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The Galápagos Marine Resources Reserve

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Paul R. Ryan, *Editor*
James H. W. Hain, *Assistant Editor*
Michelle K. Slowey, *Editorial Assistant*
T. M. Hawley, *Spring Intern*

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COVER: A marine iguana foraging for algae on the bottom in Galápagos waters. Photo by Edmund S. Hobson © National Geographic Society. **BACK COVER:** Marine iguana colony onshore. Photo by Flip Schulke, Black Star © National Geographic Society.

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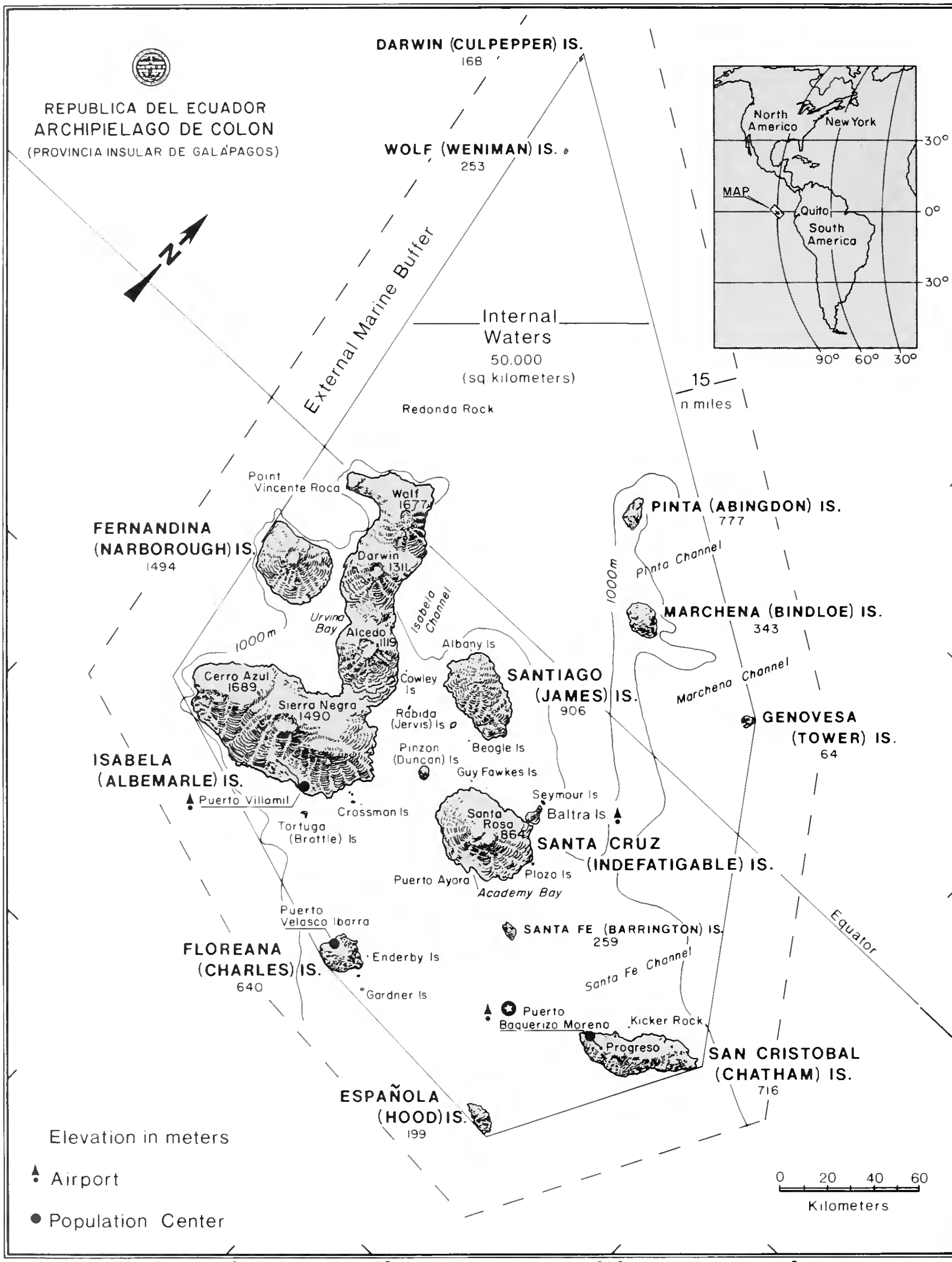


The Galápagos Marine Resources Reserve—established by Ecuadorian Presidential Decree on May 13, 1986—defined as including the water column, seabed, and marine subsoil of the interior of the Galápagos Archipelago—the area within the baselines drawn around the outer points of the islands—and within a band of 15 nautical miles surrounding these baselines. The total of 19 islands and 42 islets are located in the Pacific Ocean, 600 miles west of Ecuador, directly on the equator. The land area is 7,882 square kilometers with a coastline of 1,350 kilometers. The capital of the Galápagos is Puerto Baquerizo Moreno, on San Cristobal Island. Puerto Ayora is the largest city, with an approximate population of 5,000 out of a total Galápagos population of 8,000 to 10,000 (only 4 islands are inhabited). Elevations and depths are in meters. Boundary lines are an approximate representation. The internal waters of the reserve amount to some 50,000 square kilometers, with an additional 20,000 square kilometers representing the approximate figure for the buffer zone—a total of about 70,000 square kilometers.

PRESIDENCIA DE LA REPUBLICA

El Ecuador ha sido, es y será País Amazónico

March 2, 1987.

To *Oceanus* magazine in celebration of its special issue on the new Galápagos Marine Reserve.

The territory of Ecuador is divided by the Equator and is like two outstretched hands greeting both the Northern and Southern Hemispheres.

Ecuador is also divided vertically by the majestic Andes cordillera that towers more than 18,000 feet, with snow-crowned peaks only a few hundred kilometers away from the Pacific Ocean and the Amazon Basin. These factors combine into privileged situations. Our country has all the climates of the Earth without their extreme rigors. Its ecosystems are unique: Ecuadorian flora and fauna are extraordinarily rich and diverse and can still be found in their almost unaltered natural habitats.

Among all these wonders, is the Galápagos Islands, the "Enchanted Islands," cast upon the ocean like a handful of pearls. It was on these islands that Charles Darwin conceived his famous theory of the evolution of species by means of natural selection, perhaps because animal species, long extinct in other parts of the world, still live among the Galápagos volcanic lava and white, soft beaches as reminders of centuries past.

The Ecuadorian Government has taken appropriate measures to preserve, protect, and conserve the resources of the Galápagos Islands, especially the water column, the seabed, and the submarine subsoil of the archipelago's interior seas.

The Ecuadorian Government therefore sponsors and praises international efforts that contribute to these objectives. One must not forget that even though Ecuador maintains sovereignty over the Galápagos Islands and their surrounding waters, these islands also belong to the cultural heritage of all humankind.

LEON FEBRES CORDERO RIBADENEYRA
PRESIDENTE CONSTITUCIONAL DE LA REPUBLICA
DEL ECUADOR.

The Galápagos Marine Resources Reserve Decree

The Official Register of Ecuador—Number 434—May 13, 1986, pp. 28–29

No. 1810-A
León Febres-Cordero Ribadeneyra
Constitutional President of the Republic

Whereas

It is the duty of the National Government to protect those natural areas which stand out because of their ecological, scientific, educational, economic, and political value, in order to conserve their resources and furnish today's generations with an improved and sustained benefit from their use, while at the same time, maintaining their potential to meet the needs and aspirations of future generations;

The Ministry of Agriculture and Livestock—through the Department General of Forest Development (the present-day Department of National Forests), and by means of the technical document entitled "Preliminary Strategy for the Conservation of Outstanding Wild Areas of Ecuador," which was issued in 1979 in the execution of the Project UNDP/FAO-EC/71/527—grants the Galápagos Archipelago the highest priority within the National System of Protected Areas, due to its large number of unique features, including its terrestrial and aquatic ecosystems;

The High Commission encharged with the Revision of the Master Plan for Social Development and Conservation in the Galápagos Province—in their observations in the stated documents, as well as in the Immediate Action Plan for the Galápagos Province, promulgated by Executive Decree No. 937 of July 11th, 1985, and published in the Official Register No. 297 (Supplement) of October 22nd of the same year—recommend that the marine zones of the Galápagos Archipelago be incorporated into the Natural Areas Patrimony;

The Department of National Forests (the official organization responsible for the administration of the State's Natural Patrimony Areas)—based on studies performed by national and international organizations—recommends the establishment of a Protected Marine Area within the sea that surrounds the Galápagos Archipelago for ecological, economic, scientific, educational, and political reasons and

By virtue of the power previewed in article 78, literal a) of the Political Constitution and article 69 of the Forest, Natural Areas Conservation, and Wildlife Law.

Decrees

Art. 1—That the water column, the seabed, and the marine subsoil of the sea located within the interior of the Galápagos Archipelago—which is understood to be the area within the baselines used to measure the territorial sea of the Galápagos Archipelago, according to the Supreme Decree No. 959-A of June 28th 1971 as proclaimed in Official Register No. 265 of July 13th 1971—are declared to be a marine resources reserve, along with a band of 15 nautical miles surrounding said baselines, and fall under the exclusive domain of the State.

Art. 2—That for the management and vigilance of the marine reserve, an Interinstitutional Commission comprised of the following members will be established:

—The Minister of Agriculture and Livestock or his proxy, who will preside over the Commission;
—The Minister of Foreign Relations or his proxy;
—The Minister of National Defense or his proxy;
—The Minister of Industry, Commerce, Integration, and Fisheries or his proxy;
—The Minister of Energy and Mines or his proxy;
—A representative of the National Development Council, and
—A representative of the National Institute of the Galápagos.

The Commission may request the assistance and collaboration of the Charles Darwin Research Station and national and international organizations as deemed necessary.

Art. 3—The Ministry of Finance and Public Credit shall make the budgetary transfers required to the Ministry of Agriculture and Livestock for the adequate functioning of this Commission.

Transitionary Provision

Within the space of 360 days—starting from this date—the Interinstitutional Commission to which Art. 2 of this Decree refers shall work out a Management Plan for the Marine Reserve which will specify aspects relevant to its administration, management, development, and control.

The Ministers of Foreign Relations; of National Defense; of Agriculture and Livestock; of Finance and Public Credit; of Industry, Commerce, Integration, and Fisheries; and of Energy and Mines are encharged with the execution of this decree, from the date of its publication in the Official Register, at which time its enforcement shall go into effect.

Given in Quito, in the National Palace, on the 29th of April, nineteen hundred and eighty six.

Signers:

León Febres Cordero Ribadeneyra, Constitutional President of the Republic; Edgar Terán, Minister of Foreign Relations; Medardo Salazar Navas, Minister of National Defense; Marcel J. Laniado, Minister of Agriculture and Livestock; Francisco Swett Morales, Minister of Finance and Public Credit; Xavier Neira Menéndez, Minister of Industry, Commerce, Integration and Fisheries; Javier Espinosa Terán, Minister of Energy and Mines.

An authentic copy—certified and signed by:
Joffre Torbay Dassum, Attorney, Secretary General for Public Administration

(Final translation/R. Lester/June 11, 1986)

A Promise to the Sea, and the Politics of the Decree

by Roque Sevilla

Rachel Carson, in her book *The Sea Around Us*, explains human attraction to the sea as stemming from the fact that our blood has exactly the same mineral and water composition as the sea.

Whatever the cause, many people have a great affinity with the sea. They are cheered by its color, soothed by its murmurs, and awed by its immensity. I personally belong in this category. I have always felt very much at ease by the sea, whether playing in the waves or taking long strolls down a solitary Ecuadorian beach, watching the spectacular sunsets so unique to countries facing the ocean.

My feelings toward the sea became even stronger the day I descended for the first time with my SCUBA equipment into deep water. Suddenly I felt immersed in something to which I was profoundly attracted. At that moment, I was absolutely united with my surroundings, a part of the whole, a sensation I had never felt before.

The Palacio de Corondelet in Quito, center of most important Ecuadorian political decisions. (Photo by Ignacio de Quadras, Quito)

Although I was born and raised in Quito, Ecuador, a city which is cradled in the majestic Andes, 300 kilometers from the coast and 2,850 meters (9,350 feet) above sea level, I was able nonetheless to cultivate this sensation. I have since gone to much trouble to repay the sea for some of the pleasure it has given me.

A Promise

Two years ago, while strolling down an abandoned beach, I felt extremely depressed, confronted with the presence of so much garbage and waste. I formally promised the sea that I would do anything possible to protect it from such abuse.

A few months later, while cruising the Galápagos Islands on one of my diving trips, I met another lover of the sea, a peaceful and courteous Englishman who has dedicated most of his life to revealing the submarine wonders of the Galápagos to the world. Whenever Godfrey Merlen (see article page 20) had an opportunity, he would "lobby" for the sea, trying to convince authorities to intervene in behalf of its protection.

It was from Godfrey that I heard for the first time that Gerard Wellington, an American marine biologist from the University of Houston, Galveston, Texas, had written in 1974 an extensive study on the submarine life of the Galápagos. The conclusions of Wellington's study were fascinating: he observed an incredibly high rate of endemism (species found only in a particular locality or region) among the aquatic species, 35 percent for algae and seashells, and 25 percent for fish. Apparently, marine organisms in the Galápagos have been forced to adapt to exceptional conditions because of their relative isolation in the sea, resulting in both a great diversity of species and the endemism. As a conservationist and a diver, I was particularly struck by the percentages, and was then totally motivated to explore such a fascinating topic. Back in Quito, I tried hopelessly to find Wellington's study, *The Galápagos Coastal Marine Environments*. As usual, this type of material was not available to the general public.

National Forestry Director

A strange coincidence gave me direct access to the source of this report, as I was named National Forestry Director of the Ministry of Agriculture. The National Parks Division fell directly under my office. One of my first satisfactions was to read Wellington's study, which had fallen into total obscurity among piles of bureaucratic documents.

The report stated that the protection of the Galápagos Islands themselves is not enough, and

The Galápagos: a high rate of endemism. (Photo by G. M. Wellington/© National Geographic)

that the archipelago must be considered as an integral ecosystem with its land and sea components. Since many animals depend directly or indirectly on marine resources for their subsistence, it is absolutely necessary to protect the seas around the islands as well as the islands themselves.

The National Parks Department and the Charles Darwin Research Station had been for some time asserting the need to extend the Galápagos National Park into the marine area. These demands were not heard—or more plausibly, there was no mediator to translate scientific and conservationist arguments into a language comprehensible to politicians and authorities.

Mediator

I have spent more than 20 years selling non-tangible products and services—I started off as an agent in the stock market, then became an insurance broker. When I realized how important it was to "sell" the idea of protecting the Galápagos marine area to key decisionmakers, I knew the time had come for me use my skill as a mediator to pay my tribute to the sea.

At that time, the Woods Hole Oceanographic Institution (WHOI) had undertaken a study on coastal and marine resource management in Ecuador. By invitation, WHOI had decided to organize an international workshop in the country, with the participation of highly regarded specialists, to elicit support for the creation of a marine reserve.

But before the implementation of this plan, as Forestry Director, I lobbied the Minister of Agriculture, Marcel Laniado. The Minister was extremely open to the initiative and offered us his total support. We then immediately convened with the scientific community to elaborate on the technical justifications, background information, and objectives of the proposed marine reserve area. In the meantime, I contacted the President's legal advisor, a lawyer very supportive of conservationist issues, with whom we had worked on a preliminary version of the Presidential decree.

Success

After various meetings with government officials and presidential advisors, the final draft was approved. On April 29, 1986, the President of the Republic and six of his Ministers of State signed Decree 1810, declaring "the column of water, the seabed, and marine subsoils located within the Galápagos Archipelago, plus a 15-nautical-mile zone surrounding the Islands" to be a marine resources reserve (see decree page 4).

This event received national media coverage and was applauded by all sectors of the country. Prince Philip of England, President of the World Wildlife Federation (WWF) congratulated the President of Ecuador on this initiative and assured him that "the WWF considers it a high priority to protect and manage the extraordinary environment of the Galápagos Islands."

At present, firm steps have been taken to implement programs and projects in the marine area. The Marine Management Plan is being drawn up, and WHOI, the U.S. National Oceanic and Atmospheric Administration, the University of Rhode Island, and The Great Barrier Reef Marine Park Authority of Australia have offered their technical support.

A Difficult Road Ahead

This does not mean, however, that we can be sure that the marine environment of such an extraordinary region will be sufficiently protected. There is still a long way to go and enormous obstacles to overcome. The first obstacle is financial. Ecuador is a small Third World country with urgent problems that must be solved immediately. Very often it is difficult to convince decisionmakers of the need to invest in long-term conservation measures when so many urgent human problems demand immediate responses. In the last four years, my country has suffered tremendous social and economic damage from the 1983 and 1987 "El Niño" phenomena (see article page 42). With the present fall of oil prices, our national income has been seriously reduced. Recently we have suffered the devastation of a major earthquake that killed many people and destroyed more than 50 kilometers of our oil pipeline, interrupting our present oil exports for almost a semester. Nevertheless, I am personally convinced that Ecuador will try to meet its responsibilities in protecting the Galápagos Islands marine area. But, today, more than ever, it will need international support to fulfill its goals.

Another major obstacle is the Ecuadorian legal structure. My country has a great diversity of laws to respond to various needs, interests, and sectors. According to different circumstances, regulations are passed by Congress (laws), by the President (executive decrees), by the Secretaries of State (ministerial decrees), or by the Municipalities (bills). Many of these laws, decrees, and bills overlap and contradict themselves or hide loopholes that have been overlooked. The regulations that govern the Galápagos National Park and the urban areas of the islands are an example of the complexity of the Ecuadorian legal system. Nongovernmental organizations in Ecuador will have to play a very active role to overcome these legal obstacles.

The work of such nongovernmental organizations is above political and circumstantial pressures, and many times has proven to be more effective than governmental activities. My efforts in protecting the ocean and the Galápagos Islands would not have been possible if it had not been for the active support of Fundación Natura, Ecuador's most important nongovernmental conservation organization. The presence of such organizations in the Third World is becoming ever more prominent; they have developed great skills in promoting change and many times have proven to be more efficient, effective, and flexible in dealing with problems than governments have. The main reason for this is that the men and women who create, sponsor, and work in nongovernmental organizations are highly motivated and believe in their work. The protection of the seas and the conservation of the biosphere will be possible in the long run only through reliance on local communities and on these type of organizations.

Roque Sevilla is an economist, a member of the World Wildlife Federation International Council, and President of Fundación Natura in Ecuador.

The Galápagos Marine Resources Reserve and Tourism Development

by James M. Broadus

One of the newest and largest additions to the world's growing treasury of marine reserves, the 50,000-square-kilometer* Galápagos Marine Resources Reserve, may also be the most fascinating. The virtually pristine Galápagos marine environment is remarkable for the abundance and variety of wildlife inhabiting it, as well as for its unusual mixture of prevailing oceanographic conditions. These features have been described by G. M. Wellington (1984), who highlighted the high proportion of unique species, the diversity of habitats and species, the odd assortment of biogeographic kinships, and the scientific importance of this oceanic area.

The new reserve is fascinating, however, not only because of the spectacular nature of the Galápagos marine environment, but also because of the management issues at stake and the process through which they are being addressed. The basic issue is how to assure protection of this special place, while recognizing the demand by tourists for access to its wonders, and the desires of local inhabitants to benefit economically. Declaration of the Galápagos Marine Resources Reserve grew out of a master planning effort for the entire archipelago, and the difficult task of devising a practical management plan for the reserve provides an opportunity to improve the integration and effectiveness of tourism regulation and development efforts with fundamental conservation principles.

Artificial pressures on the Galápagos marine environment now appear relatively minor. They include some danger of small oil spills or cargo loss, trash from tourist vessels, runoff from coastal development, collecting of black coral, periodic operations of a commercial tuna fleet, and artisanal fisheries—primarily for bacalao (Spanish name for a type of grouper) and lobster. In the near term, at least, it is hard to imagine human activities imposing stresses on the marine system nearly as severe and disruptive as the natural perturbations of such large-scale events as El Niño (see article on page 42). However, the Galápagos biota has long coped with such natural variations, while human influences are more likely to be of an entirely new kind. Over a span of decades, it is likely that uncontrolled human activities would lead to unacceptable or irreversible effects. The presently undisturbed quality of the marine area is therefore a major rationale for creation of the reserve. This is a chance to perpetuate a significant unspoiled marine area before it has been subjected to heavy stress and alteration.

The Success of Marine Reserves

Establishment of marine parks and reserves has become a popular means of achieving a number of national and international goals for marine areas. The typical rationales for marine parks or reserves have been described by G. C. Ray (1976) and include protection of vital habitats; species preservation or conservation of genetic resources; provisions of research areas and assurance of comparative baseline data; recreation, education, and aesthetic goals; historical or cultural purposes; and an array of multiple-use resolutions. As early as 1962, the World Conference on National Parks invited "governments of all those countries having marine frontiers, and other appropriate agencies, to examine as a matter of urgency the possibility of creating marine parks or reserves to defend underwater areas." To date, nearly 1,000 coastal and marine protected areas have been established or seriously proposed worldwide, although many fewer than this have been fully implemented.

Habitat protection almost always plays a major role in marine reserve design; and breeding, nursery, and refuge zones for resident species are a common element. Scientific and educational values often receive greater weight than commercial economic values, although great emphasis is typically placed on maintaining recreational opportunities. The aesthetic appreciation enjoyed by

* The internal waters of the archipelago amount to approximately 50,000 square kilometers (see map page 2). The external buffer zone adds some 20,000 square kilometers for a total area of approximately 70,000 square kilometers.

Workshop on the Role of Science

A workshop on scientific research and the Galápagos Marine Reserve was held from April 20 to 24, 1987, in Guayaquil, the principal port of Ecuador. The international forum addressed the role of scientific and technical information in structuring the reserve, and the needs of the scientific community in conducting future research within the reserve.

Nine North Americans and more than 30 Ecuadorians, representing a diversity of scientific and technical institutions, participated in the workshop, which was jointly sponsored by the Marine Policy and Ocean Management Center of the Woods Hole Oceanographic Institution and the Oceanographic Institute of the Ecuadorian Navy (INOCAR).

In opening remarks, Arthur G. Gaines, the Policy Center's coordinator of foreign planning for the workshop, stated that "the process of formulating a workable management plan ultimately will involve several disciplines: law, economics, public administration, and others. Our central objective in the workshop is to address only one of these—the place and role of scientific research. From the composition of the Inter-Institutional Commission and its Technical Committee [see decree page 4], it is clear that the importance of science is recognized at the highest levels of government in Ecuador."

The Director of INOCAR, Lt. Cmdr. H. R. Moreano, summarized the work of his institute at a concluding session:

"First, the hydrographic surveys to update the charts of the Galápagos waters began some years ago and some new charts are now available, such as those of Wreck Bay, Academy Bay, Plaza Islands, Puerto Villamil, etc. Our research vessel, the R/V Orion *is presently surveying the area of Bolivar Channel, Banks and Urvina Bay, Punta Espinoza, and Tagus Cove.*

"Second, the oceanographic research, especially on the west side of the archipelago (92 degrees W), has collected almost 8 years of data with the goal of understanding the upwelling and circulation problems in the area and its implication in primary and secondary productivity.

"The last project, started in mid-1986, includes a station just south of Academy Bay for recording biological and physical oceanographic data. This project is being coordinated with the Charles Darwin Research Station.

"But the point I want to emphasize is that the information INOCAR is getting through these projects is not enough for a complete understanding of the Galápagos marine environment. This is mainly due to a lack of equipment—which is one area where international cooperation could come in. For example, during hydrographic surveys, the R/V Orion *could collect seismic, magnetic, and gravity data. This would be useful for a better understanding of the geological setting of the Galápagos Islands. Surface and subsurface current measurements using a profiler current meter, buoys, etc., could help to improve our understanding of physical problems.*

"If any foreign scientists or institutions are interested in carrying out research in Galápagos waters, a starting place would be to write a letter

visitors is also frequently a priority. Marine reserves are more likely than onshore reserves to be designed to accommodate multiple uses, and the assurance of continued traditional and artisanal uses of marine areas is a characteristic of many marine reserves. Whatever the relative weight placed on specific objectives, establishing a marine reserve can provide an organizational and administrative framework for the rational balancing of uses and goals in areas where such structure is otherwise absent. A common standard of success in many reserves is, conservatively, merely to continue the status quo while protecting marine ecosystems and water quality.

In most instances, the goals of marine reserve establishment are quite long-term in nature. Despite the relative novelty of marine reserves, several striking examples of success can be identified already. One of the oldest marine protected areas is in the United States at Key Largo in Florida. There, an impressive roster of accomplishments have been witnessed in terms of habitat protection, reef recovery from perturbation, recreational safety and management, commercial opportunities, and education. In the southern Sinai, establishment of a marine reserve by the government of Israel effectively eliminated the destructive fishing technique of dynamiting reefs. The reserve also created the basis for a healthy tourism industry in a remote area, and the government of Egypt is contemplating expansion of reserves for similar purposes. In Australia's Great Barrier Reef Marine Park, economic benefits have accrued from the combination of carefully regulated tourism with enhanced protection of natural environmental assets (see *Oceanus* Vol. 29, No. 2).

The prospect of similar benefits helped motivate the May 1986 declaration of the Galápagos Marine Resources Reserve. The reserve presents an opportunity, for the first time, to manage the

in the Galápagos Marine Reserve

to the Director of INOCAR expressing the intent of their research.

Final workshop recommendations were:

1) Science should influence the framework of the Marine Reserve management plan in two distinct ways:

a) Scientific information and methodologies serve as the basis for defining physical realities of the natural and cultural systems addressed by management.
b) Reserve Management should incorporate the needs of Ecuadorian and foreign scientists and scientific organizations for conducting future basic and applied research.

2) National and international scientific cooperation should be promoted as a means to fund and carry out the large number of research, survey, and monitoring studies needed for proper management of the reserve. The great international appeal for funding of science in the Galápagos archipelago stems from the *union* of:

a) Unusual natural features of the setting.
b) Prospects for international collaboration.
c) Ecuador's rededication to conservation of natural systems for science, education, and low impact use.

3) Because of the great size and complexity of the Marine Resources Reserve, remote sensing techniques should be used fully to define the environment, its resources and habitats, human impacts, and El Niño variability. More specifically:

a) Existing imagery should be obtained and made available to Ecuadorian scientists.
b) The Administrator of the U.S. NOAA should be urged to support launching of a new Coastal Zone Color Scanner satellite to replace the non-operational one.
c) Large-scale aerial photographs (color stereo pairs) of the entire Galápagos coast are needed for many purposes in managing the reserve: Ecuadorian agencies should use existing facilities and expertise to obtain these photos.

4) Public participation should be encouraged in setting goals and priorities for management of the reserve. An enhanced sense of stewardship should be instilled in all Ecuadorians with regard to the Galápagos archipelago.

5) The focus of these recommendations—science—is only one aspect of management formulation. The government of Ecuador should support the future efforts of the Inter-Institutional Commission and its technical and advisory committees in addressing other management components for the Marine Resources Reserve. **—PRR**

archipelago's ecosystem as a whole, and to fulfill the objective of its Biosphere Reserve status in the United Nations' International Man and Biosphere Program. This program seeks the protection of ecosystems representative of the biogeographical regions of the world, while also incorporating human activities. Authority of the Galápagos National Park (PNG), established in 1959 and incorporating some 90 percent of the islands' land area, was limited to onshore areas only. No mechanism existed to coordinate policies for the highly interdependent marine and terrestrial systems. Neither was there a clear framework within which to regulate human activities in the marine area and to assure their compatibility with national goals for environmental conservation in the archipelago.

Genesis of the Galápagos Marine Reserve

Naturalists have long marveled at the wonders within Galápagos waters (see box page 22), and a marine component for the Galápagos National Park has been envisaged since at least 1973. This is reflected in the 1974 Master Plan for the PNG, which called for an extension of Park boundaries 1 kilometer seaward of all uninhabited islands (only four of the archipelago's 19 islands are inhabited). A similar proposal was made at the Charles Darwin Research Station by G. M. Wellington in 1975, though his plan called for a seaward extension of 2 nautical miles from all islands and specified in some detail a marine zoning scheme. Partly in reaction to restrictions proposed in Wellington's zoning scheme, strong local opposition arose to resist the marine park proposal. In 1978, there were reports that the government of Ecuador intended to extend PNG boundaries 15 miles from all islands and to include all internal waters of the archipelago, but no action followed. Three years later, a High Level Commission to Study the Impacts of Tourism in Galápagos recommended a PNG extension of 1 to 5 kilometers around all the islands.

Local opposition to the idea may have been tempered a bit by then President Osvaldo Hurtado's 1982 speech declaring that an objective of a reserve would be not only to protect ecosystems, but to protect the islands' marine resources for the privileged use of local residents. This was followed in 1983 by a very moderate and permissive zoning proposal from Darwin Station marine biologist Gary Robinson that left virtually all traditional uses unaffected. Robinson suggested a 2-nautical-mile marine extension of PNG boundaries, but he also argued that inclusion of all internal waters would be best.

Researchers from the Woods Hole Oceanographic Institution (WHOI) also played a role in creation of the Galápagos Marine Resources Reserve. In 1983, a team from WHOI's Marine Policy Center was invited by the government of Ecuador to examine the status of coastal and marine resources management in the Galápagos. The WHOI team's 1984 report to the commission that was devising a master plan to balance conservation, tourism, and development, included this finding: "While national policy for the onshore area of the Galápagos Islands unambiguously stresses conservation of the natural environment, no clear policy seems to have been defined for the Galápagos marine area. The long-pending issue of a marine park or reserve for the Galápagos is one of the major questions facing coastal area and marine resources management there."

Among several policy options identified by the WHOI team for consideration by the government of Ecuador, were the following:

> *Establish policy that future creation of marine park or reserve in Galápagos waters is envisaged and initiate discussions and further study toward most appropriate definitions and timely implementation of such a park or reserve.*
>
> *Establish a marine park or reserve in the Galápagos immediately by decree, which could leave open the details of the organization and implementation of the park or reserve.*

As it turned out, this was more or less the course followed by the government. In July 1985, President Febres Cordero adopted, as national policy a "Plan for Immediate Action" that included: "Preparations should be made for an Executive Decree incorporating a marine reserve into the PNG." Further studies were pursued in the meantime, and in May 1986 the Presidential decree was issued (see page 4). During the process leading up to the decree, crucial political leadership was provided by Roque Sevilla, then director of the National Forestry Agency and an advisor to their Minister of Agriculture, Marcel Laniado. Günter Lisken, the country's Subsecretary for Industry and Tourism, also played a prominent role in establishing the policy, as did individuals in the Navy and Foreign Ministry. Interestingly, the reserve's 15-mile external band may have helped generate enthusiasm with some members of Ecuador's foreign policy establishment. They saw possible support for Ecuador's claim to a 200-nautical-mile territorial sea in the extension of control beyond the 12 nautical miles normally recognized for territorial seas in international law.*

The Central Issue—Tourism

Such subtle issues of international law, however important to Ecuador's national security concerns, do not approach the immediate practical importance and contentiousness of the central issue in the Galápagos: Tourism. Organized tourism has existed since the mid-1960s. It grew up within a framework of management and regulation similar to that for the PNG and the Darwin Station.

Indeed, for a number of years the tourism industry was itself an important force for conservation in the islands. The cooperation between tourism interests and environmentalists was even cited as an example for other natural areas with high tourism appeal. In recent years, however, indigenous pressures for economic development and associated political events have begun to disrupt this constructive relationship.

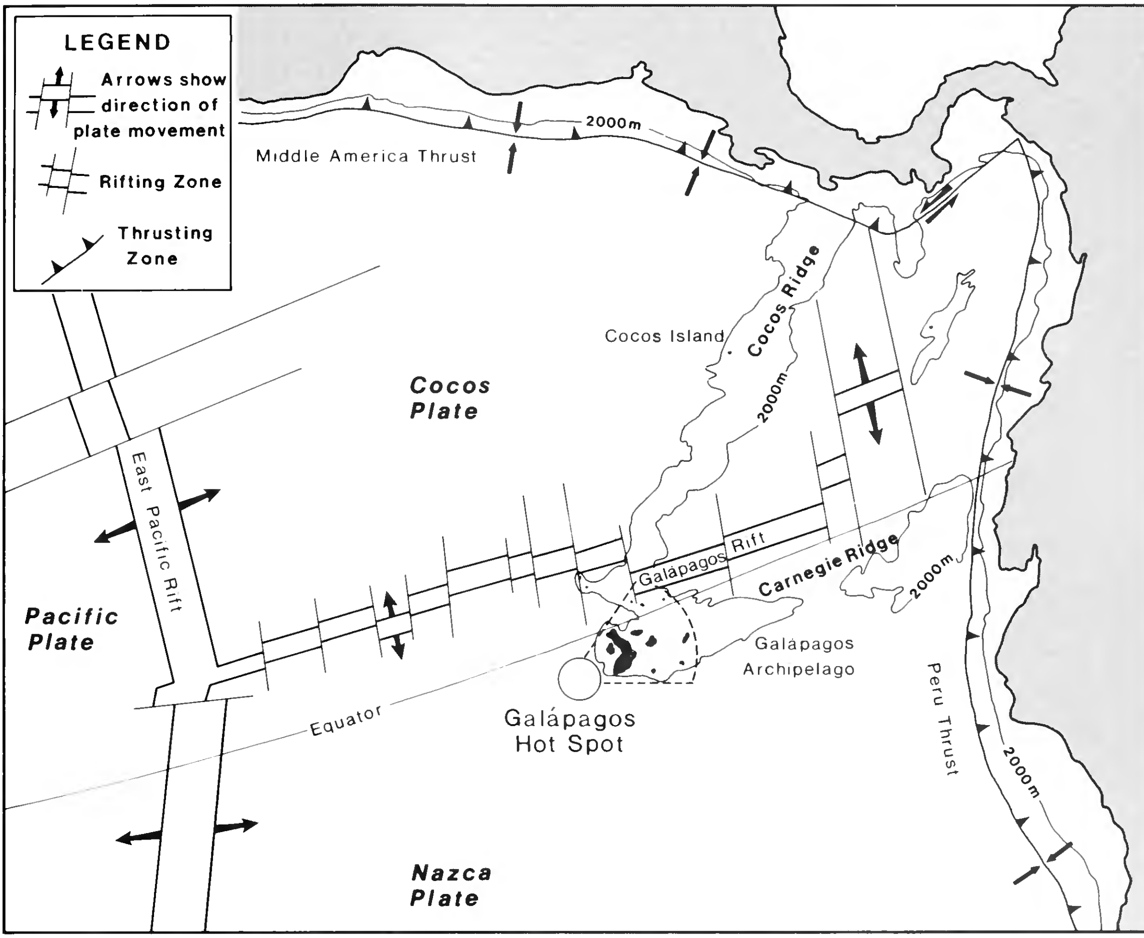
Confined to small "colonized" areas on four islands, and surrounded by arid national parklands and the Pacific Ocean, the rapidly growing Galápagos population is hard pressed for a livelihood.

Tourism now surpasses traditional farming and fishing activities as a source of employment. The annual number of visitors increased from about 4,500 in 1970 to more than 26,000 at present, with an average annual growth of 24 percent between 1976–1980.

Aside from worries about the direct effect on the environment from a growing volume of tourists, tourism growth also has the indirect effect of attracting to the islands new permanent settlers seeking a place in the industry. The permanent population now numbers more than 8,000, and in recent years the two largest colonized areas, on Santa Cruz and San Cristobal, have experienced annual population increases of about 10 percent. A ceiling on the annual number of visitors was set at 12,000 in 1973, but this was apparently surpassed in 1978. A new ceiling of 25,000 visitors was established in 1982 and confirmed in the revised master plan of 1985. This ceiling also has been surpassed. There is some pressure to raise the ceiling and little attention to the implications for permanent population increases and associated needs for additional sources of local revenue.

Quite obviously, management of the Marine Reserve will be affected by policies governing tourist access to the archipelago. By the same token, regulatory decisions on uses of the marine area will affect the tourism industry. The tourism experience in Galápagos has always been waterborne and

* Under international law, most states claim a territorial sea 12 nautical miles in width. In these waters, the coastal state has complete sovereignty, except for rights such as innocent passage and certain other historical rights. The generally common 200-nautical-mile exclusive economic zone (EEZ) implies coastal state control of the resources of the water, seabed, and subsoil.

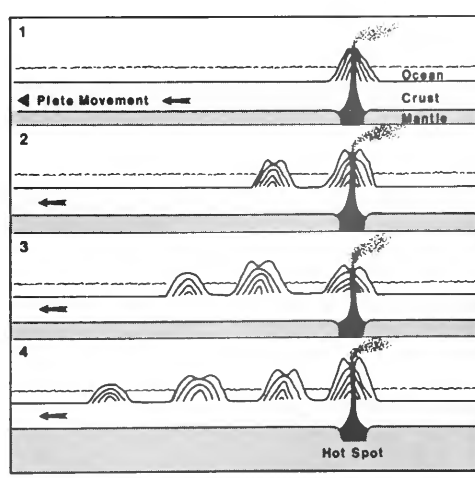


The Galápagos Islands are the tips of huge submarine volcanoes formed as a crustal plate passes over a mantle "hot spot." As a result of sea-floor spreading, the islands are moving south and east at more than 7 centimeters per year. The southeastern island of Española has the oldest dated rocks at 3.25 million years, while to the west, Fernandina and Isabela are less than 0.7 million years old. (After M.H. Jackson, Galápagos: A Natural History Guide, *1985)*

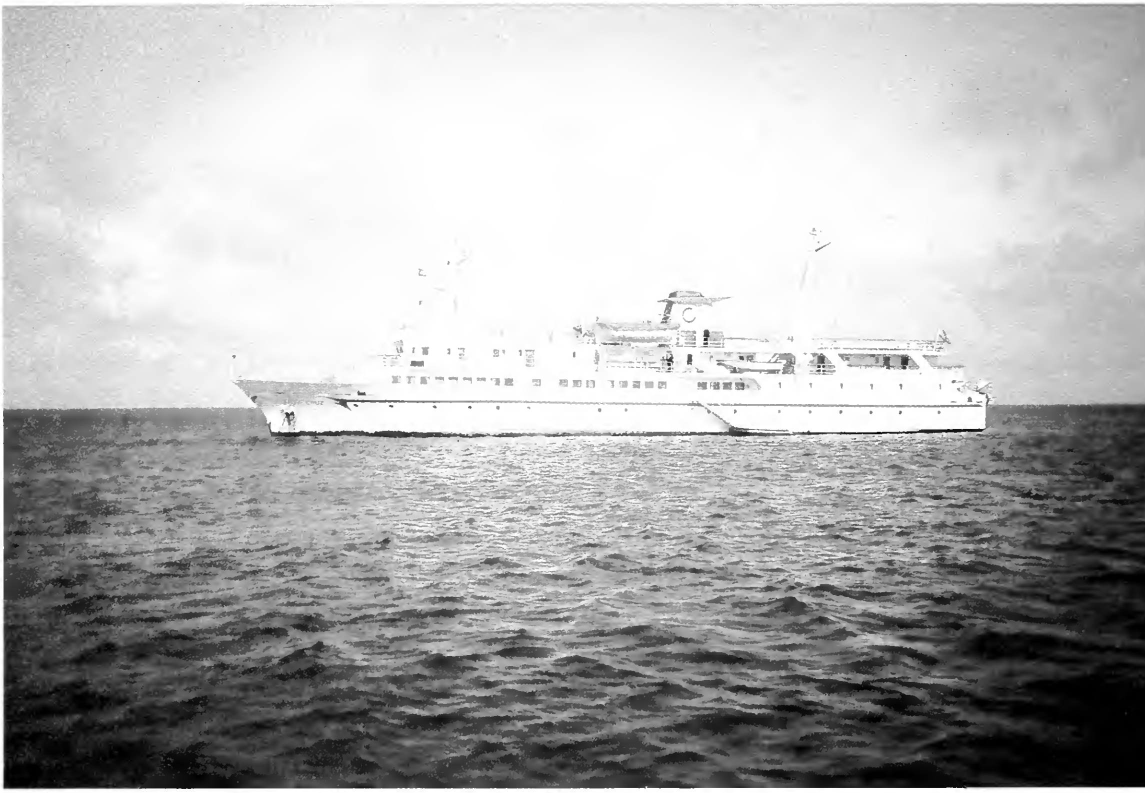
water-based. A typical tourist visit involves arrival by air (though some come by cruise ship) and almost immediate transfer onto a boat for a week or two-week tour of the islands. There are now three cruise ships (50 to 90 passengers each) operating in this way, and some 45 smaller vessels (6 to 15 passengers). Many are converted fishing boats. In 1971, there were 6 small tour boats, and 1 cruise ship.

The spectacular worldwide boom in marine recreation suggests that increasing demands for access to Galápagos waters will be expressed by tourists, and an incipient diving services trade is already emerging (see article page 20). However, there is still no mechanism for the regulation and control of such activities, and there is only a limited capability to assure the safety of diving visitors or to respond to accidents should they occur. Increasing tourist use of Galápagos waters also opens issues about the growth and control of more traditional water sports, such as spear and sport-fishing, sunbathing, recreational boating (including windsurfing), and waterskiing.

The temptation for Ecuador to relax



In the Galápagos, a stationary hot spot in the mantle gives rise to volcanoes as the sea floor moves over it. Cycles of volcanic activity leave a trail of volcanic peaks, which become older and more eroded in the direction of plate movement. (Source: M.H. Jackson, 1985)



Cruise ships bring large numbers of tourists into the new Galápagos Marine Resources Reserve, and serve as floating hotels during their stay. In addition, smaller boats can be chartered locally for day and weekly trips throughout the islands. (Photo by Arthur Gaines)

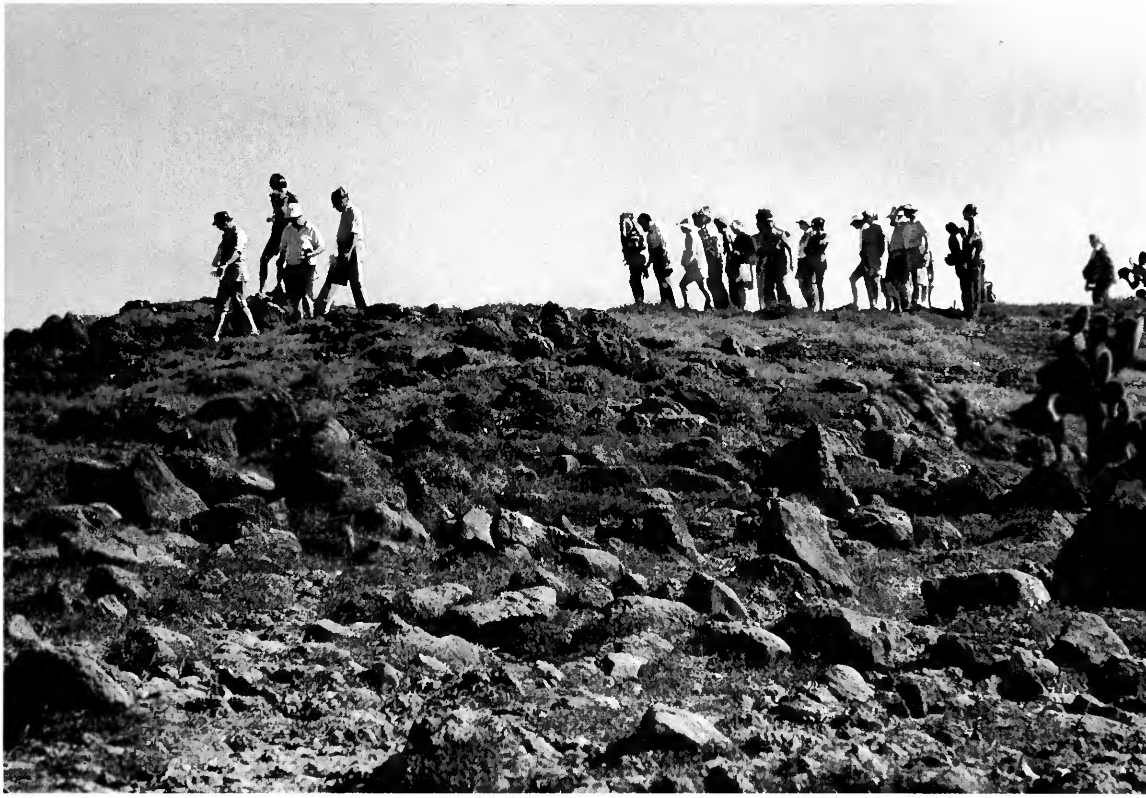
restrictions on tourism in the Galápagos must be great, for foreign revenues are at a premium and tourism is a major source. In 1980, for example, when earnings from petroleum and shrimp exports were high, tourism still generated 22 percent of the country's foreign earnings, and almost a fifth of that was from Galápagos tourism. Depending on the nature of demand for Galápagos tourism, however, some economic principles suggest that greater revenues can be earned with more restricted access and tighter controls on the market. It also has been suggested that Ecuador has many mainland tourist attractions that might be developed to rival the Galápagos, thereby taking some of the tourist pressure off the islands.

During the early years of tourism in the islands, the industry was dominated by one Quito company. In recent years, there has been a huge amount of new tourism activity. The small boat sector has grown rapidly and the variety of package tours available is proliferating. No longer must tourists "take it or leave it" with expensive, week-long boat tours. So called "economy tourism" is growing, based on hotel accommodation and day trips to nearby islands. The tourists gain, of course, in terms of savings and flexibility. The uncontrolled result for operators and the Galápagos, however, may be a maximum number of tourists and virtually no tourism profit. With associated growth in population, there must be a real concern that this process will eventually spoil the natural attraction that draws tourists in the first place.

Prognosis

Two years ago, I wrote in these pages (*Oceanus* Vol. 28, No. 1, Spring 1985) that "no proposal for the Galápagos marine area appears to be moving forward." Even then, however, the situation was hopeful: "The ingredients for progress in devising appropriate management provisions for the Galápagos marine area seem to be in place. This pristine area is of great scientific interest and of vital importance to the archipelago's terrestrial organisms. A scientific research station is already at the scene and functioning, and the station's marine research capabilities have been upgraded. A new national government is turning its attention to the situation, which commands broad public interest. A national park is a major presence onshore, and the Navy already maintains an administrative and enforcement structure in the archipelago. The Galápagos Islands themselves enjoy high international visibility. If a comprehensive management program cannot be devised and successfully implemented for this watery treasure, we must surely be pessimistic about what can be achieved for other such marine areas elsewhere in the world."

Great progress has been made in the



About 26,000 tourists visit the Galápagos yearly. Some developers seek an increase to 150,000—a number that would likely seriously stress the islands' ecosystems. (Photo by Andrew Rakoczy, National Audubon Society, Photo Researchers)

intervening two years. With the declaration of the Galápagos Marine Resources Reserve, an optimistic step has been taken. Details of the reserve's implementation must still be devised, but the policy and direction are now clear. Realistically, the goals and the planning horizon are long term. As an example, a management plan for the PNG, which has done so much to protect the islands, was first completed in 1974. The PNG itself, however, was originally established in the mid-1930s. For the Galápagos marine area, the burden of proof has now been shifted in favor of comprehensive management and protection. What this means ultimately in the face of tourism and development pressures waits to be seen.

James M. Broadus is Director of the Marine Policy and Ocean Management Center at the Woods Hole Oceanographic Institution.

Letter Writers

The editor welcomes letters that comment on articles in this issue or that discuss other matters of importance to the marine community.

Early responses to articles have the best chance of being published. Please be concise and have your letter double-spaced for easier reading and editing.

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Two Legal Opinions on the

Ecuadorian Law

by Efrain Pérez Camacho

In Ecuador, in the past century, there was already a consensus on the need of a special status for the Galápagos Islands. The Ecuadorian Constitution of 1883 calls for special laws for the Colón Archipelago—as the Galápagos used to be called in legal documents.

The most visible Ecuadorian politician of this century, J. M. Velasco Ibarra, four times president, offered to design a coherent set of rules for the management of the archipelago in 1955. "Such a law will include every aspect, among others economics, social, administrative ones, etc., to solve the multiple problems of the insular territories." Alas, such a purpose was not, and has not been fulfilled.

On the other hand, by bits and pieces, several statutes have been introduced expressly for the Galápagos on different subjects ranging from protecting and managing the park to public administration and public servants' salaries. And because the islands are a part of the Ecuadorian territory, most of continental Ecuador laws and rules, many of which encourage development, do apply. So, for the Galápagos, we encounter a dual set of rules: those special for the islands, and those general for the country.

On May 13, 1986, the Ecuadorian Government established a reserve for marine resources in the Galápagos. It included the archipelago's interior sea, a 15-nautical-mile surrounding buffer zone, the water column, and the seabed and its subsoil. A committee was established to oversee and control the reserve; its members are representatives of the following state secretaries: Agriculture (park services), Foreign Relations, Defense, Industries, and Fisheries (oversees tourism and fisheries), Energy and Mines, Planning, and the National Galápagos Institute (INGALA).

The Decree mandates that a management plan be made, which should address policy, management, development, and control of the marine reserve. The Forestry Law (decree 1529, 22 February 1983) calls for specific management plans for State natural areas that should contain, among others, the following items: basic information, inventory of the area, verification of boundaries, objectives of the area, zoning, programs of interpretation and research, direction, management, and protection of the environment.

The task of the management plan for the marine reserve in the Galápagos is a challenging one, both because of the great area involved and because it will be the first of its genre. The management plan for the Machalilla terrestrial and marine park, on the coast of continental Ecuador, has been just finished, but it can not be said that its circumstances and ecological environment are similar to the Galápagos, so the Machalilla management plan will not be of much use as a background for the Galápagos case.

The Galápagos marine reserve falls under the provisions of the Forestry Law, Natural Areas and Wildlife (Law No. 74, 24 August 1981). It is basically a biological reserve, which is defined in the law as an area of variable surface, that could be in either the terrestrial or the aquatic environment and that is dedicated to the preservation of its species.

Additionally, because of the potential for mineral resources on the Carnegie Ridge, near the archipelago, the seabed and the marine subsoil was included as well into the reserve; so the name is not just "biological reserve," but rather marine resources reserve, that encompasses both the living resources and mineral ones.

In the case of mineral resources, the idea is to spare the archipelago of the possibly disastrous ecological consequences of a future industrial exploitation in great scale.

The Forestry Law does not include among the categories of natural areas of the State the reserves of marine resources. But as the establishment of such a reserve is an administrative matter, it is well within the authority of the Executive Branch to create one. What it means is that more flexibility is given to the concept of reserve; enough for additional resources to be included in it. So, my interpretation is that for the Galápagos marine resources reserve, the Forestry Law applies, plus additional provisions to be established in the future through executive decrees.

The presidential Decree of 1986, after declaring the reserve, charged an ad hoc committee to come up with a management plan within a six

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Galápagos Marine Reserve

International Issues

by Kilaparti Ramakrishna

On May 13, 1986, the President of the Republic of Ecuador decreed the "archipelagic waters" of the Galápagos Islands along with a surrounding band of waters 15 nautical miles in breadth to be a "Marine Resources Reserve" falling under the "exclusive domain" of Ecuador. (See decree page 4).

The decree recounts several steps taken by Ecuador in the past that accorded highest priority to the protection and preservation of a large number of unique ecological features of the islands. A consensus existed in Ecuador on the need for a special status for the Galápagos Islands as early as the 19th century. In fact, the Ecuadorian Constitution of 1883 called for special laws for the Colón Archipelago, as the Galápagos were then called in legal documents.

The 1986 decree, as drafted, raises interesting international legal issues. These are issues that arise when any coastal State proposes to designate a given area as a marine park or sanctuary. The situation is a little more complex when the coastal State is a developing country, and the area covered is not entirely within its internationally recognized territorial waters.

In this connection, it is important to note that Ecuador has claimed *territorial* waters to a distance of 200 nautical miles from the appropriate baselines both along the mainland and around the Galápagos Islands and that Ecuador has not signed the United Nations Convention on the Law of the Sea of 1982 (UNCLOS), which states that the breadth of the territorial sea, over which the coastal state has sovereignty, shall not exceed 12 nautical miles.

Therefore, when the Marine Resources Reserve Decree established Ecuadorian "sovereignty" over a band of 15 nautical miles extending seaward from the archipelagic baselines drawn earlier, it had the effect of extending the Ecuadorian jurisdiction by 3 nautical miles beyond the internationally recognized limit for the territorial sea.

If, as several commentators have pointed out, the 200-nautical-mile territorial sea in Ecuador and some other South American states is comparable with the now recognized concept of "exclusive economic zone" (EEZ), the 15-mile band would gain considerable importance. The question that then needs to be addressed is: What kind of restrictions does Ecuador plan to impose in these waters? At this point in time, however, this is unclear.

Assuming that the protection and preservation of the rare and fragile marine ecosystem of the Galápagos requires that there be restrictions on freedom of navigation and on fishing, what procedures does international law provide to accomplish this? Does one look to either conventional law or state practice? The safest way may be to look at both.

UNCLOS contains a general provision that States shall take measures necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened, or endangered species and other forms of marine life (article 194.5). Likewise, if special measures are required for "recognized technical reasons," the coastal state may adopt the view that, despite the existence of international pollution standards, certain areas of their EEZs display characteristics that call for specific measures of protection (article 211.6.a). This provision generally is referred to as relating to pollution from vessels. Read in conjunction with the extent of the sovereign rights of coastal States to conserve and manage natural resources in their EEZ (article 56.1.a), this provision leads some to believe that UNCLOS provides for the establishment of special protected areas.

The key determinant, however, is the phrase "recognized technical reasons." Some government spokesmen in Ecuador have been reported explaining that the 15-nautical-mile boundary is determined by the foraging range of certain protected species of marine birds based in the reserve. It is not clear, however, if this is a sufficiently recognized technical reason. This determination can be made only by an appropriate/competent international organization, and the coastal state shall implement international rules and navigational practices so recommended by the organization.

In addition to UNCLOS, the other reference to the establishment of special areas can be found in the Convention for the Prevention of Pollution from

continued on page 19

months period that could well be extended far beyond. A management plan has several elements, like zoning, uses, etc., that we are not covering in this article, even if they do indeed present legal and institutional problems. We believe that any short-term legal and institutional study should immediately address the legal status of the fisheries and the restructuring of the public administration in the islands. As for national fisheries, there are both artisanal and commercial ones in the Galápagos.

The artisanal fisheries do not pose any immediate or significant problem as they are now. The studies conducted on these fisheries seem to agree that there is not any danger to the species of the islands that could be caused by such activities. A thorny issue, that is as ecological as it is economical and political, will be the very likely situation that must arise with the improvement of the gear and reach of those fisheries. Should they still be allowed to work their trade or what kind of legally enforceable limitations could be imposed on them?

The Ecuadorian commercial fisheries can not operate in the area of the reserve. How this will affect the national tuna fleet and how this prohibition should be interpreted in its relationship to the Fisheries Law is not known.

The main institutional problem that the Galápagos marine reserve poses is an administrative one. Administrative problems already exist for the National Park and they will be compounded by the establishment of the reserve. We have a few questions that we believe should be urgently addressed by the management plan:

- *The Galápagos National Park has functioned successfully for most of the archipelago's terrestrial area for a long time and its achievements have obtained international praise. Its main problems are financial and lack of adequate staff. Good coordination with other public offices in the islands has not always been possible. So an immediate question comes to mind: Should the marine area of the Galápagos reserve be managed by the same office that is managing the land area of the National Park?*

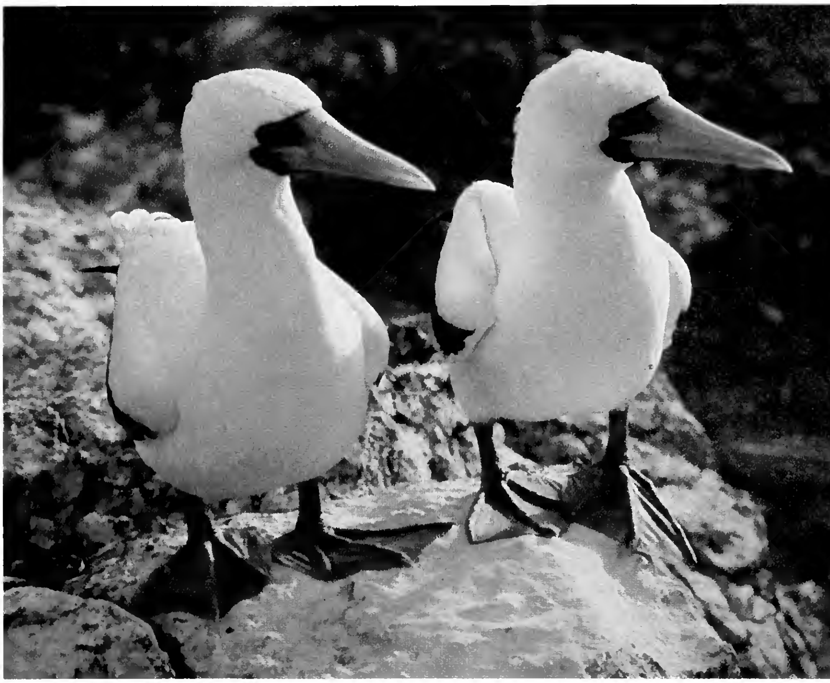
- *We have mentioned the development-oriented bias of the Municipal Law in Ecuador that is applied to the Galápagos as well. How can we adapt the Municipal Law in a way that the municipalities' actions in the islands intermingle more appropriately with the Galápagos unique environment?*

- *The public offices in the islands have different objectives. Their actions sometimes contradict and supersede, creating conflicts and hindering the work of the park and, assuredly in the future, the work of the reserve. Would it be more convenient to join the whole of the state activities under a single ad hoc authority? In that case, what should be the nature of the civil servants' work and salary regime?*

- *Furthermore, the Forestry Law, Natural Areas and Wildlife regulation allows for conservation, education, and research activities in the resources of the biological reserve. What kind of arrangement can be established that will allow scientific research to be translated into better policies for management of the reserve?*

The Ecuadorian legal system does not have an answer for these questions. Effectively, it has a developing country juridical structure, that is, one that encourages and fosters growth and development. As the Constitution of 1883 put it plainly more than 100 years ago: We need a different set of laws and regulations for the Galápagos. The new Galápagos statute must contain rules for the adequate improvement of the living standards of the islanders, delicately balanced with the preservation of the archipelago's environment: We should be seeking a true eco-development.

Efrain Pérez Comacho, an attorney, is an authority on the Public Law of Ecuador and has been a Guest Investigator at the Woods Hole Oceanographic Institution's Marine Policy and Ocean Management Center.



The new Galápagos Marine Resources Reserve includes a 15-nautical-mile external marine buffer to protect the foraging range of seabirds, such as these masked boobies. (Photo by D. J. H. Phillips)

Ships of 1973 (MARPOL Convention). Annex 1 defines "special area" as a sea area where recognized technical reasons require the adoption of special mandatory controls over oil pollution. Even here, however, the determining factors are the oceanographic and ecological requirements *as well as* traffic of a particular character. Accordingly, it may be concluded that there are difficulties in using this provision to impose a blanket ban to protect an area.

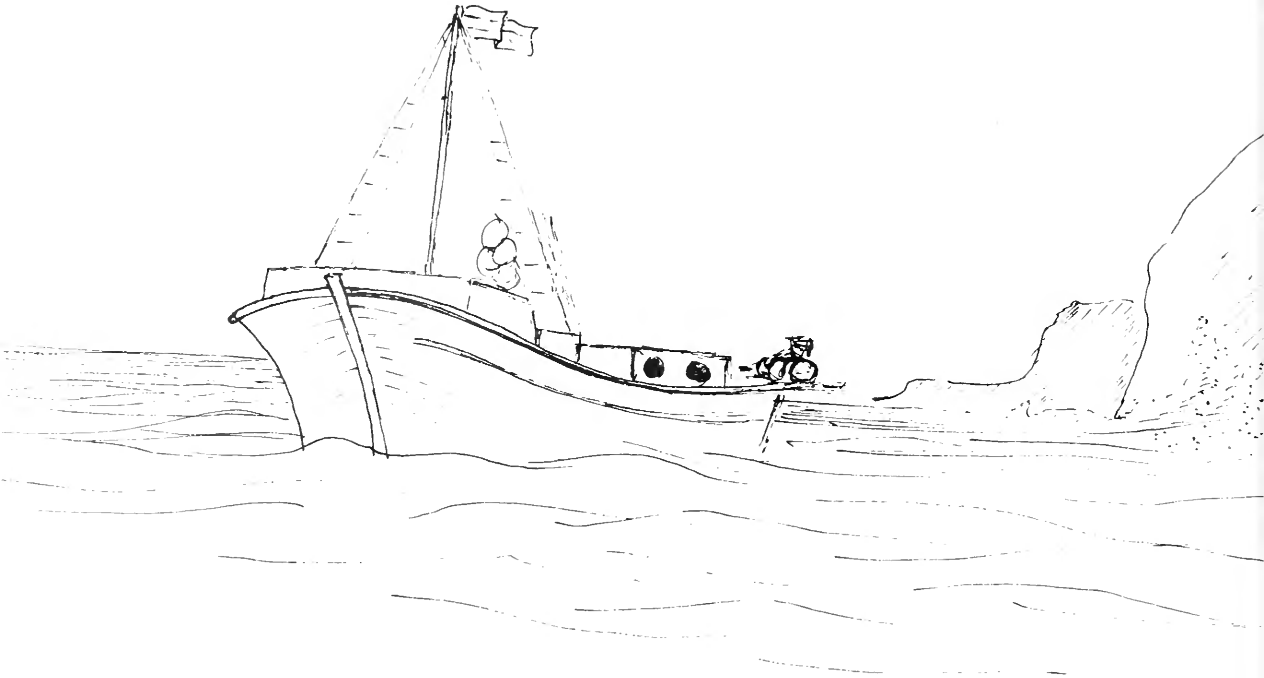
Other conventions of importance are the Protocol Concerning Mediterranean Specially Protected Areas and the Protocol Concerning Protected Areas and Wild Flora and Fauna in the East African Region. The first protocol was established in 1982 under the Convention for the Protection of the Mediterranean Sea Against Pollution (1976). The second was promulgated under the Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region (1985). Both protocols make special provision with respect to the establishment of a protected area "contiguous to the frontier or to the limits of the zone of national jurisdiction of another party," thus requiring consultations between parties and facilitating international co-operation.

In addition to provisions in these multilateral conventions, several national legislations also were in place that relate to specially protected areas in the sea. Leading examples may be found in the laws of developed countries such as Australia, New Zealand, the United States, Britain, and West Germany and in the laws of some developing countries such as Antigua and Barbuda, Barbados, and Bermuda. More detailed study is needed to substantiate whether available conventional law and state practice bring out a clearly recognizable general principle of international law and, if so, what its connotations may be.

All this notwithstanding, it is reasonable to say that a substantial body of conventional law and the makings of customary international law (not a well-developed body of law at this time) exists for the protection and preservation of unique and fragile marine ecosystems. In light of the above, the declaration by Ecuador establishing a 15-mile band around the Galápagos is not in itself a major departure from either the customary or conventional law. It must, however, be said that Ecuador has as yet done very little to gain acceptance from the competent international organizations for any "recognized technical reasons."

Treating the terrestrial and marine environments as one large marine ecosystem and adopting an ecosystem concept of management in Galápagos is urgently needed. At the same time, the Government of Ecuador should consult with the concerned/competent international organizations in obtaining wider support of the Galápagos as a specially vulnerable area and convincing them that special regulations are warranted to safeguard its environment for future generations. In the present case, the concerned/competent international organizations include the International Maritime Organization, and the Food and Agriculture Organization. It is true that these organizations may take anywhere between two to three years to bring into effect any of the accepted special regulations. Ecuador in the meanwhile would have some valid legal bases to impose the required restrictions.

Kilaparti Ramakrishna is a Fellow at the Marine Policy and Ocean Management Center, Woods Hole Oceanographic Institution. He is also a Visiting Scholar at the Harvard Law School, Cambridge, Massachusetts, and is on leave from the Indian Society of International Law, New Delhi, India.



Author's rendition of modern lobster fishing in the Galápagos, using surface-supplied air. This method consists of the use of a normal regulator supplied with air from a compressor carried on a small dinghy, which is equipped with an outboard motor.

Diving in the Galápagos

By Godfrey Merlen

The 19th and 20th centuries have opened the door to exploration and exploitation of the marine environment. Until then, investigations beneath the water had been limited to a few adventurous humans using primitive equipment and risking life and limb in the process. The Industrial Revolution made available new materials and machinery capable of compressing air to compensate for the tremendous increase of pressure with depth. This eventually led to the invention of SCUBA (self-contained underwater breathing apparatus), giving amateur and professional diver alike the flexibility of a fish. With the use of a diving mask to restore his vision to its excellent aerial quality, a new dimension was opened in which man could exercise his natural curiosity and manual dexterity.

The extent to which this has occurred during the last 40 years has led to concern—in certain areas there is grave danger of divers despoiling marine environments by over-exploiting marine resources and physically damaging areas of great beauty.

The Galápagos are now in a critical period with regard to the direction that man will follow in his use of the marine environment. In May of 1986 the internal waters of the archipelago (that is, the waters contained within the figure formed by connecting the extreme points of land) plus 15 nautical miles to seaward were proclaimed a Marine Resources Reserve by the Ecuadorian Government (see map page 2). This is a major step forward, but it is extremely important that when the laws regarding the area are established, much consideration be given to the place of diving for gain and for pleasure.

Laws governing the terrestrial islands can provide a model. Public access is allowed to the National Park (established in 1959), but that access is limited to specific areas and under strict rules to provide protection for the fauna and flora of these

remarkable islands. The marine subsurface dimension is as varied and magnificent as the terrestrial section of the islands, and will require the same type of planning if the overall integrity of the island ecosystems is to remain intact. The two sections are inextricably linked through food webs of many organisms, ranging from crabs to sea lions.

Earliest Divers

Although there can be no doubt that people were exploiting the sea for decades or even centuries before the present, the first instance of diving in the Galápagos that I can find comes from William Beebe's *The Arcturus Adventure*, which deals with his voyage in 1925 as a part of the New York Zoological Society's Oceanographic Expedition (see box page 22). This exploratory effort was made with a hard hat

At left, diver in Galápagos with porcupine fish (Photo by T. M. Rioux, WHOI)

'Before One Could Remember To Be An Ichthyologist'

Beebe in diving helmet.

EDITOR'S NOTE:
Charles William Beebe (1877–1962), an American biologist and natural historian, was a rare combination of scientist, explorer, and literary talent. Director of tropical research for the New York Zoological Society, he led many scientific expeditions—and among them several trips to the Galápagos. One of his many books, *The Arcturus Adventure*, chronicles his 1925 trip to the islands. In the chapter, "With Helmet and Hose," he expressed, with typical imagination and wit, the wonder of his first diving experiences. (In 1934, Beebe descended in a bathysphere to a record depth of 923 meters in waters off Bermuda.) A sample of "With Helmet and Hose" follows:

During the first part of the Arcturus *adventure, the sea was too rough to think of using it, even a few feet below the gangway, but when we moored close under the cliffs of Darwin Bay at Tower Island I brought up the box from the hold and unlimbered the diving apparatus. The helmet was a big, conical affair of copper, made to rest on the shoulders, with a hose connection on the right side and two oblique windows in front. Around the bottom extended a flange on which four flattened pieces of lead were hung, each weighing 10 pounds. This made a total weight of 60 pounds for the entire thing. The hose, which was of the ordinary common or garden variety, was attached at one end to the helmet and at the other to a double-action automobile pump, which screwed to a board, and was operated by a long iron lever, pushed back and forth. . . .*

Our regular mode of diving is as follows: We start out from the Arcturus *in a flat-bottomed boat which has a square, 18-inch glass set in the bottom amidships. To the stern is fastened a long, metal Jacob's-ladder, rolled up when not in use. We are towed or we row to the shore, preferably to the base of cliffs or steep rocks, as that affords considerable depth close inshore and rocky places are beloved by hosts of fish. We anchor as close to the cliffs as is safe, and roll out the ladder, so that it sways in midwater or rests upon the bottom. The pump is in the bow, the handle fixed, and the leather washer carefully screwed in. The hose is cleared of kinks, and is looped, partly overboard. A hand line is tied to the top of the helmet, and the inside of the glass windows is coated with a film of glycerine to prevent the breath of the diver from condensing and so clouding it. The four lead weights are slipped over the flange on the helmet base and all is ready for the diver. A hand water-glass is near for constant lookout for danger, and one or two long-handled harpoons.*

In bathing suit I climb down the ladder over the stern, and dip to my neck, being careful not to wet my head. Then John lifts the helmet; I give a last, quick look around, draw a deep breath, duck into it, and as it settles firmly on my shoulders, I climb slowly down. The sensation just above water is of unbearable weight, but the

weighing about 60 pounds, utilizing a hand-operated compressor located in a small boat. Beebe's descriptions of the sharks and brightly colored reef fish are interesting, but one senses a nervousness of being inside such a cumbersome piece of equipment, with its extremely limited view of the outside world.

Commercial Diving for Lobsters

Commercial diving in the Galápagos seems to have *instant I immerse this goes and the weight of the helmet with all the lead is only a gentle pressure, sufficient to give perfect stability. . . .*

From a blurred view of the water surface and the boat's stern, I sink instantly to clear vision under water. I descend three rungs and reach up for the short harpoon or grains which is put into my hand. At the fourth or fifth rung the air presses perceptibly on my ears and I relieve it by swallowing. This ceases as soon as the helmet is entirely under water. I descend slowly, swallowing now and then, and when the last rung has been reached, I lower myself easily by one arm, and lightly rest on the bottom. If serious danger threatens or the pumping should go wrong for any reason, I have only to lift up the helmet, duck out from under it and swim to the surface. The level of the water keeps constantly at the level of my neck or throat, and if I lean far forward it gradually rises to my mouth. . . .

I walked or half-walked, half-floated, toward the cliffs. The rocks were almost bare in this bay, like those between tides, and the multitudes of lesser aquatic creatures were concealed beneath them. The water was quiet, and between surges was often perfectly clear, so that I could see plainly the cliffs rising high in air above that narrow straight line which marked the division between the two kingdoms. I went as far as my hose tether would permit and reached a boulder on which, the day before, at low tide, I had sat comfortably in the clear, cool air of the upper world.

Turning back, I saw that I had become a Pied Piper of sorts, leading a host of fish which followed in my train. The sun was out now in full strength and no fish, however strange and unknown to me, could hold my eyes from the marvel of distance. As I walked toward the cliffs I had also worked a little toward the east and the view I had, as I turned, was of another slope than that over which I had come. The bottom thus far was not wholly unlike the cliff above the water, but before me now the slope fell away in a manner which was beyond all experience—a breath-stopping fall, down which one could not topple headlong, but only roll and slide slowly, to be overcome, not by swift speed of descent or smashing blow, but by a far more terrible slow increase of pressure of the invisible medium, whose very surface film is death to us. . . .

My range of vision was perhaps 50 feet in every direction, but for all I could tell it might have been 50 feet or 50 miles. The sun's rays filtered down as though through the most marvelous cathedral ever imagined—intangible, oblique rays which the eye could perceive but no lip describe. With distance, these became more and more luminous, more wondrously brilliant, until rocks died away in a veritable purple glory. No sunset, no mist on distant mountains that I have seen, could compare with this. One had to sit quietly and absorb these beauties before one could remember to be an ichthyologist.

As I was revelling in pure sensuous delight at this color of colors, a small object appeared in mid-water close to my little glass window, and was instantly obscured by half a dozen little fish which darted about it, some actually flicking my helmet with their tails. Just as I saw that the suspended object was a baited hook, a baby scarlet snapper snatched at it, darted downward, and was at once drawn up into the boat. As I looked after it an idea came to me and I followed the snapper upward by way of the ladder. When the helmet was lifted off and I could speak, I expressed my wants, and descended again. Soon there fell slowly at my feet a small stone to which was tied a juicy and scarcely dead crab. I picked this up, waved it back and forth so as to scatter the impelling incense of its body and as if by magic, from behind me, from crevices upon which I was seated, seemingly materializing from the clear water, came fish and fish and fish. . . .

. . . Adam-like, I had to give them all temporary names, until I could identify them, or christen them with my own binomial terms. It was long before I could disentangle individual characteristics from the whirling mass. The first four fishes rushed for the bait . . . so that until I could shut my mind to the abstract marvel of it and my eyes to the kaleidoscopic, hypnotic effect, ichthyology gained little of specific factual contribution. Within three minutes from the time when the crab first fell into my hand, I had 500 fish swirling around my crab and hand and head. Similes failed. I thought of the hosts of yellow butterflies I have seen fluttering at arm's length on Boom-boom Point; I thought of the maze of wings of the pigeons of St. Mark's, but no memory of the upper world was in place here,—this was a wholly new thing.

Acknowledgment

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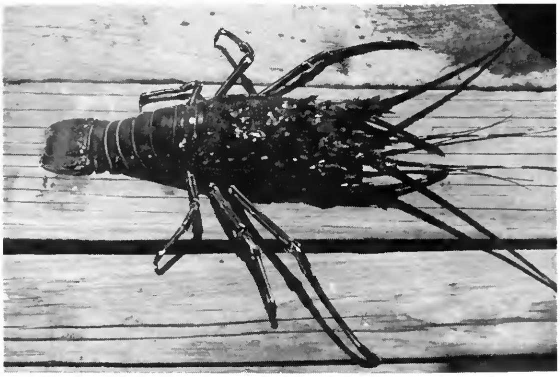
begun quite late. The first attempts to harvest resources from these waters through diving were associated with the spiny lobsters—the red, *Panulirus penicillatus*, and the blue, *P. gracilis*. It is common knowledge that one used to be able to walk along the rocky shore of the Galápagos and see the antennae of these animals just below or even above the surface of the sea, and that bags of them were gathered by native residents with little effort.

During the 1960s, however, interest began in



Much has yet to be done to ensure a future for the islands' spiney lobsters, such as the blue variety shown here.

a commercial catch. Divers captured the lobsters using face masks alone. An original plan called for the crustaceans to be stored in a large steel trap and fed on fish until an airplane equipped with dry ice came to collect them. There were reportedly about 10,000 lobsters in this trap at one time! The event failed, though, due to poor arrangements, and the lobsters were released, with 25 percent of them lost as the result of crushing.

Nonetheless, the lobster business developed rapidly with the arrival of freezer ships such as the *Villamil* and *Agrimar Chile*. These large vessels collected lobsters from a local, land-based freezer plant, and also had their own divers. By now, swim fins and snorkels had been added to the gear, and some divers were starting to use wet suits. The vessels operated as motherships to a flotilla of small dinghies and greatly accelerated the exploitation of this resource. On a round-trip from Guayaquil of 40 days duration, with 10 divers, 4,000 to 5,000 pounds of lobster tails were extracted. The price in these early days was about 9 U.S. cents per pound.

Both traps and bottom nets were eventually experimented with, but both failed. The first traps were constructed of wood, but these were destroyed by sea lions who, we assume, wished to get at the lobsters. Later, steel traps were constructed. Although initially successful, they were never used again, partly because of lack of experimentation with baits. It was still cheaper to dive for the lobster, and it was felt that people could not be trusted to leave other people's traps alone! Bottom nets, although quite effective in catching lobsters, were also destroyed by sharks and sea lions, so this experiment too was abandoned.

I suspect that SCUBA was first seen in the Galápagos during the 1960s, when some work was done with it in catching lobster. However, this failed also, since the divers found that the bulk of the equipment restricted their movement, making it difficult to pursue their prey.

In the early 1970s, a vessel named the *Marisita* arrived and began the use of surface-supplied air instead of SCUBA. This method, which is still utilized today, consists of the use of a normal regulator supplied with air from a compressor carried in a small dinghy equipped with an outboard motor. Normally two divers operate down to a depth of about 10 to 12 meters. Hand spears are still the weapon of choice, as lobsters are a wary, spiney prey. The spears also serve as protection from large moray eels which at certain islands such as Culpepper and Wenman, have been known to follow divers over the reef. This equipment allows the divers to penetrate deep into caves and recesses along rocky coasts without the bulk of SCUBA. It is a dangerous operation, however, and several divers have been killed in recent years. The gear is often in poor condition and no safety standards exist in the relentless search for this profitable crustacean.

The end of the larger vessels came recently, in the late 1970s and early 1980s, mainly because of the unwillingness of the boat owners to pay their men a steady wage, so as to guarantee them some money during slack periods, or to give them social security benefits. As it was, the divers were paid solely on their catch. Toward the end of this period, a diver received about 30 U.S. cents per pound of lobster tail. This could be profitable, but, given the poor visibility and dangerous coastal surf which occur periodically, the divers often suffered physical injuries from overextending themselves when conditions were good.

Finally the divers, noting the rapidly rising price of lobster, deserted their old masters and came to the Galápagos with their own small vessels, carrying surface compressors and refrigerators, and now receiving up to 700 sucres, or about 5 U.S. dollars, per pound of lobster tail. One cannot criticize people for trying to make a living. However, in the days of the large freezer ships, the divers fished by day alone, whereas now they fish both day and night, catching lobster in their daytime refuges as well as when they are feeding at night. There is still a certain amount of free diving (masks, fins, and snorkel) done for lobster, too, but this is mostly by local tourist boats to feed their passengers.

Black Coral

Although SCUBA may not have been popular for lobster fishing, a new resource was discovered that made SCUBA diving profitable: black coral, *Antipathes panamensis*. Black coral was known to exist here for many years. A local resident, Robert Schiess, told me that, while he was fishing for bacalao (a grouper) in the late 1940s, large clumps of black coral were often drawn up—and thrown back with a curse! If only he had known.

Today the extraction of black coral is an expanding industry, bringing a price of about 2,000 to 2,500 sucres (about 16 U.S. dollars) per pound. Remarkably beautiful when polished, the coral is often made into jewelry or other ornaments. It is difficult to enter a shop without seeing cases of it for sale. Consequently, there is little hesitation by coral gatherers or lobster fishermen to maximize the harvesting of this material.

There is no doubt that both these resources, lobster and black coral, have been exploited without control. At one stage I was informed by the Superintendent of the Galápagos National Park Service that about 2,000 pounds of lobster tail a week were being exported by air from the Galápagos. Since 1971, it has been illegal to take lobsters over 25 centimeters in length or having a tail weight of more than 180 grams, as well as gravid females. But the use of hand spears often mortally wounds the lobster before the diver gets close enough to see whether the creature is undersized or a gravid female. In 1985, a moratorium on lobster catching of any sort for four months a year (December–January and June–July) was imposed for further protection. But to judge whether these laws are obeyed is very difficult. There is so little control that there are almost no details available. During an inspection of the lobster vessel, *El Salvador*, 20 percent of the lobsters were discovered to be undersized. The only inspectorate is in San Cristobel, and as most of the lobster is exported from the airport of Santa Cruz, enforcement is virtually nonexistent.

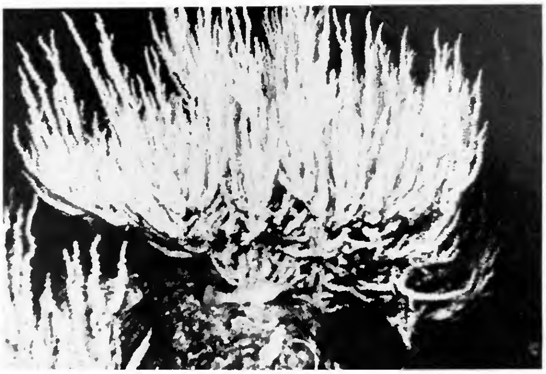
The lobster population must vary naturally from year to year depending on oceanographic conditions, but as far as I am aware, no study has been carried out to understand the dynamics of the population. It is unclear as to whether the juvenile population originates solely from Galápagos adults, or from an influx of larval forms from the central Pacific area as well. But that the population has suffered there can be no doubt. From all sides, reports come in as to the shortage of lobsters available.

It is difficult to believe that the lobster population in the Galápagos region will become extinct, since there are many areas that are extremely difficult to fish, but it does seem a shame that a locally useful industry can be spoiled by short-term greed. Clearly, more must be done to ensure a future for the lobster and the lobster industry.

The black coral industry goes on almost completely unchecked. As with the lobster, there are few statistics available, but damage is surely being done. The coral's growth rate is believed to be slow. The only brake applied to the industry is through the National Park Service where guides try to explain the problems and ask people not to bag the product. Judging from the vast amount of sale, this is not enough.

Obviously, with the introduction of the Marine Resources Reserve, we expect the implementation of laws to control the exploitation of many of the local species, including lobsters and black coral. One would expect large areas to be set aside as scientific reserves with permission to dive only (no collecting at all) with carefully controlled anchor sites and/or mooring buoys. (At many anchorage sites, diving under the vessels is like diving in a garbage dump, with old filters, plastic buckets, and so on.) Some areas will have to be set aside for traditional lobstering and fishing, and perhaps licensed coral dives, but preferably the coral business could be phased out altogether.

However, the enforcement of such laws will always be extremely difficult because of a lack of money for transport, radios, and other inspecting equipment, and a lack of wages for park personnel. The best park employees often leave the service for the more lucrative wages offered by the tour trade as guides or captains. Effective control will be expensive but is essential to the future of the region's marine resources.



Black coral, Antipathes galapagensis. *(Photo by T. M. Rioux, WHOI)*

Sport Diving

A second major use of diving equipment in the islands is also profit-motivated: the tourist trade, which utilizes both snorkel and SCUBA equipment. The very latest in designs can be seen here (although there are no dive shops on the islands). This modern gear, on the one hand, is very safe, but its introduction has accelerated the destruction of coral beds. Sport diving started about 1969 or 1970. Although it began slowly, it has now become a major industry, with a number of tour operators offering diving as an optional extra to their normal terrestrial activities. Diving around these islands is certainly fascinating and unique—one can be lucky enough to dive with penguins and flightless cormorants, with marine iguana, with sea lions and fur seals, with sharks and large grouper and snapper, rays and large eels.

There are walls of fish to be seen, yellow-tailed surgeon fish, goat fish, grunts, creole fish and white-banded angel fish. Ecologically the fish are very interesting, some with their origin in the warm tropical waters to the north, others from the cold waters to the south, and more still from the central Pacific area. There are corals of several species, including black coral colonies, whose beautiful waving fronds look like feathery submarine bushes. There are many habitats: steep walls, rocky bottoms, sand bottoms, caves, and areas rich in algae where marine iguanas and beds of garden eels may be seen feeding.

Restrictions Necessary

For commercial and sport diving to coexist, control is vital. Commercial divers need laws restricting them to protect their own future and to prevent them for despoiling areas where sport diving is active. Sport divers need laws to stop them from doing ecological damage by removing such objects as shells or endangering other divers and upsetting ecological balances by spear fishing. The philosophy of protecting areas for future generations must apply to our submarine world as much as to our terrestrial one.

The Galápagos are not an easy place to dive. The area is well known for its large animals, such as sea lions, sharks, and eels; the waters are often cold (16 to 18 degrees Celsius); sharp thermoclines exist; visibility can be excellent or very poor; and in some regions currents are very strong (2 to 4 knots). It is not an area for the inexperienced amateur diver. One needs confidence in one's equipment and confidence in one's self.

Remarkably enough, there has been no major accident among sport divers yet, be it from animal attack or failure or misuse of equipment. The sharks that are seen are relatively quiet, although several people have had close encounters with reef whitetips, and some have even been bumped by them. Once I dived through a cave and, on coming out the other side, found myself in the midst of a group of about 50 hammerhead sharks. Transformation into a rock is difficult at that point.

There is no doubt that procedures should be tightened. There is virtually no emergency help in the islands. Metropolitan Touring (the area's largest tour company) provides its yachts with an oxygen supply, but the quality of the oxygen is unknown. The nearest immediate help that can be counted on is Panama, from where the Howard Air Force Base will send an airplane free of charge. However, use of the decompression chamber in the Canal Zone carries a minimum charge of about 3,000 U.S. dollars.

Recently, David Balfour, the manager of Metropolitan Touring's office in the Galápagos, gave me some points which he considers indispensable for diving groups:

1) *Groups should be exclusively oriented to diving;*
2) *Each diver should provide a Certificate of Health and a Certificate of Diving Competency (although many of these seem to be of doubtful use);*
3) *The Galápagos tour operator should provide a guide who is a qualified diver to be responsible for and accompany each group of divers;*
4) *Only tanks, weights, and a compressor are provided in the islands. Regulators and all other equipment are the total responsibility of the diver.*

I would add that buddy diving must be the rule. When 10 divers are in the water, it is impossible for one person such as the guide to account for all people at all times. In addition, no decompression diving should be attempted.

These controls may be possible to impose on tour groups, but for the commercial diver, it is difficult to see in the near future any realistic solution. Their business is profit-motivated and they will take risks.

Scientific Diving

The most recent development in diving in the Galápagos was the arrival in 1986 of a submersible on board the vessel *Seward Johnson*, owned by the Harbor Branch Foundation. The work of the scientists on board involved collecting many forms of invertebrates and algae in the hope of discovering chemicals which may help in the control of various human ailments, such as tumors and in the production of antibiotics (see article page 69).

Securing a Future

The archipelago thus may be economically important to its residents, aesthetically pleasing to its divers, and provide medicines yet unknown. Diving in the Galápagos has grown rapidly and is basically profit-motivated. To secure a future, it is now necessary to clarify the situation and to impose and encourage conditions that will help to conserve the environment, yet at the same time allow some to make a living and others to enjoy a still magnificent undersea environment.

Godfrey Merlen, an Englishman, is a Naturalist Guide, marine artist, and underwater photographer working in the Galápagos. He recently completed a guidebook to Galápagos fishes, which is currently in press.

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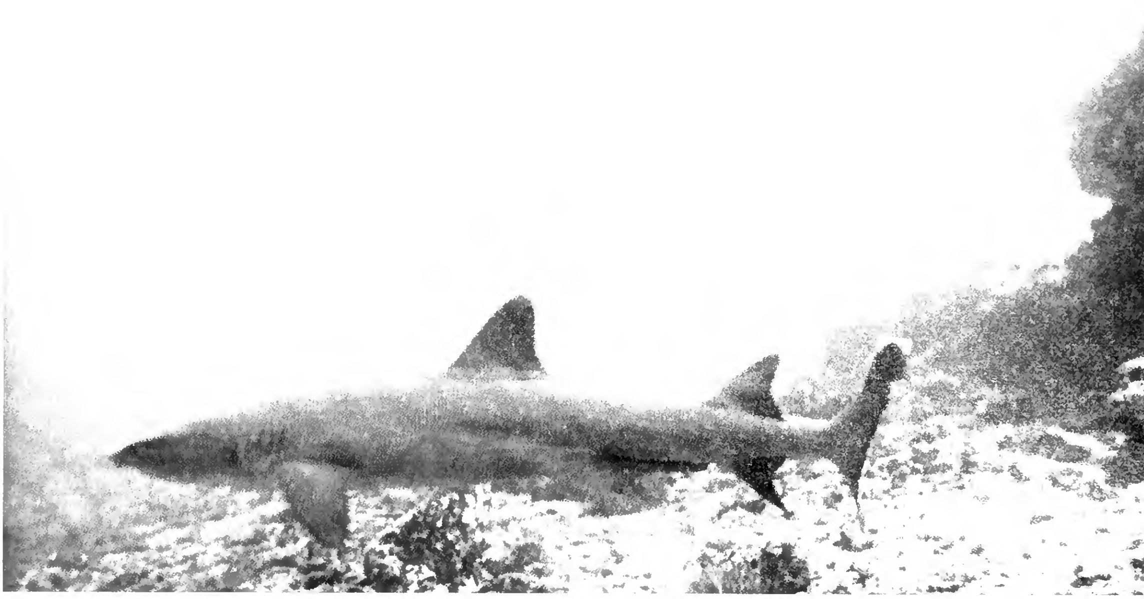
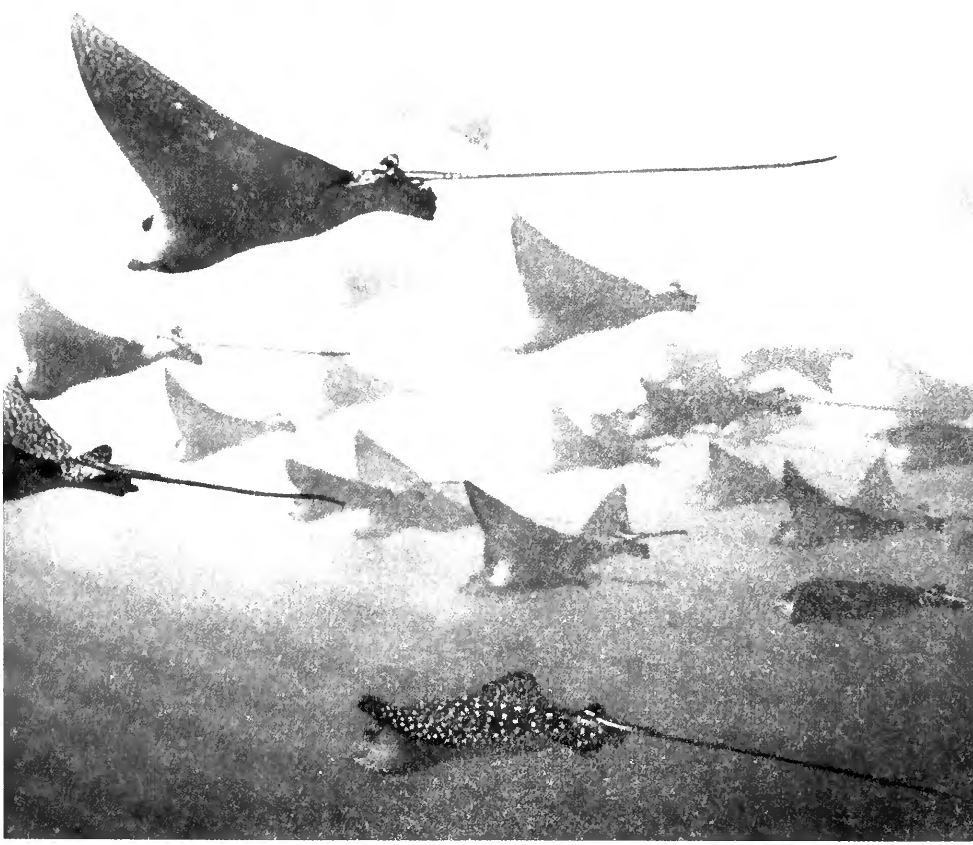
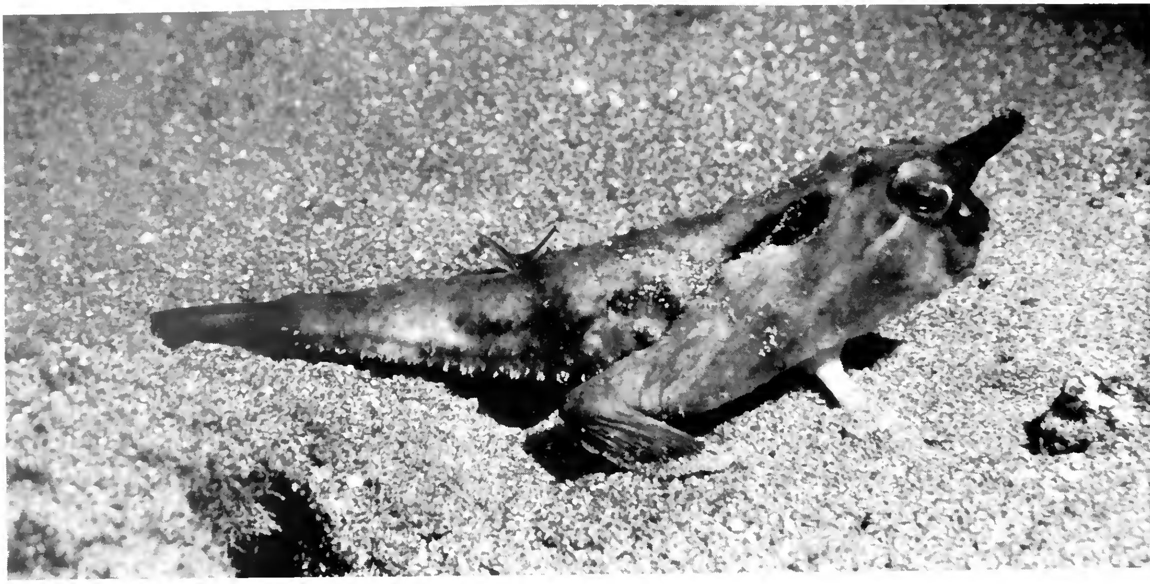


Galápagos white tip shark and turtle. (Photo courtesy of Feodor Pitcairn, © 1984, from Hidden Seascapes, *published by Little, Brown & Co.)*



A squadron of Galápagos manta rays. (Photo courtesy of Feodor Pitcairn, © 1984 from Hidden Seascapes, *published by Little, Brown & Co.)*



The Fishes of The Galápagos Islands

by John E. McCosker

More than a century and a half ago, a young naturalist named Charles Darwin visited the Galápagos Islands. Like many of his modern counterparts in marine biology he suffered from *mal de mer*, or seasickness, and was overjoyed at the sight of land. Being a curious British naturalist, he dropped a line overboard to sample the strange fishes. The 15 specimens he returned to England with were all subsequently described as new species, largely a reflection of the existing state of the art in ichthyology at the time.

Were the aquatic flora and fauna of the mainland and islands to the west better known at that time, he could have based his theories of *The Origin of Species by Means of Natural Selection . . .* on the fish, or ichthyofauna, alone. The endemism (the fact that they live nowhere else) of the Galápagos nearshore fish parallels that of the terrestrial tortoises and finches—whose ancestors found themselves in offshore isolation, then mutated, adapted, were selected upon, and evolved to become textbook examples of the process of evolution.

Oceanographic Factors

The unique nature of the fish in Galápagos waters stems from their complex geographic and oceanographic environments. These have been well summarized by Guy T. Houvenaghel, an oceanographer at the Université Libre de Bruxelles, and elsewhere in this issue.

The archipelago rises abruptly from the intersection of the Cocos and the Carnegie submarine ridges (see map page 13), forming a platform separated from the mainland by deep oceanic water no shallower than 1,300 meters. The closest inhabitable shallow reefs are those of the island of Malpelo, a small rock 435 kilometers to the northeast. These reefs probably serve as stepping-stones for certain nearshore species to or from the mainland.

In the past, geologists and paleontologists heatedly argued the age of the Galápagos. The

Above, the Galápagos batfish, Ogcocephalus darwini, *a species endemic to the archipelago, resting over a sand bottom at 10 meters. (Photo by C. Roessler)* former favored youth, perhaps no older than 3+ million years ago (MYA), and the latter, an age as far back as the Miocene (10 to 14 MYA). Recent paleontological evidence indicates that adaptive radiation of Galápagos terrestrial species occurred within the past 3 to 4 million years, apparently vindicating the geologists. Shallow water reefs may have existed several million years prior to the terrestrial emergence, however.

The archipelago consists of several emerging, steep-sided mountaintops of huge submarine volcanoes. The water barriers and/or the distance between the mountaintops has allowed the speciation of animals on shore, but this is not enough to stop the distribution of marine larvae. The endemic fishes are typically found at each of the islands possessing appropriate habitats.

A typical shore profile slopes off along sand and shell bottoms, with rich algal development in cooler waters and sparse coral development along the warmer shores. True coral reefs are absent, in that hermatypic (reef-building) corals cannot tolerate the cool temperatures of the islands. The northernmost islands (Darwin and Wolf) and banks possess the greatest abundance of coral and Indo-Pacific fauna.

Several currents meet and mix at the Galápagos. The islands are washed by the cold, salty waters of the Humboldt or Peru Current from the southeast and the warmer, fresher Panamic surface water from the east. From the west comes the Equatorial Undercurrent which, during non-El Niño years, is a stable water mass encountering the northwest edge of the archipelago and bringing with it larval and adult marine organisms from the central Pacific. During the extreme El Niño event of 1982/83, much of the shallow nearshore environment was markedly affected, including the decimation of many cold-dependent species of fishes, invertebrates, algae, and the marine iguanas (see article page 54). This event also brought numerous central Pacific tropical species to the islands.

It is likely that the extreme temperatures and ephemeral conditions associated with extreme El Niños result in the transient appearance of certain tropical Pacific species. This explains the fact that several Galápagos records are based on but a single specimen. The sharpnose pufferfish, *Canthigaster amboinensis*, and the sailfin leaffish, *Taenianotus triacanthus*, are examples of this phenomenon. Other species have been sighted but not collected, such as Klein's butterflyfish, *Chaetodon kleinii*. Such species were perhaps unable to colonize for lack of hardy larvae, or have become extinct once water temperatures became lower.

The strong equatorial surface winds create upwelling conditions along the western shores of several islands (primarily Fernandina and Isabela). That difference of 5 to 10 degrees Celsius results in lush algal growth, and the presence of fishes and invertebrates typical of the more temperate Peruvian-Chilean flora and fauna. Observations of parrotfish behavior by ichthyologists Richard H. Rosenblatt of the Scripps Institution of Oceanography and Edmund S. Hobson of the U.S. Fish and Wildlife Service attest to this phenomenon. During February 1967, an inter-El Niño year, they recorded a near surface temperature of 26.7 degrees Celsius along the northern shore of Hood Island. The southern shore

Galápagos sheephead, Semicossyphus darwini, *above a black coral-encrusted reef at 20 meters. (Photo by L. R. Taylor, Jr.)*

The Galápagos four-eyed blenny, Dialommus fuscus, *on a terrestrial sojourn in search of food. (Photo by D. J. H. Phillips)*

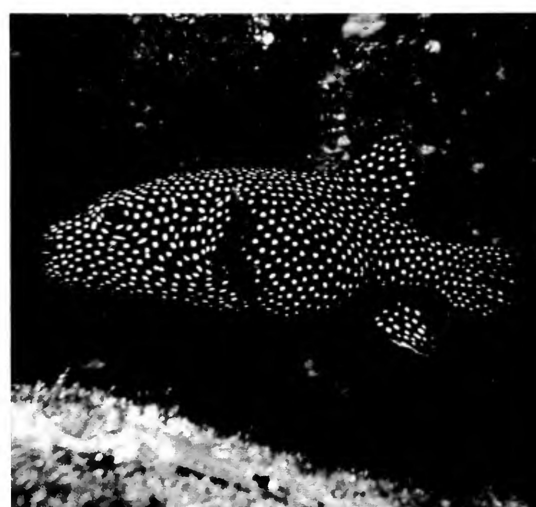
temperature was 21.7 degrees Celsius at the same depth. Only a single parrotfish species, the loosetooth parrotfish, *Nicholsina denticulata*, was seen along the southern shore. But four species of tropical parrotfishes were found along the other side of this rather small island. Thus, the upwelling phenomenon allows the presence of two rather distinct faunas on either side of an island, and significantly increases the faunal complexity of the Galápagos.

Ichthyological History

Early explorers to the Galápagos collected a few specimens of fishes, but it was Darwin that made the largest early sampling. His 15 specimens were described by his friend and fellow-naturalist, the Reverend Leonard Jenyns, in 1842. Included among those specimens was the Galápagos sheephead wrasse, which Jenyns named *Cossyphus darwini* in honor of its collector (see photo page 29 and drawing page 77).

Thirteen years later, French ichthyologist Achille Valenciennes reported on the fishes collected by an expedition aboard the frigate *La Venus* in 1838. He described 13 new species, and was the first to recognize the unique distribution of the insular fishes. Although largely ignorant of the eastern Pacific ichthyofauna, he was able to observe that the Galápagos fishes were more closely related to those of "Atlantic America" than to those of the Indian Ocean.

The first American expedition to the Galápagos was led in 1873 by Professor Louis Agassiz of Harvard University, accompanied by zoologists Franz Steindachner of Vienna and Count Louis François de Portales aboard the *Hassler*. This was followed by expeditions aboard the U.S.



Guinea fowl pufferfish, Arothron meleagris, *in its normal coloration, a species common to the tropical Indo-Pacific. (Photo by R. Ames)*

Odd Fish of the Islands

The unique oceanographic conditions of the Galápagos have acted on the shorefish fauna to allow the evolution of several remarkable species. For example, only at the Galápagos can one see the marine iguana, Amblyrhynchus cristatus *(see article page 54), making its daily procession from its volcanic perch to the sea, in search of the red algae on which it dines. In the opposite direction, one may observe the Galápagos four-eyed blenny,* Dialommus fuscus *(see photo page 30), a diminutive, mottled fish, whip-sawing its way up the shore in search of its diet of insects and shore crabs.*

The terrestrial sojourns of the blenny may take it as far as 30 meters from the sea, far from its normal predators, the groupers and snappers. Dialommus *has had to adapt to the problems of vision, locomotion, and respiration out of water. Its eye surfaces are most remarkable, in that the corneas are laterally flattened and meet at an angle of approximately 100 degrees along the vertical midline. Studies by Richard H. Rosenblatt and Jeffery Graham of the Scripps Institution of Oceanography show that such fish avoid myopia by adjusting the refraction of light incident on the cornea. In this way, the lens will produce a clearly focussed image on the retina. Gill modification, such as thickening and filament enlargement, and behavioral adaptations allow the fish to breathe air for as long as two hours.*

As a diver or snorkler, one is visually treated in the Galápagos to the harlequin wrasse, Bodianus eclancheri, *a lovely sheephead relative that exists in a myriad of color combinations. Its variable splotches of orange, crimson, black and white are reminiscent of the patterning of a Koi carp. This apparently uncontrolled harlequin coloration was studied by Steven Hoffman, then at the University of California at Santa Barbara. He explained it in terms of selective pressures in the Galápagos.*

The harlequin wrasse is a sequentially protogynous hermaphrodite (changing sex from female to male), but differs from related species in not being sexually dimorphic. It has abnormally large gonads, and the sexes are equally active. This seemingly unusual behavior is explained by Hoffman and his professor, Robert Warner. They theorize it to be a response to the predation pressures of Galápagos sea lions, Zalophus californianus wollebaeki, *and Galápagos reef sharks,* Carcharhinus galapagensis. *To avoid the extraordinary predation at the Galápagos, males of this species have increased their feeding and decreased their reproductive activities. These behaviors are quite unlike those of their mainland relatives.*

As a final example, the Galápagos batfish, Ogcocephalus darwini *(see photo page 28), is notable in that it demonstrates the influence that the absence of predators plays in isolated situations. Batfishes are small, sedentary, sand and mud bottom fishes. Along the eastern Pacific mainland, batfishes are rarely seen in shallow water and are probably limited in their range by the activity of many predators. The Galápagos batfish however, is common below 10 meters, and is so incautious as to be hand-captured by the SCUBA diver.*

—JEM

Fisheries vessel *Albatross*, and the extensive collections of Stanford University ichthyologists Edmund Heller and Robert Snodgrass aboard the sealing schooner *Julia E. Whalen*. Their activity, as well as the specimens collected by New Bedford whalers coming in for provisions at the Galápagos, brought the fish tally to 128 species by the end of the century.

In the early years of the 20th century, several wealthy Americans brought museum-associated scientists to the Galápagos aboard their fashionable yachts. William Beebe, the celebrated ichthyologist of the New York Zoological Society, visited the Galápagos aboard the *Noma* and the *Arcturus*. His accounts were published in both popular volumes (see page 22) and scientific papers. Other visits included Captain Allan Hancock's *Oaxaca* and the *Veleros I-III*. Vanderbilt's *Cressida* also made the voyage.

More extensive collecting efforts, aided by modern SCUBA techniques and rotenone ichthyocides (plant-derived fish poisons), were the 1964 Galápagos International Scientific Project, the 1977 California Academy of Sciences, and the 1984 Los Angeles County Museum expeditions. The 1977 expedition that I led discovered several new species and new records by diving to more than 60 meters. The 1984 expedition, led by ichthyologists Daniel Cohen, Robert Lavenberg, and Jack Grove was fortuitous in that many important observations and discoveries were made in the wake of the extreme El Niño event.

The curious nature of the Galápagos and its collectors has resulted in some unique captures. For example, a National Geographic team photographed a strange sailfin leaffish, *Taenianotus triacanthus*, in shallow water at Albany Island in 1978. It has never been seen since. Andre De Roy, a longtime resident of the Galápagos and avid shell collector, presented this author with the first and only known specimens of a highfinned ateleopodid, *Guentherus altivela*, and a smooth stargazer, *Kathetostoma averruncus*. He collected the stargazer by dragging a coffee can dredge in 600 meters behind his boat. In 1980, I dropped a line to the shallow 7-meter bottom while at anchor aboard the *Encantada* off Punta Espinosa. The result was the capture of a large female spotted houndshark, *Triakis maculata*, the only known specimen. These unique captures reflect the apparent scarcity of certain species, the lack of collections, and the ephemeral nature of some species occasionally arriving at the Galápagos.

Faunal Complexity

The number of fish species in the Galápagos is large when compared to that of many other tropical eastern Pacific islands. The size of this number is due to the diversity of habitats, the large area of the archipelago, and the various currents sweeping the islands. The currents bring larvae of three quite different biogeographical regions. My colleague Rosenblatt and I now consider it to contain 307 species, representing 92 families (Easter Island to the south has only 110 species, but the Hawaiian Islands have more than 470 according to ichthyologist John E. Randall of Honolulu's Bishop Museum).

The high faunal complexity of the Galápagos is directly related to its variety of habitats. Some examples are rocky shore, sand bottom, and mangrove environments. But the near absence of muddy bottom communities puts an upper limit on this complexity. Another factor limiting the number of Galápagos fish species is the difficulty that many mainland shorefish groups face in crossing 1,000 kilometers of ocean.

Ichthyologists consider the Galápagos fish fauna to be a distinct subunit of the "Panamic province"; with other elements from the Chilean (4 percent), the western Pacific (14 percent), and the eastern Atlantic provinces in addition to endemic species. Nearly 60 percent of the fishes are shared with the eastern tropical Pacific mainland. About 8 percent are worldwide in the tropics, or pantropical, such as the oceanic sharks (whitetips, whale sharks, and hammerheads), manta rays, pufferfishes, tuna, and dolphinfishes. Certain large wrasses and groupers are common to Peru and Chile, and four species, excluding the pantropicals, are common to the western Atlantic.

As previously mentioned, the high degree of endemism of Galápagos shorefishes is particularly instructive. At least 51 species, or 17 percent, are unique to the Galápagos, a condition similar to that of the Hawaiian Islands and other oceanic outposts. Among the endemics, a group of 7 species is found only at the Galápagos, Malpelo, and Cocos Island to the north.

Marine fish endemism is best explained by the vagility, or transportability of the larva and/or adult, and the duration of larval life of each species. Those fishes that are strong open ocean, or pelagic, swimmers, such as the jacks or tunas, have no difficulty in crossing the 1,000 kilometers between the mainland and the islands. Other species with protracted larval stages well-suited to pelagic life are certain groupers, blennies, damselfishes, and the almost-invisible moray eel larvae. Adult or larval forms that inhabit floating detritus, such as wrasses and certain blennies, are also able to make the crossing. This continual opportunity for genetic interchange reduces the opportunity for species to evolve.

Endemism, however, favors those forms with short larval lives unsuited to pelagic transport. Examples are croakers and grunts, which can then speciate without continual genetic swamping (but only if they fortuitously arrive in the first place). The endemic Galápagos species are usually well differentiated from their closest relatives.

The majority of endemics are most closely related to Panamic species, as one might expect from their proximity to the New World, and the great distance separating them from the western Pacific. Typical are the chaenopsid pike blennies, clinid klipfishes, and stargazers—all related to New World species. Four species are related to forms from Peru and Chile. Others do not fit the pattern, such as a burrowing snake eel, *Callechelys galapagensis*, related to a Hawaiian form; and a porgy, *Archosargus portalesii*, related only to western Atlantic forms.

Future Research

Although the nearshore fish fauna of the Galápagos, within the limits of comprehensive SCUBA collecting, is now fairly well-known, surprises remain. It is difficult to sample the craggy bottom below 50 meters, thus hindering adequate bottom net-trawling. This means that new species and new records remain to be discovered. Improvements in diving techniques will allow ichthyologists to collect in deep reef habitats.

Several long-standing handicaps, hindering Galápagos ichthyologists from becoming involved in issues of concern to their terrestrial counterparts, are about to be overcome. We will soon be able to pinpoint the geologic age of the submarine environment, and the survey of fishes is becoming ever more complete. This information will be used in comparing the evolutionary rates of marine animals to those of the finches and tortoises. We also need to explain and predict the filling of niches, or ecological saturation. In the Galápagos this information is crucial to fisheries biologists concerned with the introduction of exotic species. Finally, we are just beginning to understand the significance of the infrequent genetic influx allowed by rare climatic events, such as the extreme El Niños. Results of these projects will undoubtedly answer some questions, but pose others for future Galápagos ichthyophiles.

John E. McCosker is Director of the Steinhart Aquarium of the California Academy of Sciences in San Francisco. His research interests include the fishes of the Galápagos, and the behavior of the white shark, penguins, and coelacanths.

Marine Biological Research in the Galápagos: Past, Present, and Future

by Henk W. Kasteleijn

While the land-based biology of the Galápagos is familiar to many people, the islands' marine biology is much more poorly understood. This is unfortunate because many animals, such as the marine iguanas and seabirds, depend heavily on the marine environment. In the last 10 years, the pace of research into the Galápagos' marine biology has been increasing, but the first observations on marine life were made during the discovery of the islands themselves.

The Early Years

When Fray Tomás de Berlanga, Bishop of Panama, discovered the Galápagos in 1535, he wrote a long letter to his king in Spain. He described not only the islands and their terrestrial life, but also some of the marine creatures. He mentioned the seals and one true marine animal, the green turtle, *Chelonia mydas*.

Ambrose Cowley, a buccaneer on board the *Bachelor's Delight* with Captain Cook, remarked in his diary of June 1684 on the abundance of fish life in the Galápagos. He also wrote that green turtles (see box page 34) were so plentiful "that though wee were about 200 soules yett wee killed every morning on the Bay as many as served us all day the whole time of our abode there and might have kill'd many more. Though they differr in nature from the West India Turtle yett are very sweet wholesome meate." In addition to the green turtle, he mentioned the presence of the hawksbill and the loggerhead, which he described as "neither good flesh nor shell."

Another buccaneer, Ravennau de Lussan, made a very strange observation in 1684: "These adjacent waters are also full of fishes, that come up to die on land." Possibly a school of fish was cornered and driven ashore by sharks. Although the cause of such incidents remains unclear, one was recently filmed in the Galápagos by Dieter Plage, of Survival Anglia Films.

The large number of whales originally frequenting the Galápagos seas was first described in 1700, by Ensign Le Sieur Villefort, a French seaman aboard the frigate *Philippeaux*. The first organized reconnaissance of whales in the vicinity, however, was conducted in 1793–94 by Captain James Colnett of the Royal Navy. On this voyage, for the benefit of the British whaling industry, he also made the first workable chart of the Galápagos.

Aboard the *Rattler*, Colnett was mainly interested in the exploitable spermaceti whale, *Physeter catodon*, which he mostly saw in groups of cows with their calves. Other large whales that he found were the humpback whale and the fin whale; but he also mentioned large schools of porpoises, killer whales, and "blackfish" (small, dark, blunt-headed whales such as the melon-headed whale, pygmy killer whale, false killer whale, and short-finned pilot whale).

Captain Colnett also caught "great numbers of large Cod," within a short time at Kicker Rock, off San Cristóbal Island. These were probably the very abundant, endemic bacalao or yellow grouper, *Mycteroperca olfax*. Other species caught on the 1794 voyage were albacore, mullet, devilfish or manta ray, and bonita.

"Sharks were in great abundance," Colnett noted. He also saw squid, rocks covered with crabs, and a "few small wilks and winkles." Finally, he wrote in his journal that "A large quantity of dead shells, of various kinds, were washed upon the beach, all of which were familiar to me; among the rest were the shells of large cray-fish, but we never caught any of them alive."

One of the most famous whalers to visit the Galápagos was the American novelist Herman Melville, who was an able seaman aboard the whaling ship *Acushnet*. He chronicled his impressions of the archipelago in his short novel, *The Encantadas* (see article page 93).

For the Galápagos, the 19th century can be characterized as the century of over-exploitation. The whaling industry was at its peak from about 1790 until 1840. During this time, the whalers took blackfish, and many terrestrial and marine animals. But when the sperm whale stock in Galápagos waters was depleted, the collapse of the whaling industry in this part of the world was at hand.

Galápagos Sea Turtles

Marine turtles are perhaps the most mysterious form of all Galápagos wildlife. They remain below the waves for nearly their entire lives, hidden from the marine biologist, who's best chance to study them is during the relatively brief time they spend on land, in nesting and hatching.

The east Pacific green turtle, Chelonia mydas agassizii, *is by far the best-represented species of sea turtle in Galápagos waters. But Derek Green of the Charles Darwin Research Station admits that it is impossible to give a good estimate of their population. Green conducted an extensive study of their nesting behavior from 1970 to 1979, and was able to tag nearly 4,000 females and 10 males during the study.*

This particular species of marine turtle, averaging about 50 to 100 kilograms in weight (some large individuals can approach the weight of the Galápagos giant tortoises), is known locally as la tortuga negra, *or "black turtle." The archipelago's inhabitants also speak of a* tortuga amarilla, *or "yellow turtle," but it is very rarely seen. Biologists believe it to be a sterile mutant of* Chelonia mydas agassizii.

Two other species of sea turtles are sometimes sighted nearby, but neither nest on the islands. Green says the Indo-Pacific hawksbill, Eretmochelys imbricata, *is encountered occasionally, and that the Pacific leatherback,* Dermochelys coriacea, *was seen in the area only three times prior to 1979.*

The Galápagos are probably the most important nesting area in the east-central Pacific for the tortuga negra, *according to Green (see map page 36). The most popular beach in the archipelago for this activity is Quinta Playa, on the southeast shore of Isabela. As many as 45 females laid their eggs there one night in 1978. That year, 610 nesting females were recorded on that beach.*

Despite the many eggs laid at Quinta Playa, eggs laid at other beaches stand a much better chance of hatching. Feral pigs and the scarabeid beetle, Trox suberosus, *prey on the eggs, and both predators are prevalent on Isabela. The beetles attack turtle nests on some of the nearby beaches, but most of the other important nesting beaches on the islands are safe from them.*

The pigs pose a greater threat throughout the Galápagos. They seem to be able to identify clutches of turtle eggs the way their relatives in France locate truffles. At Espumilla beach, on James Island, feral pigs were responsible for the destruction of more than 98 percent of the eggs laid there in 1979. The (lack of a) maternal instinct in tortuga negra *females does little to help the situation, either. Darwin Station field assistant Mario Hurtado reported a case where a pig gobbled up the eggs even as the oblivious female was producing them!*

It is sometimes said that when females lay their eggs, they return to the beach where they themselves were hatched. If that is the case, in the future there should be increased nesting on beaches with less predation of eggs and hatchlings. Such beaches are Las Bachas on Santa Cruz, and Las Salinas on Baltra Island.

One of the biggest mysteries concerning the tortuga negra *is their migration patterns. Biologist Green believes that some of them are present in the Galápagos year-round, based on recaptures of tagged turtles. But he also reports that individuals tagged in the archipelago have been recovered from as far away as Costa Rica, and Peru. He says that without more recapture data it is impossible to know what proportion is truly resident and what migratory.*

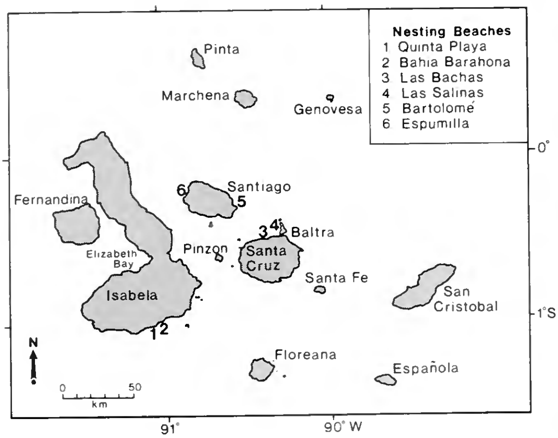
The creation of the Galápagos Marine Resources Reserve will probably have little effect on sea turtle status within its boundaries. The turtles have already been protected on the beaches throughout the islands, where they are most vulnerable; and since their flesh "is not highly esteemed" by the local inhabitants, very few have been taken from the sea in recent years.

Of course, the marine reserve can only protect those turtles that stay within it, and all three species found in the Galápagos are exploited to some extent along the South American coast. The relatively large population of marine turtles protected by the reserve is of international importance. As long as funds remain available for biologists to continue their research, the mysteries of the marine turtles will be steadily unravelled.

—TMH

Continuing beyond the collapse of the whaling industry was the fur seal hunt. But by the end of the century the Galápagos fur seal, *Arctocephalus galapagoensis*, was likewise chased to the brink of extinction.

Of course, all the whalers and hunters required food. C. H. Townsend, in an extensive study of whalers' logbooks published in *Zoologica*, estimated that more than 100,000 giant tortoises were killed within a period of 30 years. Several of the original 14 subspecies of tortoises were brought close to extinction by this exploitation (see article



Principal nesting beaches of the east Pacific green turtle, *Chelonia mydas agassizii.*

The east Pacific green turtle, *Chelonia mydas agassizii,* the only marine turtle to nest in the Galápagos. (Photo by D. J. H. Phillips)

page 86). The number of sea turtles that were slaughtered may have been as large or even larger, since they were good meat and more easily accessible. There is no information, however, on the effects of this exploitation on marine turtle populations.

Early Scientific Expeditions

The first explorer making ichthyological collections for study rather than consumption was Charles Darwin. Although a connection between the marine iguana and the sea had been noted before he arrived, Darwin was the first to verify the link. By examining their stomach contents, he learned that marine iguanas eat algae. But he also was interested in shells. He knew of the work of Hugh Cuming, who collected in the Galápagos around 1829 aboard the *Discoverer*, and noted that more than half of the 90 species he gathered were not found anywhere else (see Darwin's *Beagle* account page 72).

Robert FitzRoy, Captain of the *Beagle*, made excellent charts of the Galápagos, which were in use until 1942. At that time, the *U. S. S. Bowditch* surveyed the islands and found that FitzRoy's charts needed only slight improvement (see box page 37).

Later Scientific Expeditions

Some of the important scientific expeditions to the Galápagos of the late 19th and early 20th centuries have been recounted elsewhere in this issue, and included among them were the research voyages of the U. S. Fish Commission's *Albatross* in 1888 and 1891. Louis Agassiz's son, Alexander, accompanied the 1891 trip as chief naturalist. Using new techniques, he did much to advance the biological and geological knowledge of the islands.

Alexander Agassiz employed systematic dredging to assay the communities of jellyfish, anemones, sea urchins, and starfish near the islands. From his deep-sea work, he concluded that the Galápagos must have had a volcanic origin, since he found no topographical bottom continuity between the archipelago and the Americas.

Rollo H. Beck had already made three collecting trips to the Galápagos when he was chosen to lead the California Academy of Sciences Expedition of 1905–06. This was the longest and most elaborate collecting expedition to reach the Galápagos yet. They travelled aboard the schooner *Academy*, and spent a year and a day in the archipelago. During their stay, they collected recent as well as fossil (especially marine mollusk) material.

Many other scientific expeditions travelled to the islands, steadily increasing the knowledge of Galápagos fishes and marine invertebrates. Some of those of greatest interest with regard to marine fauna are the *St. George* expedition of 1924 and the Norwegian Zoological Expedition aboard the *Monsunen* of 1925. Karl P. Schmidt of Chicago's Field Museum of Natural History visited the islands on the *Illyria* in the early part of 1929, as head of scientific staff of the Cornelius Crane Pacific Expedition. He returned to the Galápagos later that same year on the *Mary Pinchot* as a member of the Pinchot South Sea Expedition. Schmidt made some interesting observations on marine iguanas on his first voyage, and both expeditions resulted in the description of new fish species.

Perhaps the most prominent among these early scientists was William Beebe. His work is described on page 22.

Millionaires

The wealthy readers of Beebe and Melville were often inspired to view the wonders of these enchanted islands for themselves, leading them to mount expeditions aboard their private luxury yachts. They usually carried naturalists who could explain the unique fauna and flora they encountered, and these naturalists were often able to conduct research along the way. Some of these millionaires were particularly interested in marine

*Captain FitzRoy of H.M.S. Beagle**

The importance of Robert FitzRoy's visit to the Galápagos 150 years ago has been completely overshadowed by the fact that he was accompanied by Charles Darwin. Darwin was definitely the junior partner at that time, but today FitzRoy is recalled almost solely on account of his denunciation of the Origin of Species *a quarter of a century later.*

This cause of dissension did not exist in 1835. FitzRoy was not then a serious student of the Bible and a confirmed fundamentalist, nor had Darwin become convinced of the mutability of species. Despite profound differences of temperament and political views, these two brilliant young men (FitzRoy was given command of H. M. S. Beagle *at the age of 23) were still good friends when they got back to England after sharing a cramped cabin in a tiny ship for five years.*

FitzRoy had a life-long interest in science (it was entirely on his own initiative that he invited a naturalist to be his guest on the voyage) and he showed outstanding talent in his own specialist fields. The object of the Beagle's *voyage was not to revolutionize biological theory nor to provoke the greatest intellectual debate of the century, but to chart the coasts, chiefly in South America. FitzRoy did this with remarkable skill. The buccaneer, Ambrose Cowley, had made some rough sketches in 1684 and Captain James Colnett of* H. M. S. Rattler *had improved on them in 1793, but FitzRoy's Galápagos charts are in a different class and are barely distinguishable from those in use today. The captain of the French ship,* La Génie, *who came to survey the islands in 1846, wrote of FitzRoy's achievement:*

> Nothing escaped the perspicacity of this conscientious observer: the smallest details are all indicated with really astonishing precision and following his drawing one can visualize in the most accurate manner the shape of the coast. Coming after him there is not even an opportunity to glean.

J. R. Slevin, the historian of the California Academy of Sciences' great research expedition, wrote in 1959:

> It is truly amazing that the modern chart of the Galápagos made in 1942 by the *U.S.S. Bowditch* equipped with every modern device should so closely approximate the survey made by Captain FitzRoy over a hundred years before. His little vessel was at the mercy of strong and uncertain currents, together with deadly calms so prevalent in those regions.

*When he retired from active service in 1850, Admiral FitzRoy was elected a Fellow of the Royal Society in recognition of his distinction as a scientific navigator and hydrographer: his sponsors included Charles Darwin. Later he began the organization of what became the British Meterological Office. It is unfortunate that he should be remembered, if at all, for his quarrel with Darwin and his tragic death rather than for his considerable scientific accomplishments. For more than a century his meticulously drawn charts served scientists and others navigating in the hazardous waters of the Galápagos. R. D. Keynes** sums up FitzRoy's varied achievement:*

> He deserves to be remembered not just as Darwin's captain on the *Beagle*, although the importance of the help and encouragement that he gave during the voyage, and his role in stimulating Darwin's ideas, are not to be lightly dismissed. He was also a hydrographer in the front rank, parts of whose charts of South American waters and sailing directions for them are still in use nearly 150 years after the survey was conducted. Above all he was one of the principal founders of the science of meteorology.

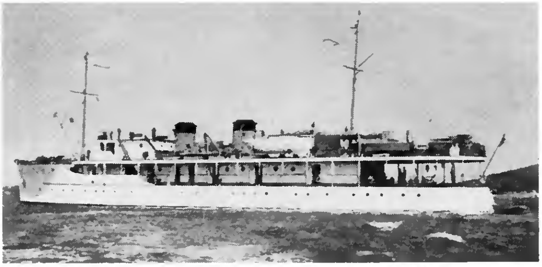
–G. T. Corley Smith

* Reprinted with permission from *Noticas de Galápagos*, 1985.
** *The Beagle Record,* edited by R. D. Keynes, Cambridge University Press, 1979.

life, and so their collections were added to the Galápagos catalog.

The Vanderbilt family enthusiastically partook of this fashion. In the 1920s and 30s, the collection of Galápagos species at the Centerport, New York, Vanderbilt Museum grew, thanks to such activities as the George Vanderbilt South Pacific Expedition of 1937. Vincent Astor took his yacht, the *Nourmahal*, to the archipelago in 1930. His expedition featured the first census of the flightless cormorants, penguins (see box page 67), and fur seals. Templeton Crocker conducted his own expeditions for the California Academy of Sciences aboard the *Zaca* in 1932 and again in 1935. This comfortable yacht was equipped with an aquarium with fresh seawater circulation, so that live specimens could be brought back to the Steinhart Aquarium in San Francisco, home of the California Academy of Sciences.

A series of expeditions to the Galápagos



The Velero III. (From 1939 Hancock Pacific Expedition Report)

organized by millionaire G. Allan Hancock began in 1927, aboard the *Oaxaca*. Hancock was particularly interested in taking scientists and students from different universities and museums on research cruises. This series of voyages also featured the very comfortable and specially equipped motor yacht *Velero III*, and lasted until 1938.

The Galápagos held a special significance for Hancock, and the results of the series of cruises are described in the impressive volumes; "The Allan Hancock Pacific Expeditions," published by the University of Southern California Press in Los Angeles. The littoral observations and collections were valuable additions to the knowledge of the islands' algae, hydrozoans, corals, flatworms, threadworms, sea cucumbers, copepods, water fleas, and crabs.

Even President F. D. Roosevelt figures into the history of biological exploration in the Galápagos. He made a long cruise through the Pacific in 1938 aboard the *U. S. S. Houston*. This expedition sampled some interesting marine fauna; particularly sponges, soft corals, sea urchins, and brittle stars.

New Techniques

With the availability of modern *SCUBA* techniques, a whole new world opened up for marine research expeditions. Animals could be collected selectively, and behavioral studies could be made for the first time. One of the first expeditions using SCUBA in the Galápagos was the International Institute for Submarine Research voyage of 1953–54. Among the many later expeditions was that of the Italian Gruppo Richerche Scentifiche e Tecniche Subacquee. In 1973, the Italians made important contributions to the knowledge of phytoplankton biomasses and primary production in the archipelago.

In 1976, the Scripps Institution of Oceanography, using their Deep-Tow vehicle, discovered thermal and chemical anomalies in the Galápagos Rift Zone, north of the archipelago. Subsequent, underwater photographs in 1977 disclosed dense benthic communities at 2,550 meters. These were dominated by previously unknown species of large bivalves, tubeworms, and crabs. The rift zone site was reviewed in 1977 (see *Oceanus*, Vol. 20, No. 3) with the unmanned vehicle *Angus*, and the deep-sea manned submersible *Alvin*, operated by the Woods Hole Oceanographic Institution (WHOI). This work led to several universities and institutions organizing the joint Galápagos Rift Biology Expedition in January 1979 (see *Oceanus*, Vol. 22, No. 2). The biological discoveries of this voyage were supported by detailed descriptions of topography, bathymetry, geology, and chemistry.

A turning point in Galápagos history was reached with the *Xarifa* Expedition of 1953–54, led by Hans Hass. He was a pioneer in discovering the frontiers of SCUBA diving, and took photographs and films of the underwater life. He and his colleague Irenaus Eibl-Eibesfeldt, who came back to the islands on his own in 1957, issued alarming reports on the status of the endemic fauna. These reports focused world attention on the Galápagos problem," and led to the establishment of the Charles Darwin Research Station, which began operation in the early 1960s.

The Charles Darwin Research Station

The problems confronting the terrestrial fauna and flora of the Galápagos in 1960 were immense. But it was questionable whether there were similar problems threatening marine species and habitats. These questions were addressed during a Galápagos symposium held as part of the 10th Pacific Science Congress in Honolulu in 1961.

Another early assessment of the marine environment was organized in 1964. The Charles Darwin Foundation, the University of California, and the California Academy of Sciences participated in this cruise, the Galápagos International Scientific Project. These studies helped to set priorities for the first scientists at the Research Station.

The first marine scientist at the Darwin Station was Guy T. Houvenaghel in 1968. He wrote his thesis in 1974 on the oceanography and geomorphology of the Galápagos marine environment. With his wife, Nadine, he described plankton and shoreline zonation. The next marine scientist was Gerard M. Wellington, now at the University of Houston, Texas. He came to the archipelago as a Peace Corps volunteer from 1973 to 1975. Wellington started an inventory of the Galápagos coastal marine environments, and recognized their vulnerability. He therefore proposed the inclusion of marine areas within existing national park boundaries. His findings and recommendations included many suggestions for the management and interpretation of a marine park, and were presented to the Department of National Parks and Wildlife in Quito.

Derek Green took over from Wellington in 1975 and continued a study on the ecology of the East Pacific green turtle (*Chelonia mydas agassizi*), started by Peter Pritchard and Miguel Cifuentes. The latter, who wrote his thesis on this project, subsequently became Galápagos National Park Service Superintendent from 1976 until 1986. This turtle project was the first major program of the station with the Ecuadorian National Fisheries Institute (INP) in Guayaquil, with which a close cooperation developed after 1976. Many Ecuadorian students took part in the turtle project, among whom was Mario Hurtado, who later worked as Assistant Director at the station from 1984 to 1986.

Studies by INP personnel were conducted from 1976 to 1980 on the artisanal fishery of bacalao, mullet, and three species of lobster—red (*Panulirus penicillatus*), blue (*P. gracilis*), and slipper (*Scyllarides astori*). The present Director of the station, Günther Reck, established and carried out this project in the Galápagos for INP. Plankton samples have been collected extensively by both INP and the Oceanographic Institute of the Ecuadorian Navy (INOCAR).

In March 1979, the station created the Department of Marine Biology and Oceanography. Two years later, Gary Robinson began work as Marine Biologist. Until he left in 1983, Robinson was mainly concerned with the planning and building of the Marine Laboratory. Priscilla Martinez assisted Robinson in a study of two species of black coral; *Antipathes panamensis*, the commercially exploited species, and its endemic relative, *A. galapagensis.* Robinson also co-edited, with Eugenia del Pino of the Catholic University of Ecuador, the important volume of articles published by the Charles Darwin Foundation, *El Niño in the Galápagos Islands: The 1982–83 Event* (see article page 42).

Non-station scientists have carried out several long-term studies as well. Andrew Laurie's marine iguana studies (see article page 54), begun in 1980, are still continuing; although they will now be taken over by Thomas Dellinger of the Max Planck Institute in West Germany. From the same institution, Fritz Trillmich has come to study fur seals and sea lions since 1976, and continues to do so.

The impact on the marine environment by the declaration of the Marine Resource Reserve (see decree page 4) remains to be seen. At the moment, a management plan is being developed, with personnel from various agencies in Ecuador, and help from the United States and Australia.

The Future: Plans and Problems

The Darwin station has a budget of about $1 million, and is staffed by between 50 and 60 people. This puts tight constraints on the scope and depth of the station's work. Therefore, the station's upcoming studies will be focused on providing the necessary information for decisions about the management plan for the Marine Resource Reserve. For example, assays of human impact will include the exploitation of black coral, artisanal fisheries, waste management, and tourist boating activities. In cooperation with national institutions, biological and chemical studies are planned, or have begun, to assess nutrients, zoo- and phytoplankton, petroleum concentrations, and cetacean activities. An inventory will be made of potentially threatened habitats, such as diving sites and beaches.

Many problems face marine researchers in the Galápagos. The station's marine laboratory, due to limited financial possibilities, is only basically equipped. Part of the diving gear has been donated by, or bought from, departing scientists, so

The most exploited fish species in the archipelago is the bacalao (Mycteroperca olfax), *a large grouper, common but endemic to the Galápagos.*

equipment is not always compatible. Since there is little available equipment on the Ecuadorian mainland, it must be imported from the United States or Europe. Thus, given the delays and difficulties in obtaining materials and spare parts, each study must be planned well in advance.

Nevertheless, present studies by visiting scientists who use the equipment and infrastructure of the marine laboratory have already given some promising results. Peter W. Glynn of the University of Miami has published a book on Galápagos corals and coral reefs with Wellington, and is currently studying the recuperation of reef-building corals after the devastation of El Niño. He has indicated that predation, in particular by the pencil-spined sea urchin, *Eucidaris thouarsii*, may be limiting the recovery of some species. Although *Pavona* and some others are recovering slowly, *Pocillopora* is still not showing signs of a good recovery.

In 1954, an area of Urvina Bay, on Isabela, was uplifted very rapidly, exposing a shallow water community. Mitchell Colgan of the University of California at Santa Cruz, who is studying this area, recently found a coral head with some 400 years of

Marine iguana (Amblyrhynchus cristatus).

The Charles Darwin Research Station

The scientific interest in the Galápagos that began with Charles Darwin continues today in his name, through the work of the Charles Darwin Research Station. The station—headquartered at Puerto Ayora on Academy Bay, Santa Cruz Island—is the offshoot and pride of the Charles Darwin Foundation for the Galápagos Islands. Since its beginning in 1960, the station has been a valuable Galápagos resource for scientists and tourists alike. But, had it not been for a few far-sighted individuals 30 years ago, who orchestrated public relations and diplomatic activities around a set of coincidences, it might never have happened.

The young Belgian ethologist (behaviorist), Irenäus Eibl-Eibesfeldt, visited the Galápagos early in the 1950s, as did San Francisco State University ornithologist Robert I. Bowman—then a graduate student. Both reported what they saw as the impending doom of the stark beauty and ecological integrity of the islands. The unfavorable publicity about the cruel conditions prevailing in the prison on Isabela Island prompted the Ecuadorian government to close it and avoid further political embarassment. Another danger was the increasing numbers of feral goats, pigs, dogs, and cats threatening the irreplacable populations of endemic rodents, finches, tortoises, and unique plants.

In 1957, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the New York Zoological Society, the International Committee for Bird Protection, and Time, Inc., sponsored a biological reconnaissance of the Galápagos under the leadership of Bowman and Eibl-Eibesfeldt. On their return, they recommended a series of protective measures for the islands' biota, and selected a site on Tortuga Bay, Santa Cruz Island, for a future research station—a site later abandoned in favor of the one on Academy Bay.

According to Bowman, the centennial of the publication of Darwin's the Origin of Species *in 1959 was the impetus to take the recommendations of the 1957 expedition to heart. UNESCO's first Director-General, Julian Huxley, presided over a committee determined to realize the ideas recently expressed, ideas that first had been voiced in the 1930s by California Academy of Sciences ornithologist Harry S. Swarth and National Academy of Sciences' Pacific Science Board then chairman, Harold J. Coolidge. The committee included Smithsonian Institution Secretary, S. Dillon Ripley; Royal Academy of Belgium Director of Science, Victor Van Straelen; future President of the International Union for the Conservation of Nature, Harold Coolidge; founder of the World Wildlife Fund, Sir Peter Scott; and Bowman, who served as Secretary-for-the-Americas of the Charles Darwin Foundation for the Galápagos Islands, which later that year was incorporated under Belgian law. Veteran biologist of the Belgian Congo Van Straelen served as first president.*

Bowman points to Coolidge especially as the one who made it all happen. "If not for him we might never have done it. He was a remarkable diplomat, able to enlist the help of prestigious organizations," such as the National Academy of Sciences, National Science Foundation, Royal Society of London, and the Max-Planck Institute, "and make all the right political connections."

The right political connections were a necessity, if the various funding sources and the Ecuadorean government were all going to act smoothly together. Coolidge, with the help of the first two secretaries-general of the CDF, Jean Dorst and Jacques Laruelle, was able to pull the right strings, and in 1959 Ecuador endorsed plans of the CDF by declaring all uninhabited areas of the archipelago a national park. Since there was no national park service at the time, the Ecuadoreans gave all administrative authority to the Charles Darwin Research Station (CDRS), which was established on Academy Bay by the CDF in 1960.

The CDF chose a young Swiss ornithologist, Raymond Lévêque, to be the first director of the CDRS. Bowman credits Lévêque with admirably facing the early challenges of the station. He had to oversee housing and road construction, choose the boundaries of reserve zones, and specify which native plants and animals required priority in conservation.

By 1964 the early work was finished and the CDRS was officially inaugurated. To insure that all the funding organizations and political bodies involved would enthusiastically support the station, according to Bowman, the CDF planned for the grandest celebration the Galápagos may have ever seen. The United States Navy, Air Force, and Army all got involved. Distinguished scientists from England, Japan, Belgium, the United States, and elsewhere, and other notables such as the artist Roger Tory Peterson, and the grandson of Charles Darwin, Commodore Barlow, were on hand for the dedication ceremonies at Academy Bay, Santa Cruz Island. The Ecuadorian government was represented by various ministers, including General Marcos Gandara, a leading member of the then ruling Military Junta of Ecuador. The general, a former engineering professor at the Catholic University in Quito took a special interest in the activities of the scientists, often seen riding the shells of the giant tortoises housed in display pens at the Darwin Station. Largely through the personal attention of General Gandara, an executive decree was issued *establishing special reserves for the protection of Galápagos wildlife. So committed was the government of Ecuador to the concept of inviolate nature reserves in the Galápagos that they stood by their decision, in the face of strong opposition, to relocate settlers illegally farming in protected regions of Santa Cruz Island. "Of course," says Bowman, "after all this, there was no way anyone could back down, and we were off and running."*

Because of the enthusiastic support of the Ecuadorean government, the station was able to move quickly on important conservation issues, such as feral animal control and surveillance of private yachts. The close ties of 20 years ago have been nurtured by the station, and many Ecuadoreans have served on the station's staff.

Effective cooperation between the CDRS and Ecuador has been a big factor in the success of both the station and the Galápagos National Park Service (GNPS), founded in 1968—again according to Bowman. In the late 1960s, CDRS director Roger Perry developed a program that brought Ecuadorian students, local school teachers, tourist guides, and scientists for seminars on conservation and research projects in the Galápagos. Many of these later became crusaders for conservation in continental Ecuador and elsewhere in Latin America. The educational program of the Darwin Foundation was successful. The cause of wildlife protection in Ecuador had a large endemic following.

Because so many young Ecuadoreans have had the opportunity to learn the methods of conservation and science in these remarkable islands, under the microscope of the global conservation community, there is a growing belief that Ecuador now has one of the finest national parks in the world. "They've been well-trained, and now they're great political fighters," Bowman says. "If we ran Yosemite as well as they do the Galápagos, we'd be better off." Other educational activities of the station include training GNPS guides and wardens, and natural history instruction for local teachers.

In the area of conservation, the efforts of the CDRS have been most successful. No known extinctions have occurred on the islands since the 1950s, although certain island populations of widespread forms have died out. For the most part, the feral animal situation is better controlled. In 1965, responding to the decimation of tortoises in certain areas, the station started a captive breeding colony. Beginning with only two males and ten females, they have now reintroduced more than 100 tortoises to Española Island.

Because of the heavy administrative load on the CDRS staff, most scientific research in the Galápagos is carried out by visiting scientists. The station is intimately involved with all the ongoing research, however. Through regulating the areas where research is conducted, and giving logistic and technical support to visiting researchers, the scientific interest of the Galápagos has remained high—attracting a growing number of scientists of many disciplines.

Presently the Darwin station employs a staff of 80 people, and about 50 visiting scientists work at the station each year—most work for just a month or two, but some have stayed for up to 2 years. Facilities of the station now include the 70-foot research vessel Beagle III, *a reasonably well-equipped laboratory, darkroom, workshop, meteorological and seismographic station, and living accommodations. For complete details, scientists interested in working at the station or obtaining visiting scientist status should contact either:*

Günther Reck, Director
Charles Darwin
Research Station
Casilla 58-39,
Guayaquil, Ecuador

Juan Black, Secretary-General
Charles Darwin Foundation
Edificio Colón
Avenue Colón 535–y 6 de deciembre
Quito, Ecuador

—TMH

continuous growth. Study of this area may permit accurate reconstruction of past El Niño events (see article page 61). This year Hal Whitehead, of Dalhousie University in Halifax, Canada, is continuing his studies on the social behavior of sperm whales. His 1985 survey gave very interesting and promising results. So the work is continuing (see article page 49).

The conservation aspect of studies done by the station is a driving force far greater than pure scientific curiosity. Nonetheless, the work of the station has demonstrated that a successful combination of the two can be found. The Galápagos underwater ecosystem is unique in its combination of high species complexity, a wide diversity of species, and a high degree of endemism. The situation of the archipelago on a junction of major current systems, and its wide diversity of habitats, serve to create a distinct regionalism of the islands. Hopefully, the Marine Resources Reserve can protect these features, and give a new impulse to marine research in the waters of the Galápagos.

Henk W. Kasteleijn is head of the Department of Marine Ecology and Oceanography of the Charles Darwin Research Station, Santa Cruz, the Galápagos, Ecuador.

Negative Effects of the 1982–83 El Niño on Galápagos Marine Life

by Gary R. Robinson

By March 1983, it was evident that the world's weather was in the grip of the strongest El Niño/ Southern Oscillation (ENSO) event ever recorded. El Niño conditions in the eastern Pacific were associated with droughts in Australia and Africa, cyclones in French Polynesia, and intense storms along the Pacific coast of North America. With almost daily exposure in newspapers and periodicals, El Niño became a household word.

The isolated Galápagos Islands are the only emergent land forms in the eastern Pacific Ocean lying directly in the path of developing El Niños. Not surprisingly, the 1982–83 event had profound effects on the archipelago's biota. A nutrient-poor blanket of warm tropical water invaded the islands, depressing the normally shallow thermocline* to great depths. Dissolved nutrients, such as nitrate, phosphate, and ammonia, usually found below the thermocline, were removed from the range of upwelling waters around the islands. Reduced availability of nutrients in the sun-lit surface layers led to reduced primary productivity, which reverberated through all levels of the trophic food web.

The effect of declining and shifting food resources was most pronounced at higher trophic levels, especially for seabirds, pinnipeds—sea lions and fur seals—and marine iguanas. Each year these animals provide nearly 26,000 visitors per year to the Galápagos National Park with some of their most memorable experiences.

Tourism Hit Hard

The strength of the 1982–83 El Niño event was dramatized by a request made by a tour company to myself and other scientists at the Charles Darwin Research Station located on Santa Cruz Island. The request was for a document describing what was occurring to the populations of marine iguanas, sea lions, fur seals, and seabirds that visitors were accustomed to seeing. How long might El Niño last, and when would the animal populations recover? The document was to be distributed to travel agents. The 1982–83 El Niño hit tourism hard. News of the conditions in the islands traveled fast and far.

Stories of marine iguanas dying at visitors' feet, of fewer or no seabirds along park trails, and starving fur seals circulated in the travel business. The problem was, the stories were true. Consequently, fewer people decided to travel to the Galápagos in 1983, preferring instead to delay their plans for some other year when conditions might be closer to normal.

The document requested by the tour company was never prepared. We had no idea when El Niño conditions would ameliorate, nor did the many scientists then working in the islands know precisely how the native fauna and flora might respond to this unprecedented event. There had been El Niños before; the last in 1976—but none on the scale of the 1982–83 event. Change was evident everywhere in the islands, and the excitement of simply observing and recording the results of it infused everyone's conversations. El Niño and its associated conditions were providing clues of how mechanisms of natural selection might operate, which, over the course of a few million years, had led to the intriguing flora and fauna inhabiting these islands today.

El Niño Sets Records

In terms of weather records, the 1982–83 event exceeded all previous marks. Climatological records at Academy Bay on Santa Cruz Island have been collected since 1965 by the Charles Darwin Research Station and furnish the basis for comparison.

The sea-surface temperature (SST) anomaly rose to 4 degrees Celsius above normal by December 1982 and stayed at that level until May 1983, when the anomaly rose to +4.5 degrees Celsius. By June, it reached a record +5.5 (Figure 1). SSTs then quickly dropped, approaching normal values by September 1983, when El Niño subsided.

Record rainfall fell on the Galápagos coincident with the warm tropical waters bathing the

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* A zone where the water temperature decreases more rapidly than the water above or below it. This zone usually starts from 10 to 500 meters below the surface and can extend to over 1,500 meters in depth.

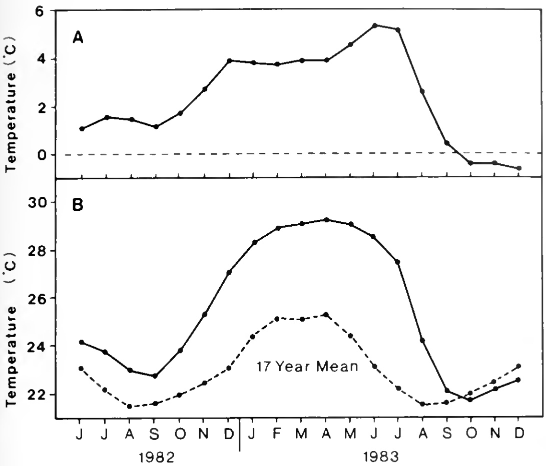


Figure 1. (A) Sea-surface temperature anomaly measured near Academy Bay, Santa Cruz Island, during the 1982–83 El Niño. Maximum anomaly exceeded +5 degrees Celsius in June 1983. Dotted line at zero indicates normal sea-surface temperature. (B) Monthly mean sea-surface temperature during the 1982–83 El Niño compared to the 17-year mean (1965–1981) at Academy Bay. (After Kogelschatz, and others, 1985)

islands. Between the months of November 1982 and July 1983 (9 months), more than 3,225 millimeters (126.9 inches) of rain fell at the coastal Santa Cruz Island weather station (Figure 2). Annual rainfall averages 374 millimeters (14.8 inches), so El Niño dumped more than nine times the usual amount of precipation. The heaviest recorded rain during the event was 136.7 millimeters (5.4 inches) on December 17. The normally arid Galápagos Islands were transformed into lush tropical islands, with an exuberant growth of entangling vines. Roads became quagmires of mud, and were often interrupted by rushing rivers after torrential rains. The floor of several volcanic craters became giant cisterns of fresh water (Figure 3).

Both the record rainfall and the rise in sea

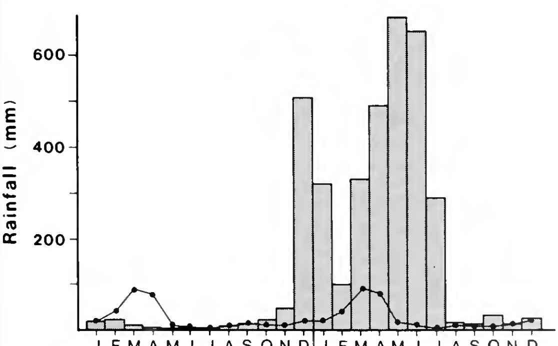


Figure 2. Rainfall recorded at the Charles Darwin Research Station on Santa Cruz Island for the 1982–83 El Niño. Total rainfall between November 1982 and July 1983 measured 3,225 millimeters (126.5 inches). Solid line with monthly dots is average rainfall for the period 1979–81, bars are actual rainfall in 1982–83. (After Robalino, 1985)

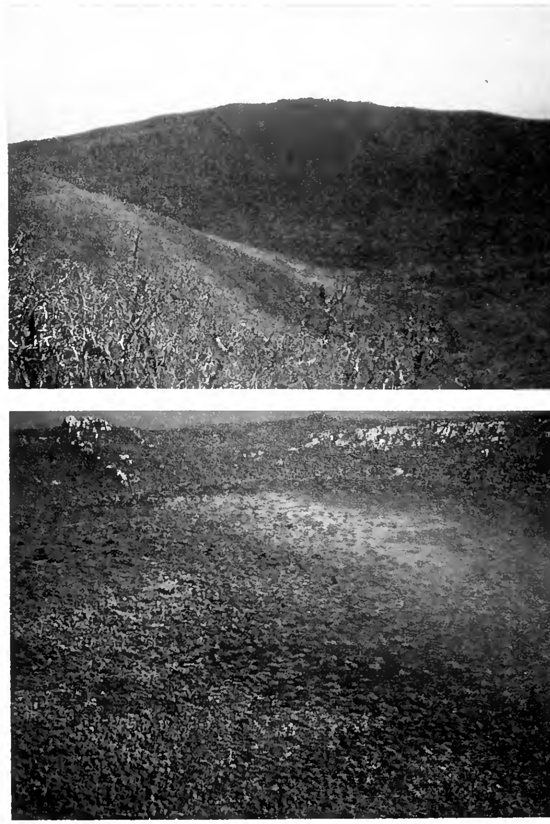


Figure 3. North crater of Pinzon Island during a normal year (A) and filled with water during the 1982–83 El Niño (B). (Photos by Linda Cayot)

level associated with El Niño were bimodal, with minimum values during February 1983 (compare Figures 2 and 4). The first pulse in rising sea level was attributed to the relaxation of sea-surface slope across the Pacific basin due to reduced tradewinds. A second pulse followed when anomalous westerly winds blew over a large portion of the central Pacific from January to May. Surface waters moved eastward toward the Galápagos, accounting for the second peak in sea-level rise around May 1983. These winds also sparked the unusual cyclones that hit French Polynesia in 1983.

Positive sea-level anomalies in the Galápagos indicated a thickening of the warm layer and increased heat content of the ocean surrounding the islands. Warm air saturated with moisture from the ocean's surface released precipitation as these air masses were forced upward by the islands. Several storms during 1983 were especially severe. Lightning had never before been observed by long-term residents of the Galápagos (a period of 45+ years). But, in 1983, lightning bolts felled palm trees and wreaked havoc on municipal power stations.

The marine environments of the Galápagos are poorly understood, as is the biology of most of its marine organisms. Numerous observations throughout the Galápagos during El Niño indicated wide perturbations in abundance, and altered

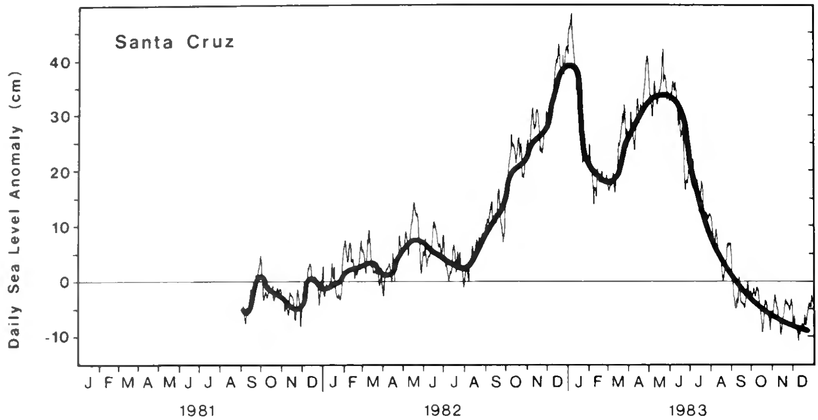


Figure 4. Daily mean sea-level anomaly at Santa Cruz from 1981 to 1983. (After Wyrtki, 1985)

patterns of distribution of marine species among the islands. Since normal year-to-year variation in population size is largely unknown for many organisms, it is difficult to judge the impact of the 1982–83 El Niño. However, our knowledge of seabirds, marine iguanas, pinnipeds, and coral communities is more complete, as the following examples show.

Waved Albatross

Apart from a few errant pairs, the waved albatross, *Diomedea irrorata*, breeds only on the tiny Galápagos Island of Española, in the southern region of the archipelago. Catherine Rechten, then associated with the Max Planck Institute in Germany, returned there in March 1983 to find torrential rains, a thick cloak of vegetation over usual nesting areas, and diminished food resources. She blamed the circumstances for the complete breeding failure of the waved albatross in 1983.

Several observations indicated that the waved albatross experienced food shortages. Adult birds arrived at nesting sites approximately two weeks later than usual. Far fewer adults laid eggs in 1983 than in 1982, and the size of eggs was noticeably smaller.

In a normal year, roughly a third of the nesting females are less than 10 years old. But in 1983, all of the egg laying birds at the study site were older than 10 years and none of them had raised a chick to fledging the previous year. In other words, raising a chick demanded considerable expenditures of energy for parent birds, which could not be fully recovered between breeding seasons because El Niño intervened. Some older individuals, having failed to fledge a chick the previous year and facing the end of their reproductive life, could not pass up the opportunity at breeding—even under the marginal El Niño conditions. Younger birds could afford to forego one laying season as many reproductive years still lay ahead.

Unfortunately for the waved albatrosses attempting to breed in 1983, El Niño soon made it impossible. Not one egg hatched, and all eggs laid in 1983 were abandoned within 20 days. Eggs normally hatch in about 63 days.

Rechten describes adult birds swimming on the surface of pools, trying in vain to retrieve eggs after heavy rains submerged them. But rains were not the only factor contributing to egg abandonment. Male birds returned much later from their foraging period at sea to relieve partners from egg incubating stints; and, when they did return, it was already too late.

For visitors to the islands though, the breeding failure of the waved albatross had desirable consequences. As Rechten writes, "Compared with other years, courtship dances were unusually frequent, as all adult pairs had failed to breed and were therefore dancing."

Birds were not celebrating release from parental duties. Rather, the courtship dance and bill fencing that the waved albatross is so noted for serves as a behavior that strenthens the bond between mates (see box page 67). Waved albatrosses typically engage in this behavior at the end of the breeding season, or after failing to raise a chick and flying away to the open sea.

Did the 1982–83 El Niño severely affect the waved albatross population? Apparently not. Based on tagging data, a 17 percent success at fledging chicks would be sufficient to balance normal mortality. Rechten's estimates of breeding success for the waved albatross were 46 percent in 1981, 8 percent in 1982, and 0 percent in 1983. Being a long-lived bird, however, one good reproductive year can make up for disastrous years, such as 1983.

Galápagos Pinnipeds

While waved albatrosses failed to produce any young during the 1983 season, and may have suffered slightly higher adult mortality because of El Niño conditions, the population was expected to rebound once conditions normalized. Galápagos pinnipeds, on the other hand, were drastically affected by El Niño, and the effect carried over to the following reproductive season.

The Galápagos supports two species of pinnipeds—the Galápagos sea lion, *Zalophus californianus wollenbaeki*, a smaller subspecies of the California sea lion; and the endemic Galápagos fur seal, *Arctocephalus galapagoensis*. Fritz Trillmich, a biologist with the Max Planck Institute, has had a long interest in pinniped biology in upwelling tropical ecosystems. For more than a decade, he has been involved with studies of population dynamics, diving behavior, and maternal-pup behavior of Galápagos sea lions and fur seals. In the journal *Oecologia* (1985), Trillmich and Dominique Limberger described the 1982–83 El Niño's impact on a population of fur seals on Fernandina Island:

> *El Niño decimated the population of fur seals by almost entirely eliminating the four youngest year classes (1980 through 1983). Adult females and non-territorial males suffered about 30 percent mortality. Large male fur seals, holding breeding territories in the early months (August to November) of El Niño apparently could not recover weight lost in territorial defense as El Niño conditions developed to their full extent following the breeding season. Nearly 100 percent mortality was observed for these individuals, which were replaced by smaller males the following reproductive season.*

How did El Niño exert its impact upon Galápagos fur seals? Shortage of food seems to be the answer, although the evidence is indirect. The fur seals' preferred prey of squid and fish apparently remained in the cool waters below the thick blanket of warm tropical water, beyond their diving abilities (greater than 50 meters). Unfortunately, no direct sampling of the distribution of these prey has been undertaken in the islands.

It was clearly evident that there was a food shortage. Trillmich and Limberger attribute the large number of stillbirths in 1982 to nutritive stress. Females that did pup successfully, stayed longer at sea between nursing periods, and pups were undernourished. In fact, none survived El Niño. The year classes of 1980 and 1981 also suffered high mortality. Young fur seals are dependent on their mothers for nourishment for the first two years of life, and do not gain full independence until a year or two later.

In effect, the strong El Niño of 1982–83 produced a big hole in the age structure of the fur seal population that may have large implications for the future reproductive output of this species. In the 1983 reproductive season following El Niño, surviving adult females had still not gained sufficient resources to support added reproductive costs as evidenced by low birth rate (11 percent of normal) and significantly lower pup birth weights.

The effect of El Niño on the Galápagos sea lions was similar to that of fur seals. Sea lion colonies on the islands appeared deserted in 1983 compared to former years, and most of the 1982 year class died, apparently abandoned by adults remaining at sea longer in search of diminishing resources. Compared to fur seals, food shortages may not have been as drastic for sea lions, as this species is capable of deeper diving. But, like fur seals, pup production in the year following the 1982–83 El Niño was much lower for the Galápagos sea lion.

Low food availability may not have been the only reason for the decline in sea lion populations. Nutritive stress and physiological stress due to the warm ocean and atmosphere may have made individuals more susceptible to disease, particularly to sea lion pox (Figure 5). The prevalence of this disease seemed to be greater in 1983 than in previous years and may have been a contributing mortality factor.

Figure 5. Young Galápagos sea lion with pox sores. Prevalence of this disease was greater during El Niño due to stress caused by elevated air and sea temperatures and by the scarcity of food. (Photo by Gary Robinson/VU)

Marine Iguanas

No creature epitomizes the uniqueness of the islands more than the marine iguana, *Amblyrhynchus cristatus* (Figure 6). When Charles Darwin visited the Galápagos islands in 1835, he described the iguana as "a hideous looking creature, of a dirty black colour, stupid, and sluggish in its movements."

In November 1982, Andrew Laurie (see article page 54) of Cambridge University, England, began his third year of observations of a large colony of marine iguanas on Santa Fe Island. At this site, marine iguanas are largely intertidal feeders, moving out onto exposed rocks as the tide drops to feed on leafy green and red algae. With increased sea temperatures and low nutrients because of El Niño, most kinds of algae were replaced by filamentous brown algae (principally *Giffordia* sp.) that colonized rocky substrates throughout the islands.

Marine iguanas continued to feed on the brown algae, but rapidly lost weight. As El Niño conditions persisted, marine iguanas starved to death, even though Laurie's examinations of dead animals revealed guts packed with filamentous brown algae. Subsequent analyses of the digestability of *Giffordia*, compared to red algae normally available to iguanas, indicated that the brown algae offered far fewer metabolizable calories.

Figure 6. Marine iguana populations throughout the islands were reduced 30 to 55 percent under El Niño conditions. Usual species of algae consumed by iguanas disappeared during 1982–83 and were replaced by a relatively unnutritious species of filamentous brown algae.

In anthropomorphic terms, it was as if El Niño had replaced a meal of steak, potato, and vegetable with soda crackers.

The marine iguana population at Santa Fe was reduced by about 65 percent. The 1983 hatchlings were relatively unaffected by El Niño conditions, probably because yolk sac reserves carried them through the adverse conditions. In contrast, the 1982 year class suffered nearly 90 percent mortality since small iguanas are entirely dependent on intertidal feeding. Increased sea level and heavy swells associated with El Niño denied them access to usual feeding areas, which, in any case, were depleted of algae.

An island-wide survey made following El Niño indicated reductions of 45 to 70 percent in marine iguana populations. How severely populations on different islands were affected depended on the extent to which iguanas fed subtidally at different sites. Subtidal diving iguanas showed higher survivorship, presumably because nutritious species of algae were still available.

El Niño's influence carried over into the following reproductive season. Normally, more than 1,800 females dig nests at the Santa Fe study site, but only 10 did so during the nesting season following El Niño. Allowing for 50 percent mortality of adult females, the 10 nesting females represented only 1.2 percent of possible egg laying females. Surviving female marine iguanas were not able to acquire sufficient resources to compensate for the 30 percent weight loss incurred during El Niño in time for the following nesting season.

Hermatypic corals

One of the more pervasive impacts of the 1982–83 El Niño was the widespread bleaching and mortality of hermatypic (reef-building) corals throughout the eastern Pacific. Peter Glynn, then with the Smithsonian Tropical Research Institute in Panama, and now with the University of Miami, was the first to report on this phenomenon occurring at coral reefs in the Gulf of Chiriqui, Panama. At the same time as his observations, corals began bleaching (losing pigment and symbiotic algae) in the Galápagos during February 1983. By the end of March, visitors to all sectors of the Galápagos were reporting "dead" corals. As El Niño progressed, bleached corals did indeed begin to die and coral skeletons were overgrown with filamentous algae (Figure 7).

Galápagos corals appeared to be very sensitive to the anomalous oceanographic conditions and exhibited very high rates of mortality. Alabaster coral, *Pocillopora sp.*, was most affected. In areas where this coral forms incipient reef framework, such as Onslow reef, all coral heads died and became carpeted with filamentous algae.

The massive corals *Pavona clavus* and *Porites lobata* also exhibited high levels of mortality. The fact that massive coral colonies measuring more than 1 meter in height died during El Niño, coupled with their known growth rates of 6 to 12 millimeters per year suggest just how unusual the event was. Such corals were easily three quarters of a century old.

Why the corals died is a different matter, though. In general, corals are expected to fare better under El Niño conditions. Clearer and warmer waters should permit algal symbionts residing in the coral's tissue to photosynthesize at higher rates. Corals are able to utilize some of the products produced by their symbionts, and consequently should grow faster. But the positive relationship of increased temperature to increased coral growth rate only exists up to a certain point. Above 29 degrees Celsius, coral growth rate rapidly declines. Factors such as increased light intensities and reduced salinities exacerbate problems corals face under persistent elevated temperatures. All of these factors were present in the Galápagos during the 1982–83 El Niño and contributed to the extensive mortality observed there.

Despite its equatorial location, coral development is not very extensive in the Galápagos Islands because of the relatively cool waters that normally encircle the islands. Marine ecologists Peter Glynn and Gerard Wellington noted, however, that incipient coral reef formations and corals themselves are surprisingly common in the Galápagos marine environment. The prevalence of corals in the islands was made visible during El Niño because bleached

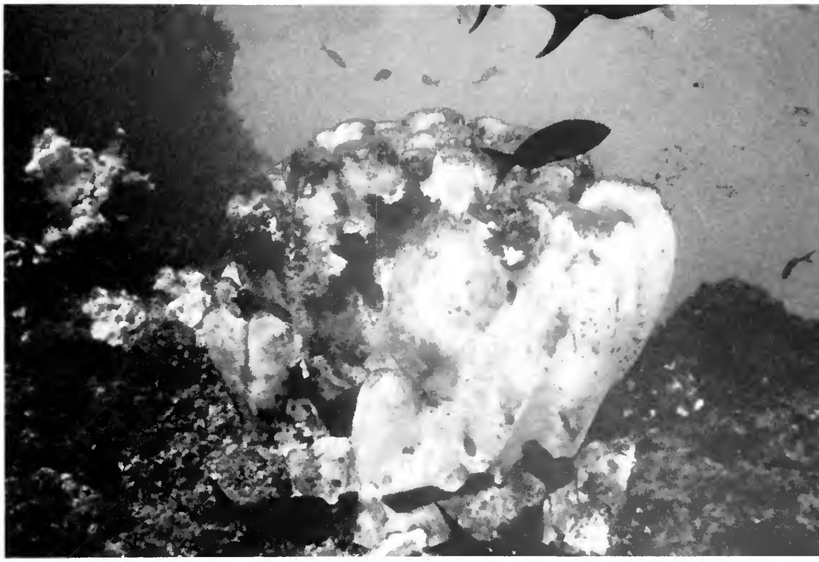


Figure 7. Bleached coral head of Pavona clavus *near Academy Bay, Santa Cruz Island during El Niño. Corals bleached (lost pigment and symbiotic algae) by February 1983, but were not colonized by filamentous algae until April 1983. (Photo by G. Robinson/VU)*

heads contrasted markedly against the background. It is ironic that Glynn and Wellington's detailed descriptions of Galápagos coral reefs was published in the same year El Niño was decimating such formations.

These events suggest one reason why coral reefs in the Galápagos may remain "incipient." Perhaps every century or two, strong El Niño events occur causing extensive coral mortality. Physical and bioerosion of dead coral framework, particularly by the pencil urchin, *Eucidaris thourasii*, may reduce the structure to rubble before living corals are able to re-establish and begin the reef building process again.

A Positive Footnote

El Niño/Southern Oscillation events are generally associated with negative impacts and the examples related here do not dispel that notion. For many marine species dependent on productive Galápagos upwelling ecosystems, El Niño had adverse impacts. Examples are the penguins, flightless cormorants, pinnipeds, marine iguanas, and blue-footed boobies. But for species with tropical affinities, such as moorish idols, *Zanclus canescens*, and filefish, *Aleutra inscripta*, the warm water conditions eliminated temperature barriers, and these species dispersed throughout the islands.

Rarely occurring El Niño events of the intensity of the 1982–83 phenomenon may set the stage for the production of new species. They push populations to the brink of extinction under their adverse conditions. But once these conditions abate, small founding populations may remain. Isolation, mutation, and genetic drift may operate on these small founding populations, making possible the evolution of new species.

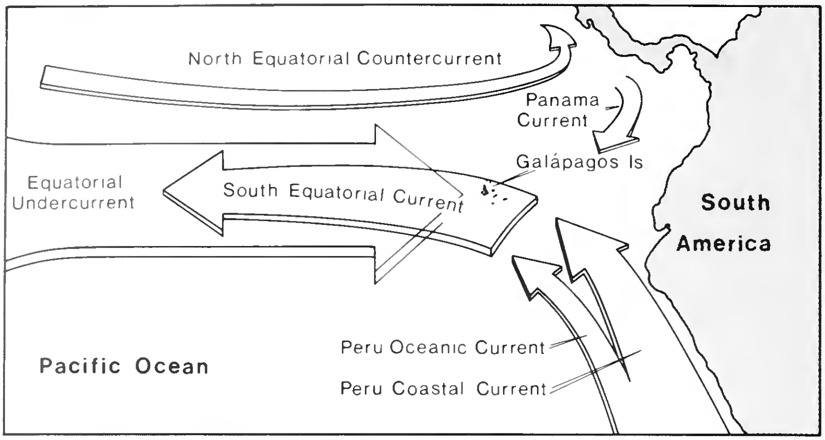
In another respect, adults or dispersal stages of marine species may accidentally come to the Galápagos because of the unique oceanographic setting—strong easterly transport of surface waters from the Indo-Pacific region, and more commonly, southerly transport via the Panama Current during El Niño conditions. The prolonged conditions of the

Galápagos Crossroads

Oceanographic and climatic variability are hallmarks of the Galápagos Islands. The islands lie along the equator about 1,000 kilometers west of mainland Ecuador in the transitional zone of the eastern tropical Pacific Ocean. Several major ocean currents run side by side here like east- and west-bound lanes of a major freeway, with the Galápagos Islands representing a crossroads intersection (see map on following page).

These current systems vary in intensity during the year in a seasonal see-saw which gives two distinct seasons to the Galápagos. They are a wet season, extending from January to March with rainfall amounts of 200 to 370 millimeters at coastal stations; and a dry season, during the months of June to December, characterized by strong local winds, cooler sea temperatures, and a persistent high fog known locally as garua (Spanish for mist).

During the dry season, the South Equatorial Current (SEC) is well-developed and brings cool water (18 to 22 degrees Celsius) to the islands. This current is derived from the Peru Oceanic Current and Peru Coastal Current, which flow along the west coast of South America. As these water masses approach the Equator, they turn westward to become the SEC. The flow of these currents is determined mainly by the strength of the southeast tradewinds, which generally blow strongest during the months of August and September. The SEC sweeps along the entire width of the Pacific, beginning just east of the Galápagos and ending in the western Pacific. As the SEC water mass is transported across the Pacific, it is gradually heated under the equatorial sun, setting up a sea-surface temperature (SST) gradient of 4 to 5 degrees Celsius from west to east. The gradient in SST is



Major ocean currents in relation to the Galápagos archipelago. These currents vary during the year, producing a dry season and wet season. The Peru Current is also known as the Humboldt Current, and the Equatorial Undercurrent is also known as the Cromwell Current. (After Grove 1984)

also reflected in the depth of the thermocline, which may be deeper than 125 meters in the western Pacific and near the surface in the Galápagos region. Tradewinds that blow across the Pacific, driving the SEC, also set-up and maintain a basinwide tilt to the ocean's surface.

The Equatorial Undercurrent (EUC, also known as the Cromwell Current) is prevalent in the Galápagos during the dry season. This current flows beneath the SEC, but in the opposite direction, from west to east. As the EUC approaches the Galápagos platform it is deflected upwards, bringing cool nutrient-rich waters to the surface.

The intense upwelling and highly productive waters of the western region of the Galápagos are distinctive of the EUC. Whales and dolphins are common in this area, as are the endemic flightless cormorant and Galápagos penguin (see box page 67). Under the EUC influence, sea-surface temperatures around the northwestern tip of Isabela Island may measure only 16 to 18 degrees Celsius—at the equator!

During the wet season, the SEC and EUC slacken because of the weakening southeast tradewinds, and the balance tips toward the Northern Ecuatorial Counter Current (NECC) system. The Equatorial Front, the dividing line between the NECC and the SEC, lies at approximately 4 degrees North of the equator during the dry season, and moves toward the islands during the months of January through March. Warm (25 to 28 degrees Celsius) tropical surface waters of reduced salinity and nutrients may flow out of the Panama bight as the Panama Current. During this season, the winds are generally mild, the seas calm, and the skies clear except for the large cumulus clouds that occasionally produce tropical downpours.

The convergence of three distinct water masses at the Galápagos has transported representative marine biota from tropical and subtropical regions of Central and South America as well as from the Indo-Pacific. The level of endemism is quite high, averaging about 25 percent. Coupled with the broad range of habitat types available (mangroves, precipitous cliffs, sandy beaches, and so on) and the complex interplay of currents dividing the various islands into distinct zones, it is not surprising that a great diversity of marine life resides in the Galápagos seas. The Galápagos marine environment is a "melting pot" of species that biogeographers recognize as a distinct biotic province. **—GR**

1982–83 El Niño may favor this sort of recruitment, and the successful establishment of tropical species. These species may ultimately become permanent members of the Galápagos marine communities, adding to their diversity.

Gary R. Robinson is Manager of the Sea Center at the Santa Barbara Museum of Natural History, and was formerly Resident Marine Biologist at the Charles Darwin Research Station in the Galápagos.

Acknowledgments

I wish to acknowledge the Charles Darwin Research Station, Galápagos National Park, and the National Institute for Galápagos for their support of marine research. Contribution No. 415 of the Charles Darwin Foundation.

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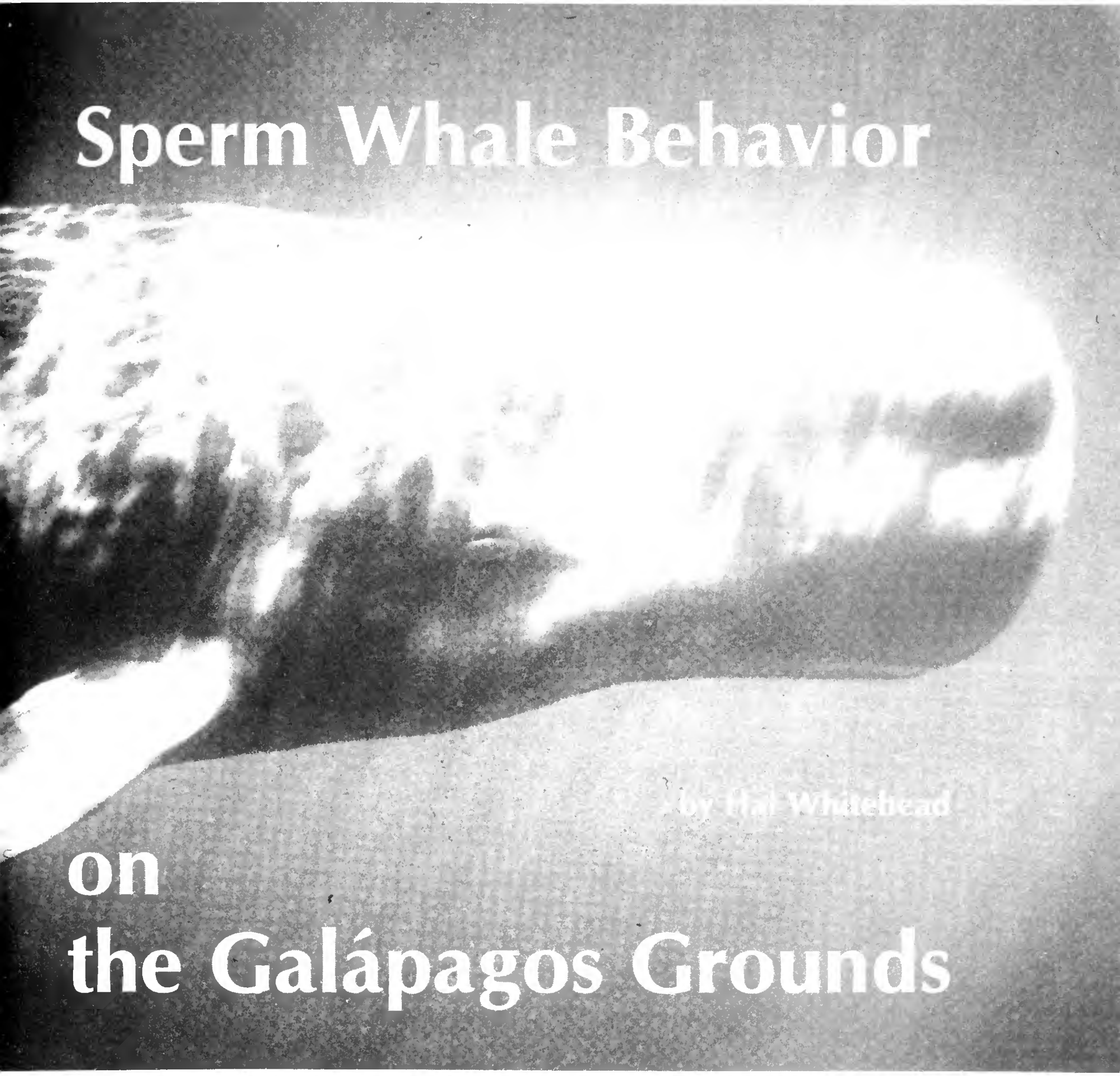
Sperm Whale Behavior on the Galápagos Grounds

by Hal Whitehead



In early 1985, we sailed our 10-meter sailboat/research vessel to the Galápagos Islands to study the social behavior of the sperm whale (*Physeter catodon*). Most biologists who visit the Galápagos are interested in the unusual, often endemic, plants, animals, and biological systems that have evolved there, or the pests that man has introduced to the islands. But the sperm whale is found throughout the world's oceans—it is one of the most widespread mammals apart from man, his pets, and other followers—and poses no known threat to endemic Galápagos organisms. Then why sail to the Galápagos to study sperm whales?

We were looking for a place where we could follow the groups of female sperm whales—the primary units of sperm whale society. These "nursery" groups are generally restricted to tropical and subtropical waters. We were hoping to examine the interactions between these groups and mature male sperm whales.

The large male sperm whales, which may sometimes reach 18 meters in length and about 60 tons in weight—about three times the mass of a mature female—are thought to spend part of the year in cold, sometimes polar, waters, but presumably return to the tropics to mate. However, the details of this mating system are unknown, and a possible source of error in the models of sperm whale population dynamics developed by the Scientific Committee of the International Whaling Commission (IWC). Their "Sperm Whale Model" assumes a harem system, with a large male taking over a group of females and defending them against other males. However, there is no concrete evidence that such a system exists, and sometimes more than one male has been found with a group of females. This led several scientists to speculate that male sperm whales might form long-term

Above, the head of a female sperm whale photographed underwater. (Photo by the author) coalitions with other males, and take over groups cooperatively, in the manner of male lions (*Panthera leo*).

Other questions arose when the South African scientist Peter Best, based on a study of parasites on sperm whale carcasses, suggested that associations between breeding male sperm whales and particular groups of females might be much briefer than an entire breeding season. To give a fair description of the social organization of sperm whales and to construct reasonably accurate models of their population dynamics, detailed studies of free-living sperm whales are needed.

The "Galápagos Grounds"

Between 1982 and 1984, Jonathan Gordon of Cambridge University in England and I had developed methods of tracking sperm whales using passive acoustics; of identifying, measuring and sexing animals photographically; and studying their diet from fecal samples. We studied sperm whales in both the Atlantic and Indian Oceans, but found no ideal area. We needed a study area with both groups of female sperm whales and large males, with calm water, and as few logistic and bureaucratic hurdles as possible. After examining whalers' records, survey reports, climatic charts, and government regulations, with the help of my colleagues, I decided to try the Galápagos.

The Galápagos Islands were first noted as a sperm whaling ground by British Royal Navy survey ships in the late 18th century. But it was the Yankee whalers who developed the industry. In the first half of the 19th century, whalers from Nantucket, New Bedford, and other New England ports took thousands of sperm whales from Galápagos waters. The sperm whales were not the only animals affected by these whaling operations: Galápagos fur seals were slaughtered for their pelts and oil, and large numbers of the giant Galápagos tortoises were captured for food (see page 86). By the 1860s, the Yankees found the Galápagos "dry cruising"—presumably most of the sperm whales had been taken. The Galápagos escaped the ultra-efficient mechanized whaling of the 20th century, and, apart from a few brief ship surveys, there was little recent information about the sperm whale population when we arrived in 1985.

We found the sperm whales principally in the productive waters west and southwest of Isabela (see map page 2), the largest island in the archipelago, where the Cromwell Current, running eastwards beneath the Equator across the Pacific, finally meets land and is forced to the surface. Captain Colnett, who headed one of the first British exploratory whaling expeditions, had recommended the same area "to all cruizers" in the 1790s.

Sperm Whale Groups

During our 2½ months in Galápagos waters, we photographed slightly more than 200 individual female and immature sperm whales. Using statistical criteria, we clustered these into 13 recognizable groups, which appeared to have a reasonably closed membership (no obvious immigration or emigration) during the time of our study. Most of these groups contained about 20 females and immatures and 1 to 2 small (3 to 4 meters long) first-year calves. The statistical analysis also suggested that we encountered most of the groups present in the waters off the Galápagos. We estimated a total population of about 270 sperm whales in the area at that time.

We were able to sail continuously with groups of whales for up to 10 days. Occasionally, as groups encountered one another, we sometimes found ourselves leaving one group to follow a second group that was known to us from a previous encounter.

Two Modes of Behavior

The sperm whales appeared to have two principal modes of behavior: "feeding" and "social." Most frequently they seemed to be feeding. Each member of the group would dive for approximately 40 minutes, and then surface to breathe for about 10. Traces of the whales' dives when seen on a recording depth sounder showed them to be diving almost always to 410 meters, ± 15 meters, both day and night. Their choice of 410 meters is a mystery at present. We have not yet identified any obvious oceanographic features 410 meters below the surface off the Galápagos. In other ocean areas, sperm whales have been tracked diving to a variety of depths. Analysis of fecal samples suggested that the Galápagos sperm whales were generally eating deep sea squids, so perhaps 410 meters has some special significance for these prey.

While apparently feeding, a group would usually spread out over several square kilometers of ocean, often aligned in a rank perpendicular to their direction of travel, apparently sweeping the ocean for food. The whales would usually appear at the surface for their breathing periods singly or in pairs; but if other whales were within a few hundred meters, they would often alter course to join up. After their breathing period, together or separately from their companions, the sperm whales would often lift their flukes into the air to begin the dive.

While at depth, a sperm whale usually made a series of clicks, about one every 0.5 to 1 seconds. These regular clicks were sometimes interrupted by pauses of one to several minutes, or by a rapid series of clicks that can sound like a creak. We think that the regular clicks are used to acoustically detect the sperm whales' prey. Do pauses and creaks indicate that the whale has found potential food?

After a bout of apparent foraging, which may last from 5 to 30 hours, the group of sperm whales will slow, and more and more animals will be visible at the surface. Instead of being spread over several kilometers of ocean, the whales begin to cluster. We may see breaches (leaps from the water) or lobtails (thrashes of the flukes onto the water surface); we hear fewer of the rhythmic "feeding" clicks, and more "codas." (Codas, such as those analyzed by William A. Watkins of the Woods Hole Oceanographic Institution, are patterns of clicks apparently used for

Sperm whale calf with two adults photographed underwater. (Photo by Linda Weilgart)

communication between sperm whales.)

At the culmination of this clustering behavior, the whole group of 20 or so sperm whales may be gathered in a compact mass at the surface. The whales lie quietly, sometimes a meter or two apart. These "social" times can last anywhere from 1 to 8 hours. As the clustering ends, flukes are raised, and the whales recommence their commute between the 410 meter depths for food and the surface for air.

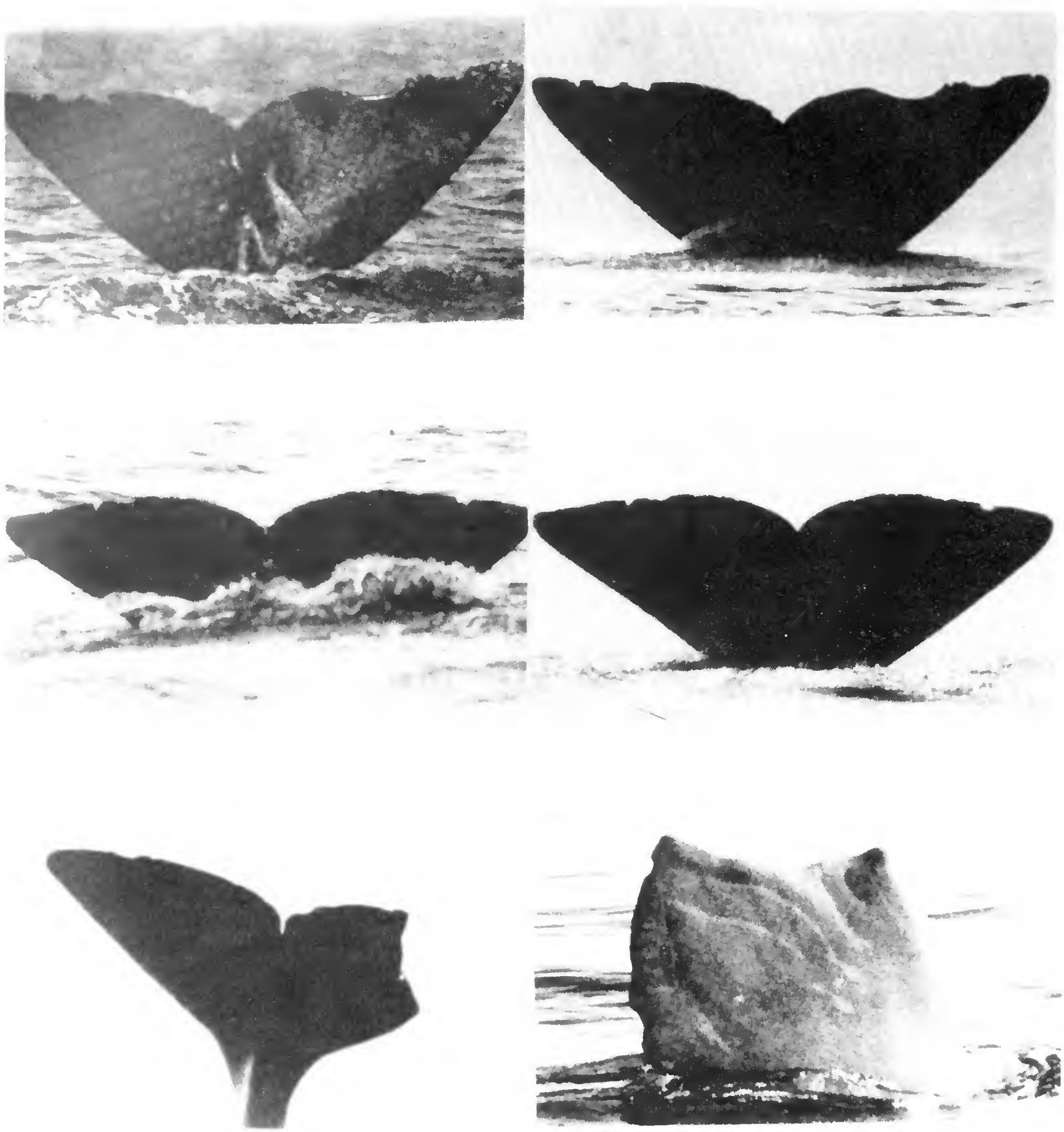
The combined effect of about 15 sperm whales at depth, each clicking once every 0.5 to 1 seconds sounds rather like radio static through a hydrophone. But this blur of clicks was the beacon that allowed us to follow a group of sperm whales at night, and at other times when we could not see them. Using a directional hydrophone, which can detect sperm whales at about 10 kilometers, we could tell the bearing and approximate range to the whales, and thus follow them.

But sometimes, in the midst of the cacophony of a feeding group of sperm whales, we would hear a deeper, louder, and more ringing click, repeating every 4 to 8 seconds rather than 0.5 to 1. These were apparently the "slow clicks" of the large, mature male sperm whales. When heard from very close range, the powerful slow clicks sounded to us much like a slammed jailhouse door might sound to a new inmate. These slow clicks could be the large males' equivalent of the 0.5 to 1 second "feeding" click of the females; a signal to receptive females; a signal to other males of the size, strength, or reproductive status of the male; or, they might serve combined functions.

Harems in Question

During our 2½ month study in the Galápagos between February and April 1985, we heard slow clicks with increasing frequency, and, during daylight, would sometimes see the huge male sperm whales themselves. They joined the groups of females that we were following for an average of about 6 hours at a time. While within the group, they seemed to behave much like the smaller whales that they were accompanying: they showed their flukes and dived; they would sidle up beside a female if nearby at the surface; and during "social times" they would lie quietly at the surface among the other whales. Sometimes we saw two, and once three, large males with a group of females, but there were no signs of aggression among them.

We were able to photographically identify seven large males, probably representing the majority of those off the Galápagos during our study. Thus, we were able to trace which groups of females, and which other males, a particular male



Sperm whales can be individually identified from photographs of their flukes. Two pictures of each of three sperm whales are shown.

associated with. We found no signs of preference: an individual male associated with a variety of groups of females as well as other males. In particular, there was no indication that males formed harems out of the groups of females, or formed consistent "coalitions" with other males. The males seemed to move between groups. Thus, male behavior may be somewhat less rigid than previously believed. A similar pattern of males moving independently between groups of females has been found with African elephants.

Reduced Number of Males?

If our observations are representative of the form

Large male sperm whale with females. (Photo by V. Papastavrou)

of sperm whale social organization at other times and in other oceans, this could have considerable bearing on attempts to model the dynamics of sperm whale populations. But another of our observations could have even more significance: the very small number of mature males present—a maximum of 2 to 3 percent of the total Galápagos population, rather than about 20 percent as several assumptions about sperm whale natural history would predict. This observation, and the possible explanations for it, will need to be examined through additional research. However, if there are relatively fewer breeding males than pure demography would predict, the relative reduction of mature males, which have born the brunt of recent whaling, may have an impact on the probability of a female becoming pregnant. This would lower the birth rate and lessen the ability of the populations to recover from whaling.

For the moment this is speculation. We need more information about the Galápagos sperm whales. We need to know whether the females that we observed form a discrete "Galápagos stock," as some scientists believe, or whether whales from a wider area of the Pacific use the Galápagos from time to time. We need to know the seasonality of breeding more accurately, and whether our other observations of the behavior of sperm whales are generally valid.

I Know Him Not

I am writing this during our second season (1986–87) "on the Galápagos grounds." We plan to spend a total of 7 months here, and then many more analyzing the data back in our laboratories. By then, we should know considerably more about the Galápagos sperm whales. But, as to their "true nature," I tend to agree with another visitor to the Galápagos with an interest in sperm whales, Herman Melville, who wrote of the central figure in *Moby Dick*: "I know him not and never will."

Hal Whitehead is an Assistant Professor of Biology at Dalhousie University, Halifax, Nova Scotia.

Huddled, or clustered "social" sperm whales. (Photo by Tom Arnbom)

Marine Iguanas:


Marine iguana (Amblyrhynchus cristatus) on Española Island. (Photo by Tui De Roy, courtesy Galápagos National Park Service)

Living on the Ocean Margin

by Andrew Laurie

The marine iguanas of the Galápagos resemble prehistoric reptiles. But, despite their formidable dinosaur appearance, recent studies have documented their general decline in numbers, and sensitivity to environmental pressures. Of particular interest are the responses of the populations to the 1982–83 El Niño event.

Origins and Characteristics

At the height of the Mesozoic, 200 million years ago, there were many marine reptiles; now only a few species of turtles, sea snakes, and crocodiles live in the sea. A handful of species of terrestrial lizards have secondarily become adapted to feeding, often

*Land iguana (*Conolophus subcristatus*) feeding on Fernandina Island. (Photo by Tui De Roy, courtesy Galápagos National Park Service)*

opportunistically, on the ocean margin. The gecko, *Lepidodactylus woodfordi*, hunts crabs just above the high-tide zone in the Philippines, and iguanid lizards of the genus Ctenosaura do the same in California and Central America. On the Columbian island of Malpelo, the lizard *Anolis agassizi*, and the skink, *Diploglossus hancocki*, live partly or entirely on crustaceans caught in the intertidal zone. Similar behavior has been described by Hans Fricke for the skink, *Cryptoblephasus butoni*, on the island of Nossi Bé near Madagascar, where they feed on insects, crustaceans, and fish.

The marine iguanas of the Galápagos are the descendants of iguanas, perhaps very similar to the green iguana (*Iguana iguana*) of the South American mainland, which arrived in the islands less than 3 million years ago, probably on rafts of vegetation swept out to sea from the rivers of the continent. There are also two species (*Brachylophus* spp.) of iguanas in Fiji, on the other side of the Pacific. Here again, they are thought to have arrived there by rafting from America where all the other 27 species of iguanine lizards live.

However, the marine iguana, *Amblyrhynchus cristatus*, is the only truly marine lizard in the world, and has been equipped by natural selection within the surprisingly short time of 2 to 3 million years with flattened tails for swimming and long claws for clinging to barnacle-covered rocks in the intertidal surf. The marine iguanas are well-equipped for both grazing at low tide on the abundant seaweed, and for diving. While the iguanas can spend long periods feeding underwater, the water in the Galápagos, despite being on the equator, is often cold—mostly because of the influence of nutrient-rich waters of the Humboldt Current. Therefore, the iguanas must warm their reptilian bodies by basking on the black lava rocks of the shoreline.

The marine iguana is widely distributed throughout the archipelago. The highest concentrations are on the western islands. The iguanas feed on soft-bodied, macrophytic marine algae, either diving for them or grazing on exposed intertidal rocks at low tide. The amount of feeding beyond the tidal range varies between sites. Larger individuals generally do more sub-tidal feeding, while the smaller ones are restricted to the intertidal zone.

Adult body size varies considerably between islands, and (less so) between sites on the same island: there is a ten-fold difference in adult male body weight between the two extremes, Isabela and Genovesa. Adult males range from 60 to 140 centimeters in length, and from 1.2 to 12.3 kilograms in weight. The snout is short, and is the feature from which the generic name (*amblys* = short, *rhynchos* = snout) has been derived. The basic coloration is black to dark grey, becoming light grey on the belly. During the breeding season, and on some islands throughout the year, the sides of the body and mid-dorsal parts of the head and legs acquire a red and greenish coloration.

Males defend mating territories for up to three months during the annual breeding season. Females lay 1 to 6 eggs in burrows dug 30 to 80 centimeters deep in sand or volcanic ash, often up to 300 meters or more inland. The eggs are left unattended and the incubation period is approximately 95 days. There have been big changes in the distribution and abundance of marine iguanas during the last 150 years, and some of the early references to marine iguanas in the literature enable interesting comparisons to be made with the present situation.

Some History

The first reference to marine iguanas is by Fray Tomás de Berlanga who found "many iguanas that are like serpents," when he discovered the islands in 1535. The buccaneers of the late 17th century wrote in their journals of enormous numbers of iguanas, which they often collected in large quantities for food.

By the late 18th century the whalers were frequenting Galápagos waters: Captain Colnett writing in 1798 regarded the "sea guana" as "the most extraordinary animal" of Galápagos, and noted that it "abounds in all these isles" and "goes to sea in herds, a fishing"!

Porter, writing in 1822, also found "myriads of guanas, of an enormous size and the most hideous appearance imaginable." He "first supposed them prepared to attack," and then tells how he and his crew soon "discovered them to be the most timid of animals, and had, in a few moments knocked down hundreds of them with our clubs, some of which we brought on board and found to be excellent eating." This was on the south coast of Isabela in a place where few iguanas remain today.

Marine iguanas were collected extensively from many of the islands of the archipelago by the various scientific expeditions of the late 18th and early 19th centuries. Henry Blake noted an abundance of marine iguanas in Tagus Cove, Isabela in 1872; today hardly any remain there.

Reasons for the Decline in Numbers

Iguanas are patchily distributed throughout the islands, with enormous concentrations in some areas and very low densities in others. Population compositions also vary greatly, with juveniles very rare or totally absent in some areas. The iguanas prefer the exposed, southern coastlines to the sheltered, northern coastlines. The greatest concentrations of marine iguanas occur where there are shallow reefs and extensive intertidal zones.

Suitable nesting sites are also important in determining the distribution of the major colonies, but females may travel considerable distances to nest.

Predation by introduced animals has a great influence on abundance and population composition. Introduced dogs, cats, rats, and pigs all eat marine iguanas or their eggs. At Cabo Berkeley and Muneco on northern Isabela, cats take almost every hatchling before they reach one year of age, so there is effectively no recruitment to the adult population. At Caleta Webb on southern Isabela, dogs were taking at least 27 percent of the population each year until a poisoning campaign eradicated them from the site in 1983.

Effects of the 1982–83 El Niño

The principal oceanographic event of the century in the Galápagos, the 1982–83 El Niño/ENSO event, had a profound effect on the iguanas. There was a distinctly increased mortality rate, and those iguanas that lived showed clear morphological, physiological, and behavioral changes.

During 1983, an unusually high mortality of marine iguanas was observed in populations on all the islands of the archipelago. A major change in the marine algal flora was observed during the same period and abnormally high sea-surface temperatures and sea-levels associated with the El Niño/Southern Oscillation event were recorded from November 1982 until July 1983. The abnormal iguana mortality began in December 1982 and continued until August 1983.

Every coastline was strewn with dead or dying iguanas—thin, emaciated creatures half their former weights—the survivors tried to eke an existence from eating sea lion feces, crabs, or corpses of other iguanas. The animals died of starvation, at least partially attributable to their inability to digest an invading species of alga, *Griffordia mitchelliae*, not previously recorded in Galápagos. This invading species was later again replaced by the normal food species of red and green algae (for example, *Gelidium, Centroceras, Spermothamnium*, and *Ulva* species).

In 1984, there was hardly any nesting, since the survivors were in very poor condition. But, since then the iguana population has shown a marked recovery, with increased rates of growth, survival, and reproduction.

In the course of our research, we monitored a number of the principal effects of the event on the life history of the iguanas:

Changes in annual rates of mortality. Annual mortality rates before the 1982–83 El Niño varied from 4 percent in adult females to 46 percent in hatchlings. They shot up during the El Niño period to 53 percent in adult females, 63 percent in adult

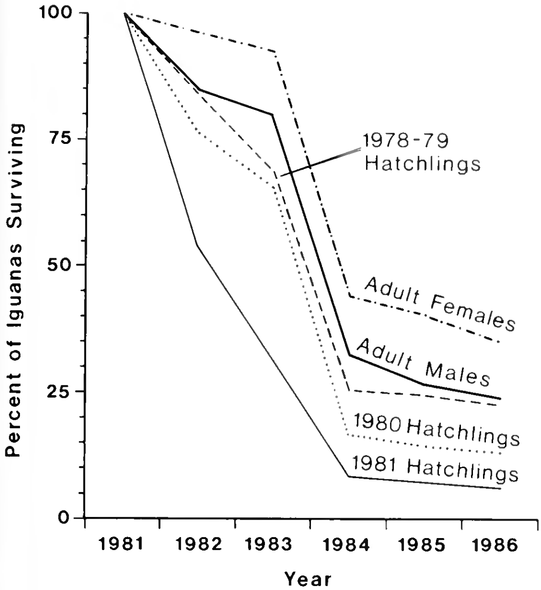


Figure 1. Cumulative percentage survival for various sex and age classes of iguanas by year from 1981 through 1986.

males and 85 percent in hatchlings. These rates have since returned to approximately pre-El Niño levels. Figure 1 shows the cumulative percentage of survivors in each year for different sex and age classes. The 1985 hatchlings suffered high first year mortality (about 60 percent) when compared with the pre-El Niño first year mortality of the 1981 hatchlings (about 46 percent). But, as there were approximately 1.8 times as many 1985 hatchlings as the average annual production between 1981 and 1983, there were more surviving yearlings of the 1985 cohort (year-class) than of the 1981 cohort. This means that population density has remained high for juveniles, but has fallen sharply for adults.

The high El Niño mortality is now being compensated for by increased growth rates, earlier breeding, more frequent breeding, and larger clutch sizes. There was selection for large body size and weight among juveniles in 1983, and there were also significant differences in their 1981 weights between juveniles that subsequently survived and those that did not survive the 1982–83 El Niño.

Growth rates. We have used the snout-vent length (SVL) of the iguana as our main measure of size and growth. Figure 2 shows the growth rates of females as the mean annual increase in SVL plotted against the SVL at the beginning of the year, for each year since 1981. In other words, it shows the mean growth rates for each size class of iguana. Growth rates were clearly depressed during El Niño, to zero in the larger animals, but rapidly increased afterwards and are now gradually decreasing again toward pre-El Niño levels. Immediately after El Niño, one and two year-olds were growing at about twice pre-El Niño rates.

Figure 3 shows the growth-curves for each hatchling cohort from 1980 to 1986. The highest first year growth was recorded in 1985 hatchlings; it has decreased for the 1986 cohort. There was considerable overlap in size distribution between the 1981 and 1982 cohorts and the 1982 and 1983 cohorts during their early growth.

Figure 4 shows the mean predicted growth in SVL for both sexes, based on the 1981–82 and the 1985–86 data on annual increments in SVL for each 1 centimeter size class and both sexes. It shows a clear shift in the curve to the left, so that both males and females could be expected to reach the mean size of 1981 breeding animals about two years earlier than in 1981. Increased adult growth rates also indicate a greater maximum attainable size.

Breeding age, nesting frequency, and clutch size. A host of changes in reproductive rate followed the period of stress and the associated recovery. As predicted, one of the consequences of the increased post El Niño growth rates was that females started breeding at 2.5 years of age in 1985, compared with 4.5 years or more in previous years. Furthermore, before El Niño, females nested approximately every two years, with about 40 percent of females nesting each year. Immediately after El Niño, there was hardly any nesting on most islands, but since then about 85 percent of females have nested each year, and the mean clutch size has risen from 2 to 3 on Santa Fe (Table 1), and from 3 to 6 on Isabela. In the 1985–86 nesting season, 1981 hatchlings nested for the first time, but 1982 and 1983 hatchlings also nested for the first time, both cohorts having attained adult size by very fast growth after El Niño.

Changes in body condition. In a method familiar to nutritionists and dieters, we prepared a measure, or index, of body weight relative to body dimension. This provides a measure of "fatness" or

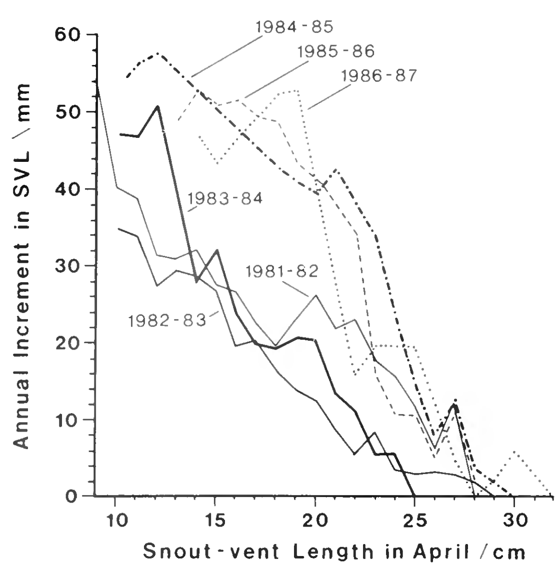


Figure 2. The average annual increase in snout-vent length (SVL), based on the SVL at the beginning of the year (April) for female iguanas, 1981 through 1987.

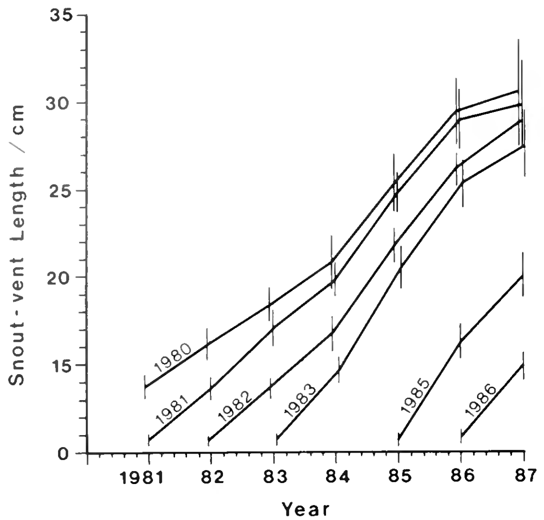


Figure 3. Growth curves for each iguana year-class from 1980 through 1986. Vertical error bars represent 1 standard deviation.

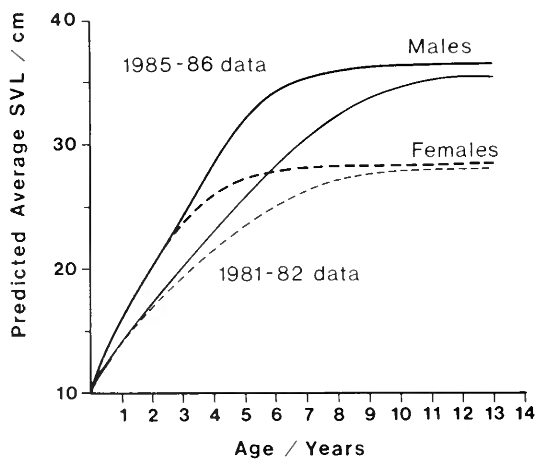


Figure 4. Average predicted growth in snout-vent length (SVL) for both males and females, based on 1981–82 data and 1985–86 data. The average size of a 1981 nesting female was 24.5 centimeters SVL, a 1981 breeding male, 31.3 centimeters SVL. The smallest 1981 nesting female was 22.5 centimeters SVL, and the smallest 1981 breeding male was 28.0 centimeters SVL.

"thinness." In our case, we used weight divided by SVL cubed: Weight/SVL^3. This yielded a suitable measure of the general condition of the iguanas across age and sex classes.

Figure 5 shows the changes in mean condition of adult iguanas (greater than 23 centimeters SVL) on Santa Fe over the 7 years 1981–1987. Results for other islands are similar. The clear trough in 1983 when many animals lost almost 50 percent of their body weight before either dying or recovering, was followed by a sharp rise in condition to well above the 1981 level, and then a return towards that level.

Population Regulation

Over time, and through both major and minor environmental perturbations, two factors seem to be most important in determining the population size of the iguanas: food and predation.

Food supply. The effects of the disappearance of the preferred algal food species during the 1982–83 El Niño were devastating, but such severe events are infrequent, probably occurring not more than once a century. There is evidence that the last event of comparable magnitude to the 1982–83 El Niño occurred in 1877–78. There are no reports of widespread iguana mortality during previous, less severe, El Niño events and although *Giffordia mitchelliae* was recorded again in early 1987, during a minor El Niño event, and there was a reduction in standing crop of red algae, no increased mortality has yet been observed. However, condition and growth rates are likely to be decreased by even minor El Niño events, and thus lead to lower reproductive output and possibly higher mortality, so all El Niño events may be important in population regulation.

Predation. Although iguanas appear to be food limited, predation on land by introduced species has probably been the main cause of the gross changes in distribution and abundance of the species during the past 150 years. Man also caught the animals for food, but has never predated the species at a significant level over large areas. Even so, there are reports from San Cristobal that iguanas are killed occasionally for dog food despite legal protection. Cats are the main culprits among the

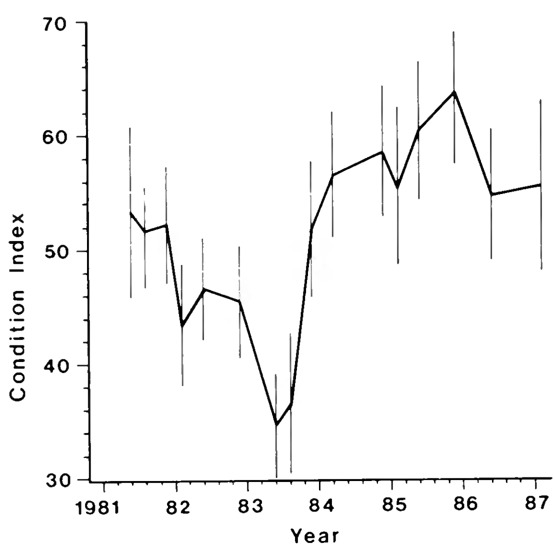


Figure 5. The "condition index," a measure of body weight relative to body dimension, for adult iguanas on Sante Fe Island between April 1981 and February 1987. Vertical error bars represent 1 standard deviation.

introduced predators—and Isabela, San Cristobal, and Santa Cruz the islands most affected.

By poisoning, dogs have been successfully eradicated from certain coastal areas, although populations remain in the highlands. Complete eradication has proved impossible so far, and in the case of cats it is probably an unrealistic aim at this stage. Local control around nesting areas of marine iguanas and other species is probably the best plan. Elsewhere, in New Zealand for example, the control of feral cat populations has proved exceptionally difficult and expensive. The task on the Galápagos, especially on Isabela, is much more difficult because of the treacherous lava shores, along which it is often difficult, or even impossible, to walk, let alone operate a cat control program. A pilot project is needed in locations where cat predation is particularly serious.

The Galápagos Marine Resources Reserve

Although the predation on land is the most immediate problem for the marine iguanas on islands with introduced predators, the long-term security of the food supply is obviously vital, and the establishment of the Galápagos Marine Resources Reserve an essential step for the long-term conservation of the species. Totally dependent on the red and green algae of the intertidal and upper subtidal zones, iguanas are particularly vulnerable to marine pollution. As the species composition of the algal flora is important there may be pollutants which, although not fatal to all algae lead to a decrease in the availability of iguana food species. Certain species could become poisonous after absorption of toxic chemicals.

Large oil spills would surely be fatal. There already have been reports of minor oil slicks. One came ashore on the south coast of Santa Fe in January 1986 and killed the algae on a small part of the intertidal zone. There is a constant danger of more spills and major accidents. Nesting beaches also could be affected, and hatchlings might be particularly at risk, being restricted by their size, to feeding at the very top of the intertidal zone.

Much of the pollution which may affect Galápagos waters, particularly that originating outside territorial waters, will not be made any easier to control by the establishment of the marine reserve. However, the legal liability of ship owners and captains for pollution within the reserve should be used, in addition to conservation arguments, to encourage correct maintenance and safety procedures, and all that is possible to reduce the risk of such accidents. Iguanas are particularly vulnerable because of their low reproductive rate. Every precaution must be taken to avoid pollution of any sort, and this includes provision of equipment in Galápagos for fighting oil spills, for example, detergent sprayers, at such times as they are considered preferable to the oil.

With the establishment of the marine reserve should come a systematic monitoring program for the marine environment, so that pollution, overfishing of fish and lobsters, and unacceptable human disturbance can be detected quickly and controlled. For instance, regulations must be enforced to limit the ever increasing pollution of the coastlines of even the most remote islands with plastic—bags, bottles, and other containers—which threaten many coastal species, including iguanas. In some cases it may be necessary to ban the import of certain pollutants—for example plastic cola bottles—to the islands, particularly when suitable alternatives are readily available.

Andrew Laurie is a Research Associate at the Max-Planck-Institut für Verhaltensphysiologie, Seewiesen, West Germany. He is also affiliated with the Department of Zoology, Large Animal Research Group, Cambridge University, England.

Acknowledgment

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The Urvina Bay Uplift:

A Dry Trek Through a Galápagos Coral Reef

by Mitchell W. Colgan, and David L. Malmquist

Strange sights are commonplace in the Galápagos. Still, it is surprising to find a place like Urvina Bay, where trees grow out of coral heads and land iguanas roam where fishes recently swam. The circumstances that produced this unusual meeting of land and water provide us with a natural outdoor laboratory to explore topics in paleoecology, sedimentology, and marine biology.

On a Wednesday morning in September, 1835, the *H.M.S. Beagle* sailed up the Bolivar Channel toward an overnight anchorage at Bank's Cove. On board was Charles Darwin. As the *Beagle* passed within sight of the shallow waters of Urvina Bay, Isabela Island, the young naturalist unknowingly bypassed a rich coral community, where at least one colony measured more than 5 meters in diameter. Indeed, Darwin found neither coral communities nor coral buildups during his 5 weeks in the Galápagos. Unlike the pivotal role they played in his theory of evolution, the islands did not play a part in Darwin's ideas about the formation of coral reefs and atolls.

In 1954, however, the floor of Urvina Bay was suddenly thrust more than 6 meters above sea level (Figures 1, 2, and 3). Now, 152 years after the *Beagle* visit, it is possible to casually take a dry walk through a coral community and visit a part of the Galápagos unknown to Darwin.

The Uplift

Urvina Bay lies between the Alcedo and Darwin volcanoes on the west-central coast of Isabela Island. Before the 1954 uplift, the coastline of Urvina Bay lay in the shape of a "7," with the rocky coast on the western flanks of the Alcedo volcano forming the vertical stroke, and the mangrove and sandy-beached shore adjacent to the Darwin volcano the horizontal. Where these two shorelines met was a shallow bay that harbored a rich coral and algal community.

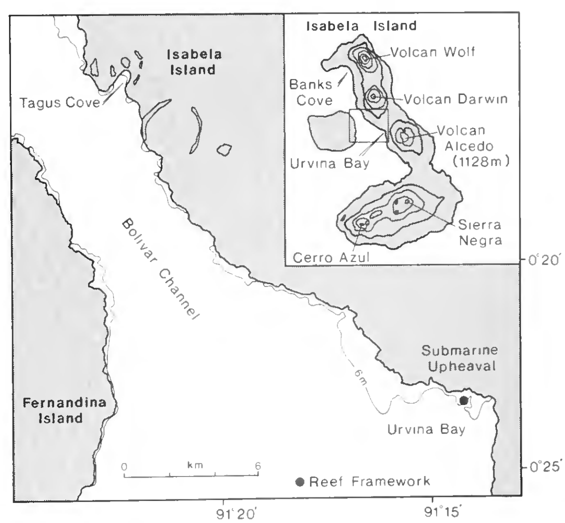

Figure 1. Urvina Bay on the west-central coast of Isabela Island, showing the pre-uplift coastline and the 6-meter depth contour.

This all changed early in 1954, when magma beneath the Alcedo volcano suddenly rose, thrusting the shoreline of Urvina Bay 1.2 kilometers seaward, exposing several square kilometers of its marine community.* Although the movement of this magma was originally thought to be a precursor to a 1954 eruption of the Alcedo volcano, Keith Howard, a scientist at the U.S. Geological Survey, has found no evidence for such an eruption.

* Other uplifts are present in the Galápagos. Almost all are smaller and more localized, and/or occurred along more steep-sided coastlines. The Urvina Bay uplift is unique because it elevated a shallow bay, thereby exposing an extensive area.

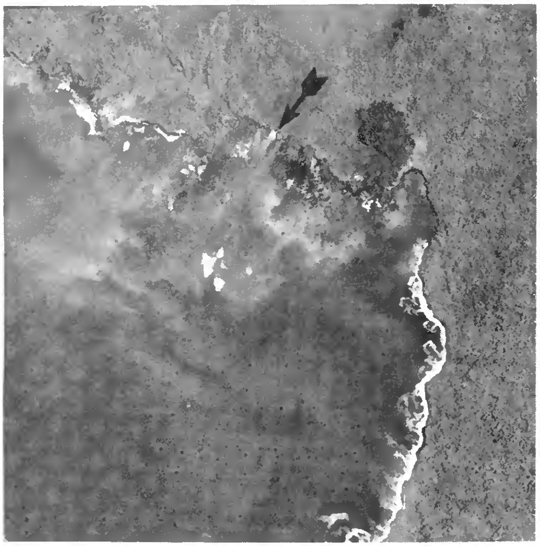

Figure 2. Urvina Bay in 1946, eight years before the uplift. The arrow points to a white, carbonate-sand beach, on either side of which grew mangrove trees.

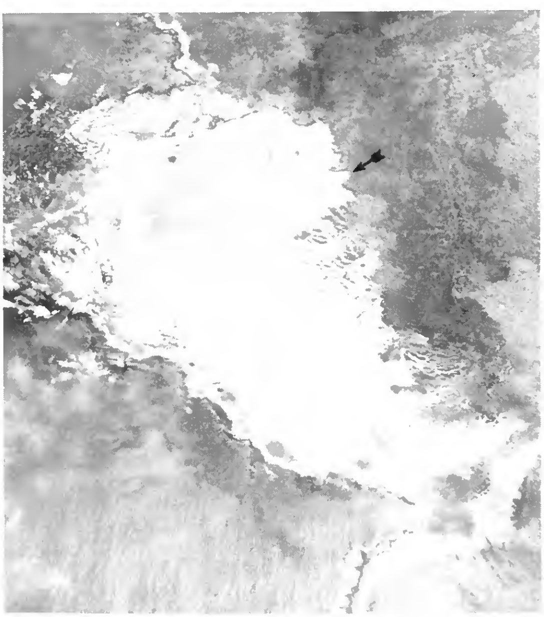

Figure 3. The same area in 1968, 15 years after a magmatic disturbance uplifted Urvina Bay. Again, an arrow points to the white, carbonate-sand beach, now more than a kilometer from the water. (Photo by Tom Simkin)

The shallow bay seen by the *Beagle's* crew had disappeared; in its place was a white, rocky coastline. Jack Couffer, a member of a Walt Disney crew filming in the Galápagos, was the first to report the event (see "The Disappearance of Urvina Bay," *Natural History*, 1956). He found "in every niche and crack and cave in the rock . . . the skeleton of some sea animal—a crab, a starfish, a sea urchin, a fish. In the depression below the rocks, the dried remains of lobsters, sea turtles, and marine worms lay mummified in the sun."

The very presence of these vertebrate and invertebrate remains indicates that the uplift occurred rapidly, perhaps overnight. Moreover, the distribution of the remains suggests that most of the water retreated from the uplift by percolating downward through the porous aa lava (aa, from the Hawaiian "to hurt" is fractured, jagged lava), rather than by flowing overland. For instance, in depressions seaward of the original mangroves are the sun-bleached bones of more than 30 sea turtles. In contrast to the remains of recently dead sea turtles scattered by currents on the modern beach, these skeletons occur in concentrated piles.* Unaltered, large-scale sand ripples and the preservation of the original angles of repose on Urvina Bay's former beaches also give evidence of the rapid downward flow of water. If the uplift had occurred over time, we would expect to see a series of terraces on the beaches, marking the level at which they temporarily equilibrated to the new sea level.

The rapid uplift and drainage preserved the integrity of the community and its sediments. Now, some 33 years after the event, we can study subtidal marine communities without getting wet (except during the heavy rains of an El Niño year!).

The Lay of the Land

The dark basaltic lava of the Darwin Volcano is Urvina Bay's foundation; its complex flow patterns and topography of collapsed lava tubes left a structural legacy that controlled the settlement and growth of the bay's marine community. Variations in water depth, degree of wave exposure, and irregularity of the porous lava provided many microhabitats where coral, calcareous algae, and mollusks settled and grew. On the uplift, the remains of these organisms produce a white-carbonate line that delineates the old mean-low-water mark. This cuts across the black basalt like a milky bathtub ring.

On the upraised shelf, there is a seaward progression from landlocked sandy beaches and mangrove swamps to areas underlain by deposits of carbonate sand up to 2 meters thick. Isolated, incipient coral reefs dot this area. More than a kilometer from the stranded mangroves of the uplifted shoreline, new mangroves grow and flightless cormorants nest in an intertidal area only 33 years old. Along the new shore, beaches have developed, and sea turtles now come to nest.

Coral Communities

Many atolls, fringing, and barrier reefs of the Pacific arose from volcanic platforms similar to Urvina Bay. But the origin of these reefs is now shrouded under thick layers of carbonate. Urvina Bay's youthfulness

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* As the reef section was uplifted, the turtles were trapped in pools. Because the area was quickly elevated above sea level, it was removed from the influence of waves and currents, which would have reworked and scattered the skeletons.

A tree grows from the center of a massive star coral, Pavona clavus. *(Photo by Mitchell Colgan)* and its abundant exposures provide a rare opportunity to document the initial steps in the growth and expansion of a coral reef.

Physical and biological forces control the composition and distribution of sediments shed by a coral community during its growth. As the community develops, the sediments change. Cores reveal the expected—an overall upward increase of carbonate deposition as the shelf matured. However, layers with high concentrations of basaltic sand interrupt the carbonate sequence. These intervals of reduced reef growth and decreased carbonate production may be linked to climatic changes.

Red calcareous algae were the first colonists on the barren basalt; these were followed by corals. Among the earliest was the sand coral *Psammocora (Plesioseris) superficialis*. In the central portion of the uplift, where large colonies of the finger coral *Pocillopora damicornis* now predominate, trenches reveal an early shift in the community from the smaller and slow-growing *Psammocora* to the larger and faster-growing *Pocillopora*.

Although the eight hermatypic (reef-building) coral species that inhabited Urvina Bay occur in nearly every subenvironment on the uplift, they are concentrated in only 10 locations. Three species—the star coral *Pavona clavus* (Figure 4), the head coral *Porites lobata*, and *P. damicornis*—have produced five monospecific reefs. At first thought, these stands might reflect distributional constraints brought about through competition or genetics. But, with few exceptions, competition between corals is not apparent. Moreover, as defined by inferred water depth and current exposure, most of the corals lived in similar environments. Without any outstanding environmental constraints on their distribution, the segregation of corals on the uplift may simply reflect chance settlement.

Because the Galápagos are bathed in relatively cool waters, they are a marginal reef-growing environment. Once coral larvae settle there, the harsh conditions may limit their sexual reproduction. Corals in the Galápagos compensate by reproducing asexually, through fragmentation and regrowth. For example, the counting of growth bands on a giant colony of *P. clavus* by Gerard Wellington, an Assistant Professor of Biology at the University of Houston, shows this coral to be at least 350 years old. Nevertheless, except for fragments at the coral's base, there are no other individuals of *P. clavus* within 50 meters of this coral. Thus, for a third of a millenium this coral grew and survived, but apparently could not sexually reproduce. Because asexual reproduction through fragmentation limits the ability of corals to disperse, Galápagan corals remain clustered in the random areas where colonization originally occurred.

Fragmentation, and hence asexual reproduction, of corals in the Galápagos is accelerated by bioerosion. We are thus faced with a contradiction worthy of Orwell's *1984*: erosion is growth. At Urvina Bay, bioeroders are common, ranging from fishes to sponges, but the most conspicuous eroder is the club-spined sea urchin *Eucidaris thouarsii*. Coral colonies on the uplift are often so heavily infested with *Eucidaris* borings that they are nothing but thin shells arching over a hollow interior. But like the saplings that spring from the stump of a fallen tree, the fragments produced by bioeroders commonly fall around the perimeter of the parent colony, where they continue the colony's growth. Many of Urvina Bay's corals apparently reproduced most successfully through this type of asexual fragmentation.

Galápagos reefs are smaller and less diverse than most Pacific reefs. Nonetheless, understanding their development should throw light on the origin and history of larger oceanic reefs in the Pacific.

Climatology

In the Galápagos, as described by P. W. Glynn and G. W. Wellington (see Selected Readings), climate and water temperature play important roles in determining the distribution of reefs and their rate of development. Seasonal pulses of cold, upwelling water, concentrated in the southwestern sector of the archipelago, largely restrict reef growth to the northeastern portion of the islands. Located in the lee of Fernandina Island, Urvina Bay is somewhat protected from these upwelling waters, and thus corals can grow on the western coast of Isabela.

The 1982/83 El Niño-Southern Oscillation (ENSO) event warmed the seas in the eastern Pacific far above normal for many months, severely harming Galápagos marine life and adding a new climatic factor into the equation of the islands' reef development (see article page 42). This El Niño killed vast numbers of corals in the Galápagos and nearly caused the localized extinction of *P. damicornis*. According to Peter Glynn, a Professor of Biology at the Rosenstiel School of Marine and Atmospheric Science of the University of Miami, such severe El Niño events may be important forces in structuring the marine communities of the eastern Pacific. The repeated thermal stresses suffered during El Niño years may be partially responsible for the small size of Urvina Bay's coral reefs.

The impact of El Niño events on eastern Pacific marine communities depends on the frequency with which the events occur in relation to the lifetime of the communities. However, the long-term record of the periodicity and ferocity of ENSO events is poorly known. Our understanding of marine and terrestrial community development under El Niño stresses thus remains incomplete. More importantly, a long-term El Niño record would help planners prepare for future El Niño events.

Urvina Bay may provide us with this record of El Niño events. Because El Niños change the temperature of the sea, they also alter the ratio of stable-oxygen isotopes that corals incorporate in their skeletons during growth. By analyzing the isotopic signal recorded in the calcium carbonate ($CaCO_3$) skeleton of the giant *P. clavus*, the thermal condition of the ocean at the time of the coral's growth can be reconstructed. Working with Glynn and others, we extracted a 4-meter core from this coral. The core represents at least 350 years of time, extending the record of El Niños to roughly 1600.

This delicate cluster of Pavona elegans *shows the exquisite preservation of the marine community on the uplift. (Photo by Mitchell Colgan)*

The isotopic analysis of the core is being done by Wellington and Rob Dunbar, an Associate Professor of Geology at Rice University.

Taphonomy and Paleoecology

Because the history of life on earth can only be reconstructed through fossil evidence, paleontologists must know what information is lost, and what retained, as a once living community passes into a fossil state. Urvina Bay is a natural laboratory in which to study this passage. Here, we can compare the dead community on the uplift to the living community in the water, and examine the changes that take place as a once living community passes into an assemblage of fossils.

Because organisms with durable hardparts are more likely to be preserved than those without, the incomplete fossil record is biased. For example, even though insects are by far the most abundant and varied of living organisms (with some 800,000+ species), they are rare as fossils. The habitat of an organism also helps dictate the likelihood of its preservation. Organisms that live or die in environments where deposition prevails are more likely to be preserved than are those inhabiting environments of erosion. The fossil record is thus strongly skewed toward marine organisms with durable skeletons.

It was not until 1940, when the Soviet paleontologist J. A. Efremov initiated the science of taphonomy (the study of fossilization), that paleontologists began to fully understand how important the imperfection of the fossil record is to their science. Taphonomy, from the Greek root

Figure 4. An incipient reef of Pavona clavus *fragments. These fragments were shed by an older colony that bioeroders destroyed before the uplift occurred. (Photo by Mitchell Colgan)*

"taphos," for burial, studies the passage of organisms from the biosphere to the lithosphere. As such, it bridges the gap between biology and paleontology.

Common sense dictates that a fossil community retains less information than its living predecessor: paleontologists commonly speak of "taphonomic loss." At Urvina Bay, this holds true for certain taxa. Though we searched the entire area of the uplift in detail, we found the remains of only 4 fish, 1 marine iguana, and 5 sea stars. Curiously, although they were reported in early descriptions of the uplift, we found no lobsters. Unlike the early paleontologists in the Arctic who reportedly ate frozen mammoth while drinking cocktails chilled by Pleistocene ice, we were unable to dine on sunbaked "langosta."

Without allowing for the obvious taphonomic loss that removed these taxa from the fossil record, we would certainly reconstruct a community different from the one visible to the snorkeler in the present-day waters of Urvina Bay. Parrotfish, wrasses, blennies, the ubiquitous damselfish, and the endemic marine iguana are important shapers of the structure of the modern community. Disregarding taphonomic loss, they would be only minor components of our reconstruction.

The preservation of most hard-shelled groups at Urvina Bay, however, is exquisite. Individuals of *E. thouarsii* are found on the uplift just as they occur in Urvina Bay today. They occupy holes of their own making in basaltic boulders and coral heads, with their jaw structure, the Aristotle's lantern, still articulated inside the urchin. The jaw commonly projects from the mouth, where its five teeth rest against the once algal encrusted but now barren surface. The urchins' spines lie in perfect halos around the skeletal test, further evidence that the uplift was rapid and that subsequent current activity was negligible.

Also beautifully preserved on the uplift, and extremely abundant, are gastropods. These are commonly found crowded in depressions. Evidently, as seawater in small pools and fissures evaporated after the uplift, the snails concentrated in these tepid and saline pockets, finally dying.

Even such delicate forms as sponges survived the uplift. These animals occur on the underside of basaltic cobbles and boulders (a lifestyle described by the term cryptic)—some retain their original form and surface texture. Other common cryptic animals found are chitons, corals, serpulid worms, and bivalves.

For hard-shelled and cryptic organisms then, a curious pattern exists at Urvina Bay. Contradicting paleontology's golden rule that the present is the key to the past, at Urvina Bay, the past of 33 years ago is a better key to the present than is the modern marine community. Instead of taphonomic loss, there has been taphonomic gain.

There are three main reasons for this reversal. First, try as we might with snorkels, wetsuits, masks, and flippers, humans are terrestrial, not marine, mammals. Unlike marine researchers, we can, on the uplift, submerge ourselves in our work without holding our breaths for the results. Visibility on the uplift is fantastic; we sometimes had "five volcano days" when Alcedo, Darwin, Cerro Azul, Sierra Negra, and Fernandina volcanoes were visible from our study site—the farthest is 60 kilometers away. Moreover, there is no surge or swell on the uplift and we, rather than the Galápagos shark, are at the top of the food chain.

Second, the carpet of fleshy algae that hides so much life in the water is absent on the uplift, revealing large numbers of gastropods, bivalves, and arthropods that would otherwise go undetected.

Third, nocturnal, infaunal, and cryptic animals, which are visible only with great effort to the marine biologist, are on the uplift clearly exposed to the equatorial sun.

Because of the exquisite preservation of the hard-shelled taxa at Urvina Bay, our future research there will concentrate on answering the question: "How much information about an original living community can a paleontologist garner based on a *complete* representation of the hard-shelled taxa of that community?" That is, even with no loss of skeletal information, what can a paleontologist say about the entire living community based on its skeletal record alone? At Urvina Bay, the juxtaposition of comparable fossil and living communities puts the answer to this question within our grasp.

Mitchell W. Colgan and David L. Malmquist are doctoral candidates in Earth Sciences at the University of California, Santa Cruz. Both are conducting thesis research at Urvina Bay, Galápagos, Ecuador, under the supervision of Léo F. Laporte.

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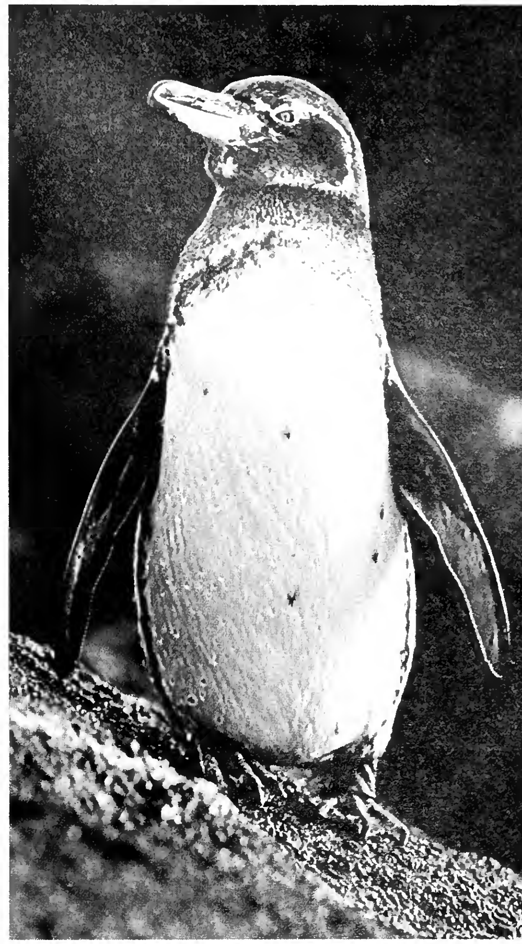
Galápagos Seabirds

Even though Darwin's finches may be the group of birds most symbolic of Galápagos ecology, the nesting seabirds of the islands form a unique community of their own. Three ocean currents—the cold Humboldt, the warm North Equatorial, and the cold, upwelling Cromwell—converge at the Galápagos, and each has brought a characteristic set of seabirds to the islands. According to ornithologist M. A. Harris, the archipelago now provides nesting sites for 14 migratory and five endemic species, representing a total of about 750,000 seabirds.

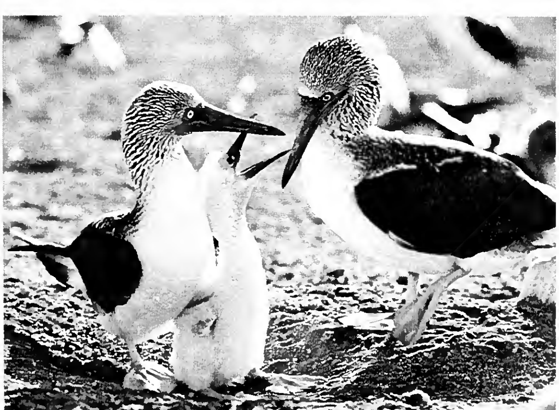
The Humboldt Current was probably the highway taken by the most unlikely bird to nest in the equator-straddling islands, the Galápagos penguin, Spheniscus mendiculus. *These penguins have long since lost touch with their nearest relatives on the Patagonian coast, and so are endemic to the Galápagos. More than 10,000 of them live in many colonies on the islands, banding together in large groups to fish the colder waters sweeping the islands.*

Keeping cool under the equatorial sun is more than a matter of comfort for these antarctic outcasts. Ornithologist D. Boersma reported a case in which one penguin, while shading its nest from the sun, became so overheated that it took a life-saving plunge into the sea. Unfortunately, by the time it returned to its nest, the eggs had overheated and never hatched.

The penguins have a non-flying partner among the Galápagos seabirds in the flightless cormorant, Nannopterum harrisi. *These two species are the rarest seabirds in the world. The cormorant is the only one of the 29 cormorant species unable to fly. It has even lost the enlarged keel on its breastbone for the attachment of flight muscles; yet after diving it still spreads out its vestigial wings to dry, in characteristic cormorant fashion. Although it feeds closer to shore than any other Galápagos seabird, Darwin failed to notice it during his 1835 voyage.*



The Galápagos penguin. (Photo by Tui De Roy, courtesy National Park Service)



Blue-footed boobies. (Photo by Tui De Roy, courtesy National Park Service)

The other large endemic seabird is the waved albatross, Diomedea irrorata. *Weighing-in at 3 to 4 kilograms, and with a wingspan of up to 2 meters, it is the largest species of albatross. It also is the only tropical species among the 13 of the family.*

Nesting pairs of Diomedea *mate for life, which can last up to 50 years. Their courtship behavior is curious in that its most elaborate display is at the end of the breeding season. This involves a clattering, bill-circling dance. During the dance, the bills slide easily over one* *another, lubricated by an oily secretion. Chicks hatch out of eggs weighing about 285 grams, and are fed a predigested, oily mixture of squid and fish by their far-ranging parents. The chicks can take in as much as 2 liters of this at one feeding, stuffing them to the point of immobility.*

The brown pelican, Pelecanus occidentalis, *while being one of the largest Galápagos seabirds, is one of the smallest species of pelican. Many visitors are awed by its vertical, 50-foot dives into the sea. On these spectacular sorties it collects up to 3 gallons of water in its expandable bill, and filters out meals of small fish. Groups of brown pelicans are also impressive as they fly almost in unison, just above the surface of the warm waters of the North Equatorial Current.*

The brown pelican. (Photo by D.J.H. Phillips)

Those waters also bring the three species of boobies to the Galápagos. They are said to have been so-named by seafarers of long ago, because of their strange appearance and behavior. "Bobo" is Spanish for clown—and the term "booby-hatch" comes from the birds' habit of diving headlong off the bows of ships, in pursuit of flying fish.

Most remarkable in appearance is the blue-footed booby, Sula nebouxii. *Because it feeds close to shore, it is seen more often than its relatives—the masked and the red-footed boobies, each of which outnumber the blue-footed. Although* S. nebouxii *does not build a nest for its eggs, it still engages in a vestigial nest-building routine. The bare ground where the eggs are laid often gets dangerously hot. So the nesting booby shades them with its body, and keeps them on top of its foot-webs.*

Another warm-water Galápagos species is the dark-rumped petrel, Pterodroma phaeopygia. *It is the most endangered of the nesting seabirds. In Hawaii, it is almost extinct as the result of predation by feral cats, rats, and dogs. In the Galápagos, these same animals have pushed this petrel into a "very precarious" situation, according to seabird ecologist Malcolm Coulter.*

The white-vented storm-petrel, Oceanites gracilis, *is a species typical of the cold Humboldt Current. While Coulter estimates that many thousands of them nest at the Galápagos, to date no nesting sites have been discovered.*

Even though increasing numbers of tourists visit the Galápagos each year, the nesting seabirds seem little affected by their influence. Visitors must be accompanied at all times by a naturalist guide. The seabirds were taken into account when the boundary of the Galápagos Marine Reserve was drawn (see map page 2). The Reserve extends 15 miles beyond the outermost islands, insuring safe fishing areas for boobies, petrels, and their neighbors.

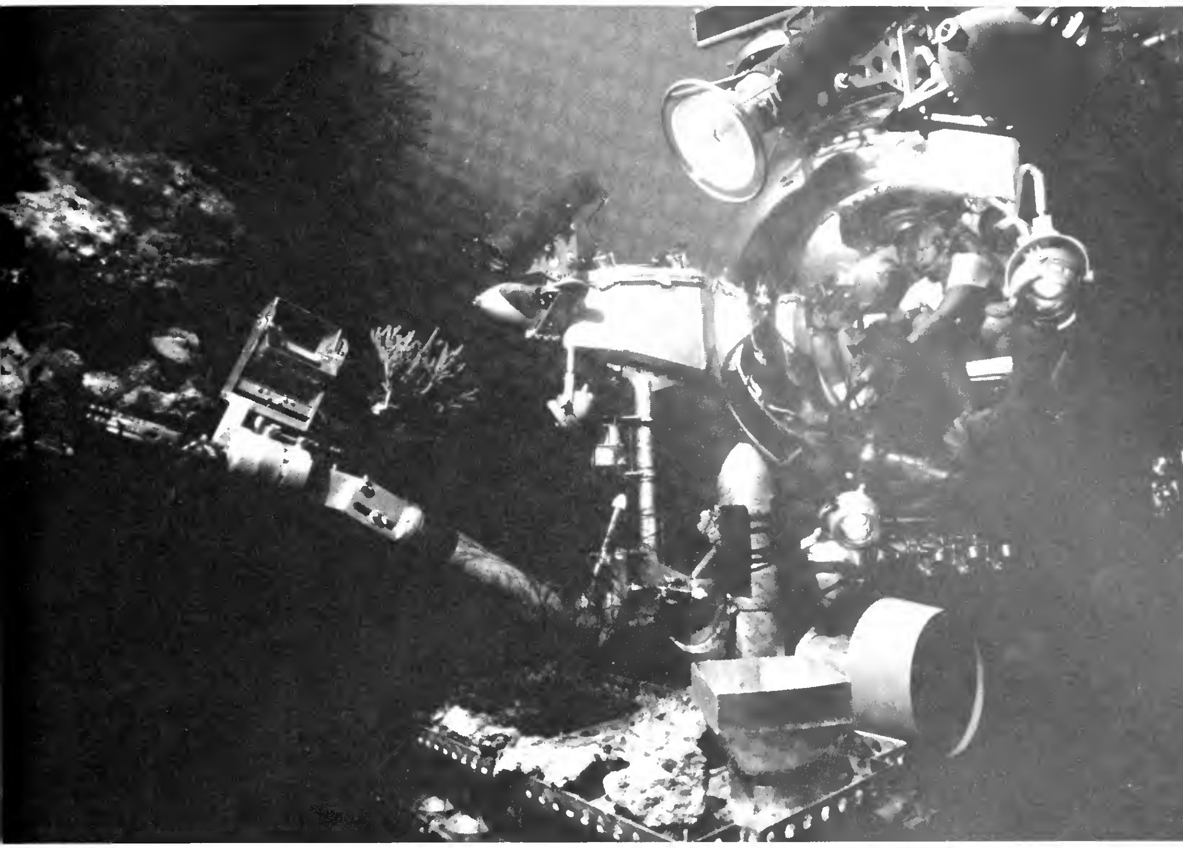
–TMH

Odd-Ball Uses for ROVs

There's a new manual for entrepreneurs called "Sunken Golf Ball Recovery." It's no problem to make $700 a day retrieving golf balls from water hazards, reports SubNotes *in its April issue.*

One man in Florida reportedly dons SCUBA gear and hauls up 300,000 golf balls a year. At $7 a dozen, that's a cool $175,000 before taxes and overhead. A southern California operator supposedly can collect 78,000 balls in a month. He sells them at the bargain-basement price of just 25¢ apiece, so his monthly income from the venture is $19,500. Not bad.

But, these entrepreneurs are missing the high-tech angle to this enterprise. Some ocean engineer should come up with a golf-ball recovery tool and basket attachment for remotely-operated vehicles (ROVs). This would open the golf-ball recovery game to non-divers. One would avoid the inconvenience of getting wet, and pocket a $1,000 a day or so to boot. It is time to stop foolin' with shipwrecks in inhospitable places, and turn the technology attention to the more mellow environs of the local golf course. Isn't this what the American dream is all about?



A Search for Unique Drugs in the Galápagos Underwater Environment

by Shirley A. Pomponi, and Susan van Hoek

Scientists from the Harbor Branch Oceanographic Institution/SeaPharm Project spent seven weeks this past winter cruising the Galápagos Islands searching for new drugs from marine organisms. Results from bioassays taken aboard the institution's research vessel *Seward Johnson* indicated that possibly as many as 15 percent of the organisms collected have anticancer, antiviral, antimicrobial, or immunomodulatory activity. More extensive testing is now under way in the Harbor Branch/SeaPharm Project laboratories in Fort Pierce, Florida.

Nearly 1,200 organisms were collected by wading, snorkeling, SCUBA diving, and diving inside the four-man, *Johnson Sea-Link I* submersible. Of these samples, nearly 700 were collected at depths from 350 feet to 2,630 feet (near maximum diving range for the

Above, the Johnson Sea-Link I. *(Photo courtesy Harbor Branch Oceanographic Institution)*

Shirley Pomponi and soft coral on a vertical wall at 70 feet. (Photo by John Reed)

submersible). The most abundant animals collected were sponges, echinoderms (primarily starfishes, sea urchins, and sea cucumbers), and soft corals, though representatives of most marine invertebrate phyla, as well as algae and ascidians (sea squirts), were also collected.

The search for cures for such diseases as cancer from marine organisms follows extensive evaluations of land organisms. To date, only about 20 clinically useful drugs are available for treatment against cancer, and these are toxic and have a limited range of activity. Scientists are now searching underwater on the presumption that the oceans may provide a vast reservoir of untapped resources.

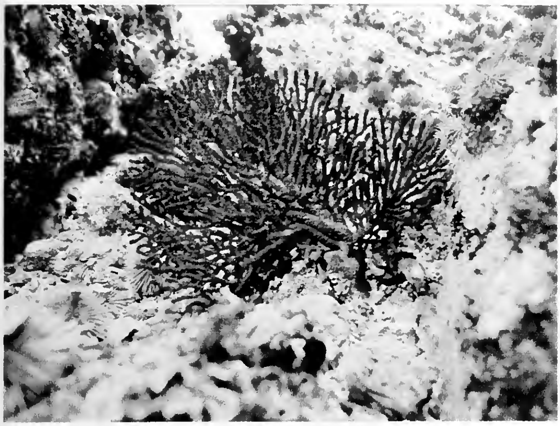
The Galápagos Islands were targeted as a possible source for new drugs because the area has a unique, relatively unexplored marine environment. Some of the most interesting collections were made west of Isabela and Fernandina Islands, the youngest and most active islands of the volcanic chain and the site of nutrient-rich, upwelled water.

Galápagos Flora and Fauna

Galápagos shallow water flora and fauna share many similarities with that of the tropical eastern Pacific, including the Gulf of California, although a few species collected, particularly echinoderms, are more closely related to species in the Indian Ocean and western Pacific. The intertidal areas are often described as barren due to the large number of grazers and predators, but cruise participant Richard C. Brusca, Curator of Invertebrates, Los Angeles County Natural History Museum, found the rocky shores to be surprisingly rich in invertebrates.

Relatively little is known about the Galápagos deep sea fauna. The *Johnson Sea-Link I* submersible, equipped with underwater video, 35-mm cameras, a manipulator arm, and a suction device gave scientists new insights into the deepwater communities that have been traditionally sampled with trawling and dredging rigs. Several new species of ascidians, or sea squirts, were discovered. Cruise participant Françoise Monniot, Curator of Marine Invertebrates at the Paris Museum of National History, reported that the sea squirts are unusual for both their large size and their taxonomic distribution. She said, "this may change the general opinion about the diversity, the origin, and the evolution" of deep water ascidians.

Preliminary examination of more than 300 Galápagos sponges indicates several new species were discovered. In addition, the deep



A sea fan on a rocky volcanic slope. (Photo by John Reed)

A cluster of green sea urchins endemic to the Galápagos, collected off Fernandina Island. (Photo by John Reed)

water "glass" sponges, or hexactinellids, were much more diverse than those previously studied at the same depths in the West Indies. Collections of choristids—a group of sponges with abundant, prickly, glass-like spicules—show similarities with species collected in the Caribbean. This may lead to new hypotheses about the origin, evolution, and relationships of that group of animals.

How the Samples Were Handled

After preserving a sample of each organism in alcohol or formalin, a small piece was made into an extract by grinding in a solvent mixture containing alcohol. The rest of the organism was preserved by freezing at minus 20 degrees Celsius. Living organisms, as well as alcohol- and formalin-preserved samples, were studied by taxonomic specialists participating in the expedition.

Extracts were tested by a team that included a virologist, a microbiologist, an immunologist, and a tissue-culture specialist. Of particular interest is the ability of the extracts to inhibit growth of cancer cells, viruses, bacteria, fungi, and yeast, as well as their potential for stimulating or suppressing the immune system. Obvious applications of this research are the development of drugs to treat cancers, viral diseases, and diseases of the immune system, such as AIDS.

The expedition was funded in part by a contract between SeaPharm and the National Cancer Institute, which will test the extracts from deep water organisms against a number of human cancers. This recently expanded interest in marine organisms as a source of anticancer drugs is based on discoveries of unique biochemicals with pharmacological activity produced by some marine plants and animals.

"Retro-spinoff," a Key By-Product

Although the primary goal of this research mission was the discovery of unique chemical compounds with pharmacological activity, important marine biological discoveries were also realized. Kenneth L. Rinehart, Natural Products Chemist at the University of Illinois, Director of Research at SeaPharm, Inc., and Chief Scientist of the expedition, dubbed such discoveries "retro-spinoff" or the gathering of new information that will become a part of the current pool of basic scientific knowledge.

Enough material was brought back from the expedition to keep scientists busy for years, especially with taxonomy (organism identification) and systematics (life histories, distribution, abundance, ecological, phylogenetic, and evolutionary relationships among organisms). Many of the samples preserved as a reference collection will be deposited at the Smithsonian Institution, Washington, D.C., and at Harbor Branch.

SeaPharm, Inc., a pharmaceutical company with headquarters in Princeton, New Jersey, specializes in the discovery and development of drugs from marine organisms. Harbor Branch Oceanographic Institution, Inc., located on the west bank of the Intracoastal Waterway between Fort Pierce and Vero Beach, Florida, is a not-for-profit organization dedicated to research in the marine sciences and to the development of tools and systems for oceanographic research.

Shirley A. Pomponi is a marine biologist specializing in sponges, and a Senior Scientist with SeaPharm, Inc. Susan van Hoek is Public Affairs Officer and a writer/editor at Harbor Branch Oceanographic Institution, Inc.

The Voyage of the Beagle

EDITOR'S NOTE: What follows is an edited version of Chapter 17 of *The Voyage of the Beagle* by Charles Darwin. The celebrated naturalist landed in the Galápagos on 16 September 1835 to begin five weeks of collecting and observing, the results chronicled in Chapter 17. In all, he visited four of the major island in the group during his stay. As this issue of *Oceanus* focuses on the new Galápagos marine reserve, most of the material we have deleted concerns Darwin's observations of terrestrial fauna and flora.

CHAPTER XVII

Galápagos Archipelago

by Charles Darwin

SEPTEMBER 15th.—This archipelago consists of 10 principal islands, of which five exceed the others in size. They are situated under the Equator, and between 500 and 600 miles westward of the coast of America. They are all formed of volcanic rocks; a few fragments of granite curiously glazed and altered by the heat, can hardly be considered as an exception. Some of the craters, surmounting the larger islands, are of immense size, and they rise to a height of between 3 and 4,000 feet. Their flanks are studded by innumerable smaller orifices. I scarcely hesitate to affirm, that there must be in the whole archipelago at least 2,000 craters. These consist either of lava or scoriæ, or of finely-stratified, sandstone-like tuff. Most of the latter are beautifully symmetrical; they owe their origin to eruptions of volcanic mud without any lava: it is a remarkable circumstance that every one of the 28 tuff-craters which were examined, had their southern sides either much lower than the other sides, or quite broken down and removed. As all these craters apparently have been formed when standing in the sea, and as the waves from the trade wind and the swell from the open Pacific here unite their forces on the southern coasts of all the islands, this singular uniformity in the broken state of the craters, composed of the soft and yielding tuff, is easily explained.

Considering that these islands are placed directly under the equator, the climate is far from being excessively hot; this seems chiefly caused by the singularly low temperature of the surrounding water, brought here by the great southern Polar current. Excepting during one short season, very little rain falls, and even then it is irregular; but the clouds generally hang low. Hence, whilst the lower parts of the islands are very sterile, the upper parts, at a height of a thousand feet and upwards, possess a damp climate and a tolerably luxuriant vegetation. This is especially the case on the windward sides of the islands, which first receive and condense the moisture from the atmosphere.

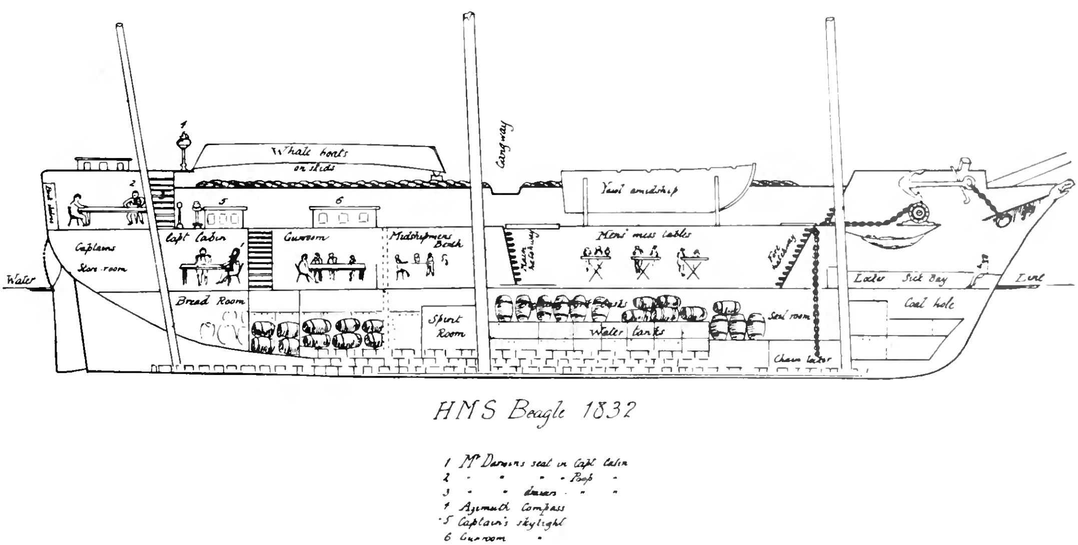
In the morning (17th) we landed on Chatham Island, which, like the others, rises with a tame and rounded outline, broken here and there by scattered hillocks, the remains of former craters. Nothing could be less inviting than the first appearance. A broken field of black basaltic lava, thrown into the most rugged waves, and crossed by great fissures, is everywhere covered by stunted, sunburnt brushwood, which shows little signs of life. The dry and parched surface, being heated by the noon-day sun, gave to the air a close and sultry feeling, like that from a stove: we fancied even that the bushes smelt unpleasantly. Although I diligently tried to collect as many plants as possible, I succeeded in getting very few; and such wretched-looking little weeds would have better become an arctic than an equatorial Flora. . . .

The Beagle sailed round Chatham Island, and anchored in several bays. One night I slept on shore on a part of the island, where black truncated cones were extraordinarily numerous: from one small eminence I counted 60 of them, all surmounted by craters more or less perfect. The greater number consisted merely of a ring of red scoriæ or slags, cemented together: and their height above the plain of lava was not more than from 50 to 100 feet; none had been very lately active. The entire surface of this part of the island seems to have been permeated, like a sieve, by the subterranean vapours: here and there the lava, whilst soft, has been blown into great bubbles; and in other parts, the tops of caverns similarly formed have fallen in, leaving circular pits with steep sides. From the regular form of the many craters, they gave to the country an artificial appearance, which vividly reminded me of those parts of Staffordshire, where the great iron-foundries are most numerous. The day was glowing hot, and the scrambling over the rough surface and through the intricate thickets, was very fatiguing; but I was well repaid by the strange Cyclopean scene. As I was walking along I met two large tortoises, each of which must have weighed at least 200 pounds: one was eating a piece of cactus, and as I approached, it stared at me and slowly walked away; the other gave a deep hiss, and drew in its head. These huge reptiles, surrounded by the black lava, the leafless shrubs, and large cacti, seemed to my fancy like some antediluvian animals. The few full-coloured birds cared no more for me than they did for the great tortoises.

23rd.—The Beagle proceeded to Charles Island. . . . In the woods there are many wild pigs and goats; but the staple article of animal food is supplied by the tortoises. Their numbers have of course been greatly reduced in this island, but the people yet count on two days' hunting giving them food for the rest of the week. It is said that formerly single vessels have taken away as many as 700, and that the ship's company of a frigate some years since brought down in one day 200 tortoises to the beach.

slope, and, choked with dust, eagerly tasted the water—but, to my sorrow, I found it salt as brine.

The rocks on the coast abounded with great black lizards, between three and four feet long; and on the hills, an ugly yellowish-brown species was equally common. We saw many of this latter kind, some clumsily running out of the way, and others shuffling into their burrows. I shall presently describe in more detail the habits of both these reptiles. The whole of this northern part of Albemarle Island is miserably sterile. . . .



Cutaway view of H. M. S. Beagle. *During the voyage, Darwin shared quarters with Captain FitzRoy. (Diagram courtesy of Frank Sulloway)*

September 29th.—We doubled the south-west extremity of Albemarle Island, and the next day were nearly becalmed between it and Narborough Island. Both are covered with immense deluges of black naked lava, which have flowed either over the rims of the great caldrons, like pitch over the rim of a pot in which it has been boiled, or have burst forth from smaller orifices on the flanks; in their descent they have spread over miles of the sea-coast. On both of these islands, eruptions are known to have taken place; and in Albemarle, we saw a small jet of smoke curling from the summit of one of the great craters. In the evening we anchored in Bank's Cove, in Albemarle Island. The next morning I went out walking. To the south of the broken tuff-crater, in which the Beagle was anchored, there was another beautifully symmetrical one of an elliptic form; its longer axis was a little less than a mile, and its depth about 500 feet. At its bottom there was a shallow lake, in the middle of which a tiny crater formed an islet. The day was overpoweringly hot, and the lake looked clear and blue: I hurried down the cindery

October 8th—One day we accompanied a party of the Spaniards in their whaleboat to a salina, or lake from which salt is procured. After landing, we had a very rough walk over a rugged field of recent lava, which has almost surrounded a tuff-crater, at the bottom of which the salt-lake lies. The water is only three or four inches deep, and rests on a layer of beautifully crystallized, white salt. The lake is quite circular, and is fringed with a border of bright green succulent plants; the almost precipitous walls of the crater are clothed with wood, so that the scene was altogether both picturesque and curious. A few years since, the sailors belonging to a sealing-vessel murdered their captain in this quiet spot; and we saw his skull lying among the bushes.

During the greater part of our stay of a week, the sky was cloudless, and if the trade-wind failed for an hour, the heat became very oppressive. On two days, the thermometer within the tent stood for some hours at 93 degrees; but in the open air, in the wind and sun, at only 85 degrees. The sand was extremely hot; the thermometer placed in some of a brown colour immediately rose to 137 degrees and how much above that it would have risen, I do not know, for it was not graduated any higher. The black sand felt much hotter, so that even in thick boots it was quite disagreeable to walk over it.

The natural history of these islands is eminently curious, and well deserves attention. Most of the organic productions are aboriginal creations, found nowhere else; there is even a difference between the inhabitants of the different islands; yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean, between 500 and 600 miles in width. The archipelago is a little world within itself, or rather a satellite attached to America, whence it has derived a few stray colonists, and has received the general character of its indigenous productions. Considering the small size of the islands, we feel the more astonished at the number of their aboriginal beings, and at their confined range. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period geologically recent the unbroken ocean was here spread out. Hence, both in space and time, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth. . . .

Of land-birds I obtained 26 kinds, all peculiar to the group and found nowhere else, with the exception of one lark-like finch from North America (*Dolichonyx oryzivorus*). The other 25 birds consist, firstly, of a hawk, curiously intermediate in structure between a buzzard and the American group of carrion-feeding Polybori; and with these latter birds it agrees most closely in every habit and even tone of voice. Secondly, there are two owls, representing the short-eared and white barn-owls of Europe. Thirdly, a wren, three tyrant-flycatchers (two of them species of Pyrocephalus, one or both of which would be ranked by some ornithologists as only varieties), a dove—all analogous to, but distinct from, American species. Fourthly, a swallow, which though differing from the Progne purpurea of both Americas, only in being rather duller colored, smaller, and slenderer, is considered by Mr. Gould as specifically distinct. Fifthly, there are three species of mocking thrush—a form highly characteristic of America.

The remaining land-birds form a most singular group of finches, related to each other in the structure of their beaks, short tails, form of body and plumage: there are 13 species, which Mr. Gould has divided into four sub-groups. All these species are peculiar to this archipelago; and so is the whole group, with the exception of one species of the sub-group Cactornis, lately brought from Bow Island, in the Low Archipelago. . . . The males of all, or certainly of the greater number, are jet black; and the females (with perhaps one or two exceptions) are brown.

The most curious fact is the perfect gradation in the size of the beaks in the different species of Geospiza, from one as large as that of a hawfinch to that of a chaffinch, and (if Mr. Gould is right in including his sub-group, Certhidea, in the main group) even to that of a warbler. . . .

Of waders and waterbirds I was able to get only 11 kinds, and of these only three (including a rail confined to the damp summits of the islands) are new species. Considering the wandering habits of the gulls, I was surprised to find that the species inhabiting these islands is peculiar, but allied to one from the southern parts of South America. The far greater peculiarity of the landbirds, namely, 25 out of 26, being new species, or at least new races, compared with the waders and web-footed birds, is in accordance with the greater range which these latter orders have in all parts of the world. We shall hereafter see this law of aquatic forms, whether marine or fresh water, being less peculiar at any given point of the Earth's surface than the terrestrial forms of the same classes, strikingly illustrated in the shells, and in a lesser degree in the insects of the archipelago. . . .

We will now turn to the order of reptiles, which gives the most striking character to the zoology of these islands. The species are not numerous, but the numbers of individuals of each species are extraordinarily great. There is one small lizard belonging to a South American genus, and two species (and probably more) of the Amblyrhynchus—a genus confined to the Galápagos Islands. There is one snake which is numerous; it is identical. Of sea-turtle I believe there are more than one species; and of tortoises there are, as we shall presently show, two or three species or races. Of toads and frogs there are none: I was surprised at this, considering how well suited for them the temperate and damp woods appeared to be. It recalled to my mind the remark made by Bory St. Vincent, namely, that none of this family are found on any of the volcanic islands in the great oceans. As far as I can ascertain from various works, this seems to hold good throughout the Pacific, and even in the large islands of the Sandwich archipelago. . . . The absence of the frog family in the oceanic islands is the more remarkable, when contrasted with the case of lizards, which swarm on most of the smallest islands. May this difference not be caused, by the greater facility with which the eggs of lizards, protected by calcareous shells, might be transported through salt-water, than could the slimy spawn of frogs?

I will first describe the habits of the tortoise (Testudo nigra, formerly called Indica), which has been so frequently alluded to. These animals are found, I believe, on all the islands of the archipelago; certainly on the greater number. They frequent in preference the high damp parts, but they likewise live in the lower and arid districts. I have already shown, from the numbers which have been caught in a single day, how very numerous they must be. Some grow to an immense size: Mr. Lawson, an Englishman, and vice-governor of the colony, told us that he had seen several so large, that it required six or eight men to lift them from the ground; and that some had afforded as much as 200 pounds of meat. The old males are the largest, the females rarely growing to so great a size: the male can readily be distinguished from the female by the greater length of its tail.

The tortoises which live on those islands where there is no water, or in the lower and arid parts of the others, feed chiefly on the succulent cactus. Those which frequent the higher and damp regions, eat the leaves of various trees, a kind of berry (called guayavita) which is acid and austere, and likewise a pale green filamentous lichen (Usnera plicata), that hangs from the boughs of the trees.

The tortoise is very fond of water, drinking large quantities, and wallowing in the mud. The larger islands alone possess springs, and these are always situated towards the central parts, and at a considerable height. The tortoises, therefore, which frequent the lower districts, when thirsty, are obliged to travel from a long distance. Hence broad and well-beaten paths branch off in every direction from the wells down to the seacoast; and the Spaniards by following them up, first discovered the watering-places.

When I landed at Chatham Island, I could not imagine what animal travelled so methodically along well-chosen tracks. Near the springs it was a curious spectacle to behold many of these huge creatures, one set eagerly travelling onwards with outstretched necks, and another set returning, after having drunk their fill. When the tortoise arrives at the spring, quite regardless of any spectator, he buries his head in the water above his eyes, and greedily swallows great mouthfuls, at the rate of about 10 in a minute. The inhabitants say each animal stays three or four days in the neighbourhood of the water, and then returns to the lower country; but they differed respecting the frequency of these visits. The animal probably regulates them according to the nature of the food on which it has lived. It is, however, certain, that tortoises can subsist even on these islands where there is no other water than what falls during a few rainy days in the year.

I believe it is well ascertained, that the bladder of the frog acts as a reservoir for the moisture necessary to its existence: such seems to be the case with the tortoise. For some time after a visit to the springs, their urinary bladders are distended with fluid, which is said gradually to decrease in volume, and to become less pure. The inhabitants, when walking in the lower district, and overcome with thirst, often take advantage of this circumstance, and drink the contents of the bladder if full: in one I saw killed, the fluid was quite limpid, and had only a very slightly bitter taste. The inhabitants, however, always first drink the water in the pericardium, which is described as being best.

The tortoises, when purposely moving towards any point, travel by night and day, and arrive at their journey's end much sooner than would be expected. The inhabitants, from observing marked individuals, consider that they travel a distance of about eight miles in two or three days. One large tortoise, which I watched, walked at the rate of 60 yards in 10 minutes, that is 360 yards in the hour, or four miles a day,—allowing a little time for it to eat on the road.

During the breeding season, when the male and female are together, the male utters a hoarse roar or bellowing, which, it is said, can be heard at the distance of more than a hundred yards. The female never uses her voice, and the male only at these times; so that when the people hear this noise, they know that the two are together. They were at this time (October) laying their eggs. The female, where the soil is sandy, deposits them together, and covers them up with sand; but where the ground is rocky she drops them indiscriminately in any hole: Mr. Bynoe found seven placed in a fissure. The egg is white and spherical; one which I measured was seven inches and three-eighths in circumference, and therefore larger than a hen's egg. The young tortoises, as soon as they are hatched, fall a prey in great numbers to the carrion-feeding buzzard. The old ones seem generally to die from accidents, as from falling down precipices: at least, several of the inhabitants told me, that they never found one dead without some evident cause. . . .

There can be little doubt that this tortoise is an aboriginal inhabitant of the Galápagos; for it is found on all, or nearly all, the islands, even on some of the smaller ones where there is no water; had it been an imported species, this would hardly have been the case in a group which has been so little frequented. . . .

The Amblyrhynchus, a remarkable genus of lizards, is confined to this archipelago; there are two species, resembling each other in general form, one being terrestrial and the other aquatic. This latter species (A. cristatus) was first characterized by Mr. Bell, who well foresaw, from its short, broad head, and strong claws of equal length, that its habits of life would turn out very peculiar, and different from those of its nearest ally, the Iguana. It is extremely common on all the islands throughout the group, and lives exclusively on the rocky sea-beaches, being never found, at least I never saw one, even 10 yards in-shore. It is a hideous-looking creature, of a dirty black colour, stupid, and sluggish in its movements. The usual length of a full-grown one is about a yard, but there are some even four feet long; a large one weighed 20 pounds: on the island of Albemarle they seem to grow to a greater size than elsewhere. Their tails are flattened sideways, and all four feet partially webbed. They are occasionally seen some 100 yards from the shore, swimming about; and Captain Collnett, in his Voyage says, "They go to sea in herds a-fishing, and sun themselves on the rocks; and may be called alligators in miniature."

It must not, however, be supposed that they live on fish. When in the water this lizard swims with perfect ease and quickness, by a serpentine movement of its body and flattened tail—the legs being motionless and closely collapsed on its sides. A seaman on board sank one, with a heavy weight attached to it, thinking thus to kill it directly; but when, an hour afterwards, he drew up the line, it was quite active. Their limbs and strong claws are admirably adapted for crawling over the rugged and fissured masses of lava, which everywhere form the coast. In such situations, a group of six or seven of these hideous reptiles may oftentimes be seen on the black rocks, a few feet above the surf, basking in the sun with outstretched legs.

I opened the stomachs of several, and found them largely distended with minced seaweed (Ulvæ), which grows in thin foliaceous expansions of a bright green or a dull red colour. I do not recollect having observed this seaweed in any quantity on the tidal rocks; and I have reason to believe it grows at the bottom of the sea, at some little distance from the coast. If such be the case, the object of these animals occasionally going out to sea is explained. The stomach contained nothing but the seaweed. Mr. Baynoe, however, found a piece of crab in one; but this might have got in accidentally, in the same manner as I have seen a caterpillar, in the midst of some lichen, in the paunch of a tortoise. The intestines were large, as in other herbivorous animals.

The nature of this lizard's food, as well as the structure of its tail and feet, and the fact of its having been seen voluntarily swimming out at sea, absolutely prove its aquatic habits; yet there is in this respect one strange anomaly, namely, that when frightened it will not enter the water. Hence it is easy to drive these lizards down to any little point overhanging the sea, where they will sooner allow a person to catch hold of their tails than jump into the water. They do not seem to have any notion of biting; but when frightened they squirt a drop of fluid from each nostril.

I threw one several times as far as I could, into a deep pool left by the retiring tide; but it invariably returned in a direct line to the spot where I stood. It swam near the bottom, with a very graceful and rapid movement, and occasionally aided itself over the uneven ground with its feet. As soon as it arrived near the edge, but still being under water, it tried to conceal itself in the tufts of seaweed, or it entered some crevice. As soon as it thought the danger was past, it crawled out on the dry rocks, and shuffled away as quickly as it could.

I several times caught this same lizard, by driving it down to a point, and though possessed of such perfect powers of diving and swimming, nothing would induce it to enter the water; and as often as I threw it in, it returned in the manner above described. Perhaps this singular piece of apparent stupidity may be accounted for by the circumstance, that this reptile has no enemy whatever on shore, whereas at sea it must often fall a prey to the numerous sharks. Hence, probably, urged by a fixed and hereditary instinct that the shore is its place of safety, whatever the emergency may be, it there takes refuge.

During our visit (in October), I saw extremely few small individuals of this species, and none I should think under a year old. From this circumstance it seems probable that the breeding season had not then commenced. I asked several of the inhabitants if they knew where it laid its eggs: they said that they knew nothing of its propagation, although well acquainted with the eggs of the land kind—a fact, considering how very common this lizard is, not a little extraordinary.

We will now turn to the terrestrial species (*A. demarlii*), with a round tail, and toes without webs. This lizard, instead of being found like the other on all the islands, is confined to the central part of the archipelago, namely to Albemarle, James, Barrington, and Indefatigable islands. To the southward, in Charles, Hood, and Chatham islands, and to the northward, in Towers, Bindloes, and Abingdon, I neither saw nor heard of any. It would appear as if it had been created in the center of the archipelago, and thence had been dispersed only to a certain distance. Some of these lizards inhabit the high and damp parts of the islands, but they are much more numerous in the lower and sterile districts near the coast. I cannot give a more forcible proof of their numbers, than by stating that when we were left at James Island, we could not for some time find a spot free from their burrows on which to pitch our single tent.

Like their brothers the sea-kind, they are ugly animals, of a yellowish orange beneath, and of a brownish red colour above: from their low facial angle they have a singularly stupid appearance. They are, perhaps, of a rather less size than the marine species; but several of them weighed between 10 and 15 pounds. In their movements they are lazy and half torpid. When not frightened, they slowly crawl along with their tails and bellies dragging on the ground. They often stop, and doze for a minute or two, with closed eyes and hind legs spread out on the parched soil.

They inhabit burrows, which they sometimes make between fragments of lava, but more generally on level patches of the soft sandstone-like tuff. The holes do not appear to be very deep, and they enter the ground at a small angle; so that when walking over these lizard-warrens, the soil is constantly giving way, much to the annoyance of the tired walker. This animal, when making its burrow, works alternately the opposite sides of its body. One front leg for a short time scratches up the soil, and throws it towards the hind foot, which is well placed so as to heave it beyond the mouth of the hole. That side of the body being tired, the other takes up the task, and so on alternately.

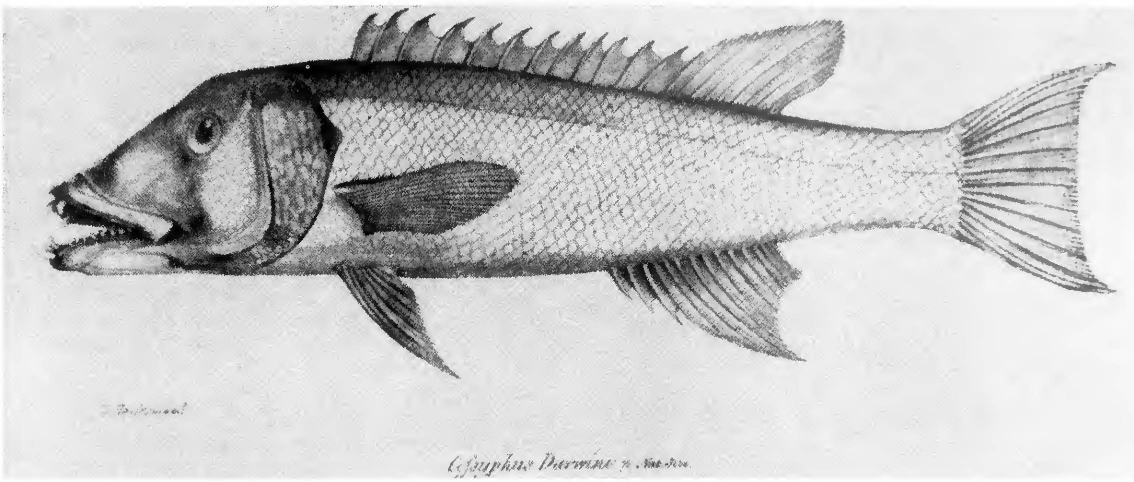
I watched one for a long time, till half its body was buried; I then walked up and pulled it by the tail; at this it was greatly astonished, and soon shuffled up to see what was the matter; and then stared me in the face, as much as to say, "What made you pull my tail?". . . .

The individuals, and they are the greater number, which inhabit the lower country, can scarcely taste a drop of water throughout the year; but they consume much of the succulent cactus, the branches of which are occasionally broken off by the wind. I several times threw a piece to two or three of them when together; and it was amusing enough to see them trying to seize and carry it away in their mouths, like so many hungry dogs with a bone. They eat very deliberately, but do not chew their food. The little birds are aware how harmless these creatures are: I have seen one of the thick-billed finches picking at one end of a piece of cactus (which is much relished by all the animals of the lower region), whilst a lizard was eating at the other end; and afterwards the little bird with the utmost indifference hopped on the back of the reptile. . . .

These two species of *Amblyrhynchus* agree, as I have already stated, in their general structure, and in many of their habits. Neither have that rapid movement, so characteristic of the genera Lacerta and Iguana. They are both herbivorous, although the kind of vegetation on which they feed is so very different. Mr. Bell has given the name to the genus from the shortness of the snout; indeed, the form of the mouth may almost be compared to that of the tortoise: one is led to suppose that this is an adaptation to their herbivorous appetites. It is very interesting thus to find a well-characterized genus, having its marine and terrestrial species, belonging to so confined a portion of the world. The aquatic species is by far the most remarkable, because it is the only existing lizard which lives on marine vegetable productions.

As I at first observed, these islands are not so remarkable for the number of the species of reptiles, as for that of the individuals; when we remember the well-beaten paths made by the thousands of huge tortoises—the many turtles—the great warrens of the terrestrial Amblyrhynchus—and the groups of the marine species basking on the coast-rocks of every island—we must admit that there is no other quarter of the world where this Order replaces the herbivorous mammalia in so extraordinary a manner. The geologist on hearing this will probably refer back in his mind to the Secondary epochs, when lizards, some herbivorous, some carnivorous, and of dimensions comparable only with our existing whales, swarmed on the land and in the sea. It is therefore, worthy of his observation, that this archipelago, instead of possessing a humid climate and rank vegetation, cannot be considered otherwise than extremely arid, and, for an equatorial region, remarkably temperate.

To finish with the zoology: the 15 kinds of sea-fish which I procured here are all new species; they belong to 12 genera, all widely distributed, with the exception of Prionotus, of which the four previously known species live on the eastern side of America.



*Galápagos sheephead wrasse (*Cossyphus darwini*). First collected by Darwin while in the Galápagos, and named by naturalist and friend, Leonard Jenyns. This drawing accompanied Jenyns's original description. (From J. E. McCosker and R. H. Rosenblatt, 1984,* Key Environments—Galápagos, *Pergamon Press)*

Of land-shells I collected 16 kinds (and two marked varieties), of which, with the exception of one Helix found at Tahiti, all are peculiar to this archipelago: a single fresh-water shell (*Paludina*) is common to Tahiti and Van Diemen's Land. Mr. Cuming, before our voyage, procured here 90 species of sea-shells, and this does not include several species not yet specifically examined, of Trochus, Turbo, Monodonta, and Nassa. He has been kind enough to give me the following interesting results: Of the 90 shells, no less than 47 are unknown elsewhere—a wonderful fact, considering how widely distributed sea-shells generally are. . . .

I took great pains in collecting the insects, but excepting Tierra de Fuego, I never saw in this respect so poor a country. Even in the upper and damp region I procured very few, excepting some minute Diptera and Hymenoptera, mostly of common mundane forms. As before remarked, the insects, for a tropical region, are of very small size and dull colours. Of beetles I collected 25 species (excluding a *Dermestes* and *Corynetes* imported, wherever a ship touches); of these, two belong to the Harpalidæ, two to the Hydrophilidæ, nine to three families of the Heteromera, and the remaining 12 to as many different families. This circumstance of insects (and I may add plants), where few in number, belonging to many different families, is, I believe, very general. . . .

It was most striking to be surrounded by new birds, new reptiles, new shells, new insects, new plants, and yet by innumerable trifling details of structure, and even by the tones of voice and plumage of the birds, to have the temperate plains of Patagonia, or rather the hot dry deserts of Northern Chile, vividly brought before my eyes. Why, on these small points of land, which within a late geological period must have been covered by the ocean, which are formed by basaltic lava, and therefore differ in geological character from the American continent, and which are placed under a peculiar climate,—why were their aboriginal inhabitants, associated, I may add, in different proportions both in kind and number from those on the continent, and therefore acting on each other in a different manner—why were they created on American types of organization? It is probable that the islands of the Cape de Verd group resemble, in all their physical conditions, far more closely the Galápagos Islands, than these latter physically resemble the coast of America, yet the aboriginal inhabitants of the two groups are totally unlike; those of the Cape de Verd Islands bearing the impress of Africa, as the inhabitants of the Galápagos Archipelago are stamped with that of America.

I have not as yet noticed by far the most remarkable feature in the natural history of this archipelago; it is, that the different islands to a considerable extent are inhabited by a different set of beings. My attention was first called to this fact by the Vice-Governor, Mr. Lawson, declaring that the tortoises differed from the different islands, and that he could with certainty tell from which island any one was brought. I did not for some time pay sufficient attention to this statement, and I had already partially mingled together the collections from two of the islands. I never dreamed that islands, about 50 or 60 miles apart, and most of them in sight of each other, formed of precisely the same rocks, placed under a quite similar climate, rising to a nearly equal height, would have been differently tenanted; but we shall soon see that this is the case. It is the fate of most voyagers, no sooner to discover what it is most interesting in any locality, than they are hurried from it; but I ought, perhaps, to be thankful that I obtained sufficient materials to establish this most remarkable fact in the distribution of organic beings.

The inhabitants, as I have said, state that they can distinguish the tortoises from the different islands; and that they differ not only in size, but in other characters. Captain Porter has described those from Charles and from the nearest island to it, namely, Hood Island, as having their shells in front thick and turned up like a Spanish saddle, whilst the tortoises from James Island are rounder, blacker, and have a better taste when cooked. M. Bibron, moreover, informs me that he has seen what he considers two distinct species of tortoise from the Galápagos, but he does not know from which islands. The specimens that I brought from three islands were young ones: and probably owing to this cause neither Mr. Gray nor myself could find in them any specific differences. I have remarked that the marine *Amblyrhynchus* was larger at Albemarle Island than elsewhere; and M. Bibron informs me that he has seen two distinct aquatic species of this genus; so that the different islands probably have their representative species or races of the *Amblyrhynchus*, as well as of the tortoise. . . .

The distribution of the tenants of this archipelago would not be nearly so wonderful, if . . . the different islands were inhabited, not by representative species of the same genera of plants, but by totally different genera, as does to a certain extent hold good: for, to give one instance, a large berry-bearing tree at James Island has no representative species in Charles Island. But it is the circumstance, that several of the islands possess their own species of the tortoise, mocking-thrush, finches, and numerous plants, these species having the same general habits, occupying analogous situations, and obviously filling the same place in the natural economy of this archipelago, that strikes me with wonder. . . .

The only light which I can throw on this remarkable difference in the inhabitants of the different islands, is, that the very strong currents of the sea running in a westerly and W.N.W. direction must separate, as far as transportal by the sea is concerned, the southern islands from the northern ones; and between these northern islands a strong N.W. current was observed, which must effectually separate James and Albemarle Islands. As the archipelago is free to a most remarkable degree from gales of wind, neither the birds, insects, nor lighter seeds, would be blown from island to island. And lastly, the profound depth of the ocean between the islands, and their apparently recent (in a geological sense) volcanic origin, render it highly unlikely that they were ever united; and this, probably, is a far more important consideration than any other, with respect to the geographical distribution of their inhabitants. Reviewing the facts here given, one is astonished at the amount of creative force, if such an expression may be used, displayed on these small, barren, and rocky islands; and still more so, at its diverse yet analogous action on points so near each other. I have said that the Galápagos Archipelago might be called a satellite attached to America, but it should rather be called a group of satellites, physically similar, organically distinct, yet intimately related to each other, and all related in a marked, though much lesser degree, to the great American continent. . . .

Darwin and the Galápagos: Three Myths

by Frank J. Sulloway

On 16 September 1835, Charles Darwin landed in the Galápagos Islands and began five weeks of collecting and observing in this famous "laboratory of evolution." While in the Galápagos, the 26-year-old Darwin visited four of the major islands, and, from the *H.M.S. Beagle*, he glimpsed numerous others. Altogether he spent 19 days on land in the Galápagos — five days on Chatham; four on Charles, where he visited the highlands settlement; one day at Tagus Cove on Albemarle Island; and nine days on James, where he collected extensively and spent three days in the highlands (Figure 1).

By current research standards, Darwin's Galápagos visit was remarkably brief. And yet his encounter with these islands was seemingly decisive for his biological thinking. As he wrote in the second edition of his *Journal of Researches*:

> *The archipelago is a little world within itself, or rather a satellite attached to America, whence it has derived a few stray colonists, and has received the general character of its indigenous productions. Considering the small size of these islands, we feel all the more astonished at the number of their aboriginal beings, and at their confined range. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period geologically recent the unbroken ocean was here spread out. Hence both in space and time, we seem to be brought somewhat near to that great fact — that mystery of mysteries — the first appearance of the new beings on this earth. (1845: 377–78)*

When and how Darwin solved this great "mystery of mysteries," and particularly the role his Galápagos visit played in this regard, have become the subject of a considerable legend in the history of science.

According to the legend, Darwin's Galápagos visit first provided him with irrefutable evidence for the mutability of species and converted him, eureka-like, to the theory of evolution. Actually, the impact of the Galápagos was largely retrospective. Darwin was first alerted to the evolutionary significance of the Galápagos species by the vice-governor, Nicholas Lawson, who informed him that he could tell "with certainty" from which island any tortoise had been brought. Darwin was on Charles Island at the time; and according to David Lack, among other commentators, he was sufficiently impressed to begin separating his collections of finches and other species by island, thus securing the necessary biological evidence to back up the vice-governor's extraordinary claim. What Lack and others did not appreciate, however, was that the bulk of the locality information on Darwin's type specimens and in his postvoyage publications was actually derived, *after* the voyage, from the carefully labelled collections of three other *Beagle* shipmates (all naval personnel). Why Darwin initially failed to heed the vice-governor's remarks about the tortoises must be understood in terms of the intimate relationship between a received theory like creationism, no matter how erroneous, and the gathering and interpretation of scientific evidence.

To begin with, it would never have occurred to a creationist, which Darwin still was in 1835, to label his collections according to island of origin within a small archipelago. As part of a presumed "center of creation," the Galápagos would have been expected to exhibit a uniform flora and fauna by island, making such detailed locality designations superfluous. In this regard, it is noteworthy that those *Beagle* specimens that were carefully labelled by island were collected by the nonscientists on board, who presumably did not realize how unnecessary such information really ought to have been.

We also fail to appreciate how complex and confusing the Galápagos evidence must initially have been, especially to a nonspecialist and nonsystematist like Darwin. It is not just the theory of evolution that introduces unifying order into many of the enigmas of Galápagos biology; creationism also made a certain reasonable sense out of the facts. From his specimen notebooks and manuscript notes it is clear, for example, that Darwin mistook many species of "Darwin's finches" for the forms that they, through adaptive evolutionary radiation, now appear to mimic. Thus he thought the warbler finch was a "Wren"; and he described the large-beaked ground finch as a "Grosbeak" and the cactus finch as an "Icterus" — the genus to which belong the orioles, blackbirds, and certain other forms possessing a long pointed bill. It is perhaps not surprising then that Darwin, having failed to recognize the closely related nature of the Galápagos finches, also failed to suspect that their island distributions might vary within the archipelago.

The evolutionary evidence provided by the famous Galápagos tortoises was also similarly clouded at the time of Darwin's visit. This taxon was then believed by most naturalists to have originated in the islands of the Indian Ocean — hence its erroneous name *Testudo indicus* — and to have been transported to the Galápagos by buccaneers. Thus when Darwin was informed that the tortoises differed by island, he probably initially thought it was a matter of local variations somehow induced by transportal to a new and unnatural environment. Moreover, those tortoises actually seen by Darwin, on Chatham and James, were too similar to be distinguished "with certainty"; so the evidence was not as striking, from Darwin's personal observations, as the vice-governor had claimed.

In any event, since tortoises were not supposed to be native to the Galápagos, such differences did not apparently bear directly on the question of what was uniquely "Galápagean," if anything, about the Galápagos. So little value did Darwin place upon the tortoise evidence that he not only failed, at the time of his visit, to collect specimens for scientific purposes, but he apparently joined his *Beagle* shipmates in eating the last of some 30 large tortoises during the cruise to Tahiti. It was only a decade later that Darwin finally encountered Captain David Porter's (1815) description of the dome-shaped and saddleback forms of tortoise and was able to insert this information into the second edition of his *Journal of Researches* (1845: 394).

The *Origin of Species* (1859) was never in any real danger, however, of being sacrificed for a bowl of tortoise soup. Darwin *had* noticed, while still in the Galápagos, that the mockingbirds differed by island; and he had taken care to separate these specimens from the four islands he had visited. Approximately eight months after leaving the Galápagos he returned to this problem in his "Ornithology" notes. There he compared this anomalous finding to that previously reported to him about the tortoises. Although he was still inclined to suspect that his mockingbirds were "only varieties" rather than true species, he nevertheless speculated that "If there is the slightest foundation for these remarks the zoology of Archipelagoes — will be well worth examining; for such facts [would *inserted*] undermine the stability of Species" (1963 [1836]: 262). Darwin thus began, in a tentative but probing manner, the real process of "discovery" about the Galápagos — a process that lay not so much in his observations or collections during his brief visit, but rather in his various reconsiderations of this evidence after his departure.

Following his return to England in the autumn of 1836, Darwin had many opportunities to re-evaluate the Galápagos evidence as expert systematists began to work out his voyage collections and he prepared his *Journal of Researches* for publication. In early March of 1837, he met with the celebrated ornithologist John Gould to discuss the results of Gould's examination of his voyage birds. Gould had immediately appreciated the anomalous but closely related nature of Darwin's Galápagos finches, including the warbler finch, and had named 13 species in three subgenera. In addition, Gould had pronounced as distinct three of the four island forms of Darwin's Galápagos mockingbirds, thus confirming the suspicions Darwin had previously felt might "undermine the stability of Species." Perhaps just as importantly, Gould convinced Darwin of the highly endemic character of the Galápagos ornithology as a whole, something that Darwin, who had not had access to museum collections during the voyage, had not previously realized. These taxonomic opinions, together with a number of others relating to his collections from the South American continent, finally convinced Darwin that species were indeed mutable and sparked his decision to begin collecting facts that might bear on this question. He subsequently commented in this connection: "In July [1837] opened first notebook on 'Transmutation of Species' — Had been greatly struck from about Month of previous March on character of S. American fossils — and species on Galápagos Archipelago. These facts origin (especially latter) of all my views."

In the wake of his conversion to the theory of evolution, Darwin quickly realized his voyage oversight in failing to label his Galápagos specimens by island. He therefore set out to rectify this problem as best he could by asking other *Beagle* shipmates, including Captain Robert FitzRoy, to supply him with the missing evidence. Unfortunately, later curators at the British Museum failed to appreciate that Darwin's published locality designations in the *Zoology of the Voyage of H.M.S. Beagle* (1841) were not derived from his own collections; and where such information was missing from his own type specimens, they added it to some of the labels, creating a number of erroneous localities. Darwin, moreover, compounded the problem by guessing where eight of his own finch specimens had come from; and in several instances he clearly guessed incorrectly. These various confusions over the type specimen localities created a taxonomic nightmare for subsequent ornithologists, who naturally puzzled over the conflicting and aberrant locality

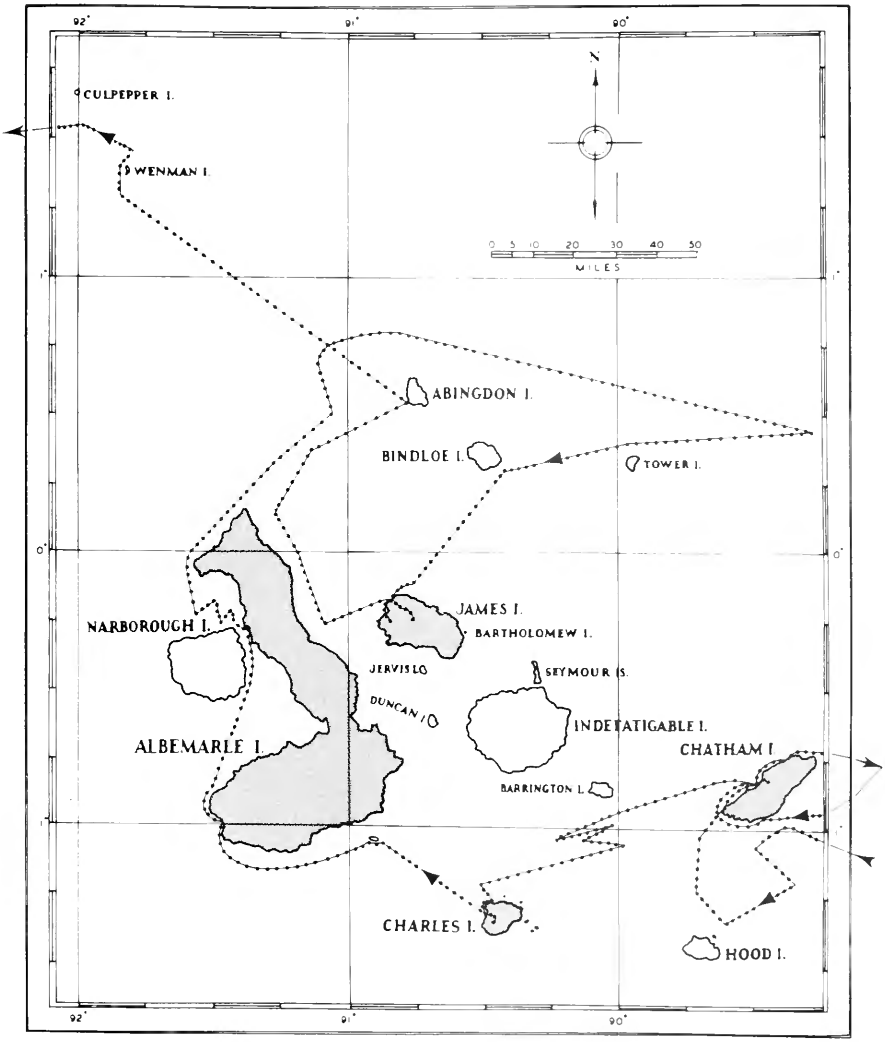


Figure 1. Darwin's route through the Galápagos in H.M.S. Beagle. *He visited the four shaded islands and made several inland excursions, also indicated on the map. The occasionally zigzag nature of the* Beagle's *route reflects the vagaries of winds and currents in the age of sail.*

designations on Darwin's specimens and found themselves hard pressed to reconcile this information with present-day distributions of Darwin's finches.

Fortunately, clarification of the retrospective and borrowed nature of the localities on many of Darwin's type specimens has now resolved most of these problems, including the status of several long-debated forms of Darwin's finches. In particular, *Geospiza magnirostris magnirostris*, an extinct form of the large-beaked ground finch, was collected by FitzRoy and others on Chatham and Charles islands, where David Steadman (1981, 1984) has recently found fossil evidence of this subspecies. Similarly, both Darwin and FitzRoy collected specimens of another extinct subspecies on Charles Island — a particularly large-billed form of the sharp-beaked ground finch ("*G. nebulosa*" Gould).

Although Darwin (1845: 395) later suggested, based on the joint *Beagle* collections, that the Galápagos finches might have different geographic distributions, he was also aware that the case was a complex one and that his own data on the subject were meagre and probably suspect. Partly for this reason he did not mention his celebrated Galápagos finches in the *Origin of Species* (1859). It is only in this century, after the splendid ornithological studies of Harry Swarth (1931), David Lack (1945, 1947), and many other researchers, that these finches have become such a convincing paradigm of evolution in action. In keeping with the Darwin-Galápagos legend, however, much of this modern evidence is often erroneously attributed to Darwin. For example, he never saw all 13 species of Galápagos finches (Gould's 13 "species" encompassed only nine of the presently recognized forms), and he was also unaware that differences in the beaks were correlated with differences in diets.

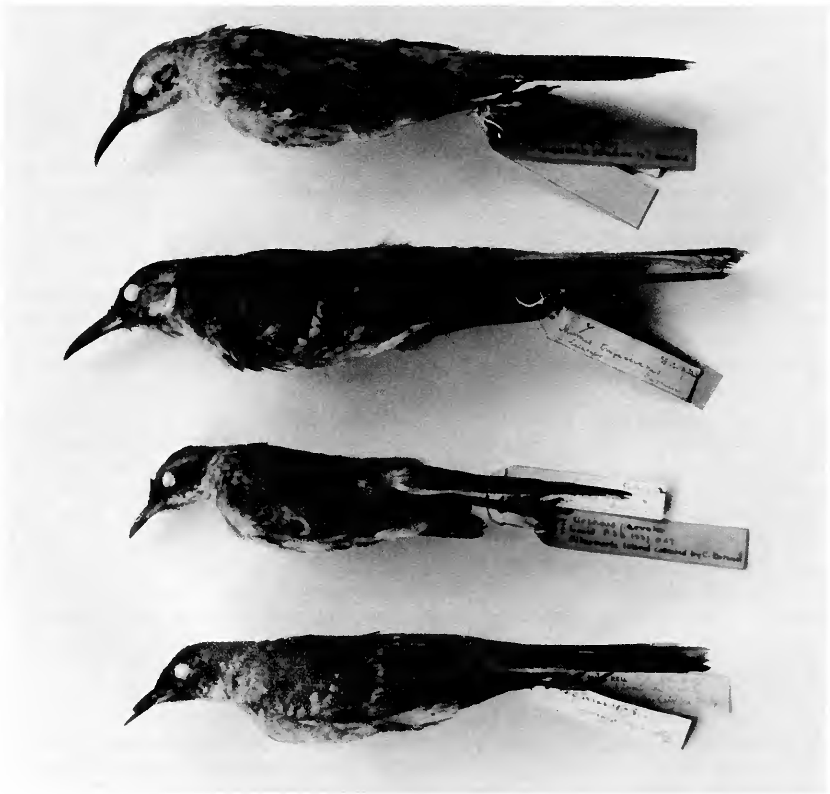
Even after he had finally become an evolutionist in 1837, Darwin's understanding of the Galápagos Islands continued to undergo a slow evolution of its own. The mockingbirds and tortoises had convinced him of the importance of geographic isolation in the evolution of new species; and in 1838, after reading Malthus's *Essay on the Principle of Population* (1798), he hit on the theory of natural selection. (Even this important insight, however, was not as sudden as Darwin later recalled.) For approximately a decade more he nevertheless failed to understand why evolution should promote widely divergent species on islands, like the Galápagos, that are seemingly identical in climate and general geographic character.

Darwin solved this vexing problem only in the mid-1840s after reading Joseph Hooker's reports on the flora of the Galápagos. Hooker had found that numerous representative species were indeed present on the separate islands, as Darwin had always suspected but had never been able to prove conclusively. In July of 1845, Darwin wrote to his friend: "I cannot tell you how delighted and astonished I am at the results of your examination; how wonderfully they support my assertion on the differences in the animals of the different islands, about which I have always been fearful."

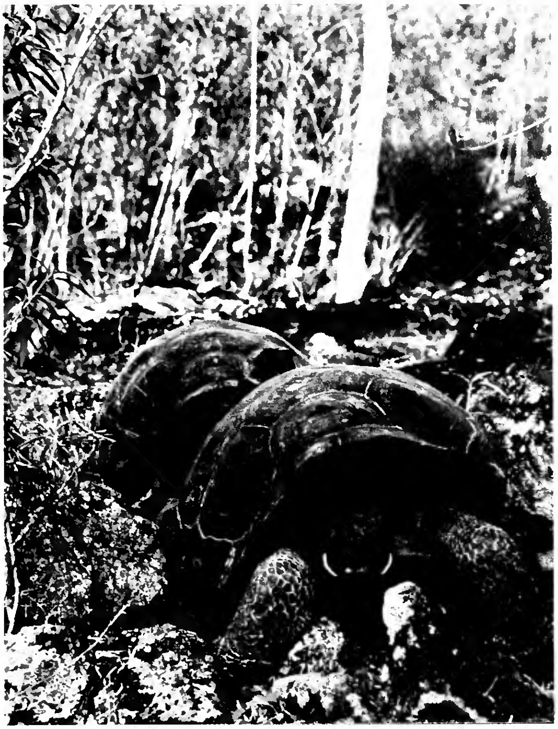
Darwin was equally impressed with Hooker's (1847) discovery that the different islands possessed plants that were apparently random colonists, present only on one island. In the margin of his copy of Hooker's paper Darwin wrote: "so the flora of different isld[s] must be very different independently of representation." Darwin now began to appreciate that although the various islands in the Galápagos might look superficially similar, they were biotically quite distinct. These biotic differences, moreover, must provide natural selection with a wide scope for expression, thus explaining how representative species had evolved so easily on each island. This basic idea, which Darwin developed in the 1850s into his principle of divergence, altered much of his general thinking about evolution and was given a prominent place in the *Origin of Species* (1859). Thus Darwin required almost two full decades to understand the biological significance of his Galápagos findings and to integrate them into his theory of evolution by natural selection.

The Darwin-Galápagos Legend

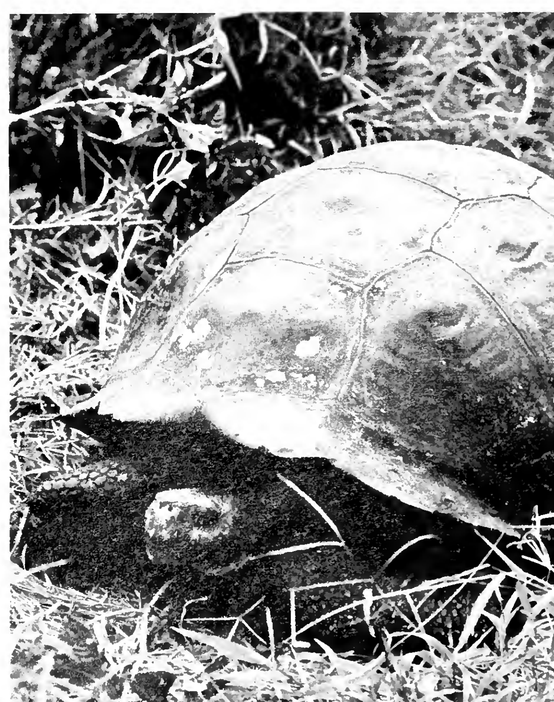
The publication of the *Origin of Species* not only revolutionized the biological sciences, but it also made Darwin into a celebrated intellectual hero—a man thoroughly worthy of scientific deification and hence destined to become the subject of legend. And because myths and legends, above all else, gravitate toward the problem of origins, Darwin's discoveries increasingly became enshrouded by the typical misconceptions of reconstructed "heroic" history. Accordingly, the true story of Darwin's conversion to the theory of evolution is a far cry from the Darwin-Galápagos legend that has arisen in the wake of Darwin's scientific triumph, and that adorns so many of the biology textbooks today. In fact, the legend, which is composed of three major component myths, tends to obscure precisely what



Darwin's Galápagos mockingbird specimens (British Museum of Natural History, Tring). From top to bottom (in the order that Darwin collected them): the Chatham Island mockingbird (Nesomimus melanotis), *the Charles Island mockingbird* (N. trifasciatus), *and the Galápagos mockingbird* (N. parvulus). *Darwin collected two specimens of the latter, one on Albermarle and the other on James islands. The fact that Darwin procured only four specimens during his Galápagos visit—one from each island—shows that he was collecting within a creationist perspective. To an evolutionist there can be no single "type" specimen, since the variation within the species is an important part of its genetic nature and not simply a "deviation from the type." (All photographs are by the author)*



Three subspecies of Galápagos tortoise. Left: a pair of Chatham Island tortoises (Geochelone elephantopus chathamensis), *displaying relatively dome-shaped carapaces. Right: the Hood Island tortoise* (G. e. hoodensis), *an extreme saddleback form similar to the now-extinct Charles Island race* (G. e. galapagoensis). *Below: the James Island tortoise:* (G. e. darwinii), *a dome-shaped form. Darwin unfortunately saw only the two similar dome-shaped forms.*



it pretends to explain, namely, the nature of scientific insight.

The first of these component myths is that of Darwin's "eureka-like" conversion during his brief visit to the Galápagos Islands. It may appeal to our romantic conception of scientific discovery to imagine the lone voyager suddenly throwing off the shackles of creationist thinking when finally confronted, in the Galápagos, with a microcosmic paradigm of evolution in action. But this myth, for all of its inherent allure, is both wrong and misleading. What this myth especially tends to obscure is the fascinating question 'Why Darwin?' That is to say, why was it that Darwin, and no one else, was converted by evidence that was widely known to many other contemporary naturalists—naturalists who, like Richard Owen and John Gould, were often far superior to Darwin in their experience and abilities as systematists? The answer to this question is closely associated with the real nature of Darwin's genius as a scientist. As the far-seeing amateur among specialists, Darwin exhibited his unique intellectual caliber in the pattern of "gifted individualism" that manifested itself in the process of his conversion. While other naturalists stood by and calmly rationalized the Galápagos evidence in creationist terms, Darwin—virtually

The remarkable diversity in the forms of the Galápagos finches is shown here by three species that initially misled Darwin into thinking they were members of separate families or subfamilies: the large-beaked ground finch (Geospiza magnirostris), *using its powerful jaws to crush a large seed; the cactus finch* (G. scandens), *feeding on the flowers of* Opuntia; *and the diminutive warbler finch* (Certhidea olivacea) *looking for insects in the highland* Scalesia *forests.*

alone—took up the heterodox challenge offered by that evidence. Expressed another way, the Galápagos did not make Darwin; if anything, Darwin, through his superior abilities as a thinker and a theoretician, made the Galápagos; and, in doing so, he elevated these islands to the legendary status they have today.

The second of the three component myths associated with Darwin and the Galápagos is the myth that these islands provided him, at an early stage, with a basic paradigm for his theory of evolution by geographic isolation and natural selection. As I have shown in the case of Darwin's finches, nothing could be further from the truth; and the same conclusion applies to Darwin's Galápagos observations as a whole, which were only slowly incorporated into his final theory. Thus the *Origin of Species* was ultimately the product of 24 years of thinking and further research (1835–59), not the five weeks that Darwin spent in the Galápagos Islands or even the five years that he spent accompanying *H.M.S. Beagle* around the world. True, the Galápagos certainly provided Darwin with some crucial hints; but Darwin's full understanding of both evolution and the Galápagos case required almost as long as it took him to publish the *Origin of Species.*

Moreover, much of Darwin's evolutionary argument, as finally presented in the *Origin*, had to be constructed from alternative sources, owing to Darwin's failure to appreciate, and to collect, the necessary Galápagos evidence in 1835. Other scientists have been collecting that "necessary" Galápagos evidence ever since, which leads me to the third of the three component myths encompassing the Darwin-Galápagos legend.

This third and last myth involves the notion that Darwin singlehandedly discovered almost everything there is to know about evolution in the Galápagos—or at least everything of *basic* importance—and hence that subsequent research in these islands has merely been a sort of mopping-up operation characteristic of "normal," postrevolutionary science. This myth, promulgated in the biology textbooks and especially in the popular literature about Darwin and the Galápagos, is largely a natural extension of the first two Darwin-Galápagos myths.

As a typical manifestation of this third myth, Darwin is frequently credited with insights about his famous Galápagos finches that were actually the product of extensive post-Darwinian ornithological research. For example, in spite of Darwin's own famous *Journal* (1845: 380) remark about one species of finch appearing to have been "modified for different ends," Darwin was by no means personally convinced that all 13 species of Galápagos finches (especially the warbler finch) were indeed derived from a single ancestor (see also Darwin, 1841: 105). Darwin's lingering doubts about the finches' possible common ancestry apparently contributed to his decision, when writing the *Origin of Species*, to omit any specific reference to this now famous biological paradigm of "evolution in action." During the remainder of the 19th century, ornithologists generally believed Darwin's finches were descended from two or three different ancestors—a warbler, a ground finch, and a separate form that gave rise to the six species of *Camarhynchus*. This issue of ancestry was not resolved for more than half a century after the *Origin of Species* was published.

David Lack's classic book *Darwin's Finches* (1947) did much to perpetuate this third aspect of the legend, even though Lack himself personally knew better. Indeed, Lack, in reversing his original position on the possible adaptive significance of the beaks among the different species of Darwin's finches (1945, 1947), went through much the same experience of *ex post facto* 'discovery' that Darwin himself did. For it was only after leaving the Galápagos Islands that Lack reached his new theoretical position and then realized the need for the kind of follow-up studies of the finches' feeding behavior that various other ornithologists have subsequently carried out.

Similar "delayed discoveries" have undoubtedly characterized the work of numerous other Galápagos researchers. Unlike Darwin, however, they have often had the opportunity to return to the Galápagos Islands in order to collect crucial data, and to make observations, that previously seemed unimportant. Thus the history of research in the Galápagos Islands has been anything but the history of "mopping up" the scientific tidbits that Darwin left behind. Rather, it is only after repeated expeditions by six generations of post-Darwinian scientists that the Galápagos archipelago has yielded—with a seeming air of reluctance—many of its richest biological treasures to the world of science. And even today, after so much scientific progress, almost as many questions remain about evolution in the Galápagos as there are answers to the mysteries that Darwin and others have successfully resolved.

Of all the scientists who have made important discoveries in the Galápagos, only to realize later that they have merely scratched the scientific surface and thereby created the need for further research, Charles Darwin perhaps expressed it best. In 1846, shortly after Joseph Hooker had so delighted him with the results of his analysis of Darwin's Galápagos plants, Darwin declared to his friend: "The Galápagos seems a perennial source of new things." The Darwin-Galápagos legend notwithstanding, these famous islands will doubtless remain "a perennial source of new things" in science; and no one would be more disappointed than Darwin if this were not the case.

Darwin in 1840, at age 31, five years after the Beagle *voyage. (By George Richmond, courtesy of Downe House, Downe, England)*

Frank J. Sulloway is a MacArthur Fellow in the Department of Psychology and Social Relations, Harvard University, Cambridge, Massachusetts.

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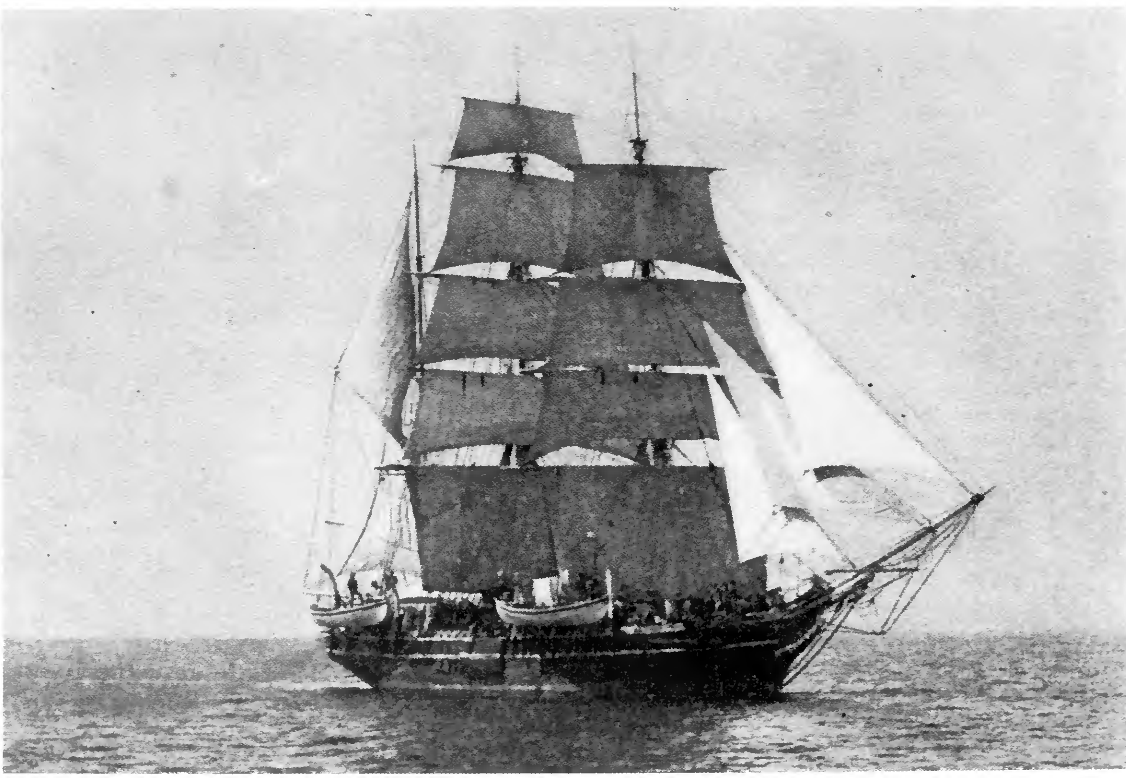
Whalers, Whales, and Tortoises



The bark Morning Star *of New Bedford: at Albemarle Island, Galápagos, July 27 to August 5, 1858; at Chatham Island from June 27 to July 11, 1861. Total catch of tortoises, 212. (From C.H. Townsend, 1927)*

by Bruce C. Epler

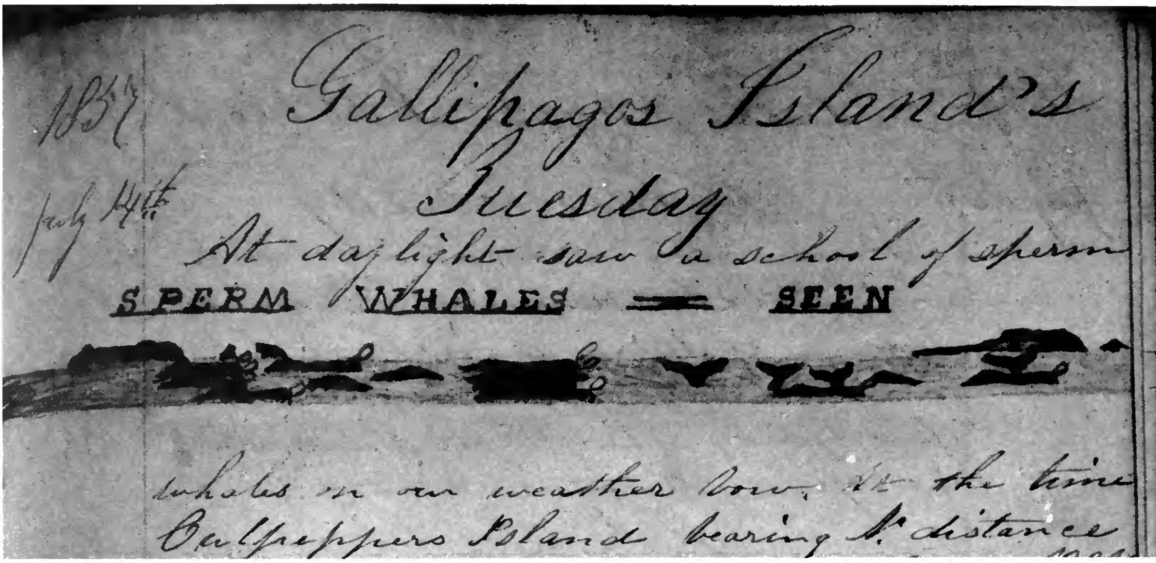
For most of us, mention of the Galápagos brings to mind images of tortoises, volcanoes, marine iguanas, or blue-footed boobies. But, it was the resources hidden beneath the seas surrounding the archipelago, namely whales, that brought visitors by the thousands between 1790 and the early 1900s. They came in search of sperm whales, and sometimes seals. What is less well-known is that they left the islands with large numbers of tortoises stored in their holds. The impact of their activities lingers on.

I hove to and sent the chief mate on shore to sound and land. At eight, P.M. he returned with green turtle and tortoises (galapagos), turtle doves and guanas but they saw no esculent vegetable, nor found any water that was sufficiently palatable to drink.

—Captain Colnett aboard the British whaler *Rattler*, June 24, 1793.

G. W. Shuster, writing in a 1983 International Whaling Commission report, recounts the *Rattler*'s return visit in April, 1794: "They saw many spermacet(i) whales, especially young ones. They killed five here and (Captain) Colnett believed he had discovered the general rendezvous of these whales from the coast of Mexico, Peru, and the Gulf of Panama who came here to calf."

Figure 1. The South Pacific, as seen by Samuel Enderby, who outfitted the British ship Rattler, *the first whaler to visit the Galápagos. This clearly illustrates the role of the Galápagos as the whaler's gateway to the Pacific. (Source: I. T. Sanderson, 1956)*



The top portion of a page from the logbook of the Bark Chili, *captained by Benjamin S. Clark. The ship visited the Galápagos several times during the mid-1850s, and returned to New Bedford on June 8, 1960, with 704 barrels of sperm oil and 128 barrels of whale oil. (Photo courtesy of the Kendall Whaling Museum)*

Whaling in The Pacific

In 1788, the British Ship *Amelia* was the first vessel to round Cape Horn and enter the Pacific in search of sperm whales. Americans were quick to follow, as no less than six American vessels rounded the Cape in 1791. Commercial mariners had never taken to the seas in the same magnitude as the whalers who came to the Pacific, in large numbers, from the United States, Britain, France and, in smaller numbers, from Holland, Spain, and the German states of Hamburg and Bremen.

The British ship *William*, the second whaler to enter Galápagos waters (the *Rattler* being the first), caught 42 of its 100 sperm whales around the islands in an 18-day period in January 1797, and the British whaleship *Cyrus* shortly afterwards achieved a full load in only a year and a half of cruising around the Galápagos.

From this modest beginning, the reputation of the rich whaling ground and unique inhabitants to be found on and around the Galápagos Islands spread through the world's whaling fleets. During the next century, tens of thousands of whales, fur seals, and tortoises would be taken. Buccaneers and explorers of the 17th century, including Captains Dampier, Davis, Cook, Wafer, Knight, Cowley, and Eaton, who had earlier used the islands as a retreat from which to raid and burn coastal towns and loot Spanish ships, consumed a goodly number of tortoises, but the amount was minuscule in comparison to the demands of the whalers.

Once in the Pacific, the whalers pressed their search along the entire coast of South America. Rich new whale grounds were discovered as the whaleships, carried by the currents and prevailing winds, crossed from the Galápagos along the Equator, where sperm whales congregated in large numbers, to the Gilbert (Kiribati) and Ellice Islands (Tuvalu). From these so-called "on the line" grounds, they sailed southward to the Vasquez grounds, and eventually to New Zealand; and north to Japan grounds (Figure 1).

New England Whaling in The Galápagos

R. Langdon (see Selected References) lists the *Lady Adams* of Nantucket, which arrived at the islands in May, 1803, as the first documented American whaling vessel to reach the Galápagos. The islands soon became a favorite cruising grounds for American whalers. In one instance, for example, in May 1809, a ship off Narborough (Fernandina) Island "spoke" 10 other whaleships in the space of one day. Melville, during a stop in the islands on board the *Acushnet* in 1841, writes,

> *The day after we took fish at the base of this Round Tower (Redondo Rock), we had a fine wind, and shooting round the north headland, suddenly decried a fleet of full thirty sail, all beating to the windward like a squadron in line. A brave sight as ever man saw. A most harmonious concord of rushing keels. Their thirty kelsons hummed like thirty harp-strings, and looked as straight whilst they left their parallel traces on the sea. But there proved too many hunters for the game. The fleet broke up, and went their separate ways out of sight, leaving my own ship and two trim gentlemen of London.*

The reasons why whalers congregated in the Galápagos are easily understood: the surrounding grounds were rich in whales and the ideal jumping-off point for trips into the Pacific. Water, wood, fresh provisions, good fishing, sand (for the cooper or for use in scrubbing the deck), dry salt (in uplifted craters), and sheltered harbors were available. They also were ideally situated to come and go from the "Offshore ground" to the southwest, the largest ground in the Eastern Pacific. The presence of large numbers of "succulent" tortoises provided an additional attraction.

A contributing factor in increasing the popularity of the archipelago was refusal by the Spaniards to recognize American sovereignty during the Revolutionary War and the War of 1812. American vessels in Spanish ports along the South American coasts were seized; those at sea were captured either by British or by Chilean and Peruvian pirates emboldened by wartime conditions. During both wars, prudent captains, in increasing numbers, sought the refuge afforded by the Galápagos. The islands became a well known rendezvous for New England whalers.

Most American logs are filled with reports of "gamming," getting together, or "companioning," cruising with vessels, often from their home port, while in the Galápagos. Vessel traffic was such that some time prior to 1793, a post office, constructed of a large covered tortoise shell, and identified by a black sign as "Hathaway's Post Office," was established on Floreana Island to facilitate mail delivery between passing ships and their countries of origin. (This post office and service are still in operation today.

The Taking of Tortoises

Tortoises, because of their ability to live confined within the holds of ships, with little or no food and water, for extended periods of time (more than a year by some accounts) were prized by whalers as an important source of fresh meat during long passages at sea. Admiral Porter, 1813, after bringing "fourteen tons" from Santiago on board the *Tartar* mentions, "They require no provisions or water for a year.. . . They have been piled away among the casks in the hold of a ship, where they have been kept for eighteen months."

Searching the islands for tortoises is, generally, an ordeal. In many areas, walking involves balancing on jumbled masses of broken lava which crumble and slip under foot, frequently penetrating shoe leather, and circumventing crevices while maneuvering through tangled thickets of brush and cactus under the weight of an unrelenting tropical sun. More than one man was lost in the process.

Sept. 25, 1842	two boats came with 22 (tortoises) lost one man
Daylight Sept. 26	sent all hands to look for lost man
Sept. 27	could not find him, left bread and water and directions in a bottle, if anyone should ever find him.

Log of the ship *Chili* at Isabela

Even though these creatures weigh up to 550 pounds, it is logical to presume that tortoises ranging from about 25 to 75 pounds were preferred, as they are more easily carried and, likely, the most tender. A tortoise per man was the usual load, the carrying of which was called "backing them down." Straps or belts were used to facilitate carrying. Larger tortoises were attached to oars so that they could be carried by two or more men. Others were killed and had their meat removed on the spot. In some instances, they were rolled onto their backs and dragged by ropes attached to their legs. (The difficulty in transporting these animals is one explanation why populations on smaller islands with low elevations fared poorly in comparison to populations in the distant highlands of larger islands.

Referring to tortoises, Melville writes:

> *. . . most mariners have long cherished a superstition, not more frightful than grotesque. They earnestly believe that all wicked sea-officers, more especially commodores and captains, are at death (and in some cases, before death) transformed into tortoises; thenceforth dwelling upon these hot aridities, sole solitary lords of Asphaltum.*

Loading tortoises aboard ship was likewise no simple process. One account of the ships Coral and Hope at San Cristobal Island between February 27 and August 2, 1948 reads:

> *This [the loading] was very hard and sometimes very dangerous work, as we were obliged to send them down to the boat by means of a rope from the tops of the cliffs which were perpendicular and above a hundred feet above the surface of the seas. Our method was this, we went in with two boats as near as possible, for we could not go in close under the cliffs on account of the surf running so very high. We anchored one boat and then made a rope fast to her and all the men got into the other boat taking with them the end of the rope by which we could slack the boat or in haul her out at pleasure.*
>
> *[Once a continuous loop of line from the cliff to the boat was arranged] the terrapin were then made fast to one part one at a time and lowered about half way down when another was made fast and lowered away, and so we were kept going, the line going round and round so that one part was going up when the other was going down and 3 terrapin on it all the time. When we got one boat full she was taken to the ship and discharged and the line was anchored by means of a stone. In this manner we got off about 200 of them. Two or three of them fell whilst lowering them down and were dashed to pieces on the rocks.*

Quantities of Tortoises Harvested

It is impossible to estimate the number of tortoises carried away in the holds of whaling vessels that frequented the islands for more than a century.

Commercial

In addition to tortoises, large numbers of fur seals, along with some sea lions, were harvested in the islands. The first mention of the commercial potential for harvesting these animals is found in the log of the British ship Rattler *which reads:*

> We saw but few seals on the beach, either of the hairy [sea lions] or furry [fur seals] species. This circumstance, however, might be occasioned, by its not being the season for whelping; as those which were killed by us, had some time to go with young; but a few hundred of them, might at any time be collected without difficulty, and form, no inconsiderable addition, to the profits of a voyage.

A review of logs at the Kendall Whaling Museum, Sharon, Massachusetts, reveals that whalers were well aware of their value, with entries such as; "only found 3 Turipin got 4 hair seals," or "boat returned with wood and two seal skins," are common.

Whalers were not the only American commercial vessels to harvest animals on the islands. Sealers frequented the islands, in much reduced number compared to whalers, throughout the 18th century. A partial record of documented sealing activities is presented below.

1816: During Fanning's voyage, in 1816, 8,000 fur seals and 2,000 sea lions were taken at the Galápagos Islands.

1823: Benjamin Morrell, "We remained among these islands about two months during which period we took about 5,000 fur seal skins."

1825: Morrell, on a return voyage found only a few seals that were taken at the south end of Isabela Island. However, when the volcanic island unexpectedly erupted on February 14, 1825, Morrell's ship was anchored off Fernandina. His account reads:

> Our ears were suddenly assailed by a sound that could only be equalled by ten thousand thunders bursting upon the air at once; while, the whole hemisphere was lighted up with a horrid glare that might have appalled the stoutest heart.
> . . . At the time the mercury in the thermometer was at 147, but on immersing it into the water, it instantly rose to 150. Had the winds deserted us here, the consequences must have been horrible.

1872–1880: Capt. C. W. Reed made four sealing voyages to the Galápagos Islands between 1872 and 1880, during which about 6,000 seals were taken. The skins are said to have been less valuable than those from Guadalupe, Santa Rosa, and Santa Cruz Islands.

1897: Captain W. P. Noyes, of the schooner Prosper, *of San Francisco, visited the Islands in 1897, and between July 16 and October 19 secured 224 seals, 139 of which were females. Although the logbook records of this voyage state that the seals were procured at distances varying from ½ to 7 miles from shore, the master subsequently stated that some of the animals were killed in caves and elsewhere on land.*

During its peak, the American whaling fleet alone contained more than 700 vessels that made repeated voyages into the Pacific. Information contained in foreign logs is not included here and is a matter of conjecture.

Thousands of log books have, regretfully, been lost over time. The ones that exist are working documents containing information of concern to the vessel owner, and provide only sporadic details on activities on the islands and places visited. We know that many vessels that took tortoises failed to record it. Given the demand for fresh food on board, one may presume that each vessel at least searched for tortoises and most were successful.

An additional problem is that many entries read "took 24 plus many," "employed giting turpin,"* "employed Turpining," "stowing Terrapin," or "seven boat loads more," so it is impossible to assign values. Even the number of animals required to fill a boat is undefined as the sizes of the boats and tortoises varied over the years. The log of the bark *Morning Star* at San Cristóbal on July 10, 1861 reads, "all three boats came on board each one brought 20 Turpin." Captain Barnard's narrative of the ship *Millwood* says "Mr. Coles had forty-five terrapin in the boat."

The most comprehensive work assessing the impact that American whalers had on the Galápagos tortoise population is a 1923 study by C. H. Townsend. It is based on log books from 79 whaling vessels that made 189 visits to the islands between 1831 and 1868 for the purpose of securing tortoises.

* Various spellings of the word terrapin are used by the whalers when referring to tortoise.

Sealing

The Galápagos sea lion. (Photo by D. J. H. Phillips)

Records reviewed by the author indicate that 22,485 fur seals and 2,000 sea lions were killed, yet this represents only a small proportion of the number actually taken.

By the 1890s Galápagos fur seals were thought to have been exterminated. The Albatross *during its 1891 voyage to the islands "found that a scattered remnant of a herd still frequented the more inaccessible rocks of the archipelago." Subsequent sealing voyages "resulted in the killing of all seals that could be found." An 1899 government report states that "It was a matter of surprise to those interested in the subject that during the past month (December, 1897) a vessel arrived at San Francisco from the Galápagos with a catch of 224 seals, as no one had anticipated that the race had survived."*

A California Academy of Sciences expedition (1905–06) visited the islands to conduct the first comprehensive survey of the archipelago. During 12 months of investigation, only one fur seal was observed.

The present population of seals is estimated to be between 30,000 and 40,000. Small clusters are found throughout the islands with the majority of the population located in the northwest of the archipelago on Marchena, Pinta, Isabela, and Fernandina islands. Sea lions, whose low-valued pelts were not sought by sealers, are widespread throughout the islands. Their population is between 20,000 and 50,000 but the sea lions have been subject to an epidemic of seal pox, and periodic influences of the El Niño, both of which are reducing their numbers.

—BCE

A summary of the total number of tortoises Townsend estimated as taken by ships in his sample is presented in Table 1. The largest catches of tortoises over specified periods of time recorded by Townsend from individual islands are:

1834	ship *Moss*	Floreana Island	350	9 days
1831	ship *Isabella*	Espanola Island	335	5 days
1831	ship *Hesper*	Espanola Island	250	6 days
1837	ship *Omega*	San Cristobal Island	240	9 days

In one instance, the log of the ship *Uncas* from Woods Hole contains the following entries:

13th March, 1834	Came to anchor at James [Santiago] all hands employed after Tirripen.
14th–17th March	All hands employed after Turpin.
18th March	At 4 P.M. got under way and steered N.N.W. with 416 terrpins.

Table 1. Total catch of tortoises arranged by decades.

Decades	Tortoises	Average/Visit	Number of visits
1831–39	4853	87	56
1840–49	4379	58	75
1850–59	2334	67	35
1860–68	1447	63	23
Totals	13,013	68	189

It is worth noting that the totals and average numbers of tortoises taken per visit steadily declined, and that a similar trend is evident in average number of visits each decade—all indicating a rapidly shrinking population.

Table 2. Total catch of tortoises (1831–1861)[1], number of races per island, status in 1906[2], and present estimated population[3].

Island	Number of races[4]	Number Taken	Status in 1906	Status in 1974
San Cristóbal	1	4,798	Nearly Extinct	500–700 discovered in 1972
Floreana	1	1,775	Extinct	Extinct
Española	1	1,698	Very rare	20 to 30[4]
Santiago	1	1,048	Rare	500 to 700[5 6]
Pinta	1	455	Rare	One tortoise found in December, 1971
Pinzon	1	356	Fairly abundant	150 to 200[5]
Santa Cruz	1	366	Not rare	2,050 to 3,100
Santa Fe	1	23	Extinct	Extinct
Fernandina	1		Very rare	Extinct[7]
Isabela	5	2,493	Rare to numerous	Total population between 5,200 and 9,100. Sub-species on two southern volcanoes reduced.[8]
Total	15	13,013[9]		

Notes:
[1] Townsend, 1927. These documented quantities represent only a fraction of the total amount taken.
[2] J. Van Denburg, 1914.
[3] MacFarland, Villa, and Toro, 1974.
[4] Separate races exist(ed) on each island, except Isabela which has 5.
[5] Captive propagation underway to re-introduce young.
[6] Eradication of introduced predators underway.
[7] Last tortoise taken by a California Academy of Sciences expedition in 1905; extinction may be attributed to volcanic activity.
[8] 3,000 to 5,000 are found on Sierra Negra.
[9] In addition, 661 tortoises have been documented as taken by scientific expeditions.

Townsend's analysis goes a step further by estimating the total number of tortoises taken from each island. His estimates, along with information of the number of races found on each island and their status in 1906 and estimated population, are summarized in Table 2.

The last reported taking of tortoises by whalers encountered by the author was 96 animals taken in 1876 by the *Abraham Barker* of New Bedford, but the practice surely continued into the 1900s. Townsend writes that Captain Smith, Master of the New Bedford Bank *Northern Light*, while on a voyage which passed in the vicinity of the Galápagos in 1875 reported buying, from a small Ecuadorian vessel sealing at the islands, 10 or 12 terrapin and a barrel of terrapin oil, which he took home and distributed among the housewives that he knew at Vineyard Haven (on Martha's Vineyard, Massachusetts).

Information on the numbers and dates of visits by various ships frequenting the Galápagos, along with data collected by the author confirm that, in addition to those identified by Townsend, approximately 1,000 visits can be documented between 1793 and 1907. Thirty-four of these occurred prior to 1831 and roughly 80 subsequent to 1868, so the period covered by Townsend contained the majority of trips.

Assuming that all documented ships acted in accordance with those identified by Townsend, at least 70,000 tortoises were carried away. Yet, data presented here represent only a fraction of the American whalers that frequented the islands. Undoubtedly, well in excess of a 100,000 were removed and killed (the whalers were not totally responsible, settlers also contributed). The actual number may run into the hundreds of thousands. The onslaught has not been totally halted. Despite nearly 30 years of conservation efforts by the Galápagos National Park Service and the Charles Darwin Research Station, carcasses apparently left by passing fishermen are still found near the coast in remote areas of the archipelago.

Bruce C. Epler is a Marine Policy Research Assistant at the Woods Hole Oceanographic Institution, and an international marine economist.

Acknowledgment

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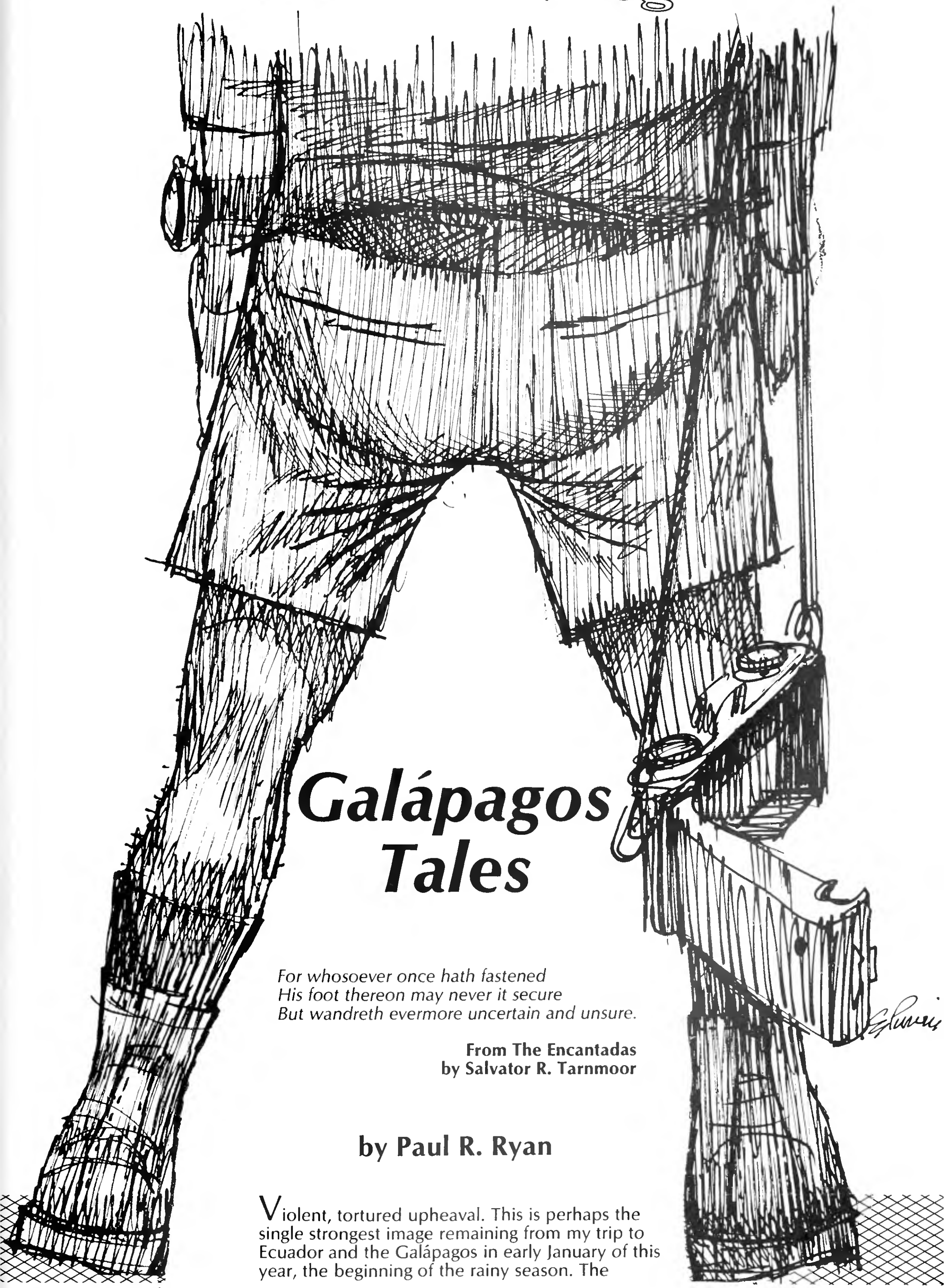
the editor's log



Galápagos Tales

For whosoever once hath fastened
His foot thereon may never it secure
But wandreth evermore uncertain and unsure.

From The Encantadas
by Salvator R. Tarnmoor

by Paul R. Ryan

Violent, tortured upheaval. This is perhaps the single strongest image remaining from my trip to Ecuador and the Galápagos in early January of this year, the beginning of the rainy season. The purpose of my visit was to prepare this issue of *Oceanus*.

I left Boston's Logan Airport on New Year's Day eve on the last flight out in the face of a major storm moving up the East Coast. We, I was accompanied by a colleague as far as Quito, were bound for New York City's La Guardia airport to make a connecting flight early the following morning. We landed in a blinding snow storm, with wind gusts up to 50 miles per hour. Already the elements were setting the mood for what was to come.

Next day, after a stop in Miami, we made the Ecuadorian port city of Guayaquil late in the afternoon. The plane's hydraulic system failed after a rough landing, and we had to spend more than three hours waiting for it to be fixed before we could proceed to Quito, where I would spend a couple of days on business before returning to Guayaquil, my jumping off point for the Galápagos Islands (Galápagos is Spanish for Tortoises). Drank three bottles of the local Club beer in an almost oppressive coastal heat in a Tennessee Williams-type of airport bar with inoperable ceiling fans, and old topographical maps of the Andes and the Encantadas (bewitched islands) on the walls.

The 40-minute flight to Quito was uneventful but unnerving as we flew the alley between the snow-capped peaks of the Andes (18,000 feet), and dropped into the colonial capital of Quito at 9,200 feet above sea level. The lights of the city were dazzling and "dropped into" is the right phraseology; the landing was the hardest I've ever experienced in a civilian aircraft, no doubt designed to test the fragile landing-gear hydraulic system. We were told the thinner air at that altitude sometimes affects the depth perception of the pilot; I felt my rear end had been only inches from becoming a runway brake pad. I looked out the window and thought of all the whale fossils that were probably uplifted and buried in the mountains outside my window:

The New York Times, Thursday, March 12, 1987.

by Malcolm W. Browne
Scientists have found fossils of whales and other marine animals in mountain sediments in the Andes, indicating that the South American mountain chain rose very rapidly from the sea.

The rare assemblage of fossils, recovered on an expedition by the American Museum of Natural History . . . is expected not only to illuminate an obscure epoch of animal evolution but also to document the rise of the Andes mountains in the past 15 million years.

Among the fossils the scientists reported bringing back were the bones of whales and other marine animals found at altitudes of more than 5,000 feet. When these animals died from 15 million to 20 million years ago, their carcasses settled to the ocean floor and were embedded in submarine sediments. But since then, the violent upthrusting of the Andean chain has carried the sediments to the tops of mountains. In geological terms, the time the fossils took to rise from ocean floor to mountain top was relatively brief.

* * *

Darwin came to the Galápagos by *Beagle*; Melville in a whaleship, the *Acushnet*, that was his "Yale College and . . . Harvard"; I came by TAME, an Ecuadorian airline, along with 353 other souls, mostly natives and a scattering of tourists. The famous British naturalist spent 35 days in the Galápagos, 19 of them on land, visiting 4 islands; I'm not sure how long Melville spent while gathering material for his short novel *The Encantadas, or Enchanted Isles*; I spent 6 days, visiting 2 islands. One of Darwin's first impressions:

They [the islands] are all formed of volcanic rocks; a few fragments of granite, curiously glazed and altered by the heat, can hardly be considered as an exception. Some of the craters are of immense size, and they rise to a height of between 3,000 and 4,000 feet . . . . Nothing could be less inviting than the first appearance. A broken field of black basaltic lava, thrown into the most rugged waves, and crossed by great fissures, is everywhere covered by stunted, sun-burnt brushwood, which shows little signs of life. The dry and parched surface, being heated by the noonday sun, gave to the air a close and sultry feeling, like that from a stove: We fancied that even the bushes smelt unpleasant. . . .

Considering that these islands are placed directly under the equator, the climate is far from being excessively hot; this seems chiefly caused by the singularly low temperature of the surrounding water, brought here by the great southern Polar current. Excepting during one short season, very little rain falls, and even then it is irregular; but the clouds generally hang low. Hence, whilst the lower parts of the islands are very sterile, the upper parts, at a height of a thousand feet and upwards, possess a damp climate and a tolerable luxuriant vegetation. This is especially the case on the windward sides of the islands, which first receive and condense the moisture from the atmosphere. . . .

This archipelago has long been frequented, first by the buccaneers, and latterly by whalers, but it is only within the last six years that a small colony has been established here. The inhabitants are between 200 and 300 hundred in number; they are nearly all people of colour, who have been banished for political crimes from the Republic of the Equator, of which Quito is the capital. The settlement is placed about 4½ miles inland, and at a height of probably 1,000 feet.

Melville's first impression was somewhat different:

Take five-and-twenty heaps of cinders dumped here and there in an outside city lot; imagine some of them magnified into *mountains, and the vacant lot the sea; and you will have a fit idea of the general aspect of the Encantadas, or Enchanted Isles. A group rather of extinct volcanoes than of isles; looking much as the world at large might, after a penal conflagration. . . .*

The special curse, as one may call it, of the Encantadas, that which exalts them in desolation above Idumea and the Pole, is that to them change never comes; neither the change of seasons nor of sorrows. Cut by the Equator, they know not autumn and they know not spring; while already reduced to the lees of fire, ruin itself can work little more upon them. The showers refresh the deserts, but in these isles, rain never falls. Like split Syrian gourds, left withering in the sun, they are cracked by an everlasting drought beneath a torrid sky. "Have mercy upon me," the wailing spirit of the Encantadas seems to cry, "and send Lazarus that he may dip the tip of his finger in water and cool my tongue, for I am tormented in this flame. . . ."

On most of the isles where vegetation is found at all, it is more ungrateful than the blankness of Aracama. Tangled thickets of wiry bushes, without fruit and without a name, springing up among deep fissures of calcined rock, and treacherously masking them; or a parched growth of distorted cactus trees.

In many places the coast is rock-bound, or more properly, clinker-bound; tumbled masses of blackish or greenish stuff like the dross of an iron-furnace, forming dark clefts and caves here and there, into which a ceaseless sea pours a fury of foam; overhanging them with a swirl of gray, haggard mist, amidst which sail screaming flights of unearthly birds heightening the dismal din. However calm the sea without, there is no rest for these swells and those rocks, they lash and are lashed, even when the outer ocean is most at peace with itself. On the oppressive, clouded days such as are peculiar to this part of the watery Equator, the dark vitrified masses, many of which raise themselves among white whirlpools and breakers in detached and perilous places off the shore, present a most Plutonian sight. In no world but a fallen one could such lands exist.

My first impressions: From several thousand feet, as we broke out of the clouds, the islands looked no different from those in the Caribbean or South Pacific. But as we [the TAME jetliner] got closer to the single runway at Baltra Airport, the true meaning of the word desert began to take form in my mind along with images of large cactus trees, parched earth, and twisted, tormented volcanic rock.

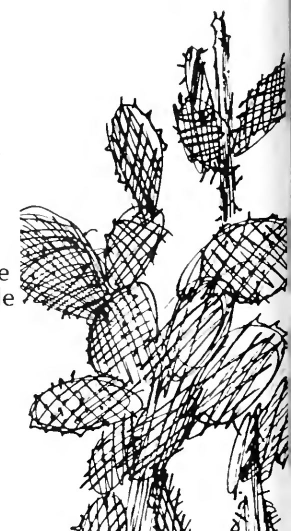
As we departed the aircraft, which was parked a fair hike from the "airport"—a large, open red-brick shed offering shade, Buoy and Gull facilities, a gift shop, and a beer and soda stand—we were herded, not unlike cattle, into lines to pay the $40 National Park entrance fee. Natives, who paid $40 for the roundtrip airfare to the Galápagos, of course, passed right on through (the National Park covers about 90 percent of the islands territory and residents live in zones outside the park and are therefore exempt from the tax unless they plan to enter the park proper) to collect their bags and ride the early, uncluttered 1950-vintage buses to the ferry for the Island of Santa Cruz. Tourists, naturalists, and working men like myself, who had paid $325 for the same roundtrip ticket, got out their handkerchiefs, passports and Traveller's Checks or Ecuadorian sucres while marveling at the hot, but relatively Arizona-like climate. A woman near me, perhaps in her late 60s, whispered to a companion: "The tour people never mentioned an entry fee."

"I wonder if the boat will be there to meet us," her traveling companion answered. " You hear so many nightmare stories about tourists being stranded in the Galápagos."

Eventually, my entry tax paid, I sought my duffle bag—borrowed from my daughter for the trip—with Prudhoe Bay, Alaska, stenciled on the side. It seemed some 23 pieces of luggage were missing—mine among them. After much desperate arguing in pidgin-Spanish and after being told to come back tomorrow (a 5-hour trip from where I was staying), the head of the baggage department was persuaded to look a final time in the plane's baggage department, now being loaded for the daily flight back to the mainland. Wonder of wonders, the baggage was found.

Some 60 of us crammed into the last grime-caked bus—probably meant to carry 40 souls without baggage at most—to the ferry. Of course, there are no paved roads on the island of Baltra, or for that matter on neighboring Santa Cruz. Paved roads, some argue, would open the door to mainland developers, while at the same time diminishing the nature of the Galápagos "experience." The final descent down the cliff road to the ferry was an exercise in pure tip-over fear. But, as they say, "we made it!" We were next herded onto the ferry—a launch built for 35 souls. Our baggage loosely rode the deck roof and, without any prospect for life preservers, we settled back to watch the whitetip shark fins circling the launch on its slow, 50-sucre ride across to Santa Cruz.

At the small dock landing on Santa Cruz, we found that the buses scheduled to take us to Puerto Ayora—a town of some 5,000 people clear across the island (it is estimated that 8,000 to 10,000 people live in the Galápagos)—had returned to Puerto Ayora empty, unaware that our baggage dilemma had delayed our arrival on Santa Cruz. Fortunately, there was a single bus remaining at the otherwise empty site waiting for a party of 12 that had gone out on a charter fishing boat. He promised to take us to Puerto Ayora when his charter returned—in about an hour's time. However, he would not let us enter the bus until his party was first seated for the return trip. At this point, I befriended a young American woman who was the daughter of a diplomat in Quito and who was traveling to the Charles Darwin Research Station to offer her voluntary services for the



summer months. She carried a canteen of purified water and generously gave me a couple of thirst-quenching sips.

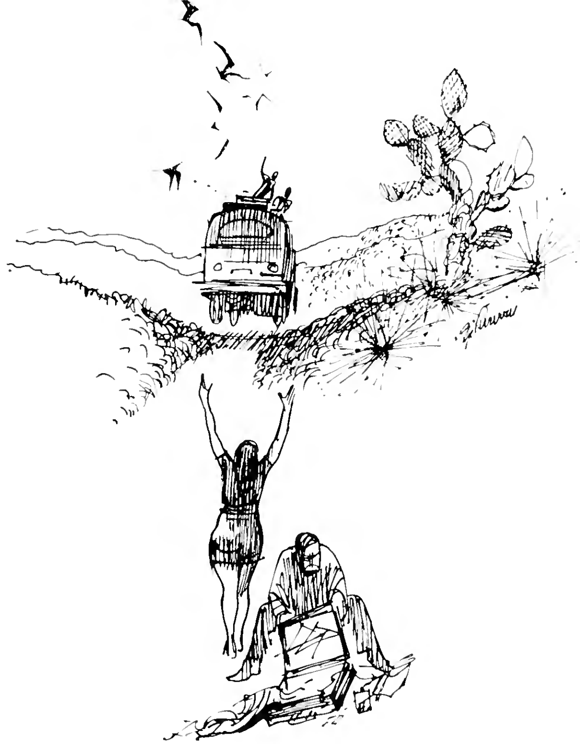
Finally, we were on our way along the straight, dirt road, pleasingly devoid of any roadside buildings, billboards, or stands. Again, the bus was filled to capacity, with a number of people standing in the aisles and three passengers riding on the roof along with most of the baggage.

At a point about half-way on the bumpy one-and-a-half lane road—as we were climbing through heavy, lush green vegetation—a bag fell off the top of the bus, breaking open and spilling the contents of cocktail dresses, frilly underwear, pointed shoes, and perfumes and toilet articles

back down along the road for some distance. The bus stopped, and a perplexed couple, perhaps Americans, got out to retrieve the bag and its contents. While retrieving their goods—the woman wore a tight, fashionable skirt and blouse; the man a heat-retaining business suit—the bus started up and pulled away.

The couple, I later learned, spent 14 hours on the road before being picked up by a bus headed back in the opposite direction to the airport. Once at the airport, they spent 30 hours waiting to get space on a return flight to mainland Ecuador. Oh, I forgot to mention, on arrival their bag was slung off the roof into a puddle of oil.

Meanwhile, as I progressed onward, the first Galápagos animals that I saw from the bus windows—I saw no stores, no shops, no gas stations—were grazing jersey cows and some domesticated horses in farm fields. Banana tree groves, tobacco plants, and corn plots were also evident. About an hour out of Puerto Ayora, the bus stopped for bladder drains and a look at two deep volcano craters.



It was about 7 p.m. when we pulled into the town's main square near the harbor. It was past sunset but with still enough light to see the cactus and generally parched terrain. The "boom town" nature of Puerto Ayora—the largest metropolis in the Galápagos and the hub of the tourist trade—was readily apparent. The streets were unpaved and dusty, and the one-story building facades chipped and cracked, the once bright wall colors bleached dull by a relentless sun. New construction starts here and there dotted the streets—their tell-tale piles of brick and bags of cement stacked on the sidewalks. Children smiled engagingly from entrance ways. I noted a pizza parlor.

It was a 30-minute hike with bags (there were no taxis in the town) to my first-class hotel—"the Galápagos," owned by an American who happened, at this moment, to be vacationing by motorcycle in the jungles of Thailand. I was impressed by the poisonous fruit tree in the courtyard. As I was shown my cottage, I was assured I would see large black spiders on the wall occasionally, but not to worry, they were harmless and preyed on the large (2-inch) flying cockroaches that sometimes put in an appearance. The gentle pounding of the sea on lava rocks outside my window was a reassuring sound. The town generator, I was told, would shut off at midnight, and anyone wanting to read or walk would have to light candles or a flashlight.

The bar was generally unattended, guests being introduced to the honor system. Beer, cokes, 7-up, and Gitig (a local mineral water) were available, along with a limited rum, gin, and whiskey supply. One signed a chit at the bar after mixing one's own drink. While I was there, it was seldom patronized after 9 p.m.

There were six people staying at the Galápagos Hotel when I arrived. Four of them were frequent visitors to Woods Hole, including one summer resident of Penzance Point and two subscribers to *Oceanus*. It is indeed a small world. They were all naturalists of one ilk or another, four of them already hardened by the rigors of photographic safaris in East Africa.

In the morning, a cow bell, gently rung, announced breakfast at 7 a.m., which was served until 7:30 a.m. on six large picnic tables in the main lobby. Coffee, fruit, pancakes, sometimes eggs or bacon, and juice was the main fare. I was greeted on the paved cement path to breakfast by two sun-bathing marine iguanas. Yes, I must be in the Galápagos after all, I remember thinking, marveling at these magnificent beasts who stirred memories of the dinosaur periods. They seemed not to mind my presence in the least.

* * *

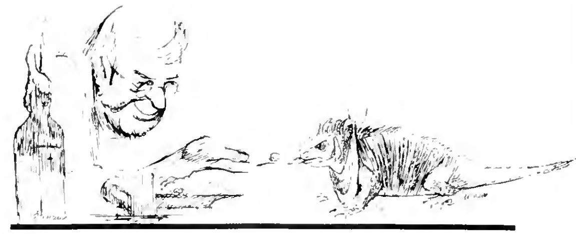
Later that morning, I stumbled on a group of marine iguanas on the black lava rocks behind the hotel. This was an area that served as a back lawn with short, stubby vegetation among the rocks down to the sea.

It was breeding season and two large males were butting heads in a contest for territorial rights. I raced back to my cottage and grabbed my camera, borrowed from the Woods Hole Oceanographic Institution for the trip. The shot counter was on 10 and I felt lucky that I would not have to load film.

I got back in time to witness the end of the head-butting contest, getting some wonderful shots. I was impressed by the speed of the two iguanas when head butting. They would circle each other and then, in a lightning-fast move, bang heads. Finally, one of the iguanas, looking a little dazed, backed off. The other large iguana shortly chose a smaller female iguana and began the mating process, which lasted a good 20 minutes.

Three baby iguanas, perhaps six inches long, watched from a perch on a rock above the burrow where the pair was mating. I thought I had some world-class shots of this type of behavior. Later, upon opening my camera, I discovered that there was, indeed, no film in it.

* * *



The Galápagos are home for a number of European exiles. The Angermeyers fall into this category. Carl and his two brothers left Germany as youths in 1937 to take up residence. They hunted wild goats, caught rock lobsters and groupers, and farmed. Carl, a boat captain and artist among his many talents, has given shelter to a large number of marine iguanas in his home. Angermeyer's pets have developed tastes for more than just seaweed and algae, they also enjoy boiled rice, pancake batter, and raw fish from one's fingers.

* * *

Came across this item in my nighttime reading in the Galápagos. It seems a group of Americans led by a "casual adventurer and scientific fiction reader" founded a colony in 1959 on San Cristobal Island for the purpose of exploiting the island's resources.

R. E. L. Faris and others, writing in the *Pacific Sociological Review*, tell us that the leader's ideal of society was one based on "clear thinking and scientific principles."

> *The Galápagos Islands were perceived by the leader to be rich in marketable resources. At various times he made mention of the possibilities of profit from coffee-growing, cattle-raising, lobster-fishing, seaweed-gathering, tourist-entertaining, and scientific research, especially biological studies. The plan of organization known as "Filiate Science Antrorse" (meaning together with science we move forward) did not take into serious consideration the Ecuadorian residents of the islands. The final document of organization of F.S.A., however, lured more than 100 persons to the islands, representing 36 family units, each of whom turned over $2,500 of their savings, committing their future lives to this scheme.*
>
> *Most of the recruits were drawn from applicants living in the State of Washington. They were chiefly young persons with moderate incomes, including aircraft workers, farmers, truck drivers, firemen, salesmen, a janitor, a plumber, and some school teachers. One feature they all seemed to have in common was a dissatisfaction with their present condition of life, a mixture of idealism, and a yearning for a new and more exciting direction in a so-far adventureless career.*
>
> *A series of disappointments, including lack of seaworthiness of their ship, the* Alert, *lack of fishing skills among its members, depletion of the local lobster resource, irreparability of the refrigeration plant at Puerto Baquerizo Moreno, unavailability of their*

hoped-for coffee-plantation in the highlands of San Cristobal, political troubles in Ecuador resulting from this "Yankee Invasion," and debilitating diseases such as dysentery and hepatitis, resulted in a total collapse of the venture. By January, 1961, almost 14 months after the first group of colonists had reached San Cristobal, all but one of the original colonizers had left the Galápagos. Thus, in little more than a year, 106 persons had come and gone from their utopian island, spent an estimated $165,000, experienced personal bankruptcy, and become generally disillusioned.

—from Contributions to Science from the Galápagos by Robert I. Bowman, Key Environments, 1984.

* * *

One morning I visited Tortuga Bay in a small launch that left from the hotel dock. A large brown pelican perched calmly on a piling observed our departure. There were nine in the party, including an American naturalist guide who was born in the islands and who operated a cattle and vegetable farm when not working as a tour guide. It was about an hour and a half down the coast to the bay. As we left, we got a good view of the glistening visiting yachts and local touring schooners moored in the harbor outside Puerto Ayora.

Once outside the reefs, the sea was choppy. Saw two giant turtles at a distance. On entering Tortuga Bay, I saw a seven-foot whitetip shark break water in a thrashing motion. He was in shallow water, probably feeding. Colleagues had advised me before I left that 1) sharks were plentiful in Galápagos waters; 2) none had ever killed a tourist, although native commercial divers had been known to disappear from time to time; 3) it was not uncommon for bull and other sharks to charge and nudge divers on occasion; and 4) the watchword was to be wary. I kept near the launch while doing some snorkling in Tortuga Bay. The water was turbid and one could only see about three feet. Did manage to get within two feet of a blue-footed boobie, however, who seemed very interested in observing the behavior of our group. Did not see any turtles in Tortuga Bay but did see a couple of magnificent flamingos, a lovely white fine-sand beach, and two cans filled high with human visitors' trash.

* * *

I was disappointed that the owner of the Galápagos Hotel was on vacation. He is an avid chess player, as I am whenever I get the chance, which is not often. The hotel owner has a human-size board where chess pieces are moved by long shuffle board-like sticks from two king-size lifeguard chairs at either end of the board.

My six-day visit came to an end looking for XL teeshirts to take home. The shops were small but numerous along the road to the center of town and full of black coral jewelry items, despite the fact that it is reportedly illegal to harvest black coral. One shop owner explained: "It may be illegal to harvest it, but it is not illegal to make jewelry from it."

While the plane ride back to Woods Hole was uneventful, I should mention that a military C-145 crammed with Ecuadorian troops took off from Quito for Guayaquil shortly before my Eastern flight to Panama. Before we would arrive in Panama, Ecuadorian Air Force commandos would seize President Leon Febres Cordero, a 54-year-old millionaire businessman, as a hostage in exchange for the release of an Air Force general being held in custody for two uprisings against the Defense Minister despite a Congressional amnesty. Just another upheaval in a land of upheavals.

* * *

The Galápagos Islands have the image among those who read the ads and articles in slick magazines around the world of being a Pacific paradise, a place to visit on a luxurious cruise boat at some point in life when one is embarked on seeing the remote wonders of the world. On such a cruise one can enjoy all the amenities of life while vicariously bearing witness to the realities.

The Galápagos Islands are not a paradise in the commercial advertising sense of the word, although they very well may be "treasure islands" to scientific researchers. This raises the question of tourism, which is the single greatest management issue for the newly created Galápagos Marine Resources Reserve (see Broadus article page 9)— the *raison d'etre* for this issue. At present, the islands entertain more than 25,000 tourists a year with a population of from 8,000 to 10,000 residents scattered over the four inhabited islands in the archipelago. A battle is shaping up between conservationists who are defending the unique and pristine qualities of "Darwin's laboratories" on the one hand, and the developers who want to open the islands to high-rise hotels, 150,000 tourists a year, and the Pacific paradise image on the other. This, of course, would help to make them and Ecuador richer.

But there is another disturbing factor in the equation. Some argue that the residents of the islands, many of whom live on the brink of survival and who could use a large measure of fitness, would not benefit from increased tourism—that most of any newly created jobs would go to persons with hotel and tour experience on mainland Ecuador. It is not, for this writer, a convincing argument. Whatever the decision on development of the islands, attention must be paid to the plight of the people, both those who live in the archipelago and those in mainland Ecuador on an equal basis.

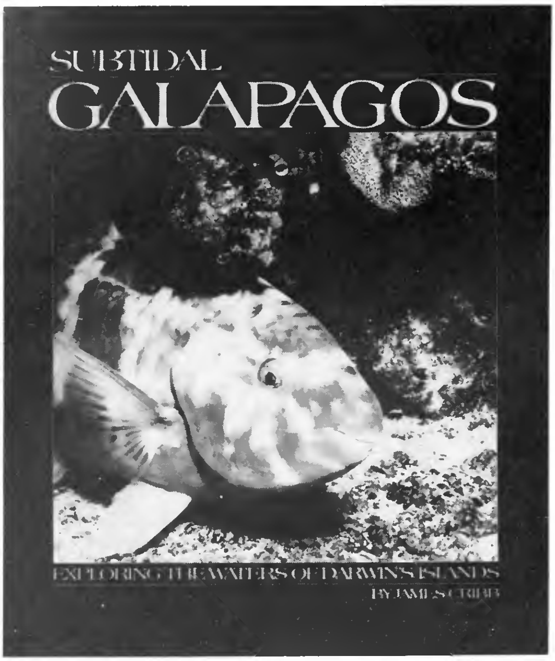
Probably the best idea I heard during my visit was a suggestion that mainland Ecuador has many undeveloped areas of tourist interest comparable to those of the Galápagos. Why not develop these attractions, thereby taking the pressure off the Galápagos to accommodate more tourists and leaving the islands as a "paradise" lost to science, nature, volcanism, and time.

Paul R. Ryan is Editor of Oceanus, published by the Woods Hole Oceanographic Institution.

Acknowledgment

Sketches by Sig Purwin, Woods Hole, MA.

book reviews



***Subtidal Galápagos* by James Cribb. 1986. Camden House Publishing Ldt., Ontario, Canada. 153 pp. $29.95.**

Three major ocean currents—the cool fertile Humboldt, the warm tropical El Niño and the Cromwell, a subsurface current that carries nutrient-rich waters—converge in the Galápagos to produce an underwater world which rivals its more publicized terrestrial counterpart in uniqueness and diversity. James Cribb sets out to explore this fascinating, little known marine environment, and to bring the reader along on his adventure.

Introductory chapters are dedicated to identifying some of the logistics involved in coordinating such an undertaking, and a brief but clear description of the complex oceanographic and climatic factors that are responsible for the coexistence of subantarctic and tropical life forms in waters surrounding the archipelago. The remaining chapters present accounts of voyages through four marine provinces. The journey begins by visiting the central islands with their broad representation of marine creatures, continues on to the cool waters and plunging volcanic cliffs of the western islands, and then to the shark-infested waters surrounding the southern islands. The last area visited is the northern islands, where tropical species including coral abound.

The well-written and often exciting narrative is greatly enhanced by 117 color photographs. The extraordinary collection of marine creatures photographed are a testimony to the beauty and brilliant colors to be found in this extraordinary world and leave the reader with an appreciation of both the Galápagos marine and terrestrial environments. Publication of the book is timely as the interior waters of the archipelago and a 15-mile buffer zone were decreed a Marine Resources Reserve in May, 1986.

The publication could be improved by better coordination of text and photographs as the reader is often caught up in a description but unable to find a corresponding photograph.

Anyone interested in learning more about the Galápagos marine environment without getting into scientific nomenclature will find *Subtidal Galápagos* appealing. The book is a must for those contemplating a diving trip to the islands and a valuable addition to any browsing table or collection of nature books.

Bruce Epler,
Research Assistant,
Marine Policy and Ocean Management Center,
Woods Hole Oceanographic Institution

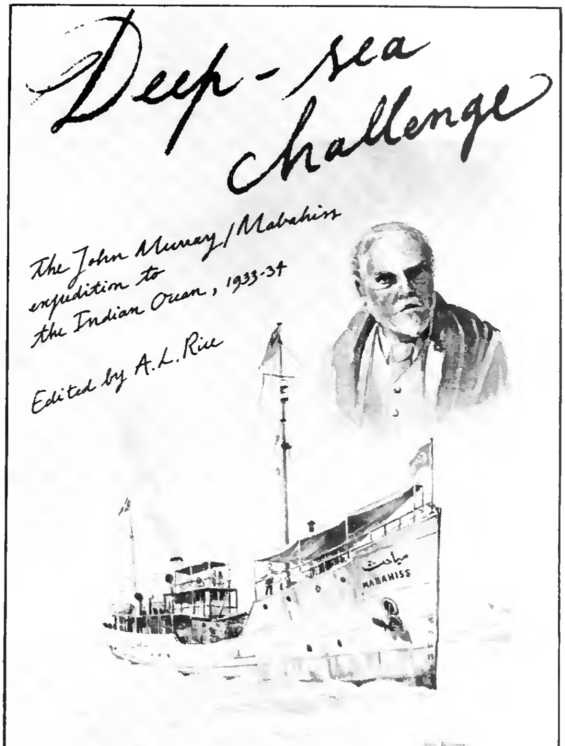
***Deep-Sea Challenge: The John Murray/Mabahiss Expedition to the Indian Ocean, 1933–34,* A. L. Rice, ed. 1986. UNESCO Press, Paris. Distributed in the U.S. by Bernan Associates-UNIPUB, Lanham, MD. 336 pp. $30.00.**

While perusing the book stacks in the library of the Marine Biological Laboratory some 40 years ago, trying to educate myself in oceanography, I found that the decade 1915–1935 seemed to mark the puberty of physical oceanography. There, I encountered expedition reports of research ships such as the *Meteor*, *Discovery*, *Dana*, and *Snellius*, and became especially interested in the 11 volumes of the *John Murray Expedition, 1933–1935* and the story behind it.

Sir John Murray, the scientific editor of the *HMS Challenger Reports*, had discovered commercially valuable phosphate in rock samples brought to him from Christmas Island in the Indian Ocean, and with the help of a local plantation owner, George Clunies Ross, "King of the Cocos," had exploited the deposits very profitably. He made enough money to establish a fund for research after his death in 1914. The fund grew with time, and it was decided to sponsor an oceanographic expedition to the northwest Indian Ocean. The Egyptian government loaned the expedition their newly acquired steam vessel *Mabahiss*; the fund paid for salaries of officers, crew, and scientists, all running costs such as food and coal, shipping, travel expenses, and scientific equipment, for the nine months of the expedition, and for publication of the results. The total budget was £20,000. (It would probably cost 100 times that today: a factor of 20 through inflation, and a factor of five because it always costs more for the government to sponsor anything.)

During a lecture stint at Yale in the 1950s, I came to know E. F. (Bill) Thompson, who had been the physical oceanographer on the Murray expedition. He also had been responsible for the cruises of the Royal Society's vessel, *Culver*, off Bermuda that followed. He had access to the working papers for both these field studies, but unfortunately never pursued their publication. I considered this a loss to the scientific community, as the results of the Murray expedition had always seemed to me to be only partly written up.

However, the leader of the John Murray Expedition, Lt. Col. R. B. Seymour Sewell evidently left a typescript version of a journal that he kept during the cruise. This forms the core of *Deep-Sea Challenge*, and a very good



Unesco

book it is. Included are: (a) a good account of the origin of the expedition by A. L. Rice, (b) biographical notes on the chief participants, by Rice with the help of S. A. Morcos, (c) the history of the *Mabahiss* herself, and (d) a scientific appreciation of the results of the expedition by Rice and Sir George Deacon. There also are some rather wonderful photographs.

The reader will avoid a shock on page 74 if he is prepared to substitute Figure 35 on page 258 for Figure 12. On the whole, the book is nicely produced, informative, and fascinating reading for those who take an interest in oceanic research of past generations.

Henry Stommel,
Senior Scientist,
Woods Hole Oceanographic Institution

EDITOR'S NOTE: The late Sir George Deacon was the subject of a profile in *Oceanus* Vol. 28, No. 1; Henry Stommel was profiled in *Oceanus* Vol. 27, No. 1.

***The Ocean of Truth: A Personal History of Global Tectonics* by H. W. Menard. 1986. Princeton University Press, Princeton, NJ. 353 pp. $29.50.**

To a beginning student of marine geology, the theory of plate tectonics must appear to be such a smoothly operating mechanism that he or she has little doubt of its ability to coordinate many different aspects of the rocks and sediments of the Earth. In fact, the student may find it difficult to conceive of the many fits and starts, changes of concepts, and searches for new tests that occurred during the main formative years, 1961–1966.

Menard was one of a score of principal investigators whose efforts led to general acceptance of plate tectonics. These investigators included some who worked nearly alone and others who were aided by many assistants. Prior to 1961, knowledge of the ocean floor was mainly descriptive and had been gained through use of what now would be viewed as quaint methods and equipment. The need for broad generalizations about the origin of oceans and continents was recognized, and preliminary efforts were made, but with little success, owing to insufficient and inadequately coordinated data. The real push began with short articles by R. S. Dietz and H. H. Hess that forecast the modern concept of sea-floor spreading, but could not prove it. These articles essentially by-passed large gaps in knowledge to link existing large pieces of knowledge in a reasonable but new way.

Menard's book is a summary of subsequent efforts to learn whether and how sea-floor spreading occurs. He notes many of the complications that resulted from multiple-simultaneous discoveries, rejection of manuscripts by journal editors as too controversial or too different, classification of some data by the U.S. Navy, and strong positions taken by some investigators who had access to data of only one sort or from only one ocean, and who radically changed their views when new data became available. The most influential investigators were from Scripps Institution of Oceanography, Lamont Geological Observatory, Princeton University in the United States, and from Cambridge University in England. Investigators at other organizations had lesser roles, and those in most other countries made essentially no contribution during the formative years of sea-floor spreading.

Data of many kinds eventually were incorporated in the study, but of course they usually were not available at the times of greatest need—thus accounting for many of the delays and uncertainties during the investigations. Most of the background data were available from previous long-term shipboard studies supported mainly by the U.S. Office of Naval Research and the National Science Foundation through grants and contracts to investigators at oceanographic organizations. Funds for new critical data, and for syntheses with previous data were provided by these same funding agencies. The kinds of information sought ran the gamut of geology and geophysics: physiography (continental rises, trenches, mid-ocean ridges, transform faults, oceanic islands), distribution and depths of earthquake epicenters, kinds of rock on ocean floors and their ages, magnetic reversal anomalies imprinted on cooling igneous rocks, measurements of gravity, inferences about composition and movements of underlying mantle rocks, thicknesses, compositions, and ages of overlying marine sediments, and supplementary paleomagnetic orientations of mainly continental rocks. Special tools for measurements of seismic profiles, magnetics, gravity, and especially deep-sea drilling had to be invented or be much improved. Increased precision in dating of cores by isotopes and paleontology also occurred.

By the end of 1966, the concept of sea-floor spreading had been well established at least in the minds of those who had done most of the work. The much improved methods continued to be used to investigate details and new secondary questions, and these efforts have spread far more widely than the efforts during the few years of the greatest progress in understanding. This is typical of revolutions in science and it can last for a century or more, as illustrated by the similar revolution in biology led by Charles Darwin more than a century earlier.

Marine geology is much indebted to Bill Menard for his recording of the uncertain and indirect evolution of the broadest generalization of geology, a field that is little more than a century old. During the score of years since 1966 some of the most active investigators have died, and more will go during the next decade, but Menard's summary has captured the essence of the revolution. His summary of conversations, meetings, letters, publications, and personalities is an effective history of a scientific revolution available for consultation by those who might otherwise believe that a scientific revolution is more smooth, reasonable, and orderly than a political one.

K. O. Emery,
Scientist Emeritus,
Woods Hole Oceanographic Institution

Books Received

Aquaculture

Shellfish and Seaweed Harvests of Puget Sound by Daniel P. Cheney and Thomas E. Mumford, Jr. 1987. University of Washington Press, Seattle, WA. 164 pp. + xv. $8.95.

Atmospheric Science

Atmospheres and Ionospheres of the Outer Planets and Their Satellites by Sushil K. Atreya. 1986. Physics and Chemistry in Space 15. Springer-Verlag, New York, N.Y. 224 pp. + xiii. $69.50.

The Ceaseless Wind: An Introduction to the Theory of Atmospheric Motion by John A. Dutton. 1986. Dover Publications, Inc., New York, N.Y. 617 pp. + xix. $16.95.

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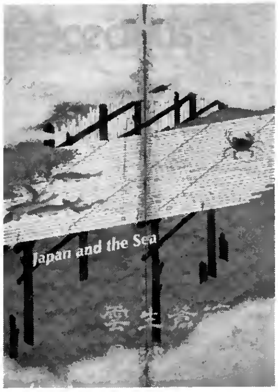

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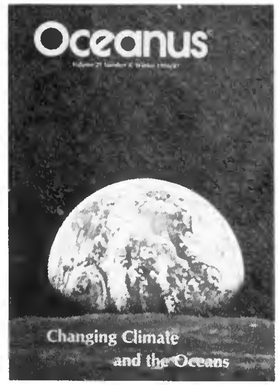

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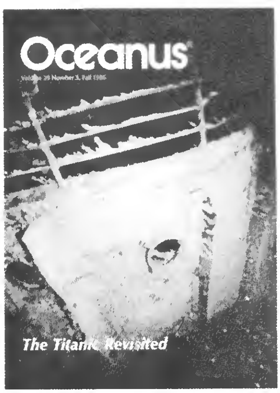

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