory aquaria to which a mince of oyster tissues, heavily infected with Dermocystidium marinum, had been added. All of the oysters were kept in this environment for a period of 24 hours. They were then returned to the pier trays and held for another week. Another infectious mince of tissues was fed to

*1 Contributions from the Virginia Fisheries Laboratory, No. 62.

TABLE I.

History of six series of oysters used in experiments.

Series	Source	Date 1st Artificial Infection	Date 2nd Artificial Infection	Experiment Begun	Experimental Environment
V-M-1	James River	9 July 54	13 July 54	20 July 54	Low Temp. at 15°C.
V-M-2	Rappahannock River	14 July 54	19 July 54	27 July 54	Low Temp. at 15°C.
V-M-3	James River	9 July 54	13 July 54	20 July 54	Lab. Vat. at 28°C.
V-M-4	Rappahannock River	19 July 54	19 July 54	27 July 54	Lab. Vat. at 28°C.
V-M-5	James River	9 July 54	13 July 54	20 July 54	Pier Tray at 26-30°C.
V-M-6	Rappahannock River	14 July 54	19 July 54	27 July 54	Pier Tray at 26-30°C.

the oysters to ensure infections and they were again returned to the pier trays for one week. Earlier observations had revealed that oysters subjected to the "feeding" technique at temperatures above 26°C. would become heavily infected and die within a period of four or five weeks.

Six experimental series were set up, each consisting of 50 oysters. The history and treatment of each series are shown in Table I. Series V-M-1 and V-M-2 were placed in a lead-lined vat, of about 150-liter capacity, containing water which was aerated and maintained at a temperature of 15°C. Series V-M-3 and V-M-4 were placed in a similar vat kept at a temperature of 28°C. Series V-M-5 and V-M-6 were held in trays suspended from the laboratory pier. The temperature of the river water varied from 26° to 30°C.

The oysters were examined at frequent intervals and gapers, i.e. oysters which could not maintain closure of the shells, were removed. The thioglycollate culture technique, described by Ray (1952 and 1952a), was used for diagnosis of the fungus disease in the gapers. The intensities of infections were classified as "heavy", "moderate", "light", or "negative" according to the system employed by Ray et al (1953).

The results of the tests for Dermocystidium marinum and the mortalities in the six series of oysters are shown in Figure 1. Over the period of approximately six weeks there was a mortality of only 10 percent among the oysters (Series V-M-1 and V-M-2) held at 15°C. Of the 10 oysters which died in the group only one was found to be free of infection. Heavy or moderate infections were present in three of the gapers. Ninety-nine of the 100 oysters (Series V-M-3 and V-M-4) held at 28°C. in the closed laboratory vat had died by the end of the six-week period. All of these deaths occurred during the first four weeks of the experiment. The intensities of the fungus infections found in the nonendemic James River gapers were much greater than those noted in the endemic oysters.

Series V-M-5 and V-M-4, which were held in a tray suspended from the pier, had a total mortality of 53 percent. Thirty-seven of the gapers were taken from the nonendemic group and only 16 from the endemic group over the six-week period.

Two tests of samples of live oysters from each of the series of oysters held at low temperature were conducted during the six weeks. The first test was made from tissues of five oysters on August 23. Each of the nonendemic oysters was infected. No infections were found in the sample of endemic oysters. The second test was conducted on August 31 and again revealed light infections in each of the nonendemic oysters. Only two of the five endemic oysters were infected.

Conclusions

1. Oysters which were fed a tissue mince from heavily infected gapers andheld in a closed, aerated aquarium at 28°C. became infected with Dermocystidium marinum. All of the oysters were killed by the disease in a period of approximately four weeks.

2. When oysters were experimentally infected and held at a temperature of 15°C. the progress of the fungus infection was arrested and mortalities caused by the disease were negligible.

3. Experimentally infected oysters suspended in endemic waters from the laboratory pier died at a slower rate than oysters held in a closed aquarium at approximately the same temperature.

4. The results suggest that oysters taken from an endemic area are less susceptible to infection by Dermocystidium than oysters collected from nonendemic waters.

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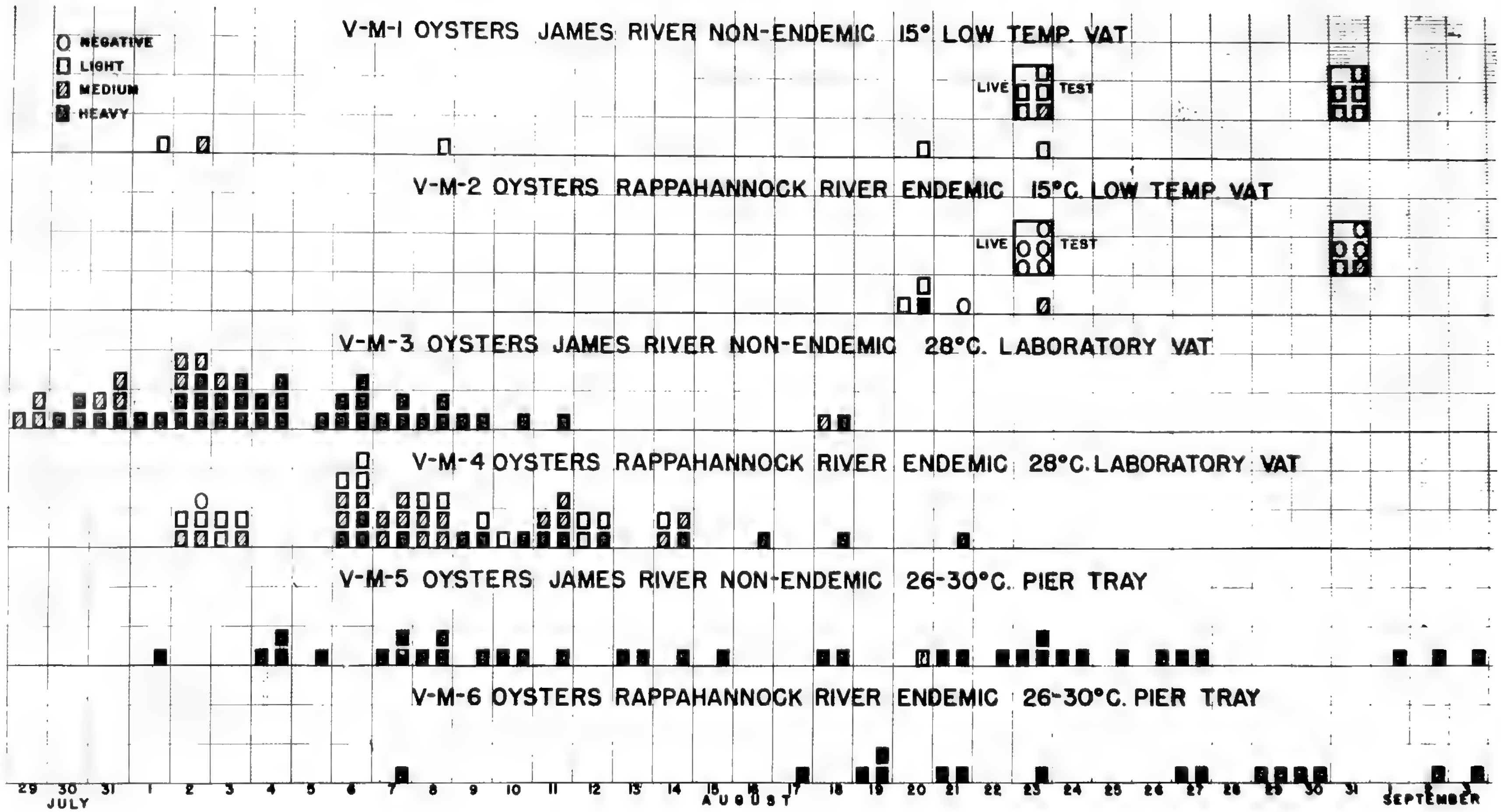

Fig. 1. Results of the tests for D. marinum in the six series of oysters.

THE DISTRIBUTION OF OYSTER DRILLS IN NORTH CAROLINA

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The common name of "oyster drill" or "borer" is generally applied to at least three genera of carnivorous gastropods. These are distributed over a wide area embracing the entire range of our common eastern oyster, Crassostrea virginica. Carriker (1955) in his survey of the literature reports the distribution of Urosalpinx cinera (Say) and Eupleura caudata Say along the Atlantic Coast from Canada to Florida. A third genus, Thais, is found along the Atlantic coast south of Chesapeake Bay and throughout the Gulf of Mexico (Clench, 1947). Representatives of the three genera are found in North Carolina waters.

From the paleontological evidence, Carriker (1955) writes that Urosalpinx cinerea evolved somewhere along the middle Atlantic coast and spread southward and northward. Richards (1950) records Urosalpinx cinerea from the Miocene and Pliocene geological periods in North Carolina and Eupleura caudata from the late Pliocene formations. The earliest records are from geological formations that are located about 100 air miles from the present coastline.

There is little information on the distribution and abundance of oyster drills in North Carolina. Carriker (1955) reviewed some of the references indicating the presence of drills in North Carolina. Winslow (1886,1889) did not report the presence of any drills, but writes that conchs were noticed in some areas of Pamlico Sound near the inlets and that Urosalpinx would probably be found. Grave (1904) reported drills (Urosalpinx) in the region of Swanquarter along the northwest shore of Pamlico Sound but they were not sufficiently numerous to cause noticeable damage. Some of the experimental beds planted by Grave (1904) in Newport River and North River did suffer drill damage. Galtsoff and Seiwell (1928) found large numbers of drills and egg cases in August, 1927, in the region of Styron Bay, a tributary of Core Sound, and reported that numbers of young oysters were considerably reduced by Urosalpinx. Federighi (1931) wrote that the greatest infestation of drills occurred in Chesapeake Bay and in the waters north of it, while south of Chesapeake Bay the pest was insignificant. Federighi (1931) conducted studies on drills at Beaufort, N. C., and reported that drills in North Carolina were found on beds exposed at low water.

DISTRIBUTION

The most common and perhaps the most destructive drill, because of abundance, is Urosalpinx cinerea. Specimens have been collected from the intertidal zone on exposed oyster beds and piling from Little River at the South Carolina state line northeastward along the coast in the various sounds to Oregon Inlet. Generally, the drills are more numerous in the vicinity of the inlets. A few Urosalpinx have been collected from trash aboard fishing trawlers working at a depth of 18 to 20 fathoms southeast of Cape Lookout.

The distribution of Urosalpinx in Pamlico Sound is primarily limited to the vicinity of the inlets. A few isolated individuals were found in three areas between June, 1948, and September, 1954, at Brant Island slue, along the south edge of Middle Ground shoal and southeast of Great Island. In the spring of 1955 Urosalpinx were found on the natural oyster rocks at the mouth of Neuse River, off Jones Bay and in the vicinity of Point of Marsh. The oyster rocks at the mouth of Neuse River are surrounded by soft mud and are located at depths of 17 to 20 feet. Roelofs and Bumpus (1953) present yearly variations in runoff that are reflected in the salinity distribution of Pamlico Sound. During 1953 and 1954 there was a gradual increase in salinity which reached the highest peak since 1948 when salinities of 20 ‰ were recorded in the Neuse River off Oriental, North Carolina. With this subsequent rise in salinity a westward distribution of Urosalpinx was noted 10 miles beyond the previous findings as shown in Figure 1.

The abundance of Urosalpinx varies from scattered single individuals to concentrations of 106 per square yard. Three sample plots from which drills were handpicked from an exposed oyster reef in Lockwood Folly River contained 13 drills per square yard. In Saucepan Creek, Brunswick County 12 drills per square foot were collected on October 15, 1952, above the low water mark. At the Institute of Fisheries Research pier in Bogue Sound 120 drills have been collected from a single piling between the high and low water levels. A cluster of serpulid tubes 10 inches in diameter, tonged from New River on April 15, 1954, contained 21 Urosalpinx and two Eupleura.

Eupleura caudata has been collected only below the low water mark. No individuals have been found in the intertidal zone. Eupleura has been collected in Masonboro Sound, Topsail Sound, New River, Bogue Sound, Core Creek, and in the ocean east of Beaufort Inlet. Several individuals were dredged from a depth of 50 feet between Cape Lookout and Beaufort Inlet. The largest individual collected to date was 24 mm. in height from Masonboro Sound.

Thais haemastoma floridana has been collected at the mouth of White Oak River, Bogue Sound, Beaufort Inlet, in the bight of Cape Lookout, at Ocracoke Inlet, and in Pamlico Sound north of Long Shoal. The greatest concentration has been found on the oyster rocks at Ocracoke Inlet. Thais collected at Ocracoke Inlet on April 12, 1955, ranged in total height from 60 to 83 mm. The range in size of Thais collected at Fort Macon on June 2, 1955, was 44.5 to 71.5 mm.

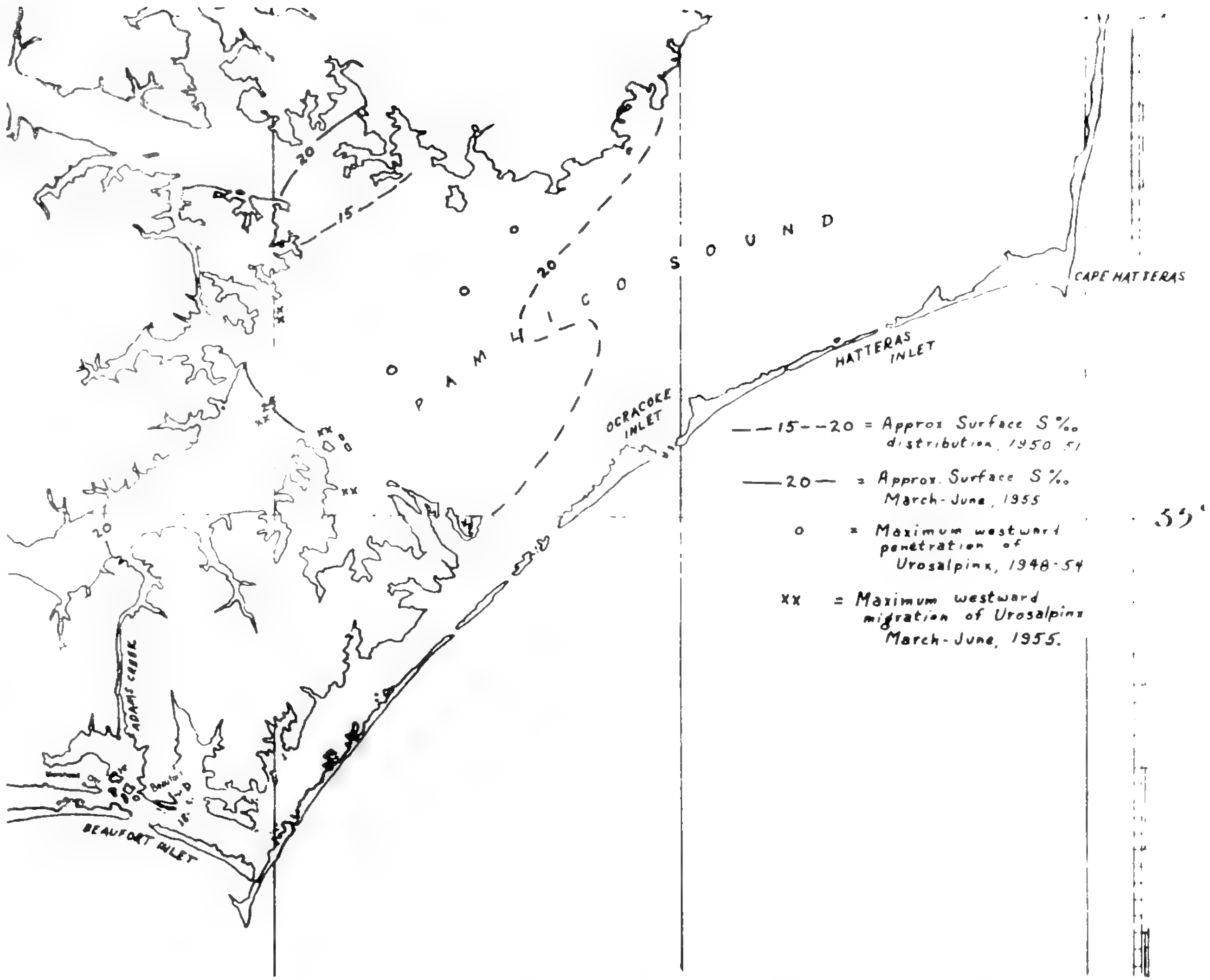

Fig. 1. The distribution of surface salinity and Urosalpinx cinerea in Western Pamlico Sound, North Carolina.

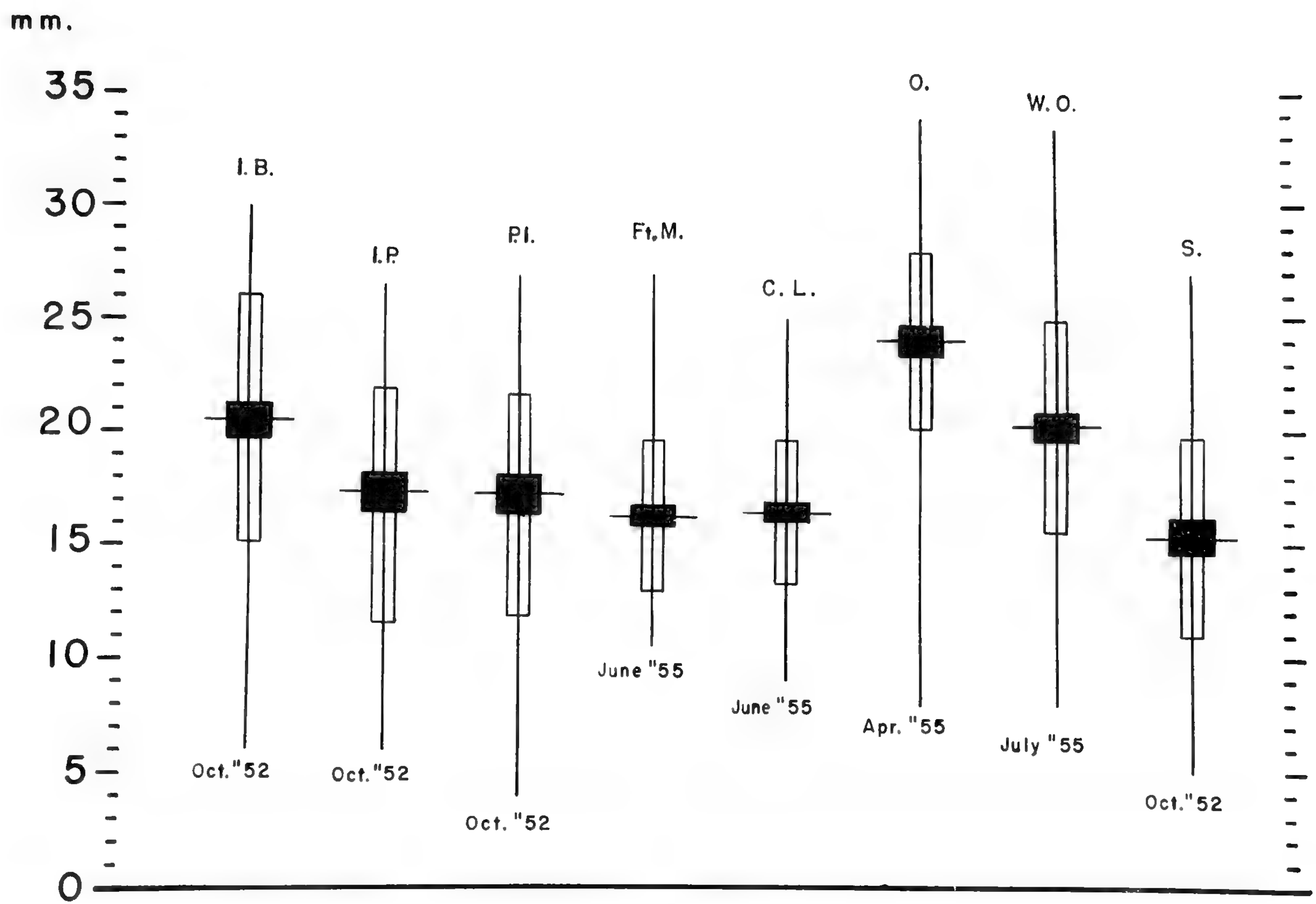

Fig. 2. Comparison of the length of Urosalpinx cinerea from different areas in North Carolina.

Size Distribution of *Urosalpinx*

From eight localities on the North Carolina coast 4,590 specimens of *Urosalpinx* were collected and measured. Sample comparison diagrams in Figure 2 present a comparison of samples according to mean length from the different localities. In each of the diagrams the range of variation in length is represented by the vertical line; the mean is represented by the horizontal line; one standard deviation on either side of the mean is indicated by the solid rectangle. The sexes were not separated and no attempt was made to distinguish age groups. The largest individuals measured 34 mm. and were collected at Ocracoke (Fig. 2,O.) and 33.5 mm., at White Oak River (Fig. 2,W.O.).

The salinities at the different locations where drills were collected (Fig. 2) ranged from 23 to 37 ‰. The Bogue Sound samples (I.B., I.P.) were collected within 100 yards of each other. One sample (I.B.) was collected from a small oyster rock near the shore and the other (I.P.) from the piling of an adjacent pier. The difference in mean length between the two samples (I.B. & I.P.) was greater than the difference between the samples collected at Saucepan Creek, Brunswick County (S) and from the piling (I.P.). The distance between these two stations is about 110 air miles. The salinities in Saucepan Creek range from 0 to 5 ‰ at low water to 23 to 35 ‰ at high water. At the institute pier in Bogue Sound the salinities are more stable, ranging from 28 to 36 ‰.

Federighi (1930) compared the lengths of *Urosalpinx* collected at Norfolk, Virginia, in 1927 with specimens collected at Beaufort, North Carolina, in 1928. The animals from Norfolk averaged 21 to 25 mm. in length compared with 13 to 17 mm. for those from Beaufort. Federighi (1930) concluded that *Urosalpinx* grow to larger size in brackish waters than in saline waters since the difference in the two localities averaged approximately 10 ‰, with the higher salinities at Beaufort. The variations reported above (Fig. 2) do not appear to result from marked salinity differences between areas. It is possible that variations may be due to differences in growth rate between sexes and age groups.

Sex determinations were made of the drills collected. From a total of 4,589 *Urosalpinx*, 54.7 percent were females, 44.2 percent were males, and 1.1 percent were classed as indeterminates. The one percent group had a greatly reduced penis, generally less than one-half normal size. In many cases there was merely a trace or small protuberance in the region where the penis is located. The data on sex determinations will be presented in a later paper.

Summary

Three genera of oyster drills are found in North Carolina. *Urosalpinx cinerea* and *Eupleura candata* are widely distriburted throughout the coastal region. *Thais haemastoma floridana* is concentrated near the inlets.

The distribution of _Urosalpinx_ in Pamlico Sound was greatly extended when salinities increased during 1953 and 1954. Oyster drills are found in abundance in many localities and are a contributing factor in reducing the oyster population below low water.

Measurements of total length of _Urosalpinx_ show marked variations in size distribution between some areas.

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TRAPPING OYSTER DRILLS IN VIRGINIA

I. THE EFFECT OF MIGRATION AND OTHER FACTORS ON THE CATCH[1]

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Introduction

Virginia oystermen have tried trapping of drills as a control measure and discarded it as ineffective and too costly. It is true that their efforts were sporadic and lacking in persistence, and the effects of their trapping were not adequately appraised. They expected returns in the form of increased yields too quickly. Nevertheless, these brief trials have convinced even the most progressive oystermen that trapping drills is not the answer to their predation problem. In Chesapeake Bay, consequently, no conscious effort is made to control drills. Oyster grounds are often allowed to lie fallow for several years, a practice which may decrease the drill population if the grounds are properly cleaned, but the reasons behind this rotation are vague and usually associated with the character of the bottom. To regulate drills oystermen have been urging the development of chemical controls and mechanical dredges.

On the seaside of the Eastern Shore of Virginia, the problem of drill control is more acute and urgent; consequently, many oystermen exercise some type of check on these predators. Whereas in Chesapeake Bay chiefly spat and yearling oysters are lost to the drills and the evidences of damage are not apparent at harvest time, in Eastern Shore waters, rapid growth of thin-shelled oysters together with a large race of drills permits predation of all sizes of oysters including significant numbers of those ready for market. These losses are conspicuous and the importance of drills is fully recognized.

On the Eastern Shore several methods have evolved for restricting damage by drills. For many years the State of Virginia has paid 75 cents to $1.00 per gallon for drills picked from the public grounds at low tide. On private grounds thorough cleaning by dredging followed by trapping and hand-picking are believed by many to be necessary and effective measures. Some planters have used the stratagem of leasing new ground from the state for each crop and turning back the old with a substantial population of drills on it. Other planters have found that moving seed from the intertidal seedbeds in midwinter, when the drills have moved to lower tidal levels and become inactive, is effective in preventing the transplantation of drills. The latest and perhaps the most effective method of obtaining drill-free seed is the use of a rotary drum which sorts out drills at a cost of five to ten cents a bushel. This device, developed originally by Mr. H. M. Terry of

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[1]Contributions from the Virginia Fisheries Laboratory, No. 63.

Willis Wharf, Virginia, though not yet widely used, has great promise for the industry on Eastern Shore.

The status of drill trapping as a management tool is unsettled. In Chesapeake Bay drill traps are considered ineffective; on the Eastern Shore they are used but their importance has not been adequately demonstrated. Yet in Delaware Bay, Stauber (1943), in the most extensive investigation of drills along the Western Atlantic, has apparently demonstrated that trapping together with other control activities can greatly increase yields. Stauber's unpublished manuscript, which has been extensively quoted and paraphrased by Carriker (1955), presents a comprehensive picture of the control and manipulation of drill populations in Delaware Bay and deserves the scrutiny of the large group of workers now investigating drills under the impetus of Saltonstall funds. It appears that Stauber's conclusions on control of drills can be summarized in three principles: (1) Continuous control measures must be applied by a majority of oystermen; (2) All of the control measures, that is cleaning grounds, trapping before and after planting, cleaning the seed of drills, destruction of egg cases, etc., must be used when indicated; frequent sampling of drill populations to establish the need for particular control measures is necessary; (3) The correct timing and sequence of these measures is essential.

If drill control is feasible in Delaware Bay, why can it not be applied in Chesapeake Bay? J. B. Engle of the U. S. Fish and Wildlife Service is now conducting experiments in Chesapeake Bay and on the Eastern Shore of Maryland in an attempt to answer this question. Meanwhile, numerous phases of the biology of drills, which although pertinent to their control are yet obscure, need to be studied. Among these are the age composition of the population, and the effects on control measures of type of bottom, availability of food, migration, and size of plot.

In most studies the age composition of the drills and recruitment to the populations have been ignored. Thus one of the best indices of the effects of control measures is unused. In fact no adequate method of assessing the density and status of drill populations has yet been developed. Reduction of drill populations has been measured in terms of the trends of successive catches obtained during control activities. These catches may be influenced by many factors of the environment and the true population level thereby masked.

Cole (1942) attempted to separate age-groups by dissecting length-frequency curves according to the freehand drawing method of Buchanan-Wollaston and Hodgson (1929). He apparently concluded that after an age of one to two years the annual increment in height is only two or three millimeters and that this estimate is confirmed by the distance between the growth marks on the tip of the shell bordering the siphonal canal. This may be correct but the attempt to separate age-groups with such narrow ranges of height seems precarious. Although he avoids the use of the term annuli, he apparently concludes that these growth marks are such. A clear demonstration of the meaning of these growth marks is needed. The near-absence of yearlings and sometimes two-year-olds in Cole's samples is remarkable also.

Perhaps the most confused subject in the biology of drills is the availability and choice of food. The kinds and amounts of food available for drill populations to use are probably quite incompletely known, yet the whole theory behind trapping is that of differential choice of available foods. For example, the extensive inshore areas covered with eel-grass may be important nursery grounds for Urosalpinx and to ignore this area in attempts to control drills on nearby oyster grounds may be shortsighted.

The relation of migration and size of plot in control activities is the basis of the experiment reported in this paper. The oyster industry of Virginia utilizes public and private grounds which are interlaced spatially throughout our tidal waters in an intricate pattern. We have many grounds of an acre or two which are adjacent to public grounds not attended in respect to drill control. What is the minimal size of oyster plots wherein drill control is feasible and migratory populations of drills less important than resident populations? Stauber indicates considerable success in controlling drills on 20-acre plots and believes that migration is secondary to the effects of the resident population.

Trapping Drills on Wormley's Rock

In 1952 a study was begun of the effects of trapping on the control of drills in a small plot. Wormley's Rock, an abandoned public ground which was long ago depleted and is prevented from recovering by failure of the set to survive, was chosen for the experiment. Much of the sponge-riddled shell, encrusting sponges and other debris which fouled the ground was removed by dredging for several days, but very few drills were caught in the dredges. Two adjacent plots of three acres each were defined by stakes and approximately 10,000 bushels of shell planted. Trapping was begun on the experimental plot in late April and continued almost weekly until October; the control plot was not disturbed. Eight lines each having eight traps were placed in the experimental plot with the traps 50 feet apart and kept as stationary in position as possible (Fig. 1). The trapping was done in 15 to 18 feet of water. and. in contrast to most similar experiments, traps were attached to a taut main line by 20 to 25 foot snoods. Thus each trap remained upon the bottom with a minimum of dragging until it was fished. Traps were fished, always at periods of slack tides, from small rowboats and records kept of the numbers of drills on individual traps. Adjacent to Wormley's Rock are private grounds which in the summer and fall of 1952 had a crop of large oysters ready for market. It was hoped that evidence of migration could be detected without the use of marked drills and that the data would be amenable to the statistical analysis applied to latin squares. However, the arrangement of traps in a latin square was specially planned to detect the movements of marked drills released in various concentrations and at locations within and outside the trapped plot. Unfortunately, the release of marked drills was deliberately withheld in the belief that their presence might complicate the analysis of the movements of the natural population. The use of marked drills, once deferred, was an objective never accomplished. Depletion of the drill population was an objective secondary to a study of drill movements but setting and survival of spat were observed on both plots as an indication of the practicality of trapping.

Approximately 9,000 drills, or an average of 152 drills per trap, were removed from the three-acre experimental plot in 1952. The catch per unit of effort (Fig. 2) indicates that Eupleura were much more available during

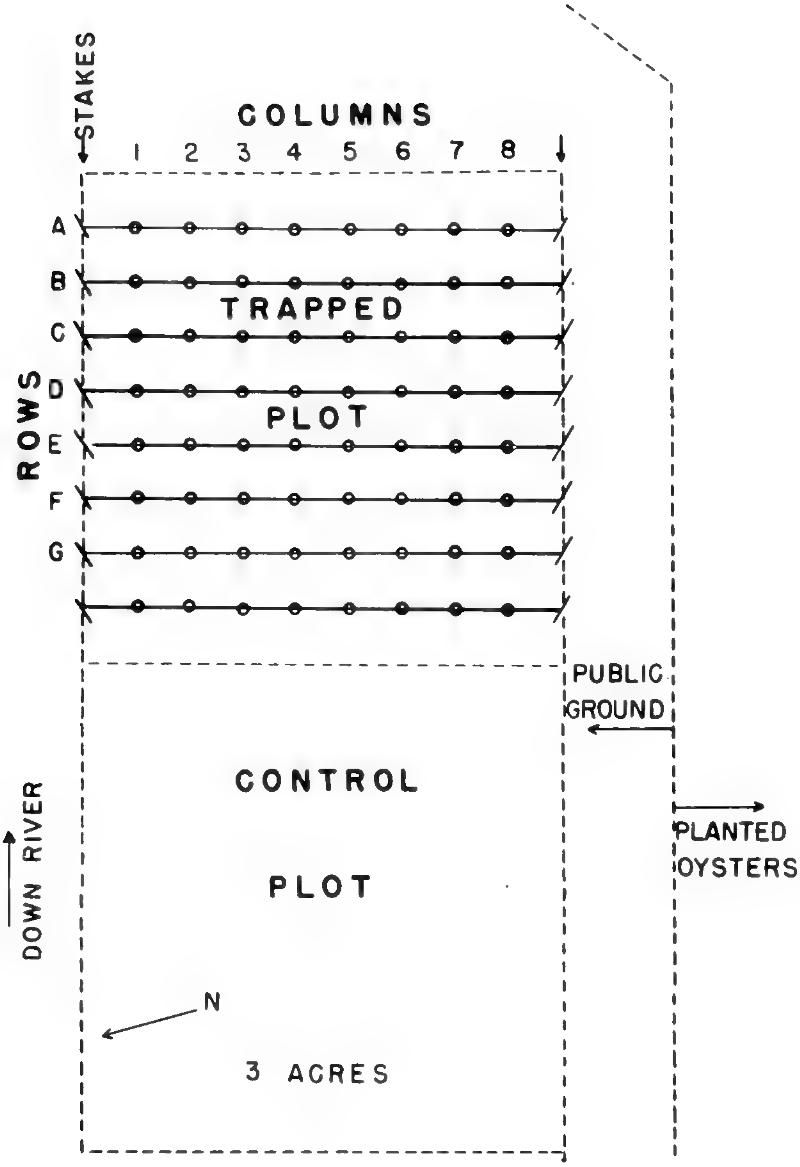

Fig. 1. A sketch of the drill-trapping experiment on Wormley's Rock, York River, Virginia, 1952. Eight traps were attached to each of eight lines (A to H) running at right angles to the current. Traps were approximately 50 feet apart.

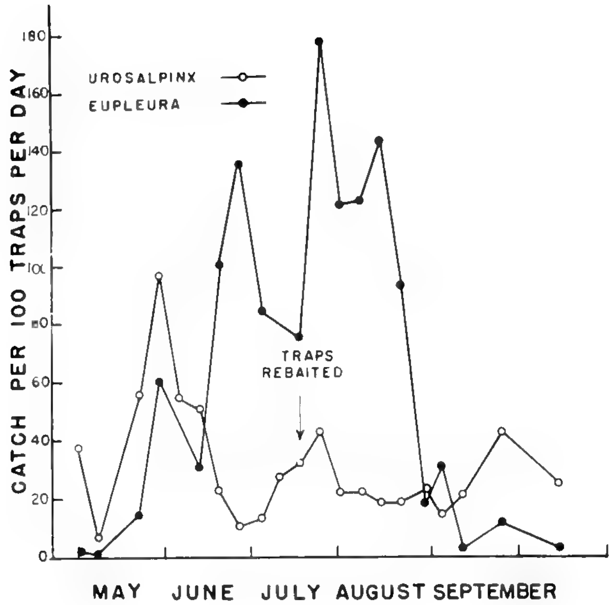

Fig. 2. The availability of drills on Wormley's Rock, York River, baited with seed oysters.

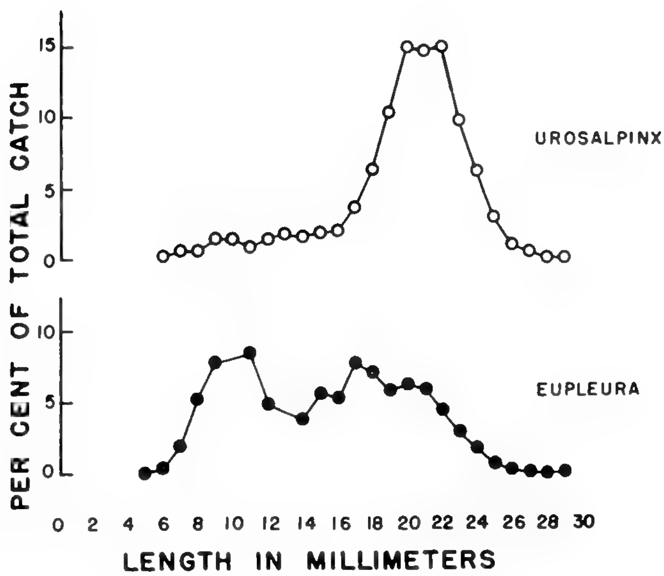

Fig. 3. The length-frequency distribution of all drills caught by traps at Wormley's Rock, York River, Virginia, May to October 1952.

the warmest months of the summer but that Urosalpinx were caught more frequently earlier and later in the season. The greatest catches of Urosalpinx occurred at the end of May when water temperatures exceeded 20°C. (Hewatt and Andrews, 1954), and preceded the peak period of egg-laying by almost a month. It is possible that drill activities were inhibited in early May by salinities which dropped to 11 parts per thousand at Gloucester Point, (Hewatt and Andrews, 1954). The catch of Urosalpinx did not seem to be greatly affected by rebaiting but the greatest catches of Eupleura came in mid-summer immediately after new bait had been put out. There was no clear evidence of depletion of either species of drill.

The catch of Urosalpinx consisted almost entirely of large drills over 15 mm. in height. Smaller drills, presumed to belong to the 1951 year-class, were very few in number. The length-frequency curve for all Urosalpinx shows a single mode at 20 to 22 mm. (Fig. 3). The early catches of Eupleura also consisted mostly of large drills but a distinct group of small drills entered the catch in mid-June. These small drills appeared suddenly in the catch of June 19 (Fig. 4) on row A with a total of 301 Eupleura as compared to 44 on row B which had the next highest catch. By June 26 the catch had increased in all traps but especially in rows B and C and column 1. Thus the catches increased in all the traps on the margins of the plot except those next to the control plot, and the catches were very high in the corner A8 nearest the private oyster grounds. The bimodal frequency distribution of Eupleura lengths persisted throughout the summer although the pattern of greater catches on the outside traps became less distinct. It is believed that these small Eupleura under 15 mm. were yearling drills of the 1951 year-class.

Drills of the current year-class did not appear until July 31 when a few Urosalpinx one and two millimeters in length were found but not included in the counts. It is probable that some current year-class drills were included in the later catches of September and October but small Urosalpinx were always scarce. Eupleura of the current year-class were either absent or not recognized as such. On Wormley's Rock there was little evidence that drills hatched in 1952 increased the catch in late summer.

The distribution of the total catch by traps from April to October is depicted by contour maps in Figure 5. For Urosalpinx a more or less linear decrease diagonally from the southeast corner (A8) to the northwest corner (H1) can be seen, and this is apparently related to the distance from the planted oyster beds. If it is assumed that the lowest catches, those found in the northwest corner, approximate a measure of the resident population, then this depleted ground sustained a meagre group of drills and migration appears to have been of considerable importance. The catch of Eupleura was greatest in the southeast corner but also high along all margins of the plot except that bordering the control plot. Again migration, although not measured, appears to have been of considerable importance.

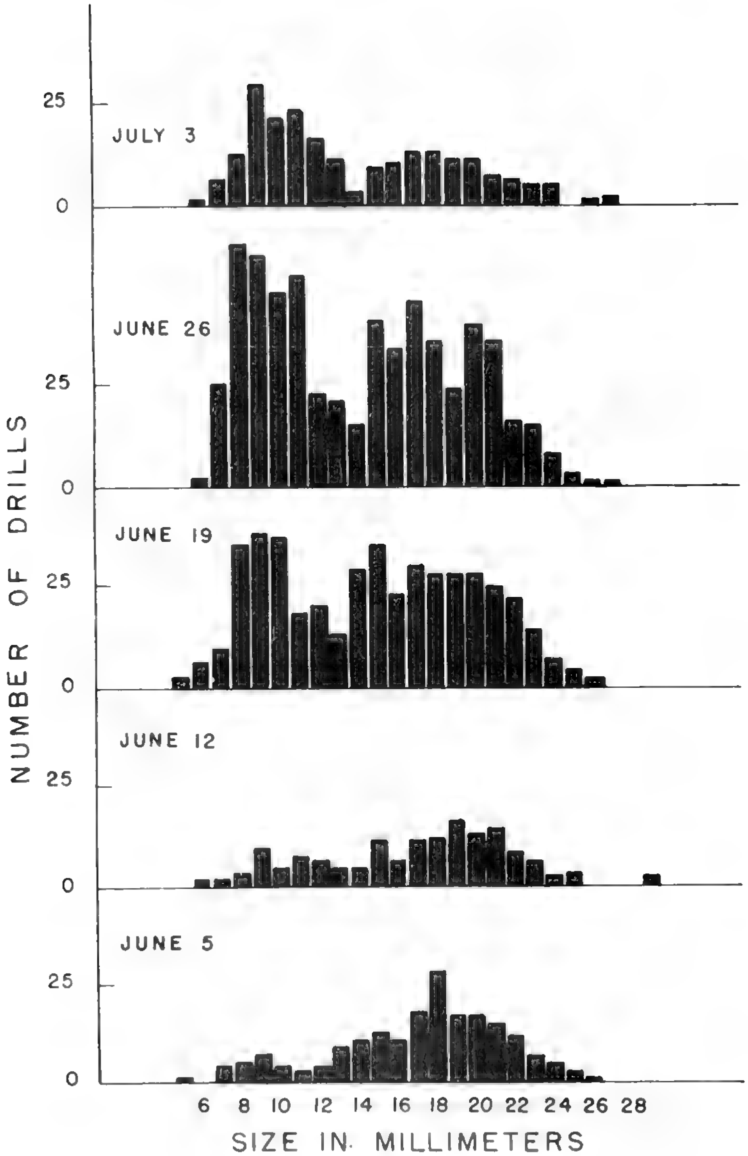

Fig. 4. The length-frequency distribution of Eupleura in successive weekly catches at the time of the sudden appearance of small drills.

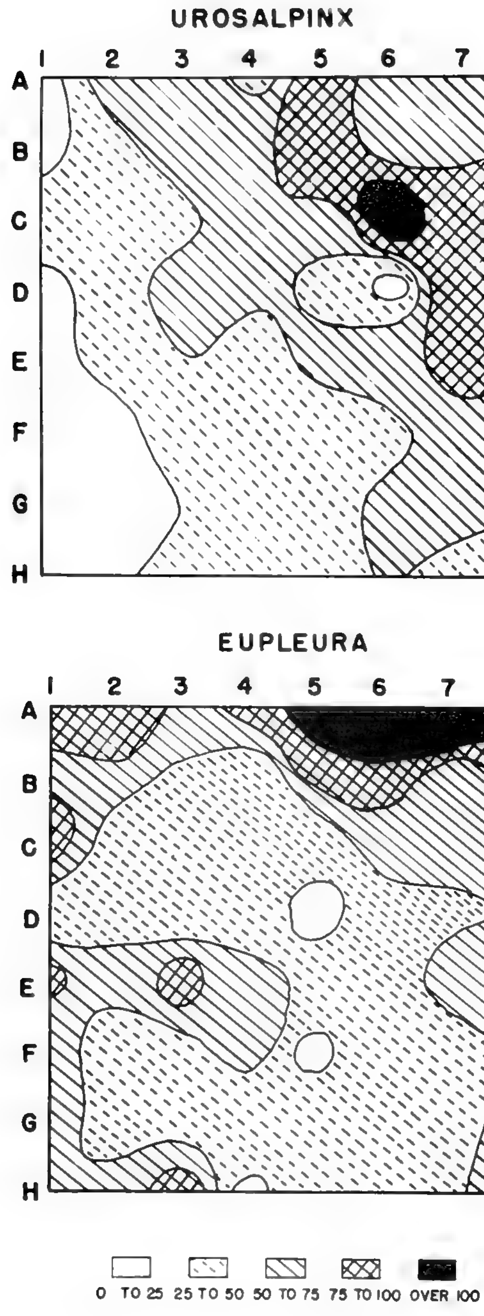

Fig. 5. The distribution of total catch of drills per trap from May to October 1952. The number of drills is indicated by the symbols.

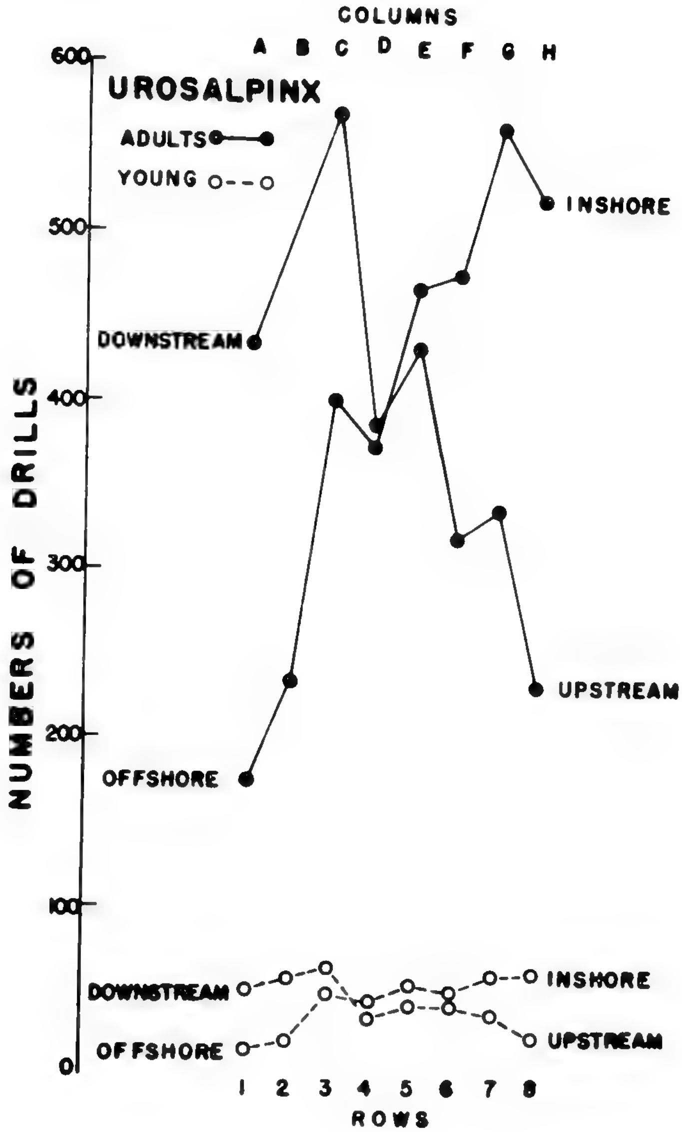

Fig. 6. The distribution by columns and rows of the seasonal catch of adult and young Urosalpinx in respect to position upstream, downstream, inshore, and offshore.

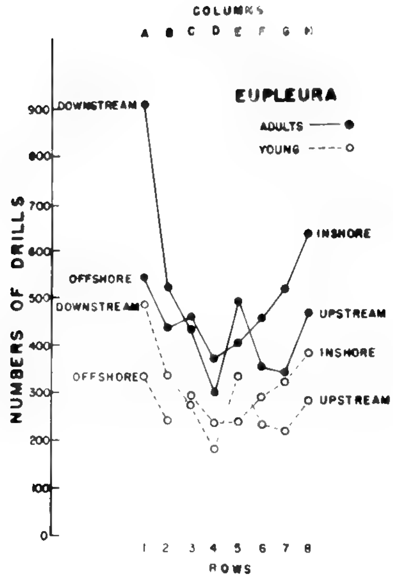

Fig. 7. The distribution by columns and rows of the seasonal catch of adult and young Eupleura in respect to position upstream, downstream, inshore, and offshore.

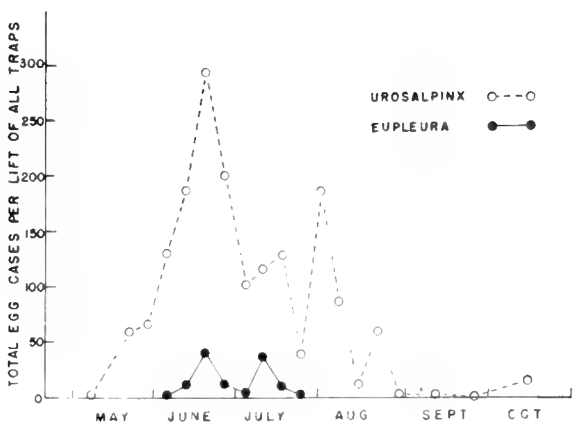

Fig. 8. The seasonal spawning patterns of drills as indicated by counts of egg cases.

Table 1.

The ratio of _Urosalpinx_ and _Eupleura_ caught in traps in Virginia. Traps were fished weekly or monthly and rebaited occasionally.

Date	Location	Number of _Urosalpinx_	Number of _Eupleura_	Percent of _Eupleura_
	York River			
June to Aug. 1943	Wormley's Rock	603	250	29.3
June & July 1948	Wormley's Rock	198	61	23.5
April to Oct. 1952	Wormley's Rock	3342	5813	63.5
	Gloucester Point			
July 1953 to Nov. 1955	Laboratory pier	7343	332	4.3
July 1953 to Nov. 1954	Burke's pier	1651	49	2.9
July to Nov. 1953	Ferry pier	77	8	9.4
July 1954 to Oct. 1955	Off end of Laboratory pier	456	15	3.2
June to Sept. 1942	Hampton Roads			
	Darling's ground			
	Plot 11	1035	126	10.9
	Plot 18	1318	31	2.3
	Plot 20	144	97	40.2
	Ballard's ground			
	Plot A	6851	3956	36.6
	Plot A1	683	286	29.5

A diagram of the distribution of total catch by rows and columns is given in Figure 6 and 7. Small drills under 16 mm. in height, assumed to be young of the year, are given separately. Large and small Eupleura occurred in approximately equal numbers but large Urosalpinx greatly exceeded the small ones in abundance. The catch of large Urosalpinx was much higher downstream and inshore but there was no apparent difference in the small ones. Although the catch of Eupleura was highest downstream and inshore, there was a tendency in both size groups for all borders to have higher catches than the middle of the plot.

According to the literature, Eupleura is comparatively rare, and its predominance in the catches from Wormley's Rock was unexpected. During 1952, Eupleura comprised 63 percent of the catch and the highest percentage for one week's catch was over 93 percent. In Table 1 the sporadic occurrence of Eupleura is suggested; it has been comparatively abundant on Wormley's Rock for many years but is scarce on the sandy shores at Gloucester Point. In Hampton Roads (Newcombe and others, unpublished data) the catch of Eupleura varied with the plots fished, age of the bait and the season. For example, in 1942 on Plot A of Ballard's Ground on Hampton Bar, 46 traps fished on August 10 yielded 15 Eupleura or 2 percent of the drills caught. Rebaited on August 12 and set in a new location on the same plot, 62 traps caught 2,295 Eupleura a week later or 56 percent of the total catch. At the same time traps on another plot (Darling's No. 18) were rebaited but not moved to new locations and these caught no more than 4 percent Eupleura either before or after rebaiting. McHugh (1956) has suggested that Eupleura responds much more quickly to new bait than Urosalpinx. This has been noted also in trays of newly-transplanted seed oysters placed on the bottom at Gloucester Point.

Egg deposition by Urosalpinx began in mid-May and reached a peak in mid-June; some eggs were laid throughout the summer (Fig. 8). Eupleura in contrast, deposited very few egg cases on the baited traps and these were laid in a relatively short period in June and July. All egg cases were removed manually from the baited traps each week.

Discussion

The catch on Wormley's Rock in 1952 of 152 drills per trap, both species included, is much lower than those reported from other areas (Carriker, 1955). Stauber (1943) considered that a catch of 100 drills per trap per season justified trapping from the standpoint of cost but he caught as high as 760 per trap at the beginning of seven years of continuous trapping and 50 per trap at the end of the experiment. Based upon large numbers of drills trapped from a 20 acre plot, he reported densities of nearly five drills per square meter at the beginning and about 0.12 at the end of the experiment. He considered the lower density to be about the minimum level of drill abundance which could be produced by trapping. In the first year of trapping on Wormley's Rock the density of Urosalpinx, per square meter, based upon the total catch from the three-acre plot for the year, was only

0.28 and this includes drills which migrated into the small plot. If both species are included the density still remains below 1.0 drill per square meter. Although these counts are minimal estimates since not all drills are caught, it appears that prior to the manipulations of the experiment, Wormley's Rock may have sustained a very small population of drills, perhaps not subject to much further depletion. While the object of the Wormley's Rock experiment was not primarily to deplete the drill population, it should be noted that Stauber apparently reduced abundance by the use of 25 traps per acre in the early years and 10 traps per acre in the later years. About 21 traps per acre were used on Wormley's Rock, and, as in Stauber's experiments, there was no evidence of depletion of drills the first year.

Stauber (1943) found that in Delaware Bay the peak catches of Urosalpinx occurred in late April or May when temperatures were between 10 and 15°C., and that after temperatures exceeded 15°C. egg deposition began. In Virginia in 1952 the pre-egg-laying activity described by Stauber occurred in late May at temperatures exceeding 15°C., and egg deposition began in the last half of May when temperatures were above 20°C. Thus in Virginia drill movements and reproductive activities occurred later in the season and at temperatures approximately 5°C. higher than those observed in Delaware Bay. These observations, for one year only, confirm those of Federighi for Hampton Roads (1931), and agree with Stauber's tenets that according to the latitude of the region physiological "species" of drills exist with different critical temperatures for spawning and other activities.

On Wormley's Rock the season of activity for Eupleura was shorter and may have been limited in the spring by temperatures. In September, however, when water temperatures were about 25°C., the low catch of Eupleura may have been related to the sets of barnacles and oysters which occurred. Late deposition of eggs and maximum catches in the warmest part of the summer have led to the impression that Eupleura prefers a warmer climate than Urosalpinx.

The relative importance of resident and migratory drill populations was not resolved in this study for the evidence of migration is circumstantial and quantitative data are lacking. Although one may doubt that drills would leave an established population of oysters on the private grounds to migrate to 64 traps on a barren ground, the planting of 10,000 bushels of clean shell on the public ground with all the fouling organisms attracted thereby, could easily have provided the stimulus for migration. Without marked drills to confirm migration, however, this planted shell added confusion to the experiment in so far as the study of the resident population of drills is concerned. The evidence for immigration of drills on the trapped plot is derived mostly from the distribution of catches. For Eupleura, which was caught most heavily on the marginal traps, it might be argued that these traps fished a larger area than those in the center of the plot. The observations that Eupleura appeared suddenly in the marginal traps and that later catches became more uniform over the plot suggest that area fished was not the sole factor involved.

Shells from the two plots never had any appreciable set of oyster spat although shells suspended off the bottom in wire bags did have a fair set in early September. Unfortunately, setting observations were not pursued diligently enough to determine the cause of lack of survival of set. Survival of spat on the two plots was to have been a measure of the practicality of drill trapping. A sample of shell dredged from the experimental plot in the spring of 1953 contained no spat.

After rebaiting traps Stauber (1943) also reports a big increase in the catch of drills during the summer when temperatures were rather steady. He does not refer to the preference of Eupleura for new bait which has been so striking in Virginia waters at times. Detailed studies of the food preferences of Eupleura have not yet been made, but with the knowledge that Eupleura is the most abundant drill on some grounds, it can no longer be treated as another casual predator similar in habits to Urosalpinx. Lack of data on distribution makes it impossible to estimate the importance of Eupleura in Virginia waters. The appearance of approximately 37 Eupleura per trap on Hampton Bar one week following rebaiting indicates that the population of this predator is not negligible on this large oyster-producing area. The rather scattered data suggest that Eupleura may be on the increase in Chesapeake Bay; on the other hand, as Carriker suggested, this may be a cyclic response to factors such as temperatures and salinities. It has been observed that Eupleura tolerates more mud on the bottom than Urosalpinx and Wormley's Rock does tend to be a little muddy despite its basically shelly bottom. The bottom in front of the Virginia Fisheries Laboratory at Gloucester Point, which has few Eupleura, is almost pure sand that shifts during storms.

In addition to preferences as to type of bottom and food, Eupleura may exhibit differences in habits such as less tendency to climb. We have never found Eupleura on the pilings of local piers where Urosalpinx is abundant, yet they will climb up on oysters in traps. The near absence of Eupleura egg cases on the traps in the presence of so many adults is puzzling and suggests that they do not seek out elevated objects for egg deposition with the same avidity as Urosalpinx. The occurrence of small numbers of young Urosalpinx in an area where egg cases are fairly abundant, and the great abundance of young Eupleura in the presence of few egg cases, although the two relate to different year-classes, are situations which seem perverse and indicate that certain important factors remain concealed in the trapping studies. Even if nearly all the small Eupleura caught on Wormley's Rock migrated from adjoining grounds, it is still inexplicable why small Urosalpinx did not migrate also.

Summary

The usefulness of trapping cannot be properly evaluated because adequate procedures to estimate populations have not been developed. At present the effects of trapping are inferred by observing seasonal or annual trends in the catch.

The relative importance of migratory and resident populations of drills in the predation of oysters, particularly on small plots, is unresolved. One year of trapping on a three-acre plot on abandoned public grounds suggested that considerable migration occurred. *Eupleura* was much more abundant than *Urosalpinx* in the catches. The greatest catches of *Urosalpinx* were in late May immediately before egg deposition, and *Eupleura* were most available during the warm months of June, July, and August.

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TRAPPING OYSTER DRILLS IN VIRGINIA
II. THE TIME FACTOR IN RELATION TO THE CATCH PER TRAP*1

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In using traps to remove drills from oyster ground, assuming that trapping is an effective method of reducing the activities of these pests, it is important to keep costs at a minimum. One way of reducing the cost of trapping is to increase the time interval between lifts, but if the efficiency of traps varies with time, the nature of this relationship should be considered in choosing the optimum fishing interval.

The influence of time on the catch must also be known to determine the significance of the catch per trap in drill trapping experiments. Dr. Andrews, in the first paper of this series, used the catch per 100 traps per day as an index of availability. Are these indices comparable when the period between lifts of the traps varies, as it sometimes did on account of bad weather or for other reasons?

To test these points, 20 traps baited with seed oysters were set from the pier of the Virginia Fisheries Laboratory (Fig. 1). The traps were arranged in two series of 10 each, on opposite sides of the pier, each trap lying on the bottom about half-way between adjacent pairs of pilings, 11 feet apart. The water depth at mean low water ranged from 51 inches at the offshore end of the series to 14 inches at the inshore end. The mean tidal range at Gloucester Point is about 33 inches, therefore, the average depth over the traps varied from 67 to 30 inches.

Other traps were set at approximately the same distance apart, and in water of about the same depth, at two nearby piers located about 500 feet on each side of the laboratory pier (Fig. 1). These traps, five at each pier, were fished at irregular intervals.

The bait was not changed or augmented during these experiments. The traps were lifted individually, shaken vigorously over a screen of 16 meshes to the inch, and returned to the water. The accumulated debris was washed thoroughly by pouring salt water over the screen, and the drills were sorted out. The catches of the individual traps were segregated for later identification, counting, and measuring.

Two sets of experiments were conducted. In the first, the catches in daily lifts of the traps were compared against weekly lifts. In the second series, weekly and bi-weekly catches were compared. The frequency of fishing was alternated between the two series, to eliminate the effects of differential

*1 Contributions from the Virginia Fisheries Laboratory, No. 64.

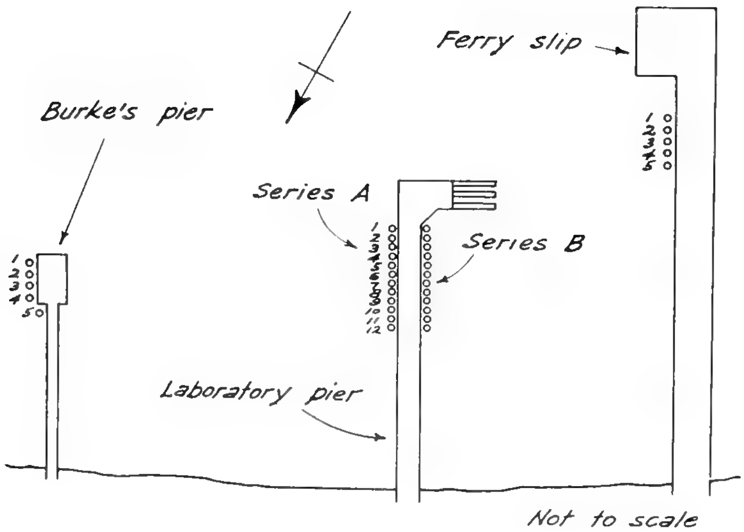

Fig. 1. Diagrammatic chart of the arrangement of experimental drill traps alongside the pier of the Virginia Fisheries Laboratory and adjacent piers. The traps are indicated by circles and serial numbers.

availability of drills on the two sides of the pier. Each series was lifted alternately daily and weekly for a total of six weeks. The same procedure was followed with the weekly and bi-weekly lifts, alternating the treatment between series each two-week period for a total of 12 weeks.

Urosalpinx cinerea was by far the most common species in the traps, although *Eupleura caudata* was taken rather regularly in small numbers. The total catch of *Urosalpinx* in all the experiments was 8,409, the total catch of *Eupleura* only 369. It is interesting to note that among hundreds of drills picked by hand off the pilings of various piers at Gloucester Point, not one *Eupleura* was found, yet the species was present in the area, as demonstrated by its capture in traps and in collections made by hand among the eel-grass beds in shallow water, and by the occurence of its characteristic egg cases on shells in shallow water. This is in sharp contrast to the species composition of the catch in traps on Wormley's Rock, about two miles below the Laboratory, where *Eupleura* appeared to be about twice as abundant as *Urosalpinx*.

EXPERIMENTAL RESULTS

The Catch in Series A and B

The 10 traps in series A rather consistently caught fewer drills than the 10 in series B. No serious attempt was made to discover the reason for this difference, although several possible explanations would merit investigation. Series A, on the east side of the pier, was shaded from the direct rays of the sun during the warmest part of the day; it was less protected from wave action than series B, which was sheltered behind the L-shaped extension at the outer end of the pier; on the average the traps in series A were in slightly deeper water. Since the experiments were divided equally between the two series, the effect of the position of the trap on the catch could be segregated, and it was possible to allow for the series effect in the statistical analysis.

In addition to the controlled experiments described above, the traps were fished at various time intervals to gather information for other purposes. In these experiments also, series B caught more drills than series A. The total numbers caught in each experiment at the Laboratory pier are listed in Table I.

Experiments with *Urosalpinx*

Comparison of daily and weekly fishing

Ten traps fished daily for six weeks caught 408 Urosalpinx, or 9.8 drills per 10 traps per day. Ten traps fished weekly for the same period caught 361 *Urosalpinx*, or 8.6 drills per 10 traps per day. The weekly catches are summarized in Table II. The expected catches were computed by dividing the total in each week's experiment according to the ratio established by the total catch

Table I

Comparison of the catch of drills in traps in series A and B during equal time intervals at the Virginia Fisheries Laboratory Pier

Urosalpinx Series A	*Urosalpinx* Series B	*Eupleura* Series A	*Eupleura* Series B	Source of information
333	436	56	41	Controlled experiment: daily vs. weekly lifts
760	780	17	30	Controlled experiment: weekly vs. bi-weekly lifts
1988	2357	64	104	Miscellaneous experiments
3081	3573	137	175	Totals

Table II

The catch of *Urosalpinx* per week in traps lifted daily and weekly, at the Virginia Fisheries Laboratory pier. Catches in series A and B are indicated by letters. The expected catches were computed by dividing the total catch in each week's experiment according to the ratio established by the total catch in the two series for the six experiments (333 A to 436 B).

	Daily		Weekly		
Date	Observed	Expected	Observed	Expected	X^2
15 July 1953	71 A	70	90 B	91	0.02
22 July 1953	41 B	39	28 A	30	0.23
29 July 1953	22 A	22	29 B	29	0.00
24 June 1954	124 B	117	83 A	90	0.96
1 July 1954	76 A	67	78 B	87	2.14
8 July 1954	74 B	72	53 A	55	0.13
Totals	408	387	361	382	3.48

Table III

The catch of *Urosalpinx* per two-week period in traps lifted weekly and bi-weekly at the Virginia Fisheries Laboratory pier. Catches in series A and B are indicated by letters. The expected catches were computed as for table 2, in the ratio 760 A to 780 B.

Date	Weekly Observed	Weekly Expected	Bi-weekly Observed	Bi-weekly Expected	X^2
28 April 1954	189 A	168	151 B	172	5.18
12 May 1954	267 B	211	149 A	205	30.16
26 May 1954	176 A	152	133 B	157	7.56
9 June 1954	101 B	100	97 A	98	0.02
29 July 1954	57 A	52	49 B	54	0.94
12 August 1954	79 B	87	92 A	84	1.50
Totals	869	770	671	770	45.36

in the series of six experiments. None of the individual chi-square values was significant at even the five percent level of probability, nor were the summed or the pooled chi-square values highly significant statistically. It follows that, although somewhat fewer *Urosalpinx* were caught in the weekly lifts, this does not prove that drills are caught more efficiently by lifting the traps daily.

Comparison of weekly and bi-weekly fishing

Ten traps fished weekly for 12 weeks caught 869 *Urosalpinx*, or 10.3 drills per 10 traps per day. Ten traps fished every 14 days for the same period caught 671 *Urosalpinx*, or 8.0 drills per 10 traps per day. The biweekly catches are summarized in Table III. Two of the six individual chi-square values were significant at much better than the one percent level of probability, one at about the two percent level, and the remainder were not highly significant statistically. The summed chi-square values and the pooled chi-square values, however, were both highly significant statistically ($X^2 = 45.36$, P much less than 0.01; and $X^2 = 25.46$, P much less than 0.01, respectively). The odds are much less than one in one hundred that the observed difference in catch between weekly and bi-weekly lifts was due to chance.

The catch per unit time in miscellaneous experiments

The catch of many other trapping experiments, in which traps remained on the bottom for periodsof four to 15 days, were examined for information on the catch per unit time. There was no conscious effort in these experiments to vary the time between lifts according to the numbers of drills in the catch, except in winter, when the time intervals were increased because the catching rate was low. To avoid bias from this cause, catches made during November to March inclusive were not included in the analysis.

There appears to be a general tendency in all these data for the catch per unit of effort to vary inversely with the time interval between lifts of the traps. For example, when all catches from the laboratory pier, exclusive of the controlled experiments, were grouped according to fishing interval, they varied from 9.9 *Urosalpinx* per 10 traps per day when the mean time between lifts was 5.2 days, to 4.6 *Urosalpinx* per 10 traps per day when the mean time was 13.8 days. Similarly, the collections made from Burke's pier ranged from 13 drills per 10 traps per day when the mean time was 6.9 days, to 8 drills per 10 traps per day when the time was 13.8 days (Table IV). The catches in traps set from the ferry slip were too small to produce significant results.

Figure 2 illustrates, for all the experiments reported above, the relationship between fishing period and the catch per unit time. The lack of coincidence between the various curves is related principally to differences in the availability of *Urosalpinx* at the times or places in which the experiments were carried out. If these curves were adjusted for availability, they would correspond remarkably well.

Table IV

The relation between the duration of fishing and the catch of *Urosalpinx* per unit of effort in traps fished from piers at Gloucester Point, Virginia

Mean time interval between lifts in days	Number of Observations	Mean catch per 10 traps per day	Location
1	6	9.8	Laboratory pier Controlled experiments
7	6	8.6	
7	6	10.3	
14	6	8.0	
5.2	5	9.9	Laboratory pier Miscellaneous Collections
7.2	47	8.6	
11.5	4	6.0	
13.8	12	4.6	
6.9	23	13.0	Burke's pier Miscellaneous Collections
13.8	11	8.0	

Table V

The catch of <u>Eupleura</u> per week in traps lifted daily and weekly at the Virginia Fisheries Laboratory pier. The catches in series A and B are indicated by letters. The expected catches were computed as for table 2, in the ratio 56 A to 41 B.

Date	Daily		Weekly		X^2
	Observed	Expected	Observed	Expected	
15 July 1953	29 A	22	9 B	16	5.29
22 July 1953	7 B	3.5	1 A	4.5	6.22
29 July 1953	5 A	4.5	3 B	3.5	0.13
24 June 1953	12 B	6.5	3 A	8.5	8.21
1 July 1954	8 A	7	4 B	5	0.34
8 July 1954	6 B	7	10 A	9	0.25
Totals	67	50.5	30	46.5	20.44

TABLE VI

The catch of *Eupleura* per two-week period in traps lifted weekly and bi-weekly at the Virginia Fisheries Laboratory pier. The catches in series A and B are indicated by letters. The expected catches were computed as for table 2, in the ratio 17 A to 30 B.

Date	Weekly		Bi-weekly		
	Observed	Expected	Observed	Expected	X^2
28 April 1954	5 B	3.8	1 A	2.2	1.03
12 May 1954	2 A	2.5	5 B	4.5	0.16
26 May 1954	4 B	4.5	3 A	2.5	0.16
9 June 1954	6 A	2.9	2 B	5.1	5.19
29 July 1954	2 A	1.8	3 B	3.2	0.03
12 August 1954	11 B	8.9	3 A	5.1	1.37
Totals	30	24.4	17	22.6	7.94

Table VII

The relation between the duration of fishing and the catch of *Eupleura* per unit of effort in traps fished from piers at Gloucester Point, Virginia

Mean time interval between lifts in days	Number of observations	Mean catch per 10 traps per day	Location
1	6	1.60	Laboratory pier Controlled experiments
7	6	0.71	
7	6	0.71	
14	6	0.40	
5.3	6	0.44	Laboratory pier Miscellaneous Collections
7.3	47	0.38	
11.5	4	0.17	
13.9	15	0.08	
6.9	23	0.46	Burke's pier Miscellaneous Collections
13.8	11	0.16	

Experiments with *Eupleura*

Comparison of daily and weekly fishing

Ten traps fished daily for six weeks caught 67 *Eupleura*, or 1.6 drills per 10 traps per day. Ten traps fished weekly for the same period caught 30 *Eupleura*, or 0.7 drills per 10 traps per day. The weekly catches are summarized and compared with the expected catches, computed as for *Urosalpinx*, in Table V. The summed chi-square value was highly significant statistically ($X^2 = 20.44$, P less than 0.01), and the pooled chi-square also was highly significant ($X^2 = 14.12$, P much less than 0.01). Fewer *Eupleura* were caught in the weekly lifts, and the odds are less than one in 100 that this difference could have occurred by chance.

Comparison of weekly and bi-weekly fishing

Ten traps fished weekly for 12 weeks caught 30 *Eupleura*, or 0.35 drills per ten traps per day. Ten traps fished every 14 days for the same period caught 17 *Eupleura*, or 0.2 drills per 10 traps per day. The catches are summarized in Table VI. The summed chi-square value was not highly significant statistically ($X^2 = 7.94$, P about 0.25), and the pooled chi-square gave similarly inconclusive results ($X^2 = 3.59$, P somewhat greater than 0.05). Although fewer *Eupleura* were caught in the bi-weekly lifts, the difference is not highly significant. This lack of significance may have been related to the small catches.

The catch per unit time in miscellaneous experiments

Catches in the miscellaneous trapping experiments, when analysed in the same way as for *Urosalpinx*, appeared to show a decline in the catch of *Eupleura* per unit of effort as the time between lifts increased. The miscellaneous catches from the laboratory pier varied from 0.44 *Eupleura* per 10 traps per day when the mean fishing period was 5.3 days, to 0.08 drills per 10 traps per day for a mean period of 13.9 days. Similarly the catch per unit of effort in the collections from Burke's pier decreased as the fishing period increased (Table VII).

Figure 3 illustrates the apparent decline in the catch of *Eupleura* per unit time as the time between lifts increased. As for *Urosalpinx*, the lack of coincidence between individual curves appears to be caused by differences in the availability of drills in space and time.

SUMMARY AND CONCLUSIONS

To interpret the results of experiments in trapping oyster drills, it is usually necessary to reduce the catches to some standard form, based on the catch per unit number of traps per unit time. The question immediately arises: does the trap continue to catch efficiently, irrespective of the length of time that it fishes, and if not, what is the relation between catch per unit of effort and time?

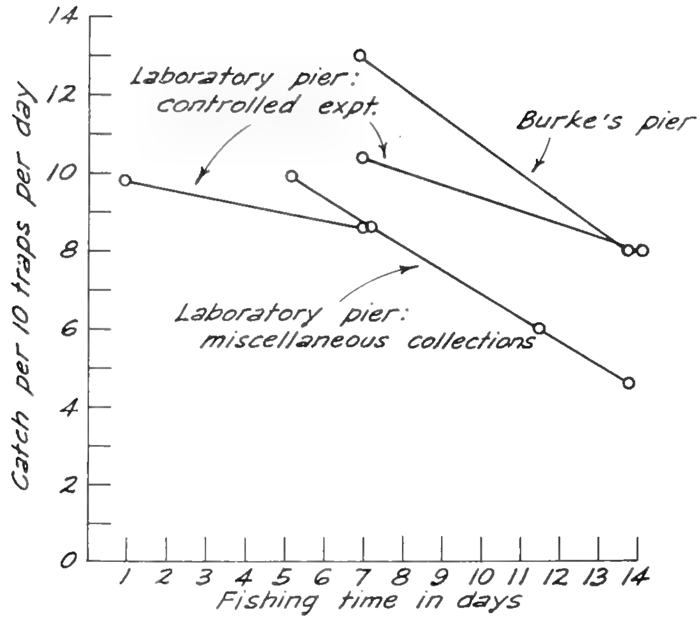

Fig. 2. The catch of <u>Urosalpinx</u> per 10 traps per day in relation to the time interval between lifts of the traps.

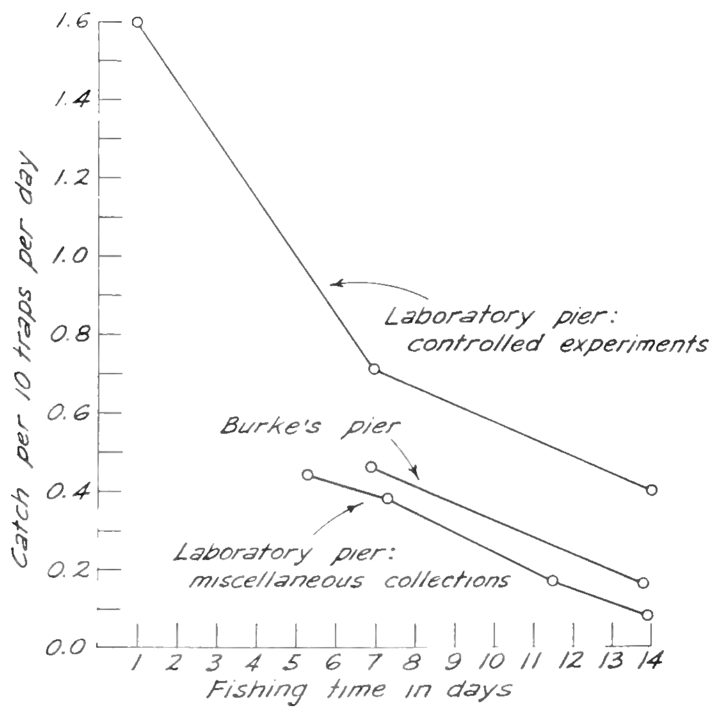

Fig. 3. The catch of <u>Eupleura</u> per 10 traps per day in relation to the time interval between lifts of the traps.

Experiments conducted from the pier of the Virginia Fisheries Laboratory seem to show, for both *Urosalpinx cinerea* and *Eupleura caudata*, that the rate of catching declines with time. For *Urosalpinx* this decline is not significant statistically over the first seven days. There is very little doubt that if trapping were to be found effective in curbing predation by this species, the catch in weekly lifts of the traps would be so little, if at all, less than the total daily catch for a week, that weekly fishing could be justified biologically, and especially economically.

If the traps are fished only every other week, the catch per unit of effort drops appreciably, to about two-thirds of the daily catch for *Urosalpinx* and about one-quarter for *Eupleura*. The greater decline for *Eupleura* and the apparently rather abrupt decrease for this same species between daily lifts and weekly lifts, is probably real, for recent experiments still underway seem to show that *Eupleura* is much more destructive of small oysters than *Urosalpinx*. Thus the relatively greater decline in the catch per unit of effort with time is probably caused by destruction of the smaller, and presumably more attractive, oysters.

Perhaps the most important conclusion arising from these experiments is that drill traps constructed of wire mesh and baited with seed oysters are not "traps" in the strict sense of the word. The reduced efficiency of traps as the period of fishing increases may come about in one of two ways:

(1) Migration of drills takes place both toward and away from the traps; at first the migration is entirely toward the bait simply because there are no drills on the bait to move away from it; gradually a dynamic equilibrium is approached, beyond which no permanent changes in the numbers of drills on each trap takes place; or

(2) Although the movement is always toward the bait, the presence of drills in the trap deters the migration of others, until the bait becomes saturated with drills. Tentative results of experiments now being conducted seem to favor the first view.

As is usual in scientific investigations, this study has raised more questions than it has answered. Experiments now under way were designed to answer some of these questions:

(1) What relationship, if any, is there between the equilibrium catch of drill traps and the density of drills on the bottom being trapped?

(2) Why does the catch of *Urosalpinx* decrease very little, if at all, during the first week or so of fishing, whereas the catch of *Eupleura* drops precipitately in the first seven days?

(3) What effect on the catch is produced by the gradual mortality of the seed oysters used as bait?

(4) Do drills enter the traps because they are attracted to the bait, or simply because the bait offers an additional area on which to crawl and feed?

FEEDING HABITS OF THE SOUTHERN OYSTER DRILL, THAIS HAEMASTOMA

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Introduction

The southern oyster drill, *Thais haemastoma floridana* (Conrad) and *Thais haemastoma haysae* (Clench), considered one of the primary predators of the Gulf oyster, warrants much more investigation. Proper control and management of this predator depend directly upon its behavior under the varied conditions encountered on the Gulf of Mexico.

This paper deals with laboratory experiments on the feeding preference of the drill with reference to oyster meats, amounts of oyster tissue remaining at the time drilled oysters first gape and the drilling site. The results of these experiments are based upon laboratory conditions and particular temperatures, salinities, and other factors encountered during the course of the experiments. The results, therefore, may not be comparable to observations made under natural conditions and the different seasonal variations encountered on the Gulf.

Very little has been or is being done to effectively control the depredations of the southern oyster drill. A large portion of the oyster bottoms of the Gulf are commercially barren of oysters because of this snail. Until an effective preventive measure such as biological control can be found, this snail will continue to be a serious limiting factor in the production of oysters in the Gulf Coast states.

I wish to express my sincere thanks and appreciation to Dr. Philip A. Butler of the U. S. Fish and Wildlife Service Shellfish Laboratory, Pensacola, Florida, for his able help and constructive criticism in conducting these experiments and in writing this paper.

Review of the Literature

Very little published material exists on the southern oyster drill. Butler (1954a) has published material on several phases of its life history, with good descriptions of its habits. His paper is the most complete work on this drill published to date. St. Amant's (1938) unpublished master's thesis is an earlier comprehensive study of *Thais* which particularly emphasizes embryology and morphology. The work published by Clench (1927, 1947) is strictly taxonomic. Ingle's (1953) paper discusses the growth rate of *Thais*, while McConnell (1954) gives a brief resume of the drill problem in Louisiana. Schecter (1942) published a paper on the salinity tolerance of this drill. Burkenroad (1931) studied several phases of its life history but could not confirm certain findings of several earlier investigators.

Methods

These experiments were conducted in a water table supplied with running sea water from a pump in the U. S. Fish and Wildlife Shellfish Laboratory in Pensacola. Drills were placed in separate compartments in the table. White painted asbestos board was placed in the bottom of each compartment to facilitate observations. Two groups of drills were used, small ($\frac{1}{2}$ - $1\frac{1}{2}$ inches) and large ($1\frac{1}{2}$ - $2\frac{1}{2}$ inches). The percentage of tissue destruction in oysters was estimated at the time the valves of oysters first gapes. The experiments were conducted in five series from May 24 through June 28, 1955. Semi-starved snails and oysters with cleaned shells were used to obtain faster results.

Temperatures and salinities were typical for the Pensacola area for the period of time covered by the experiments.

Data from the five series have been combined as no evidence was found to show variations in the feeding habits of the drill due to salinity and temperature changes.

Tissue Preference

The quantity of oyster tissue remaining at the time the valves of oysters first gaped due to penetration by the drill was estimated. This tissue was subject to destruction by such secondary predators as fish, crabs, flatworms, and other drills.

The question of how much tissue remains, if any, at the time the valves of an oyster gape is of primary importance to both the boring drill and to secondary predators. If a drill loses part of its meal to secondary predators it must kill other oysters to make up for the loss, thus increasing the destruction of the oyster population.

Eighty-eight observations were made of newly gaping oysters. On the average one-fourth of the oyster tissue remained within the valves. This consisted approximately of half of the adductor muscle, one-third of the gills, and one-fifth of the remaining soft parts. Only three of the 88 oysters were eaten completely before the valves gaped. Destruction of the adductor muscle varied from no destruction to complete destruction. However, in practically all cases at least half of the muscle was destroyed before the valves gaped.

The actual quantity of tissue destroyed by boring Thais varied from 10 to 100 percent at the time the valves of the oyster opened. One-third of the oysters opened when their tissues were 70 percent destroyed; one-half when 80 percent destroyed; and over 95 percent, when 95 percent of their tissues were destroyed (see Table I). This high percentage of tissue destruction was probably due to the preference shown by the drills for the softer tissues, gills, and adductor muscle, in this order. Had the adductor muscle been destroyed first, there would have been much more tissue available to secondary predators because the valves would have gaped sooner.

Table I

Number and percentage of drilled gaping oysters and degree of tissue destruction

Percentage of tissue destruction	Number of gaping oysters	Percentage of gaping oysters
100	88	100.0
95	85	96.6
90	52	59.1
80	44	50.0
70	29	32.9
60	17	19.3
50	12	13.6
40	12	13.6
30	7	7.9
20	5	5.6
10	3	3.4
0	0	0.0

In general, for every bushel of oysters killed by drills, at least one-fourth of that bushel is available to secondary predators.

Drilling Site

A total of 219 observations disclosed that 85.8 percent of the oysters were drilled through the edge of the shell between the valves (marginal) and 14.2 percent were drilled through the center portion of the valves (central) as does Urosalpinx cinerea.

The preference for drilling (whether marginal or central) was recorded for both large and small snails using mixed sizes of oysters (Table II). The small snails drilled oysters at the margin 79.5 percent and the large drills 89.7 percent of the time. When on small oysters (1-2 inches), small snails drilled at the margin 81.8 percent and large snails 95.6 percent of the time.

Menzel and Hopkins (1954) found that young snails 20-35 mm. in height drilled through the center of the shell of small oysters in the manner of the east coast snail, Urosalpinx cinerea, and snails 35-55 mm. drilled less frequently by this method and more frequently between the edges of the valves. They found that large snails 55 mm. and over nearly always killed oysters by drilling between the valves, usually near the posterior end of the oyster.

The results of these experiments confirm the findings of Menzel and Hopkins to a limited degree. However, in this case, a difference of 13.8 percent in the area drilled by large and small snails does not seem large enough to permit the generalization that small snails drill through the central portion, and large snails through the margin of the oyster.

The area most drilled, in order of frequency, was the posterior dorsal, posterior ventral, anterior ventral, and anterior dorsal surface (Table III). Since most of the drills, both large and small, attacked the posterior surface, it may be hypothesized that drills detected the exhalent current of water from the oyster.

No preference was noted for the shell areas over the adductor muscle attachments. However, in the few cases where drilling occurred through this area the proboscis was extended beyond the muscle into the soft parts which were eaten first.

At no time was the drill observed to drill a hole through the central portion of the valves and then move around to the gaping valves to consume the oyster. The tissue was always consumed through the drilled hole.

In several instances snails in adjacent compartments were observed to take advantage of the oyster killed by their neighbor by extending their proboscides between the valves of the prey for a free meal. This is a good example of secondary predation in which the snail responsible for opening the oyster did not consume the entire meat.

Table II

Number and percentage of oysters drilled at the margin and through the central portion of the valve by large and by small snails.

	Height of Snail (in.)	Drilled through center of valve		Drilled through edge of valve	
		Number	Percent	Number	Percent
SMALL SNAILS	½--1	8	29.6	19	70.4
	1--1½	9	16.1	47	83.9
	Total	17	20.5	66	79.5
LARGE SNAILS	1½--2	12	11.0	97	89.0
	2--2½	2	7.4	25	92.6
	Total	14	10.3	122	89.7
Grand Total		31	14.2	188	85.8

Table III

Area of oyster shell drilled by large and by small drills

Height of snail	Posterior dorsal		Posterior ventral		Anterior ventral		Anterior dorsal	
(in.)	No.	Percent	Number	Percent	Number	Percent	No.	Percent
1½ - 1	18	66.7	8	29.6	1	3.7	0	0
1 - 1½	27	54.0	19	38.0	3	6.0	1	2.0
Total	45	58.4	27	35.1	4	5.2	1	1.3
1½ - 2	56	60.2	31	33.3	4	4.3	2	2.2
2 - 2½	14	60.9	9	39.1	0	0	0	0
Total	70	60.4	40	34.5	4	3.4	2	1.7
Grand Total	115	59.6	67	34.7	8	4.1	3	1.5

When shells are examined for cause of oyster mortality it is likely that much of the damage inflicted by drills will not be noticed. Drilling marks at the edge of the valves are sometimes difficult to observe particularly when soft new growth is present. Thus under the conditions existing on an oyster reef, much of the evidence of drill predation is soon obliterated. Because of this fact it is difficult to determine the amount of damage caused by these drills.

Summary

1. At the time the valves of oysters gaped as a result of drill penetrations an average of one-fourth of the tissue remained consisting of half the adductor muscle, one-third of the gills and one-fifth of the other soft parts.

2. For every bushel of oysters killed by the drill, at least one-fourth of that bushel would be available to secondary predators.

3. Muscle destruction varied from 0 to 100 percent at the time the valves gaped, but in over 90 percent of the cases at least half of the adductor muscle was destroyed.

4. A preference was shown for the other soft parts, gill, and adductor muscle, in that order. This insures that in most cases the valves of oysters will stay closed allowing the snail to eat most of the meat.

5. Under laboratory conditions 85.8 percent of the snails drilled oysters at the margin of the valves and 14.2 percent drilled holes through the central part of the valve as does *Urosalpinx cinerea*.

6. With mixed sizes of oysters, small snails drilled 79.5 percent and large snails 89.7 percent at the margin.

7. Small snails drilled 81.8 percent, and large snails, 95.6 percent of the small oysters (1-2 inches) at the margin.

8. The areas most drilled in order of frequency were the posterior dorsal, posterior ventral, anterior ventral, and anterior dorsal surfaces. This was typical for all size groups of drills.

9. At no time was the drill observed to drill a hole through the central portion of the valve and then move around to the gaping valves to consume the oyster.

10. Drill entrance marks at the edges of the valves were sometimes difficult to observe, particularly when soft new shell growth was present.

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CRABS AS PREDATORS OF OYSTERS IN LOUISIANA

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The Gulf coast is well provided with oyster predators. In Louisiana these include the black drum, the sheepshead, skates, and other fishes; the conch or drilling snail Thais haemastoma and other predaceous snails; the flatworm Stylochus ellipticus which kills many spat; and blue crab, several mud crabs, and the stone crab.

Thais haemastoma, the so-called oyster conch or bigorneau, has received most attention as a menace to oyster culture, but it is not necessarily the most important predator. We have evidence that crabs may be even more destructive both to old oysters and to spat.

Blue crabs, Callinectes sapidus, occur wherever oysters grow in the Atlantic and Gulf states. We think they are probably more abundant in Louisiana than in any other state-- and we are both natives of Virginia. Blue crabs have often been accused of killing oysters. We have watched them working on oyster beds in Louisiana. When the tide rises over an oyster reef, blue crabs follow the advancing edge of the water and go from oyster to oyster testing each one. If an oyster does not yield to the first attack, the crab goes on to the next oyster. Occasionally a crab seems to find a weak oyster, suddenly attacks it in full force, and in a few minutes the oyster is open and the crab is eating its meat. These observations made us doubt that the blue crabs kill many healthy oysters other than spat. Cage experiments also failed to show much higher mortality of adult oysters in cages with blue crabs than in cages without crabs. But spat in cages with blue crabs were killed at a very rapid rate, in one experiment at the rate of 19 spat per crab per day. Therefore, we rate the blue crab as an important predator of spat, but as only a scavenger of adult oysters, eating ones which are either dead or so sick that they would soon die without the help of a crab.

The stone crab, Menippe mercenaria, is abundant from North Carolina to Mexico. It has always been recognized by Louisiana oystermen as an important enemy of oysters. We think it is even more important than it has been rated, for we have found it to be the culprit in several cases of oyster mortality which the local oystermen blamed on drums. Our first experiment with the destructive powers of Menippe was in 1947, when we made a small experimental planting of painted oysters on an old subtidal reef. We had wondered why the reef contained only broken shells and no live oysters. We soon found out, for between July and January practically all of the planted oysters were reduced to the same state. The stone crabs not only killed the oysters; they even broke the shells into bits.

Further knowledge of stone crabs was obtained from tray experiments. In Louisiana it is not possible to conduct experiments on mortality or growth of oysters in open trays as in Maryland or Virginia. The trays must be lined and covered with hardware cloth to keep predators out, or the experiment may come to a sudden end in a few days. However, even hardware cloth does not always keep out stone crabs. Their strong claws make efficient pliers and wire cutters, and when the wire gets a little old and corroded, they can cut holes and force their way in.

Figure 1 shows a stone crab. Note the size and the powerful claws capable of crushing a full grown oyster. Each square is 10 by 10 millimeters.

Figure 2 shows some small crabs which entered an oyster tray through a hole in the hardware cloth and some of the oysters which they killed. The "gnawed" holes in the shells are typical of stone crab work.

Figure 3 shows a screen which was designed for getting data on the quantity of oysters killed by stone crabs on a planted bed. Oysters, shells, and mud tonged from the bed were placed on this screen (Fig. 4), washed, and sorted. Bits of newly broken shells were thus more readily identified and evaluated.

Figure 5 shows a sample obtained from a planted bed using this screen. The oysters are in the bucket and the bag. The shells in the small pile beside them represent oysters recently killed by stone crabs. The shell fragments made up nearly 28 percent by volume of this sample. The average of all samples was 14 percent shell fragments. By another method it was estimated on another occasion that a minimum of three to 12 percent of all planted oysters in this locality were killed by Menippe. The true figure was probably much higher for the estimate did not include fragmented shells. We never did devise a sampling method which would give accurate figures on the mortality caused by Menippe on planted beds.

Figure 6 shows a floating rack of live boxes or cages used in experiments on predation. Each such rack held five live boxes. Usually two racks were used side by side and identical numbers of oysters of equal size were put in each of a pair of live boxes; a predator was put in one of each pair, and the other served as a control. In this way experiments were conducted with crabs of various sizes at all seasons of the year, and the crabs were tested against oysters of various sizes. In summary we found that large stone crabs could kill the largest oysters we could find, and that even small (two inch) stone crabs could kill market-size oysters. Some

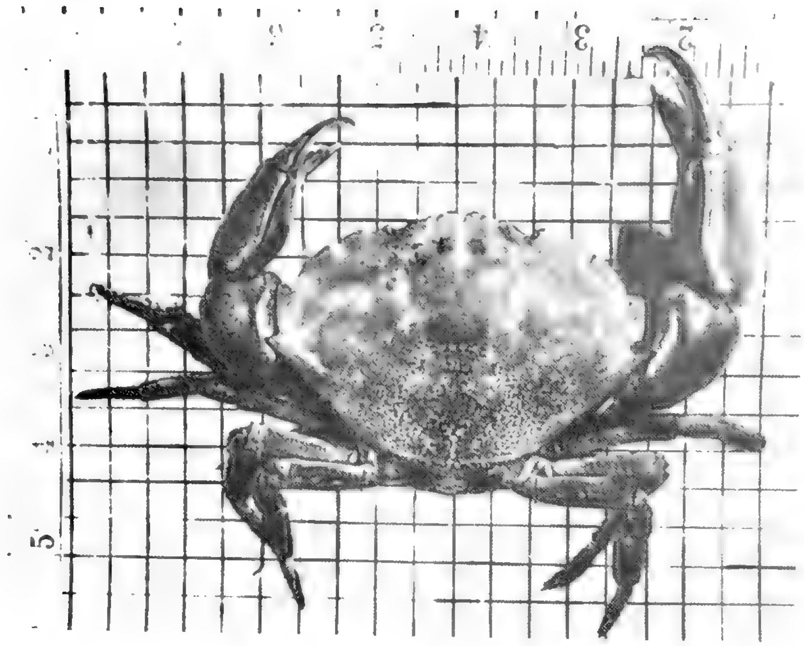

Fig. 1. The stone crab Menippe mercenaria. Each square in the background is equivalent to 10 x 10 millimeters.

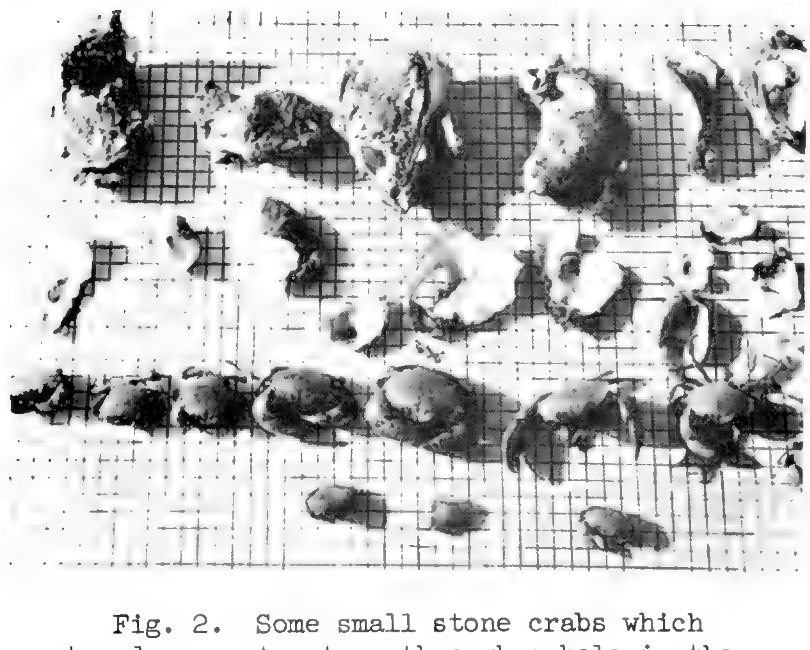

Fig. 2. Some small stone crabs which entered an oyster tray through a hole in the hardware cloth, and some of the oysters which they killed. The "gnawed" holes in the shells are typical of stone crab work.

Fig. 3. A screen designed for collecting data on the quantity of oysters killed by stone crabs on a planted oyster bed. Oysters, shells, and mud tonged from the bed are placed on this screen, washed, sorted, and counted.

Fig. 4. A closer view of the contents of the screen shown in Fig. 3.

Fig. 5. A sample obtained by means of the screen. Oysters are shown in the bucket and in the bag, and the shells in the pile in front represent oysters recently killed by stone crabs.

Fig. 6. A floating rack of live boxes or cages used in experiments on predation.

oysters were killed by stone crabs in every month of the year, but the rate of killing was much slower in winter and no oysters were killed when the water temperature dropped below 10°C. The rate of killing was highest in autumn months. For the entire year the average rate of killing of oysters of all sizes by stone crabs of all sizes was approximately 0.6 oyster per crab per day, or 219 per crab per year. At this rate each stone crab would kill as many oysters as 15 conchs (conchs were tested in similar experiments in the same type of floating racks.) A few mud crabs were tested also. They compared fairly well with the smaller stone crabs. (Table I give a summary of the crab predation in cage experiments.)

Figure 7 shows sampling of stone crab populations on intertidal mud flats and oyster reefs. Note the dead oysters piled around each stone crab hole.

Figure 8 shows measured plots which were sampled by removing everything from the area in order to count the stone crabs hidden under the oysters.

We estimated roughly that there were about eight stone crabs per 100 square feet of bottom in this particular locality, or 3,480 stone crabs per acre. If each crab ate 219 oysters in a year, as our experiments indicated, such a population of stone crabs could destroy 760,000 oysters per acre, or about 1000 bushels, if enough oysters were available.

We acknowledge with thanks the contribution of our able assistants, Billy G. Welch, Billy Walls, T. Jack Clark, Julius C. Carver, John R. Finegan, Jr., Robert A. Lafleur, and R. J. Willoughby.

Table I

Rate of crab predation in cage experiments each month

	Average number of oysters killed per crab per day						
	Water Temp. °C.		Stone Crab		Mud Crab	Blue Crab	
Month	Min.	Max.	Exp. 3,6	Exp. 2,11	Exp. 7	Exp. 7	Exp. 11
Nov. '47	13	22	(3)0.83[a]	(2)2.83[a]			
Dec. '47	9	20	0.11[a]				
Jan. '48	2	18	0.06[a]				
Feb. '48	5	22	0.11[a]				
Mar. '48	10	22	0.05[a]				
Apr. '48	15	26					
May '48	23	28	(6)0.56[b]				
June '48	24	30	0.31[b]		0.17[b]	0.10[b]	
July '48	25	31	0.25[b]		0.09[b]	0.07[b]	
Aug. '48	26	31	0.40[b]		0.04[b]	2.47[a]	
Sept. '48	22	29	0.24[b]	(11)2.82[a]		6.76[a]	2.75[a]
Oct. '48	11	25		2.19[a]			0.93[a]
Nov. '48	11	24		0.41[b]			
Dec. '48	9	22		0.40[b]			

[a] Including spat.

[b] Not including spat (none in cage).

Fig. 7. An investigator sampling a stone crab population.

Fig. 8. Measured plots from which all shell and other hard objects were removed in a search for stone crabs hidden under oysters and shell.

TECHNICAL PAPERS

ON THE DEMAND FOR AND PROCESSING

OF SHELLFISH

THE DEMAND FOR EASTERN OYSTERS

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As all of you connected with the industry know, the production of market oysters has been relatively stable over the past 10 to 12 year period. With this substantial fixity of supply the demand for the product has assumed more than its normal importance in the demand-supply relationship. If the productinn of oysters had remained absolutely unchanged the demand would have been the sole determinant of prices and consequently the chief regulator of the allocation of economic resources to the industry. Largely because of natural factors the condition of absolute inelasticity of supply has been approximated throughout most of the post-war period and for that reason I think it is important and timely for oyster producers and dealers to take a sharp look at the nature of the demand for their product. Before analyzing the present situation and future prospects it will be useful to review briefly certain historical facts relating to demand. Such a review will help in appraising recent developments and contribute to a realistic outlook.

The long term trend in the production of oysters has been definitely downward. This is true in spite of increasing population and improving standards of living in this country, and is in rather sharp contrast to the trend in the production of red meat (beef, pork, veal, lamb, and mutton). Eastern oyster production declined from about 108 million pounds in 1920 to about 66 million in 1950, while meat output increased from approximately 15 billion pounds to 22 billion over the same period. The decrease in the oyster harvest has occurred at the rate of about 1.5 percent a year on the average during the period since 1920, and the deviations from this average were fairly great only during the worst years of the depression of the 1930's.

There is fairly strong evidence that this long term trend is a reflection of a gradual but steadily lessening demand for oysters prior to World War II. In that period the reduced production had not forced prices up significantly as would have been the case if demand had remained approximately the same. After the entry of this country into World War II a whole new set of economic forces came into play, as will be discussed later.

It is not possible to assign any definite reasons for the slackening in demand for oysters between 1920 and 1940. It is probably true that biological scarcity or natural depletion of supply is not sufficient alone to explain the decline in consumption, although it should be pointed out that absolute shortages or difficulty in obtaining an economic good may cause consumers to become weaned away from it. Similarly, it may be argued that the high costs of production, expecially labor costs, due to the in-ability of the industry to mechanize, may reflect back through high prices not only to reduce the amount of the product purchased immediately but also, from lessened use, may change the habits and tastes of the consumers. In other words, in some cases supply factors and demand factors are interacting, and a reduction in supply for whatever reason may in turn react to reduce demand. Another way in which supply factors may have affected demand is that the preoccupation with production problems which has prevailed in the industry in recent years may have reduced the amount of selling effort exerted. In many cases in recent years it has been relatively easy to sell the limited supplies available at acceptable prices without vigorous selling efforts.

Other speculative reasons for the probable downward trend in demand are: increased competition from shrimp, crabmeat, and lobster for the cocktail and society trade; replacement of table d'hote menus by a la carte menus in the better restaurants; the harm which typhoid scares of the 1920's did to oyster sales; and the growing availability and popularity of other "snack" items. The demand for oysters as an item of diet is based largely upon their distinctive flavor and the opportunity they afford for variety, rather than as an economic source of animal proteins. It is true that the oyster is a balanced food in the sense that it contains all three types of foodstuffs, carbohydrates, protein, and fat, but is has less than half of both the caloric value and the protein content of beef (380 compared with 919 calories to the pound and nine or ten percent protein against about 21 percent.) The oyster, moreover, has long been a rather high-priced food item, the taste for which is probably acquired.

Improvements in the technology of transportation and refrigeration during the past half century probably retarded the downward trend in demand for oysters somewhat by making the fresh product, which is generally admitted to be superior to the canned, available in practically all markets throughout the country. At any rate, the production of canned oysters fell from 660,857 standard cases and 10,451,118 pounds of meats in 1940 to 472,346 standard cases and 6,817,252 pounds in 1951, a relatively greater decline in weight canned than in production.

Statistical investigations have shown that in the short run the price of oysters per pound of meats received by the fisherman in the post-war period is determined mainly by three factors: volume of production of oysters, the size of the total national disposable personal income (personal income after income taxes), and the price of meat as measured by the Bureau of Labor Statistics Meat Price Index. As might be expected, the greater the production of oysters the lower the price to the fishermen, but the greater the personal income and the price of meat the higher the oyster prices. Of the three determinants, the production of oyster meats has the greatest absolute effect and the size of personal income the least.

One of the most important practical aspects of the nature of the demand for oysters is the relationship between the prices so determined and the quantities that can be sold at various prices. This is what is called, in the jargon of economics, the price elasticity of demand. Several statistical analyses of different types all have indicated that this elasticity in the case of oysters is less than unity. What this means is that if oyster prices decline the additional quantity that could be sold at the lower price would not be great enough to offset the decline in revenue per unit of sales and that the total dollar receipts of sellers at the reduced prices would be lower than before. Or, looking at the matter in a slightly different way, this means that if the oyster industry is to sell significantly larger quantities of the product than at present on the basis solely of price competition for the consumer's dollar it will have to cut prices and costs rather drastically.

Possibly not too much reliance should be placed on these stastical indications, however, since in the post-war period there has been little variation in production and consequently in consumption and it is not safe to make predictions much beyond the range of observed data. But it should be pointed out that the conclusion of slight price elasticity of demand is in line with what is known about the demand for food items in general. If it is valid, moreover, it has very important practical business and official policy implications in that if significantly larger quantities of oysters are to be sold, in the near future, assuming that the present level of demand persists, they will have to be sold at materially reduced prices which would necessitate sharply reduced costs of production if profit margins are to be maintained. In addition, as will be discussed later, it appears that costs can be reduced materially only by increasing the physical productivity of the oyster beds.

The conclusions relative to the price elasticity of demand for oysters were reached on the basis of an assumption that other factors, the prices of competing foods and per capita income, remain constant. Actually the competitive position of oysters with respect to prices, especially as compared with red meat, poultry and fish, has worsened significantly since 1950. The Bureau of Labor Statistics index number for oysters was 10 to 15 points higher than the corresponding combined index for meat, poultry and fish during most of 1953 and 1954 after being lower than the latter through most of 1950. While these facts reflect a strong demand for the available supplies of oysters in the recent past they may be portents for the future expansion of the industry.

The long term downward trend in demand for and production of oysters seems to have been at least interrupted by World War Ii, especially during the period 1942-1947 or 1948. The relative shortage at the artifically held ceiling prices of meat and other protein foods and the rationing of many of these items gave a fillip to the demand for fishery products in general and for oysters in particular. Some of this increase in demand seems to be holding in the post-war period. The income elasticity of demand for oysters (the increase in the total amount of money spent for the item as compared with the increase in total disposable income) over the period from 1940 to 1952 is greater than that for food in general, for meat, and for fish in general, and is exceeded only by that for shrimp among closely competing food products.

Since oysters are a relatively expensive food item, the maintenance of some of the improvement in the demand for them is no doubt due in part to the continuing high level of prosperity in the post-war period. The production of oysters was especially hard hit by the depression of the 1930's and there is nothing to indicate that the same sort of thing will not happen again if a serious decline in economic activity occurs in the future. The oyster trade, in short, is especially sensitive to cyclical fluctuations.

Consistent with these facts are the findings of the consumer preference surveys conducted by the U.S. Department of Agriculture Bureau of Human Nutrition and Home Economics and the Fish and Wildlife Service of the United States Department of the Interior. The percentage of families using fresh, frozen, and canned shellfish was found to be highest for each type of commodity in the highest bracket of income ($5,000 a year and over) (U.S. Dept. Int., 1951). This is true even though the households in the higher economic brackets do not consume significantly larger amounts of marine foods per person--they simply consume the more expensive type of item, including shellfish (U.S. Dept. Agr., 1949).

As to the type of product demanded, scores of interviews with members of the industry at all levels of distribution, including large institutional buyers, have established definitely the type of oyster the consumer desires. It is a fair-sized specimen, within the size classifications, standard or select. It is plump, the lighter in color the better, clean, free from grit and slime (the ropy blood and plasma coagula), not discolored even by benign organisms such as the pink yeast, and, of course, not sour. The vast majority of the wholesalers and retailers is convinced that appearance is more important in the sale of oysters than rich or strong oyster flavor. In fact, it may be seriously questioned whether the full flavor of a strictly fresh oyster on the half-shell is sufficiently bland for popular taste. In addition, the dealers demand a "dry pack", or cans free from excess liquor. Finally, at least 60 percent and perhaps more of the oysters should be packed in consumer sized packages.

What has been said about the elasticity of demand for oysters and the competitive price position of the product emphasizes the importance to the industry of any possibilities of reduction of costs of production and it seems quite clear that the best, if not the only, real opportunity for reducing costs lies in increasing the physical productivity of the oyster beds. The desirability, or even necessity, if the industry is to survive, of this increase naturally leads to a consideration of forces which might act as barriers to its attainment. One such barrier could be public policy.

It is beyond the scope of an economic analysis to appraise fully public policy relating to oyster resources. To do so would be to ignore too many pertinent factors in the culture other than the economic -- the sociological, political, and psychological. But an economic report may properly call attention to strictly economic considerations which usually are included in overall policy determination. On strict economic grounds a strong case can be made for a policy of encouraging private ownership and cultivation of the oyster bottoms. It can be demonstrated both theoretically and empirically that the greatest value per unit of economic resources employed can be produced under a system of private property.

A private enterpriser who owns a plot of oyster bottom of, say, superior productivity would, of course, want to determine the optimum number of units of productive effort to be expended upon the resource. He would tend to increase productive effort up to the point at which an additional unit of effort would increase his income by no more than the cost of the extra productive unit. Or in the technical language of economics, he would equate his marginal cost and his marginal revenue. In so doing he would maximize the "economic rent" or surplus of product over and above what inferior grounds would yield. Also, of course, he would realize an average return per unit of production effort expended greater than the average costs of such units, or a profit over and above all costs, including a normal return on capital invested and all wages including wages of management. Under the institution of common ownership, oystermen tend to exploit the superior bottom first or more intensively than the others until its average productivity is reduced to equality with that of the next best ground. This process continues, theoretically, until the average productivity of all the plots has been reduced to equality. Competition among the fishermen would force this point of equality down until the returns just barely covered the total costs of production. Thus the additional income possible under the institution of private property is dissipated under the system of common ownership. What is more, since under the latter there are no costs of growing oysters to the individual oysterman, there is nothing of an economic nature to prevent the fisherman from stripping the beds to such an extent that they cannot replace themselves. And of course no one has any incentive to plant or cultivate oysters, for he could not appropriate the harvest.

The empirical evidence in favor of private cultivation in the oyster industry is perhaps even more impressive than the theoretical.

> The total acreage of oyster bottoms in our coastal waters can be estimated only approximately. According to present computations there are in the territorial waters of the United States about 1,428,400 acres officially designated as oyster producing bottoms. A small proportion of this area, not exceeding 185,000 acres of privately-leased or owned bottoms produces 54.5 percent of the total oyster crop. There is, thus, a very great difference in the productivity of cultivated and natural oyster beds. (Galtsoff, 1943).

Such evidence of superior productivity could be multiplied many fold but time prevents the citation of other cases.

All of these considerations point toward certain desirable industry actions and policies if the long term downward trend in oyster production is going to be more than merely interrupted. Preoccupation with problems of production should not be allowed to interfere with expanded selling effort, both individual and collective, for if the present level of demand cannot be raised the indications are that significantly larger quantities of oysters can be sold only at markedly reduced prices. The industry should try always to give the consumer the kind of product she wants at the lowest possible price and to develop new products and new uses - in short, retain the present demand and add to it. On the other hand, no matter what the elasticity of demand actually is, it would always be advantageous, both to the industry and the consuming public to be able to reduce costs of production. The best opportunity for this desirable development lies in increasing the physical productivity of the oyster beds. Finally, both economic theory and actual experience indicate that productivity is likely to be greatest under legal and institutional arrangements which encourage the free enterprise system in oyster cultivation.

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NEW TYPES AND USES OF CANS

John Dingee

Can Manufacturers Institute

The main factors in the progress of the can industry have been the improvements in the quality of steel, making it possible to use better and faster machinery; the development of research and engineering departments, which have opened new horizons for the can maker and the can user; the cooperation of the steel companies in putting forth every effort to advance the technology of steel.

There has been a continuous revolution in can making since 1900. In 1900 only two billion cans were made for 250 products, representing about 25 industries. Today, 36 to 38 billion cans are made, covering approximately 2,000 products and representing 120 industries. Each family used 100 cans per year in 1900, and they used 800 per family in 1954. In the last ten minutes over $3\frac{1}{2}$ million cans moved off the retail shelves of America. In 1954, 4,143,329 tons of steel were fabricated for the purpose of making cans. This made the 36 to 38 billion cans noted before. It would also make 2,029,480 autos, 42,065,860 washing machines, 35,052,500 refrigerators, and 69 Empire State Buildings.

Every working day of the year 100,000,000 cans of food are packed and distributed. Your production makes up a part of this total. Sixty-five can companies make these food cans, as well as all of the general line cans produced. Twenty make fish and shellfish cans. These companies range in size from ones with eight employees to those with over 35,000 employees.

Sixty-five to seventy fish and shellfish items are canned, and about 12 to 15 types of soup. Approximately 400 food products are packed in cans. These items range from oysters to bananas, yes bananas! From rattle snake hors d'oeuvres to rhubarb. If you want it in a can, the odds are that some-one packs it.

Some 2,000 products of the general line type (other than food) are packed in cans also, involving over a thousand different shapes and sizes. These range from cans for special parts for electronic devices to containers for high velocity shells---and of course the large volume motor oil cans.

In cooperation with the food industry, can manufacturers have helped to keep the price of food at a smaller level of increased cost than any other country. (Europe 60 percent of income, Asia 80 percent, this country 25 percent for food).

Research is going on in metallurgy, corrosion control, adhesives, soldering, welding methods, organic coatings, and waxes, mechanical engineering aspects of container contruction, plastics, alloys, coating, etc. In fact, today there are approximately 2,100 employees in industry working in thirty-seven research laboratories solving these complex problems, not to mention the greater number of engineering and production people also assisting in the solution of these problems.

New plastic cements have recently been developed to eliminate the need for solder. This opens the door for progress in new types of cans and new products for cans. It also eliminates the solder margins, so the entire can may be lithographed, making for better point-of-sale eye appeal. Motor oil, liquid detergents, waxes, dry goods, insecticides, polishes, and lighter fluids are now using this type of can. Also frozen citrus concentrates are canned in this manner. In this product it is a first step toward a completely tinless can for this large volume food item.

New coatings and enamels are being designed to work on tin plate, C. T. S. (Chemically treated steel), and C. M. Q. (Steel without tin) to make the industry dependent only on domestic synthetic materials. Great progress has been made. Working on the problem of rust development on untinned or untreated steel between the mill and the can plant is going on and is being solved right now. C. T. S. (Chemically treated steel) is being worked on now to make it a complete substitute for tin plate. This solution is still a few years away, however; high speed soldering of C. T. S. is in the final stages of solution at present.

Some of the new types of cans and new products in cans are: frozen citrus concentrate (over a billion six-ounce cans have opened a whole new field for cans for frozen foods), precooked frozen pies (over 50 million cans), frozen fish sticks (over 20 million cans), frozen turkey dinners, and other complete meals.

Quart motor oil cans ($1\frac{1}{2}$ billion cans) were the first tinless cans perfected. Now practically the whole petroleum industry has been converted to tin-free cans. Pet food (2 billion cans) is now moving into tinless cans. Liquid detergent cans in a new dripless style are becoming a large volume item in their second year. Liquid shortening in tinless cans is now being market tested. This will be a large volume item. Other items moving into tinless cans are anti-freeze, varnishes, pharmaceuticals, insecticides, waxes, and tobacco, to name only a few of the major items.

Whole milk in cans is on the verge of bursting into the realm of reality and will revolutionize the distribution methods of this industry, saving millions of dollars in the process. Don't be surprised to see the "milkman" become a legend like the familiar iceman. This is expected within the next decade. Aerozols, or correctly, low pressure containers, have made tremenduous strides. Over 400 known items are packed now, and the only thing that holds this field back is the need for individual testing and formulation on each product.

Oven-fresh cakes are one of the new items packed by a concern in New York in four different types: golden, silver, marble, and raisin. They are baked, sealed, vacuumized, and need no further cooking. (Side-light, highest vacuum of any product is used on these cakes.)

Soft drinks are on the way. A good barometer is that Pepsi Cola is testing in Chicago; Dr. Pepper, in Dallas; Coca Cola is studying test areas; and Canada Dry is already making good progress. Pabst Blue Ribbon is testing its new soft drink in five markets in the mid-west. Hi-C, a non-carbonated orange and grape drink has had phonomenal success. The volume in this field is expected to reach 8 to 10 billion cans within the next five to ten years. Savings in cost of handling, shipping, and distribution are the potent factors.

Other items moving into the volume field are poultry, which lends itself to brand name advertising and promotion. Canned drinking water is being used by the armed forces, by the Red Cross for emergency conditions, and in disaster areas, and it is also being stored by defense authorities in case of atomic attack. Many problems had to be overcome to make it possible to pack water commercially in cans.

Even the research scientists are not sure what form or shape the can of the future will take or the type of metals that will be found satisfactory to meet all of the needs of food products and nonfood products. It is certain that they will be produced by techniques that today are only ideas or dreams in the minds of the research, manufacturing, and engineering personnel.

One of the largest projects in the can industry today is that known as "Operation Survival." It was started a number of years ago by one of the larger can companies, and millions of dollars have been spent and will continue to be expended until the can is completely free of the need for tin.

Many items, as mentioned previously, have been freed of this need of tin. Many more will follow. "Operation Survival" has stimulated effort throughout the industry and is developing or causing to be developed many improvements in cans other than the initial goal. Included in research studies are new metals, new coatings, new processes and manufacturing methods. Already since 1941, 260,000 tons of tin with a value of $500,000,000 have been saved.

During this study, process-welding of side seams has been investigated. Out of this it has been proved that high speed processing is practical. The problem is equipment. Welding gives added strength for processing food, beer, soft drinks, and other beverages which need to be processed under high temperatures and pressures. Welded side seams are so strong, the metal will fracture before the side gives out. Its good points are: applicable to all metals, whereas solder can only be used by a few; its strength; it makes available certain non-solderable, chemically treated steels for use in food cans; elimination of a number of steps (450 a minute) in the present can manufacturing process.

New metals will play a big part in the can of the future. The main object is to be dependent only on domestic metals and alloys. Those metals showing the most promise at this time are titanium, aluminum, nickle, and zinc.

Varieties of untinned steels, aluminum coatings on steel, nickle plated steel, and plastics coated on steel. Various methods of aluminum coating on steel, such as cladding, electroplating, and vapor compositions are being tested at this time with good initial results. Drawn aluminum cans are being tested and have proven feasible. Certain food products have been held for over two years without deterioration.

Along with the study of metals, coatings, etc., has gone the study and research for processing of food products. Antibiotics is proving possible and would eliminate heat sterilization. Subtilin is one antibiotic that is proving particularly effective in tests on certain types of foods (eliminates food spoiling bacteria). Atomic radiation is another process being tested in cold sterilization tests (extends shelf life of food). This is a long-range program, perhaps 15 or 20 years in the future, but a real possibility which could be speeded up if forced by wars or disasters, which unfortunately seem to be the times when greatest technological advances are made.

In the next 20 years an additional 10 billion pounds of food will be required by our growing population. This demand keeps the can industry on its toes in order to supply you with the necessary cans.

Who can say what changes are coming in the next generation? Some world-wide emergency may arise to make today's tin can an out-moded relic in a very short space of time. One thing is sure, that the can industry is continually working to solve its problems, and when the time comes, it will be ready to measure up to both domestic and governmental demands.

The "Can of Tomorrow" will come out of this effort. From our research departments, our engineering departments, will come the practical realities of the can we do not know about today.

PROPOSED CHANGES IN PHS MANUAL FOR SANITARY CONTROL OF HARVESTING AND PROCESSING OF SHELLFISH*

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I was very pleased when Dave Wallace invited me to attend your annual meeting, and to talk for a few minutes about the proposed changes in the shellfish-sanitation manual. This meeting gives me an unparalleled opportunity to discuss shellfish sanitation with both industry representatives and regulatory officials, and is a fine example of government and industry working toward solution of a common problem.

Certainly, shellfish sanitation is such a common problem. Control is essential from the health-agency standpoint because, in past years, shellfish have been implicated many times in the spread of disease.

The shellfish industry also has a stake in maintaining a high level of product purity. Certainly, no shellfish grower or packer would want to be responsible for illness or death among persons who have purchased his product. Second, and of importance both to management and labor, is the economic consequence of widespread public reaction which would result from a disease outbreak traceable to oysters or clams. The consequence of a serious breakdown in shellfish sanitation would probably be felt throughout the fisheries industry.

Shellfish-sanitation problems are unique, and call for a highly specialized control program. With most foods, sanitary control can be centralized in plant inspection and product examination. For example, in milk sanitation, adequacy of pasteurization is easily ascertained by use of sealed recording instruments and the phosphatase test. In many foods, a considerable degree of consumer safety is afforded either by the nature of the product or by cooking.

But with shellfish, nature teamed up against us. The oyster can grow in areas subject to sewage pollution; in fact, it will accumulate bacteria within itself to the point of contamination greater than that in the water in which it grew. The oyster is a food product which furnishes a relatively good growth medium for bacteria. Finally, the oyster does not take kindly to overcooking--and many are consumed raw. The sum of these qualities is a knotty problem in sanitation.

* "Shellfish" is defined to mean only oysters, clams, and mussels. The certification system does not apply to crabs, lobsters, or shrimp.

The undisputed fact that we have no widespread outbreaks of shellfish-borne disease recently should not be deemed a cause for lowering sanitary standards. This is a logical cause-effect relationship. There is no epidemic disease because of strict sanitary control.

We have reason to believe there is still a substantial amount of food poisoning due to shellfish. Fortunately, these outbreaks are small and involve only a few persons at any given time or place. From a statistical or epidemiological standpoint, such outbreaks are almost impossible to find or investigate in the general population. It is only when one has a "captive" population that a positive correlation can be shown between shellfish and disease.

The cause of residual shellfish-borne illness is not easily explained; it is probably due to illicit harvesting from closed, sewage polluted areas. However, we have no positive evidence to support this proposition.

In some instances, dirty plant conditions or poor refrigeration during shipment may be responsible for contaminated shellfish. A few years ago, it was noted that shipments of shellfish to Canada showed excessively high bacteria counts. A bacteriological standard was established by the Canadian authorities, and shipments not meeting the standards were rejected (Kelly and Arcisz, 1954). There was an almost immediate improvement in bacteriological quality of the product following adoption of these standards.

Industry has a real responsibility for maintaining sanitary conditions in the plants and the distribution system. By and large, industry has accepted this responsibility, and close operating relationships are maintained between the industry organizations--The Oyster Institute of North America and the Pacific Coast Oyster Growers Association--and the government control agencies. But there are instances where this system breaks down. There are a few dealers who either ignore the disease potential of the product which they handle, or who just don't care. They regard the health and fishery authorities as an evil which they must tolerate and consider the disease potential of shellfish as a figment of someone's imagination.

Health authorities and the shellfish industry have a mutual public duty to prevent contaminated shellfish from reaching the market. In general, we have accomplished this by working together. Let us hope that we can continue such an approach.

Most of you are familiar with the shell-fish sanitation manual (U. S. Publ. Health Serv.). You know it is the guide used by Public Health Service officers in making yearly evaluations of your plants; that, in many instances, it serves as a guide to your state shellfish-control authority; and, that most state shellfish regulations parallel the manual requirements. Thus the PHS shellfish-sanitation manual is important to you in your daily business.

As most of you know, the manual is being revised. Early in February, a draft copy of the revised manual was sent to all interested state and federal agencies and to shellfish-industry organizations. Most of you have seen copies of this draft, and a few of you have commented on it. I must emphasize that this is a working draft only, and will doubtless be subject to many revisions before a final text is decided upon.

Three guidelines have been used in revising the shellfish-sanitation manual. These are: (1) fill in existing deficiencies in the old manual; (2) make the manual easier to use; and (3) modernize by dropping obsolete requirements and adding new requirements to reflect technological advances.

It has been stated many times that the shellfish-certification program is a joint endeavor, with regulatory agencies and industry having mutual responsibilities. This is an ideal arrangement, since it gives industry a chance to solve its own problems---if it chooses to do so. If industry does not exercise its prerogatives as a program partner, and does not take an active part in finding solutions to sanitation problems it will, to a considerable extent, have surrendered its share of the partnership.

The recent history of industry cooperation is not uniformly unblemished. Whereas the oyster industry was well represented at the 1954 National Shellfish Conference, the clam industry of New England and the Middle Atlantic States was almost without representation. To me, this indicates minimal program interest by the clam industry. On the other hand is the recent example of an oyster-industry organization employing a sanitarian to help with sewage-disposal problems around growing areas.

Most of our real problems are in growing-area control; however, I will not discuss these now, since the new manual will be concerned only with sanitation in harvesting and processing operations.

Next is sanitation on harvesting boats. Two points are involved. First is the sanitary handling of shellfish aboard the harvesting boat. Second is the matter of sewage disposal.

The first may seem inconsequential to you who think of oyster harvesting in terms of dredge boats. However, you must consider that small skiffs are used in many areas for harvesting, that oysters or clams are piled on the floorboards, and that the skiff may travel through heavily contaminated harbor waters. We have frequently observed an inch or more of water sloshing around in the bottom of an outboard-powered skiff loaded with clams. If this water is from a polluted harbor area, there is an excellent chance that the shellfish will be contaminated.

You may dismiss the question of protecting shellfish from the sun as unimportant, but you should remember that clam dredge-boats operate during summer months. Clams, despite their notoriously poor keeping qualities, are stored aboard these boats in the hot sun for as much as a full day before they are taken ashore and shipped to market in a refrigerated truck.

Sewage disposal from shellfish-harvesting boats has been discussed for years. The existing requirement of providing an excreta container on board each shellfish-harvesting boat has proven almost unenforceable. Oystermen see no reason why their crews should refrain from discharging excreta overboard into shellfish-growing waters when no similar restriction is placed on pleasure boats or on fishing boats.

The most cogent argument against use of excreta containers is the possibility that shellfish on the harvesting boat may be contaminated by an overturned or leaky container. There is a further problem of disposal of the contents of the excreta container at a shore source.

A health organization cannot concur in the premise that there is no harm in discharge of fresh sewage into water in which a food product is grown. The ultimate solution is to avoid discharge of sewage from any source---fishing boat or pleasure craft---into oyster-growing areas. Such a goal cannot be achieved at the present time, and we must, therefore, adopt some feasible scheme for limiting sewage discharge in oyster-growing areas---at least during the time when oysters are being harvested.

Maintenance of records of the source of shellstock has been a backbone of the certification system. Mixing of shellstock from several areas is inevitable with present industry practice, and we see no valid reason for requiring that the practice be changed. However, there is good reason for requiring that dealers, including buy-boat operators, keep accurate records of the source of shellstock which they purchase. The problem of shellstock identity has become particularly pressing in the clam industries.

A major change in the manual concerns shellstock washing. Muddy shellstock is a primary cause of unclean plants. In addition. there is evidence that bacteria contained in the mud may be responsible for high bacteria counts in shucked oysters. It is true that bacteria in the bottom sediments might have little public-health significance. However, where a bacteriological standard is used, this additional count becomes important. The bacteria contributed by mud could easily make the difference between acceptance or rejection of a given shipment of oysters, since ordinary bacteriological examination would not distinguish "mud" bacteria from "oyster" bacteria.

Since mud is more easily washed from the shellstock at the time of harvesting, the primary responsibility for washing should rest with the harvester. But this may not be laid down as a hard and fast rule, because in some areas shellfish are harvested during low tide, when there is no water on the beds. Obviously, some provision will have to be made for handling shellfish during freezing weather.

Screening of packing rooms has been a certification requirement for years. The new manual will extend the need for screening to the entire plant during seasons when flies are present. Last fall, I was in some plants in which the fly situation was completely out of control. There were thousands of flies in the shucking rooms, and many, many flies in the packing rooms. Toilet rooms were poorly screened and, in addition, there were many outdoor toilets within a radius of one-half mile.

It is impossible to produce a sanitary product under such conditions. and no such plant operator should expect his local control agency or a federal health agency to give him a clean bill of health. The choice is simple---either control flies in the plant during the summer and early fall, or refrain from operating until the fly season is over.

I agree that it is not easy to keep flies out of the shucking room where large quantities of shell must be moved in and out. However, it is not impossible. Fly control must be achieved if plants are going to be certified during the fly seasons.

Lighting requirements have been increased from 10 foot-candles to 30 foot-candles. Offhand, it might seem that there is little relationship between lighting and sanitation; however, in practice, one frequently finds a very positive correlation. Poorly lighted plants are frequently dirty plants; well-lighted plants are rarely dirty. The 30 foot-candle requirement simply reflects improvements in lighting, and brings the manual into accord with present-day practice. Many plants now have a lighting intensity of about 30 foot-candles, so the requirement will be of little concern to them.

The number of handwashing facilities has been doubled to bring the provision into agreement with the National Plumbing Code. However, even with the new requirement, there would be a theoretical 15-minute delay for workers in the morning and following the lunch period. There have been comments that one lavatory per ten employees is more than is needed. Certainly, that many lavatories is not needed during most periods of operations. The tie-up in lavatory facilities comes--or at least should come--in the morning at start of work and after the noon lunch period.

More important than the number of lavatories is the principle: do employees actually wash their hands before they start to work in the morning, after each work interruption, and after the lunch period? This is one of the most important plant-sanitation practices, and yet it is one which frequently is ignored.

General equipment-construction standards have not been changed significantly. Virtually 100 percent of the equipment now in use is fabricated of stainless steel or nickel alloy. The minor rewording of the manual will have a significant effect on not more than a half-dozen packing plants in the United States.

The design and construction of much equipment used in the oyster industry is unsatisfactory, although excellent---and costly---materials are used. It is common knowledge that soldered joints do not stand up under rough use in oyster plants. Rolled soldered seams in stainless steel or nickle alloy usually cannot be repaired by local craftsmen. Nevertheless, industry continues to purchase equipment with soldered joints, although seamless or welded-joint equipment is frequently available. In view of the difficulties which oystermen have in obtaining satisfactory equipment, and of their large investment, the manual will continue to accept equipment with soldered joints, provided that it is properly maintained.

Sanitary construction of returnable containers has been a problem for years. Theoretically, there is nothing wrong with the returnable container if it is used properly. In practice, we find that oysters in returnable containers are not properly cooled, and also that containers are not properly cleaned. If industry is to continue use of the returnable container, provision must be made for cooling the product and for adequate container cleaning. The material used for returnable containers and the method of fabrication continue to be a fundamental part of the equipment-construction item. This is unchanged from the present manual (U.S. Publ. Health Serv.).

Review of bacteriological data and visits to plants indicate serious deficiencies in the shucking-room procedure. First is the shucking of muddy shellstock. This results in bringing a vast amount of mud and dirt into the plant. Plant cleanliness is complicated, and as mentioned, additional bacteria may be introduced into the final pack. Shellstock washing will be required.

Second is dip buckets. Bacteriological examination has shown extremely high bacterial counts in dip buckets, because water is not changed in the buckets at frequent intervals. Strict policing could probably force shuckers into putting clean water in the dip buckets at frequent intervals; however, it is impossible to have an inspector in the plant at all times. Therefore, dip buckets have been prohibited.

Third is the elapsed time between shucking and refrigeration. Under the worst observed conditions, shucked shellfish may be held on the shucking bench for as much as a working day. To control the growth of bacteria, refrigeration should be started as soon as possible after the oyster is removed from the shell. Factors which contribute to this delay include: use of large shucking containers, bench grading, and return of overage. Several manual changes have been proposed to reduce the time interval between shucking and the start of refrigeration.

Shucking containers should be of such size that a shucker might ordinarily be expected to shuck the container full in about an hour.

The practice of returning overage from the skimmer to the shucker has been prohibited. Possible alternatives include use of a uniform-sized shucking container, or crediting of fractional parts of gallons to shuckers. Undoubtedly, there are other solutions.

Last is bench grading of shellfish which, under the worst conditions, may cause some oysters to remain on the shucking bench for the entire day. I know of no solution, other than to prohibit bench grading or to require each shucker to empty all shucking containers at the same time.

Handling of single-service containers has been very unsatisfactory in many plants. Cartons of single-service containers and covers are left open from the end of one season to the next. Container-storage rooms are not rodent-proofed, and containers are stored on the floor in such a manner that they provide harborage for rodents.

Because of these deficiencies, the new manual proposes that each single-service container be given a bactericidal rinse prior to filling. This will be a costly and time-consuming operation. The alternative appears to be a vast improvement in container handling, with bactericidal treatment required only if the container package has been broken.

Refrigeration of shucked stock has been a continuing source of trouble in many plants for years.

Use of low temperatures to inhibit growth of pathogenic or toxin-producing bacteria is an important public-health measure. As temperature decreases, a biological chain reaction takes place. Bacterial growth and enzyme action are slowed or inhibited, the spoilage rate is decreased, and shelf-life is lengthened.

Growth of pathogenic or toxin-producing bacteria is ordinarily inhibited at a temperature of about 50°F., although at least one investigator has noted that some strains of *Salmonella* will develop at 50°F., but not at 41°F. Chilling the final pack to a temperature of 40°F. or less would insure against multiplication of pathogenic, toxin-producing, and indicator-group bacteria.

We have no data on bacteriological quality of shucked shellfish stored at 40°F. as compared with storage at 50°F. Experience with other foods indicates that it would be desirable from a quality-control standpoint, but this has not been verified.

The present draft of the manual requires that shucked shellfish be cooled to between 32° and 50°F. within two hours after shucking. This was an admirable requirement, but I believe that, with ordinary industry practice, it is virtually impossible to attain.

The new manual provision, therefore, will require cooling to 50°F. within two hours after packing. However, comments received from state and federal agencies indicate a general preference for further product cooling to 40 or 45 degrees.

With a good operating procedure, shucked shellfish can move from the shucker to the cold room in about two hours. There will then be a further delay in cooling of the packed product of from two to 24 hours, depending on the size of the container and type of refrigeration. This time can be reduced by precooling shellfish before packing. While we believe precooling is highly desirable, there does not seem to be public health justification for including this as a manual requirement. You may have a different opinion.

If repacking is involved, there may be a further period in which the oysters again reach room temperature and go through another cooling cycle. Thus, some repacked shellfish may have been stored at room temperature for as long as 48 hours.

From the public-health standpoint, such practices are certainly not conducive to production of a high-quality product. I doubt that they add anything to the quality of the product from a consumer standpoint.

Therefore, a major change has been made in the requirements for temperature control during repacking. The revised manual will require either that repacking be accomplished with such speed that the internal temperature of the shellfish does not exceed 50°F., or that the repacking room be air-conditioned to a temperature of 50°F. or less.

Sealing of containers to prevent contamination or adulteration of the product after it leaves the packing or repacking plant has been a requirement of the certification system since its inception back in the twenties.

However, several years' experience on the west and Gulf coasts has shown no evidence of tampering with nonsealed pint or 1/2-pint containers. It is proposed, therefore, that the requirement for positive sealing be dropped for small containers.

There are, of course, many minor changes in the manual. These include: (a) deletion of the requirement for an intervening toilet-room vestibule; (b) a new requirement for an automatically regulated hot-water system; (c) a reduction in the number of toilet fixtures required, in accordance with the recommendations contained in "Report of the Coordinating Committee for a National Plumbing Code" (U. S. Dept. Comm., 1951); (d) a requirement for a cleanable blower drain-valve; and (e) a requirement of adequate clean-up facilities, including a sink. Most of these revisions will affect only a small percentage of the operators.

I know many of you have firm ideas on other items which should be changed and/or included in the coming revision. We attach a high value to your opinions on such matters, and urge that you get your ideas to us within the next few weeks.

I hope I have given you some idea of the changes we propose, and also have impressed on you our need for your assistance in developing a manual which will accomplish its purpose with a minimum of interference with plant-operating procedure.

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