ESSAYS IN THE NATURAL SCIENCES IN HONOR OF CAPTAIN ALLAN HANCOCK

ON THE OCCASION OF HIS BIRTHDAY
JULY 26, 1955


1888

George Allan Hancock

ESSAYS IN THE NATURAL SCIENCES IN HONOR OF CAPTAIN ALLAN HANCOCK

ON THE OCCASION OF HIS BIRTHDAY
JULY 26, 1955

Los Angeles

LOS ANGELES
UNIVERSITY OF SOUTHERN CALIFORNIA PRESS

Printed in the United States of America
1955

DEDICATION

More than a year ago, a member of the staff of the Allan Hancock Foundation suggested the possibility of a commemorative volume to be dedicated to Captain Allan Hancock, founder and director (1938-1954) of the Allan Hancock Foundation, on the occasion of his birthday in July, 1955. The idea was discussed with other staff members and received instantaneous approval, as it did also from the present director.

Contact was made with scientists in various parts of the United States and other countries who had participated in scientific cruises of the *Velero III* and the *Velero IV* under the command of Captain Hancock, or who had carried on research on material collected on these or similar cruises. The ready and enthusiastic response was most gratifying and testifies to the high esteem in which Captain Hancock is held in the scientific world.

The research papers contributed by these scientists, together with results of research by members of the staff, comprise this volume. The monumental work of editing, arranging, proof-reading, and seeing through the press has been done by the editor of the Hancock Foundation Publications, assisted by members of the staff of the Foundation Library. The project was made possible financially through the generosity of the Chancellor and the President of the University of Southern California.

It is with a deep sense of gratitude and affection that this volume is dedicated to Captain Allan Hancock.

The Staff

Allan Hancock Foundation for Scientific Research

AN APPRECIATION

Perhaps, strictly speaking, neither "preface" nor "foreword" is the proper term to apply to the opening lines introducing these congratulatory papers presented to Dr. G. Allan Hancock upon the occasion of his eightieth anniversary. More accurately I have called them "an appreciation." This testimony could well be extended far beyond these brief notes, for I have never known a man whose major interests were more numerous and broad and whose approach was more detailed and determined. Born at a time when the material, intellectual, and spiritual worlds were approaching a period of the most rapid development and the widest change, his advantages of birth, his alertness of mind, and his understanding sympathies placed him mid-current in the onrushing stream of world events. Buried in his very door-yard lay relics of past ages to be exhumed, identified, and preserved for the centuries to come—a priceless heritage for scientists of all time. Perhaps it was because of this circumstance that he dedicated himself to the support of scientific research. Born in an area still rich with the traditions of the early Spanish landholders, he grew to love the science and the arts of the rancho and the new and prosperous community which in time surrounded his extensive experimental acres.

Even as a boy he enjoyed music and soon learned to regard it more seriously as a medium of re-creation and stimulation. While other instruments in turn had their appeal, his real and lasting love was bestowed upon the cello—this he studied with a seriousness and earnestness that soon placed him and his group of musicians among the leading orchestras of the southwest. For many years, in spite of the arduous and demanding interests of his agricultural, industrial and scientific life, a part of each day was set aside for study and practice until he mastered the most intricate passages of the great composers.

A sluggish railroad with obsolete equipment which transported the meagre products of the fringe land to its seaside junction became, under his vision and far-sighted management, a busy transportation system serving not only its one-time limited domain but also, in time of war, the state and the nation. Interested in aviation from its beginning, he not only became a pilot in the more primitive days of air travel but in 1928 sponsored the longest test flight of its time over land and sea. His interest has continued through the period of the intricate and complex developments in the airplane needed to meet the demands of the present day; and from the school which he established, more than eight thousand trained flyers manned the fighters of the air when they were most needed. And for all of this we appreciate him.

But perhaps we admire Dr. Hancock most of all for his comprehensive understanding of the wider fields of education and for his devotion to the conservation of past achievements, the spread of present-day knowledge, and the support of that research which, adding to the sum total of present-day knowledge, will make life richer in the future. His establishment of the Allan Hancock Foundation for Scientific Research is in my thinking the surest and highest expression of his character. The ships he built for his expeditions, culminating in the *Velero IV,* one of the best-equipped scientific vessels afloat, express both his courage and his determination. To care for the vast amount of material accumulated as a result of his expeditions and to provide means whereby it could be studied, he provided a building and equipped it with laboratories and with an outstanding biological library. In this building is now housed a unique collection including some of the most valuable and rare biological materials in the world. From this library and these laboratories, through this Foundation, the past speaks with emphasis, the present reveals the world in all her wonders, and the future holds out encouragement and hope to all who would seek to understand and obey the injunction "Know thyself."

And notwithstanding the long years of hard work and the many important and critical projects which have consumed time and strength, Dr. Allan Hancock still devotes himself to the conservation of the best of the old and the discovery of the best of the new. His knowledge of life and his capacity for making friends preserve his youth and his enthusiasm. May his days be crowned with satisfactions unnumbered! For all time he will live in the gratitude of the University of Southern California, where he has invested so generously both of his treasure and of himself, and in the hearts of all who love truth and seek it faithfully.

RUFUS B. VON KLEINSMID

Response of Captain Allan Hancock *to the presentation of the Commemorative Volume*

July 27, 1955

Mr. President, University Officials, my co-workers, and friends—this is a real pleasure. It is on occasions like this that we can relax and come to know each other better.

In business associations as well as in the home, it is important to establish and maintain a friendly climate. There is always need in our daily lives to understand and appreciate one another and to help each other develop our individual talents and abilities.

Let me say right off that EIGHTY is not a stopping place. It is only a new beginning: The number of years involved are of no importance. They have come and gone, like yesterday's football game. We can say that it was a great game while it lasted, but today's game is the one that really counts.

Anniversaries like this are a time for evaluation. We know where we have been, but we must take a long look ahead and plan for tomorrow. There is work to be done. Retirement is something that has never occurred to me, and it never will. The word retirement, itself, suggests a state of stagnation.

The will to work and accomplish new and greater things for our mutual benefit is the battery that sparks our future. The electric power generated in that battery is a thing unseen. So is our thinking a thing unseen, but it has unlimited power. "As a man thinketh, so is he!"

The future of American thinking will make the pattern for our lives. There have been many changes in our way of living during the past fifty years. Changes will come more rapidly during the next fifty years. Man is only beginning to discover countless secrets of nature and the universe. He is employing only a small fraction of the intelligence with which he is endowed.

There is no time to reflect with horror upon mistakes of the past. We must look eagerly forward to the challenge of the future. Let us welcome every change that helps to build better men, better universities, and better communities. May we be worthy of each other's confidence and rely on each other to share the responsibility of creating a better world in which to live. If we do this, tomorrow will always be better than today.

TABLE OF CONTENTS

A PIONEER OF INTERNATIONAL DEEP SEA RESEARCH

By

Hans Pettersson

Oceanographical Institute, Göteborg, Sweden

Few sciences seem more predestined for international cooperation than the sciences of the sea. Realizing this, Otto Pettersson, together with a few colleagues from the Scandinavian countries, at the beginning of this century took the initiative in the formation of the International Council for the Exploration of the Sea. A most important and fruitful work was carried on by this group in the comparatively shallow but economically important seas around northwestern Europe, especially during the first few decades of this century. Exact research methods were developed and accurate instruments constructed and tested for physico-chemical oceanography. In addition, coordinated cruises were organized within the North Sea and adjacent waters, the results from which showed new aspects of the structure and movements of the water masses, their content of living organisms, plankton and fishes, as well as the most adequate means of preventing destructive overfishing by the novel highly developed technique of fishing gear.

A quarter of a century before this new departure took place, a pioneer of deep-sea research, Prince Albert of Monaco, had already become engaged in work of a very high caliber, the results from which soon attracted the attention of the whole world to his small princedom on the Côte d'Azur. As an officer in the Spanish navy, in his early youth the young prince had formed a passionate interest in the ocean, at first as a navigator but in due time as an indefatigable worker in marine research. Starting with a sailing yacht of 200 tons, the "Hirondelle," he made daring cruises not only in the Mediterranean but also in adjacent parts of the open Atlantic Ocean. He soon found this ship too small for his purpose and in the following decades he had three larger and better equipped research ships built for his cruises, the "Princesse Alice I" of 600 tons with an auxiliary engine of 350 HP, the "Princesse Alice II" of 1400 tons and 1000 HP and finally, in 1911, the magnificently equipped "Hirondelle II" of 1650 tons and 2000 HP.

During the last two decades of the nineteenth and the first decade of the twentieth century the Prince carried out deep-sea cruises, extended as far as the West Indies in the west, Newfoundland in the north west, Spitzbergen in the north, and almost to the equator in the south. His favorite field of work, to which he returned again and again, was the Açores with its fantastic submarine surroundings. With a modest self-irony he used to call it "my kingdom."

In all the different branches of oceanography, bathymetry, sediment sampling and investigation, chemistry and movements of the water masses, their illumination and their plankton, he did pioneer work largely with the aid of instruments constructed by himself. His chief interest, however, was concentrated on the organisms, fishes and invertebrates inhabiting the great depths, especially the deep ocean floor. From these at that time very little explored depths, his yacht brought back rare or previously unknown specimens of abyssal life. He even used the large sperm whales as collectors of deep-sea squids, after having obtained an unknown cephalopod from the stomach of a cachalot harpooned near the Açores.

In order to find space for the treasures culled from the deep, the Prince had a magnificent Musée Océanographique built on the very brink of the steep Monaco Rock. The construction was commenced in 1899 but the Museum could not be inaugurated until in the spring of 1910. This "palace of the sea" was thrown open to the public and still forms one of the chief tourist attractions on the Côte d'Azur, with thousands of eager visitors queuing up before its dazzling white portal every day during the tourist season. In spacious exhibition halls the strange animals inhabiting the ocean are displayed, as well as the gear used to catch them. There is also an exhibit of unrivalled completeness displaying the instruments and methods used in oceanographic research from its early days, kept up to date through the acquirement of the latest novelties. A beautiful aquarium in the basement is also open to the public and scientific research is pursued in a number of laboratories, to which foreign research workers are always welcome.

In Paris the Prince also founded an "Institut Océanographique" devoted to research in oceanography and to lectures before the general public. Eminent scientists of different nationalities are invited to this institute to give lectures on their own investigations.

Prince Albert was a firm believer in international cooperation and invited research workers from different countries to join him in his cruises, affording them unique opportunities to pursue their special lines of investigation. He appointed a special "Comité de Perfectionnement" to advise on the future activities of his foundations, with a special clause that at least one third of its members should be of foreign, *i. e.* non-French, nationality.

In 1914 there were great plans for a series of cruises across the Atlantic Ocean. The different European countries had been invited to send naval ships to the opening of the Panama Canal in the fall of 1915. Otto Pettersson and his colleagues in the International Council wanted to utilize this opportunity for an organized "synoptical" study of the upper layers of the whole north Atlantic, using the ships sent across for oceanographic investigations during the passage. Being a close friend of the Prince, Pettersson put the proposal before him. It had an enthusiastic reception and the Prince called together in Monaco a representative meeting of oceanographers to draw up the plans for this cooperation. He agreed to become the "Lord High Admiral" of the whole enterprise and to come in person on board his yacht, the "Hirondelle II," lying at that time ready for cruises in the harbour of Monaco. Grants for the purpose were readily obtained from the Swedish and other governments. Then the first world war broke out in August 1914 and the whole plan had to be shelved. The Prince held the German Kaiser personally responsible for this catastrophe and broke off his earlier friendly relations with him. The war naturally also interrupted the Prince's own work on the high seas. The excellent tool of marine research he had built and equipped, the "Hirondelle II," had to lie idle in the Monaco Harbour and when the war was over the political and financial instability which was its aftermath made an early resumption of its activities impossible. After the death of Albert in 1922 it had to be sold and was acquired by a film company, which made little use of the ship.

One of the lasting foundations made by Prince Albert was the International Hydrographic Bureau which, on his invitation and largely with his support, was set up at Monaco. To this institution he confided the publishing of his world map of the ocean depths, the "Carte Générale

Bathymétrique," usually called the "Monaco Map." It is still being edited from the Bureau and the publication of the fourth edition has just been started, although, mainly for lack of funds, the working up of new data, enormously increased through the use of echo-soundings, has perforce been much retarded. It is not only of great scientific importance but also from an aesthetic point of view most decorative and it should certainly be acquired both by oceanographic institutes and by museums, schools, and other seats of learning and instruction.

The activities of the Prince were not limited to oceanography alone. He took a keen interest also in pre-history and had a special museum in Monaco devoted to archeological finds, especially those made to the east of Monaco on the Franco-Italian frontier in the Roches Rouges, of skeletons and artifacts from the Cro-Magnon race formerly inhabiting these caves.

Through munificent donations the Prince tried to assure the financial future of his different foundations and the series of publications he had started. However, the devaluation of the franc following on the first and still more the second world war made the interest from this capital dwindle to a small fraction of its original value. Largely thanks to the relatively great income from entrance fees to the Museum in Monaco its activities, although on a reduced scale, could be continued and even those of the Oceanographic Institute in Paris secured.

It is sincerely to be hoped that Monaco will ultimately resume its position as a center of European deep-sea research not only for its great traditions from Albert's time but also for its favored position, quite close to relatively great depths and with free access to the Mediterranean, one of the most fascinating of all seas with its active and extinct volcanoes, its highly varied bottom configuration, and its early importance in the migration of animals and men from Africa to Europe and vice versa, which make it eminently worthy of intensive study. Fortunately the young Prince Rainier III, the present ruler of Monaco, seems to have inherited from his great grandfather an absorbing interest in the sea and its living world. It is to be hoped that under his rule his princedom may once more become a focus of deep-sea research.

Unfortunately the present outlook for international cooperation in deep-sea research in Europe is not hopeful. A promising nucleus for international cooperation in the study of the deep sea and of the ocean floor, its geology and its fauna, the "Joint Commission on Oceanography" set up under the protection of the Unesco has been disbanded after several years of successful activities by the Executive Board of the International Council of Scientific Unions.

Captain Allan Hancock, to the celebration of whose eightieth birthday this paper is a modest contribution, seems to the present author to have gone through a development resembling that of Albert of Monaco. Early attracted to the ocean, first as a navigator, later as an investigator, he has built and equipped in succession four oceangoing research ships of increasing perfection, the *Velero I-IV* and made numerous cruises in the eastern parts of the Pacific Ocean. He has assembled a staff of competent scientists to aid him in this work and he has created a center of research, the Hancock Foundation at the University of Southern California. Moreover, like the Prince of Monaco, he has taken a great and active part in paleontological research and has presented to the Los Angeles County Museum the fossils of prehistoric animals excavated from the Rancho La Brea Asphalt Pits. Later he presented to Los Angeles County the entire tract of about 32 acres containing these Asphalt Pits, with the condition that the scientific features be preserved for all times so they can be visited and studied by interested scientists.

May the present author be permitted to wish him many more years of active work and studies, adding a fervent wish that he may also take an active interest in the international cooperation in deep-sea research, in which his own country appears destined to take a leading part in the future.

The "Hirondelle II"

Insert:

Albert I, Prince of Monaco

THE FUTURE OF MARINE INVERTEBRATE SYSTEMATIC RESEARCH

By

Fenner A. Chace, Jr.

Curator, Division of Marine Invertebrates
U. S. National Museum

During my oral examination 20 years ago, one question produced the intended disquieting reaction so effectively that inadequate answers to it still chase themselves through my mind. The question was: "What is the future of systematic research?" Obviously we do not know the answer. Neither do our colleagues in other branches of biology, or in most other professions, know the future of their chosen fields. As far as the invertebrate groups are concerned, it matters little; there is a tremendous job to be done and far too few workers are trying to do it.

A perusal of many recent books, magazine articles, and even movies and comic strips would indicate that the average American is becoming increasingly interested in the sea and its inhabitants. We are told that this environment, covering more than 70 per cent of the earth's surface, is the last frontier awaiting exploration and exploitation. Yet where can we turn to obtain reliable information about many of the animals living in this vast world of water?

Who can provide us with accurate data on jellyfishes whose poison may be more deadly than that of the most dangerous snake?

Where is there today a specialist on the sipunculid worms, of which some are the chief food of many of our northern fishes and others are probably instrumental in breaking down the coral reefs of the tropics?

How can we obtain a reasonably prompt analysis of plankton, those numberless tiny drifting forms on which the entire economy of the sea depends?

Several invertebrate animal groups are almost completely ignored by taxonomists of this generation and few of them, except insects and mollusks, are receiving even part-time attention from more than one or two experienced specialists. The continuation of such limited taxonomic interest can only mean an indefinite delay in achieving a comparatively stable nomenclature and in acquiring knowledge of the relationships, distribution, and habits of animals on which the solution of more practical problems may rest.

Various methods have been proposed for improving this state of affairs. It is generally agreed that sound systematic research is dependent on the competitive efforts of a number of well-trained specialists on each animal group and upon adequate collections and ample libraries. There are those who believe that taxonomic studies can best be fostered by centralizing collections of each group so as to minimize the travel necessary to examine a sufficient series of specimens. Some have suggested that all material of the less popular groups should be deposited in the U. S. National Museum. Partly because of this, the steel stacks housing the vast marine invertebrate reference collections of that institution have become filled almost to the limit of their capacity. Unfortunately, the staff entrusted with the care of these collections has not grown in proportion and it cannot identify and catalogue the specimens properly and provide prompt assistance to specialists in other institutions.

As curator of these collections, it is only natural that I should hope and work for the gradual expansion of our facilities and staff so that this century-old establishment can maintain its position of leadership in the field and can more nearly cope with the duties assigned to it. But even if the overburdened taxpayer and his representatives could be persuaded to increase the Federal appropriation by the many times necessary to support all invertebrate systematic research, I could not honestly support the idea. In these days of great international tensions and unprecedented weapons of annihilation, it is important that there be more than a single center for the systematic study of invertebrates.

There are other ways of supporting systematic research. Marine biology has benefited more than is generally realized or acknowledged from the services of taxonomists who were able to carry on their studies with little or no compensation and from the generosity of individuals like Alexander Agassiz, Prince Albert I of Monaco, and Allan Hancock.

These men, unlike many who have sponsored both government and private expeditions, realized the importance of providing for the care and study of the collections they amassed. It is to be hoped that generations to come will produce more like them, but these few benefactors cannot be expected to support all of the facilities necessary for an adequate program of systematic research on marine invertebrates. In recent years grants in aid from both government and private foundations have become increasingly important deciding factors in the success or failure of particular research programs but they are, and should be, too short-lived to support the almost life-long education of the experienced taxonomist.

It seems to me that we must look to the private institutions, especially our universities, for continued and even increasing encouragement of the systematic studies that are basic to all biological research. It is there that we can expect to find the most immediately justifiable excuse for systematic research—the thirst for knowledge. The college graduate who is largely responsible for the support of our private universities is likely to be more sympathetic toward a program of this kind than is the person with more limited education who pays most of the bills of our Federal and state governments. Louis Agassiz could never have raised the private donations necessary to finance the building of the Museum of Comparative Zoology at Harvard if his audiences had been interested only in immediate personal dividends.

Although monographic studies of large groups of animals on a world-wide scale can hardly be attempted by workers at universities where extensive systematic collections and libraries are lacking, real contributions can be made by those willing to confine their attention to smaller groups or to faunal areas. It must be realized, however, that the fruits of systematic research mature slowly. Any intelligent program of systematic research must therefore be a long-range one. The goal of taxonomic stability, even in a small group, is seldom achieved through the efforts of one individual. Succeeding generations, profiting not only from his publications but also from the collections he has accumulated, will finally attain it. Every precaution should be taken to prevent the loss or deterioration of collections in spite of the demands of specialists in other fields for the space and jars they occupy.

Although many biologists in our universities have only scorn for taxonomic research, there are others who sincerely regret that they must dissuade promising students from continuing their interest in systematic zoology because of the paucity of jobs in that field. This need not be so if the faculties and administrators of these universities can be convinced of the importance of knowing not only how a certain animal reacts to varying environments and stimuli but what the animal is and which of its relatives might prove to be more favorable subjects for observation and experimentation.

Let us not worry about the unpredictable future of marine invertebrate systematic research until we have made greater progress toward our present goal. Let us not discourage those who would help us attain that goal by telling them that the job is finished or that taxonomy is too subjective to be called a science. Let us instead guide their enthusiasm toward the more obscure groups where the job is still far from finished. If we give them the best possible training in systematic zoology and provide them with security comparable to that enjoyed by their faculty colleagues, some of them will eventually minimize the instability that is the target of most of the criticism and ridicule. Let us give an opportunity to the most promising of those who feel as Darwin felt when he wrote, "I could not employ my life better than in adding a little to Natural Science." Perhaps one of them, too, will add more than a little.

THE IMPORTANCE OF SYSTEMATICS IN LIMNOLOGY AND OCEANOGRAPHY

(Extension of Remarks before Berkeley Meeting of American Society of Limnology and Oceanography, December, 1954)

By

Joel W. Hedgpeth

Scripps Institution of Oceanography

"I have always felt that each working naturalist owes it as a duty to science to produce some general systematic work . . ."

Alfred Goldsborough Mayer,
Medusae of the World, 1910

"Never more than in this present day when experimental research has gained so wide and lasting, and, on the whole, beneficient a hold in biology, has there been need of fidelity to description and classification."

Wm. E. Ritter (1916)

"This widespread need for taxonomy (or some kind of dependable system of biological classification) deserves more consideration, especially sympathetic consideration, than it usually receives."

W. E. Allen, Turtox News, April, 1941.

(Contribution No. 121, Scripps Institution of Oceanography, New Series)

Some forty years ago William Emerson Ritter, founder of Scripps Institution of Oceanography, deplored the idea that systematic biology had nothing further to contribute to science, and discussed "the monstrousness of the fallacy into which biologists have fallen in conceiving taxonomy as an outgrown stage of biology," and, further, "something of the wretched consequences that have resulted from the fall." (Ritter, 1916). To be sure, Ritter was primarily concerned with the implications of this attitude for biological theory and the interpretation of Nietzsche (who was taken more seriously in those days than now), rather than its effect on the work of hydrobiological institutions; but much of what he had to say then is still valid today: "The sooner it is borne in upon the minds of all students of living beings, no matter with what aspects of such beings they may be occupied, that they are engaged in the great task of describing and classifying the living world; and, so far as 'pure biology' is concerned, are doing nothing else, the sooner will objective biology get itself set off from subjective biology and the sooner will philosophical biology become purged of the morbific growths which now impair its health and mar its beauty." (*op. cit.*, p. 464).

Today the attitude towards systematic biology is perhaps not as antagonistic, and in some hydrobiological institutions takes the form of saying that while systematic biology (or taxonomy—which many confuse with the legalistic aspects of nomenclature *per se*) is a fine and necessary aspect of science, it is best practiced by someone else, elsewhere, preferably in a museum. In other words, "Let George do it." Such an attitude is in some ways more harmful than the notion that systematic biology is now a closed chapter in the history of science. Surely no one would have been as prompt to reject this attitude as Ritter, and indeed significant systematic work is still going on at the institution he founded. Nevertheless, it is also true that systematists are not given posts in hydrobiological institutions by virtue of their being systematists alone nor are students admitted on the understanding that they are to devote their time to systematic problems. With the accent on dynamic interpretations of "parameters" and Chlorella nurseries, the fact that a student or researcher is interested in systematic problems is considered of secondary interest, and the unfortunate systematist who applies for a post as such is told, in effect, to go, get himself hence to a museum. (This is not, however, intended to imply that the giver of such advice shares Hamlet's altruistic motives.)

Even if there were enough museums and enough curatorial posts for everybody who wanted them, this would be an inadequate view of the function of systematics in institutions so concerned with the interactions of organisms and their ambient medium as those devoted to limnology and oceanography. Perhaps it is time to emphasize that by systematics we have in mind the analytical appraisal of categories in nature, both as species and populations, as well as the more descriptive phases that are usually associated with the term "systematics." Taxonomy is roughly the same thing, but for some semantic reason the word excites contempt rather than interest in some minds. Perhaps this is based on the impression that museums, especially public museums that must serve the taxpayer in the provinces with his jar of bugs or box of shells as well as the specialist with his research collection, have seldom done more than identify material and produce monographs on collections of dead organisms, and this is all that is known about "taxonomy." In justice to the unfortunate museum curator, it must be said that he has time for little else.

Some taxonomists—or systematists—who work in universities and research institutions (where they may have been hired by inadvertence) have tried to lighten their burden somewhat by sugar-coating their interests with the term "biosystematics." Well, a rose by any other name —but when the ships close for action a good pirate flies his colors, so let us continue to use the term systematics (although "biosystematics" might have some value if we also recognized "geosystematics," *i. e.*, the description and classification of new seamounts and trenches, and similar verbal confections).

Systematics, then, is that branch of biology devoted to the study of dynamic processes as expressed in the structure and comparative morphology of organisms; so defined, systematics cannot easily be practiced in museums since it requires continuous reappraisal of living populations rather than assembled relics; such systematics, we are tempted to say, is too good for museums. Certainly institutions devoted to research in aquatic environments are continuously collecting the finest type of material for such critical systematic work, and the "let George do it" attitude is not only short sighted, it is impractical and a disservice to science. There are simply not enough Georges for what has to be done; or if there are, they are not employed in posts where they may best function. There is no dearth of students interested in systematics and there is no dearth of work yet to be done, even in the routine cataloging of local flora and fauna. And, as we learn more about the environment and the distribution of organisms in relation to factors not considered in earlier work, we must re-examine and re-evaluate that former work. Hence our need for a continued supply of expert systematists, even—or perhaps particularly—in groups that are considered well known and thoroughly described, is perpetual. The dependence on past knowledge and reappraisal of previous work is one of the most characteristic aspects of science in general. Many of Aristotle's biological observations are still valid although his theories are no longer important, and we still repeat the old observations in the light of new theories. Such analytical description appeals to many students, and there is no finer way to present many problems in biology than from the viewpoint of systematics. Inevitably some students are fatally infected, and want to become systematists. They should be—and sometimes are—encouraged to do so, even when it is understood that the possibility of being employed in this field is small.

However, it is not for the sake of making jobs that other institutions besides museums should be encouraged to employ systematists. No single institution can be expected, of course, to hire enough specialists to represent all the plant and animal groups requiring identification and study, and such attempts to provide complete coverage would be unnecessary duplication. What seems to be needed, more than the policy that limnological and oceanographic institutions should hire systematists, is the recognition that systematists are just as promising scientists as the parameter parsers and nucleic acid merchants. It may be that the lack of enthusiasm expressed in some quarters for systematic biology is based on the realization that the objective definition of a species is a counsel of perfection, *i. e.*, that systematics cannot reduce all its terms to entities that may be digested by a computing machine. Such a holier than thou attitude is presumptuous when it is remembered that all human knowledge is derived through the subjective filtering of our senses, that some minds may be as incapable of distinguishing between two and three as some eyes are of telling red from green.

This aloofness toward systematics is not, of course, peculiar to limnological and oceanographic institutions. It seems to be a general attitude, general enough, in fact, to inspire a conference under the auspices of the National Research Council on April 22, 1953 (Schmitt *et al.*, 1953). While the finding of this conference that "fewer groups of plants and animals are being worked on by fewer people" should deeply concern the director of every limnological and oceanographic institution, it is unfortunate that the conferees recommended expanding the staffs and endowments of museums and "other institutions carrying on systematic work" without also calling upon the principal consumers of systematic work to recognize their own obligation to support systematics. This is not to deny the need for expanding museum staffs, particularly in our National Museum, to which by law must be sent the collections made in the course of government financed investigations. Such collections are being received, especially from recent investigations in the south Pacific islands, at a rate far beyond the capacity of the staff to keep up with them. But there is little evidence that anyone outside the museum realizes that there is an implied obligation to study these collections as they accumulate.

It is instructive, at this point, to remember that Scripps Institution of Oceanography was founded by a systematist (who specialized in ascidians), that one of the great systematic classics was written by Fridtjof Nansen as a doctoral dissertation, that Darwin spent eight years monographing barnacles to solidify his reputation (systematics was in high esteem in those days, and no biologist who had not done some sound taxonomy was considered worth his salt), that K. Moebius, V. Hensen and C. J. G. Petersen all cut their teeth on systematic problems. It is well to remember that another ascidian specialist, William Herdman, founded the Port Erin station on the Isle of Man, and what was said of the continuation of his policies by his successor: "In these days when a newcomer considers himself entitled not only to ignore the traditions of his office, but even to break them down, Johnstone's decision to follow and develop the policy of Herdman at Port Erin showed that his judgment was sound even when in conflict with his private inclinations." (Cole, 1934)

Even more instructive than such examples is the example of broadening horizons in systematic biology set by the Allan Hancock Foundation in the relatively short period that it has been in existence. Not only has the Foundation accumulated tremendous and important collections and a remarkable working library in the manner of a traditional museum, and provided for the publication of studies upon these collections, including the importation of specialists from other parts of the world to prepare particular monographs, it has also embarked on a program of ecological survey of the nearby sea bottom. Already this work has excited the interest of ecologists in other parts of the world since its preliminary results suggest that ecological conditions on the sea bottom may not be as uniform in various parts of the world as postulated by some European workers. Such work would have been impossible when the Foundation was originally established because not enough was known of the systematics of the animal life, and it would be impossible today without the staff of systematists to analyse the collections as they are made. It should be further emphasized that this work is being carried out by the same staff that started out years before as "pure" systematists. A systematist in a hydrobiological institution cannot, if he is really interested in the full implications of his studies, remain a cabinet naturalist, while in museums there is more frequently than not little opportunity to be anything else. The example of the Hancock Foundation in employing and supporting systematists fully justifies our contention that the best systematists should not be allowed to wither away in museums, but should be employed where they have the opportunity to make the most of their talents and inevitably broadening interests.

To paraphrase Alfred Goldsborough Mayer, it is the duty of every limnological and oceanographic institution to see that systematics is represented on its staff and that the work of such systematists is well supported. This support should be augmented by the realization that a systematist serves not only his own institution but the entire scientific fraternity, and that it is an obligation to allow him time to meet at least some of the demands that are inevitably made upon his knowledge. This is, of course, enlightened self-interest, for in this way the services of specialists in the various groups may be pooled in the cause of increasing knowledge among men, to which we are all dedicated.

LITERATURE CITED

COLE, F. J.
1934. "J. J." A biographical note, *in* James Johnstone Memorial Volume, University Press, Liverpool, pp. 1-11.

RITTER, WM. E.
1916. The place of description, definition and classification in philosophical biology. Scientific Monthly, November, 1916, pp. 455-470.

SCHMITT, W. L. et al.
1953. Conference on the importance and needs of systematics in biology. National Research Council, Washington, D. C., 53 pp. plus appendices. (Mimeographed.)

THE CASE FOR A WARM-TEMPERATE MARINE FAUNA ON THE WEST COAST OF NORTH AMERICA

By

John S. Garth

Allan Hancock Foundation

The Pacific Coast of the Americas, from Bering Strait to the Strait of Magellan, is the longest stretch of uninterrupted coastline in the world. Extending in a northwesterly to southeasterly direction from Latitude 66° N to Latitude 54° S, it has but two significant indentations, the Gulf of California and the Bay of Panama. It should be expected that along such a continuous coastline the major faunal regions would be represented in regular succession, as are their terrestrial counterparts, the biotic provinces. It is therefore something of a paradox to read in Ekman, "Zoogeography of the Sea" (1953, p. 144), that one of the more important regions, the warm-temperate, is wanting. To quote directly: ". . . the whole of the North American [Pacific] coast from and including the northern part of Lower California and northwards corresponds . . . to the boreal region [on the Atlantic side], the southern boundary of which [corresponds with] the south-western entrance to the English Channel . . . as regards surface temperatures. . . . Thus there is practically no room for a warm-temperate fauna on the Pacific Coast of North America, . . . if 'warm temperate' is taken to mean the same as far as America is concerned as it does in Europe."

With all due respect to Professor Ekman, for whose scholarship and erudition I have profound admiration, this is simply not the case. Not only is there room for a warm-temperate fauna on the Pacific Coast of North America, but such a fauna does in fact exist. That the literature fails to reveal this, or that Professor Ekman has failed to recognize it from the literature, may be laid to the predilection of systematists for writing for those of our respective specialties, rather than presenting the facts essential to an understanding of the overall distribution pattern in a form available to ecologists and zoogeographers. Let us consider Ekman's sources: for the mollusks, Schenck and Keen (1936); for the decapod crustaceans, W. L. Schmitt (1921); for the echinoderms, W. K. Fisher (1911, 1928, 1930); for the fishes, Jordan, Evermann, and Clark (1930): truly a boreal element among zoologists. (The number of ranges of northern species that stop at Monterey, I maintain, represents not the distribution of species, but of early zoologists, to whom the Southland was *terra incognita.*) To be sure, the coastline from San Luis Obispo to Monterey was inaccessible before the opening of San Simeon Highway; that from Malibu to Ventura before the opening of Alternate U. S. Highway No. 101. Of the Channel Islands, only Santa Catalina could be reached by public transportation, while the Mexican islands of Los Coronados, Cedros, San Benito, and Guadalupe were, and still are, attainable only by sea-going expeditions. Finally, the mainland of Baja California south of Ensenada has but recently been traversible by roads of more than dubious quality.

Field work of the Allan Hancock Foundation and its laboratory vessel, the *Velero IV,* has been concentrated in the region it is now proposed to define. In February, 1947, a series of shore stations was made from Santa Barbara north to Monterey for the purpose of delimiting more closely the faunal change that occurs in the littoral zone in the vicinity of Pt. Conception. In March and April, 1949, the *Velero IV* explored the west coast of Lower California and the Gulf of California, and in December, 1949, a cruise was made to Guadalupe Island, Mexico. In April and May, 1950, a voyage was made to Magdalena Bay, with a stop at San Benito Islands. In April, 1951, a cruise was made to Viscaino Bay and Cedros Island, while in October and November, 1951, collecting was done at Turtle Bay and Pta. Eugenia. In January and February, 1954, the west coast of Lower California was again visited enroute to Acapulco, Mexico. In addition to these longer voyages, numerous short trips to all the Channel Islands were made in the course of surveys of the offshore basins. As a result of this work the Southern California—northern Lower California littoral is becoming better known faunistically than would have been thought possible a few decades ago.

In developing a warm-temperate fauna I shall draw most of my examples from the brachyuran Crustacea. Not only are they the group with which I am most familiar, but they illustrate the points to be made as well as could be desired. Of the short-tailed crabs the genus *Cancer*, because of its commercial importance, is perhaps the best known. Its center of distribution is the North American west coast, with nine species present. Of these two, *Cancer magister* and *C. oregonensis*, occur from Alaska to Central California; five, *C. productus*, *C. antennarius*, *C. branneri*, *C. jordani*, and *C. gracilis*, extend varying distances both north and south of Pt. Conception; while two, *C. anthonyi* and *C. amphioetus*, occur exclusively south of Pt. Conception. The short-range species indicate a subdivision of the boreal into cold- and warm-temperate subregions, although the long-range species tend to obscure this.

A second group of importance are the kelp crabs. Of the genus *Pugettia*, represented in the American Pacific by five species, one, *P. gracilis*, is exclusively northern, two, *P. producta* and *P. richii*, extend both north and south of Pt. Conception, while two, *P. dalli* and *P. venetiae*, are exclusively southern. The large kelp crab, *Taliepus nuttallii*, ranges from Santa Barbara to Magdalena Bay, and the small kelp crab, *Epialtus hiltoni,* known previously from Santa Catalina Island and Laguna Beach, has been found south to Magdalena Bay wherever surf grass, *Phyllospadix*, occurs. As with the genus *Cancer*, the short-range species define a cold- and a warm-temperate subregion.

A third group of decapods are the pebble crabs. The genus *Lophopanopeus*, as revised by Menzies (1948), is represented by *L. bellus*, which ranges from Washington State to Mission Bay, with a sharp break at Pt. Conception defining the subspecies *L. bellus diegensis*. A second species, *L. leucomanus*, ranges from Channel Islands (Monterey, Lockington) to Rosarito Beach. A third species, *L. frontalis*, ranges from San Pedro to San Ignacio Lagoon and occurs in the Gulf of California. *Cycloxanthops novemdentatus* ranges from Monterey Bay to San Martin Island, *Paraxanthias taylori* from Monterey Bay to Magdalena Bay, and *Pilumnus spinohirsutus* from San Pedro to Magdalena Bay.

A fourth group of Brachyura are the swimming crabs. *Portunus xantusii* presents a typical warm-temperate range: Santa Barbara to Magdalena Bay and Gulf of California. Other members of this genus are tropical.

Of the grapsoid crabs, *Pachygrapsus crassipes* occurs from Crescent City to Margarita Island, outside Magdalena Bay, and in the northern Gulf of California. Among the oxystomatous crabs *Randallia ornata* ranges from Mendocino Bay to Magdalena Bay. Of the parthenopid crabs *Heterocrypta occidentalis* has been taken from Half Moon Bay to Dewey Channel, opposite Pta. Eugenia. The range of *Podochela barbarensis*, Pt. Mugu to Pta. Abreojos and Gulf of California, is warm-temperate, while a spider crab of limited range is *Libinia setosa*, found from San Juanico Bay to Magdalena Bay only.

Enough examples have been given to establish point one, that the region from Pt. Conception to Pta. Entrada, outside Magdalena Bay, supports a large number of endemic species, which may be of either boreal or tropical genera. Let us now proceed to compare this endemic fauna with that of warm-temperate faunas of other continents and oceans.

Having just completed a report on the Brachyura of the Lund University Chile Expedition, I am perhaps best prepared to discuss the fauna of northern Chile and Peru. Here Ekman (1953, p. 209) has no difficulty in recognizing a warm-temperate fauna, the northern limit of which he places at Pta. Aguja, Latitude 6° S (it will be remembered that the boundary between temperate and tropical faunas occurs here at a much lower latitude than elsewhere in the world), the southern limit in the vicinity of Chiloe Island, Latitude 42° S. Below this the Anti-boreal region extends to the tip of South America. But when we compare the marine faunas of north Chile-Peru and Southern California-northern Lower California, there can be no doubt that the two regions are analogous.

After an absence from the tropical littoral the genus *Cancer* is again strongly represented, with four species present. Of these two, *C. edwardsi* and *C. plebejus*, are long-range species, extending southward to Trinidad Channel and Port Otway, respectively, while two, *C. porteri* and *C. polyodon*, are short-range species extending only to Valparaiso and Chiloe Island, respectively. As in the Northern Hemisphere, the short-range species define the warm-temperate region.

The genus *Pugettia* is not represented in the Southeastern Pacific, but the giant kelp crabs, genus *Taliepus*, are represented by two species instead of one. *T. dentatus*, the long-range species, ranges from Callao, Peru, to Port Otway, Magallanes Territory, and perhaps to the tip of South America, while *T. marginatus*, the short-range species, occurs from Independencia Bay, Peru, to Talcahuano and Guayacan, Chile. *T. marginatus* is therefore the analogue of *T. nuttallii*, the single, short-range species of North America.

Among the pebble crabs, *Cycloxanthops sexdecimdentatus*, ranging from Paita to Chinchas Islands, Peru, is the analogue of the northern *C. novemdentatus*. The genera *Lophopanopeus*, *Paraxanthias*, and *Pilumnus* are absent.

Among the grapsoid crabs the genus *Cyclograpsus* occurs with two species, *C. crenatus*, San Lorenzo Island, Peru, to Lota, Chile, and *C. punctatus*, even more restricted on the mainland but occurring also at Juan Fernandez Island. The single northern species is *C. escondidensis* of the Gulf of California.

There is no short-range *Portunus* on the South American west coast corresponding to *P. xantusii* of California-Lower California, and no oxystome corresponding to *Randallia ornata*. There is, however, a short-range spider crab, *Libinia rostrata* of Peru, that is the counterpart of the short-ranged *L. setosa* of the west coast of Lower California.

Enough examples have been given to demonstrate that similar faunas occur in Southern California-northern Lower California and in northern Chile-Peru, and that if the latter is warm-temperate and is set off from the Anti-boreal, the former should be called warm-temperate and be set off from the boreal as well. The bipolarity of twin species, according to Ekman, is of particular importance because it indicates common origin of comparatively recent date. Hubbs (1952) points out that most so-called bipolar species are in fact biboreal or bitemperate, and argues ably that it was during one or more Pleistocene periods of global cooling that their transgression of the tropics occurred.

A comparison of the fauna of Southern California-northern Lower California with that of the Iberian Peninsula, which occupies a corresponding position in the eastern North Atlantic, must await the study of a collection of crabs sent from Cadaquez, Spain, on the Bay of Biscay, by Dr. Zariquiey Alvarez. Suffice it to say here that, according to Nobre (1936), two species of *Cancer*, *C. pagurus* and *C. bellianus*, occur in Portugal, the latter in Madeira, the Azores, and Cape Verde Islands as well. The balance of the paper will develop the affinities of the region under discussion with the northern part of the Gulf of California.

The Gulf of California has its mouth well within the tropics, but its head in the north-temperate zone. Long considered as supporting an exclusively Panamic fauna (Cf. Steinbeck and Ricketts, 1941, pp. 306, 476), it has been shown recently by Hubbs (1948, p. 463) to have California coastal types of fishes in its upper portion. The same may be said for its crab fauna, as has been suggested above. Southern California-northern Lower California species occurring in the northern Gulf are *Hepatus lineatus*, *Podochela barbarensis*, *Pilumnoides rotundus*, *Pachygrapsus crassipes*, and *Uca crenulata*. This relationship has been greatly strengthened by as yet unpublished studies of the Scammon

Lagoon-Viscaino Bay region, which show at least four additional Gulf of California species occurring in this sheltered situation, but not elsewhere on the open west coast. Species pairs found on outer and inner peninsular coasts are *Libinia setosa-L. mexicana*, *Herbstia parvifrons-H. camptacantha*, *Randallia ornata-R. angelica*, and *Speocarcinus granulimanus-S. ferrugineus*. The latter two differ from each other but slightly; their taxonomic status as full species is therefore in doubt.

If the intertidal regions of the Gulf of California from Agua Verde Bay on the west coast to Puerto San Carlos on the east can be added to the warm-temperate Lower California west coast from Pta. Entrada northward, we have in effect a Pacific Mediterranean region, of which the present communication with the ocean, unlike the Strait of Gibraltar, now lies within the tropics. That the present situation did not obtain in the very recent past is indicated by the geological history of the region. According to Beal (1948, p. 119), a rise of sea level of about 1600 feet occurred during the Pleistocene, reducing the peninsula to about two thirds its present length and isolating the Cape district south of La Paz. Communication was then possible across Magdalena plain, opposite the southern limit of our warm-temperate region. The difference between the two crab faunas is no greater than might be expected from Pleistocene isolation. It is certainly less than that between the Bay of Panama and the Caribbean, where the last confluence has been dated as late mid-Pliocene. (Note: Beal's estimate should be revised downward in the light of present knowledge concerning Pleistocene fluctuations in sea level. A rise of several hundred feet is sufficient for the purpose of this discussion, however.)

All available evidence points to the conclusion that surface water temperatures have been warmer in this area in the recent past, rather than colder. A fossil find by Kanakoff (1948) in Newport Bay places *Callinectes bellicosus* and *Uca monilifera* in the Southern California upper Pleistocene fauna. The former now comes no farther north than Scammon Lagoon, the latter is restricted to the Gulf of California. No later than the middle of the last century warm water conditions prevailed off central California, as shown by the Pacific Railroad Survey in connection with fishes (Hubbs, 1948, p. 464). In 1859 *Pleuroncodes planipes*, a galatheid shrimp, occurred abundantly in Monterey Bay (Schmitt, 1921, p. 163); it now rarely comes north to San Diego and Santa Catalina Island.

The following figures are given by Ekman (1953, p. 143) for surface temperatures in the northeastern Pacific as compared with the northeastern Atlantic:

	Feb.	Aug.
Lower California, ocean coast, 30° N	16° C	15° C
Lower California, ocean coast, 28° N	17-18	19
Lower California, Cape San Lucas, 23° N	21	27

	Feb.	Aug.
English Channel, SW mouth, 48-50° N	9° C	17° C
Cape Blanco, W Africa, 21° N	18-19	20
Cape Verde, W Africa, 15° N	19-20	25

The following figures are given by Ekman (1953, p. 209, after Schott, 1935) for surface temperatures along Pacific South America:

	Feb.	Aug.
Chiloe, 43° S	16° C	9.5° C
Iquique, 20° 20′ S	19	15.5
Callao (Lima), 12° S	19	16

It will be observed that Chiloe, with temperatures of 16 and 9.5° C, compares with the English Channel, with temperatures of 9 and 17° C, taking into account the reversal of seasons. But, as the dividing point between the cold-temperate and warm-temperate regions, Chiloe Island corresponds faunistically, not to Pta. Eugenia at Latitude 28° N, but to Pt. Conception at Latitude 34° 30′ N, which has an August mean temperature of 16.5° C according to Ekman (1953, fig. 45, after McEwen, 1912). (A comparable August figure for Pt. Conception of 16° C and a February figure of 13.5° C, based on averages of bucket temperatures to 1946, were obtained from the Scripps Institution of Oceanography.) Thus the mouth of the English Channel corresponds more closely to Pt. Conception than to Pta. Eugenia, if both winter and summer, and not just summer temperatures be taken into account.

Finally, the reasons why neither Chiloe Island nor Pt. Conception is a total barrier to cold-water species might be considered. The prevailing currents, the Peru in the south, the California in the north, are cold water currents. Directed from the poles toward the Equator, they tend to constrict the warm tropical water to a band of narrow width, from 23° N to 6° S Latitude. It is evident that they must similarly compress and force equator-ward the warm-temperate waters on either side of the tropical-water belt. Furthermore, they are constantly replenishing warm-temperate waters with larval forms of cold-water decapod crustaceans. That these boreal and Anti-boreal littoral species, the long-range species, are able to persist in a warm-temperate situation is due not so much to their eurythermy as to the upwelling of cooler sub-surface water that occurs most pronouncedly at certain localities in these mid-latitudes. It has been increasingly apparent of late that the range of the cold-water littoral forms in the lower latitudes is not continuous, but discontinuous, and that their last strongholds are the rocky promontories and headlands, the very sites at which upwelling occurs.

In conclusion, it has been shown that there is a warm-temperate marine fauna on the west coast of North America extending from Pt. Conception to Pta. Entrada and including the northern part of the Gulf of California. This has been done by considering the distribution of the brachyuran Crustacea as a representative group with respect to (a) the number of endemic species and species-pairs occurring in this region, and (b) the number of analogous species occurring in the corresponding Southern Hemisphere region of northern Chile and Peru. That the warm-temperate region has not always been as closely delimited as at present has been demonstrated by (a) the inter-glacial and post-glacial history of the Lower California-Gulf of California region and (b) cyclical temperature fluctuations taking place off central California during the past century. Reasons for the reduced size of the warm-temperate region as compared to that of other continental shores, and for the persistence in it of long-range boreal species are (a) the direction and character of prevailing ocean currents and (b) the upwelling of cold water near shore. The narrowness of the continental shelf is also a factor in restricting the area that can be occupied by warm-temperate benthic forms.

LITERATURE CITED

BEAL, C.
1948. Reconnaissance of the Geology and Oil Possibilities of Baja California. Geol. Soc. Amer. Mem. 31:1-138, pls. 1-10, 2 maps.

EKMAN, S.
1953. Zoogeography of the Sea. xiv, 417 pp., text-figs. 1-121. Sidgwick and Jackson Ltd., London.

FISHER, W. K.
1911, 1928, 1930. Asteroidea of the North Pacific and Adjacent Waters. U. S. Natl. Mus. Bull. 76, part 1, vi, 419 pp., pls. 1-122; part 2, iii, 245 pp., pls. 1-81; part 3, iii, 356 pp., pls. 1-93.

HUBBS, C. L.
1948. Changes in the Fish Fauna of Western North America correlated with Changes in Ocean Temperature. Jour. Mar. Res. 7:459-482, text-figs. 1-6.

1952. Antitropical Distribution of Fishes and other Organisms. Proc. 7th Pacific Sci. Cong., Auckland, New Zealand, Feb.-Mar., 1949, vol. 3, Meteorology and Oceanography: 324-329.

JORDAN, D. S., B. W. EVERMANN, and H. W. CLARK
1930. Check List of the Fishes and Fishlike Vertebrates of North and Middle America north of the Northern Boundary of Venezuela and Colombia. U. S. Rpt. Comm. Fisheries for 1928, part 2, 670 pp. Washington.

KANAKOFF, G.
1948. An Upper Pleistocene Invertebrate Fauna from the Newport Bay Mesa, Orange Co., Calif. Paper read before a joint meeting of the Paleontological and Geological Societies of America at Pasadena, California, on April 10, 1948. (Unpublished.)

MCEWEN, G. F.
1912. The Distribution of Ocean Temperatures along the West Coast of North America deduced from Ekman's Theory of the Upwelling of cold Water from the adjacent Ocean Depths. Internatl. Rev. Gesam. Hydrobiol. und Hydrog. 5:243-286, text-figs. 1-4.

MENZIES, R. J.
1948. A Revision of the Brachyuran Genus *Lophopanopeus*. Allan Hancock Pubs., Occas. Paper. 4:1-45, pls. 1-6, 3 graphs.

NOBRE, A.
1936. Fauna Marinha de Portugal. IV. Crustáceos Decápodes e Stomatópodes marinhos de Portugal. Ed. 2. viii, 213 pp., pls. 1-61. Pôrto.

SCHENCK, H. G. and A. MYRA KEEN
1936. Marine Molluscan Provinces of Western North America. Proc. Amer. Philos. Soc. 76:921-938, text-figs. 1-6.

SCHMITT, W. L.
1921. The Marine Decapod Crustacea of California. Univ. Calif. Pubs. Zool. 23:1-470, pls. 1-50, text-figs. 1-165.

SCHOTT, G.
1935. Geographie des Indischen und Stillen Ozeans. xix, 413 pp. C. Boysen, Hamburg.

STEINBECK, J. and E. F. RICKETTS
1941. Sea of Cortez. A Leisurely Journal of Travel and Research. 598 pp., pls. 1-40, 2 charts. Viking Press, N. Y.

THE CIRCUMPOLAR DISTRIBUTION OF ARCTIC-ALASKAN BRYOZOA

By

RAYMOND C. OSBURN, PH.D., D.SC.

The similarity of the bryozoan fauna of the Greenland area with that of northern Europe has suggested to several students of this group that many of the arctic species may be circumpolar in distribution. However, until recently we have had only very incomplete data except for the region extending from Greenland to Nova Zembla and the Kara Sea, or approximately from 75° West Longitude to 75° E. L., considerably less than one half the way around the borders of the Arctic Ocean. The much greater extent, 210°, from the Greenland region westward to the Kara Sea, was almost unknown as far as the Bryozoa are concerned, with just a few references to some of the species, and the arctic area north of the Pacific Ocean was practically untouched. This lack of information led Nordgaard[1] (1918) to state: "I am of opinion that the arctic fauna is not a homogeneous one around the pole. We may divide in two principal groups, viz.: 1. The arctic fauna of the Atlantic region. 2. The arctic fauna of the Pacific region." Nordgaard's error is due to the fact that he had no data on the true arctic fauna of the Pacific region, but accepted the "Alaska" records from Hincks and Robertson which were from southern Alaska, south of the Aleutian peninsula and therefore in the Boreal Zone.

---

[1] Bryozoa from the Arctic Regions. Tromsø Museums Aarshefter 40, Nr. 1, p. 95.

Osburn[2] (1923) studied the Bryozoa collected by the Southern Party of the Canadian Arctic Expedition and gave records of 47 species which extended their range westward from Greenland. But only 18 of these were from as far west as Alaska and all of them were already known from the Atlantic-Arctic region. This fact led him to state his belief that "when our records of arctic Bryozoa are more complete for the entire area around the North Pole, we will find that practically all of the true arctic species are circumpolar in distribution."

Borg[3] (1933) attempted an analysis of the arctic and boreal species and listed 93 species which he considered to be purely arctic ("rein arktisch"), of which only 32 were supposed to be circumpolar. But Borg, like Nordgaard, was limited by lack of information on the Pacific-Arctic area.

Recently, through the courtesy of the Hancock Research Foundation of the University of Southern California, Osburn[4] has had the opportunity to study a collection of 113 bryozoan species made by Professor and Mrs. G. E. MacGinitie at the Arctic Research Laboratory, Point Barrow, the most northwestern part of arctic Alaska. Some of these same species have also been taken at Nunivak Island and the Pribilof Islands in the eastern part of the Bering Sea, but well north from the Aleutian peninsula.

The analysis of this interesting series shows that of the 113 species from Point Barrow all but 11 were already known from the more eastern area, Greenland to the Kara Sea, all occurring under strictly arctic conditions. This leads us definitely to two conclusions: 1, that there is no significant difference between the bryozoan faunas of the Pacific-Arctic and Atlantic-Arctic areas, and, 2, that there is a preponderance of circumpolar species in the Arctic Ocean, whether or not they are all "rein arktisch."

As we have no definite knowledge of the place where any of these species originated, it appears futile to discuss whether certain ones arose in the polar zone and extended their range southward, or if the reverse

---

[2] Rept. Canadian Arctic Exped. 1913-18. Vol. 8, part D; Bryozoa. Ottawa. 13 pp.

[3] Über die geographische Verbreitung der innerhalb des arkitschen Gebietes gefundenen marinen Bryozoen. Arch. für Naturgeschichte, n.f., Bd. 2, Heft 1, pp. 136-143.

[4] Bryozoa of the Pacific Coast of America. Allan Hancock Pacific Expeditions, Vol. 14, Pts. 1, 2, 3, 1950-52-53.

be true. The patent facts remain that many of the species have considerable temperature tolerance, that there is no sharp line of demarcation between the Bryozoa of the arctic and boreal zones, and that most of those found in the Arctic Ocean are circumpolar in distribution, regardless of how they arrived there.

The Bryozoa of the Atlantic-Arctic region—Greenland to the Kara Sea—are probably as well known as those of any other part of the world. The southward extension of the range of these has been traced along the coasts of Labrador, Newfoundland, the Gulf of St. Lawrence and southward to Cape Cod or farther. The Pacific-Arctic fauna is at last well enough known to enable us to make safe comparisons. The southern range of many of these species was determined by the earlier work of Hincks, the O'Donoghues, and Robertson from southern Alaska and British Columbia to along the coast of California. The very numerous collections made more recently by Captain Allan Hancock in the Velero III have further extended the southern range of numerous species in the cooler waters off the coasts of Oregon and California.

Bryozoa appear to thrive as well in the icy waters of the polar seas as they do elsewhere, and the number of species is about the same—compare the 192 species recorded from Greenland waters with the 203 listed from the West Indies and Gulf of Mexico. As for the 113 species recorded from Point Barrow, Alaska, it must be remembered that this collection was made in a very limited area and with simple dredging apparatus, and that more extensive collecting will undoubtedly increase the number considerably.

Species of local distribution appear to occur frequently throughout the Arctic Ocean, as they do elsewhere. Thus 11 of the species from Point Barrow have not yet been noted elsewhere and have been described as new. Similarly, a number of those formerly described from Greenland, Spitzbergen, Franz Josef Land, etc., are as yet known only from the type locality. No doubt some of these will be found to have a wider range when our knowledge of polar Bryozoa is more complete. It is worthy of note that two species originally described from Spitzbergen and not noted since, *Hippodiplosia cancellata* (Smitt) 1867 and *Euritina arctica* Osburn (*Discopora impressa* Smitt, 1871, *non* Reuss 1846), appeared in the Point Barrow collection, half way around the pole from the type locality.

The following table shows the distribution of the 113 species from the Pacific-Arctic at Point Barrow, their occurrence in the Greenland region and farther east, and also the southern range of the same species along the Atlantic and Pacific coasts. An "x" marks the occurrence of a species in the Point Barrow and Greenland areas, while other distribution is indicated by locality records. Of the 113 from Arctic Alaska, 58 are also found south of the Bering Sea on the Pacific coast, 17 of them as far as to California or even farther. On the Atlantic coast 68 of these same species from Point Barrow extend southward from Greenland, some only to Labrador, 35 to Cape Cod or farther.

GEOGRAPHICAL DISTRIBUTION OF PACIFIC-ARCTIC BRYOZOA

CYCLOSTOMATA	Alaska and south	Greenland and south	North of Europe
Proboscina incrassata (Smitt)	x	x	Kara Sea
Oncousoecia canadensis Osburn	x	x Maine	
" *diastoporides* (Norman)	x Southern Alaska	x Cape Cod	Barents Sea
Plagioecia grimaldi (Jullien)	x	x Newfoundland	
" *ambigua* Osburn	x		
Diplosolen obelium (Johnston)	x Southern California	x Cape Cod	Northern Norway
Diaperoecia intermedia (O'Donoghue)	x British Columbia		
" *harmeri* Osburn	x	x Cape Cod	
Tubulipora flabellaris (Fabricius)	x Southern California	x Cape Cod	Barents Sea
Bathysoecia bassleri Osburn	x		
" *hastingsae* Osburn	x	x Maine	
Crisia eburnea (Linnaeus)	x	x North Carolina	Northern Norway
" *cribraria* Stimpson	x	x Cape Cod	
Borgiola pustulosa Osburn	x		
Lichenopora canaliculata (Busk)	x		Antarctic
" *verrucaria* (Fabricius)	x Southern California	x Long Island Sound	Nova Zembla
Disporella hispida (Fleming)	x Lower California	x Gulf of Mexico	Barents Sea

	Alaska and south	Greenland and south	North of Europe
CTENOSTOMATA			
Alcyonidium polyoum (Hassall)	x California	x North Carolina	Spitzbergen
" *pendunculatum* Robertson	x Puget Sound		
" *disciforme* (Smitt)	x	x	Kara Sea
" *enteromorpha* Soule	x		
Flustrella corniculata (Smitt)	x California	x	Spitzbergen
" *gigantea* Silen	x		
Vesicularia fasciculata Soule	x		
Bowerbankia gracilis aggregata (O'Donoghue)	x Southern California		
CHEILOSTOMATA - ANASCA			
Eucratea loricata (Linnaeus)	x British Columbia	x Cape Cod	Kara Sea
Electra crustulenta arctica Borg	x California	x Cape Cod	Franz Josef Land
Carbasea carbasea (Solander)	x Southern Alaska	x Hudson Bay	Nova Zembla
Terminoflustra membranaceo-truncata (Smitt)	x British Columbia	x	Northern Norway
Membranipora serrulata (Busk)	x	x Newfoundland	Kara Sea
Hincksina nigrans (Hincks)	x Southern Alaska	x Gulf of St. Lawrence	Franz Josef Land
" *gothica* Osburn	x		
Cauloramphus cymbaeformis (Hincks)	x	x Cape Cod	Spitzbergen
Callopora aurita (Hincks)	x	x Cape Cod	White Sea

Callopora craticula (Alder)	x Southern Alaska	x Cape Cod	Kara Sea
" *lineata* (Linnaeus)	x Southern California	x Cape Cod	Nova Zembla
" *whiteavesi* Norman	x Southern Alaska	x Hudson Strait	Barents Sea
Bidenkapia spitsbergensis (Bidenkap)	x	x	Spitzbergen
" *s. alaskensis* Osburn	x		
Tegella arctica (d'Orbigny)	x Southern Alaska	x Cape Cod	Kara Sea
" *armifera* (Hincks)	x Southern California	x Cape Cod	Northern Norway
" *magnipora* Osburn	x Southern Alaska		
" *unicornis* (Fleming)	x Southern California	x Cape Cod	Barents Sea
Amphiblestrum trifolium (S. Wood)	x	x Maine	Nova Zembla
Doryporella spathulifera (Smitt)	x Southern Alaska	x	Franz Josef Land
Microporina borealis (Busk)	x British Columbia	x	Spitzbergen
Euritina arctica Osburn	x		Spitzbergen
Tricellaria erecta (Robertson)	x Southern Alaska		
" *gracilis* (Smitt)	x Southern Alaska	x Maine	White Sea
" *pribilofi* (Robertson)	x Puget Sound		
" *ternata* (Solander)	x Southern California	x Cape Cod	Northern Norway
Scrupocellaria scabra paenulata (Norman)	x Southern Alaska	x Hudson Strait	Spitzbergen
Bugula pacifica (Robertson)	x Southern California		

	Alaska and south	Greenland and south	North of Europe
Dendrobeania murrayana (Johnston)	x Puget Sound	x Cape Cod	Kara Sea
" *multiseriata* (O'Donoghue)	x		
Membraniporella crassicosta (Hincks)	x	x Gulf of St. Lawrence	
Cribrilina annulata (Fabricius)	x Southern Alaska	x Cape Cod	Kara Sea
Reginella spitsbergensis (Norman)	x	x Hudson Strait	Franz Josef Land
CHEILOSTOMATA - ASCOPHORA			
Hippothoa hyalina (Linnaeus)	x Peru	x Gulf of Mexico	Spitzbergen
" *expansa* Dawson	x Southern California	x Maine	Franz Josef Land
Harmeria scutulata (Busk)	x	x Hudson Strait	Spitzbergen
Hincksipora spinulifera (Hincks)	x	x Gulf of St. Lawrence	Spitzbergen
Umbonula arctica (Sars)	x Puget Sound	x Cape Cod	Spitzbergen
" *patens* (Smitt)	x	x	Spitzbergen
Cylindroporella tubulosa (Norman)	x British Columbia	x Cape Cod	
Stomachetosella cruenta (Norman)	x Puget Sound	x	Nova Zembla
" *distincta* Osburn	x		
" *sinuosa* (Busk)	x Puget Sound	x Cape Cod	Barents Sea
Posterula sarsi (Smitt)	x Southern Alaska	x Maine	Kara Sea
Ragionula rosacea (Busk)	x	x Labrador	Kara Sea
Pachyegis brunnea (Hincks)	x British Columbia		

Pachyegis princeps (Norman)	x	x Gulf of St. Lawrence	Spitzbergen
Emballotheca stylifera (Levinsen)	x	x	Kara Sea
Schizomavella porifera (Smitt)	x	x Cape Cod	Spitzbergen
Hippodiplosia cancellata (Smitt)	x		Spitzbergen
" *pertusa* (Esper)	x British Columbia	x Cape Cod	Kara Sea
" *reticulato-punctata* (Hincks)	x British Columbia	x Maine	Kara Sea
Hippoporella hippopus (Smitt)	x	x Maine	Barents Sea
Stephanosella biaperta (Michelin)	x British Columbia	x Cape Cod	Spitzbergen
Escharoides jacksoni (Waters)	x	x Hudson Strait	Nova Zembla
Microporella arctica (Norman)	x	x Hudson Strait	Nova Zembla
Porella compressa (Sowerby)	x	x Hudson Bay	Nova Zembla
" *acutirostris* Smitt	x Southern California	x Cape Cod	Franz Josef Land
" *concinna* (Busk)	x British Columbia	x Cape Cod	Franz Josef Land
" *minuta* (Norman)	x	x	Northern Norway
" *umbonata* Nordgaard	x	x	
Smittina altirostris Osburn	x		
" *arctica* (Norman)	x	x	Kara Sea
" *bella* (Busk)	x	x Maine	Northern Norway
" *minuscula* (Smitt)	x	x Hudson Strait	Spitzbergen
Parasmittina alaskensis Osburn	x		
" *jeffreysi* (Norman)	x	x	Kara Sea
" *trispinosa* (Johnston)	x Puget Sound	x North Carolina	Northern Norway

	Alaska and south	Greenland and south	North of Europe
Rhamphostomella bilaminata (Hincks)	x Southern Alaska	x Cape Cod	Barents Sea
" *costata* Lorenz	x Puget Sound	x Cape Cod	Barents Sea
" *fortissima* Bidenkap	x		Spitzbergen
" *gigantea* Osburn	x		
" *hincksi* Nordgaard	x Southern Alaska	x	
" *ovata* (Smitt)	x Southern Alaska	x Cape Cod	Barents Sea
" *spinigera* Lorenz	x Southern Alaska	x Hudson Strait	Jan Mayen
Cystisella saccata (Busk)	x	x Newfoundland	Nova Zembla
" *bicornis* Osburn	x Southern Alaska		
Mucronella connectens (Ridley)	x	x Hudson Strait	Spitzbergen
" *labiata* Levinsen	x	x	Kara Sea
" *microstoma* (Norman)	x British Columbia	x	Northern Norway
" *ventricosa* (Hassall)	x Oregon	x Cape Cod	Kara Sea
Hemicyclopora polita (Norman)	x	x	Spitzbergen
Lepraliella contigua (Smitt)	x	x Nova Scotia	Spitzbergen
Costazia nordenskjoldi (Kluge)	x		Northern Europe
" *surcularis* (Packard)	x British Columbia	x Nova Scotia	Nova Zembla
" *ventricosa* (Lorenz)	x	x	Franz Josef Land
Myriozoum subgracile d'Orbigny	x Southern Alaska	x Hudson Bay	Kara Sea
Myriozoella plana (Dawson)	x Southern Alaska	x Gulf of St. Lawrence	Nova Zembla

ENDEMISM IN THE NORTH PACIFIC OCEAN, WITH EMPHASIS ON THE DISTRIBUTION OF MARINE ANNELIDS, AND DESCRIPTIONS OF NEW OR LITTLE KNOWN SPECIES

By

OLGA HARTMAN

Allan Hancock Foundation

Recent studies in the soft ocean bottoms of the San Pedro Basin, California, in depths of 4 to 495 fathoms, have disclosed the presence of an unknown, greatly diversified metazoan invertebrate fauna. Its geographic extent to north or south of the region studied is not yet known, but the horizontal limits of its components have been established within the area studied (Hartman, 1955).

Through extensive studies over many years, it has been established for European seas that the animals living within the bottom, or the Infauna, are very nearly the same in all areas, from Arctic to tropical seas (Thorson, 1951, pp. 481-489). Distinct communities of greater or lesser extent have been named, and the presence of dominants and recessives has been noted so that the composition of a given area is predictable within limits.

Current studies on the Infauna of ocean bottoms of southern Californian waters have shown that the bottom-dwelling animals differ from those of other parts of the world not only in the presence of many species or genera not known elsewhere, but also in the absence of some known to occur in European and other seas. This conclusion is based mainly on a study of the marine annelids, which have been remarkably abundant and diversified in many samples, and to a lesser extent on some other groups of invertebrates, especially amphipods and mollusks, which have been examined by authorities on these groups. Analyses are being made of more than 300 measured samples taken by the *Velero IV,* research vessel of the University of Southern California. More than 283 species of polychaetous annelids have been identified. They have shown that there is a high degree of endemism, not only on specific, but also on generic levels.

The *U.S.S. Albatross*, operating jointly under the direction of the U. S. Bureau of Fisheries, the University of California, and Stanford University, had earlier, from March to June 15, 1904, established 276 stations, mainly in localities near the Channel Islands of southern California and in Monterey Bay, in depths to 1400 fathoms. The marine annelids were largely studied by Moore (1909 to 1923), who named and described 182 species; of these less than two per cent were cosmopolitan or widely distributed or known from geographic areas extending beyond the northern Pacific Ocean. Most of them have remained nearly or quite unknown except through their original accounts.

Analyses of the samples which come from the current studies in basins of southern California have revealed the presence of many species named by Moore. Other species are also being identified. Analyses of these samples have consistently shown that polychaetous annelids are the most abundant animals in quantity and diversity in the areas investigated.

The purpose of this report is to describe a small part of this fauna and to show that some species of cosmopolitan character, which are also present, differ from typical representatives in more distant parts of the world, in morphological characters which may have more than varietal or trivial importance.

Three benthonic species and one subspecies are described: *Cossura candida*, new species in the CIRRATULIDAE; *Myriochele gracilis*, new species, and *Owenia fusiformis collaris*, new subspecies, in the OWENIIDAE; and *Artacamella hancocki*, new genus and species in the TEREBELLIDAE. Records of extended distribution are given for *Artacama coniferi* Moore. *Protis pacifica* Moore, a little known deep water serpulid, is reported commensalistic with an undescribed species of *Cyclopecten* Verrill (Pelecypoda). *Poeobius meseres* Heath, a pelagic annelid, is discussed, especially for its affinities with the FLABELLIGERIDAE.

The studies are based on collections made by the research vessel, *Velero IV*, of the University of Southern California. A collection of *Poeobius meseres* comes from Dr. Martin W. Johnson, of the Scripps Institution of Oceanography. I am indebted to Mr. Gilbert Grau for the generic name of the deep water pecten. Special acknowledgement is due Captain Allan Hancock, who provided both the *Velero IV* and the research facilities of the Allan Hancock Foundation. It is a pleasure to dedicate these studies to Captain Hancock, Founder and first Director of the Foundation.

The endemic nature of polychaetes in the northern and eastern Pacific areas is clearly established through the presence of many species and genera largely or entirely limited to the Pacific. Many such genera are small, monotypic or known for few species. Some are littoral, others abyssal, and only a very few are pelagic. In the POLYNOIDAE, the commensal genus *Arctonoë* Chamberlin is known for three species, all from the northern Pacific; *Halosydna* Kinberg is represented by twelve of the fifteen known species; *Hololepida* Moore by two of the three known species; the commensal *Hesperonoë* Chamberlin is known for only two species, both from the northeastern Pacific.

In the POLYODONTIDAE, *Peisidice* Johnson is known for a single species from the northern Pacific. In the SIGALIONIDAE, *Sthenelanella* Moore is limited to California. In the HESIONIDAE, the commensal *Hesionella* Hartman, 1939[1] is represented by a single species from California. In the PILARGIIDAE, *Loandalia* Monro is represented by two of the three known species. The PISIONIDAE are known for three genera; two, *Pisione* Grube and *Pisionella* Hartman, are known only from the eastern Pacific, the first with two, the second with a single species.

In the NEREIDAE, *Cheilonereis* Benham is known for only two species, of which one is northeastern Pacific, the other Australian. In the GLYCERIDAE, *Hemipodus* Quatrefages is entirely Pacific, with four of the six known species coming from the eastern Pacific. In the ARABELLIDAE, the parasitic *Labidognathus* Caullery is known for only two species, of which one comes from California; *Notocirrus* Schmarda is known for four species, of which two come from the Pacific. In the SPIONIDAE, *Boccardia* Carazzi is represented in the Pacific by six of

---

[1] *Hesionella* Wesenberg-Lund, 1950, p. 14, erected for *H. problematica*, off southwest Iceland in 555 meters, is a different genus. It is here renamed *Wesenbergia*, new genus; its only species is *Wesenbergia problematica* (Wesenberg-Lund). The genus differs from *Hesione* Savigny in having two pairs instead of a single pair, of antennae.

eight known species. The MAGELONIDAE, with a single genus *Magelona* F. Müller, has at least six of eleven known species limited to the northeastern Pacific. The family LONGOSOMIDAE is known for a single genus and species from southern California. In the CHAETOPTERIDAE, *Mesochaetopterus* Potts is entirely Pacific, with four of the six known species coming from the eastern Pacific.

In the OPHELIIDAE, *Thoracophelia* Ehlers is known for two species of which one is from California, the other from southern South America; *Euzonus* Grube, as emended by Annenkova,[2] includes three species, of which one is Russian Arctic, two are Californian. In the CAPITELLIDAE, *Anotomastus* Hartman, *Capitita* Hartman, *Leiocapitella* Hartman and *Mediomastus* Hartman are represented by single species from the northeastern Pacific. In the SABELLARIIDAE, *Phragmatopoma* Mörch is known for only six species, of which five are eastern Pacific, one West Indian; *Idanthyrsus* Kinberg is represented by three of five known species.

In the AMPHARETIDAE, *Moyanus* Chamberlin, *Paiwa* Chamberlin and *Sosanopsis* Hessle are represented each by a single species from the eastern Pacific; *Schistocomus* Chamberlin is represented by three species,[3] of which two are from the northern Pacific, the third from India. In the TEREBELLIDAE, *Neoleprea* Hessle is known for four species, all Pacific; *Ramex* Hartman is known for a single species from California; *Scionides* Chamberlin is known for two species, one from California, the other from the West Indies; *Scionella* Moore and *Spinosphaera* Hessle are known each for only two species, both from the northern Pacific.

In the SABELLIDAE, *Eudistylia* Bush is known for only three species, *Schizobranchia* Bush for two, *Megachone* Johnson for one, all from the northern Pacific; *Pseudopotamilla* Bush is represented by four of the six known species. In the POEOBIIDAE, the single pelagic genus and species, *Poeobius meseres* Heath, is not known outside the northern Pacific Ocean.

---

[2] *Pectinophelia* Hartman, 1938, characterized by having pectinately or dendritically divided branchiae and known for two species, *P. dillonensis* and *P. williamsi*, both by Hartman, from California, is believed to be congeneric with *Euzonus* Grube, as emended by Annenkova, 1935, p. 236.

[3] *Schistocomus hiltoni*, Fauvel, 1932, pp. 219-220, pl. 8, figs 15-19, from Madras, India, in 5-10 fms, is here named *S. fauveli*, new name. It differs from *S. hiltoni* Chamberlin in that the first setigerous segment has a pair of subulate and a pair of pinnately divided branchiae; the second and third setigerous segments have each a pair of pinnate branchiae. In *S. hiltoni* the first branchial segment is asetigerous and its branchiae are unipinnate; the first setigerous segment has a pair of subulate branchiae; the next two segments have each a pair of bipinnately divided branchiae.

The list of endemic species is far more considerable and comprises, for California alone, more than 500 species. Fewer than two per cent of the total number are cosmopolitan.

Descriptions of some new and little known species follow.

CIRRATULIDAE

Members of this family have been conspicuously abundant in samples from the San Pedro Basin, California. Especially abundant in depths to 300 fathoms are representatives of seven genera: *Tharyx* Webster and Benedict, *Chaetozone* Malmgren, *Caulleriella* Chamberlin, *Acrocirrus* Grube, *Cirratulus* Savigny, *Cirriformia* Hartman, and *Cossura* Webster and Benedict. Species of three to five genera may occur together in an area covering not more than three square feet of surface. This is especially so for species of *Tharyx*, *Chaetozone*, *Caulleriella*, *Cossura*, and *Cirratulus*. Most often present, but seldom in great numbers, is a species of *Cossura*, described below.

Cossura Webster and Benedict, 1887

Type *C. longocirrata* Webster and Benedict

The body is long, cylindrical, and tapers to both extremities; it consists of many segments. It resembles smaller cirratulids, except that there are no paired lateral filaments or branchiae. A single long tentacle is inserted middorsally on one of the anterior segments. Parapodia are biramous; each is a short, papillar mound or ridge from which the simple, distally pointed setae project in fan-shaped series. Setae are essentially of one kind and emerge in alternating double rows. The prostomium is a simple rounded or subconical lobe, either with or without a pair of simple eyespots at the sides. The first one or two visible segments are apodous.

Cossura is unlike typical cirratulids and may have more direct affinities with members of the subfamily CTENODRILINAE Monticelli, especially with the genera *Raphidrilus* Monticelli and *Zeppelinia* Vaillant (see Fauvel, 1927, pp. 109-110) which also have a single median antenna and simple pointed setae.

A single species, *C. longocirrata* Webster and Benedict, has been attributed to the genus. It was first described from Eastport, Maine, in mud and sandy mud in 6-12 fathoms and was further reported and redescribed from western Europe (Eliason, 1920, p. 58, fig. 17; Thulin, 1921, pp. 3-9, figs. 1-6, and Wesenberg-Lund, 1950, p. 34, pl. 8, fig. 36) but with some differences. The original species was said to have two buccal segments lacking parapodia, the long median tentacle inserted on the second setigerous (or fourth visible) segment, and the prostomium without eyes. Specimens from western Europe are said to have a single buccal segment; the long median tentacle is inserted on the second setigerous (third visible) segment, and the prostomium has a pair of eyespots. Whether these differences are specific or the result of fixation cannot be ascertained without examination of collections from Maine to determine if they agree with the original account.

Another species of the genus has been found abundant in the soft bottoms of San Pedro Basin, California. This differs from the Atlantic specimens in having two buccal segments, the median tentacle on the third setigerous (fifth visible) segment, and the prostomium without eyespots.

Cossura candida, new species

Plate 1, figs. 1-5

Cossura, nr. *longicirrata* [sic] Hartman, 1954, p. 11

Cossura n.sp. Hartman, 1955, p. 172

Collections: Many specimens have been reported earlier in the quantitative samples from San Pedro Basin, California, in 6 to 440 fms. The greatest number of individuals in a single sample (more than 250) came from Los Angeles Outer Harbor, in 7 fms.

Length of larger or adult individuals is 7-8 to 10 mm; width is 0.5 to 0.7 mm in the anterior region; segments number 50 to 75. The prostomium is a depressed conical lobe, a little longer than wide, and lacks eyespots. The first two visible segments are apodous (fig. 1). Parapodia are biramous from the first segment and lateral in position; the two rami are so near together that the setae of a side seem to form a single continuous series (fig. 3). The median tentacle is long and cylindrical and is inserted on the middorsum of the third setigerous segment (fig. 1).

Setae are best developed in the anterior third of the body behind the insertion of the tentacle. Notopodia have up to 6 to 8 pairs of setae in bi-serial arrangement, with a row of shorter ones in front alternating with a row of longer ones behind. Neuropodia have about 6 to 8 pairs of shorter setae. All are stiff, distally pointed, and very spinous along the outer edge (fig. 4). Seen from the cutting edge, the spinelets are in dispersed arrangement (fig. 5).

The proboscis, everted in some individuals, is a soft, lobed pouch extending from a short cylindrical base and terminating distally in about 12 digitate, subequal lobes; it resembles that of some orbiniids. The body ends in a few, poorly marked segments and an anal ring provided with three long filaments, one pair lateral and the other midventral (fig. 2).

Distribution: This is widely dispersed in soft bottoms of San Pedro Basin, California, in 6 to 440 fms, with the greatest concentrations in Outer Los Angeles Harbor. Other collections come from San Francisco Bay, California (reported as *Cossura*, nr. *longicirrata* [sic] Hartman, 1954, p. 11) and from low intertidal areas along the western shores of Lower California, Mexico.

OWENIIDAE

Owenia delle Chiaje, 1841

It is generally agreed that *Owenia fusiformis* delle Chiaje has a geographic range that extends from Arctic Ocean (as *Ammochares assimilis* Sars, 1851) through tropical (as *Ammochares brasiliensis* Hansen, 1882, from Brazil) into south temperate seas (as *Ammochares tegula* Kinberg, 1867, from Argentina, and *A. tenuis* Haswell, 1883, from Port Jackson, Australia) and from the Philippine Islands(as *Ammochares orientalis* Grube, 1878). It is further known from the western side of the northern Atlantic Ocean (as *Ammochares artifex* Verrill, 1885, from New England, and as *A. aedificator* Andrews, 1891, from North Carolina) and from the northern Pacific Ocean (as *Ammochares occidentalis* Johnson, 1901, from Washington). As *O. fusiformis* it is recorded from Japan (Okuda, 1937). Its known bathymetric range extends from shallow littoral (Watson, 1901, p. 237) to abyssal, in 2975 fms (McIntosh, 1885, p. 410).

Watson (1901, pp. 230-260) and Caullery (1944, pp. 49-52) have given essential details of morphology and anatomy and there are long published accounts on synonymies.

Many individuals of *Owenia* have been taken in San Pedro Basin, California. As they consistently differ from *O. fusiformis* in characters which are believed to be more than varietal, they are here described as a new subspecies.

Owenia fusiformis collaris, new subspecies

Plate 2, figs. 6, 7

Owenia sp., Hartman, 1955, p. 179

Collections: Many specimens come from San Pedro Basin, California, in 5 to 48 fms (see Hartman, 1955, p. 179).

The tube is fusiform, with the distal ends attenuated; externally it is closely covered with sand and shell particles. The largest measure about 90 mm long and 8 mm wide near the center. The animal preserved in the tube is about 54 mm long and 3.12 mm across. The branchial crown in larger individuals is greatly branched so that there are well over a hundred tips; the branching is close and the entire crown very short for its great width.

A conspicuous, thin, membranous, entire thoracic collar that is uniformly high all around, except for a pair of ventrolateral notches, conceals as much as half of the branchial base, as well as the dark brown pigment band that separates the crown from the thorax. A similar dark pigment is present on the crown as a band partly encircling the subterminal filaments, best seen on the inner side of the crown. A pair of darkly pigmented, crescentic areas resembling eyes is present on the ventral base of the crown on its outer side. A large dark brown, shield-shaped area is present on the dorsal side of the thorax between the setigerous fascicles of the first three segments; it extends nearly across the dorsum and is limited to this region.

The third setigerous segment has setal fascicles which are smaller and shorter than those of the first two and fourth fascicles; they lie about midway between the second and fourth fascicles and are smaller than the others. Uncinal ridges resemble those of the stem species. The uncini differ in having two very long, straight teeth (fig. 6) set in a nearly straight line (fig 7); there is no shoulder at the subdistal end of the shaft, such as occurs in the stem species.

O. fusiformis collaris differs from the stem species in having a high, thoracic, membranous collar; the uncini have much longer teeth and lack a shoulder. The subspecific name refers to the thoracic collar.

Distribution: This subspecies occurs in shallower depths of San Pedro Basin, California, associated especially with sandy muds.

Myriochele Malmgren, 1867

Myriochele gracilis, new species

Plate 2, figs. 1-5

Myriochele n.sp., Hartman, 1955, p. 177

Collections: Many individuals come from San Pedro Basin, California, in 26 to 440 fms (Hartman, 1955, p. 177).

Tubes are uniformly small, measuring 15 to 20 mm long and 0.65 mm across at the greatest width. They taper distally to both ends, and are externally neatly covered with a single layer of bits of siliceous sponge spicules of uniform size (fig. 2). The animal within is about two-thirds as long as the tube; it adheres closely to the inner mucoid lining, and can be removed only by tearing the tube to bits. It encompasses 18 setigerous segments; externally it is smooth and unadorned except for the setae, which project in stiff series (fig. 1).

The prostomium is subspherical (fig 1) and has an anteroventral oral region; it extends back as a narrow neck region about as long as the first setigerous segment. The first three segments are not unusually long or short, but resemble those farther back. Uncini are first present from the fourth setigerous segment arranged in short, transverse ridges, closely appressed to the body wall, and present in the parapodia to the anal end.

As is typical of the genus, the uncini are very small and numerous and all are essentially similar, except for the development of the distalmost tooth. Each is long-shafted and terminates distally in a beaked hook; there is a conspicuous shoulder (fig. 3). A smaller tooth (figs. 3-4) may be present in varying stages of development, or it may be absent. The pygidium is terminal and the anal end lacks ornamentation (fig. 1).

In some of the collections from San Pedro Basin, one finds an occasional anterior end, freed from a tube, which agrees with those dissected out from the tubes in all essential details except for the larger size and a pair of very long, tentacular processes emergent from the oral end (fig. 5). The prostomium is similarly subspherical, the neck region is prolonged to about the same degree, the first three setigerous segments have like proportions, and the uncini are the same. The paired tentacular processes are continuous with the dorsolateral part of the prostomium; they are longitudinally grooved on the ventral side, and conspicuously splashed with dark brown pigment on their upper side. A pair of basal enlargements is weakly separable from the base of the tentacles. From their position and insertion on the dorsolateral side of the prostomium, they appear to be branchial rather than palpal.

An effort has been made to dissect similar processes from individuals preserved in the tube and partial success has been attained in that there seem to be tentacular structures which are much folded in the buccal region. The small size of mature individuals and the slender proportions of the body make dissection difficult.

M. gracilis differs from the widely distributed *M. heeri* Malmgren, which is recorded from colder parts of the northeastern Pacific (Berkeley and Berkeley, 1952, p. 41) in that the prostomium is subcircular, not cylindrical and that the first three setigerous segments are proportionately longer and well separated from one another, not short and somewhat fused. The uncini differ in their proportions.

Distribution: M. gracilis comes from San Pedro Basin, California, in 26 to 440 fms with its greatest concentrations in 30 to 54 fms. It is associated with soft bottoms and many other species of annelids (Hartman, 1955).

TEREBELLIDAE

Subfamily ARTACAMINAE Chamberlin

This subfamily has been known for a single genus, *Artacama* Malmgren, in which five or six species have been named. It is unique in having a buccal segment that is modified on its ventral side to form a conspicuous, proboscis-like organ adorned with papillae, ridges, or other surface structures.

Artacama is characterized by having 17 thoracic segments provided with pointed setae, first present from the fourth segment; there are three pairs of branchiae. Uncini appear on the fifth segment and are avicular in shape.

A species of a different genus has been recovered from quantitative samples in San Pedro Basin, California (Hartman, 1955); it differs generically as shown below.

Artacamella, new genus

Type *A. hancocki*, new species

The thorax consists of 15 setigerous segments and the abdomen of many more. Branchiae number three pairs and are inserted on segments one to three; they are simple, unbranched, and taper distally to slender ends. The prostomium is an inconspicuous lobe. The ventral part of the peristomium, or lower lip, is modified to form a conspicuous proboscis that projects forward; it is rugose on both upper and lower surfaces. The upper part of the peristomium is a broad, vaguely three-lobed membrane, accompanied by a pair of large, lateral lobes. The many slender tentacles inserted on its dorsal side are of two kinds. A few anteriormost are larger, broader, longitudinally grooved in their subdistal part and taper distally. Most of the tentacles are slenderer, cylindrical or seemingly annular. Thoracic uncini are long handled; abdominal hooks are avicular in shape.

Artacamella differs from *Artacama* Malmgren in having 15, instead of 17, thoracic setigerous segments. The proboscis-like organ is rugose instead of papillated. Thoracic uncini have a long handle and are not avicular. The first setigerous is the first uncinigerous segment. Peristomial eyes are present in *Artacamella*, not absent as in *Artacama*.

Artacamella hancocki, new species

Plate 3, figs. 1-6

Collections: Off Los Angeles light, California, in 11 fms. (no. 46b[4]) (1); off Point Fermin light, in 23 fms (no. 80b) (6); off Point Fermin light, in 50 fms, green sandy mud (no. 99b) (1); off Salta Verde Point, Santa Catalina Island, in 28 fms (no. 164a) (2); off Long Point, Santa Catalina Island, in 19 fms (no. 224d) (3).

Length of a large individual is 18.5 mm, width about 1.2 mm. The body consists of 15 thoracic and 50 or more abdominal setigerous segments. Smaller specimens are about 13 mm long and 0.5 mm wide and have fewer segments. The proboscis-like organ is a large, conspicuous, ridged structure that extends far in front of the oral aperture (fig. 2). On its ventral side (fig. 1) are 17 longitudinal ridges of uniform width which continue around the sides so as to appear transverse on the dorsal side. They are replaced abruptly by a broad series of dorsal stripes (fig. 2). The mouth is visible as a transverse slit at the posterior mid-dorsal position of the proboscis. Above it is an inconspicuous prostomial region, giving rise on each side to a much larger three-lobed peristomial part. This consists of a much folded medial part and a pair of large lateral lobes (fig. 2). There are many slender tentacles inserted on the large paired lappets on the side facing the branchiae. These tentacles consist largely of slenderer subcylindrical processes that appear to be transversely ridged, due to the presence of transverse rows of short ciliary

---

[4] These numbers are published with ecological data in Hartman, 1955, p. 66.

hairs (fig. 1). In addition, in anterior or lateral series, there are fewer, larger, broader, longitudinally grooved tentacles (fig. 2).

Branchiae number three pairs and are much longer than the longest oral tentacles. They are inserted so that the first pair is farthest apart, the second nearest together, and the third with only a narrow middorsal space separating them (fig. 1). Numerous peristomial eyespots are best seen by laying aside some of the cylindrical oral tentacles; they form two or three irregular rows on the peristomium, located between the dorsal bases of the large lateral lappets. The eyes are uniformly small and reddish brown (preserved).

The ventral side of the thorax is nearly smooth except for segmental grooves; ventral scutes are inconspicuous. Thoracic parapodia are small and obscure on the first two or three segments and thereafter increase in size. Notopodial lobes are short, papillar and their setae emerge in close fascicles. The corresponding neuropodia form elongate ridges, from which the uncini emerge in single series. Setae are long, slender and weakly limbate. Thoracic uncini are present from the first setigerous segment; they are best developed in the middle thoracic segments. Uncini are long handled (fig. 5), have a curved shaft, a subdistal shoulder, and extend distally as a large fang that is almost at right angles to the shaft. A semicircle of about seven smaller teeth surmounts the fang (fig. 6).

Abdominal parapodia are simple, uncinal lappets; they lack the auricular lobes that are present in *Artacama coniferi* (below). The uncini occur in single series, at the distalmost edge of the ridges. Uncini are avicular (figs. 3, 4); a larger fang is surmounted by many small teeth in two rows.

It is a pleasure to name this species for Captain Allan Hancock, Founder and first Director of the Allan Hancock Foundation.

Distribution: Artacamella hancocki is known only from San Pedro Basin, California, in 11 to 50 fms.

Artacama Malmgren

Artacama coniferi Moore, 1905

Artacama coniferi Moore, 1905, pp. 853-855, pl. 44, figs. 11-13
Artacama conifera Berkeley and Berkeley, 1952, pp. 74-75, figs. 150, 151

Collections: Stations 496-36[5] (1); 992-39 (1); 1183-40 (1); 1471-42 (1); others are from the Chukchi Sea, northwest of Alaska, in shallow depths.

---

[5] The data for the hyphenated station numbers have been published in Fraser, 1943.

The thorax consists of 17 setigerous segments. The proboscis-like organ is prolonged, conical, and distinctly papillated (Berkeley and Berkeley, 1952, fig. 150). Notopodial setal fascicles are present from the third branchial segment; uncini are present from the second setigerous segment. Abdominal parapodia have a large, subcircular lobe at the upper edge of uncinal ridges (as shown by Berkeley and Berkeley, 1952, fig. 151). Branchiae number three pairs; they form palmate tufts, with up to 30 filaments in a tuft. Peristomial eyespots are absent.

Distribution: The present records extend the distribution from the Chukchi Sea, northwest of Alaska, to the Gulf of Lower California, western Mexico, in 20 to 315 fms.

SERPULIDAE

Protis Ehlers, 1887

This is a small genus of nonoperculated serpulids, related to *Protula* Risso and distinguished from it chiefly by its much smaller size and the structure of its collar setae. In *Protula*, the setae are simple, tapered blades; in *Protis* some have a subdistal finlike expansion and a deep notch that separates the fin from the tapering end. Tubes are white, approximately cylindrical except where attached to a substratum. In size the animal has a known range from 8.5 mm long by 1 mm wide, to 41 mm long by 1 mm wide.

The type of the genus, *P. simplex* Ehlers, is known through one individual taken off Florida, in 860 fms (Blake Expedition); *P. torquata* Hoagland, 1919, comes from intertidal rocky crevices in Puerto Rico. The third species was described from two individuals taken off Santa Rosa Island, California, in 243-265 fms (U.S.S. Albatross Expedition). It is here more extensively recorded from southern California.

Protis pacifica Moore, 1923

Plate 4

Protis pacifica Moore, 1923, pp. 253-254.

Collections: Station 1613-48, Oct. 2, 1948, 33° 29′ 03″; 118° 19′ 17″. In 400-430 fms. 5.5 mi off Long Point, Santa Catalina Island, California, attached to living valves of *Cyclopecten* sp.; many others come from the deepest parts of San Pedro Basin, California, reported as serpulid (Hartman, 1955, p. 147) from an impoverished area.

The tube is chalky white, approximately cylindrical at its distal or free end, or flattened where attached to a substratum. Its external surface is somewhat rugose due to the presence of irregularly spaced annulated ridges (plate 4). Its maximum length is 36 mm or more. A single living pecten shell may have five serpulid tubes in varying stages of development, with the largest tube extending posteriorly beyond the mollusk. All of the tubes are attached to the dorsal or left valve of the mollusk, and usually directed so that the oral aperture of the annelid is at or near the siphonal end of the mollusk. A kind of commensalism is suggested by the relative positions of the tubes on the shell.

The pecten has been determined to be an undescribed species of *Cyclopecten* Verrill, 1897 (fide Mr. Gilbert Grau). Both it and the serpulid have been found almost invariably in the deepest parts of San Pedro Basin, California, where they are associated with tubes of a deep-water chaetopterid.

Distribution: Protis pacifica is known only from deep water off the coast of southern California.

POEOBIIDAE Heath, 1930

Poeobius meseres Heath, 1930

Plate 1, fig. 6

Poeobius meseres Heath, 1930, pp. 223-249, 2 figs., 3 pls.; Pickford, 1947, pp. 287-319, 3 pls.

Collections: Numerous specimens were taken from deep water tows off northern California, Sept. 1, 1951, at station 30 of the *Northern Holiday* Cruise, by Dr. Martin W. Johnson, to whom I am indebted for a gift of the specimens.

Poeobius meseres is associated with chaetognaths, which resemble it in shape, size and general appearance. The two differ grossly in that *Poeobius* has no setigerous oral end. The overall length is about 25 mm. The conspicuous lateral compression of the body increases from the anterior third of the body to the tail, so that there appear to be dorsal and ventral keels. In some individuals the anterior end is completely withdrawn (as shown by Heath, 1930, pl. 1, figs. 1, 4) into the gelatinous sheath which encompasses the body. In others the prostomium and anterior structures are extruded so that their natural relations are visible (fig. 6). These details are here shown for the first time. Their remarkable resemblance to the flabelligerids is indicated.

As the individuals have been preserved in formalin, the internal organs are easily identified. All signs of segmentation are lacking except in the midventral ganglia, where nine nodes are visible. The body consists of eleven segments (Heath, 1930). There is no color except in parts of the alimentary tract, including the green intestinal coil, the brown gonadial organ immediately behind it, and the white mucus-secreting anal gland at the far posterior end (Pickford, 1947). The single pair of nephridia are visible at the forward end dorsal to the alimentary tract and the shorter buccal pouch lies ventral to the gut. The cardiac body lies over and in front of the intestinal coil.

The prostomium and peristomium are completely fused; together they surround the oral aperture. A slight convexity at the middorsal end of the upper lip may represent the prostomium. There are no visible eyes or other pigmented light receptors. The large, paired palpi are inserted dorsolaterally and are longitudinally ridged along their entire length (fig. 6). A pair of conspicuous nuchal grooves is located at the posterior base of the palpi and a similar grooved structure lies farther back extending across the middorsum. These ciliated depressions resemble the nuchal organs of other sedentary polychaetes (Rullier, 1950, pp. 18-24).

The body behind the nuchal organs is slightly constricted, though not set off from the following tentacular region. The tentacles form a transverse paired series, numbering five to seven long tentacles on a side; they are separated middorsally by a narrow smooth space. These tentacles differ from the palpi in that they are shorter, smaller, and cylindrical instead of grooved.

The prostomium, peristomium, palpi and tentacular region are capable of being withdrawn into the buccal cavity so that in retraction the tentacles are directed forward (Heath, 1930, pl. 1, fig. 4); the palpi are then neatly folded in the buccal pouch.

These cephalic structures, preceding a trunk region that is thickly sheathed in a gelatinous membrane, recall the similar parts present in species of *Flabelligera* Sars, family FLABELLIGERIDAE. The resemblances extend to some anatomical parts. Reduction of nephridial pairs to a single one at the anterior end is known in *F. diplochaitos* and some other sedentary polychaetes. Transverse septa are reduced in number; the musculature of the body wall is reduced except in the cephalic region; the alimentary tract is bent on itself; a cardiac body is extensive (Günther, 1912, pp. 93-186). The anterior end, including palpi, tentacles and accessory parts, is completely retractile into the buccal region.

In *Flabelligera*, a thick mucus sheath encases the body; the mucus is formed by many gland cells in the epidermis and excreted through pores over the surface of the body. A thick mucus sheath is present also in species of *Myxicola* Koch, member of the family SABELLIDAE.

Distribution: Poeobius meseres is known only from the northern Pacific, from southeast Alaska to California, in about 350 meters.

LITERATURE CITED

Annenkova, N. P.

1935. Ueber *Dysponetus pygmaeus* Levinsen und *Euzonus arcticus* Grube. Doklady. Akad. Nauk SSSR. 3(8) no. 5(65):233-236.

Berkeley, Edith and C. Berkeley.

1952. Polychaeta Sedentaria. Canadian Pacific Fauna, 9. Annelida. 9b (2):1-139, 292 figs.

Caullery, M.

1944 Polychètes Sédentaires de l'Expédition du *Siboga:* Ariciidae, Spionidae, Chaetopteridae, Chlorhaemidae, Opheliidae, Oweniidae, Sabellaridae, Sternaspidae, Amphictenidae, Ampharetidae, Terebellidae. *Siboga*-Expéditie. Leiden, 24^2 bis (liv. 139) :1-204, 157 figs.

Ehlers, E.

1887. Reports on the Results of Dredging . . . during the years 1868-1870 . . . in the Gulf of Mexico (1877-78), and in the Caribbean Sea (1878-79) in the U.S. Coast Survey Steamer "Blake." Report on the Annelids. Bull. Mus. Compar. Zool. Harvard Univ. 15:vi,1-335, 60 pls.

Eliason, A.

1920. Biologisch-Faunistische Untersuchungen aus dem Öresund. V. Polychaeta. Lunds Univ. Aarsskr., N.F., Avd. 2, 16(6):1-103, 18 figs., 1 map.

Fauvel, P.

1927. Polychètes Sédentaires. Faune de France. 16:1-494, 152 figs.
1932. Annelida Polychaeta of the Indian Museum, Calcutta. Indian Mus. Mem. 12(1):1-262, 9 pls., 40 figs.

Fraser, C. M.

1943. General Account of the Scientific Work of the *VELERO III* in the Eastern Pacific, 1931-41. Part III. A Ten-Year List of the *VELERO III* Collecting Stations. Allan Hancock Pacific Exped. 1(3):259-431, 115 charts.

Guenther, K.

1912. Beiträge zur Systematik der Gattung *Flabelligera* und Studien über den Bau von *Flabelligera (Siphonostoma) diplochaitus,* Otto. Jenaische Ztschr. f. Naturw. n.s. 48:93-186, 55 figs., pl. 7.

Hartman, O.

1938. Descriptions of New Species and New Generic Records of Polychaetous Annelids from California of the families Glyceridae, Eunicidae, Stauronereidae and Opheliidae. Univ. Calif. Pubs. Zool. 43:93-112, 63 text-figs.
1954. The Marine Annelids of San Francisco Bay and its Environs, California. Allan Hancock Found. Pubs. Occas. Paper. 15:1-20.
1955. Quantitative Survey of the Benthos of San Pedro Basin, southern California. Part I. Preliminary results. Allan Hancock Pacific Exped. 19(1):1-185, 2 charts, 7 plates.

HEATH, H.
1930. A connecting link between the Annelida and the Echiuroidea *(Gephyrea armata)*. Jour. Morph. 49:223-249, 2 figs., 3 pls.

HOAGLAND, R. A.
1919. Polychaetous Annelids from Porto Rico, the Florida Keys, and Bermuda. Bull. Amer. Mus. Nat. Hist. 41:571-591, pls. 29-32.

McINTOSH, W. C.
1885. Report on the Annelida Polychaeta collected by H.M.S. *Challenger* during the years 1873-76. *In* Great Britain. Challenger Reports. Zool. 12:xi, 1-554, 94 pls.

MOORE, J. P.
1905. New Species of Ampharetidae and Terebellidae from the North Pacific. Proc. Acad. Nat. Sci. Phila. 57:846-860, pl. 44.
1909. The Polychaetous Annelids Dredged by the U.S.S. "Albatross" off the Coast of Southern California in 1904. 1. Syllidae, Sphaerodoridae, Hesionidae, and Phyllodocidae. *Ibid.* 61:321-351, pls. 15-16.
1911. The same. III. Euphrosynidae to Goniadidae. *Ibid.* 63:234-318, pls. 15-21.
1923. The same. IV. Spionidae to Sabellariidae. *Ibid.* 75:179-259, pls. 17-18.

PICKFORD, GRACE E.
1947. Histological and Histochemical Observations upon an Aberrant Annelid, *Poeobius meseres* Heath. Jour. Morph. 80:287-319, 3 pls.

RULLIER, F.
1950. Rôle de l'organe nucal des Annélides polychètes. Bull. Soc. Zool. de France. 75(1):18-24.

THORSON, G.
1951. Animal Communities of the Level Sea Bottom. Ann. Biol. [Paris] sér. 3. 27(7):481-489.

THULIN, G.
1921. Biologisch-faunistische Untersuchungen aus dem Öresund. VI. Ueber *Cossura longocirrata* Webster und Benedict und über die Röhren von *Disoma multisetosum* Oersted. Lunds Univ. Aarsskr. N.F., Avd. 2. 17(10):1-14, 17 figs.

WATSON, A. T.
1901. On the Structure and Habits of the Polychaeta of the Family Ammocharidae. Jour. Linn. Soc. London. Zool. 28:230-260, pls. 23-25.

WESENBERG-LUND, ELISE
1950. Polychaeta. *In* The Danish Ingolf-Expedition. 4(14):1-92, 10 pls., 67 charts, 2 text-figs.

PLATE 1

Figs. 1-5, *Cossura candida*, n.sp. (2116-52)

1. Anterior end showing prostomium, two buccal segments and first five setigerous segments, with basal part of median tentacle, in dorsal view, x 47.
2. Posterior end, showing three anal filaments, in dorsal view, x 47.
3. Parapodium from a median segment, showing setae, in posterior view, x 151.
4. Distal end of a longer seta, seen from the side, x 583.
5. Part of a spinous seta, seen from the front, x 583.

Fig. 6. *Poeobius meseres* Heath.

Anterior end with palpi and tentacles, in dorsal view, x 26.5.

PLATE 2

Figs. 1-5, *Myriochele gracilis*, n.sp. (2175-52)

1. Entire animal, removed from tube, showing large ova through body wall in middle region of body, seen in right lateral view, x 13.
2. Entire tube, with animal enclosed, x 13.
3. Uncinus from anteromedian region, seen from the side, x 5610.
4. Uncinus seen from the distal end, showing thick fang, x 5610.
5. Anterior end of another specimen, taken out of a tube, with everted tentacles, seen from the left side, x 20.

Figs. 6, 7, *Owenia fusiformis collaris*, new subspecies (2142-52)

6. Uncinus with shaft and distal teeth, seen from the side, x 5840.
7. A similar uncinus seen from the front, x 5840.

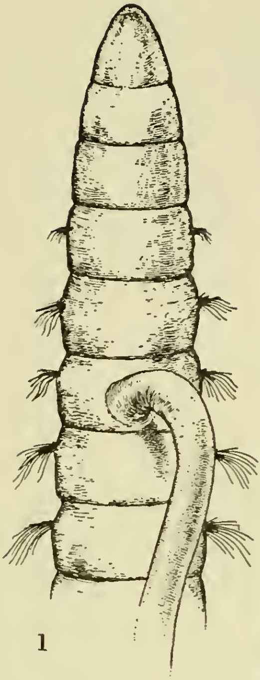
PLATE 3

Figs. 1-6, *Artacamella hancocki*, n.sp. (2233-52)

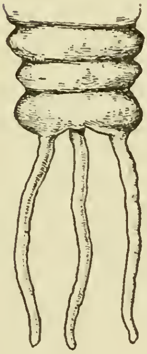
1. Anterior end through first five setigerous segments, in left lateral view, x 40.
2. Anterior end, showing proboscis-like organ, oral aperture and tentacular processes, in dorsal view, x 40.
3. Abdominal uncinus, seen from the side, x 3400.
4. Abdominal uncinus, seen from the front, x 3400.
5. Thoracic uncinus, seen from the side, x 1925.
6. Thoracic uncinus, seen from the front, x 1925.

PLATE 4

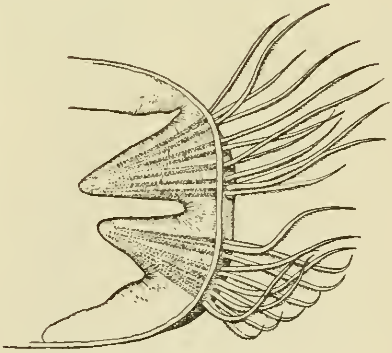
Protis pacifica Moore (1613-48), attached to dorsal, left valve of *Cyclopecten* sp., x 12.



1



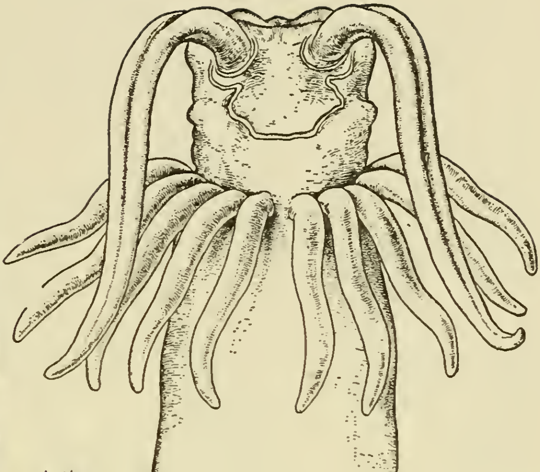
2



3

4

5



6

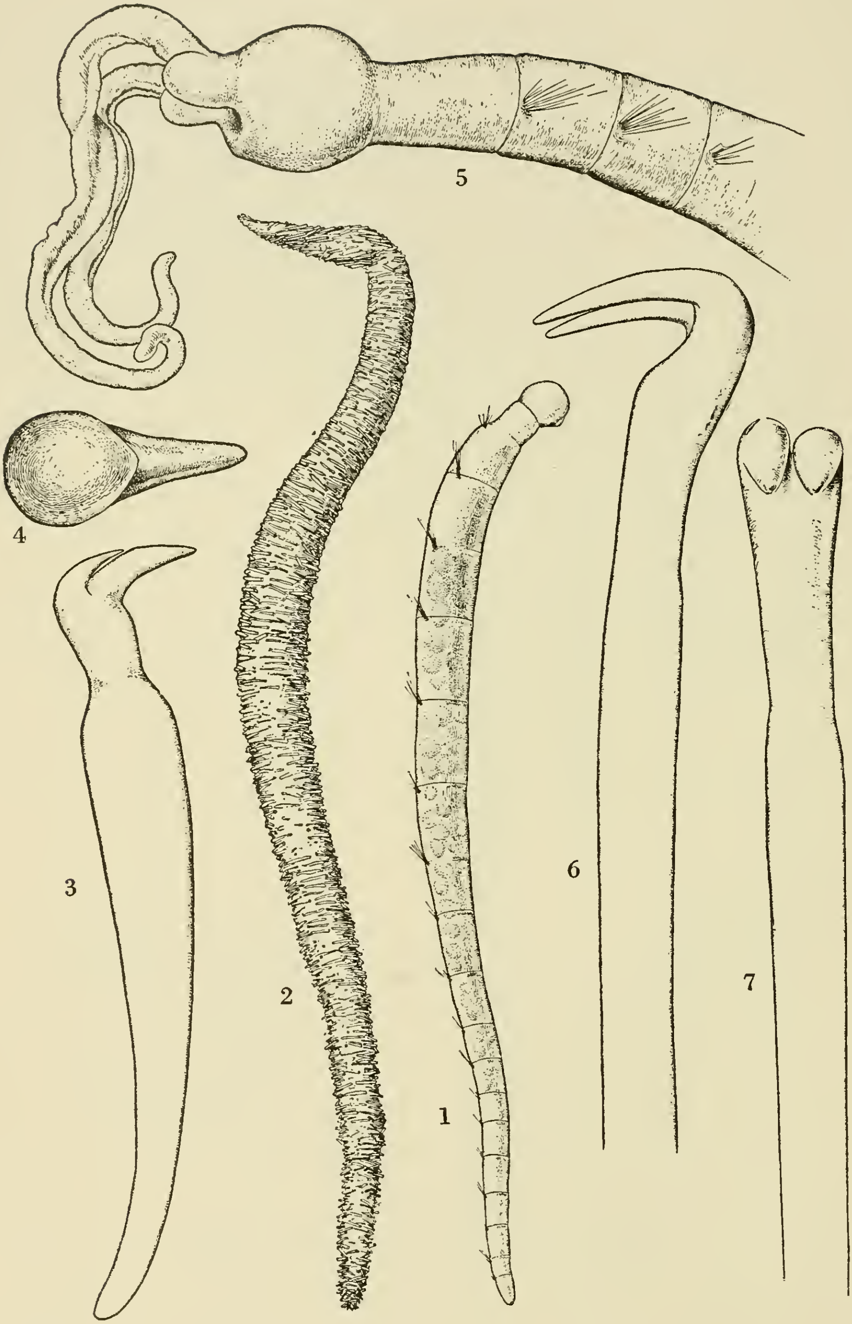

5
4
3
2
1
6
7

PLATE 3

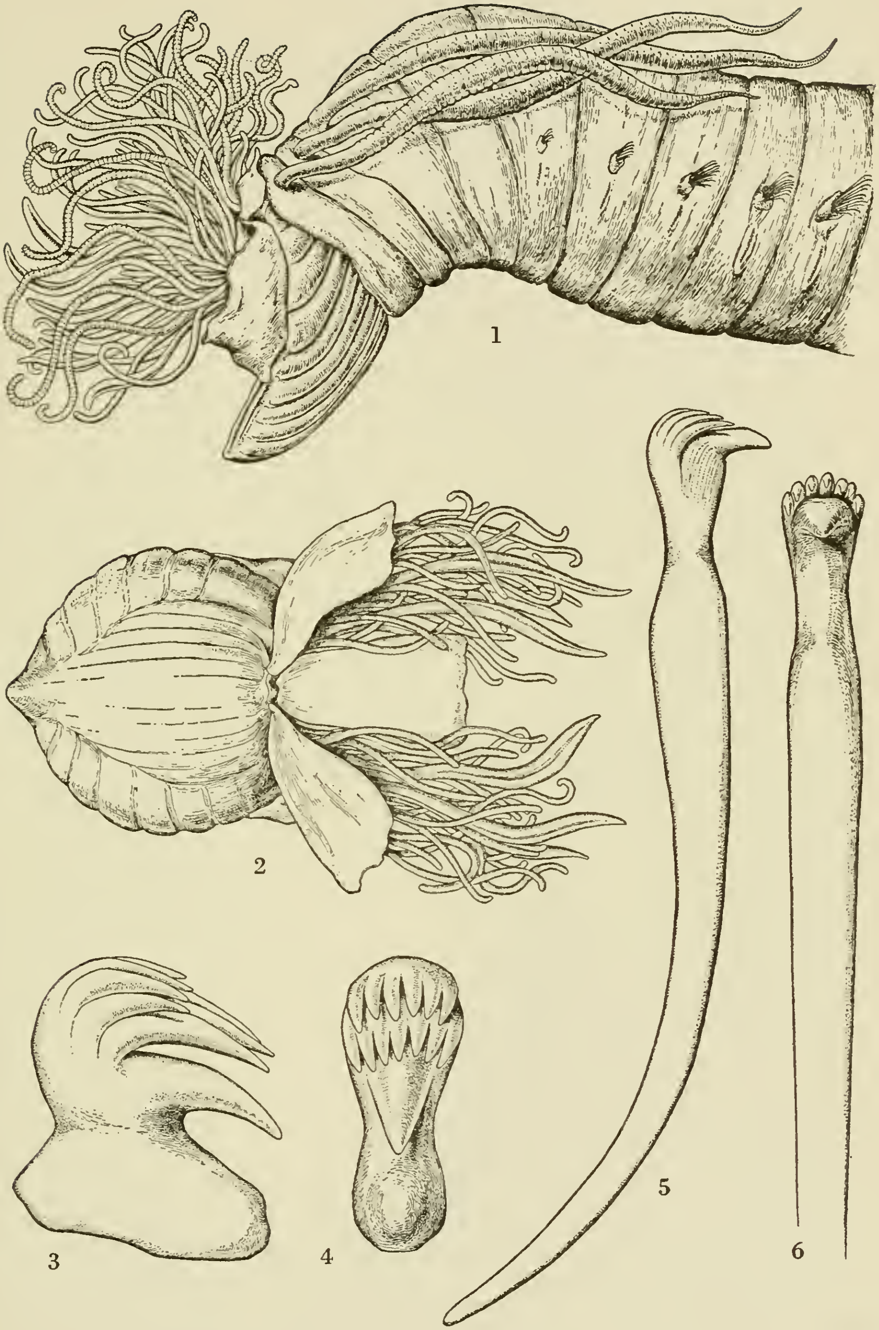
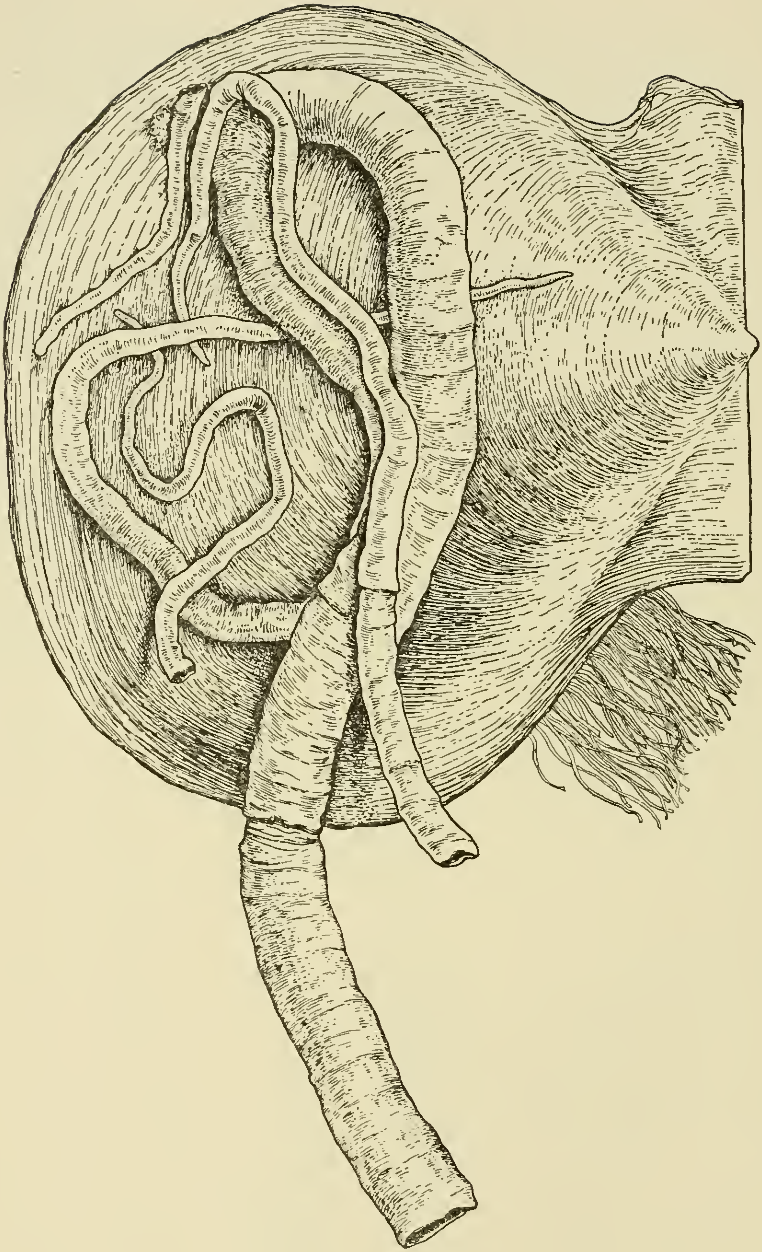


PLATE 4



NEW LIGHT ON THE BIOLOGY OF *SPIRULA*, A MESOPELAGIC CEPHALOPOD

By

ANTON FR. BRUUN

The Galathea Expedition 1950-52, Copenhagen

1. INTRODUCTION

In many parts of the world, especially in the tropics, the beautiful white shells of the small cephalopod, *Spirula*, may be found cast ashore. Often they are the most abundant species amongst the shells, and if the sediment were fossilized, the *Spirula* shells would form the most characteristic fossil. These accumulations represent mixtures of oceanic and littoral species, which will constitute a puzzle to the future geologist. I do not intend to discuss similar puzzles of the past, but shall confine myself to the problems concerning *Spirula*. The discrepancy between the countless numbers of shells found, even in high latitudes (e.g., Mörch, 1868), and the few living specimens caught, to this day, induces one to extract all possible information from any new catch.

Until the time of the Danish Dana-Expeditions of 1920-22, only 13 living specimens had been captured. The leader of these expeditions, Johannes Schmidt (1922), gave his observations on live specimens, as well as a short outline of results derived from the study of the 95 specimens caught on the expeditions. Ninety-three more specimens were added during the *Dana's* circumnavigation of the globe in 1928-30, on which voyage I had the good fortune to be one of Johannes Schmidt's assistants. In 1943 I attempted to extract all the biological information which could be gained from this limited but unique material, which was so much larger than all other combined collections.

The Galathea Expedition Round the World, 1950-52, was especially aimed at the benthic fauna of the deep sea, while the Dana expeditions had specialized in the oceanic pelagic fauna; therefore we did not expect to catch *Spirula*, with the possible exception of a few stray specimens like those taken by the earlier expeditions while studying the bottom animals. One specimen was actually caught in this way. Another single haul yielded 26 specimens, and the conditions were such as to cause me to consider to what extent the conclusions I reached in 1943 should be revised. I hope that this reconsideration of the problem will encourage scientists who have the opportunity of collecting in ocean areas where *Spirula* must be extremely common to study this highly interesting cephalopod.

Colman (1954) suggests that there may be special difficulties in catching *Spirula* because of its vertical movements. I think the main reason is that too few have tried to catch the animal where it lives. During the Dana Expedition of 1928-30 the leader, Professor Johannes Schmidt, asked that a special effort be made to show a live *Spirula* to our guest on board, the late Dr. Th. Mortensen. This was done at Dana Station 4014, close to the Canary Islands, where *Spirula* has been taken frequently in pelagic catches. We towed the stramin-nets for an hour at depths chosen according to our previous experience, and Dr. Mortensen and I were equally happy about the resulting seven specimens. This experience would indicate that a special study of the biology of *Spirula* would be a very rewarding task for a research vessel and would undoubtedly give positive results.

2. NEW RECORDS

Galathea Station 203, at which the 26 specimens were caught, is situated off the coast of Natal, South East Africa (25°36′ S., 35°21′ E.), with depths ranging from 660 to 720 meters. The gear used was a Danish commercial otter-trawl, of the light type used for herring, about 32 meters wide at the opening. The 2200 meters of wire were paid out at an inclination of 30°-34°. The entire operation was carried out successfully according to the Kullenberg system (Kullenberg, 1951). The haul, which started at 20.00 h., was of 70 minutes duration, and the direction was 170°. The weather was remarkably fine: wind S. E. to E. 1, sea S. E. 1, swell 1. The reason for trawling in relatively moderate depths was partly to ascertain the efficiency of the gear and partly to get some material for a comparison between the benthic fauna of the slope and that of the abyssal depths. The result was a large catch of about 300 fishes, comprising approximately 40 species, and many hundreds of invertebrates, especially crustaceans.

As would be expected from the procedure, which consisted of lowering and hauling the trawl, wide open all the while, the animals were a mixture of pelagic and benthic types. Full details can be given only when all the species have been studied by specialists, but some preliminary identifications, which will give an impression of the animal communities containing *Spirula*, will be sufficient for the present purpose.

Among the pelagic fishes were noted: *Argyropelecus*, *Sternoptyx*, *Polyipnus*, *Gonostoma*, *Vinciguerria*, *Cyclothone*, myctophids, *Neoscopelus*, *Astronesthes*, *Stomias*, *Chauliodus*, *Nansenia*, *Stylephorus*, *Leptocephali*, and *Bothus*-larvae. Other genera represented bottom fishes or species living near the bottom, such as: *Etmopterus*, *Coloconger*, *Ariosoma*, *Physiculus*, *Haloporphyrus*, *Coryphaenoides*, *Malacocephalus*, *Neobythites*, *Selachophidium*, and *Setarches*. Other typical benthic animals were a number of crabs like *Platymaia* and *Geryon*, shrimps or prawns like *Sabinea* and *Nematocarcinus*, and the small lobster *Nephropsis*. More animals could be mentioned, but this should be sufficient to give a general idea of the haul.

Another haul, at Station 202 (25°20′ S., 35°17′ E.) had been made earlier in the same afternoon (16.20 h.), but the depth was a little less: 525 to 570 meters. This catch consisted of more than 500 specimens of fishes comprising at least 35 different species. There were also many invertebrates, but not a single *Spirula*. Although one should not attach too much importance to the differences between two such hauls, it may be of interest to note some genera of bottom fishes *not* found at Station 203: *Gonorhynchus*, *Ateleopus*, *Synagrops*, *Chascanopsetta*, *Symphurus*, *Peristedion* and *Chaunax*. *Chlorophthalmus* was here represented by 135 specimens, but by only one at Station 203. At Station 202 pelagic types like *Yarrella, Polyipnus* and myctophids were also caught. Some of the differences observed are probably caused by the difference in depths, but final conclusions must await a more detailed study.

The Galathea Expedition caught only one more *Spirula*. At Station 280 (1°56′ N., 77°05′ E., April 9, 1951) a live immature specimen, ventral mantle length 20 mm, was found imbedded in soft ooze, which was brought up from about 4500 meters in an open shrimp otter-trawl. This specimen was kept alive overnight in a refrigerator, and the next day a fine piece of color film was made of its characteristic movements, which were first described by Johannes Schmidt (1922). Eventually it died from the heat produced by the powerful light used by the photographer.

Since my report of 1943 was published, two more specimens have been found in the Dana collections: Dana Station 3946 I (3°26′ S., 42°58′ E.); 2 meters stramin-net, 600 meters wire; ventral mantle length 3.4 mm, a very young specimen, with only 4 chambers in the shell. Dana Station 4010 III (27°19′ N., 16°41′ W.); 2 meters stramin-net, 300 meters wire; ventral mantle length 19 mm, immature. Another specimen had been found previously in this same haul and included in the report of 1943.

3. SIZE, SEX, SHELL

Since 26 specimens from one haul are so many more than from any previous single catch, some details are here recorded for comparison with earlier observations (Plate 1).

TABLE 1

Size and Sex

Ventral mantle length mm	Male	Female
40	1	. .
39	. .	. .
38	. .	. .
37	. .	2
36	. .	3
35	1	5
34	. .	5
33	. .	3
32	. .	5
31	. .	1
Total	2	24

All the females have well-developed ovaries. The eggs are probably near mature size, about 1 mm in diameter. The males have fully developed hectocotyli, the smaller specimen with six, the larger one with seven finger-like projections on the left hectocotylized arm.

The sizes are just as would be expected in mature animals, much the same as in earlier Indian Ocean records. The shell has been measured across the dorso-ventral diameter, related to the ventral mantle length, and expressed in percentages in Table 2. The females have been tabulated with Atlantic specimens, and no important differences are noted.

TABLE 2

Diameter of Female Shells Expressed in Percentage of Ventral Mantle Length

% of ventral mantle length	Atlantic specimens	Station 203
55	1	2
54	. .	1
53	1	5
52	. .	6
51	1	3
50	2	3
49	. .	2
48	3	2

The shell diameter of the smaller male was 51% and that of the larger one 48%.

4. HORIZONTAL DISTRIBUTION

The Galathea specimen from Station 280 was found fairly close to the place where one had been taken earlier. The specimens from Dana Station 3946 and Galathea Station 203 are new records of live specimens from East Africa, although not unexpected, because the *Dana* caught a specimen just to the west of the Agulhas Bank, and I suggested (1943, p. 20) that it "had been carried round the Cape from an area centering somewhere in the Mozambique Channel."

Besides the additional specimen from Dana Station 4010 III, already mentioned in the literature, I have found only two short references. Some specimens were caught by the Rosaura Expedition at Station 15 (18°21′ N., 75°25′ W.). Colman (1954), after giving observations on the live specimen from this locality, adds that later on three more were caught, all very young. As no exact location is indicated it may therefore be assumed that these three also were found within the known range of *Spirula.* Nybelin (1951) mentions a single specimen from 22°41′N., 23°10′ W., and this is also well within the known area of distribution.

5. VERTICAL DISTRIBUTION

It may seem strange that the few Galathea specimens would cause a reconsideration of the vertical range of *Spirula*, but the special conditions of the haul at Station 203, together with other information about pelagic animals obtained during the expedition, has induced me to try to give a more concise definition of the ecological characteristics of *Spirula.*

In 1943 *Spirula* was shown as having a world-wide distribution in tropical and subtropical regions, being most common near the steep slopes of continental and island shelves. The vertical distribution was given as 200-1750 meters, except in areas of upwelling, where the animal is found at 100 meters. Thus it would belong neither to the surface group nor to the true bathypelagic species. It was also stated that its distribution, considered as a whole, was not clearly limited by any single factor. It is the lower depth limit which should be studied further because it was based on a statistical treatment of catches from open nets. The upper limit, however, was quite well fixed because a large number of negative hauls had been made between it and the surface in areas where *Spirula* is caught regularly in deeper layers. The important factor in the depth range is the temperature.

Observations made by the *Dana* in 1930 indicate the temperature conditions in the Mozambique Channel close to Galathea Station 203.

Depths in meters	Temperatures, Centigrade	
	Dana Station 3962 24°33′ S., 38°26′ E.	Dana Station 3964 25°14′ S., 36°21′ E.
0	26.50	28.56
100	23.03	24.56
200	19.73	20.67
300	15.46	16.76
400	13.84	14.42
500	12.56	12.84
600	11.38	11.38
800	9.60	9.10
1000	7.23	7.10

At Galathea Station 203 the catch must have been made between the bottom (greatest depth, 720 meters) and about 200 meters; hence the temperature range must be between 10° and 20° C. The lower limit (10° C.) is just about the temperature which can be used for practical purposes to distinguish between the upper warm water masses, the thermosphere, and the deeper cold water masses, the psychrosphere, of the lower ocean latitudes. The polar limits of the thermosphere occur where the 10° C. isotherm comes to the surface.

TABLE 3

Analysis of Dana Catches From Stations in the West Indies of Depths Less Than 1000 Meters. Temperature Observations From Dana Stations in the Area.

Meters of wire	Number of hauls		Number of specimens	Depth in meters	Temperature range (C.)
	Negative	Positive			
0	3	0	0	0	24.8-25.5
50	9	0	0	. .	
100	16	0	0	. .	
200	1	0	0	. .	
300	15	0	0	100	23.2-25.2
500	3	0	0	. .	
600	13	3	4	200	19.0-20.2
700	1	1	1	. .	
800	10	5	6	. .	
1000	7	12	17	. .	
1200	2	0	0	400	13.4-15.0
				500	10.9-13.0
				600	8.8-9.9
				800	6.2-6.9

In Table 3 I have analyzed the Dana catches from stations of depths less than 1000 meters in the West Indies (published in 1943), and given the temperature observations from Dana stations in the area (Hydrographical observations 1937). The actual depth of the pelagic nets was supposed to be about one third of the wire length. Here again the upper temperature range is near 20° C., while the lower catches were made at temperatures above 14° C. This means that all the specimens must have been caught well within the thermosphere, but about 200 meters or more below the surface. It should be pointed out that all hauls were made during the night, at which time any mesopelagic animal would be expected to occur at its normal upper range.

At Dana Station 3786 VIII in the Celebes Sea (depth 970 meters) a specimen was caught in a 2 meter stramin-net with 800 meters of wire out, which would indicate a maximum fishing depth of about 270 meters. The temperatures of a nearby station (3784) showed 11.9° C. at 200 meters, 10.1° C. at 300 meters and 4.0° C. at 1000 meters.

With these observations in mind, I have given the distribution of *Spirula* together with certain isotherms. The 10° C. surface isotherm has been drawn to show the polar limits of the thermosphere. The numerous hauls made all over the North Atlantic by many expeditions should be sufficient to show that the 10° C. surface isotherm, as expected, gives no clue to the distribution pattern. The 10° C. isotherm at 400 meters, and to some extent the 9° C. isotherm, have also been indicated. It is obvious that all catches of *Spirula* fall within the regions where the temperature is about 10° C. or higher at a depth of 400 meters (Plate 2).

I have not plotted the record by Okada (1933) because I do not know the exact locality. It is probably from Japanese waters, an area where one would expect *Spirula* to occur. In the South Atlantic off South America, in the Indian Ocean off West Australia, and in the Pacific off Central America there are places where one might also expect *Spirula* to live. It seems quite unlikely, though, that the eastern parts of the South Atlantic and the South Pacific would offer the temperature conditions required.

As indicated in the 1943 comparison of the eastern and western North Atlantic, the supply of food does influence the population numbers of *Spirula*, but I think the temperature may eventually turn out to be the dominant factor. It would be very interesting to have attempts made to catch *Spirula*, especially close to the slopes of southeastern Japan and Pacific Central America. Temperature observations at the depths of the fishing should naturally also be made.

In 1943 I gave 1750 meters as the lower depth limit for *Spirula.* I am now inclined to think that this is too deep, even though a certain number of specimens were found in nets which had worked at that depth. Because the nets were open when being hauled the arguments given had to be based on statistics. I shall continue to doubt that *Spirula* lives below the thermocline, in the true psychrosphere, until the use of reliable closing nets disproves this supposition.

6. *SPIRULA* AS A TYPE OF MESOPELAGIC ANIMAL

While it is clear that *Spirula* does not normally live in the photic layers of the oceans, and therefore is not epipelagic, I would like to have it called mesopelagic, to avoid confusion with the term bathypelagic. I suggest that the word bathypelagic be applied to species living in the aphotic zone and in the psychrosphere between about 4° and 10° C. Animals living at still lower temperatures in deep water can be called abyssopelagic. Mesopelagic animals would accordingly be those found in the aphotic zone of the thermosphere. In addition, several of the pelagic fishes which were caught at Galathea Station 203 with *Spirula* deserve a critical study as to ecological type. If *Argyropelecus*, *Sternoptyx*, *Polyipnus*, *Astronesthes* and *Stylephorus* were found under conditions quite normal for them, I would prefer to have them called mesopelagic also, not bathypelagic.

LITERATURE CITED

BRUUN, A. F.
1943. The Biology of *Spirula spirula* (L.). Carlsberg Foundation's Oceanographical Expedition round the World 1928-30. Dana-report. 24:1-46, 2 pls.

COLEMAN, J. S.
1954. Gear, Narrative and Station List. The "Rosaura" Expedition. Bull. Brit. Mus. (N. H.) Zool. 2:119-130.

KULLENBERG, B.
1951. On the Shape and Length of the Cable during a deep-sea Trawling. Swedish Deep-Sea Expedition 1947-1948. Report 2(Zool.):31-44.

MØRCH, O. A. L.
1868. Faunula Molluscorum Insularum Faeroënsium. Vidensk. Medd. Dansk Naturhist. Foren. 1867:67-111.

NYBELIN, O.
1951. Introduction and Station List. *In* Reports of the Swedish Deep-Sea Expedition. Göteborg. Vol. II. Zool. 1:1-28, 5 text-figs., 1 map.

OKADA, Y.
1933. The soft part of *Spirula*. Venus [Kyoto] 4:144-145, text-figs.

SCHMIDT, J.
1922. Live Specimens of *Spirula*. Nature [London] 110:788-790.

SCHOTT, G.
1935. Geographie des Indischen und Stillen Ozeans. Hamburg. XIX, 413 pp.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING.
1946. The Oceans, N. Y. x, 1087 pp.

THOMSEN, H.
1937. Hydrographical Observations made during the "Dana"-Expedition 1928-30 with an Introduction by Helge Thomsen. Carlsberg Foundation's Oceanographical Expedition round the World 1928-30. Dana-report. 12:1-46.

PLATE 1

The total catch of 26 *Spirula spirula* (L.) from Galathea Sta. 203. The hectocotylized ventral arms of the two males (above) are clearly seen. (H. V. Christensen photograph)

PLATE 2

Distribution of *Spirula spirula* (L.): new records added to map in Bruun, 1943. Isotherms from Schott 1935 and Sverdrup, Johnson & Fleming 1946.


cm
0 1 2 3 4 5

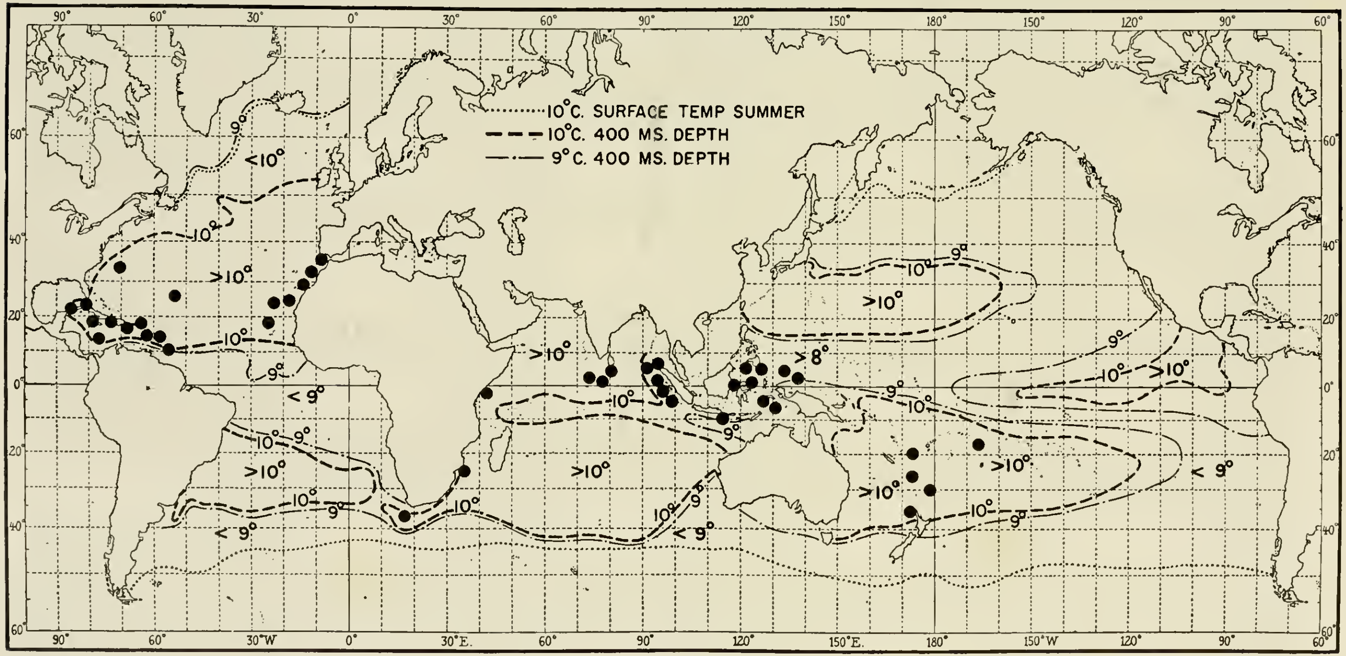

10°C. SURFACE TEMP SUMMER
10°C. 400 MS. DEPTH
9°C. 400 MS. DEPTH
<10°
>10°
< 9°
> 8°
10°
9°
90°
60°
30°W
0°
30°E.
90°
120°
150°E.
180°
150°W
120°
90°
60°
40°
20°
0°

Plate 2

OBSERVATIONS ON THE BRACHIOPOD COMMUNITIES NEAR SANTA CATALINA ISLAND

By

N. T. Mattox

Allan Hancock Foundation
Department of Biology, University of Southern California

During the course of biological studies in the Channel Island area conducted from the research ship *Velero IV*, attention was drawn to those collections which contained living brachiopods. Approximately thirty collections made near the shores of Santa Catalina Island contained these interesting animals. As was pointed out by Cooper (1948), very little has been presented on the ecology of living brachiopods; our knowledge of how they live, their relationship to each other, or their living animal associates is very meager. Some reports on modern brachiopods have given distributional and bathymetric data, but little other ecological information. Davidson (1886-1888) and Dall (1920) gave some data on range, depth, and bottom conditions. The most recent and complete compilation on eastern Pacific brachiopods, by Hertlein and Grant (1944), summarized the geological history, taxonomic, bibliographic, distributional, and bathymetric information on all of the known Cenozoic species of this area.

The observations here presented may be considered as additions to our knowledge of the ecology of living brachiopods. These results and findings are not to be taken as complete and final. Such a report is not yet possible because of the generally inaccessible location of the area and the incomplete nature of the collections and their analyses.

The area studied lies off the north eastern shore of Santa Catalina Island between the region of Long Point and the north west end of the island (Fig. 1), located geographically approximately from 33°22′ to 33°28′ north latitude and 118°22′ to 118°38′ west longitude. The entire area along the eastern shore of Catalina has been well sampled during the past twenty years so that the general habitat in which living brachiopods occur can be indicated. Brachiopods have been found here mainly at depths of from 30 to 80 fathoms on the rather steeply sloping shelf of the island, but in some instances as deep as 120 fathoms. The substratum here is in general solid, with many rocky and pebble areas as well as sand and some sandy mud bottoms.

Fig. 1. Outline map of Santa Catalina Island. "x" indicates locations of collections containing brachiopods. The contour lines represent the 50 and 100 fathom depths.

The available temperature records for this area indicate seasonal surface variations from 14 to 22° C. At the 50 fathom depth the annual variation is little more than one degree from the average of 10° C. Periodic upwellings of cool waters have been recorded along the northern limits of this shore, providing for a circulation of water and a cooling which usually results in a 5 degree variation in surface temperature within a very short time. A wind driven and tidal current runs over this area during most of the year. A calm area is present to the south of Long Point which is not rich in animal life. Chlorinity records at the 50 fathom depth indicate a rather regular average of near 18.8% (Emery, 1954).

Four species of brachiopods, about which some minor taxonomic problems exist, have been taken in these collections off the shore of Catalina. The most conspicuous form is the "California pink lamp shell," *Laqueus californianus* (Koch, 1848). This species has been taken by the hundreds in some dredge hauls over certain areas in past years, but more recently such concentrations have not been discovered, only rather small groups or clusters having been taken. This suggests that the population may fluctuate in size considerably from year to year.

Typically *Laqueus* occurs in grape-like clusters, several individuals attaching to some solid object or to each other. One such cluster contained 31 individuals attached to the shell of a larger and older *Laqueus.* They have also been found attached to the living shells of other species of brachiopods (Fig. 2), and in several instances to the living shell of the "California frog shell," *Bursa californica* Hinds. These latter cases result in transportation of *Laqueus* which is not possible for the typical articulate brachiopod. In the Catalina area this species has been taken from 30 fathoms to 120 fathoms. Beyond the 50 fathom region, it has been noted that the typical large form and pink color give way to smaller form and a color which fades to white. These latter characters approach those of the questionable and more northern subspecies, *vancouveriensis* Davidson, 1887. In other areas *L. californianus* has been taken in depths of 861 fathoms (Dall, 1920).

Laqueus californianus is a member of the family Terebratellidae and is a relatively recent species known only since the Pliocene, about 7,000,000 years. The distribution of the living forms extends from British Columbia south to Point Loma, California, with the greatest concentration from central to southern California.

The next most abundant species in the Catalina area is *Terebratalia occidentalis* (Dall, 1871). It usually occurs in smaller numbers, approximately 1 to 100 *Laqueus,* and is typically found singly or in small clusters. It has been taken in clusters with *Laqueus* (Fig. 2). In this area *T. occidentalis* is extremely variable as to the form of the shell. These variations within one collection may range from a complexly ribbed form with as many as 24 ridges resembling the Pliocene species *T. arnoldi* Hertlein and Grant, 1944, to a very smooth shell indistinguishable from the subspecies designated as *T. occidentalis obsoleta* (Dall, 1891) (Fig. 4). Within the same collection variations have also been found that seem to coincide with the elongated shell of *Miogryphus willetti* Hertlein and Grant (see Plate II, figs. 5 and 6, Hertlein and Grant, 1944). On the basis of these observed variations it is the writer's opinion that the species *T. arnoldi* and *M. willetti* should be questioned, and that the subspecies *T. occidentalis obsoleta* designation is untenable. Variations in shell form are undoubtedly the result of differences in the environmental conditions in which the animals live. An examination of the gross anatomy of these variants failed to indicate any significant differences.

Terebratalia occidentalis, also of the family Terebratellidae, is an older genus than *Laqueus*, dating back approximately 30,000,000 years to the Oligocene. The geographic distribution of the living forms extends from San Francisco, California, south to Cabo Lucas, Baja California.

Another variable species of brachiopod found in the Channel Island area in much smaller numbers than the above mentioned species is *Terebratalia transversa* (Sowerby, 1846). This species has been observed here only in isolated conditions, not attached to other brachiopods. The variations observed range from the relatively smooth-shelled form of typical *T. transversa* to the heavily ribbed form that has been described as the subspecies *T. transversa caurina* (Gould, 1850) (see Figure 5). The shell color ranges from grey to reddish in this area, adding to the doubt as to the tenable status of the subspecies *caurina* designation. These variations may be genetic or due to micro-ecological conditions, but in the writer's opinion do not justify subspecific designation. Off the shore of nearby Santa Cruz Island this species is found in larger numbers and occurs there with the smaller brachiopod *Terebratulina unguicula* (Carpenter, 1864).

Terebratalia transversa has occurred since the Miocene, dating back approximately 20,000,000 years. The geographic distribution of the living form is more extensive than for *T. occidentalis,* extending from Alaska to Ensenada, Baja California. This species has been taken to a depth of 877 fathoms.

The fourth species found living in the sandy bottoms of this area is the inarticulate brachiopod *Glottidia albida* (Hinds, 1844) (Fig. 3). This long-stalked, unattached species is not common here, but there are indications that it may live in colonies or groups. For example, one bottom-sampler collection in 45 fathoms yielded 43 individuals from a 2 square-foot area. Off Catalina this species has been taken at 8, 15, and 45 fathoms and seems to be restricted to lesser depths than the other species found in the area. *G. albida* has been recorded from intertidal flats to 80 fathoms in other regions.

Glottidia albida is a member of a very old group, the Lingulacea, which dates back to the Cambrian, about 550,000,000 years. This species has been found since the upper Eocene, about 40,000,000 years ago. The living forms have been recorded from Monterey Bay, California, south to Acapulco, Mexico.

In order to have a better understanding of the ecology of the living brachiopods in the Catalina area, an attempt has been made to record their conspicuous animal associates. Most of the collections have been made with a biological dredge which has yielded large numbers of animals, although many of the small forms are lost through the mesh of the dredge.

In addition to dredge hauls several quantitative samples have been taken in this area with bottom-sampler grabs of known area coverage. These are random samples whose location can be predetermined only as to the geographic location of the sample. The following list represents the animals taken in one such sample from an area of six square-feet in 36 fathoms off the Isthmus of Catalina Island. The animals have been identified as completely as is presently feasible. The numbers indicate the number of individuals of that particular kind found in this single sample. The list of animals is arranged phylogenetically and alphabetically within each major group.

Sample #2961-54; October 9, 1954; 0.4 mi SW of Ship Rock, Catalina Island; 33°-27′-52″ NL, 118°-29′-53″ WL; 36 fathoms; shell and sand bottom; 6 square feet area.

Protozoa
  several undetermined Foraminifera

Porifera
  Leuconia heathi (Urban)—1
  encrusting yellow sponge—1

Coelenterata
  Plumularia sp.—2 colonies
  Paracyathus stearnsi Verrill—3
  Acanthoptilum gracile Gabb—8
  anemones—7

Nemertea
  undetermined species—4

Aschelminthes
  Nematoda sp.—10

Bryozoa
  Antropora tincta (Hastings)—1 large colony

Phoronida
  Phoronis sp.—6

Brachiopoda
  Laqueus californianus (Koch)—3
  Terebratalia occidentalis (Dall)—2

Sipunculoidea
Sipunculids, 2 species—7
Annelida
Hirudinea
Pontobdellid—1
Polychaeta
Ammotrypane sp.—2
ampharetids—spp.—5
Anaitides sp.—1
Aricidea sp.—3
Axiothella sp.—2
Chloeia sp.—3
Chaetopterus sp.—1
Chaetozone sp.—2
capitellid—2
Chone sp.—2
Dorvillea sp.—1
Eulalia sp.—2
Glycera sp.—1
Goniada sp.—3
Haploscoloplos sp.—1
hesionid—1
Lepidasthenia sp.—5
Lanice sp.—2
Laonice sp.—1
Lumbrineris sp.—2
Maldane sp.—3
Myriochele sp.—2
nephtyid—1
Nereis sp.—1
Nothria spp.—2
Owenia sp.—1
Peisidice sp.—1
Placostegus sp.—2
Polycirrus sp.—1
polynoid—1
Praxillella sp.—1
Protula sp.—2
Pherusa sp.—2
Prionospio spp.—3
Phyllochaetopterus sp.—2
Pectinaria sp.—4
Pista sp.—2
Rhamphobrachium sp.—1
Scalibregma sp.—2
Sternaspis sp.—1
Stroblosoma sp.—2
sabellids spp.—4
Sthenelanella sp.—2
sigalionids—2
Spiochaetopterus sp.—2
spirorbid—1
serpulid—1
syllid—1
Spiophanes sp.—1
Tharyx sp.—1
Timarete sp.—1
Thalenessa sp.—1
Thelepus sp.—2
Terebellides sp.—2
Vermiliopsis sp.—2

Arthropoda
Ostracoda
undetermined sp.—31

Cirripedia
Mitella polymerus (Sowerby)—22

Cumacea
undetermined sp.—1

Amphipoda
Heterophoxus pennatus Shoemaker—1
Pontharpinia tridentata Barnard—1
undetermined—16

Isopoda
undetermined—5

Decapoda
Podochela barbarensis Rathbun—2

Mollusca
Gastropoda
Acteocina intermedia Willett—1
Balcis catalinensis (Bartsch)—1
Micranellum crebricinctum (Carpenter)—10
Sinum scopulosum Conrad—1
Turbonilla sp.—1
Volvulella tenuissima Willett—3

Pelecypoda
- *Amygdalum pallidulum* (Dall)—2
- *Cardiomya pectinata* (Carpenter)—4
- *Clinocardium nuttalli* (Conrad)—4
- *Cyrilla minuta* (Carpenter)—7
- *Kellia suborbicularis* (Montagu)—3
- *Lima subauriculata* Montagu—1
- *Nemocardium centifilosum* (Carpenter)—16
- *Nuculana hamata* (Carpenter)—1
- *Nuculana taphira* (Dall)—7
- *Pandora bilirata* Conrad—1
- *Parvilucina tenuisculpta* (Carpenter)—26
- *Pseudochama exogyra* (Conrad)—1
- *Saxicava arctica* (Linné)—5
- *Solamen columbianum* (Dall)—3
- *Sphenia fragilis* Carpenter—2
- *Tellina carpenteri* Dall—4
- *Verticordia ornata* (d'Orbigny)—1

Echinodermata
- Asteroidea
  - *Astropecten* sp. juvenile—4
- Ophiuroidea
  - *Amphiacantha amphacantha* (McClendon)—11
  - *Amphiodia urtica* Lyman—44
  - *Ophiopholis bakeri* McClendon—6
  - *Ophiothrix spiculata* LeConte—2
- Holothuroidea
  - *Parastichopus californicus* (Stimpson)—2
  - *Thyone benti* Deichmann—4

Hemichordata
- *Schizocardium* sp.—2

Chordata
- Urochordata
  - undetermined species—4

The above list, even though not a complete one for all of the animals of the Catalina area, gives a picture of the community of which the brachiopods are a part. It shows that in this small bottom area there were at least 115 different kinds of animals and nearly 500 individuals living together. This represents a concentration of benthic life not usually appreciated.

A general but incomplete survey, using the biological dredge, has added considerably to the list of the more conspicuous animals living in the Catalina area. The following series gives those animals thus encountered and represents the more obvious additions to the community list. With some groups the relative abundance of some forms has been noted and indicated by the following symbols: AB—abundant; C—common; F—few.

List of animals, in addition to those in list of Station #2961-54, found in the "brachiopod community" near Catalina Island; collected in a series of samples using a biological dredge in depths of 30 to 80 fathoms, 1954.

- Porifera
  - *Geodia* sp.—AB
  - *Tethya* sp.—C
  - *Leucetta losangelensis* de Laubenfels—F
  - Several unidentified encrusting forms
- Coelenterata
  - Hydrozoa
    - *Abietinaria expansa* Fraser
    - *Acryptolaria conferta* (Allman)
    - *Sertularia furcata* Trask
    - *Obelia surcularis* Calkins
  - Anthozoa
    - *Euplexaura marki* (Kukenthal)
    - *Leioptilus quadrangularis* (Moroff)—C
    - several unidentified anemones
- Platyhelminthes
  - undetermined Polyclad
- Nemertea
  - *Cerebratulus* sp.
  - *Lineus* sp.
- Aschelminthes
  - numerous unidentified Nematoda
- Entoprocta
  - *Barentsia* sp.
- Bryozoa
  - *Bugula californica* Robertson—C
  - *Crisia* sp.
  - *Dendrobeania curvirostrata* (Robertson)
  - *Diaperoecia californica* (d'Orbigny)
  - *Fenestrulina malusi* (Audouin)
  - *Microporella malusi* (Busk)
  - *Philodopora pacifica* (Robertson)
  - *Schizoporella insculpta* Hincks
- Brachiopoda
  - *Terebratalia transversa* (Sowerby)
  - *Glottidia albida* (Hinds)
- Echiuroidea
  - *Thalassema* sp.
  - Several undetermined forms
- Annelida
  - Polychaeta
    - *Aphrodita armifera* Moore—C
    - *Aphrodita japonica* Marenzeller
    - *Eunice multipectinata* Moore
    - *Lepidometria* sp.
    - *Nephthys squamosa* Ehlers—C
    - *Pectinaria californiensis* Hartman—C
    - *Protula* sp.
    - *Sternaspis scutata* (Renier)—AB
    - *Travisia brevis* Moore—AB
    - several undetermined forms
- Arthropoda
  - Amphipoda
    - *Ampelisca cristata* Holmes
    - *Ampelisca lobata* Holmes
    - *Ampelisca romigi* Barnard
    - *Ampelisca vera* Barnard
    - *Aruga aculata* Holmes
    - *Aruga dissilis* (Stout)
    - *Caprella* sp.
  - Decapoda
    - *Cancer gracilis* Dana—C
    - *Cancer jordani* Rathbun
    - *Clythrocerus planus* Rathbun
    - *Crago communis* (Rathbun)—C
    - *Heterocrypta occidentalis* (Dana)—C
    - *Mursia gaudichaudi* (Milne Edwards)
    - *Paguristes bakeri* Holmes—C
    - *Paguristes turgidus* (Stimpson)
    - *Pandalus platyceros* Brandt
    - *Paralithodes rathbuni* (Benedict)
    - *Pugettia venetiae* Rathbun

- Pycnogonida
  - Nymphonids—undetermined

Mollusca

- Amphineura
  - *Lepidozona catalinae* Willett
- Scaphopoda
  - *Cadulus tolmiei* Dall
  - *Dentalium rectius* Carpenter—C
- Gastropoda
  - *Acteon punctocaelata* (Carpenter)
  - *Aglaja* sp.
  - *Anisodoris nobilis* (MacFarland)
  - *Antiplanes perversa* (Gabb)—C
  - *Armina californica* (Bergh)
  - *Balcis rutila* (Carpenter)
  - *Bittium catalinensis* Bartsch
  - *Boreotrophon triangulatus* (Carpenter)
  - *Bursa californica* Hinds—C
  - *Callistoma tricolor* Gabb
  - *Cancellaria cooperi* (Gabb)—C
  - *Cancellaria crawfordiana* Dall
  - *Capulus californicus* Dall
  - *Cavolina tridentata* Forskal
  - *Conus californicus* Hinds
  - *Crepidula nivea* C. B. Adams
  - *Elaeocyma empyrosia* (Dall)
  - Eolid (undetermined)
  - *Epitonium tinctum* (Carpenter)
  - *Gastropteron* sp.
  - *Haminoea virescens* (Sowerby)—C
  - *Hemitoma bella* (Gabb)—F
  - *Kelletia kelleti* Forbes
  - *Megasurcula carpenteriana* (Gabb)
  - *Nassarius insculptus* (Carpenter)—C
  - *Neosimnia loebbeckeana* (Weinkauff)
  - *Philine* sp.—C
  - *Pleurobranchaea* sp.—C
  - *Pterynotus carpenteri* Dall
  - *Pterynotus petri* (Dall)
  - *Puncturella cucullata* (Gould)
  - *Puncturella galeata* (Gould)
  - *Pusula californica* (Gray)
  - *Solariella peramabilis* Carpenter
  - *Triophora* sp.
  - *Tritoniopsis aurantia Mattox*—F
  - *Turritella cooperi* Carpenter
- Pelecypoda
  - *Acila castrensis* Hinds
  - *Botulina denticulata* (Dall)
  - *Cardita ventricosa* Gould—C
  - *Cardium* juvenile
  - *Crenella decussata* Montagu
  - *Delectopecten vancouverensis* Whiteaves
  - *Dermatomya tenuiconcha* (Dall)
  - *Glycymeris subobsoleta* Carpenter
  - *Lima dehiscens* Conrad
  - *Lyonsia californica* Conrad
  - *Modiolus capax* (Conrad)
  - *Modiolus saccullifer* (Berry)
  - *Pecten (Pecten) diegensis* Dall
  - *Pecten (Chlamys) hastatus* Sowerby
  - *Semele pulchra* (Sowerby)
  - *Solen rosaceus* Carpenter
  - *Sportella californica* Dall
  - *Tellina buttoni* Dall—C
  - *Thyasira barbarensis* Dall
  - *Trachycardium quadragenarium* (Conrad)

Echinodermata

- Asteroidea
  - *Astropecten californicus* Fisher—C
  - *Astropecten ornatissimus* Fisher
  - *Henricia leviuscula* (Stimpson)
  - *Ludia foliolata* Grube—C
  - *Mediaster aequalis* Stimpson—AB
  - *Odontaster crassus* Fisher
  - *Scleraster hertopaes* Fisher
- Ophiuroidea
  - *Ophiura leutkeni* Lyman—C
- Echinoidea
  - *Allocentrotus fragilis* (Jackson)—C
  - *Gonimaretis laevis* H. L. Clark
  - *Lovenia cordiformis* A. Agassiz
  - *Lytechinus anamesus* A. Agassiz & H. L. Clark—AB
  - *Spatangus californicus* H. L. Clark

- Holothuroidea
  - *Cucumaria piperata* Stimpson
  - *Leptosynapta* sp.
  - *Pentamera populifera* (Stimpson)—C
  - *Stichopus johnsoni* Theel—C
  - *Stichopus parvimensis* H. L. Clark
- Crinoidea
  - *Floremetra perplexa* A. H. Clark—C

Chordata

- Fishes
  - *Cephaloscyllium uter* (Jordan & Gilbert)
  - *Coryphopterus nicholsi* (Bean)
  - *Cryptotrema corallinum* Gilbert
  - *Hippoglossina stomata* Eigenmann & Eigenmann
  - *Icelinus cavifrons* Gilbert
  - *Icelinus fimbriatus* Gilbert
  - *Icelinus quadriseriatus* (Lockington)
  - *Icelinus tenuis* Gilbert
  - *Odontopyxis trispinosa* Lockington
  - *Oxyjulis californica* (Günther)
  - *Porichthys notatus* Girard
  - *Sebastodes pinniger* (Gill)
  - *Sebastodes semicinctus* Gilbert
  - *Zaniolepis frenata* Eigenmann

The writer here wishes to acknowledge the assistance of the following persons in the identification of some of the animals listed here: Dr. John S. Garth, the Decapoda; Dr. Olga Hartman, the Annelida; Miss Janet Haig, the Decapoda and fishes; Mr. Fred C. Ziesenhenne, the Echinodermata.

An examination of the two lists given here readily indicates the great diversity of forms encountered in the area under study. It is hoped that their presentation will aid in a better understanding of the animal associates of living brachiopods. It is seen that the polychaetous annelids are the most diverse and numerous of all the groups represented. The mollusks and echinoderms are the next most conspicuous groups. In different dredge hauls different types of animals were conspicuous, such as sea pens, brittle stars, gastropods, and other mollusks. In some samples the sea urchin, *Lytechinus anamesus*, was taken by the hundreds and was by far the most conspicuous animal. It is probable that this area does not represent a unified community, but rather there are different associations dominated by different forms such as the sea pens, sea urchins, and brittle stars. The brachiopods are one of several forms that seem to be distributed over these various associations. No single group or type of animal may be indicated as a true dominant over the entire area. Some few may be competitors for space and some of the carnivorous species may exert a minor influence on the numbers of others. There is no form that has definitely been shown to influence the brachiopod population to a marked degree. It is possible that such carnivorous forms as the rather common *Philine* and other opisthobranchs may utilize the brachiopods as an item in their diet. The brachiopods, being sessile, would be easy prey for these snails;

however, this is only speculation. In summary it is indicated that the brachiopods living in this area are but a small part of an extremely changeable and diverse community or group of communities off the eastern shore of Catalina Island.

LITERATURE CITED

COOPER, G. A.
1948. Annotated bibliography of brachiopod ecology. Natl. Res. Coun. Report of the committee on treatise on marine ecology and paleoecology 1946-1947. Report No. 7:38-44.

DALL, W. H.
1871. Notes on California Mollusca. Cal. Acad. Sci. Proc. 4:182, pl. 1, fig. 7.
1891. Scientific results of explorations by the U. S. Fish Commission Steamer Albatross. Proc. U. S. Natl. Mus. 14:173-191.
1920. Annotated list of the recent Brachiopoda in the collection of the United States National Museum, with descriptions of thirty-three new forms. Proc. U. S. Natl. Mus. 57:261-377.

DAVIDSON, T.
1886-88. A monograph on recent Brachiopoda. Pts. I-III. Trans. Linn. Soc. London. 2nd. ser. IV:1-248, pl. 1-30.

EMERY, K. O.
1954. Source of water in basins off southern California. Jour. Mar. Res. 13 (1):1-21.

GOULD, A. A.
1850. Terebratula caurina. Proc. Bost. Soc. Nat. Hist. 3:347.

HERTLEIN, L. G. AND U. S. GRANT IV.
1944. The Cenozoic Brachiopoda of western North America. Univ. Calif. Los Angeles Pubs. Math. & Phys. Sc. 3:1-236.

HINDS, R. B.
1844. The zoology of the voyage of H. M. S. Sulphur under the command of Capt. Sir. E. Belcher during 1836-'42, Mollusca:71, pl. 19, fig. 4.

KOCH, B.
1848. Terebratula californiana. *In* Martini und Chemnitz. Conch. Cab. Bd. VII, abt. 1:38, pl. 26, figs. 21-23.

SOWERBY, G. B.
1846. Descriptions of thirteen new species of Brachiopoda. Proc. Zool. Soc. London. pt. 14:91-95.

Fig. 2. A cluster of 15 *Laqueus californianus* attached to two *Terebratalia occidentalis.*

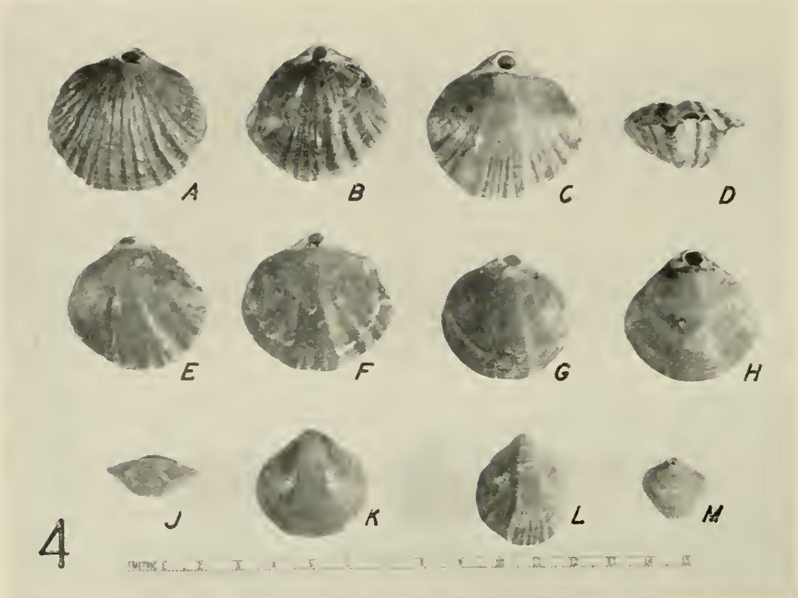
Fig. 3. Two individuals of *Glottidia albida.*

Fig. 4. A group of *Terebratalia occidentalis* arranged to indicate shell variation. Individual "a" resembles *T. arnoldi*; "b-f" are typical *T. occidentalis*; "g-j" resembles the subspecies *obsoleta*; "k and l" resemble form of *Miogryphus willetti.* All are from one area off Catalina Island.

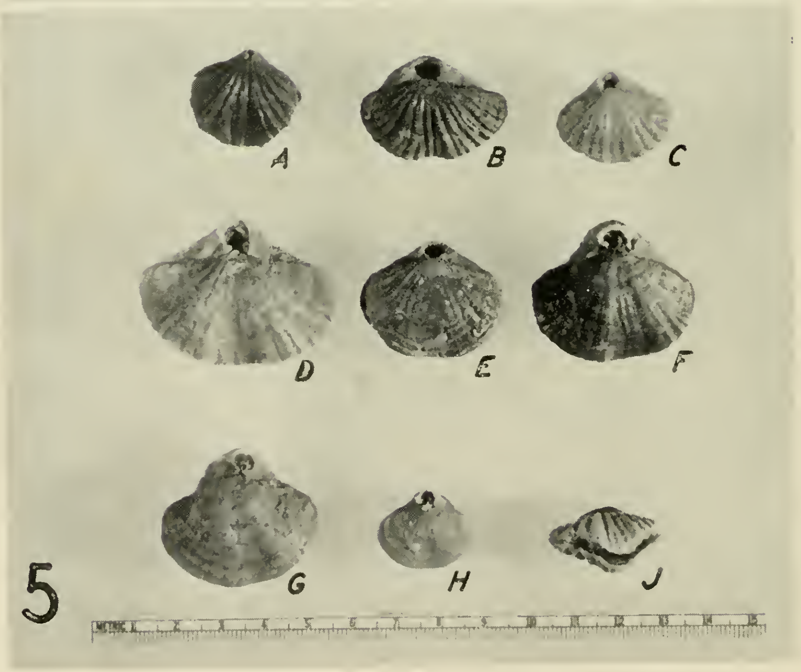
Fig. 5. A group of *Terebratalia transversa* indicating shell-form variation. "a, b, c, d, and j" represent the form described as subspecies *caurina* (individual "l" from Oldroyd collection labeled as *T. transversa caurina*) ; individuals "e, f, g, and h" are typical *T. transversa* (individuals "e and h" are from the Oldroyd collection labeled as *T. transversa*).

3

2



4



5

THE WOOD BORING HABITS OF *CHELURA TEREBRANS* PHILIPPI IN LOS ANGELES HARBOR

By

J. Laurens Barnard

University of Southern California

The taxonomic and ecologic history of the peculiar amphipod *Chelura terebrans* dates from the year 1839, when Philippi first described the animal from marine wood borings collected at Trieste. Since that time the species has been considered a wood borer by most writers. Little evidence has been given to support this view, other than: (1) the fact that the animal lives in deteriorated wood associated with such other organisms as the gribble, *Limnoria* sp., and the shipworm, *Teredo* sp.; (2) the presence of wood fragments in the gut of *C. terebrans.*

The present paper gives evidence that *C. terebrans* is a true wood boring agent and attempts to sketch a brief picture of its ecology in Los Angeles Harbor. Previous reports on this animal from California have been made by Barnard (1950, 1951).

The writer is indebted to Dr. John L. Mohr, Dr. John S. Garth and Mr. Charles Horvath for help in collecting materials and otherwise in preparing this paper. The work was supported through the generosity of the Allan Hancock Foundation and the Department of Zoology at the University of Southern California. Mr. Joseph W. Bamberger helped in making the photographs.

METHOD OF CULTURE

Living specimens of *C. terebrans* were studied in Los Angeles Harbor and in the laboratory. Both natural and induced populations in the field were examined. The term "natural" is not used in the normal sense as pilings in which the creatures live are a product of mankind. Induced populations are those infesting wooden test blocks which had been placed in the harbor.

Laboratory populations were kept in gallon jars half full of filtered, unaerated seawater. Best culture results were obtained when the animals were removed from the originally infested wood collected in the harbor and transferred to clean blocks of Douglas Fir. These blocks had been soaked and washed in seawater for a month prior to use in order to remove sap and other pollutants, as newly immersed wood produces a gelatinous exudate which traps and kills the animals when they attempt to cling to it. Seawater was filtered to remove diatoms, other organisms, and silt, then stored at about 8° C. in order to prevent bacterial growth. Although the harbor water in which the chelurids live contains these filtered agents the same water, though aerated, soon becomes stale. Chelurid populations were maintained in the aquaria for about two years, although the water temperature ranged from 17° to 23° C., about 8° above the range in the harbor.

Wood originally infested in the harbor and brought to the laboratory was unsatisfactory for maintaining cultures both because of the high concentration of animals per unit of water and because of the presence in most of the wood of preserving agents which soon contaminate the water. Successful cultures were maintained only with fewer than 200 animals in each aquarium.

BURROWS MADE IN THE LABORATORY

Blocks of Douglas Fir exposed to chelurids in the laboratory within two weeks showed evidence of erosion, consisting of a surface furrowing in the soft layers of the wood between the darker and harder annular rings (fig. 1C). The longer the exposure, the deeper and longer the furrows became (figs. 1D, 2E, F). The wood blocks were placed so that the same side always faced the outside light. In each of the experiments the original furrowing started on the darker sides of the block and as the furrows were extended toward the lighter side their increasing depth apparently provided shade for the animals.

After exposure to the chelurids for periods up to 24 months, the furrows were two to three times as deep (5-7 mm) as the height of the animals. Examination of the furrows under a stereomicroscope showed the concave surfaces to be quite smooth.

SELECTIVITY IN BURROWING

The furrows produced by the chelurid populations were made by collective activity rather than individual effort. Ten animals in one experiment were observed daily for 30 days in order to plot their positions in relation to individual furrows. Each animal was recognizable by its size and sex. The movements and positions of each animal for the time period were random, indicating that individual furrows were the result of the browsing action of several chelurids.

CHARACTER OF CHELURID POPULATIONS

Eight Douglas Fir blocks were strung on a weighted rope and submerged beneath the pier at the California Yacht Basin in outer Los Angeles Harbor. One of these blocks was collected every 28 days, preserved in 4% formalin and subsequently dissected with knives and needles and the animals counted. Both *Chelura terebrans* and *Limnoria tripunctata* Menzies (1951) were found in these blocks.

The data presented in fig. 1A shows that *L. tripunctata* invaded the block during the first month of exposure, while *C. terebrans* did not appear until the third month. Fifteen similar experiments, tried at other places in the harbor, showed that in some cases where limnoriid activity was particularly high, up to eight chelurids would be found as early as the first month of exposure. However, no chelurids appeared on the test blocks placed in the inner harbor although at several of these stations limnoriid activity was higher than at some of the stations in the outer harbor where *Chelura* occurred. Chelurids were also found with another limnoriid, *L. quadripunctata* Holthuis (1949).

In all of the induced population experiments, at the first appearance of chelurids, whether in the first or the fourth month of exposure, there were already present from four to twelve times as many limnoriids. The first limnoriids appeared in almost circular burrows, the openings of which led into tunnels lying parallel or slightly oblique to the wood surface. Other adult limnoriids, as well as juveniles hatched from the first migrants, started burrows of their own in or near the openings of the first holes, thus enlarging the size of the original cavities. Increase in the number of burrows resulted in an irregular honeycombing of the area. Partitions between some burrows were paper-thin and roofed-over caverns appeared. It was in these exposed limnoriid galleries that the first chelurids were found.

The first chelurid inhabitants were always adult or sexually mature animals while juvenile animals appeared a month or more later. It was apparent that they were hatched from egg-bearing females of the first population, since they were of the same size as hatched juveniles observed in the laboratory. The effect of this change in character of the early populations (from an entirely adult to a mixed population including juveniles) on the average body length of the animals at each collection is illustrated in fig. 1B.

One may consider two hypotheses concerning migration in chelurids: (1) juvenile chelurids attempting to migrate are unable to survive on the new wood or are subject to predation by other animals; (2) adult chelurids only are subject to migration pressures, possibly in conjunction with mating behaviour. The first hypothesis was tested when fresh wooden blocks were placed within two inches of chelurid infested wood, eliminating any long migration path; but no juveniles appeared until some time after the arrival of the first adults. The facts that more juveniles than adults are present in an established population of chelurids and that juveniles, unlike adults, are small enough to invade individual limnoriid holes are evidence that juvenile chelurids do not migrate. Unfortunately, as the writer has been unable to observe chelurids mating, the second hypothesis must remain unproved. It is possible that migration is a passive result of mating by the chelurids while swimming in the water outside the burrows and that after mating the animals seek a protective niche, which may or may not be the same wood from which they came. Laboratory experiments show that chelurids are unable to return to the wood from which they swim (unless by accident) if they are more than three inches from it. When farther away than this they swim in irregular paths until within three inches of some large, opaque object, toward which they then swim.

CHELURID BURROWS IN NATURE

On test blocks exposed for short periods of time (2-3 months) chelurids are found in the uncovered and abandoned limnoriid tunnels and in the large caverns formed from the combined action of limnoriids. The laboratory experiments show that chelurids, unlike limnoriids, do not bore discrete, circular burrows but engage in a browsing type of erosion resulting in hemicylindrical furrows. This same kind of furrowing is found in nature in the enlarged and unroofed limnoriid burrows, some of which must be produced by chelurid activity. Blocks of wood infested only with limnoriids were dried to kill the gribbles, then introduced into laboratory aquaria containing from 20 to 50 chelurids. Within a month of exposure, many of the discrete limnoriid burrows had been unroofed and interconnected to form furrows.

When chelurids were present in wood collected in the harbor, adults were always found inhabiting the outer tiers of the eroded wood but juveniles often were found in the deepest tiers of limnoriid galleries where adult chelurids were too large to penetrate.

NEED OF CHELURIDS FOR PROTECTED NICHE

The fact that chelurids failed to appear as original infestants of freshly exposed wood led to further experiments to test their need for a protected niche. Fresh blocks of wood were prepared with a series of ⅛ inch wide furrows sawed on all sides. Each of these, along with a smooth block used as a control, was immersed in the California Yacht Basin and collected after an exposure of 40 days. The results of one of these experiments, begun on March 23, 1951, and ended on May 3, 1951, are given below:

	Number of animals infesting blocks	
	Chelura terebrans	*Limnoria tripunctata*
Smooth block	4	165
Grooved block	108	2063

Repeated experiments of this kind showed that the presence of furrows on blocks freshly exposed allowed larger populations of migrant borers to survive than did smooth wood. Thus, we may infer (1) that migration rates are higher than indicated by the smooth block controls, and (2) that few or no chelurids survive the attempt to occupy smooth wood. It is possible that predators such as polychaetes (see Reish, 1954) and fish are responsible for reducing the number of migrating animals. Because limnoriids can excavate a protective niche in wet Douglas Fir within 24 hours (demonstrated in a laboratory experiment) while chelurids may take upwards of four weeks, the gribbles are more successful as first infestants.

ABILITY TO DISTINGUISH TYPES OF BORING

Many environmental factors may affect natural populations of wood borers. Some of these variables are enumerated below:

1. The structure of the wood, depending on the species of tree, softness, and orientation of the grain.
2. Length of exposure of the wood in the water.
3. Presence or absence of preservatives.

4. Location of the wood sample in relation to tidal changes; whether it is periodically exposed to drying.

5. Physicochemical variables of the seawater, such as temperature, salinity, oxygen tension, turbidity, pollutants.

6. The interaction of the species of wood boring animals present in the area under consideration.

7. The effects of other animal and plant species, such as the fouling organisms.

All of these factors enter into the possible appearance and condition of specimens of wood collected in harbors.

Although several writers have claimed ability to recognize woods infested with *Limnoria* only, distinguishing them from those infested with both *Chelura* and *Limnoria*, the writer has often had difficulty in doing this.

Allman (1847, p. 368) stated that "Timber which has been subjected to the ravages of *Chelura* presents a somewhat different appearance from that which has been attacked by *Limnoria*. . . . In the latter we find narrow cylindrical burrows running deep into the interior, while the excavations of *Chelura* are considerably larger and more oblique in their direction, so that the surface of the timber thus undermined by these destructive animals is rapidly washed away by the action of the sea, and the excavations are exposed in the greater part of their extent, the wood appearing ploughed up, so to speak, rather than burrowed into."

In harbor areas one may obtain samples of wood which fit Allman's descriptions. In fig. 2A is a sample of wood bored by limnoriids in which the soft layers of the wood have been deeply eroded; but the hard layers are also riddled with holes and broken off nearly as deeply as the soft layers. The general appearance of the wood is that of a homogeneous accumulation of small subcircular holes; none of the large caverns typical of chelurid-infested wood is seen. In fig. 2C is a sample of wood infested with both limnoriids and chelurids, which shows the large and irregular caverns associated with chelurid activity and occasionally with limnoriid activity alone. This might resemble Allman's description of "ploughed up."

Several simple laboratory experiments were performed under idealized conditions in order to ascertain differences in wood bored by different combinations of animals. Two wooden blocks cut from the same piece of Douglas Fir were placed in separate aquaria and each exposed for four months to an original population of *L. tripunctata.* At the end of four months, when the limnoriids had a good start, twenty chelurids were added to one of the aquaria and the other was kept as a control. After twelve more months of exposure the blocks were examined and were so similar in appearance as to defy any gross differentiation (see figs. 2B, D). Both blocks showed surface troughs "typical" of chelurid action alone, indicating that limnoriids were capable of making these same troughs. However, it must be noted that the limnoriid population in the control block had grown so large that individual animals were seen at the surface of the block. On the chelurid-limnoriid block only chelurids were seen at the surface. It is possible that under idealized laboratory conditions (clean water and lack of predators) the limnoriids had multiplied to such an extent that space was scarce and many were forced to browse at the surface. In nature, the writer has watched heavily infested pieces of wood for as long as 75 minutes without seeing limnoriids moving at the surface.

DEPENDENCE OF CHELURIDS UPON LIMNORIIDS

The general ecological dependence of chelurids on the activities of limnoriids was ably summarized by Yonge (1949, pp. 186-187) : *Chelura* "probably enlarges pre-existing cavities but it is doubtful whether this animal can excavate a burrow unaided by the previous activities of the gribble." It "always lives in the more superficial layers of the wood which have already been honeycombed with the formation of channels and pits in which it can live protected." If one considers *Chelura* in its natural environment, the statements made by Yonge are valid. We have seen that under artificially protected conditions chelurids will excavate their own furrows on smooth wood; but it is assumed that predation would eliminate any of these animals attempting to do this in nature, or that chelurids would reject smooth wood in favor of eroded wood. One must also consider the fact that chelurids are more sensitive to environmental conditions than are limnoriids, as the latter are found in great abundance in certain parts of Los Angeles Harbor unaccompanied by chelurids. This is true in many other harbors, as evidenced by the voluminous data on borers presented in the various Clapp reports (Clapp, 1951-1954). Evidently, the need for a preformed, protected burrow makes *Chelura* dependent on the prior activities of a species of *Limnoria*, but *Chelura* does not always occur where *Limnoria* has established a favorable niche.

Johnson *et alia* (1936, p. 19) suggested in relation to the immunity of hardwood from *Chelura* that it is due to "the size and shape of *Chelura*, and not to a difference in boring ability. Hardwood provides a greater resistance than softwood against crustacean attack, and while the tiny flattened form of *Limnoria* may quickly burrow its way to a safe depth, *Chelura*, under the same circumstances, would normally remain too long exposed to molestation from predatory enemies." Two factors must be considered here: first, that chelurids are restricted not only from hard woods but from smooth, soft woods as well; and second, that the shape of the animal probably has little to do with its boring ability, which is determined by the activity and habits of the borer, by the fact that it is a browsing type of borer rather than by its shape. The rapidity with which *Limnoria* encloses itself in a burrow in a short time as compared with the poorly developed excavations of *Chelura* seems difficult to explain on any other basis than the habit of the limnoriid to provide its own protection. On the other hand, the wood-digestability of limnoriids may be less efficient than that of chelurids and more wood needs to be consumed by the former. The feces of chelurids are darker than those of limnoriids but this may be explained by the fact that chelurids browse on the surface wood which has become darker through the action of the seawater.

One further possibility must be considered: that chelurids might be browsing on microscopic organisms which grow on the wood and the ingestion of woody matter is a consequence of the scraping off of this other food material. Continued exploration of the habits and physiology of both limnoriids and chelurids is needed to answer these questions.

SUMMARY

1. Although *Chelura terebrans* has not been found living in nature in the absence of *Limnoria*, reproducing populations can be cultured separately in the laboratory and maintained at least two years.
2. The browsing, furrowing action on wood of *C. terebrans* contrasts strongly with the progressive tunneling of limnoriids.
3. The inability of *C. terebrans* to excavate a protective burrow in a short time prevents its successful infestation of marine timbers until limnoriids have prepared holes large enough for invasion by adult chelurids.
4. Adult chelurids invade marine timbers first, juvenile animals not appearing until some time later and apparently only as offspring of adults already present.
5. The surface appearance of eroded timber cannot be relied on in all cases to indicate the presence or absence of chelurids.

LITERATURE CITED

ALLMAN, G. J.

1847. On *Chelura terebrans,* Philippi, an amphipodous crustacean destructive to submarine timber-works. Ann. and Mag. Nat. Hist. ser. 1, 19: 361-370, pls. 13, 14.

BARNARD, J. L.

1950. The occurrence of *Chelura terebrans* Philippi in Los Angeles and San Francisco Harbors. Bull. So. Calif. Acad. Sci. 49 (3): 90-97, pls. 32, 33.

1951. The role of *Chelura* in the destruction of marine timbers. Marine Borer Conf., U.S. Navy. Civ. Eng. Res. Eval. Lab., Port Hueneme, Calif., May 10-12, 1951. Rept.: P-1 to P-5.

CLAPP, W. F., Labs., Inc.

1951-1954. Fourth, Fifth, Sixth, Seventh . . . Progress report on marine borer activity in test boards operated during . . . 1950, 1951, 1952, 1953.

HOLTHUIS, L. B.

1949. The Isopoda and Tanaidacea of the Netherlands, including the description of a new species of *Limnoria.* Leyden Rijks. Mus. van Natuurlijke Hist. Zool. Meded. 30 (12): 163-190, 4 text-figs.

JOHNSON, R. A., F. A. MCNEILL, AND T. IREDALE

1936. Destruction of timber by marine organisms in the Port of Sydney. New South Wales. Maritime Services Board Suppl. Rept. No. 1: 99 pp., several text-figs.

MENZIES, R. J.

1951. A new species of *Limnoria* (Crustacea: Isopoda) from Southern California. Bull. So. Calif. Acad. Sci. 50 (2): 86-88, pl. 30.

PHILIPPI, A.

1839. Einige zoologische Notizen. Arch. f. Naturgesch. 5:113-134, pls. 3, 4.

REISH, D. J.

1954. Polychaetous annelids as associates and predators of the crustacean wood borer, Limnoria. Wasmann Jour. Biol. 12 (2): 223-226.

YONGE, C. M.

1949. The Sea Shore. London. 311 pp., 61 color photos., 62 half-tones, 88 text-figs.

PLATE 1

Fig. A. Abundance of chelurids and limnoriids on test blocks suspended in the harbor on Sept. 29, 1951, and retrieved every 28 days thereafter for 7 intervals. California Yacht Harbor.

B. Percentage of adult and juvenile chelurids on the same test blocks as in fig. A. Black portions of the histograms represent adults; clear portions, juveniles. Above the histograms is a curve representing the average length of the animals from each collection.

C. Chelurid furrows after one month of exposure in the laboratory; cross section, x 2.

D. The same furrows as in fig. C after 3 months exposure.

E. Another block of wood exposed to chelurids for five months, showing a different orientation of the grain, x 2.

F. Oblique view of the same chelurid furrows seen in fig. C.

PLATE 2

Fig. A. Limnoriid infested wood from Los Angeles Harbor, x ⅓.

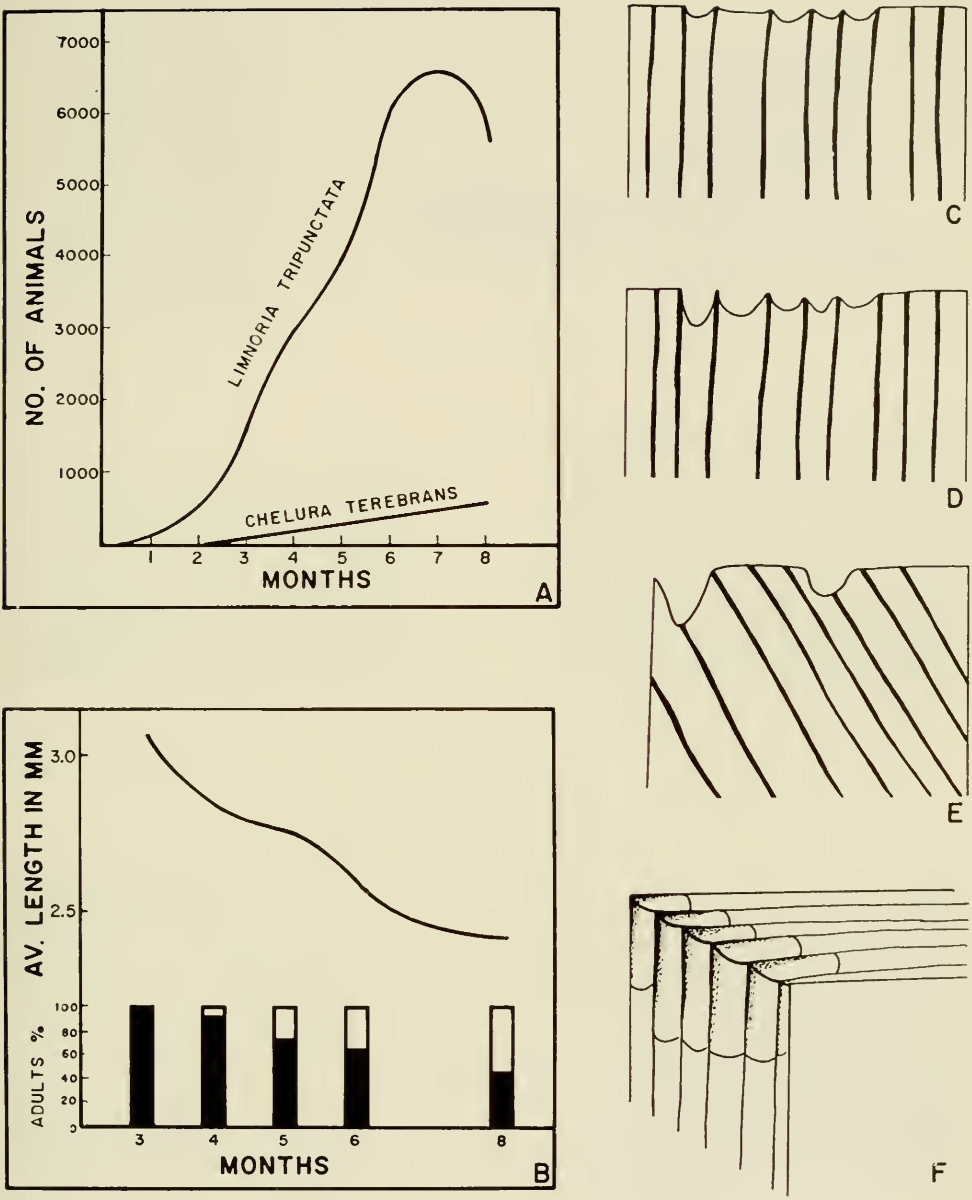
B. Limnoriid infested wood exposed for 16 months in the laboratory, x ½.

C. Limnoriid-chelurid infested wood exposed for 12 months in Los Angeles Harbor, x ⅓.

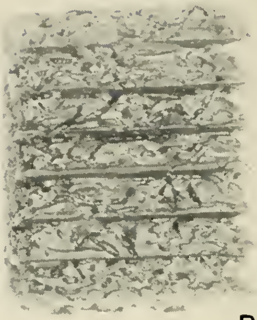
D. Limnoriid-chelurid infested wood exposed for 16 months in the laboratory, x ⅜.

E. Chelurid furrows produced in the laboratory after exposure for three months, x ⅝.

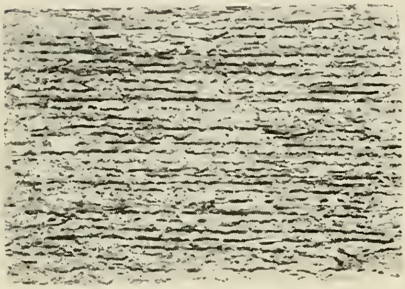
F. Another block with chelurid furrows produced in the laboratory after exposure for three months, x ⅝.


7000
6000
5000
4000
3000
2000
1000
NO. OF ANIMALS
LIMNORIA TRIPUNCTATA
CHELURA TEREBRANS
1
2
3
4
5
6
7
8
MONTHS
A
3.0
2.5
AV. LENGTH IN MM
100
80
60
40
20
0
ADULTS %
3
4
5
6
8
MONTHS
B
C
D
E
F

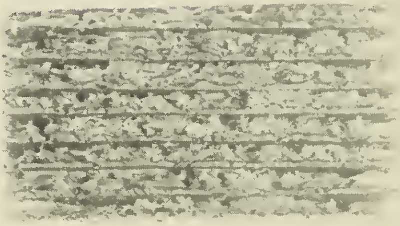
A



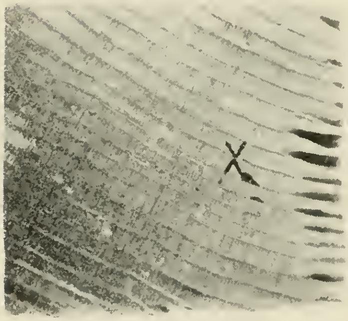
B



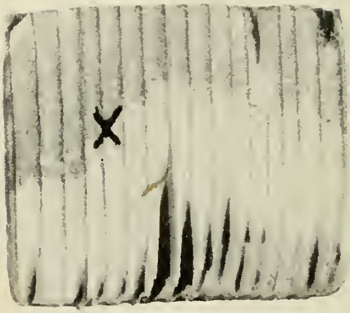
C



D



E



F

CHARTING THE "ENCHANTED ISLES"

By

Joseph R. Slevin

California Academy of Sciences

There can be little doubt that the Galapagos Archipelago or the "Enchanted Isles," as they were called by the Spaniards, is one of the most remarkable spots, speaking from a zoological standpoint, that can be found in this world of ours. For those who are not familiar with the position of this "zoological paradise" made famous by Charles Darwin, who visited it in 1835 as a naturalist with His Britannic Majesty's Ship *Beagle* on its cruise to South America, it can easily be placed by picturing one's self on the coast of Ecuador and then following the equator some 500 miles out to sea. Mount Pitt on Chatham Island, the easternmost one of the group, is 502.5 miles northwest of Marlinspike Rock, Cape San Lorenzo, Ecuador.

The Archipelago consists of some fifteen islands and numerous islets and rocks extending from Latitude 1° 40′ N to 1° 26′ S and from Longitude 89° 16′ 58″ to 92° 1′ W. Albemarle, shaped somewhat like a boot, is the largest of the group, being approximately seventy miles in length and forty five in breadth at the southern end, the widest part. Narborough, James, Indefatigable, Chatham, Charles, Bindloe, Abingdon, Tower and Hood, respectively, are next in size and importance, while the remainder range from islets of a mile or less to mere rocks.

The position of the Galapagos Archipelago was fairly well known to the early navigators. Bishop Tomás de Berlanga, carried there by strong currents while on a voyage from Panama to Peru in 1535, took the latitude and placed the islands between half a degree and a degree and a half south of the equator. He was not far off in his calculations as the main portion of the Archipelago does extend 1° 25′ south of the equator. Early navigators placed the islands about two degrees west of the 80th meridian; but Dampier, one of the buccaneers, claimed they were farther to the west and in this he was correct, for the main portion lies west of the 90th meridian and all of it west of the 89th. Mercator in his "Orbis Terrarum Compendiosa Descriptio" of 1587 represented the Galapagos as a cluster of islets just above the equator and in his Map of the New World, 1622, as just below it. Tatton's map of 1600 showed the Archipelago as just below the equator and Herrar's map of 1601 is practically identical. None of the cartographers seemed to doubt that the islands were on or close to the equator.

The islands appeared on Ortelius' "Theatrum Orbis Terrarum," published at Antwerp in 1570, as *Insulae de los Galopegos* and in his "Peruviae Auriferae Regionis Typus" of 1574 as *Isolas de Galapagos*, represented as one island with two adjacent islets. The Chinese Maps of the World published by the Jesuit Father Matteo Ricci (1584-1608) showed an area labeled "South Seas" with a group of islands in the approximate position of the Galapagos, though no name was given them. After 1570 the islands appeared on many maps of the early cartographers but without names. No attempt was made to attach individual names until William Ambrose Cowley made his chart in 1684.

From a study of Cowley's map, the islands can be properly placed. The large bight on the west coast of Duke of Norfolk Island [Indefatigable] marked "Sandy Beach" is Conway Bay and this gives a fix for Duncan Island, though that island is a little off position. Albemarle and James are decidedly off. Taking this into consideration one can see that Duncan Island is the Sir Anthony Deans* Island of Cowley. His chart located the following islands: The Duke of Albemarle's Island, The Earl of Abingdon's Island, Captain Bindlos's Island, Brattles Island, King Charles's Island, Crossman's Island, Lord Culpeper's Island, Dassigney's Island [Chatham], Sir Anthony Dean's Island [Duncan], Ewres Island [Tower], King James's Island, Sir John Narbrough Island, Duke of Norfolk's Island [Indefatigable], Lord Wenman's Island, Albanie Island, and Cowley's Inchanted Island.

A map printed for H. Moll of London in 1744 entitled "A Map of South America with all the European Settlements and whatever else is remarkable from the latest and best observations" shows the islands in their relative positions and gives the old English names, as does a

---

*A famous shipwright in the reign of King Charles II.

chart by Samuel Dunn printed in 1787 by Laurie and Whittle of London. A chart with no more identifying data than the name "Nueva y Correcta Carta Del Mar Pacifico ó del Sur," dated 1744, shows some twelve islands and uses the old Spanish names, such as Isla de Esperanza, San Clemente, Isabel, Carenero, and María del Aguado. With the exception of Isabel [Albemarle] it is impossible to identify them by comparing them with a modern map. The survey made in 1793 by Captain Alonzo de Torres of the Royal Spanish Armada under orders of the Viceroy of Peru was useless as a navigational chart but added some new names to individual islands, though it is not possible in most cases to attach them correctly. The only ones of which we can be reasonably certain are Isla de Guerra [Culpepper], Isla de Nuñez Gaona [Wenman], and Santa Gertrudis [Albemarle].

In 1793-1794, Captain James Colnett made a chart in which the islands are placed fairly correctly in their relative positions, the first chart that could be considered workable. Arrowsmith of London printed a chart in 1798 based on Colnett's but not nearly so complete, as coastlines were omitted and Indefatigable, which is called Norfolk, is represented as a mere islet. Also he omitted much useful information contained in the original chart, such as places to water, careen ships and gather wood. It is noteworthy that the famous Galapagos "post office" is marked on the original chart though no mention is made of it in Colnett's log.

In the early 1800's, three other charts of the Galapagos were made, apparently the work of Captain Colnett though none was as complete as his first one. All have the same error in the coastline of Albemarle, each one showing a large bight in the southeast corner of the island (the worst feature in Colnett's chart) which, of course, is an error and was corrected in the survey of H. M. S. *Beagle* in 1835. The charts in question are those of Captain Porter of the U. S. Frigate *Essex*, Captain P. Pipon, R. N., of H. M. S. *Tagus*, and Captain John Fyffe of H. M. S. *Indefatigable.* None of them can be said to equal the original chart of Captain Colnett.

It was not until 1835 that a real survey was undertaken by H. M. S. *Beagle* under the command of Captain Robert Fitzroy, R. N. This distinguished officer made a complete survey of the archipelago and produced a good navigational chart that was published by the Hydrographic Office of the Admiralty and used by all countries from the date of the survey until the year 1942, when another survey was made by the U. S. S. *Bowditch.* During the cruise of the *Beagle,* many detailed anchorages were made on the following islands: Albemarle, at Iguana Cove and Tagus Cove; Charles, at Post Office Bay; Chatham, at Freshwater Bay and Tarrapin Road; Hood, at Gardner Bay; James, at Sulivan Bay.

Ships of the Royal Navy going to and homeward bound from their station at Esquimault, B. C., stopped at the Galapagos to look for shipwrecked sailors on its inhospitable shores and took advantage of their visits to plot additional anchorages. In 1846 H. M. S. *Pandora* surveyed Conway Bay, Indefatigable Island, and re-surveyed Post Office Bay, Charles Island, and Freshwater Bay, Chatham Island. Midshipman G. W. P. Edwardes of the *Daphne* made a sketch of Freshwater Bay, showing the difficulties encountered in watering on a rocky coast five miles off a lee shore, with the prevailing winds from the southeast. The British later plotted two more anchorages: Sappho Cove, Chatham Island, by H. M. S. *Sappho,* and Webb Cove, Albemarle Island, by H. M. S. *Cormorant.*

In addition to the islands and islets, there are several rocks which were considered worthy of names, the two outstanding ones being Kicker Rock, off the northern coast of Chatham Island, which has been referred to as "Sleeping Lion" and spoken of many times by Captain Colnett as the "remarkable rock," and Roca Redonda, about fifteen miles off the north point of Albemarle, no doubt so named because of its shape, *redonda* meaning square sail. Both these rocks are pictured on the chart of Captain Pipon. Both Captain Colnett and Captain Porter on the *Essex* had difficulty with the currents setting them too close to Redonda and narrowly escaped hitting it.

The Italian, French and United States navies also participated in mapping the Galapagos. In 1882 and 1885, the Italian corvette *Vettor Pisani* visited Wreck Bay, Chatham Island, and in 1887 Midshipman Estienne of the French corvette *Decrès* plotted an anchorage at Black Beach, Charles Island. In 1909 the U. S. S. *Yorktown* charted Cartago Bay on the east coast of Albemarle and in 1925 a reconnaissance of Darwin Bay, Tower Island, was made by the U. S. S. *Marblehead.* In May, 1932, Captain Garland Rotch of the yacht *Zaca,* while on the Templeton Crocker Expedition of the California Academy of Sciences to the Galapagos Islands, made two sketch surveys of anchorages not yet charted, one on the northeast side of Narborough Island, which he called California Cove, and the other of Academy Bay, Indefatigable Island, locally known as Puerto Presidente Ayora.

The islands, as well as their capes and bays, have for the most part been named after the ships which surveyed them or after people connected with the history of the islands. Indefatigable has also been known as Norfolk Island after the Duke of Norfolk and as Porter's Island after Captain David Porter of the U. S. Frigate *Essex*. It was named Bolivia by Vilamil, who also gave the name of Olmedo to James Island. Nameless Island has been known as Bewel Rock and Isla sin Nombre, while Isla Wolf has been applied to Wenman and Isla Darwin to Culpepper. On Albemarle Island, Bank's Bay was named after Sir Joseph Banks, the famous botanist; Essex Point was named by Captain Porter after his ship, the *Essex*; Tagus Cove, called Bank's Cove by Colnett, was renamed for H. M. S. *Tagus*; Cape Berkeley was so called in honor of the Honorable Captain Berkeley, R. N., and Cape Rose honors the memory of Jean Rose, buccaneer and companion of Edward Davis; while Webb Cove is named after Lieut. G. A. C. Webb, R. N., of H. M. S. *Cormorant*. On James Island, Cowan Bay (sometimes called James Bay) was named by Captain Porter in memory of Lieut. John S. Cowan of the Frigate *Essex*, who was killed in a duel and buried there; and Sulivan Bay is named in honor of Lieut. James Sulivan of H. M. S. *Beagle*. Sappho Cove on Chatham Island is named for the ship which surveyed it, H. M. S. *Sappho*. On Indefatigable Island, Academy Bay is named after the American schooner *Academy*, and Conway Bay after H. M. S. *Conway*.

In 1892 the Republic of Ecuador renamed the Galapagos the "Archipiélago de Colón" in honor of the famed mariner Christopher Columbus, and that is still the official name. The Galapagos Islands seems to be preferred, however, and is more commonly used. Most of the islands also have at least two names. The following list gives the English and Spanish names as they appear on modern charts.

ENGLISH	*NAMED AFTER*	*SPANISH*
Abingdon	Earl of Abingdon	Pinta
Albany		
Albemarle	George Monk, Duke of Albemarle	Isabela
Baltra (South Seymour)		
Barrington	Admiral the Honorable Samuel Barrington, R. N.	Santa Fé
Bartholomew	Lieut. David Ewen Bartholomew, R. N.	Bartolomé
Bindloe	Captain John Bindloe	Marchena
Brattle	Nicholas Brattle	Tortuga
Caldwell	Admiral Caldwell, R. N.	
Champion	Andrew Champion, whaler	
Charles	King Charles II	Santa María, Floreana
Chatham	William Pitt, First Earl of Chatham	San Cristóbal
Cowley	Ambrose Cowley, buccaneer	
Crossman	Richard Crossman	
Culpepper	Lord Culpepper	
Daphne	H. M. S. *Daphne*	
Duncan	Admiral Viscount Duncan, R. N.	Pinzón
Eden		Edén
Enderby	Samuel Enderby, whaler	
Gardner (near Charles)		
Gardner (near Hood)		
Guy Fawkes	Guy Fawkes, the English conspirator	
Hood	Admiral Viscount Samuel Hood, R. N.	Española
Indefatigable	H. M. S. *Indefatigable*	Santa Cruz, Chávez
James	King James II	San Salvador, Santiago
Jervis	Admiral John Jervis, Admiral of the Fleet, R. N.	Rábida
Nameless		Sin Nombre
Narborough	Admiral Sir John Narborough	Fernandina

Onslow		
Seymour (North Seymour)		
Tower		Genovesa
Watson		
Wenman	Lord Wenman	

The last general survey of the Galapagos was made by the U. S. S. *Bowditch* in 1942. In this survey there was at least one major correction, the removal of the well-formed crater on Indefatigable Island, which had appeared on all charts previous to that date. It is now known that it does not exist. Since the islands were used as a military base during World War II, they have been flown over and mapped from the air and the great mountains no longer hold any secrets.

MAP 1

Although the Galapagos appeared as early as 1570 on the charts of Abraham Ortelius, it was not until 1684 on the chart of Ambrose Cowley, the English buccaneer, that any attempt was made to place them in their relative positions and give the islands individual names; so Cowley's chart may be rightly called the first chart of the islands.

MAP 2

The tracing made by Captain Alonzo Torres, of the Spanish Frigate *Santa Gertrudis,* although over one hundred years after Cowley, does not compare with the efforts of the English buccaneer.

MAP 3

The chart used in 1812 by Captain David Porter, of the United States Frigate *Essex,* is practically a replica of the one made in 1793-1794 by Captain James Colnett, of the British ship *Rattler.*

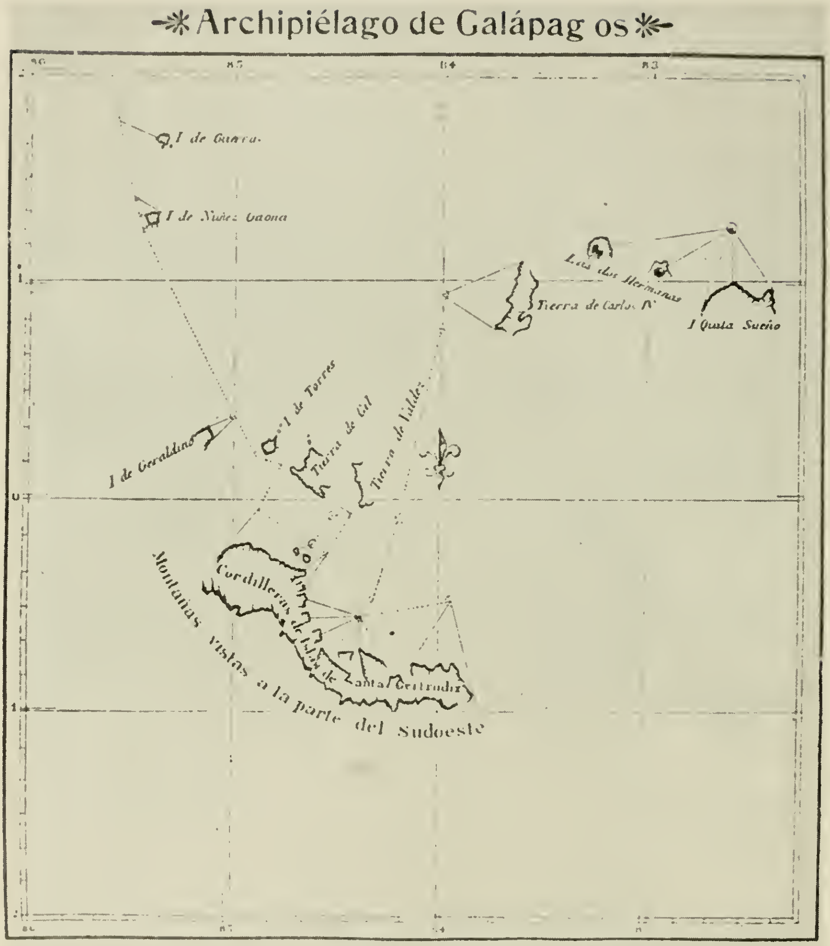
MAP 4

The survey made, in 1835, by His Britannic Majesty's Ship *Beagle* furnished the standard chart of the Galapagos used by maritime nations for over one hundred years, and with the exception of some corrections in elevations is practically the same as that made by the U. S. S. *Bowditch* in 1942. The only striking alteration is the depicting of Indefatigable Island. It is now an established fact that there is no great central crater as shown on the British Chart, the top being composed of numerous volcanic cones and broken-down minor craters.

Map 1

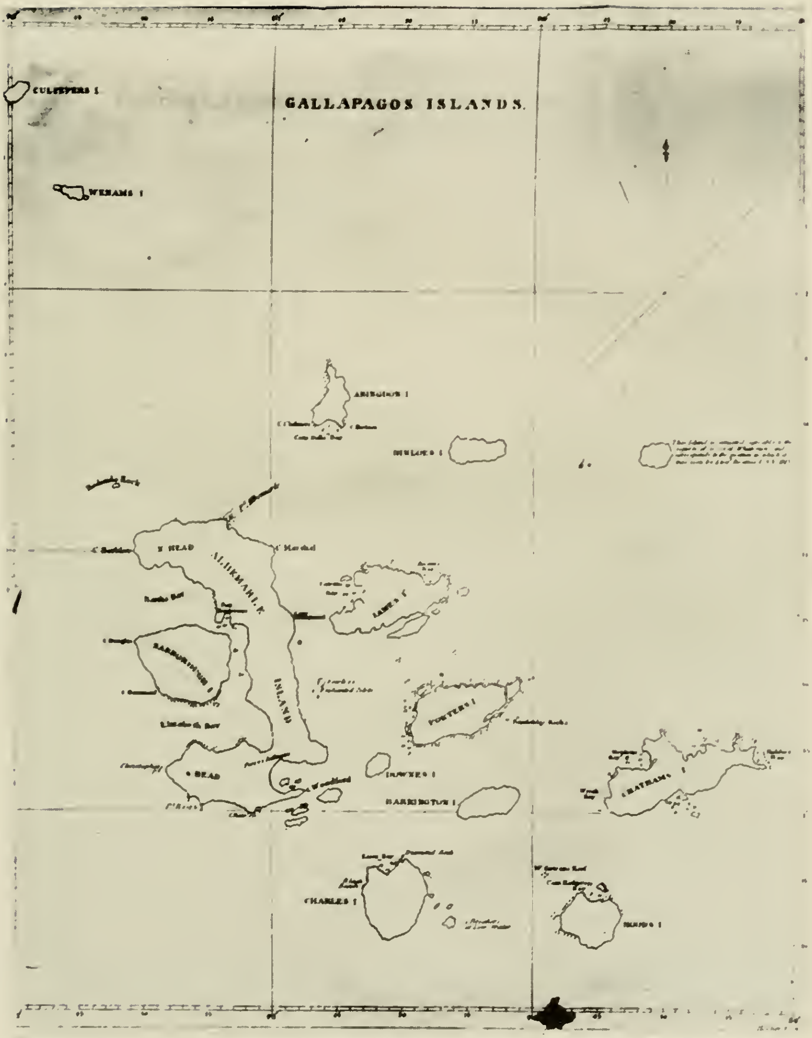

GALLAPAGOS ISLANDS, Described by Ambrose Cowley in 1684
Lord Culpepers Island
Lord Wenmans Island
Dorsey Rocks
THE GREAT SOUTH SEA
Round Rock
Low Bay
EARL of ABINGDONS ISLAND
South Bay
Bindloss Id
Earnes Id
Redondo Rock
Albemarle Pt
Albany Point
York Road
Equinoctial Line
Albany I
Monks Bay
THE DUKE of ALBEMARLE'S I
Cowleys Inchanted Id
King James's Islands
Norfolk Road
Dassigneys Id.
Rock
DUKE of NORFOLK'S ISLAND
Deans Id
Narbrough Id
Elizabeth Bay
Christophers Pt
Brattles Id
Crossmans Id
King Charles's Island
Sta Maria de l'Aguada
Longitude West 84 from the Lizard
Note. The Island Santa Maria de l'Aguada according to its situation from Albemarle Island is added from the Chart published by Mr Arrowsmith

MAP 2

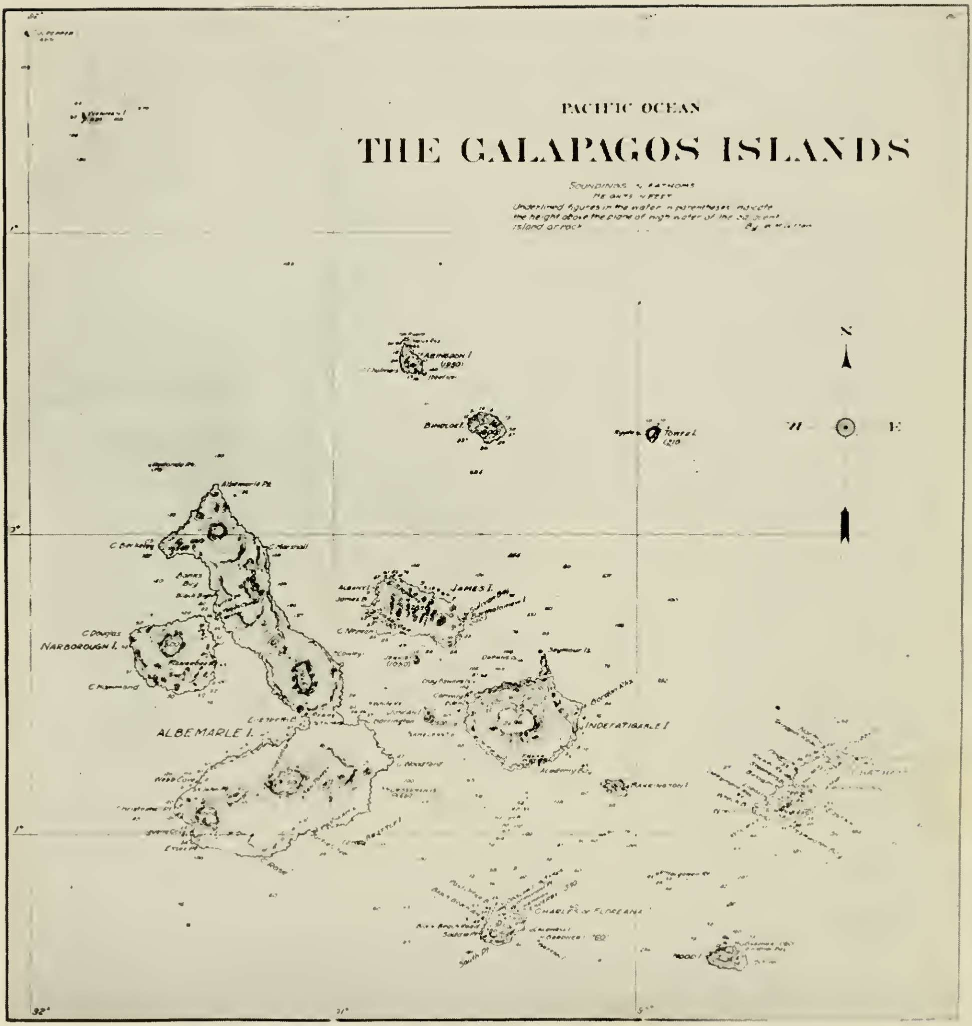


Mapa trazado en 1793 por los marinos españoles de la fragata "Santa Gertrudis".

MAP 3


GALLAPAGOS ISLANDS.
CULPEPERS I
WENAMS I
ABINGDON I
BINDLOES I
C Berkeley
N HEAD
ALBEMARLE ISLAND
C Marshal
Banks Bay
NARBOROUGH I
Elizabeth Bay
S HEAD
JAMES I
PORTERS I
BARRINGTON I
CHATHAMS I
CHARLES I
HOODS I

Map 4


PACIFIC OCEAN
THE GALAPAGOS ISLANDS
Soundings in fathoms
Heights in feet
Underlined figures in the water in parentheses indicate the height above the plane of high water of the adjacent island or rock
Abingdon I.
(1950)
Bindloe I.
Tower I.
(210)
N
W
E
Albemarle Pt.
C. Berkeley
C. Marshall
Banks Bay
Albany I.
James B.
James I.
C. Douglas
Narborough I.
C. Hammond
ALBEMARLE I.
Cowley
Daphne Is.
Seymour Is.
Indefatigable I.
Academy Bay
Barrington I.
Duncan I.
Jervis I.
Post Office Bay
Charles or Floreana
South Pt.
Hood I.
Chatham I.

MARINE MOLLUSKS COLLECTED AT THE GALAPAGOS ISLANDS DURING THE VOYAGE OF THE *VELERO III,* 1931-1932

By

LEO GEORGE HERTLEIN and A. M. STRONG

California Academy of Sciences

INTRODUCTION

The marine mollusks discussed in the present paper were collected by the senior author while a member of the first Expedition of the *Velero III* to the Galapagos Islands in 1931-1932. A general account of the itinerary of this expedition may be found in a paper by Fraser (1943, pp. 50, 260, 262, 272-273). Collections were assembled during December and January at ten localities representing seven islands: Albemarle, Charles, Chatham, Indefatigable, James, South Seymour and Tower. Nearly all the specimens were taken along the beaches or in very shallow water. A number of expeditions to the Galapagos Islands have collected chiefly the larger marine shells; therefore, during the present expedition, special efforts were made to obtain small forms in order to increase the knowledge concerning that portion of the molluscan fauna occurring in the islands.

Preliminary identifications of the species represented in this collection were made by the junior author shortly after the return of the expedition, but other duties led to delay in the completion of the report for publication. Several papers dealing with other portions of the collections assembled during the expedition have been published. One by the senior author dealing with the marine mollusks taken at Malpelo and Cocos Islands was published in 1932, and a report by Hanna & Hertlein on the non-marine mollusks of Cocos Island appeared in 1938. Pliocene fossils collected at Port San Bartolomé (Turtle Bay), Lower California, during a brief stop there by the expedition, were discussed in a paper by the senior author in 1933. A paper by the present authors dealing with mollusks collected in Panamanian waters was published in 1938, and one concerned with fossil mollusks of Pleistocene age taken at the Galapagos Islands during this expedition appeared in 1939. References to these papers can be found in the bibliography accompanying the present work.

ACKNOWLEDGMENTS

The senior author wishes to express his appreciation to Captain G. Allan Hancock for the privilege of accompanying the expedition which afforded opportunity to assemble the present collection. This voyage and the assembling of collections were made under most pleasant circumstances, further enhanced by the hearty cooperation of the entire crew of the *Velero III*. Special thanks are due Dr. John S. Garth of the Allan Hancock Foundation, Mr. Karl Koch and Mr. C. B. Perkins of the San Diego Zoological Society, and Mr. George Stone, photographer with the expedition, for their aid at various times in collecting specimens. Dr. A. Myra Keen, Department of Geology, Stanford University, aided in the identification of the species of Vermetidae and some of the species of small pelecypods cited in this paper. Special acknowledgment is due Dr. G. D. Hanna, Curator of the Department of Geology, California Academy of Sciences, who prepared the photographs used to illustrate the species represented on the plate, and who also aided in the identification of the species of *Terebra*.

BRIEF REVIEW OF EARLIER LITERATURE

The early mariners who reached the Galapagos Islands apparently gave but little attention to the interesting mollusks which occur there. Colnett (1798, p. 57), who arrived at the islands in 1793, mentioned the occurrence of ". . . a few small wilks and winkles. A large quantity of dead shells, of various kinds, were washed upon the beach; all of which were familiar to me."

Hugh Cuming, on his boat "Discoverer," collected extensively along the west coast of South America and north to the Gulf of Fonseca in Central America. During this work, he visited the Galapagos Islands, apparently between 1827-1829 (see Carpenter, 1857, pp. 179-180; Howell, 1941), where he assembled a collection of shells. Most of these were described over a period of years, beginning about 1832, by Broderip, the Sowerbys, Reeve, Deshayes, H. & A. Adams, and others.

The first comprehensive list of molluscan species from the islands was compiled by Carpenter (1857, pp. 359-361). Twenty years later, E. A. Smith (1877) reported on a collection of shells taken at the islands by Commander Cookson of the "Peterel." Two years later, a list of shells collected by Simeon Habel was published by Wimmer in 1879. Stearns (1893), in a comprehensive paper containing a review of the earlier works dealing with the conchology of the Galapagos Islands, cited the species (288 species and 30 varieties) known to occur there and described four new marine species and one new land snail. A brief paper by Pilsbry & Vanatta (1902) contained the results of a study of the shells collected by the Hopkins Stanford Galapagos Expedition of 1898-1899. Many species dredged by the "Albatross" in deep water about the islands were described in papers by Dall, especially in one which appeared in 1908, and numerous species were recorded occurring in the archipelago in his paper on Peruvian mollusks in 1909. Many of the microscopic gastropods occurring in the islands were described in various papers by Dall and Bartsch. Tomlin (1927-1928) recorded the mollusca collected by James Hornell in 1924 at five of the islands in the Galapagos group during brief stops there by the "St. George" Expedition. Marine shells collected in the islands in 1925 by Alf Wollebaek, Director of the Zoological Museum, Oslo, Norway, were reported upon by Soot-Ryen in 1932. Later, lists of species taken in the islands appeared in papers by Schwengel (1938) and by Bartsch & Rehder (1939).

COLLECTING STATIONS AT THE GALAPAGOS ISLANDS

Loc. 27221 (C.A.S.). Black Bight (Caleta Black) about a mile west of Tagus Cove at the south end of Banks Bay, Albemarle Island, on black sandy beach. L. G. Hertlein, coll., January 5, 1932.

Loc. 27222 (C.A.S.). Caleta Buccaneer [Buccaneer Cove] just east of Cabo Cowan, which forms the eastern promontory of James Bay, James Island. L. G. Hertlein, coll., January 9, 1932.

Loc. 27227 (C.A.S.). Anchorage off Bassa Point, Chatham Island. L. G. Hertlein, coll., December 31, 1931.

Loc. 27231 (C.A.S.). Darwin Bay, Tower Island. L. G. Hertlein, coll., January 19-24, 1932.

Loc. 27232 (C.A.S.). Conway Bay, Indefatigable Island. L. G. Hertlein, coll., January 12-13, 1932.

Loc. 27233 (C.A.S.). Beach near lagoon near point east of Postoffice Bay, Charles Island. L. G. Hertlein, coll. January 2, 1932.

Loc. 27238 (C.A.S.). Landing at Black Beach near tortoise pen, Charles Island. L. G. Hertlein, coll., January 2, 1932.

Loc. 27244 (C.A.S.). Postoffice Bay, Charles Island. L. G. Hertlein, coll., January 2-3, 1932.

Loc. 27248 (C.A.S.). Freshwater Bay, Chatham Island. L. G. Hertlein, coll., December 31, 1931.

Loc. 27255A (C.A.S.). Beach along west side of South Seymour Island. L. G. Hertlein, coll., January 14, 1932.

LIST OF SPECIES

An asterisk (*) indicates that the Galapagos Islands are the type locality or one of the localities cited for the species at the time of original description. The symbol "†" indicates that the species or subspecies is here recorded in the Recent fauna of the Galapagos Islands for the first time or that specimens in this collection formed the basis of such a record in an earlier publication by the present authors.

PELECYPODA

Antigona (Periglypta) multicostata (Sowerby)
**Apolymetis cognata* (Pilsbry & Vanatta)
Arca (Acar) gradata Broderip & Sowerby
†*Arca (Arca) pacifica* (Sowerby)
Arca (Barbatia) reeveana d'Orbigny
Arca (Arcopsis) solida (Sowerby)
†*Basterotia peninsularis* (E. K. Jordan)
**Brachidontes (Hormomya) multiformis houstonius* Bartsch & Rehder
Cardita megastropha (Gray)
Cardium (Laevicardium) elenense Sowerby
Cardium (Trachycardium) consors Sowerby
Chama frondosa mexicana Carpenter
Chama squamuligera Pilsbry & Lowe
**Chione pertincta* Dall
Chione undatella (Sowerby)
**Ctena galapagana* (Dall)
Ctena mexicana (Dall)
†*Diplodonta (Phlyctiderma) caelata* (Reeve)
Diplodonta subquadrata Carpenter
**Divaricella lucasana* Dall & Ochsner
†*Glycymeris (Axinactis) inaequalis* (Sowerby)
†*Gouldia californica* Dall
Isognomon chemnitzianum (d'Orbigny)

†*Kellia suborbicularis* (Montagu)
†*Lasaea petitiana* (Recluz)
Lima pacifica d'Orbigny
Modiolus capax (Conrad)
†*Nuculana (Saccella) elenensis* (Sowerby)
Ostrea palmula Carpenter
†*Pecten (Chlamys) lowei* Hertlein
†*Pitar consanguineus* (C. B. Adams)
†*Semele corrugata* (Sowerby)
**Semele punctata* (Sowerby)
**Semele (Elegantula) rupium* (Sowerby)
†*Tellina (Moerella) amianta* Dall
†*Tellina (Elliptotellina) pacifica* Dall
Tellina sp.
†**Transennella galapagana* Hertlein & Strong

GASTROPODA

Acanthina grandis (Gray in Sowerby)
Acmaea filosa Carpenter
Acmaea mitella Menke
Acmaea sp.
†*Alaba supralirata* (Carpenter)
**Alvania galapagensis* Bartsch
**Alvania halia* Bartsch
**Alvania lara* Bartsch
Alvania sp.
**Anachis atramentaria* (Sowerby)
**Anachis incerta* (Stearns)
**Balcis (Balcis) ochsneri* (Bartsch)
†*Balcis (Balcis) panamensis* (Bartsch)
†*Balcis (Vitreolina)* cf. *B. (V.) adamantina* (de Folin)
†*Balcis (Vitreolina) falcata* (Carpenter)
Bulla punctulata A. Adams
**Caducifer cinis* (Reeve)
†*Caecum firmatum* C. B. Adams
Calliostoma sp.
**Cancellaria haemastoma* Sowerby
Cantharus sanguinolentus (Duclos)
Cassis (Cypraecassis) tenuis Wood
**Cerithiopsis curtata* Bartsch
†*Cerithiopsis eiseni* Strong & Hertlein
Cerithiopsis sp.
Cerithiopsis sp.
Cerithium adustum Kiener
Cerithium uncinatum (Gmelin)
Cheilea equestris (Linnaeus)
†*Clathurella trichodes* (Dall)
Conus brunneus Wood
Conus fergusoni Sowerby
Conus lucidus Wood
**Conus nux* Broderip
Conus purpurascens Broderip
**Conus tiaratus* Broderip
Crepidula aculeata (Gmelin)
Crepidula arenata (Broderip)
Crepidula onyx Sowerby
Crucibulum imbricatum (Sowerby)
Cymatium costatum (Born)
**Cymatium lineatum* (Broderip)

Cymatium vestitum (Hinds)
*_Cymatosyrinx testudinis_ (Pilsbry & Vanatta)
Cypraea nigropunctata Gray
†_Cypraeolina margaritula_ (Carpenter)
*_Daphnella thalia_ Schwengel
*_Diodora inaequalis_ (Sowerby)
†_Diodora_ cf. _D. panamensis_ (Sowerby)
*_Engina earlyi_ Bartsch & Rehder
*_Engina maura_ (Sowerby)
*_Engina pyrostoma_ (Sowerby)
†_Engina rufonotata_ (Carpenter)
*_Epitonium (Asperoscala)_ cf. _E. (A.) emydoneus_ Dall
Epitonium sp.
*_Erato marginata galapagensis_ (Schilder)
Fasciolaria princeps Sowerby
*_Fissurella obscura_ Sowerby
*_Fissurella rugosa_ Sowerby
†_Fossarus abjectus_ (C. B. Adams)
†_Fossarus angiostomus_ (C. B. Adams)
Fossarus sp.
†_Haminoea_ sp.
†_Heliacus planispira_ Pilsbry & Lowe
Hipponix antiquatus (Linnaeus)
*_Hipponix grayanus_ Menke
Hipponix pilosus (Deshayes)
*_Latirus tuberculatus_ (Broderip)
*_Latirus varicosus_ (Reeve)
†_Lucapinella callomarginata_ (Carpenter in Dall)
Malea ringens (Swainson)
†_Mangelia melanosticta_ Pilsbry & Lowe
†_Macromphalina souverbiei_ (de Folin)
Marginella (Cystiscus) minor C. B. Adams
†_Marginella (Cystiscus) polita_ Carpenter
†_Marginella (Cystiscus) regularis_ Carpenter
Marginella (Hyalina) californica Tomlin
Marginella (Persicula) phrygia Sowerby
†_Metaxia convexa_ (Carpenter)
Microcithara uncinata (Sowerby)
*_Mitra effusa_ Swainson in Broderip
*_Mitra gratiosa_ Reeve
Mitra (Strigatella) tristis Swainson in Broderip
*_Mitrella ocellata baileyi_ (Bartsch & Rehder)
Modulus cerodes A. Adams
*_Monilispira ochsneri_ Hertlein & Strong
*_Morum tuberculosum_ (Sowerby in Reeve)
Murex (Muricanthus) princeps Broderip
*_Nassarius nodicinctus_ (A. Adams)
Neosimnia aequalis (Sowerby)
Nerita funiculata Menke
Nerita scabricosta ornata Sowerby
*_Ocenebra parva_ (E. A. Smith)
†_Odostomia (Chrysallida) excelsa_ Dall & Bartsch
†_Odostomia (Chrysallida) rinella_ Dall & Bartsch
*_Odostomia (Miralda) galapagensis_ Dall & Bartsch
Odostomia (Miralda) sp.
Olivella gracilis (Broderip & Sowerby)
Pedipes angulatus C. B. Adams
Phyllocoma scalariformis (Broderip)
†_Polinices caprae_ (Philippi)
Polinices uber (Valenciennes)
†_Pyramidella (Pharcidella)_ cf. _P. (P.) panamensis_ Dall & Bartsch

†*Pyramidella (Triptychus) olssoni* Bartsch
Pyrene castanea (Sowerby)
Pyrene fuscata (Sowerby)
**Pyrene haemastoma* (Sowerby)
†*Pyrene lucasana* (Dall)
**Rissoina dina* Bartsch
†*Rissoina* cf. *R. laurae* (de Folin)
†*Rissoina signae* Bartsch
†*Seila assimillata* (C. B. Adams)
Serpulorbis margaritarum (Valenciennes)
Strombus granulatus Swainson
†*Sulcoretusa luticola* (C. B. Adams)
**Tectarius galapagiensis* (Stearns)
**Tegula cooksoni* (E. A. Smith)
**Tegula snodgrassi* (Pilsbry & Vanatta)
**Terebra albemarlensis* Dall & Ochsner
Thais callaoensis (Gray)
Thais columellaris (Lamarck)
Thais (Vasula) melones (Duclos)
Thais patula pansa (Gould)
Thais planospira (Lamarck)
Thais speciosa (Valenciennes)
**Tralia vanderbilti* Schwengel
†*Tricolia perforata* (Philippi)
**Triphora galapagensis* Bartsch
**Trivia fusca* (Gray in Sowerby)
**Trivia maugeriae* (Gray in Sowerby)
**Trivia pacifica* (Gray in Sowerby)
**Turbonilla (Chemnitzia) houseri* Dall & Bartsch
**Vanikoro galapagana* Hertlein & Strong
Vermetus cf. *V. complicatus* (Dall)
†*Vermicularia pellucida eburnea* (Reeve)
**Williamia galapagana* Dall

The temperature of the surface waters about the Galapagos Islands varies greatly at times. Records show variation of from 66°F. to 86°F. These differences in temperature are due chiefly to the influences of the various currents, the warm south Equatorial Current and Equatorial Countercurrent, and the cool Humboldt Current. Although at times the waters are quite cool for equatorial latitudes, their general condition is decidedly warm, as indicated by the presence of tropical and subtropical genera and subgenera of mollusks such as *Antigona* (*Periglypta*), *Arca* (*Arca*), *Cassis* (*Cypraecassis*), large *Conus*, large *Fasciolaria*, *Morum*, *Murex* (*Muricanthus*), *Strombus*.

The present list is comprised of 164 species and subspecies, 37 pelecypods and 127 gastropods. The identifications of six of these are uncertain but they are compared to known species. In addition to the foregoing, ten species are present which, because of their imperfect preservation or for other reasons, are cited as to genera only. Among these is one genus (*Haminoea*) here recorded from the islands for the first time.

Fifty-five species and subspecies in this list were originally described from the Galapagos Islands and 29, at the present time, are not known to occur elsewhere. Forty-five species in this collection are recorded in the Recent fauna of the Galapagos Islands for the first time in this paper or in other publications by the present authors.

Five of the 164 species are wide-ranging cosmopolitan forms occurring in warm marine waters in widely separated regions. The species in the present collection represent only a portion of the total molluscan fauna of the Galapagos Islands, but the predominantly Panamic character is revealed by the occurrence of 130 of these species in the waters of the Panamic province, with 100 occurring as far north as the Gulf of California. In contrast to this, only ten species occur in the waters of southern California, and an equal number have been recorded as occurring in the cooler Peruvian waters south of Punta Aguja. Omitting the cosmopolitan forms, we have only eight species ranging north or south of tropical or subtropical west American waters. Many of the species in the present collection are known to occur also as fossils of Pleistocene age in the archipelago. The comparatively short and shallow expanses of waters separating the islands, as well as the strong local currents, furnish favorable conditions for the distribution of marine species of mollusks. No definite conclusions concerning distribution of species among the various islands are drawn from a study of the present limited collection.

ANNOTATED LIST OF SPECIES

CLASS PELECYPODA

Family Nuculanidae

Nuculana (*Saccella*) *elenensis* (Sowerby)

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 2 valves.

Family Arcidae

Arca (*Arca*) *pacifica* (Sowerby)

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 1 valve.

Arca (*Barbatia*) *reeveana* d'Orbigny

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 18 valves; Tower Island, Loc. 27231 (C.A.S.), 5 valves; Indefatigable Island, Loc. 27232 (C.A.S.), 25 young valves; Charles Island, Loc. 27233 (C.A.S.), 14 valves; James Island, Loc. 27244 (C.A.S.), 1 valve; South Seymour Island, Loc. 27255A (C.A.S.), 8 valves.

Arca (*Acar*) *gradata* Broderip & Sowerby

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 20 valves; Chatham Island, Loc. 27227 (C.A.S.), 4 valves; Indefatigable Island, Loc. 27232 (C.A.S.), 25 specimens; Charles Island, Loc. 27233 (C.A.S.), 4 valves, also Loc. 27238 (C.A.S.), 2 valves. South Seymour Island, Loc. 27255A (C.A.S.), 7 valves.

Arca (*Arcopsis*) *solida* (Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 26 valves; Indefatigable Island, Loc. 27232 (C.A.S.), 40 valves; South Seymour Island, Loc. 27255A (C.A.S.), 3 valves.

Family Glycymeridae

Glycymeris (*Axinactis*) *inaequalis* (Sowerby)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 valve.

Family Isognomonidae

Isognomon chemnitzianum (d'Orbigny)

Localities: Indefatigable Island, Loc. 27232 (C.A.S.), 16 specimens; Tower Island, Loc. 27231 (C.A.S.), 6 specimens.

Family Ostreidae

Ostrea palmula Carpenter

Locality: Albemarle Island, Loc. 27221 (C.A.S.), several badly worn valves.

Ostrea mexicana Sowerby is identical with this species. It has been recorded from the islands under that name by earlier authors.

Pecten (*Chlamys*) *lowei* Hertlein

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 1 valve.

Family Limidae

Lima pacifica d'Orbigny

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 valves.

Family Mytilidae

Brachidontes (*Hormomya*) *multiformis houstonius* Bartsch & Rehder

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 18 valves; Tower Island, Loc. 27231 (C.A.S.), 6 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 10 specimens (both valves together) and a number of single valves.

Modiolus capax (Conrad)

Locality: South Seymour Island, Loc. 27255A (C.A.S.), 1 specimen.

Family Carditidae

Cardita megastropha (Gray)

Plate A, Fig. 13

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 1 valve; Tower

Island, Loc. 27231 (C.A.S.), 1 valve; South Seymour Island, Loc. 27255A (C.A.S.), 1 valve.

Family Chamidae

Chama squamuligera Pilsbry & Lowe

Locality: Tower Island, Loc. 27231 (C.A.S.), 9 specimens.

Chama frondosa mexicana Carpenter

Locality: Tower Island, Loc. 27231 (C.A.S.), 9 valves.

This species was cited from Tagus Cove, Albemarle Island, by Pilsbry & Vanatta (1902, p. 551) under the name of *Chama frondosa purpurascens* Conrad.

Family Diplodontidae

Diplodonta (*Phlyctiderma*) *caelata* (Reeve)

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 1 valve.

A single small valve appears to be referable to this species.

Diplodonta subquadrata Carpenter

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 4 valves.

Family Lucinidae

Ctena galapagana (Dall)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 25 valves; Chatham Island, Loc. 27227 (C.A.S.), 3 valves; Indefatigable Island, Loc. 27232 (C.A.S.), 4 valves; Charles Island, Loc. 27238 (C.A.S.), 1 valve; South Seymour Island, Loc. 27255A (C.A.S.), 1 valve.

The largest specimen in the present collection from Tagus Cove, Albemarle Island, measures: length, 30.8 mm.; height, 28.6 mm.

Ctena mexicana (Dall)

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 3 small valves.

Divaricella lucasana Dall & Ochsner

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 2 valves.

Family Leptonidae

Kellia suborbicularis (Montagu)

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), about 50 specimens.

Lasaea petitiana (Recluz)

Locality: Tower Island, Loc. 27231 (C.A.S.), 3 specimens (both valves together) and several single valves.

Family Sportellidae

Basterotia peninsularis (E. K. Jordan)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 10 valves; Tower Island, Loc. 27231 (C.A.S.), 1 valve.

Family Cardiidae

Cardium (*Laevicardium*) *elenense* Sowerby

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 7 valves; Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens (both valves together) and a number of young valves; South Seymour Island, Loc. 27255A (C.A.S.), 1 specimen.

Cardium (*Trachycardium*) *consors* Sowerby

Locality: South Seymour Island, Loc. 27255A (C.A.S.), 1 valve.

Family Veneridae

Antigona (*Periglypta*) *multicostata* (Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 2 valves; South Seymour Island, Loc. 27255A (C.A.S.), 3 valves.

Pitar consanguineus (C. B. Adams)

Localities: Indefatigable Island, Loc. 27232 (C.A.S.), 1 valve; South Seymour Island, Loc. 27255A (C.A.S.), 1 valve.

Chione pertincta Dall

Plate A, Fig. 11

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 34 valves.

Chione undatella (Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 7 valves; South Seymour Island, Loc. 27255A (C.A.S.), 8 valves.

Gouldia californica Dall

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 5 valves.

Transennella galapagana Hertlein & Strong

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), several hundred specimens.

Family Tellinidae

Tellina (*Moerella*) *amianta* Dall

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 10 specimens (both valves together) and 30 single valves.

The present specimens are juvenile shells which closely resemble *Tellina amianta* Dall.

Tellina (*Elliptotellina*) *pacifica* Dall

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 4 specimens (both valves together) and 25 single valves.

Tellina sp.

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 5 valves.

Apolymetis cognata (Pilsbry & Vanatta)

Plate A, Figs. 14, 15, 16

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 24 valves.

Family Semelidae

Semele corrugata (Sowerby)

Locality: South Seymour Island, Loc. 27255A (C.A.S.), 1 valve.

Semele punctata (Sowerby)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 valve.

Semele (*Elegantula*) *rupium* (Sowerby)

Amphidesma rupium Sowerby, Conch. Illustr., *Amphidesma,* Cat.

issued with part 19, sp. No. 12, pl. 19, figs. 10, 10,* issued between January 18 and March 8, 1833. "Lord Hood's Island. var. f. 10* Galapagos Islands. Mr. Cuming."—Sowerby, Proc. Zool. Soc. London for 1832, p. 199, issued March 13, 1833. "Hab. in Oceano Pacifico." "Found in coarse gravel in the crevices of rocks in coral reefs at Lord Hood's Island. A variety which is white all over, both inside and out, occurs in clefts of rocks and in coarse gravel at the Gallapagos Islands."—Reeve, Conch. Icon., Vol. 8, *Amphidesma*, sp. 9, pl. 2, fig. 9, 1853. "Hab. Lord Hood's and Galapagos Islands, Pacific Ocean (in the crevices of rocks and coral reefs) ; Cuming."

Semele floreanensis Soot-Ryen, Nyt. Mag. Naturvid., Bd. 70 (Medd. Zool. Mus., Oslo, No. 27), p. 322, pl. 2, figs. 11, 12. April 30, 1932. Floreana (Santa Maria; Charles) Island, Galapagos Islands.

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 valves.

Semele crenata originally described from Moreton Bay, Australia, was compared with the present species by Adams & Angas (Proc. Zool. Soc. London for 1863, p. 426, issued April, 1864).

CLASS GASTROPODA

Family Cavoliniidae

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Family Scaphandridae

Sulcoretusa luticola (C. B. Adams)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Family Bullidae

Bulla punctulata A. Adams

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 12 adult and many young specimens; Chatham Island, Loc. 27227 (C.A.S.), 1 specimen; Charles Island, Loc. 27233 (C.A.S.), 2 specimens; South Seymour Island, Loc. 27255A (C.A.S.), 3 specimens.

Family Akeridae

Haminoea sp.

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 very young specimen.

This is the first record of the occurrence of this genus at the Galapagos Islands.

Family Ellobiidae

Pedipes angulatus C. B. Adams

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 27 specimens; Tower Island, Loc. 27231 (C.A.S.), 4 specimens.

Tralia vanderbilti Schwengel

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 14 specimens.

Family Siphonariidae

Williamia galapagana Dall

Williamia galapagana Dall, Proc. Calif. Acad. Sci., 4th Ser., Vol. 2, Pt. 1, No. 11, p. 382, December 31, 1917. "Station on floating seaweed at the Galapagos Islands; specimens collected on the beach at Hood and Chatham Islands."—Dall & Ochsner, Proc. Calif. Acad. Sci., 4th Ser., Vol. 17, No. 5, p. 179, 1928.—Hubendick, Kungl. Svensk. Vetenskapsakad., Handl., Ser. 3, Bd. 23, No. 5, p. 72, 1946.

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 20 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens.

Family Terebridae

Terebra albemarlensis Dall & Ochsner

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 4 specimens.

Family Conidae

Conus brunneus Wood

Localities: Chatham Island, Loc. 27227 (C.A.S.), 2 specimens; Charles Island, Loc. 27233 (C.A.S.), 1 specimen.

Conus fergusoni Sowerby

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Conus lucidus Wood

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Conus nux Broderip

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 4 specimens.

Conus purpurascens Broderip

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 11 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen; Charles Island, Loc. 27244 (C.A.S.), 8 specimens, and Loc. 27238 (C.A.S.), 4 specimens; James Island, Loc. 27222 (C.A.S.), 2 specimens; South Seymour Island, Loc. 27255A (C.A.S.), 4 specimens.

Conus tiaratus Broderip

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 7 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen; Charles Island, Loc. 27233 (C.A.S.), 11 specimens.

Family Turridae

Monilispira ochsneri Hertlein & Strong

Plate A, Fig. 8

Monilispira ochsneri Hertlein & Strong, Nautilus, Vol. 62, No. 3, p. 102, January (issued March 18), 1949. Type "from Chatham Island, Galapagos Islands." A new name for *Pleurotoma bicolor* Sowerby, 1834, not *Pleurotoma bicolor* Risso, 1826.

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 12 specimens.

Cymatosyrinx testudinis (Pilsbry & Vanatta)

Pleurotoma testudinis Pilsbry & Vanatta, Nautilus, Vol. 36, No. 4, p. 132, April, 1923. A new name for *Pleurotoma roseobasis* Pilsbry & Vanatta, 1902, not *Pleurotoma* (*Drillia*) *roseobasis* E. A. Smith, 1888; *Pleurotoma roseotincta* Dall, 1923, not *Pleurotoma* (*Clathurella*) *roseotincta* Montrouzier, 1872.

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens.

Clathurella trichodes (Dall)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen; Tower Island, Loc. 27231 (C.A.S.), 5 specimens.

Mangelia melanosticta Pilsbry & Lowe

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 100 specimens; Tower Island, Loc. 27231 (C.A.S.), 30 specimens.

Daphnella thalia Schwengel

Daphnella thalia Schwengel, Proc. Acad. Nat. Sci. Philadelphia, Vol. 90, p. 2, fig. 2, May 13, 1938. From "Wreck Bay, Chatham Island."

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

A single specimen, somewhat worn, appears to be referable to this species.

Family Cancellariidae

Cancellaria haemastoma Sowerby

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 8 specimens.

Family Olividae

Olivella gracilis (Broderip & Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 6 specimens.

Family Marginellidae

Marginella (*Hyalina*) *californica* Tomlin

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 15 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 10 specimens.

Marginella (*Persicula*) *phrygia* Sowerby

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens.

Marginella (*Cystiscus*) *minor* C. B. Adams

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 40 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 15 specimens.

Marginella (*Cystiscus*) *polita* Carpenter

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 6 specimens; Tower Island, Loc. 27231 (C.A.S.), 11 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 20 specimens.

Marginella (*Cystiscus*) *regularis* Carpenter

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 23 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen.

Cypraeolina margaritula (Carpenter)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 6 specimens; Tower Island, Loc. 27231 (C.A.S.), 15 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 20 specimens.

Family Mitridae

Mitra effusa Swainson in Broderip

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens.

Mitra gratiosa Reeve

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 12 specimens.

Mitra (*Strigatella*) *tristis* Swainson in Broderip

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 26 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens.

Family Fasciolariidae

Fasciolaria princeps Sowerby

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Latirus tuberculatus (Broderip)

Plate A, Fig. 1

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens; Tower Island, Loc. 27231 (C.A.S.), 3 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 1 specimen.

Compared to *Latirus ceratus* (Wood), the shell of the present species has a lower spire and the nodes on the angulation of the body whorl are bluish-black rather than white.

Latirus varicosus (Reeve)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 small worn specimen.

Family Buccinidae

Cantharus sanguinolentus (Duclos)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens; Chatham Island, Loc. 27227 (C.A.S.), 1 specimen; Tower Island, Loc. 27231 (C.A.S.), 3 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 1 specimen.

The genus *Gemophos* with the type *Buccinum gemmatum* Reeve was proposed recently by Olsson & Harbison (Acad. Nat. Sci. Philadelphia, Monogr. No. 8, p. 225, 1953) to include many west American and Caribbean species formerly assigned to the genus *Cantharus*.

Engina earlyi Bartsch & Rehder

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 2 specimens.

Engina maura (Sowerby)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 5 specimens.

Engina pyrostoma (Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 10 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen.

Engina rufonotata (Carpenter)

Locality: Tower Island, Loc. 27231 (C.A.S.), 1 specimen.

Caducifer cinis (Reeve)

Buccinum cinis Reeve, Conch. Icon., Vol. 3, *Buccinum*, sp. 84, pl. 11, fig. 84, December, 1846. "Hab. Gallapagos Islands (under stones); Cuming."

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 10 juvenile specimens.

Family Nassariidae

Nassarius nodicinctus (A. Adams)

Plate A, Fig. 9

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 50 adult and a number of young specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 1 adult and several young specimens.

Family Pyrenidae

Pyrene castanea (Sowerby)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 5 adult and many young specimens.

Pyrene fuscata (Sowerby)

Albemarle Island, Loc. 27221 (C.A.S.), 25 specimens; Chatham Island, Loc. 27227 (C.A.S.), 2 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 4 specimens; Charles Island, Loc. 27233 (C.A.S.), 2 specimens and Loc. 27238 (C.A.S.), 2 specimens.

Pyrene haemastoma (Sowerby)

Plate A, Fig. 10

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens.

Pyrene lucasana (Dall)

Locality: Tower Island, Loc. 27231 (C.A.S.), 9 specimens.

Mitrella ocellata baileyi (Bartsch & Rehder)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 20 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 50 specimens.

"This form is much darker than the typical *Nitidella guttata* Sowerby, which comes from Panama." (Bartsch & Rehder.)

Microcithara uncinata (Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 10 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 2 specimens.

Anachis atramentaria (Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 35 specimens; Tower Island, Loc. 27231 (C.A.S.), 40 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 14 specimens.

Anachis incerta (Stearns)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), several hundred specimens; Tower Island, Loc. 27231 (C.A.S.), about 100 specimens.

Family Muricidae

Murex (*Muricanthus*) *princeps* Broderip

Locality: Charles Island, Loc. 27238 (C.A.S.), 1 specimen.

Ocenebra parva (E. A. Smith)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 34 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens.

Family Thaididae

Thais callaoensis (Gray)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens; Chatham Island, Loc. 27227 (C.A.S.), 1 specimen.

Thais columellaris (Lamarck)

Localities: Chatham Island, Loc. 27227 (C.A.S.), 2 specimens; Tower Island, Loc. 27231 (C.A.S.), 4 specimens.

Thais (*Vasula*) *melones* (Duclos)

Localities: Indefatigable Island, Loc. 27232 (C.A.S.), 1 specimen; Tower Island, Loc. 27231 (C.A.S.), 3 specimens; Charles Island, Loc. 27238 (C.A.S.), 2 specimens.

Thais patula pansa (Gould)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens; Tower Island, Loc. 27231 (C.A.S.), 2 specimens; Charles Island, Loc. 27233 (C.A.S.), 1 specimen and Loc. 27238 (C.A.S.), 1 specimen.

Thais planospira (Lamarck)

Locality: Tower Island, Loc. 27231 (C.A.S.), 3 specimens.

Thais speciosa (Valenciennes)

Purpura speciosa Valenciennes in Humboldt & Bonpland, Rec. d'Obser. Zool., Vol. 2, p. 316, 1832. [Publication noticed by Duclos in Ann. Sci. Nat., Vol. 26, No. 101, p. 109, May, 1832.] "Habitat prope portum Acapulco."—Reeve, Conch. Icon., Vol. 3, *Purpura*, sp. 56, pl. 11, fig. 56, 1846. Original locality cited.

Purpura centiquadra Duclos, Ann. Sci. Nat., Vol. 26, No. 101, p. 109, pl. 2, fig. 8, May, 1832. ". . . rapportée d'Acapulco par M. de Humboldt. . . ."

P[urpura] triserialis Blainville, Nouv. Ann. d'Hist. Nat. Paris, Vol. 1, p. 226, post May, 1832. "De l'Océan Pacifique, sur les côtes de la Californie, d'où elle a été rapportée par M. P. E. Botta."—Tryon, Man. Conch., Vol. 2, p. 163, pl. 47, fig. 54, 1880. "Acapulco; Mazatlan."

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 small specimen.

Acanthina grandis (Gray in Sowerby)

Plate A, fig. 19

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen; Charles Island, Loc. 27238 (C.A.S.), 2 specimens.

Family Epitoniidae

Epitonium (*Asperoscala*) cf. *E.* (*A.*) *emydoneus* Dall

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 6 specimens.

Epitonium sp.

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Family Eulimidae

Balcis (*Vitreolina*) cf. *B.* (*V.*) *adamantina* (de Folin)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Balcis (*Vitreolina*) *falcata* (Carpenter)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 4 specimens.

Balcis (*Balcis*) *ochsneri* (Bartsch)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens.

Balcis (*Balcis*) *panamensis* (Bartsch)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 4 specimens.

Family Pyramidellidae

Pyramidella (*Pharcidella*) cf. *P.* (*P.*) *panamensis* Dall & Bartsch

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 16 badly worn specimens.

Pyramidella (*Triptychus*) *olssoni* Bartsch

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 17 specimens.

Turbonilla (*Chemnitzia*) *houseri* Dall & Bartsch

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 8 specimens.

Odostomia (*Chrysallida*) *excelsa* Dall & Bartsch

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 47 specimens.

Odostomia (*Chrysallida*) *rinella* Dall & Bartsch

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 5 specimens.

Odostomia (*Miralda*) *galapagensis* Dall & Bartsch

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens.

Odostomia (*Miralda*) sp.

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 1 specimen.

Family Amphiperatidae

Neosimnia aequalis (Sowerby)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Family Cypraeidae

Cypraea nigropunctata Gray

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 6 adult and a number of young specimens; Charles Island, Loc. 27233 (C.A.S.), 1 specimen; South Seymour Island, Loc. 27255A (C.A.S.), 5 specimens.

Family Triviidae

Trivia fusca (Gray in Sowerby)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 16 specimens.

Trivia maugeriae (Gray in Sowerby)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 5 specimens.

Trivia pacifica (Gray in Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 15 specimens; Chatham Island, Loc. 27227 (C.A.S.), 1 specimen.

Erato marginata galapagensis (Schilder)

Hespererato galapagensis Schilder, Proc. Malacol. Soc. London, Vol. 20, Pt. 5, p. 264, fig. 46 (p. 281), July, 1933. "Type from Albemarle Island, Galapagos."

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 67 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 11 specimens.

Family Strombidae

Strombus granulatus Swainson

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Family Cassididae

Cassis (*Cypraecassis*) *tenuis* Wood

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 4 specimens; Charles Island, Loc. 27233 (C.A.S.), 1 specimen.

Morum tuberculosum (Sowerby in Reeve)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen; Chatham Island, Loc. 27227 (C.A.S.), 1 specimen; Charles Island, Loc. 27238 (C.A.S.), 2 specimens.

Family Tonnidae

Malea ringens (Swainson)

Locality: Charles Island, Loc. 27233 (C.A.S.), 2 specimens.

Family Cymatiidae

Cymatium costatum (Born)

Plate A, Fig. 17

Locality: South Seymour Island, Loc. 27255A (C.A.S.), 2 specimens.

This is a cosmopolitan species occurring in warm marine water in widely separated regions. Our record (1939, p. 370) of the occurrence of *Cymatium wiegmanni* (Anton) in the Pleistocene of James Island is referable to *C. costatum*. However, Anton's species has been recorded by Schwengel (1938, p. 1) as occurring in the Recent fauna at Chatham Island.

Cymatium lineatum (Broderip)

Plate A, Fig. 18

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens.

Cymatium vestitum (Hinds)

Locality: Tower Island, Loc. 27231 (C.A.S.), 1 specimen.

Phyllocoma scalariformis (Broderip)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens.

Family Triphoridae

Triphora galapagensis Bartsch

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 100 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen; Indefatigable Island, Loc. 27232 (C.A.S.), 11 specimens.

Family Cerithiopsiidae

Cerithiopsis curtata Bartsch

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens; Tower Island, Loc. 27231 (C.A.S.), 5 specimens.

Cerithiopsis eiseni Strong & Hertlein

Locality: Tower Island, Loc. 27231 (C.A.S.), 2 specimens.

Cerithiopsis sp.

Locality: Tower Island, Loc. 27231 (C.A.S.), 1 specimen.

Cerithiopsis sp.

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens.

Seila assimillata (C. B. Adams)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 12 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens.

Metaxia convexa (Carpenter)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen; Indefatigable Island, Loc. 27232 (C.A.S.), 2 specimens.

Family Cerithiidae

Cerithium adustum Kiener

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 15 specimens; Tower Island, Loc. 27231 (C.A.S.), 9 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), about 100 young specimens; Charles Island, Loc. 27233 (C.A.S.), 5 specimens, and Loc. 27238 (C.A.S.), 2 specimens; South Seymour Island, Loc. 27255A (C.A.S.), 1 specimen.

Cerithium uncinatum (Gmelin)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 5 specimens.

Family Caecidae

Caecum firmatum C. B. Adams

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 11 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 12 specimens.

Family Vermetidae

Vermicularia pellucida eburnea (Reeve)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), about 50 young specimens; Tower Island, Loc. 27231 (C.A.S.), 20 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 6 specimens.

Serpulorbis margaritarum (Valenciennes)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 4 specimens.

Vermetus cf. *V. complicatus* (Dall)

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 15 specimens.

Family Littorinidae

Tectarius galapagiensis (Stearns)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 20 specimens; James Island, Loc. 27222 (C.A.S.), 16 specimens; Tower Island, Loc. 27231 (C.A.S.), 8 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 3 specimens.

Family Fossaridae

Fossarus abjectus (C. B. Adams)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 8 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen.

Fossarus angiostomus (C. B. Adams)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 4 specimens; Tower Island, Loc. 27231 (C.A.S.), 10 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 4 specimens.

Fossarus sp.

Locality: Tower Island, Loc. 27231 (C.A.S.), 30 specimens.

Family Modulidae

Modulus cerodes A. Adams

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 8 adult and a number of young specimens.

Family Architectonicidae

Heliacus planispira Pilsbry & Lowe

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens.

Family Litiopidae

Alaba supralirata (Carpenter)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 25 specimens.

Family Rissoidae

Alvania galapagensis Bartsch

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 25 specimens; Tower Island, Loc. 27231 (C.A.S.), 14 specimens.

Alvania halia Bartsch

Localities: Tower Island, Loc. 27231 (C.A.S.), 6 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 1 specimen.

Alvania lara Bartsch

Localities: Tower Island, Loc. 27231 (C.A.S.), 7 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 75 specimens.

Alvania sp.

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 300 specimens.

Family Rissoinidae

Rissoina dina Bartsch

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 200 specimens.

Rissoina cf. *R. laurae* (de Folin)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 10 badly worn specimens.

Rissoina signae Bartsch

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 5 specimens; Tower Island, Loc. 27231 (C.A.S.), 14 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 13 specimens.

Family Hipponicidae

Hipponix antiquatus (Linnaeus)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 9 specimens; Tower Island, Loc. 27231 (C.A.S.), 10 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 32 specimens.

Hipponix grayanus Menke

Plate A, Fig. 12

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 16 specimens; Tower Island, Loc. 27231 (C.A.S.), 18 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 16 specimens.

Hipponix pilosus (Deshayes)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 40 specimens; Chatham Island, Loc. 27227 (C.A.S.), 4 specimens; Tower Island, Loc. 27231 (C.A.S.), 25 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 75 specimens.

Family Crepidulidae

Crepidula aculeata (Gmelin)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 25 specimens; South Seymour Island, Loc. 27255A (C.A.S.), 4 specimens.

Crepidula arenata (Broderip)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 11 specimens.

Crepidula onyx Sowerby

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Family Calyptraeidae

Crucibulum imbricatum (Sowerby)

Locality: Indefatigable Island, Loc. 27232 (C.A.S.), 1 specimen.

Cheilea equestris (Linnaeus)

Plate A, Figs. 4, 5

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 36 specimens; Chatham Island, Loc. 27227 (C.A.S.), 10 specimens; Tower Island, Loc. 27231 (C.A.S.), 2 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 40 specimens; South Seymour Island, Loc. 27255A (C.A.S.), 1 specimen.

Family Naticidae

Polinices caprae (Philippi)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Polinices uber (Valenciennes)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 20 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 6 specimens.

Family Vanikoridae

Vanikoro galapagana Hertlein & Strong

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens. Somewhat worn, juvenile specimens, apparently this species.

Family Vitrinellidae

Macromphalina souverbiei (de Folin)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 3 specimens.

Family Acmaeidae

Acmaea filosa Carpenter

Plate A, Fig. 6

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 2 specimens; Chatham Island, Loc. 27227 (C.A.S.), 1 specimen.

The specimens here recorded closely resemble *Acmaea strigatella* Carpenter but appear to fall within the variation of *A. filosa.*

Acmaea mitella Menke

Plate A, Figs. 2, 3

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 specimen.

Acmaea sp.

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 25 juvenile specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 10 juvenile specimens.

Family Phasianellidae

Tricolia perforata (Philippi)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 50 specimens; Tower Island, Loc. 27231 (C.A.S.), 10 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 15 specimens.

Family Trochidae

Tegula cooksoni (E. A. Smith)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 65 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 1 specimen.

Tegula snodgrassi (Pilsbry & Vanatta)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 75 specimens including many young shells.

Calliostoma sp.

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 very young specimen.

Family Neritidae

Nerita funiculata Menke

Locality: Chatham Island, Loc. 27227 (C.A.S.), 1 specimen.

This species has usually been cited in the literature under the name of *Nerita bernhardi* Recluz, 1858, a *nomen nudum.*

Nerita scabricosta ornata Sowerby

Localities: Chatham Island, Loc. 27227 (C.A.S.), 2 specimens; Tower Island, Loc. 27231 (C.A.S.), 1 specimen.

Family Fissurellidae

Fissurella obscura Sowerby

Plate A, Fig. 7

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 6 adult and a number of young specimens; Tower Island, Loc. 27231 (C.A.S.), 16 specimens; Chatham Island, Loc. 27227 (C.A.S.), 4 specimens; South Seymour Island, Loc. 27255A (C.A.S.), 10 specimens.

Fissurella rugosa Sowerby

Locality: South Seymour Island, Loc. 27255A (C.A.S.), 1 specimen.

Diodora inaequalis (Sowerby)

Localities: Albemarle Island, Loc. 27221 (C.A.S.), 50 specimens; Chatham Island, Loc. 27227 (C.A.S.), 3 specimens; Indefatigable Island, Loc. 27232 (C.A.S.), 12 specimens.

Diodora cf. *D. panamensis* (Sowerby)

Locality: South Seymour Island, Loc. 27255A (C.A.S.), 3 worn juvenile specimens.

Lucapinella callomarginata (Carpenter in Dall)

Locality: Albemarle Island, Loc. 27221 (C.A.S.), 1 young specimen.

LITERATURE CITED

BARTSCH, P. AND H. A. REHDER

1939. Mollusks Collected on the Presidential Cruise of 1938. Smithson. Miscell. Coll. 98(10):1-18, pls. 1-5, June 13.

CARPENTER, P. P.

1857. Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America. Rept. Brit. Assoc. Adv. Sci. for 1856:159-368 + list of plates, pp. 1-4, pls. 6-9.

COLNETT, J.

1798. A Voyage to the South Atlantic and round Cape Horn into the Pacific Ocean. (Printed for the Author by W. Bennett: London). xviii, 179 pp., 1 portrait, 6 charts, 2 pls. (engravings), 1 line drawing.

DALL, W. H.

1908. Reports on the dredging operations off the west coast of Central America to the Galapagos, to the west coast of Mexico, and in the Gulf of California, . . . carried on by the U. S. Fish Commission Steamer "Albatross," during 1891 . . . XXXVII. Reports on the Scientific Results of the Expedition to the eastern tropical Pacific . . . XIV. The Mollusca and the Brachiopoda. Bull. Mus. Compar. Zool., Harvard Univ. 43(6): 205-487, pls. 1-22, October.

1909. Report on a Collection of Shells from Peru, with a Summary of the Littoral Marine Mollusca of the Peruvian Zoological Province. Proc. U. S. Natl. Mus. 37:147-294, pls. 20-28, November 24.

DALL, W. H. AND W. H. OCHSNER

1928. Tertiary and Pleistocene Mollusca from the Galapagos Islands. Proc. Calif. Acad. Sci. ser. 4, 17(4):89-139, pls. 2-7, 5 text-figs., June 22.

FRASER, C. MCLEAN

1943. General Account of the Scientific Work of the Velero III in the Eastern Pacific, 1931-41. Pt. I. Historical Introduction, Velero III, Personnel. Allan Hancock Pac. Exped. 1(1):1-48, pls. 1-16, July, 1943. Pt. II. Geographical and Biological Associations. 1(2):49-258, pls. 17-128, December, 1943. Pt. III. A Ten-Year List of the Velero III Collecting Stations. 1(3):259-424, charts 1-115; An appendix of collecting Stations of the Allan Hancock Foundation for the year 1942, pp. 425-431, December.

HANNA, G. D. AND L. G. HERTLEIN

1938. Land and Brackish water mollusca of Cocos Island. Allan Hancock Pac. Exped. 2(8):123-135, 1 fig. in text, August.

Hertlein, L. G.

1932. Mollusks and Barnacles from Malpelo and Cocos Islands. Nautilus. 46(2):43-45, October 22.

1933. Additions to the Pliocene Fauna of Turtle Bay, Lower California, with a note on the Miocene Diatomite. Jour. Paleo. 7(4):439-441, December.

Hertlein, L. G. and A. M. Strong

1939. Marine Pleistocene Mollusks from the Galapagos Islands. Proc. Calif. Acad. Sci. ser. 4, 23(24):367-380, pl. 32, July 20.

Howell, J. T.

1941. Hugh Cuming's Visit to the Galapagos Islands. Lloydia. 4:291-292, December. [See also "Some notes on the Life and Explorations of Hugh Cuming" by W. J. Clench, Occ. Papers on Moll., Mus. Compar. Zool., Harvard Univ. 3:17-28, pl. 7, July 30, 1945.]

Ingram, W. M.

1948. The Cypraeid Fauna of the Galapagos Islands. Proc. Calif. Acad. Sci. ser. 4, 26(7):135-145, pl. 2, figs. 10-11, June 28.

Pilsbry, H. A. and E. G. Vanatta

1902. Papers from the Hopkins Stanford Galapagos Expedition, 1898-1899. XIII. Marine Mollusca. Proc. Washington Acad. Sci. 4:549-560, pl. 35, September 30.

Schwengel, Jeanne

1938. Zoological Results of the George Vanderbilt South Pacific Expedition, 1937. Pt. 1. Galapagos Mollusca. Proc. Acad. Nat. Sci. Phila. 90:1-3, figs. 1-3, May 13.

Smith, E. A.

1877. Mollusca [No. IV in Account of the Zoological Collection made during the visit of H. M. S. 'Peterel' to the Galapagos Islands. Communicated by Dr. Albert Günther]. Proc. Zool. Soc. London. 1877:69-73, pl. 11, February 6.

Soot-Ryen, T.

1932. The Norwegian Zoological Expedition to the Galapagos Islands 1925, conducted by Alf Wollebaek. II. Pelecypods from Floreana (Sancta Maria) Galapagos Islands. Nyt Mag. f. Naturvid. 70:313-324, pls. 1-2, April 30. (Medd. Zool. Mus. Oslo, No. 27.)

Stearns, R. E. C.

1893. Scientific Results of Explorations by the U. S. Fish Commission Steamer "Albatross." XXV. Report on the Mollusk-Fauna of the Galapagos Islands with descriptions of new species. Proc. U. S. Natl. Mus. 16:353-450, pls. 51-52, September 29.

Strong, A. M. and L. G. Hertlein

1939. Marine Mollusks from Panama collected by the Allan Hancock Expedition to the Galapagos Islands, 1931-1932. Allan Hancock Pac. Exped. 2(12):177-245, pls. 18-23, August 21.

Tomlin, J. R. leB.

1927-28. The Mollusca of the "St. George" Expedition. I. The Pacific Coast of S. America. Jour. Conch. 18(6):153-170, December, 1927; 18(7): 187-198, May, 1928.

Wimmer, A.

1879. Zur Conchylien-Fauna der Galápagos-Inseln. Sitz. K. Akad. Wiss. (Wien). Math.-Nat. Cl. 80(5):465-514, December.

PLATE A

Fig. 1. *Latirus tuberculatus* (Broderip). From Loc. 27221 (C.A.S.), Black Bight at south end of Banks Bay, about 1 mile north of Tagus Cove, Albemarle Island, Galapagos Islands. X 1.04. p. 128.

Fig. 2. *Acmaea mitella* Menke. From the same locality as the specimen shown in Fig. 1. X 1.6. p. 140.

Fig. 3. *Acmaea mitella* Menke. View of the interior of the specimen shown in Fig. 2. X 1.6.

Fig. 4. *Cheilea equestris* (Linnaeus). From Loc. 27227 (C.A.S.), Bassa Point, Chatham Island, Galapagos Islands. X 1.4. p. 139.

Fig. 5. *Cheilea equestris* (Linnaeus). From the same locality as the specimen shown in Fig. 4. X 1.38. View of the interior of a smaller specimen.

Fig. 6. *Acmaea filosa* Carpenter. From the same locality as the specimen shown in Fig. 4. X 1.6. p. 140.

Fig. 7. *Fissurella obscura* Sowerby. From the same locality as the specimen shown in Fig. 1. X .8. p. 141.

Fig. 8. *Monilispira ochsneri* Hertlein & Strong. Holotype, No. 9426 (Calif. Acad. Sci. Dept. Geol. Type Coll.), from Loc. 23207 (C.A.S.), Chatham Island, Galapagos Islands. X 1.6. p. 126.

Fig. 9. *Nassarius nodicinctus* (A. Adams). From the same locality as the specimen shown in Fig. 1. X 1.6. p. 129.

Fig. 10. *Pyrene haemastoma* (Sowerby). From the same locality as the specimen shown in Fig. 1. X 1.05. p. 130.

Fig. 11. *Chione pertincta* Dall. From the same locality as the specimen shown in Fig. 1. X .8. View of the exterior of a left valve. p. 122.

Fig. 12. *Hipponix grayanus* Menke. From the same locality as the specimen shown in Fig. 1. X 1.3 p. 138.

Fig. 13. *Cardita megastropha* (Gray). From Loc. 27255A (C.A.S.), on beach along west side of South Seymour Island, Galapagos Islands. X .9. View of exterior of a left valve. p. 120.

Fig. 14. *Apolymetis cognata* (Pilsbry & Vanatta). From the same locality as the specimen shown in Fig. 1. X .58. View of the exterior of a right valve. p. 123.

Fig. 15. *Apolymetis cognata* (Pilsbry & Vanatta). From the same locality as the specimen shown in Fig. 14. X .6. View of the exterior of a left valve.

Fig. 16. *Apolymetis cognata* (Pilsbry & Vanatta). View of the interior of the specimen shown in Fig. 15. X .6.

Fig. 17. *Cymatium costatum* (Born). From the same locality as the specimen shown in Fig. 13. X .78. Anterior portion of shell incomplete. p. 134.

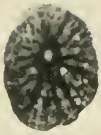
Fig. 18. *Cymatium lineatum* (Broderip). From the same locality as the specimen shown in Fig. 1. X 1.1 p. 135.

Fig. 19. *Acanthina grandis* (Gray in Sowerby). From the same locality as the specimen shown in Fig. 1. X 1. p. 132.

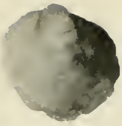
All the specimens illustrated on this plate are in the type collection of the Department of Geology of the California Academy of Sciences.

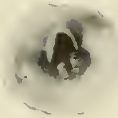
PLATE A

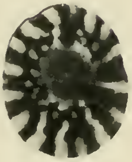

1


2


3


4


5

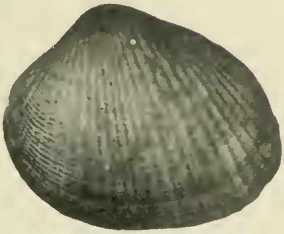

6


7


8


9


10

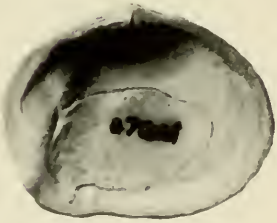

11


12


13


14


15


16


17


18


19

A REPORT ON THE POISONOUS FISHES CAPTURED DURING THE WOODROW G. KRIEGER EXPEDITION TO THE GALAPAGOS ISLANDS[1]

By

Bruce W. Halstead and Donald W. Schall[2]

INTRODUCTION

This paper is the third of a series of epidemiological reports concerning the poisonous fishes of the tropical Pacific. The first report (Halstead and Bunker, 1954a) dealt with the Phoenix Islands and the second (Halstead and Bunker, 1954b) with Johnston Island. For a general résumé of the over-all problem of poisonous fishes and ichthyosarcotoxism, the reader is referred to two earlier reports by the senior author (1951, 1953).

The problem of poisonous fishes has a direct bearing on the development of future protein food sources of the Pacific area. The existing confusion and lack of precise data regarding the identity, geographical distribution and biology of toxic fishes and the source of these poisons are problems with which future fisheries economists and scientists must cope.

The fish fauna of the Galapagos Islands, because of the geographical

---

[1] This investigation was supported by a research grant from the Division of Research Grants and Fellowships, National Institutes of Health, Public Health Service, and a contract from the Office of Naval Research, Department of the Navy (Contract No. NONR-205(00)).

[2] Department of Biotoxicology, School of Tropical and Preventive Medicine, College of Medical Evangelists, Loma Linda, California.

location, is of particular interest to students of poisonous fishes. Although numerous species are known to occur in the West Indies, Red Sea, and in parts of the Pacific, nothing has been published on poisonous fishes in the tropical far eastern Pacific. According to Myers (1940), the fish fauna of the Cocos-Galapagos region is a blend of Panamanian and Indo-Pacific forms, many of the latter found nowhere else in the Americas. As the zoogeography of this area made it reasonable to assume that poisonous fishes would be present, the basic objective of the expedition was to determine if they did occur in this region, with the hope that the knowledge gained thereby would contribute directly to a better understanding of the origin and distribution of toxic fishes in the tropical Pacific.

The expedition was made possible by the generosity of Mr. Woodrow C. Krieger, president of the Douglas Oil Company of California, and the Office of Naval Research, Department of the Navy. In addition to making his yacht, the "Observer," available to the scientific party, Mr. Krieger also installed on it special laboratory and refrigeration facilities. Grateful acknowledgement is made for the invaluable contributions of both Mr. Krieger and the Office of Naval Research. The scientific party included Norman C. Bunker, Jeanne M. Bunker, Leonard S. Kuninobu, Donald G. Ollis, and the senior author. We left Newport Bay, California, on 3 December 1952 and went first to Punta Arenas, Costa Rica, then to Cocos Island. The remainder of the trip can be traced on the accompanying map. The expedition ended at Guayaquil, Ecuador, on 18 January 1953. The reports on Cocos and La Plata Islands will be published elsewhere.

FIELD STATIONS

The Galapagos Islands (Archipiélago de Colón), located on the equator 600 miles west of Ecuador, are volcanic in origin, consisting principally of lava, sandstone, and granite. Although Crossland (1927) reported corals growing in the vicinity, Chubb (1933) says there are no coral reefs; and we saw none. The archipelago comprises six principal islands, nine smaller ones, and numerous islets, with a total land area of 2,868 square miles. The weather is surprisingly mild and the trade winds blow with regularity from April to December. The surface temperature of the water on the southwest side of Albemarle Island was 15.5°C.; on the northeast, 26.6°C. This difference is caused by the cool Peru Current coming from the south along the coasts of Chile and Peru and meeting in the Galapagos area the warmer Equatorial Countercurrent from the Gulf of Panama.

The twenty-nine field collection stations made in seven different parts of the archipelago may be briefly described as follows:

Field Numbers K52-24 to 29 are from Darwin Bay, at the southeastern end of Tower Island, flanked by steep cliffs except for the narrow beach at the northern end. Marine iguanas, sea lions, and various oceanic birds were abundant. Mullet, surgeonfish, and blennies were taken at the western end of the beach, in tidepools to 3 meters in depth. The bulk of the specimens—triggerfish, snappers, squirrelfish, hemiramphids, parrotfish, pomacanthids, pomacentrids, mullet, pompano, and surgeonfish—were taken at the base of the cliffs in 1 to 2 fms. Smaller collections were made in the deeper portions of the bay, to 150 fms. Sharks were observed swimming near the surface of the bay. The water was relatively murky and the surface temperature within the bay was 25°C.

Field Number K53-1 is from Wreck Bay, at the southwestern end of Chatham Island. The bottom is sand interspersed with volcanic rocks and slopes gently down to 9 fms near the entrance. Small amounts of brown algae were observed floating on the surface of the water. Grouper, snapper, *Umbrina*, and a species of *Paranthias* were taken with hook and line, and a single specimen of *Hemiramphus* was taken by night light with a dip net. The water was slightly turbid; surface temperature, 21°C.

Field Numbers K53-2 to 4, 4a represent two collections made at Indefatigable Island, one at Academy Bay in about 6 meters of water, yielding pomacentrids, parrotfish, grouper and triggerfish; the other at Seymour Bay, at the entrance of the large saltwater lagoon, and within the lagoon itself. Academy Bay, on the southern side of the island, has a highly irregular shore line and is littered with jagged volcanic boulders and gravel. A number of rocky reefs at the west end provide good collecting ground. The bottom, of sand interspersed with gravel and boulders, slopes gently down to a depth of about 16 fms. The water was relatively clear, with a temperature of 22.5°C. Seymour Bay, on the northern side of the island, has a less irregular and rocky shore line, with many broad sandy beaches. The bottom, of sand with scattered rocks, slopes gradually out to deeper water, reaching the 10-fathom line about 1400 meters from shore. The lagoon is shallow, less than a fathom in its deepest part. The water is murky; temperature not taken. The variety of fish species within the lagoon was limited, consisting primarily of such genera as *Orthopristis*, *Haemulon*, *Gerres* and bottom fishes. Night light fishing off the entrance was the most profitable of any during the entire trip, for specimens of needlefish and flyingfish.

Field Numbers K53-5 to 12 apply to stations in Sulivan Bay, lying in the lee of Bartholomew Island, which is off the eastern end of James Island. The shore line is highly irregular, of black volcanic rock only occasionally interrupted by white sandy beaches. Tidepools are numerous. The water was relatively clear; surface temperature, 24.5°C. Because of the wide variety of ecological biotypes within such a limited area, Sulivan Bay was one of the most interesting and profitable stops of the trip. Manta rays were abundant. Night light fishing was excellent. Fishes collected were: haemulids, diodons, snappers, flyingfish, halfbeaks, parrotfishes, pomacentrids, wrasses, moray eels, blennies, and sharks.

Field Numbers K53-13, 14, 16 and 20 represent collections taken in the vicinity of Tagus Cove, off Albemarle Island. The shores are steep and inaccessible, the only landing place being near a ravine at the north end of the cove. The water is from 6 to 14 fms deep and is quite murky; surface temperature, 20.5°C. Night light fishing was very productive, as hundreds of *Sphaeroides annulatus* were attracted to the surface, where they were speared with ease. Puffers were more plentiful than in any other area visited, but limited to a single species. Also collected were: wrasses, groupers, mackerels, haemulids, dolphin, barracudas, and *Caulolatilus*.

Field Numbers K53-15, 17, 18 are from stations off Narborough Island, about 2½ miles west of Tagus Cove. On the eastern side, the shore is well populated with large marine iguanas, penguins, and flightless cormorants. The water was rather murky; temperature, 21°C. Fishes collected were: wrasses, pomacentrids, groupers, and pomacanthids.

Field Numbers K53-19, 21 are from stations off Charles Island: at Post Office Bay, where a broad sandy beach is interrupted at irregular intervals by rocky tidepools and the bottom, of sand and volcanic rock, slopes smoothly to deep water; and in the lee of Onslow Island, lying off Cormorant Point. The water was quite clear; temperature, 23°C. Fishes taken were: diodons, snappers, puffers, squirrelfishes, mullets, pomacentrids, haemulids, and scorpionfishes.

MATERIALS AND METHODS

Specimens were collected with the use of rotenone, spear, dynamite, or dipnet. Soon after collection, the smaller ones were sorted, labeled, placed in plastic bags according to the station where they were taken, and placed in a deep freeze unit. From the larger specimens samples were taken in the field of the muscle, liver, intestines, and gonads. An identification number was assigned to the tissue sample and a duplicate number given to the dissected fish, which was then placed in a barrel of 10 percent formalin, for future taxonomic purposes. The material in the deep freeze remained frozen until tested in the laboratory at Loma Linda, California.

Except for the families of Exocoetidae, Muraenidae, and Scaridae, all of the fishes listed in this report were identified by Dr. Boyd Walker of the Department of Zoology, University of California at Los Angeles. The exocoetids were identified by Dr. Grace Orton of the Scripps Institution of Oceanography of the University of California at La Jolla. Dr. Leonard P. Schultz of the U.S. National Museum identified the scarids. The muraenids were identified by the authors. Our sincere appreciation is expressed to these individuals for their valuable contributions to this report.

There is no single comprehensive systematic treatise on the fishes of the Galapagos Islands. The following works were useful: Beebe and Tee-Van (1941), Clark (1936), Fowler (1938 and 1944), Garman (1899), Gilbert and Starks (1904), Günther (1869), Heller and Snodgrass (1903), Herre (1936), Jordan and Evermann (1896), Jordan, Evermann and Clark (1930), Meek and Hildebrand (1923), and Snodgrass and Heller (1905). Hildebrand's (1946) "A Descriptive Catalog of the Shore Fishes of Peru" was particularly useful. The nomenclature proposed by Hildebrand is largely followed in this report.

The reader is referred to a previous report (Halstead and Bunker, 1954a) on the poisonous fishes of the Phoenix Islands for a résumé of the screening techniques of earlier workers. The technique described here has been adopted as the routine screening procedure for this laboratory and is a modification of one originally suggested by Doctors Karl F. Meyer and Hermann Sommer of the University of California.

Samples were removed, when possible, from the muscle (M), liver (L), intestines (I), gall bladder (GB), and gonads (G), from each fish to be tested. With small specimens, it was sometimes necessary to remove the entire viscera (V) as a single sample, and in rare instances it was necessary to use the entire fish to obtain sufficient material for extraction purposes. An effort was made to secure about 7 gm. of flesh for each sample. Two ml. of distilled water were added for each gram of flesh. The material was then homogenized in a Waring Blendor and the homogenate centrifuged at 2000 r. p. m. for 25 minutes. One ml. of the clear supernatant fluid was injected intraperitoneally in each of four weanling white laboratory mice of the California Caviary Strain (CC_1)

weighing 15 to 25 gm. Their reactions were observed and recorded for a period of 36 hours.

The classification used here is an arbitrary one which does give some idea as to the degree of toxicity of a fish species within a particular geographical area. This method makes no attempt to differentiate between virulence and concentration. Moreover, as the interpretation of *weakly positive* results in terms of human symptomatology is not clearly understood yet, the reader is cautioned about arriving at hasty conclusions regarding the results of this study.

Negatve (N), if the mouse continues to remain asymptomatic during the maximum test period of 36 hours, or dies after that time.

Weakly Positive (WP), if the mouse shows definite symptoms, such as lacrimation, diarrhea, ruffling of the hair, hypoactivity, ataxia, etc., but the *animal recovers.*

Moderately Positive (MP), if the mouse develops hypoactivity, ruffling of the hair, lacrimation, diarrhea, paralysis, etc., and *dies within a period of 1 to 36 hours.*

Strongly Positive (SP), if the mouse develops hypoactivity, ataxia and paralysis, usually followed by clonic or tonic convulsions of varying degrees, paradoxical respiration, respiratory paralysis and *death occurs within a few seconds to one hour.*

TABLE I

An Analysis of Galapagos Islands Fishes With Reference to Their Toxicity

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	ACANTHURIDAE—Surgeonfish			
R144-1,2,3,4	*Acanthurus crestonis* (Jordan and Starks)	K52-24	M,L,G,I	N
R209-1,2,3,4	" " " " "	"	M,I	N
			L	MP
			G	WP
R99-1,5	*Xesurus punctatus* (Gill)	K53-19	M,V	WP
R192-1,2,5	" " "	K53-6	M	N
			L	MP
			V	WP
R249-1,3,5	" " "	K53-13	M,G,V	N
R308-1,2,4	" " "	K53-6	M,L,I	N
R336-1,2,4	" " "	"	M,L,I	N
R351-1,2,3,4	" " "	"	M,L,G,I	N

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	BALISTIDAE—Triggerfish			
R73-1,2,4	*Balistes verres* Gilbert and Starks	K53-6	M	WP
			L,I	N
R76-1,2,4	" " " " "	K52-24	M,L	N
			I	WP
R131-1,2,4	" " " " "	K53-4	M	N
			L	WP
			I	SP
R206-1,2,4	" " " " "	K52-29	M,L,I	N
R229-1,2,4	" " " " "	K52-24	M,L	N
			I	WP
R335-1,2,3,4	" " " " "	K53-6	M,L,G,I	N
R342-1,2,3	" " " " "	"	M,L,G	N
R355-1,2,3,4	" " " " "	K53-2	M,L,G	N
			I	WP
	BELONIDAE—Needlefish or Saltwater Gars			
R301-1,5	*Strongylura stolzmanni* (Steindachner)	K53-4A	M,V	N
	BLENNIIDAE—Blennies			
R314-1,3,5	*Ophioblennius steindachneri* Jordan and Evermann	K53-7	M,G	N
			V	MP
	BRANCHIOSTEGIDAE—Blanquillo			
R167-1,3,5	*Caulolatilus princeps princeps* (Jenyns)	K53-13	M,G,V	N
	CARANGIDAE—Pompano, Jacks			
R347-1,2,3,4	*Decapterus* sp.	K53-16	M	WP
			L,I	N
			G	MP
R349-1,2,3,4	*Seriola colburni* Evermann and Clark	K53-10	M,L,G,I	N
R317-1,3,4	*Zalocys stilbe* Jordan and McGregor	K52-29	M,G	N
			I	MP
	CHAETODONTIDAE—Butterflyfish			
R497-1,5	*Chaetodon nigrirostris* (Gill)	K53-12	M,V	N
R498-1,5	" " "	"	M	N
			V	MP
R577-8	" " "	K53-13	WF	N
R59-1,5	*Holacanthus passer* Valenciennes	K52-29	M	N
			V	WP

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	CHAETODONTIDAE—Butterflyfish (Continued)			
R153-1,5	*Holacanthus passer* Valenciennes	K53-17	M,V	N
R162-1,5	" " "	K52-24	M,V	N
R169-1,5	" " "	K53-6	M	N
			V	MP
R183-1,2,4	" " "	K52-24	M,I	MP
			L	N
R245-1,2,4	" " "	"	M,L,I	N
	CORYPHAENIDAE—Dolphins			
R127-2,3	*Coryphaena hippurus* Linnaeus	K52-24	L,G	N
R141-1,2,3,4	" " "	K53-16	M,G,I	N
			L	MP
R135-1,2,3,4	" " "	"	M,L,G,I	N
R356-1	" " "	"	M	N
	DIODONTIDAE—Porcupinefish			
R406-1,2,4	*Chilomycterus affinis* Günther	K53-8	M,L	N
			I	MP
R386-1,2,3,4	*Chilomycterus* sp.	K53-21	M,I	N
			L,G	WP
	EXOCOETIDAE—Flyingfish			
R242-1,2,4	*Cypselurus callopterus* (Günther)	K53-4A	M,L,I	N
R284-1,5	" " "	"	M	N
			V	WP
R323-1,2,4	" " "	"	M	N
			L,I	MP
R332-1,3,4	" " "	"	M,I	WP
			G	MP
R370-1,2,3,4	" " "	K53-9	M,L,G,I	N
R156-1,3,4	*Fodiator acutus rostratus* (Günther)	K53-4A	M,G,I	N
R279-1,2	" " " "	"	M,L	N
R294-1,5	" " " "	"	M,V	N
R328-1,2	" " " "	"	M,L	N
	FISTULARIIDAE—Cornetfish			
R143-1,3,4	*Fistularia petimba* Lacépède	K52-24	M,G,I	N
	GERRIDAE—Mojarras; Silverperch			
R168-1,5	*Gerres cinereus* (Walbaum)	K53-3	M,V	N

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	GERRIDAE—Mojarras, Silverperch (Continued)			
R201-1,5	*Gerres cinereus* (Walbaum)	K53-3	M,V	N
R226-1,5	" " "	"	M,V	N
R233-1,3,4	" " "	"	M,G	N
			I	MP
	HAEMULIDAE—Grunts, Roncos			
R63-1,3,4	*Anisotremus scapularis* (Tschudi)	K53-8	M,G,I	MP
R64-1,4	" " "	K53-18	M,I	MP
R404-1,2,3,4	" " "	"	M,G,I	N
			L	WP
R405-1,2,3,4	" " "	"	M,L,G,I	N
R148-1,5	*Haemulon scudderi* Gill	K53-3	M,V	N
R61-1,5	*Orthopristis cantharinus* (Jenyns)	K53-5	M,V	WP
R62-1,5	" " "	K53-18	M,V	MP
R71-1,5	" " "	K53-5	M,V	N
R75-1,5	" " "	K53-6	M,V	N
R78-1,5	" " "	K53-19	M,V	N
R96-1,5	" " "	K53-18	M,V	MP
R97-1,5	" " "	"	M	N
			V	WP
R149-1,5	" " "	"	M	WP
			V	N
R177-1,5	" " "	K53-3	M,V	N
R180-1,3,4	" " "	K53-1	M,I	N
			G	MP
R261-1,5	" " "	K53-13	M	MP
			V	WP
R273-1,3,4	" " "	K53-5	M,G,I	N
R280-1,2,4	" " "	"	M,L,I	N
R302-3,4,5	" " "	K53-19	G,I	N
			V	MP
R346-1,3,4	" " "	K53-5	M	N
			G	WP
			I	MP
R379-1,2,3,4	" " "	K53-9	M,L,G,I	N
R380-1,2,3,4	" " "	K53-19	M,G	N
			L,I	MP
	HEMIRAMPHIDAE—Halfbeaks			
R350-1,2,4	*Euleptorhamphus longirostris* (Cuvier)	K53-5	M,L,I	N
R298-1,5	*Hyporhamphus unifasciatus* (Ranzani)	K53-4A	M,V	N
R65-1,3	*Hemiramphus saltator* Gilbert and Starks	K52-24	M	WP
			G	N
R139-1,5	" " " " "	"	M,V	N

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	HOLOCENTRIDAE—Squirrelfish			
R300-1,5	*Holocentrus suborbitalis* Gill	K53-6	M,V	N
R327-1,5	" " "	"	M,V	N
R371-1,5	" " "	K53-19	M,V	N
R219-1,5	*Myripristis occidentalis* Gill	K53-6	M,V	WP
R285-1,2,3	" " "	"	M,G L	N WP
R304-1,3,5	" " "	"	M,G,V	N
R319-3	" " "	"	G	N
R322-1,3,4	" " "	"	M,G,I	N
	KATSUWONIDAE—Skipjacks			
R353-1,2,3,4	*Euthynnus lineatus* Kishinouye	K53-7	M,L,G,I	N
	KYPHOSIDAE—Rudderfish			
R237-1,2,3,4,6	*Doydixodon freminvillei* Valenciennes	K53-13	M,L,G,I,IC	N
R267-1,2,4	" " "	"	M,L,I	N
R281-1,2,3	" " "	"	M,L,G	N
R271-1,5	" " "	K53-6	M,V	N
R331-1,5	" " "	K53-7	M V	N MP
R337-1,3,4	" " "	K53-13	M,G I	N WP
	LABRIDAE—Wrasses			
R220-1,5	*Bodianus diplotaenius* (Gill)	K53-6	M,V	WP
R293-1,2,4	" " "	"	M,L,I	N
R295-1,4	" " "	K53-13	M,I	N
R66-1,3,4	*Bodianus eclancheri* (Valenciennes)	K53-17	M,G,I	N
R79-1,3,5	" " "	K53-18	M,G,V	WP
R203-1,2,4	" " "	K53-13	M,L I	N WP
R352-1,4	" " "	"	M,I	N
	LAGOCEPHALIDAE—Swellfish, Puffer			
R57-1,2,4	*Sphaeroides annulatus* (Jenyns)	K53-9	M L,I	WP SP
R117-1,2,3,4	" " "	K53-14	M,I L,G	N SP
R118-1,2,3,4	" " "	"	M L,G I	N SP MP

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	LAGOCEPHALIDAE—Swellfish, Puffer (Continued)			
R119-1,2,3,4	*Sphaeroides annulatus* (Jenyns)	K53-14	M,I	N
			L,G	SP
R120-1,2,3,4	" " "	"	M,L,G,I	SP
R121-1,2,3,4	" " "	"	M,L,G,I	SP
R122-1,2,3,4	" " "	"	M,L,G,I	SP
R123-1,2,3,4	" " "	"	M,L,G,I	SP
R124-1,3,4	" " "	"	M,G	SP
			I	MP
R381-1,2,4	" " "	K53-19	M,L,I	SP
R382-1,2,3,4	" " "	K53-1	M,L,G,I	SP
R383-1,2,3,4	" " "	"	M,L,G,I	SP
R384-1,2,3,4	" " "	"	M,L,G,I	SP
R385-1,2,3,4	" " "	"	M,L,G,I	SP
R393-1,2,3,4	" " "	K53-14	M,G	N
			L,I	SP
R394-1,2,3,4	" " "	"	M,L,G	N
			I	MP
R395-1,2,3,4	" " "	"	M,G,I	N
			L	SP
R396-1,2,3,4	" " "	"	M,L,G	SP
			I	N
R397-1,2,3,4	" " "	"	M,G,I	N
			L	SP
R398-1,2,3,4	" " "	"	M	N
			L,G,I	SP
R399-1,2,3,4	" " "	"	M	N
			L,G,I	SP
R400-1,2,3,4	" " "	"	M	N
			L,G,I	SP
R401-1,2,3,4	" " "	"	M,L,G,I	SP
R402-1,2,3,4	" " "	"	M,L	SP
			G,I	N
	LUTJANIDAE—Snappers			
R172-1,2,3,4	*Lutjanus argentiventris* (Peters)	K52-25	M	MP
			L,G,I	N
R173-2,3,4	" " "	"	L,G,I	N
R69-1,5	*Lutjanus viridis* (Valenciennes)	K53-6	M	WP
			V	N
R137-1,3,5	" " "	K52-24	M,G,V	N
R150-1,5	" " "	"	M	WP
			V	SP
R202-1,5	" " "	"	M,V	MP
R212-1,2,3,4	" " "	"	M,I	N
			L	WP
			G	N
R243-1,3,5	" " "	"	M	WP
			G,V	N

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	LUTJANIDAE—Snappers (Continued)			
R291-1,3,5	*Lutjanus viridis* (Valenciennes)	K53-6	M,G,V	N
R338-1,5	" " "	"	M	N
			V	MP
R339-1,2,3	" " "	"	M	N
			L,G	WP
	MUGILIDAE—Mullets			
R84-1,4	*Chaenomugil proboscideus* (Günther)	K53-18	M,I	N
R85-1,4	*Mugil cephalus* Linnaeus	"	M,I	N
R312-1,2,3,4	" " "	K52-29	M,L,G,I	N
R268-1,4	*Xenomugil thoburni* (Jordan and Starks)	K53-6	M,I	N
R494-1,5	" " " " "	K53-19	M,V	N
R495-1,5	" " " " "	"	M,V	N
	MURAENIDAE—Moray eels			
R182-1,5	*Muraena insularum* Jordan and Davis	K53-7	M,V	N
R219-1,5	" " " " "	"	M,V	WP
R325-1,2	" " " " "	"	M,L	N
R391-1,2,3,4	" " " " "	K53-17	M,L	N
			G,I	MP
R474-1	" " " " "	K53-7	M	N
R490-1	" " " " "	"	M	N
R575-1	" " " " "	"	M	N
	POMACENTRIDAE—Damselfish			
R82-1,5	*Abudefduf saxatilis* (Linnaeus)	K53-19	M	N
			V	MP
R83-1,5	" " "	"	M,V	N
R217-1,5	" " "	K53-2	M	N
			V	MP
R297-1	" " "	"	M	N
R412-1,2,3,4	*Microspathodon bairdi* (Gill)	K53-19	M,L,G,I	N
R164-1,5	*Microspathodon dorsalis* (Gill)	K52-24	M,V	N
R187-1,5	" " "	K52-29	M,V	N
R246-1,5	" " "	K52-24	M,V	N
R290-1,3	" " "	"	M,G	N
R160-1,5	*Pomacentrus arcifrons* Heller and Snodgrass	K53-2	M,V	N
R191-1,5	" " " " "	"	M,V	N
R286-1,3,4	" " " " "	"	M,G,I	N
R358-1,5	" " " " "	K52-24	M,V	MP
R359-4,5	" " " " "	"	V	MP
R361-1,5	" " " " "	"	M,V	N

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	POMACENTRIDAE—Damselfish (continued)			
R372-1,5	*Pomacentrus arcifrons* Heller and Snodgrass	K52-24	M,V	N
R373-5	" " " " "	"	V	MP
R374-1,5	" " " " "	"	M,V	N
R375-1,5	" " " " "	"	M,V	N
R376-1,5	" " " " "	"	M	N
			V	MP
R377-1,2,5	" " " " "	"	M,L,V	N
R576-8	" " " " "	"	WF	N
R72-1,5	*Pomacentrus leucorus* Gilbert	K53-17	M	WP
			V	N
R310-1,3	" " "	K53-6	M	N
			G	MP
R574-5	" " "	K53-13	V	MP
R581-8	" " "	K53-6	WF	N
R583-8	" " "	K53-2	WF	N
	PRIACANTHIDAE—Big eye			
R152-1,2,3,4	*Priacanthus cruentatus* (Lacépède)	K52-24	M,L,G	N
			I	MP
R235-1,5	" " "	"	M,V	N
R259-1,2,3,4	" " "	"	M,G,I	N
			L	MP
R275-1,4	" " "	K53-6	M,I	N
	SCARIDAE—Parrotfish			
R128-1,2,3,4	*Scarus noyesi* Heller and Snodgrass	K52-24	M,L	MP
			G,I	WP
R129-1,2,3,4	" " " " "	"	M,L,G,I	N
R132-1,2,3,4	" " " " "	"	M,L,G,I	N
R142-1,2,3,4	" " " " "	"	M,L,G,I	N
R174-1,2,3,4	" " " " "	"	M,I	N
			L,G	MP
R181-1,2,3,4	" " " " "	"	M,G,I	N
			L	WP
R193-1,2,3,4	" " " " "	"	M,I	N
			L	MP
			G	WP
R194-1,2,3,4,5	" " " " "	"	G,I	N
			L,V	MP
			M	WP
R272-1,4	" " " " "	K52-29	M,I	N
R282-1,2,3,4	" " " " "	K53-6	M,L,I	N
			G	MP
R289-1,2,3,4	" " " " "	K53-2	M,I	N
			L,G	MP
R315-1,3,4	" " " " "	K53-6	M,G,I	N

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	SCIAENIDAE—Croakers, Roncadores			
R309-1,2,4	*Odontoscion eurymesops* (Heller and Snodgrass)	K53-13	M,L,I	N
R343-1,2,3,4	" " " " "	"	M,G,I	N
			L	MP
R145-1,3,4	*Umbrina galapagorum* Steindachner	K53-1	M,G,I	N
	SCOMBRIDAE—Mackerel			
R155-1,5	*Pneumatophorus peruanus* Jordan and Hubbs	K52-24	M,V	N
R231-1,2,3,4	" " " " "	K53-13	M,L	N
			G,I	WP
R247-1,5	" " " " "	K52-24	M	N
			V	WP
R306-1	" " " " "	K52-29	M	N
R320-1,2,3,4	" " " " "	K53-16	M,I	N
			L,G	MP
	SERRANIDAE—Seabass			
R263-1,4,5	*Epinephelus labriformis* (Jenyns)	K53-6	M,I	N
			V	MP
R274-1,3,4	" " "	K53-17	M,G,I	N
R287-1,2,3,4	" " "	K53-7	M,L,G,I	N
R316-1,2,3,4	" " "	K53-6	M,L,G	N
			I	WP
R321-1,2,3,4	" " "	K53-7	M,L,G	N
			I	WP
R324-3,4	" " "	K53-15	G,I	N
R329-2,4	" " "	K53-6	L,I	N
R341-1,2,4	" " "	K53-15	M	WP
			L,I	N
R482-1,5	" " "	K53-17	M	N
			V	WP
R483-1,5	" " "	"	M,V	N
R210-1,2,3	*Mycteroperca olfax* (Jenyns)	K53-15	M,L,G	N
R270-1,4,5	" " "	K53-6	M,I,V	N
R305-1,2,4	" " "	K53-2	M,L,I	N
R311-2,4	" " "	K53-13	L	N
			I	WP
R340-1,2,4	" " "	K53-15	M	N
			L	MP
			I	WP
R296-1,3,4	*Paralabrax albomaculatus* (Jenyns)	K53-13	M	WP
			G	N
			I	MP
R348-1,2,3	" " "	"	M,G	WP
			L	N

Extract No.	*Family, Species, and Vernacular Names*	*Field No.*	*Part of Fish*	*Results*
	SERRANIDAE—Seabass (continued)			
R354-1,2,4	*Paralabrax albomaculatus* (Jenyns)	K53-1	M,I L	N WP
R154-1,5	*Paranthias colonus* (Valenciennes)	K53-13	M V	N MP
R186-1,5	" " "	K52-29	M,V	N
R190-1,5	" " "	"	M V	MP N
R269-1,5	" " "	K53-6	M,V	N
R326-1,2,3,4	" " "	K53-1	L,G M,I	N WP
R333-1,5	" " "	K52-29	M,V	N
R362-1,2,4	*Rypticus bicolor* (Valenciennes)	K53-7	M,L I	N MP
R363-1,3,4	" " "	"	M,G I	N MP
R364-1,5	" " "	"	M V	N SP
R365-1,4	" " "	"	M,I	N
R484-1,5	" " "	K53-6	M,V	N
R485-5	" " "	"	V	N
R566-1	" " "	K53-17	M	N
R584-8	" " "	K53-13	WF	N
	SPARIDAE—Porgies, Pargos			
R350-1,2,4	*Calamus brachysomus* (Lockington)	K53-5	M,L,I	N
	SPHYRAENIDAE—Barracudas			
R102-1,5	*Sphyraena idiastes* Heller and Snodgrass	K53-20	M,V	N
R103-1,2,3,4	" " " " "	"	M L,I G	N MP WP
R104-1,5	" " " " "	"	M,V	N
	TETRAODONTIDAE—Puffer, Globefish			
R93-1,2,4	*Arothron hispidus* (Linnaeus)	K52-24	M,L,I	SP
R407-0,1,2,3,4	" " "	K53-8	M,L,G,I GB	SP MP
R408-1,2,3,4	" " "	"	M,L,G,I	SP
R92-1,2,4	*Arothron setosus* (Smith)	K52-24	M,L,I	SP
R94-1,2,4	" " "	"	M,L,I	SP
R409-3,4	" " "	K53-8	G,I	N
R413-1,2,4	" " "	K52-24	M,I L	N SP

TABLE II

SHOWING THE RELATIVE ANATOMICAL DISTRIBUTION OF POISON IN GALAPAGOS ISLANDS FISHES

Species	*Total No. Specimens Tested*	*Muscle*		*Liver*		*Gonads*		*Intestines*		*Viscera*		*Whole Fish*		*Intestinal Content*		*Gall Bladder*	
		No.	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*
Acanthurus crestonis (Jordan and Starks)	2	2	0	2	50	2	50	2	0	—	—	—	—	—	—	—	—
Xesurus punctatus (Gill)	6	6	17	4	25	2	0	3	0	3	67	—	—	—	—	—	—
Balistes verres Gilbert and Starks	8	8	13	8	13	3	0	7	57	—	—	—	—	—	—	—	—
Strongylura stolzmanni (Steindachner)	1	1	0	—	—	—	—	—	—	1	0	—	—	—	—	—	—
Ophioblennius steindachneri Jordan and Evermann	1	1	0	—	—	1	0	—	—	1	100	—	—	—	—	—	—
Caulolatilus princeps princeps (Jenyns)	1	1	0	—	—	1	0	—	—	1	0	—	—	—	—	—	—
Decapterus sp.	1	1	100	1	0	1	100	1	0	—	—	—	—	—	—	—	—
Seriola colburni Evermann and Clark	1	1	0	1	0	1	0	1	0	—	—	—	—	—	—	—	—
Zalocys stilbe Jordan and McGregor	1	1	0	—	—	1	0	1	100	—	—	—	—	—	—	—	—

Chaetodon nigrirostris (Gill)	3	2	0	—	—	—	—	—	—	2	50	1	0	—	—	—	—
Holacanthus passer Valenciennes	6	6	17	2	0	—	—	2	50	4	50	—	—	—	—	—	—
Coryphaena hippurus Linnaeus	4	3	0	3	33	3	0	2	0	—	—	—	—	—	—	—	—
Chilomycterus affinis Günther	1	1	0	1	—	—	—	1	100	—	—	—	—	—	—	—	—
Chilomycterus sp.	1	1	0	1	100	1	100	1	0	—	—	—	—	—	—	—	—
Cypselurus callopterus (Günther)	5	5	20	3	33	2	50	4	50	1	100	—	—	—	—	—	—
Fodiator acutus rostratus (Günther)	4	4	0	2	0	1	0	1	0	1	0	—	—	—	—	—	—
Fistularia petimba Lacépède	1	1	0	—	—	1	0	1	0	—	—	—	—	—	—	—	—
Gerres cinereus (Walbaum)	4	4	0	—	—	1	0	1	100	3	0	—	—	—	—	—	—
Anisotremus scapularis (Tschudi)	4	4	50	2	50	3	33	4	50	—	—	—	—	—	—	—	—
Haemulon scudderi Gill	1	1	0	—	—	—	—	—	—	1	0	—	—	—	—	—	—
Orthopristis cantharinus (Jenyns)	17	16	31	3	33	6	33	7	29	11	55	—	—	—	—	—	—
Euleptorhamphus longirostris (Cuvier)	1	1	0	1	0	—	—	1	0	—	—	—	—	—	—	—	—
Hyporhamphus unifasciatus (Ranzani)	1	1	0	—	—	—	—	—	—	1	0	—	—	—	—	—	—
Hemiramphus saltator Gilbert and Starks	2	2	50	—	—	1	0	—	—	1	0	—	—	—	—	—	—
Holocentrus suborbitalis Gill	3	3	0	—	—	—	—	—	—	3	0	—	—	—	—	—	—
Myripristis occidentalis Gill	5	5	20	1	100	4	0	1	0	2	50	—	—	—	—	—	—
Euthynnus lineatus Kishinouye	1	1	0	1	0	1	0	1	0	—	—	—	—	—	—	—	—

Species	*Total No. Specimens Tested*	*Muscle*		*Liver*		*Gonads*		*Intestines*		*Viscera*		*Whole Fish*		*Intestinal Content*		*Gall Bladder*	
		No.	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*	*No.*	*% Pos.*
Doydixodon freminvillei Valenciennes	6	6	0	3	0	3	0	3	33	2	50	—	—	1	0	—	—
Bodianus diplotaenius (Gill)	3	3	33	1	0	—	—	2	0	1	100	—	—	—	—	—	—
Bodianus eclancheri (Valenciennes)	4	4	25	1	0	2	50	3	33	1	100	—	—	—	—	—	—
Sphaeroides annulatus (Jenyns)	24	24	58	23	96	22	77	24	75	—	—	—	—	—	—	—	—
Lutjanus argentiventris (Peters)	2	1	100	2	0	2	0	2	0	—	—	—	—	—	—	—	—
Lutjanus viridis (Valenciennes)	9	9	44	2	100	5	20	1	100	7	29	—	—	—	—	—	—
Chaenomugil proboscideus (Günther)	1	1	0	—	—	—	—	1	0	—	—	—	—	—	—	—	—
Mugil cephalus Linnaeus	2	2	0	1	0	1	0	2	0	—	—	—	—	—	—	—	—
Xenomugil thoburni (Jordan and Starks)	3	3	0	—	—	—	—	1	0	2	0	—	—	—	—	—	—
Muraena insularum Jordan and Davis	7	7	14	2	0	1	100	1	100	2	50	—	—	—	—	—	—
Abudefduf saxatilis (Linnaeus)	4	4	0	—	—	—	—	—	—	3	67	—	—	—	—	—	—
Microspathodon bairdi (Gill)	1	1	0	1	0	1	0	1	0	—	—	—	—	—	—	—	—
Microspathodon dorsalis (Gill)	4	4	0	—	—	1	0	—	—	3	0	—	—	—	—	—	—
Pomacentrus arcifrons Heller and Snodgrass	13	10	10	1	0	1	0	2	50	11	36	1	0	—	—	—	—
Pomacentrus leucorus Gilbert	5	2	50	—	—	1	100	—	—	2	50	2	0	—	—	—	—

Priacanthus cruentatus (Lacépède)	4	4	0	2	50	2	0	3	33	1	0	—	—	—	—	—	—
Scarus noyesi Heller and Snodgrass	12	12	17	10	60	11	45	12	9	1	100	—	—	—	—	—	—
Odontoscion eurymesops (Heller and Snodgrass)	2	2	0	2	50	1	0	2	0	—	—	—	—	—	—	—	—
Umbrina galapagorum Steindachner	1	1	0	—	—	1	0	1	0	—	—	—	—	—	—	—	—
Pneumatophorus peruanus Jordan and Hubbs	5	5	0	2	50	2	100	2	50	2	50	—	—	—	—	—	—
Epinephelus labriformis (Jenyns)	10	8	13	5	0	5	0	8	25	3	67	—	—	—	—	—	—
Mycteroperca olfax (Jenyns)	5	4	0	4	25	1	0	4	50	1	0	—	—	—	—	—	—
Paralabrax albomaculatus (Jenyns)	3	3	67	2	50	2	50	2	50	—	—	—	—	—	—	—	—
Paranthias colonus (Valenciennes)	6	6	33	1	0	1	0	1	100	5	20	—	—	—	—	—	—
Rypticus bicolor (Valenciennes)	8	6	0	1	0	1	0	3	67	3	33	1	0	—	—	—	—
Calamus brachysomus (Lockington)	1	1	0	1	0	—	—	1	0	—	—	—	—	—	—	—	—
Sphyraena idiastes Heller and Snodgrass	3	3	0	1	100	1	100	1	100	2	0	—	—	—	—	—	—
Arothron hispidus (Linnaeus)	3	3	100	3	100	2	100	3	100	—	—	—	—	—	—	1	100
Arothron setosus (Smith)	4	3	67	3	100	1	0	4	50	—	—	—	—	—	—	—	—
SUMMARY	241	224	22	110	46	107	36	131	41	88	38	5	0	1	0	1	100

TABLE III

ANALYSIS OF THE FAMILIES TESTED AND PERCENTAGES FOUND TOXIC

Families	*Number Species Tested*	*Percentage Positive*
Acanthuridae	2	100
Balistidae	1	100
Belonidae	1	0
Blenniidae	1	0
Branchiostegidae	1	0
Carangidae	3	67
Chaetodontidae	2	100
Coryphaenidae	1	100
Diodontidae	2	100
Exocoetidae	2	50
Fistulariidae	1	0
Gerridae	2	50
Haemulidae	3	67
Hemiramphidae	3	33
Holocentridae	2	50
Katsuwonidae	1	0
Kyphosidae	1	100
Labridae	2	100
Lagocephalidae	1	100
Lutjanidae	2	100
Mugilidae	3	0
Muraenidae	1	100
Pomacentridae	5	60
Priacanthidae	1	100
Scaridae	1	100
Sciaenidae	2	50
Scombridae	1	100
Serranidae	5	100
Sparidae	1	0
Sphyraenidae	1	100
Tetraodontidae	2	100
TOTAL	57	67

DISCUSSION AND SUMMARY

The way in which fishes become poisonous is not yet thoroughly understood, although an ever increasing number of data indicates that the process is a result of their food habits. A more complete discussion of this subject has been published by Halstead and Bunker (1954). There are probably many factors governing the degree of toxicity of a fish, viz., abundance of certain types of food, availability of certain organic chemical constituents in that food, and the physiology of the fish.

The 57 species of fishes reported in this paper, of which a majority are shore inhabitants, are largely representative of those likely to be used as food in the regions discussed. Of the families tested, the following ones are either valuable or potentially useful food fishes: Acanthuridae, Belonidae, Carangidae, Chaetodontidae, Coryphaenidae, Exocoetidae, Gerridae, Haemulidae, Hemiramphidae, Holocentridae, Katsuwonidae, Kyphosidae, Labridae, Lutjanidae, Mugilidae, Muraenidae, Priacanthidae, Scaridae, Sciaenidae, Scombridae, Serranidae, Sparidae, and Sphyraenidae. It was found that 77% of these families contained toxic species.

TABLE IV

Summary of Tables I, II, and III

	Species	Specimens	Muscle	Viscera	Liver	Gonads	Intestines	Whole Fish
Total Tested	57	241	225	88	110	107	131	5
Total Found Toxic	38	122	50	33	51	39	54	0
Percent Found Toxic	67	51	22	38	46	36	41	0

Of the 241 specimens tested, 122 or approximately 51% were toxic, the viscera being generally more toxic than the somatic musculature. Of 217 specimens for which both musculature and viscera (including liver, intestines, gonads, etc.) were tested, 116 or 53% were poisonous. Of these 116 specimens, 50 or 43% had toxic musculature; 107 or 92% had toxic viscera; and 41 or 35% had both. In general, if the musculature was poisonous, so were the viscera. These results should be carefully evaluated as there is a great deal of variation of toxicity within a given species, and the toxin content of the various organs of the fish vary also between specimens. Too few specimens were collected for most of the species for us to present a complete statistical analysis. Once again the reader is warned against arriving at conclusions about the edibility of species listed as "weakly positive," as it is difficult to interpret this reaction in terms of human symptomatology. In some cases they have been sufficiently toxic to hospitalize humans; in others, the significance of the reaction is questionable. If the puffers of the families Tetraodontidae and Lagocephalidae, which are violently poisonous to humans, were excluded, and the "weakly positive" specimens classed as negative, the percentage of "moderately positive" specimens unquestionably toxic would still be 26%.

TABLE V

DISTRIBUTION OF THE TOXIN IN MUSCLE AND VISCERA AS FOUND IN 215 SPECIMENS

	Viscera	Muscle	Viscera and Muscle
Number of Toxic Specimens	107	50	41
Percent Toxic of a Total of 217 Tested Specimens..........	49	23	19
Percent Toxic of a Total of 116 Toxic Specimens............	92	43	35

LITERATURE CITED

BEEBE, W. AND J. TEE-VAN
1941. Eastern Pacific Expeditions of the New York Zoological Society. 24, 25, 28. Fishes from the Tropical Eastern Pacific. Zoologica [N. Y.] 26:89-122, 245-280, 6 pls., 74 text-figs.

CHUBB, L. J.
1933. Geology of the Galapagos, Cocos, and Easter Islands. Bull. Bernice P. Bishop Mus. 110:1-67, 9 figs., 5 pls.

CLARK, H. W.
1936. The Templeton Crocker Expedition of the California Academy of Sciences, 1932. No. 29. New and Noteworthy Fishes. Proc. Calif. Acad. Sci. iv,21:383-396.

CROSSLAND, CYRIL
1927. The Expedition to the South Pacific of the S. Y. "St. George." Marine Ecology and Coral Formations in the Panama Region, the Galapagos and Marquesas Islands, and the Atoll of Napuka. Trans. Roy. Soc. Edinburgh. 55:531-554, 11 figs., 1 pl.

FOWLER, H. W.
1938. The Fishes of the George Vanderbilt South Pacific Expedition, 1937. Acad. Nat. Sci. Phila. Monog. 2:1-349, 12 pls., map.
1944. Results of the Fifth George Vanderbilt Expedition (1941). The Fishes. Acad. Nat. Sci. Phila. Monog. 6:57-529, 268 figs., 20 pls.

GARMAN, S.
1899. Reports on an Exploration off the West Coasts of Mexico, Central and South America, and off the Galapagos Islands . . . by the U. S. Fish Commission steamer "Albatross," during 1891. The Fishes. Mem. Mus. Compar. Zool., Harvard Univ. 24:1-431, 97 pls.

GILBERT, C. H. AND E. C. STARKS
1904. The Fishes of Panama Bay. Mem. Calif. Acad. Sci. 4:1-304, 33 pls.

GUENTHER, A

1869. An Account of the Fishes of the States of Central America, based on Collections made by Capt. J. M. Dow, F. Godman, Esq., and O. Salvin, Esq. Trans. Zool. Soc. London. 6:377-494, pls. 63-87.

HALSTEAD, B. W.

1951. Ichthyotoxism—a Neglected Medical Problem. Med. Arts and Sci. 5(4):1-7, 8 figs.

1953. Some General Considerations of the Problem of Poisonous Fishes and Ichthyosarcotoxism. Copeia. 1953(1):31-33.

HALSTEAD, B. W. AND N. C. BUNKER

1954a. A Survey of the Poisonous Fishes of the Phoenix Islands. Copeia. 1954 (1):1-11, 2 tables.

1954b. A Survey of the Poisonous Fishes of Johnston Island. Zoologica [N. Y.] 39(2):61-77, 1 fig., 5 tables.

HELLER, E. AND R.E. SNODGRASS

1903. Papers from the Hopkins-Stanford Galapagos Expedition, 1898-1899. XV. New Fishes. Proc. Washington Acad. Sci. 5:189-229, 19 pls.

HERRE, A. W.

1936. Fishes of the Crane Pacific Expedition. Field Mus. Nat. Hist. Zool. Ser. 21:1-472, 50 figs.

HILDEBRAND, S. F.

1946. A Descriptive Catalog of the Shore Fishes of Peru. U. S. Natl. Mus. Bull. 189:1-530, 95 figs.

JORDAN, D. S. AND B. W. EVERMANN

1896. The Fishes of North and Middle America. U. S. Natl. Mus. Bull. 47 (4 pts.):1-3313, 392 pls.

JORDAN, D. S., B. W. EVERMANN, AND H. W. CLARK

1930. Check List of the Fishes and Fishlike Vertebrates of North and Middle America north of the Northern Boundary of Venezuela and Colombia. U. S. Bur. Fish. Rpt. for 1928, Part 2:1-670.

MEEK, S. E. AND S. F. HILDEBRAND

1923. The Marine Fishes of Panama. Field Mus. Nat. Hist. Zool. Ser. 15 (3 pts.):1-1045, 102 pls.

MYERS, G. S.

1940. The Fish Fauna of the Pacific Ocean, with Especial Reference to Zoögeographical Regions and Distribution as They Affect the International Aspects of the Fisheries. Sixth Pac. Sci. Congr. Proc. 3:201-210.

SNODGRASS, R. E. AND E. HELLER

1905. Papers from the Hopkins-Stanford Galapagos Expedition, 1898-1899. XVII. Shore Fishes of the Revillagigedo, Clipperton, Cocos and Galapagos Islands. Proc. Washington Acad. Sci. 6:333-427.

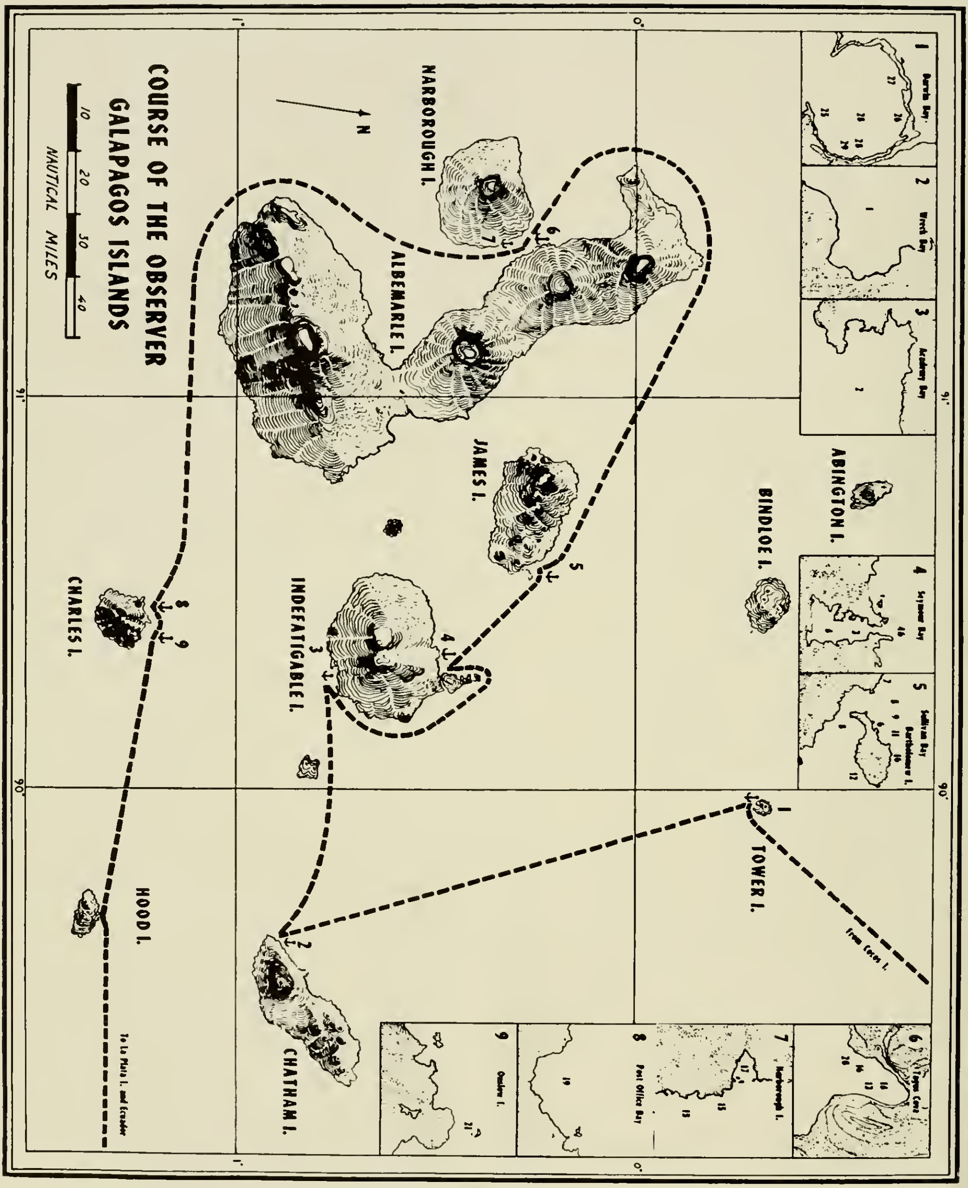
PLATE 1

The "Observer" anchored off the northern tip of Charles Island

PLATE 2

Map showing the itinerary of the "Observer" in the Galapagos Islands.

PLATE 2


COURSE OF THE OBSERVER
GALAPAGOS ISLANDS
NAUTICAL MILES
10
20
30
40
N
NARBOROUGH I.
ALBEMARLE I.
JAMES I.
ABINGTON I.
BINDLOE I.
TOWER I.
INDEFATIGABLE I.
CHARLES I.
HOOD I.
CHATHAM I.
From Cocos I.
To La Plata I. and Ecuador
1°
0°
91°
90°
1 Darwin Bay
2 Wreck Bay
3 Academy Bay
4 Seymour Bay
5 Sullivan Bay Bartholomew I.
6 Tagus Cove
7 Narborough I.
8 Post Office Bay
9 Onslow I.
1
2
3
4
5
6
7
8
9

A NEW SPECIES OF *MYOSOMA* FROM THE PACIFIC (ENTOPROCTA)

By

John D. Soule

Allan Hancock Foundation;
School of Dentistry,
University of Southern California

Recently a very interesting entoproct was noted during the examination of a number of bryozoans collected in the Philippine Islands and sent to the author through the courtesy of Mr. Jose S. Domantay. Subsequent study has revealed what is apparently a new species of the genus *Myosoma.*

The author respectfully wishes to dedicate this new western Pacific member of the phylum Entoprocta to Captain Allan Hancock, patron of marine biological research. The Hancock Foundation, under the auspices of Captain Hancock, has offered its facilities to a number of research workers from many parts of the world, including the Philippine Islands, Egypt, Norway and New Zealand, giving these systematists the opportunity to study and publish reports from material contained in the Hancock collections. In recognition of Captain Hancock's contributions to international goodwill and to the dissemination of scientific knowledge, it is fitting to so dedicate to him this exotic species.

Phylum ENTOPROCTA Nitsche, 1869

Family Pedicellinidae Johnston, 1847

Colonial entoprocts, the zoids arising from a creeping segmented stolon. For an excellent key to the genera of the Pedicellinidae see Osburn, 1953, page 761.

Genus *Myosoma* Robertson, 1900

"Zoarium with stolon composed partly of successive polypide-bearing segments and partly of alternate non-polypide-bearing segments; both stalk and calyx muscular, the muscle fibers continuous from one into the other; lophophore oblique." Robertson, 1900, page 324.

The genus *Myosoma* was erected by Miss Robertson in 1900 on the basis of material collected at Dillon Beach, California, the type locality. In addition to the specimens from the type locality, Miss Robertson reported the presence of the genus in collections from San Pedro, California, and Fort Point, California. There is no further mention of the genus in the literature for fifty-three years, until *Myosoma spinosa* Robertson 1900 was recorded by Osburn, who found it in collections taken at Dillon Beach, California, Newport Bay, California, and La Jolla, California.

From a re-examination of specimens of *Myosoma spinosa* Robertson from Dillon Beach, California, and after study of the species described below, the greater part of Miss Robertson's observations were confirmed. However, with reference to the musculature of the pedicel (stalk, Robertson), it was found that while some muscle fibers are placed longitudinally and others diagonally, in neither *Myosoma spinosa* nor in the new species described below was the heavy "ventral muscle" band described by Miss Robertson in evidence.

Myosoma spinosa Robertson, 1900, the sole species known for almost fifty-five years, is the genotype.

Myosoma hancocki Soule, new species

Diagnosis: With the characters of the genus. Zoarium forming dense tangled masses upon the substratum. Stolon creeping, composed of both polypide-bearing and sterile segments. Polypide consisting of a raised pedicel, bearing at its apex a calyx. Pedicel with musculature arranged both longitudinally and diagonally. Pedicel devoid of spines. Calyx with lophophore obliquely placed. Calyx devoid of spines. Tentacles numbering 14. Dioecious.

Description: The zoaria form prominent tangled masses, making the determination of the path of an individual stolon rather difficult. The stolons ramify, criss-cross to form a mat upon the substratum. In the present specimens, the stolons rested upon the stems of trophosomes of the hydroid *Bougainvillia* sp? There are non-polypide bearing or sterile stolonal segments occurring with no apparent order or regularity.

The reptant segmented stolons give rise to erect, well chitinized polypides consisting of two distinct anatomical regions, the pedicel and the calyx. The pedicel is muscular, possessing muscle fibers that are placed diagonally as well as muscle fibers that parallel the long axis of the pedicel. The chitinous cuticle, in preserved specimens, shows many fine transverse wrinkles or annulations. Miss Robertson described a heavy ventral muscle band traversing the length of the pedicel and continuing into the calyx. As mentioned above, the present study does not confirm this observation in either *Myosoma spinosa* Robertson or *Myosoma hancocki.* The pedicels of *Myosoma hancocki* are completely lacking in spines. In sexually mature individuals, the length of the pedicel ranges from 515 μ to 745 μ, well short of the length attained by *Myosoma spinosa.*

The calyx has an obliquely situated lophophore with its crown of ciliated tentacles. The anatomical pattern is typically entoproctan, having a "U" shaped alimentary tract with both the oral and the anal apertures opening into the lophophore. Also within the calyx are found the reproductive organs, the nephridia and the nerve ganglion with its sensory fibers.

Myosoma hancocki is dioecious, the reproductive organs are paired and laterally placed. The male and female individuals occur together within the same zoarium and along the same stolon. The calyx in sexually mature individuals ranges in size from 250 μ to 345 μ in length and from 180 μ to 230 μ in width, being notably smaller than the calyces of *Myosoma spinosa.* An examination of a large number of polypides failed to reveal a single calyx possessing spines.

Holotype: AHF number 135.

Repository: Allan Hancock Foundation, The University of Southern California, Los Angeles, California.

Type locality: Malabon, Rizal Province, on fish pond gates of the Dagat-dagatan Saltwater Experimental Station, March, 1954, collector, Jose S. Domantay.

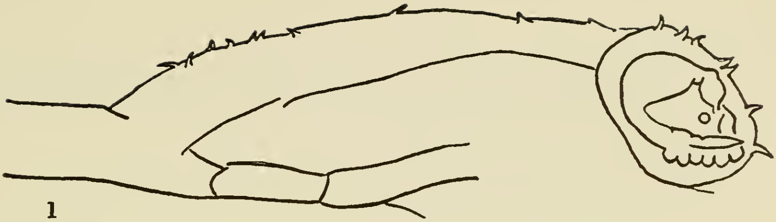
Fig. 1. *Myosoma spinosa* Robertson, 1900, a portion of a zoarium showing a zoid and stolon.

Fig. 2. *Myosoma hancocki* new species, a portion of a zoarium showing three mature zoids, an immature zoid and stolon. Cf. Fig. 1.

Fig. 3. *Myosoma hancocki* new species, female zoid showing anatomy.

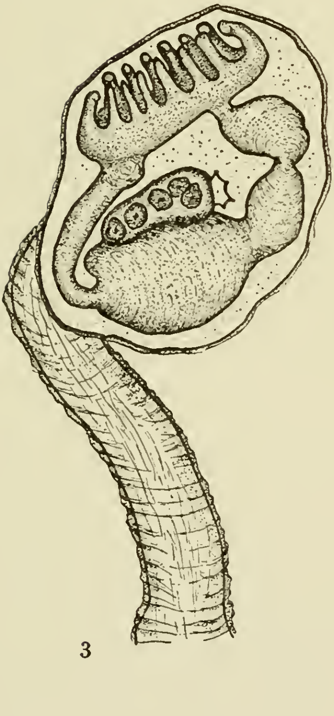
Fig. 4. *Myosoma hancocki* new species, male zoid showing anatomy.

Figs. 1 and 2 drawn to the same scale and Figs. 3 and 4 drawn to the same scale. Camera lucida. Dorothy F. Soule, illustrator.

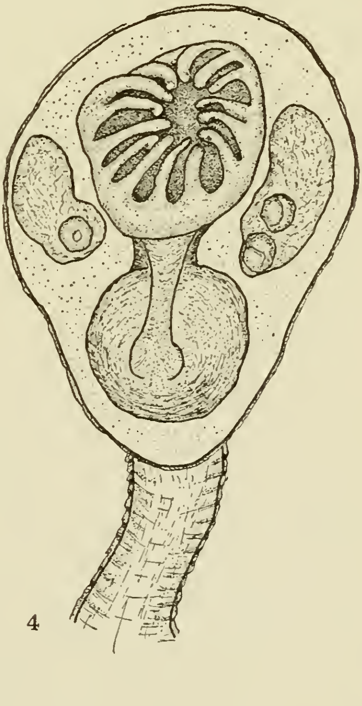


1

2



3



4

LITERATURE CITED

Osburn, R. C.
1953. Bryozoa of the Pacific Coast of America. Part 3, Cyclostomata, Ctenostomata, Entoprocta, and Addenda. Allan Hancock Pacific Exped. 14: 613-841, pls. 65-82. (Entoprocta, pp. 759-773, pl. 82)

Robertson, Alice
1900. Studies in Pacific Coast Entoprocta. Proc. Calif. Acad. Sci. ser. 3, Zool. 2(4):323-348, pl. 16.

A NEW RECORD OF *ATHYONE GLASSELLI* (DEICHMANN)

By

Elisabeth Deichmann

Museum of Comparative Zoology, Harvard University

On March 23, 1954, Mr. Gil Bane of Los Altos, California, collected two holothurians at Guaymas, Sonora, Mexico. They were found about 10 yards from the water edge, covered by sand. Although this is a common habit of many holothurians, the poor condition of the specimens—the anterior end lost and most of the inner organs ejected—made one suspect that in this case the animals had lived at slightly greater depth and were washed up after a storm and had later accidentally been covered by sand.

Examination of the spicules proved that the two specimens represented *Athyone glasselli* (Deichmann) of which hitherto only the type was known. The latter was collected in 1936 by Mr. Steve Glassell, at Punta Penasco, about 200 miles north of Guaymas. The type was taken in shallow water, likewise covered by sand, but the oral end with the tentacles was present although the animal succeeded in ejecting most of its inner organs when captured. One may therefore conclude that the species normally does live hidden in sand, in shallow water.

In spite of the poor condition of the present material, which looks like two old flattened tennis balls, it supplements the original description, especially with regard to the earlier stages of the spicules. A new description is therefore given, with some remarks about the possible relation of this form to Troschel's material of *"Anaperus peruana"* and to the common *"Thyone"* of the Gulf of Mexico, *T. briareus.*

(In one of the individuals was discovered an ovigerous female of an oyster crab. According to Dr. Fenner A. Chace, U. S. National Museum, it is a new species and seems to be related to *Pinnotheres hirtimanus* H. Milne Edwards, from the waters around Cuba.)

Athyone glasselli (Deichmann)

Thyone glasselli Deichmann, 1936, p. 65, text figures; 1937, p. 171, fig. 2.

Athyone glasselli Deichmann, 1941, p. 119.

Diagnosis: Large species which superficially resembles the Atlantic form, *Thyone briareus* (Lesueur), with numerous feet and 10 tentacles of which the two ventral ones are small. Skin leathery with few spicules, color brownish to blackish, mottled, with dark introvert and tentacles. Calcareous ring stout, short-tubular, with well developed tails on the radials, and tall interradials which posteriorly are excavated. One dorsally attached stone canal and two ventrally placed Polian vesicles. Gonads as two tufts of tubes placed near the middle of the body. Longitudinal muscles strong, fleshy, in contracted specimens projecting like ridges.

Spicules as small tables, with oval to squarish disk with 4 to 8 holes and two pillars ending in many spines, with age reduced to oval or round plates. Feet with well developed end plate, surrounded by elongate, perforated plates; in the wall two-pillared, elongate supporting tables which in older individuals become reduced to spectacle or lozenge-shaped plates or rods. Introvert with delicate tables with numerous holes in the disk and low, two-pillared spire; rosettes present, as also in the tentacles.

Type specimen: In the Museum of Comparative Zoology.

Type locality: Punta Penasco, Sonora, Mexico.

Distribution: Known from the type locality and Guaymas, Sonora, Mexico.

Depth: Found in shallow water, covered by sand.

Specimens examined: The type and the two "headless" individuals, about 7 cm in diameter, strongly contracted, from Guaymas.

Remarks: As noted in the original description, the species resembles superficially *Thyone briareus* (Lesueur) from the Gulf of Mexico, Florida, and the Atlantic Seaboard northwards to Woods Hole, Massachusetts. However, in fully expanded condition the species must be somewhat larger than *briareus* and it appears also to be a more robust form in agreement with its life along the exposed shore of the tropical Pacific. As far as known it lives hidden in sand whereas *T. briareus* is found in muddy localities, often attached to "eel grass."

In view of what we know about the distribution of other Panamic forms it is not unlikely that *A. glasselli* ranges from the northern end of the Gulf of California to the shores of northern Peru, and the reason why it has escaped notice is because of its burrowing habits.

If it should occur as far south as Peru, it raises the question whether or not part of Troschel's material of *"Anaperus peruana"* refers to this species, namely the material in Berlin which Selenka in 1868 unhesitatingly united with his own *T. tenella*, described in 1867, and Troschel's *Anaperus carolinus*, from Texas and South Carolina respectively—both straight synonyms of Lesueur's *T. briareus.*

It is unfortunate that we do not know whether Troschel had one or two species before him or whether his *"peruana"* was based partly upon Lesson's description, partly upon a species which actually resembled *briareus*. The fact that his material had tentacles filled with spicules so they "creaked" when scratched with a knife indicates Lesson's species, as also the length—6 inches—and the deep purplish color. On the other hand, his description of a calcareous ring with short posterior projections, coupled with the fact that Selenka united Troschel's *peruana* with the Atlantic *briareus* (*tenella* and *carolinus*) makes one wonder whether Troschel had some material of *A. glasselli* before him, for so far this is the only West coast species which resembles *T. briareus.*

The type of Lesson's *peruvianus* is lost, but the name *Anaperus peruvianus* (Lesson) is now given to a large purplish species of which there are three specimens extant in museums: one in the American Museum, New York, two in the Zoological Museum in Copenhagen (see Deichmann, 1952).

If *A. glasselli* should be discovered in the Peruvian waters its name will remain unchanged, but to its synonymy should be added: *Anaperus peruana* Troschel, 1846 (*partim*)—nec *Holothuria peruviana* Lesson, 1830. This represents a correction to the conclusions reached in 1941, before the material of Lesson's species had been re-described.

As far as relationship is concerned *Athyone* and *Anaperus* are well separated; the latter has, among other characters, tentacles of equal size, simple ring without posterior prolongations, and a most striking reddish pigment which is extracted by alcohol so that it often discolors the labels in the jar wherein the specimen is kept.

When more material becomes available of *glasselli* it will be possible

TEXT FIGURES 1-15

Spicules from *Athyone glasselli* (Deichmann) from
Guaymas, Sonora, Mexico

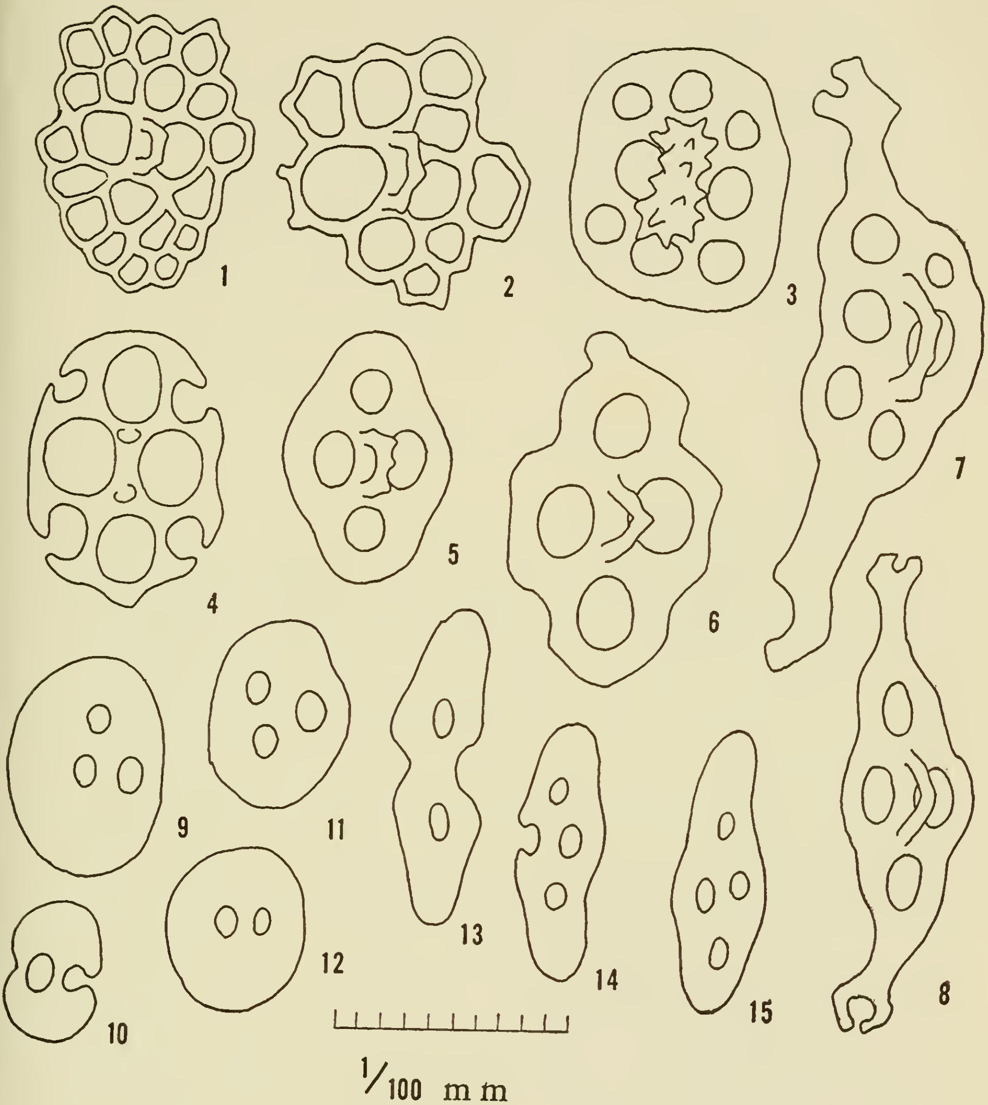
Figs. 1-2 Tables from posterior part of introvert.

Figs. 3-5 Tables from anterior part of body.

Figs. 6-8 Supporting tables from feet in anterior part of body.

Figs. 9-15 Disks of reduced tables and supporting tables from posterior part of body of same individual.

Magnification: Divisions of scale indicate 1/100 mm.


1
2
3
7
4
5
6
9
11
13
14
15
8
10
12
1/100 mm

to make a thorough comparison between that form and *T. briareus*. It is not impossible that the latter species then will be transferred to the genus *Athyone*, thus relieving the genus *Thyone s. str.* of a species which definitely does not belong in it. The presence in the Pacific form of a peacrab closely related to a West Indian species may be another point in favor of considering *glasselli* and *briareus* congeneric.

I wish to thank Mr. Gil Bane for giving me this opportunity to add some additional information to our knowledge of a not too well known species, and for his generosity in depositing one of the specimens in the Museum of Comparative Zoology.

LITERATURE CITED

Deichmann, Elisabeth

1936. A new species of *Thyone* from the west coast of Mexico. Proc. New England Zool. Club. 15:63-66, text-figs.

1937. Holothurians from the Gulf of California, the West Coast of Lower California and Clarion Island. The Templeton Crocker Expedition, 9. Zoologica [N. Y.] 22:161-176, text-figs. 1-3.

1941. The Holothurioidea collected by the Velero III during the years 1932 to 1938. Pt. 1. Dendrochirota. Allan Hancock Pac. Exped. 8:61-195, 6 text-figs., pls. 10-30.

1952. The rediscovery of the Holothurian *Holothuria peruviana* Lesson. Amer. Mus. Novitates. 1553:1-7, text-figs. 1-15.

Selenka, E.

1867. Beiträge zur Anatomie und Systematik der Holothurien. Zeitschr. Wiss. Zool. 17:291-374, pls. 17-20.

1868. Nachtrag. *Ibid.* 18:109-119, pl. 8.

Troschel, F. H.

1846. Neue Holothurien-Gattungen. Arch. f. Naturgesch. 12(1):60-66.

A REVIEW OF THE GENUS *OPHIODERMA* M. & T.

By

Fred C. Ziesenhenne

Allan Hancock Foundation

The numerous variations in color of the littoral species of *Ophioderma* known from the Pacific coast of tropical America have presented a problem to the taxonomists for many years, chiefly because so few individuals of each species were known. During the years 1933 to 1954 the Velero Expeditions have collected a large number of specimens of *Ophioderma* from the western coasts of tropical America and the offlying Pacific islands. In addition a number of Atlantic specimens were collected in 1939 from the coasts of Panama, Colombia, Venezuela, and various islands, especially Tobago. This vast amount of material has given us more knowledge of some of the species, which in many cases had been established on a single specimen.

It has been the writer's good fortune as a member of the Velero Expeditions to help collect this material and later study it in the Allan Hancock Foundation. In addition he has had the opportunity to study the large collections of *Ophioderma* in the Museum of Comparative Zoology and the United States National Museum. The five species he has not been able to examine are indicated in this paper by an asterisk.

The genus as accepted today includes 21 species. Three have doubtful localities, while two others are reported from the eastern Atlantic. The remaining 16 belong only to American waters. One is known from both the Atlantic and Pacific, while 11 are reported from the western Atlantic and 4 from the Pacific. The majority are shallow water forms, with only 3, one Atlantic, one Pacific, and one in both Pacific and Atlantic, being reported from deeper waters.

To help future workers on this group, a key is given to all the accepted species, with the literature and distribution for each. Only the Pacific species are discussed in greater detail.

Genus *OPHIODERMA* M. & T.

Ophioderma Müller und Troschel, 1842, Syst. Ast., p. 83, 86.

Ophiocryptus (partim) H. L. Clark, 1915, Jour. Entom. Zool., vol. 7, no. 1, p. 64.

Diagnosis: Differs from the other genera of the family Ophiodermatidae in having four interradial genital slits confined to the underside of the disk, arms twice the length of the disk diameter, and flat disk plates.

Type species: Asterias longicauda Retzius 1805.

Remarks: There are two other genera in the family Ophiodermatidae which have four genital slits, *Ophioncus* Ives and *Ophiocryptus* H. L. Clark. The former, however, has arms barely the length of the disk diameter, while the latter has large convex disk scales. Both are monotypic and restricted to California waters, and range northward beyond the limit of *Ophioderma*. The three species of *Ophiocryptus* described by H. L. Clark and Nielsen are now considered juvenile stages of *Ophioderma*.

KEY TO THE SPECIES OF OPHIODERMA

1. Upper arm plates divided into numerous smaller plates . . . 2
1. Upper arm plates not divided into numerous smaller plates . . 8
2. Radial shields completely covered 3
2. Radial shields normally exposed, sometimes partly covered in *longicaudum* and *teres* 4
3. Distal margin of under arm plate bi-lobed, heart-shaped. Locality doubtful: East Indies . . . .
1. *propinquum** Koehler
3. Distal margin of under arm plate convex. West Indies . . .
2. *guttatum* Lütken

4. Arm-spines 7 or less 5

4. Arm-spines 8 or more 6

5. Arm length 4 to 5 times disk diameter. Disk grains excessively large, flat, tile-like; no exposed scales on disk. West Indies . .
3. *squamosissimum* Lütken

5. Arm length 3 times disk diameter. Granules small, round; a few disk scales may be exposed; a few upper arm plates may be fused into one piece. Locality doubtful; South Africa . . . . . .
4. *wahlbergii** Müller & Troschel

6. Arms short, about 2½ times disk diameter, arms never banded. Panamic . . . .
5. *teres* (Lyman)

6. Arm length 3½ times disk diameter, or more 7

7. Arm length 3½ times disk diameter, arms banded. West Indian
6. *cinereum* Müller & Troschel

7. Arm length 4½ times disk diameter, arms not banded. East Atlantic . . . .
7. *longicaudum* (Retzius)

8. Radial shields normally exposed; sometimes partly covered in *phoenium* and *panamense* 9

8. Radial shields covered by disk granulations 12

9. Arm-spines 9, rarely 10 10

9. Arm-spines 10 to 12 11

10. Upper arm plates narrow, arms 4 to 5 times disk diameter, oral shields large, sub-cordate. Havana. 110 to 200 fathoms . . .
8. *pallidum** (Verrill)

10. Upper arm plates broader than long, arm length 3 to 4 times disk diameter. Atlantic . . . .
9. *phoenium* H. L. Clark

11. Adoral shields concealed; 10 to 12 arm-spines, arms banded. Panamic . . . .
10. *panamense* Lütken

11. Adoral shields exposed, 10 arm-spines. Atlantic . . . . .
11. *rubicundum* Lütken

12. Adoral shields exposed 13

12. Adoral shields not exposed 19

13. Five arm-spines, rarely 6. Panamic . . . .
12. *pentacanthum* H. L. Clark

13. Seven arm-spines or more 14

14. Lowermost arm-spine largest 15

14. Arm-spines of equal size 16

15. Arm length 6 times disk diameter. West Indies and Panamic. 73 to 300 fathoms . . . . 13. *elaps* Lütken

15. Arm length 3 times disk diameter. S.W. Africa . . . . 14. *leonis** Döderlein

16. Arms broad, not finely tapering at the tips 17

16. Arms slender, finely tapering at tips 18

17. Arm-spines 7 to 9, long, delicate, not flattened, slightly longer than arm segment. Panamic . . . . 15. *variegatum* Lütken

17. Arm-spines 8 to 9, subequal, pointed, slightly more than one-half the length of arm segment. Atlantic . . . . 16. *brevispinum* (Say)

18. Arm-spines 8 to 9, well spaced, not flattened, almost the length of arm segment. Arm length 5 to 6 times disk diameter. Atlantic 17. *januarii* Lütken

18. Arm-spines 9 to 10, broad, flat, closely compacted, about ⅔ the length of arm segment; arm length less than 5 times disk diameter. Atlantic . . . . 18. *holmesii* (Lyman)

19. Arm-spines equal, arms short, length 3 to 4 times disk diameter. Atlantic . . . . 19. *brevicaudum* Lütken

19. Lowest arm-spine largest, arm length 4 times disk diameter . . 20

20. Arm-spines 8, short, compact, half the length of arm segment, large granules on adoral plate. Locality doubtful. Pacific . . . 20. *tonganum** Lütken

20. Arm-spines 9 to 10, flat, less than length of arm segment, small granules on adoral plates. Atlantic . . . . 21. *appressum* (Say)

1. *Ophioderma propinquum**

Ophioderma propinqua Koehler, 1895, Mém. Soc. Zool. France, vol. 8, p. 404, pl. 9, fig. 5.

Ophioderma propinquum H. L. Clark, 1923, Annals South African Mus., vol. 13, p. 352.

Java, East Indies, Indian Ocean.

This species seems to be valid but it is highly doubtful if it came from the Indian Ocean as the genus has not been reported from that area since.

It is being retained in the key in the hope that more material may be collected in the future.

2. *Ophioderma guttatum*

Ophioderma guttata Lütken, 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 197, pl. 1, figs. 8a-8b.
Littoral. Jamaica and Tobago Islands. Rare.

3. *Ophioderma squamosissimum*

Ophioderma squamosissima Lütken, 1856, Vidensk. Medd. Dansk Naturhist. Foren., p. 8; 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 194, pl. 1, figs. 7a-7b.

Ophioderma squamosissmum H. L. Clark, 1933, Sci. Survey of Porto Rico and Virgin Islands, vol. 16, pt. 1, p. 72.
Littoral. Buccoo Reef, Tobago Island; West Indies.
Exceedingly rare.

4. *Ophioderma wahlbergii**

Ophioderma wahlbergii Müller und Troschel, 1842, Syst. Ast., p. 87; H. L. Clark, 1923, Annals South African Mus., vol. 13, p. 353.
Locality doubtful. Port Natal, South Africa.

The species has been taken only once and both H. L. Clark (1923, p. 353) and Th. Mortensen (1933, p. 382) share the belief that the locality given is problematic. It is included in the key in the hope that some future worker will be able to tie it in with material from a reliable locality.

5. *Ophioderma teres*

Ophiura teres Lyman, 1860, Proc. Boston Soc. Nat. Hist., vol. 7, p. 198; 1865, Mem. Mus. Compar. Zool., vol. 1, no. 1, p. 37, fig. 1.

Ophioderma teres Meissner, 1901, Bronn's Thier-reich, vol. 2, abt. 3, buch 3, p. 915.

Ophioderma teres var. *unicolor* H. L. Clark, 1940, Zoologica [N. Y.], vol. 25, pt. 3, p. 342.

Littoral to 10 fathoms. Reef, ten miles west of Point Malarrimo, Baja California, Mexico, south to La Plata Island, Ecuador;

Galapagos Islands, and the Gulf of California. Common. 77 specimens in Hancock Collection.

As early as 1889 Ives noticed the variation in color and characteristics of *O. teres* and *O. panamense.* Nielsen (1932, pp. 328-330) and Clark (1940, p. 342) have also discussed the relative merits of the distinguishing characteristics of *O. teres.*

In the Hancock Collection there are 77 specimens collected from the west coast of Baja California, Mexico, the Gulf of California south to Ecuador, and the Galapagos Islands. Lyman's description was of an adult from Panama with a disk diameter of 32 mm and an arm length of 133 mm, and listed four outstanding characters: broken upper arm plates, concealed radial shields, proportionately shorter arms, and purple-brown color without mention of banding. Nielsen (1932, p. 333) added: "A more reliable character are [*sic*] the roundish arms of *O. teres*, those of *O. panamense* being more flattened." Only 15 of our largest specimens agree with the above five characteristics and thus could be classed as typical *O. teres.*

The largest specimens were taken at the extreme northern range, from a reef located 10 miles west of Malarrimo Point, west coast of Baja California, Mexico. The series ranges in size from 25 to 42.5 mm in disk diameter and 91 to 162 mm in arm length. The radial shields in this lot are concealed by granules, while the largest specimen from the Galapagos Islands (disk diameter 37 mm, arm length 143 mm) has exposed radial shields and five sets of pore pairs. Another series of fifteen specimens from Guaymas Bay, Sonora, Mexico, have concealed radial shields. They range in size from 17 to 35 mm in disk diameter and 51 to 136 mm in arm length. These specimens have the upper arm plates divided into four or five plates basally and two to three distally. The arms are strongly rounded and the color is a uniform brown on the upper surfaces and a lighter brown on the under side.

The smallest specimens were collected at Espiritu Santo Island in the Gulf of California and have a disk diameter of 10 mm and an arm length of 21 mm. In general the smaller specimens have exposed radial shields and fewer divisions of the upper arm plates. The color is a rich chocolate brown on the upper surface with thin black-lined irregular rings on the disk; within the rings the color is a lighter brown. There is definitely no banding of the arms. The color pattern of the upper disk continues on the under interbrachial areas. The mouth parts and the oral shields are lighter brown, the under arms within the disk diameter rich golden-yellow, fading gradually to the arm tips and blending into the chocolate brown of the upper arm.

Six specimens from the Galapagos Islands differ in having a more pentagonal disk and more delicate arms, with an average arm length of 2.8 times the disk diameter. The upper disk is a reddish-brown without any markings or black-lined rings. The under side is a lighter reddish-brown without markings and the arms are of the same color. The typical robust chocolate brown phase with black-lined rings on disk and golden-yellow under arms was also found in the Galapagos Islands.

Three individuals taken at Port Utria, Colombia, are of the heavy robust form with arms three times the disk diameter in length. The upper disk is brown, uniformly speckled with a light tan, the specks becoming larger distally and extending out on the upper arms to the tips. The spots on the upper arm plates are in two transverse rows running across the arm. Basally there are about 20 spots on the upper arm segment, reducing proportionately to about 12 distally except for the extreme arm segments. The under disk and oral shields are speckled and the mouth parts and under arms are yellow, the color blending distally into the brown of the upper surface. The southernmost specimens from La Plata, Ecuador, are typical in form and have the characteristic chocolate brown disk with thin black-lined rings inclosing areas of lighter brown on both the upper and under disk. The mouth parts and basal arm plates have the golden-yellow coloring.

The color of *O. teres* varies usually according to geographical location and habitat, though several color phases have been taken at the same location. Therefore the writer does not believe it is justifiable to distinguish each color phase as a variety or subspecies as H. L. Clark (1940, p. 342) did for the large size adult, which is uniformly dark brown. Adult dark brown specimens in the Hancock Collection have been taken from the west coast of Baja California, Mexico; Gulf of California, Mexico; and the Galapagos Islands.

One may summarize the most distinctive characteristics of *O. teres* as:

1. Fragmentation of the upper arm plates, becoming more pronounced in the larger specimens.
2. Higher, more pronounced rounded arms, especially in the larger specimens, in contrast to the flat arms of *O. panamense.*
3. The brown color, without arm banding, even in the youngest specimens.

6. *Ophioderma cinereum*

Ophioderma cinereum Müller und Troschel, 1842, Syst. Ast., p. 87.

Ophioderma antillarum Lütken, 1859, Norsk Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 190, pl. 1, figs. 1a-1c.

Ophiocryptus hexacanthus H. L. Clark, 1915, Jour. Entom. Zool., vol. 7, p. 64; 1918, Bull. Mus. Compar. Zool., vol. 62, p. 337.

Ophioderma cinereum H. L. Clark, 1915, Mem. Mus. Compar. Zool., vol. 25, p. 301.

Littoral to 94 fathoms. Florida to Brazil, Gulf of Mexico, Caribbean area, Bermuda, Puerto Rico, and Caledonia Bay, Panama. Common. 116 specimens in Hancock Collection.

7. *Ophioderma longicaudum*

Asterias longicauda Retzius, 1805, Diss. Ast., p. 28.

Ophioderma longicaudum Müller und Troschel, 1842, Syst. Ast., p. 86 pl. 9, fig. 1.

Littoral. Mediterranean Sea, Spain, and Azores. Common. One specimen in the Hancock Collection.

8. *Ophioderma pallidum**

Ophiura pallida Verrill, 1899, Bull. Nat. Hist., Iowa Univ., vol. 5, no. 1, p. 7, pl. 2, fig. 3.

Ophioderma pallidum H. L. Clark, 1915, Mem. Mus. Compar. Zool., vol. 25, p. 302.

110 to 200 fathoms. Off Havana, Cuba. Rare.

9. *Ophioderma phoenium*

Ophioderma phoenium H. L. Clark, 1918, Bull. Mus. Compar. Zool., vol. 62, pp. 333-335, pl. 6, figs. 1-2; 1933, Sci. Survey of Porto Rico and Virgin Islands, vol. 16, pt. 1, p. 71.

Littoral to 14 fathoms. Buccoo Reef, Tobago Island, British West Indies, and Caledonia Bay, Panama. Rare. Three specimens in the Hancock Collection.

10. *Ophioderma panamense*

Ophioderma panamensis Lütken, 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 193.

Ophioderma panamense H. L. Clark, 1910, Bull. Mus. Compar. Zool., vol. 52, p. 340, pl. 8, fig. 2.

Ophiocryptus granulosus Nielsen, 1932, Vidensk. Medd. Dansk Naturhist. Foren., vol. 91, p. 334, fig. 38.
Littoral to 10 fathoms. San Pedro, California, south to Payta, Peru; Galapagos Islands, Cocos Island, Guadalupe Island, Socorro Island, Clarion Island and the Gulf of California. Very common. 2389 specimens in the Hancock Collection.

In 1940 a series of 284 specimens of *Ophioderma panamense* ranging in disk diameter from 2.3 to 21 mm and in arm length from 6 to 77 mm was collected on a rocky reef at low tide at Puerto Refugio, Angel de la Guarda Island, Gulf of California, Mexico. In this series, 96 specimens have a disk diameter of 6 mm or less, 30 have 7 mm, and many more have less than 9 mm. A study of the development of the growth of *O. panamense* as illustrated by this series follows.

Specimens with a disk diameter of less than 3 mm are entirely covered with granules except for the outer third of the under arm plates. The length of arms averages 2.3 times the disk diameter, and only four arm-spines are developed at this stage.

Specimens with a disk diameter between 3 and 3.5 mm show less granulation. The granules are lost on the center of the upper and under arm plates, except for the four basal segments. The side arm plates, disk, and mouth parts are concealed by granules and five arm-spines are developed.

Specimens with disk diameters between 3.5 and 4 mm have still fewer granules present. A few distal arm segments, side arm plates, four basal arm segments, and the disk are covered by granules, and there are fewer granules on the mouth parts. The arm length varies from 2 to 2.5 times the disk diameter. The arm-spines are still five in number. The color banding on the arms becomes very distinct at this stage.

At the 4 mm disk diameter stage, the granules are disappearing from the side arm plates, the madreporite becomes prominent and exposed, and a few scattered granules remain on the basal under arm plates. The upper arm plates are practically free of granules. The arms are now 2.5 to 3 times the disk diameter in length. The arm-spines are still five in number but have grown considerably longer.

At the 5 mm disk diameter stage, the oral shields are exposed. The upper and under arm plates are free of granules and only the four basal side arm plates bear granules. The mouth parts still retain much of the granulation. The arm-spines are longer, but still number only five, with the arm length now averaging 3 times the disk diameter.

At the 6 mm stage only the disk and mouth parts are granulated; all arm plates and the oral shields are free of granules. Six arm-spines are now present and the arm length is 3 to 3.5 times the disk diameter. The white arm banding is confined to the distal third of the arms.

At the 8 mm disk diameter stage, 7 arm-spines appear; at 10 to 11 mm, 8; at 17 mm, 9; and at 20 mm, the full number of arm-spines is present. Specimens exceeding 15 mm in disk diameter have an arm length of 3.5 to 4 times the disk diameter.

The color phases of *O. panamense* have been discussed by Ives (1889, p. 76), Nielsen (1932, pp. 328-330), and H. L. Clark (1940, p. 343). There appear to be three dominant phases with numerous variations. It would be difficult to name sub-species or varieties that would be distinctive in large series, as the color seems to be the only difference in the specimens. Rather than add more names, it is preferable to refer only to color phases.

The commonest and simplest color combination is that observed by Lockington (Ives, 1889, p. 76) in which the disk is brown to olive and the arms greenish, with the arms banded distally with white. There are 3 or 4 white bands in small specimens and up to 8 or more in adults. Some 1740 specimens of this phase were collected in the Gulf of California and south to Tangola Tangola Bay, Mexico. They prefer sandy or muddy inter-tidal areas, still water, tidal pools, lagoons, etc., where they are found in large numbers under rocks, coral clumps, and algae holdfasts. Some specimens have broken upper arm plates and broken and regenerating arms, indicating that they might have been crushed by moving rocks. A few such animals with crushed upper arm plates might be confused with *O. teres*, but the white arm bands are a distinctive character for separating this form. The majority of the specimens of this color phase have concealed, or partially concealed, radial shields.

A second color phase, of which 122 specimens were taken in the Gulf of California, seems to be associated with coral heads or rock shingle beaches usually free of sand and mud and is the most colorful of all littoral species. In general structure it appears heavier and more robust, with stouter arms and with the radial shields exposed except occasionally. This is probably because of its more exposed habitat. At nine stations it was taken along with specimens of the green color phase, the latter being the more numerous. The disk may be brown, gray, green, mottled or splashed with tan, white, yellow, old rose, carmine, brown or light green.

Commonly there is a white or cream central splash that may radiate out from the center of the disk. The arms are broadly banded for their entire length in dull gray, green, or slate blue, alternating with 3 to 5 bands of dark brown, maroon, dull rose, reddish-brown or combinations of these colors. Very few specimens are colored alike or have the same pattern. The under side is usually lighter, with faint arm banding seen on some specimens. The under arm plates are light gray, pale yellow, light green or light brown.

Of the third color phase 527 specimens were collected from San Pedro to Cape San Lucas, on rocky exposed coast open to the breakers and the wash of the sea. It is found intertidally under rocks, on ledges, among kelp holdfasts, and in rocky crevices. It has banded arms but the basic color varies according to the latitude. It is noteworthy that it attains a larger size than the other forms, several specimens from the entrance of Newport Bay, California, having a disk diameter of 45 mm and an arm length of 198 mm. The common color pattern of the California west coast specimens is a light tan disk with brown and darker specks in the center, radiating out interbrachially. The radial shields are exposed, with the outer margin bordered by concentric rings of light yellow spots, within which are irregular light spots. The disk at the arm bases is heavily mottled with white. The upper arm plates are pale brown with a fine white transverse line along the proximal edge. Every third or fourth arm segment is a dull white band, covering either one or two segments. The under side of the disk is light brown speckled with yellow and tan. Mouth parts, oral shields and under arm plates are light tan, with only faint traces of the arm banding.

Another series of specimens from a reef 10 miles west of Malarrimo Point, Baja California, Mexico, have a uniform chocolate brown upper disk. The upper arms are chocolate with white to grayish arm bands the entire length of the arms. Distally the bands become lighter and more conspicuous; basally, on older specimens, the banding is inconspicuous and dull. The under side of the disk is grayish-tan, with irregular lighter spots; the under arms are grayish with duller arm banding.

Two large series collected from Turtle Bay, Baja California, Mexico, have a reddish-brown upper disk, becoming lighter brown on the under side and often mottled with cream to gray centrally on the upper surface. The upper arms are reddish-brown with mottled white and gray bands the full length of the arm. The basal arm banding in the adult becomes more inconspicuous with greater size. The oral shields are olive-gray and the under arms light brown, becoming darker distally and with faint banding continuous from the upper arms.

Specimens from Thurloe Bay, Mexico, have a uniform light brown disk, and arms of the same color, with cream and gray mottled bands extending the full length. The under disk is a straw tan, uniform, without any markings. The under arms are light tan proximally, becoming darker distally and showing a faint arm banding.

Specimens from the islands of Clarion and Socorro, west of Mexico, have an olive green disk with brown, reddish, or even cream splotches or central disk markings. The arms are a lighter shade of green, with dark green arm bands basally; distally the arm bands become lighter, almost white at the arm tips. The under disk is light green, often tinged with tan, brown or olive. The under arms and oral shields are light green with creamy mottlings, with the arms becoming darker distally and showing faint banding. The arm bands are conspicuous in the younger forms, but become inconspicuous with increase in size.

Some of the specimens from the Galapagos Islands have the same color patterns as the Clarion Island forms. Smaller specimens lack the green. The disks are reddish-brown uniformly speckled with white, yellow, tan, and brown, giving a salt and pepper effect. The arms are brightly banded with white, gray, and yellow mottled bands alternating with dark brown and slate gray. The under side of the disk also has the specklings over a reddish-brown color, fading into pale yellow proximally. The oral shields and mouth parts are yellow, with the under arms banded proximally with yellow. Distally the bands gradually become as dark as the upper arm bandings.

Specimens of *O. panamense* from Central America are predominately green. The disks are light to dark olive green with tan, gray or light green markings. The arms are darker green with alternating bands of light green which become mottled white and gray distally. The under disk is a yellowish tan proximally, becoming a speckled red and blending into the upper disk coloration. The under arms are a pale green wash which becomes darker distally and shows arm banding. A few forms are more reddish and brown on the upper disk but are still uniformly speckled. Specimens from Bahia Honda, Panama, have light brown disks speckled with lighter tan, yellow and white, with larger irregular chocolate brown markings. The arms are light brown, banded with grayish-cream for the entire length. The under side is light straw tan with faint arm bands.

The South American specimens from the coasts of Ecuador, Colombia and Peru have varying shades of olive green with yellow, tan or light green mottling on the disk. The arms are olive green with inconspicuous arm banding proximally, the bands gradually becoming lighter distally to a dirty white and very conspicuous. The under disk is cream, yellow, or brown proximally, becoming darker distally and blending into the olive green of the upper disk. The oral shields and under arms are light olive green, with inconspicuous arm bands.

Of the 2389 specimens of *O. panamense* studied, the most consistent character is the banding of the arms, which is present even in the smallest specimen with a disk diameter of only 2.3 mm. In contrast, no specimens of *O. teres* have banding on the arms. For distinguishing these two species the literature gives as characteristics of *O. teres* its relatively short arms, its 9 arm-spines as against 11 for *O. panamense*, its covered radial shield, and the division of the upper arm plates into three to five plates. Only the last character is reliable, though some *O. panamense* display fragmented upper arm plates which are apparently the result of mechanical damage.

The Hancock material shows that the colorful coral-dwelling *O. panamense* has relatively short and heavy arms, supposed to be a characteristic of *O. teres*. Some large specimens of *O. teres* have the radial shields exposed, while others of equal size have them concealed; the common green white-banded Gulf of California phase of *O. panamense* has the radial shields concealed in the majority of specimens. So the exposed radial shield as a characteristic of *O. panamense* is of little value. Finally, the largest specimens of *O. teres* have 13 arm-spines and the largest *O. panamense* have 12, proving that number of arm-spines is an unreliable character.

11. *Ophioderma rubicundum*

Ophioderma rubicunda Lütken, 1856, Vidensk. Medd. Dansk Naturhist. Foren., p. 8; 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 192, pl. 1, figs. 2a-2c.

Littoral to 9 fathoms. Bahamas, Florida, and Dutch West Indies. Not common.

12. *Ophioderma pentacanthum*

Ophioderma pentacantha H. L. Clark, 1917, Bull. Mus. Compar. Zool., vol. 61, pp. 443-444, pl. 3, pl. 4, figs. 1-2.

25 to 100 fathoms. Galapagos Islands and Gulf of California. Rare. One specimen from the Gulf of California in the Hancock Collection.

13. *Ophioderma elaps*

Ophioderma elaps Lütken, 1859, Norsk Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 195.

Ophioderma clypeata Koehler, 1914, U. S. Natl. Mus. Bull. 84, p. 7, pl. 18, figs. 2, 6.

73 to 300 fathoms. Off Grenadines, Montserrat, Island of Pines, and Galapagos Islands. Rare. One specimen from 73 fms, Galapagos Islands, in Hancock Collection.

14. *Ophioderma leonis**

Ophioderma leonis Döderlein, 1910, Denkschr. Mediz.-Naturwiss. Gesell., vol. 16, p. 252, pl. 5, figs. 1-1a.

Ophiura tongana Lyman, 1882, Challenger Repts., Zool., vol. 5, Ophiuroidea, p. 9, *non Ophioderma tongana* Lütken.

Ophioderma leonis H. L. Clark, 1923, Annals South African Mus., vol. 13, p. 351; Mortensen, 1933, Vidensk. Medd. Dansk. Naturhist. Foren., vol. 93, pp. 381-382, fig. 83.

Littoral to 10 fathoms. Southwest Africa. Rare.

15. *Ophioderma variegatum*

Ophioderma variegata Lütken, 1856, Vidensk. Medd. Dansk Naturhist. Foren., p. 21; Ljungman, 1866, Öfvers. K. Vetensk.-Akad. Förhandl., vol. 23, p. 304.

Ophiura variegata Verrill, 1867, Trans. Conn. Acad. Arts and Sci., vol. 1, p. 254.

Ophioderma variegatum Nielsen, 1932, Vidensk. Medd. Dansk Naturhist. Foren., vol. 91, pp. 330-332, fig. 36.

Seldom littoral, down to 60 fathoms. Usually taken in large numbers in dredge hauls on hard and coralline bottom in 10 to 30 fathoms; a delicate form brilliantly colored in tropical waters. A few specimens were collected at low tide in the Galapagos Islands and the Gulf of California. Gulf of California, Mexico, to Panama, Cocos Island, Socorro Island, Clarion Island, and the Galapagos Islands. Common. 504 specimens in the Hancock Collection.

16. *Ophioderma brevispinum*

Ophiura brevispina Say, 1825, Jour. Acad. Nat. Sci. Phila., vol. 5, p. 149.

Ophioderma serpens Lütken, 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 198, pl. 1, figs. 6a-6c.

Ophioderma brevispinum H. L. Clark, 1915, Mem. Mus. Compar. Zool., vol. 25, p. 300.

Littoral to 63 fathoms. Massachusetts to Florida, Gulf of Mexico, and Caribbean area. Common. 107 specimens in the Hancock Collection.

17. *Ophioderma januarii*

Ophioderma januarii Lütken, 1856, Vidensk. Medd. Dansk Naturhist. Foren., p. 7; 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 199, pl. 1, figs. 5a-5c.

Littoral. Tobago Island, British West Indies, and Brazil. Rare.

18. *Ophioderma holmesii*

Ophiura holmesii Lyman, 1860, Proc. Boston Soc. Nat. Hist., vol. 7, p. 255.

Ophioderma holmesii Meissner, 1901, Bronn's Thier-Reich, vol. 2, abt. 3, buch 3, p. 915.

Littoral. Charleston, South Carolina. Rare.

19. *Ophioderma brevicaudum*

Ophioderma brevicauda Lütken, 1856, Vidensk. Medd. Dansk Naturhist. Foren., p. 8; 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 196, pl. 1, figs. 3a-3c.

Ophioderma brevicaudum H. L. Clark, 1933, Sci. Survey of Porto Rico and Virgin Islands, vol. 16, pt. 1, p. 69.

Littoral. Florida, Bahamas, Dutch West Indies, and Bermuda. Common. 132 specimens in the Hancock Collection.

20. *Ophioderma tonganum**

Ophioderma tongana Lütken, 1872, Overs. K. Danske Vidensk. Selsk. Forhandl., pp. 76, 106; Mortensen, 1933, Vidensk. Medd. Dansk Naturhist. Foren., vol. 93, pp. 381-382.

This species was described from one specimen reported to be from Tonga Island in the South Pacific, where the genus does not occur. The type specimen has been lost (Mortensen, 1933, p. 382); but it is retained in the key until more material is available, as the species seems to be valid and the locality may be incorrect.

21. *Ophioderma appressum*

Ophiura appressa Say, 1825, Jour. Acad. Nat. Sci. Phila., vol. 5, pp. 151-152.

Ophioderma virescens Lütken, 1859, Norske Vidensk. Selsk. Skr., ser. 5, vol. 5, p. 194, pl. 1, figs. 4a-4d.

Ophioderma appressum H. L. Clark, 1933, Sci. Survey of Porto Rico and Virgin Islands, vol. 16, pt. 1, p. 68.

Littoral. South Carolina to Brazil; Bermuda, Haiti, Dutch West Indies, and eastern Atlantic; Senegal and Angola. Very common. 96 specimens in the Hancock Collection.

LITERATURE CITED

CLARK, H. L.

1910. The Echinoderms of Peru. Bull. Mus. Compar. Zool., Harvard Univ. 52:321-358, pls. 1-14.

1915. Catalogue of Recent Ophiurans. Mem. Mus. Compar. Zool., Harvard Univ. 25:165-376, pls. 1-20.

1915a. A Remarkable New Brittle Star. Jour. Entom. and Zool. 7:64-66.

1917. Reports on the Scientific Results of the Expedition to the tropical Pacific . . . on the U. S. Fish Commission Steamer "Albatross," from August, 1899, to March, 1900 . . . XVIII. Reports on the Scientific Results of the Expedition to the eastern tropical Pacific . . . by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905 . . . XXX. Ophiuroidea. Bull. Mus. Compar. Zool., Harvard Univ. 61:429-453, pls. 1-5.

1918. Brittle-Stars, New and Old. Bull. Mus. Compar. Zool., Harvard Univ. 62:265-338, pls. 1-8.

1923. The Echinoderm Fauna of South Africa. Annals So. African Mus. 13:221-435, pls. 8-23, figs. 1-4.

1933. A Handbook of the Littoral Echinoderms of Porto Rico and the other West Indian Islands. Sci. Survey of Porto Rico and the Virgin Isls., N. Y. Acad. Sci. 16(1), 147 pp., 7 pls.

1940. Eastern Pacific Expeditions of the New York Zoological Scoiety. XXI. Notes on Echinoderms from the West Coast of Central America. Zoologica [N. Y.] 25:331-352, pls. 1-2, figs. 1-4.

DÖDERLIN, LUDWIG

1910. Asteroidea, Ophiuroidea, Echinoidea. *In* Schultze, L. Zool. u. Anthrop. Ergeb. einer Forschungsreise im Westl. u. Zentralen Süd-Africa. vol. 4, lfg. 1. Mediz.-Naturwiss. Gesell. Denkschriften. 16:245-258, pls. 4-5.

IVES, J. E.

1889. Variation in *Ophiura panamensis* and *Ophiura teres*. Proc. Acad. Nat. Sci. Phila. 41:76-77.

KOEHLER, RENÉ

1895. Catalogue Raisonné Échinodermes Recueillis par M. Korotnev aus Iles de la Sonde. Mém. Soc. Zool. de France. 8:374-423, pl. 9.

1914. A Contribution to the Study of Ophiurans of the U. S. National Museum. U. S. Natl. Mus. Bull. 84:1-173, pls. 1-18.

LJUNGMAN, A. V.

1866. Ophiuroidea Viventia hus usque cognita. Öfvers. K. Vetensk.-Akad. Förhandl. 23:303-336.

LUETKEN, C. F.

1856. Bidrag til Kundskab om Slangestjernerne. Vidensk. Medd. Dansk Naturhist. Foren. 1856:1-26.

1859. Additamenta ad historiam Ophiuridarum. Part 2. Ophioderma. Norske Vidensk. Selsk. Skr. 5. Raekke, Naturvid. og Mathem. Afd. 5:187-200, pl. 1, figs. 1-8.

1872. Ophiuridarum novarum vel minus cognitarum Descriptiones nonnullae. Overs. K. Danske Vidensk. Selsk. Forhandl. 1872:75-158. pls. 1-2, text-figs.

LYMAN, THEODORE

1860. Descriptions of New Ophiuridae, belonging to the Smithsonian Institution and to the Museum of Comparative Zoölogy at Cambridge. Proc. Boston Soc. Nat. Hist. 7:193-204, 252-262.

1865. Ophiuridae and Astrophytidae. (Illus. Cat. Mus. Compar. Zool., at Harvard Coll., No. 1) Mem. Mus. Compar. Zool., Harvard Univ. 1:1-200, pls. 1-2, figs. 1-19.

1882. Report on the Ophiuroidea dredged by H. M. S. Challenger, during the years 1873-1876. *In* Rpt. of the Sci. Results of the Voyage of H. M. S. Challenger. Zool. 5(1):1-387, pls. 1-48.

MEISSNER, MAXIMILIAN

1901. Die Schlangensterne. In Bronn's Klassen u. Ordnungen des Thier-Reichs. Bd. 2, Abt. 3, Buch 3, pp. 745-966, pls. 1-11, figs. 1-10.

MORTENSEN, TH.

1933. Papers from Dr. Th. Mortensen's Pacific Expedition 1914-16. LXV. Echinoderms of South Africa. Vidensk. Medd. Dansk Naturhist. Foren. 93:215-400, pls. 8-14, figs. 1-91.

MUELLER, JOHANNES UND F. H. TROSCHEL

1842. System der Asteriden. Braunschweig. xx,135 pp., 12 pls.

NIELSEN, EIGEL

1932. Papers from Dr. Th. Mortensen's Pacific Expedition 1914-16. LIX. Ophiurans from the Gulf of Panama, California and the Strait of Georgia. Vidensk. Medd. Dansk Naturhist. Foren. 91:241-346, figs. 1-42.

RETZIUS, A. J.

1805. Dissertation sistans species cognitas Asteriarum. Lundae. 37 pp.

SAY, THOMAS

1825. On the Species of the Linnean genus Asterias, inhabiting the Coast of the United States. Jour. Acad. Nat. Sci. Phila. 5:141-154.

VERRILL, A. E.

1867. Notes on the Radiata in the Museum of Yale College, with descriptions of New Genera and Species. Trans. Conn. Acad. Arts and Sci. 1:247-351.

1899. Report on the Ophiuroidea collected by the Bahama Expedition in 1893. Bull. Labor. Nat. Hist., Iowa Univ. 5(1):1-86, pls. 1-8.

SEASONAL INFECTIONS OF THE SNAIL, *CERITHIDEA CALIFORNICA* HALDEMAN, WITH LARVAL TREMATODES

By

W. E. Martin

Allan Hancock Foundation and Biology Department,
University of Southern California

INTRODUCTION

Although Cort, McMullen and Brackett (1937, 1939), Dubois (1929), McCoy (1928), Rankin (1939), Sewell (1922), and Wesenberg-Lund (1934) have reported on seasonal trematode infections in freshwater snails, only the work of Miller and Northup (1926) has dealt with such seasonal infections in a species of marine snail. Therefore it seemed advisable to increase our knowledge of seasonal trematode infections of marine snails and particularly of a Californian species, since Miller and Northup worked with *Nassa obsoleta* collected in the vicinty of Woods Hole, Massachusetts.

Cerithidea californica Haldeman literally carpets the mud flats of many southern Californian estuaries. This snail is a favorable host for more than twenty species of trematodes which have been found by the author at various times during the past six and one-half years. However, the present study was limited to one year beginning November 1953 and ending October 1954. Collections of at least 1000 snails were made at or near the middle of each month. All collections were made from a small pond on an island in Upper Newport Bay, California. This pond is connected by a narrow outlet to the main channel of the Bay and therefore is subject to tidal exchange. At low tide the pond is approximately fifty by one-hundred twenty feet but, because of the flat terrain, high tide may increase both dimensions by from ten to twenty feet. The pond is rarely disturbed by humans and this accounts, at least in part, for its popularity as a feeding place for many species of shore birds. The feces of these birds assure a rich growth of algae upon which the *Cerithidea* feed and also supply trematode eggs for the infection of the snails.

The percentages and types of trematode infections were determined by microscope examinations of the tissues after crushing the snails. Only snails 20 mm or more in length were included in this study.

OBSERVATIONS

The number of snails examined per month ranged from 1000 to 1215. In all, 12,995 were studied. The percentages of infected snails varied from 54 to 74 (Fig. 1).

High percentages of infection were found in December, January and May while the low percentages of the range were recorded for February, June, July and October. The seventeen species of trematodes identified are listed in Table I in order of their frequency of infection. Some infections were too young to be classified and they are listed as unidentified. The peaks and lows of infection by month are also included.

TABLE I

Species	*No. of infections*	*Peak*	*Low*
Euhaplorchis californiensis	2261	March	February
small xiphidiocercaria	1360	October	July
small strigeid	1059	May	September
Y-bladder cercaria	780	March	October
large xiphidiocercaria	716	February	October
large pigmented echinostome	526	January	April
Parastictodora hancocki	521	April, July	February
fin-tailed echinostome	331	November, December, August	October
Parorchis acanthus	229	May	June, October
Catatropis sp.	204	January	June, September
schistosome cercaria	162	December	April
Cloacitrema michiganensis	81	August	October
Phocitremoides ovale	66	November	January
Cercaria buchanani	29	June	July
small opisthorchioidea cercaria	15	January	April, July, August, September, October
large strigeid	7	January	October
small echinostome	6	August	January, February, March, April, May, June, September, October
Unidentified	327	February	October
	8680		

More than one month is listed for a "peak" or a "low" when the percentages were the same for those months. For the three rare cercariae the "lows" were actually non-appearances during the months listed. Heterophyid cercariae, *Euhaplorchis californiensis* and *Parastictodora* *hancocki*, and xiphidiocercariae were more frequently found than were those of other types. Infections with *Euhaplorchis californiensis* varied from a low of 10 per cent in February to a high of 27 per cent in March. Infections of the small xiphidiocercaria, next to *E. californiensis* in frequency, ranged from a low of 4 per cent in July to a peak of 22 per cent in October.

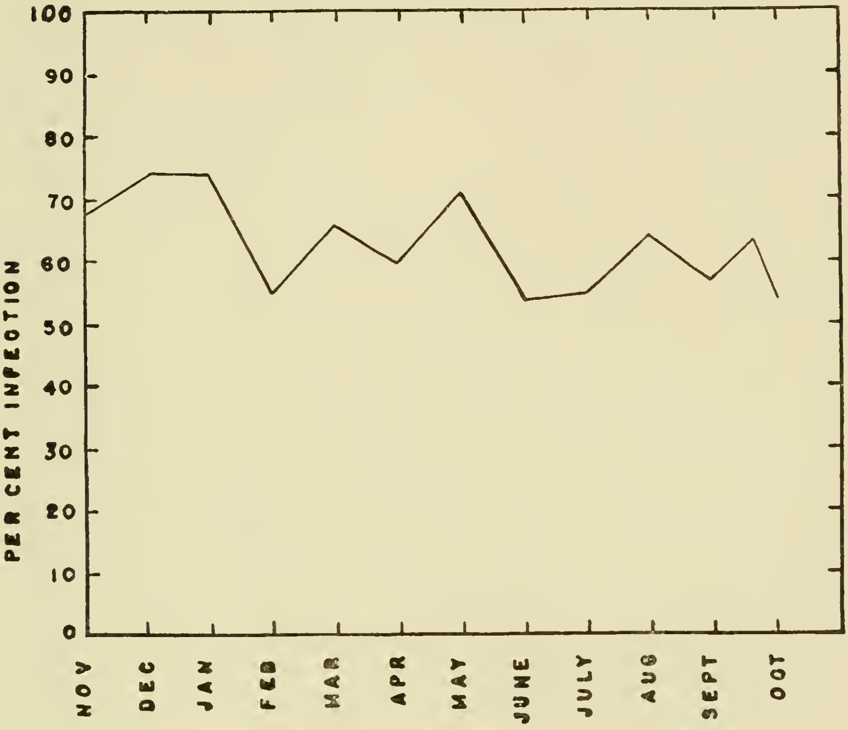


Figure I

The number of unidentified infections was highest in February and lowest in October. February's high probably is a reflection of the recent heavy exposure of the snails to infective stages of the trematodes resulting when the bird population is increased by migratory species.

Figure II

In the infection numbers listed in Table I are included 667 double and 23 triple infections. The seasonal distribution of double infections is shown in Figure II.

Certain combinations of cercariae in double infections occurred much more frequently than others. Table II lists the combinations in their order of frequency.

TABLE II

Frequency of Double Infections

Species	*Frequency*
Euhaplorchis californiensis + Y-bladder cercaria	158
Euhaplorchis californiensis + small strigeid cercaria	87
Small xiphidiocercaria + Y-bladder cercaria	76
small strigeid + Y-bladder cercaria	55
small strigeid + large xiphidiocercaria	45
Y-bladder cercaria + large xiphidiocercaria	43
Catatropis sp. + small xiphidiocercaria	32
E. californiensis + schistosome cercaria	28
small strigeid + small xiphidiocercaria	22
Catatropis sp. + large xiphidiocercaria	15
Y-bladder cercaria + unidentified	14
Parastictodora hancocki + small strigeid	10
schistosome + Y-bladder cercaria	8
Catatropis sp. + Y-bladder cercaria	7
P. hancocki + Y-bladder cercaria	7
fin-tailed echinostome + schistosome	7
Phocitremoides ovale + Y-bladder cercaria	6
Cercaria buchanani + *E. californiensis*	6
large pigmented echinostome + schistosome	4
large xiphidiocercaria + schistosome	4
Catatropis sp. + unidentified	3
Catatropis sp. + small strigeid	3
schistosome + *P. hancocki*	3
large pigmented echinostome + *E. californiensis*	3
P. hancocki + small strigeid	2
Catatropis sp. + *E. californiensis*	2
schistosome + small strigeid	2
C. buchanani + large xiphidiocercaria	2
C. buchanani + small xiphidiocercaria	2
C. buchanani + small strigeid	2
large pigmented echinostome + Y-bladder cercaria	2
schistosome + small echinostome	1
schistosome + small xiphidiocercaria	1
E. californiensis + unidentified	1
Y-bladder cercaria + unidentified	1
Y-bladder cercaria + *P. hancocki*	1
Y-bladder cercaria + fin-tailed echinostome	1
small strigeid + unidentified	1
	667

Purely on a basis of chance, double infections involving species with the higher infection numbers should occur most frequently. However, this was not always the case as is shown by the following frequencies of double infections for the top seven species listed in Table I. The Y-bladder cercaria, although fourth in total number of infections, occurred most frequently in double infections (373 times). *Euhaplorchis californiensis* was second with 282, the small strigeid third with 207, the small xiphidiocercaria fourth with 133, the large xiphidiocercaria fifth with 109, *Parastictodora hancocki* sixth with 23, and large pigmented echinostome seventh with 9. Proceeding down the list of species in Table I to *Catatropis* sp., schistosome cercaria, and *Cercaria buchanani*, we find the respective numbers of double infections, 62, 58, and 12. Although the infection numbers for the latter three species are considerably lower than that of the large pigmented echinostome, their frequencies of double infections are higher. Obviously, something other than chance is involved.

The seasonal distribution of triple infections was: 0 in November, 1 in December, 4 in January, 1 in February, 8 in March, 2 in April, 4 in May, 0 in June, 0 in July, 1 in August, 0 in September, and 2 in October. The following table lists the triple infections in order of their frequency.

TABLE III

Triple Infections

Species	*Frequency*
small strigeid + Y-bladder cercaria + *E. californiensis*	9
small strigeid + Y-bladder cercaria + large xiphidiocercaria	3
schistosome + Y-bladder cercaria + *E. californiensis*	3
small strigeid + Y-bladder cercaria + small xiphidiocercaria	2
Catatropis sp. + schistosome + small xiphidiocercaria	2
Catatropis sp. + schistosome + *E. californiensis*	1
fin-tailed echinostome + schistosome + *E. californiensis*	1
small xiphidiocercaria + schistosome + Y-bladder cercaria	1
small strigeid + schistosome + Y-bladder cercaria	1
	23

In the triple, as in the double infections the Y-bladder cercaria is most frequently involved.

DISCUSSION

As shown in Figure I, the percentages of total infections varied from 54 to 74 during the year. December—January and May were the peak months. These peaks probably reflect the increased exposure of the snails to trematode infections which must occur during those parts of the year when the local bird population is augmented with migratory species. The graph of total infections does not indicate the seasonal variation of infections for particular species of trematodes. Certain species, i.e. *Catatropis*, which probably use only migratory birds as hosts, show marked peaks during the period or periods of bird migration and marked depressions between these periods. Other species may maintain a fairly uniform infection rate throughout the year, which probably indicates that definitive hosts are available each month. Another factor which possibly may effect the infection rate per month and which has not been investigated, is the duration of each infection. The evaluation of this factor would involve the elucidation of all the life cycles, the infection of parasite-free snails and, of necessity, the conduction of a long-term project. Some of the life cycles of the trematodes considered here have been worked out experimentally by Martin (1950 a, b, c), Robinson (1952), and Stunkard and Cable (1932). Portions of the life cycles of certain other species have been described by Martin and Gregory (1951) and Maxon and Pequegnat (1949).

Most of the trematode larvae included in this study develop in the digestive gland of *Cerithidea californica* but certain species, such as the large strigeid, *Cercaria buchanani*, *Catatropis* sp., and the Y-bladder cercaria develop in the mantle wall or in organs of the snail anterior to the digestive gland. The fact that these last named species do not compete for a place in the digestive gland of the snail may explain, in part, their success in establishing infections of the multiple type.

Multiple infections involving echinostomes were relatively rare. In this connection it should be noted that Cort, McMullen, and Brackett (1937) found no cases of double infections involving echinostomes in their study of 7,259 *Stagnicola emarginata angulata*. Various reasons for the nonconformity to expectancy, based on chance, have been offered by Cort, et al. (1937), and others. Inhibition of one infection upon the development of another and possible lethal effects of certain combinations have been suggested but actually we know essentially nothing about this intriguing problem. Plans to make an analysis of experimentally induced multiple infections are being formulated in our laboratory.

SUMMARY

A study has been made of trematode infections in the marine or brackish-water snail, *Cerithidea californica* Haldeman, over a twelve-month period. A total of 12,995 snails were studied, of which at least 1000 were examined each month.

The percentages of infection ranged from 54 to 74 with "peaks" in December, January, and May and "lows" in February, June, July, and October.

Heterophyid and xiphidiocercariae occurred more frequently than other types.

Six hundred sixty-seven double and twenty-three triple infections were found. The combination of species in these multiple infections did not always fit the frequency pattern which should have resulted if only chance were operative.

LITERATURE CITED

CORT, W. W., MCMULLEN, D. B. and BRACKETT, S.

1937. Ecological studies on the cercariae in *Stagnicola emarginata angulata* (Sowerby) in the Douglas Lake Region, Michigan. Jour. Parasit. 23:504-532.

1939. A study of larval trematode infections in *Helisoma campanulatum* *smithii* (Baker) in the Douglas Lake region, Michigan. Jour. Parasit. 25:19-22.

DUBOIS, G.

1929. Les cercaires de la région de Neuchatel. Bull. Soc. Neuchateloise des Sci. Nat. 53(n.s. 2):1-177.

MARTIN, W. E.

1950a. *Euhaplorchis californiensis* n. g., n. sp., Heterophyidae, Trematoda, with notes on its life cycle. Trans. Amer. Micr. Soc. 69:194-209.

1950b. *Parastictodora hancocki* n. gen. n. sp. (Trematoda: Heterophyidae), with observations on its life cycle. Jour. Parasit. 36:360-370.

1950c. *Phocitremoides ovale* n. gen., n. sp. (Trematoda:Heterophyidae), with observations on its life cycle. Jour. Parasit. 36:552-558.

MARTIN, W. E. and GREGORY, V. L.

1951. *Cercaria buchanani* n. sp., an aggregating marine trematode. Trans. Amer. Micr. Soc. 70:359-362.

MAXON, MARION G. and PEQUEGNAT, W. E.

1949. Cercariae from upper Newport Bay. Jour. Ent. and Zool. 41:30-55.

MCCOY, O. R.

1928. Seasonal fluctuation in the infestation of *Planorbis trivolvis* with larval trematodes. Jour. Parasit. 15:121-126.

MILLER, H. M. and NORTHUP, F. E.

1926. The seasonal infestation of *Nassa obsoleta* (Say) with larval trematodes. Biol. Bull. 50:490-506.

RANKIN, J. S.

1939. Ecological studies on larval trematodes from western Massachusetts. Jour. Parasit. 25:309-328.

ROBINSON, H. W.

1952. A preliminary report on the life cycle of *Cloacitrema michiganensis* McIntosh, 1938 (Trematoda). Jour. Parasit. 38:368.

SEWELL, S.

1922. Cercariae Indicae. Indian Jour. Med. Res. 10:1-327.

STUNKARD, H. W. and CABLE, R. M.

1932. The life history of *Parorchis avitus* (Linton), a trematode from the cloaca of the gull. Biol. Bull. 62:328-338.

WESENBERG-LUND, C.

1934. Contributions to the development of the Trematoda Digenea. Pt. II. The biology of the freshwater cercariae in Danish freshwaters. Mem. Acad. Roy. Soc. Sci. et Lett. Danemark, Ser. 9, 5(3) 1-223.

TWO NEW MONOGENETIC TREMATODES FROM ELEPHANT FISHES *(CALLORHYNCHUS)* FROM SOUTH AFRICA AND NEW ZEALAND*

By

Harold W. Manter

University of Nebraska

The elephant fishes are Holocephali of the family Callorhynchidae, genus *Callorhynchus*. The Chimaeridae is a related family. The Holocephali in widely separated parts of the world tend to have distinctive, related parasites. An aspidogastrid trematode, *Macraspis elegans* Olsson, 1869, known from *Chimaera monstrosa* in the North Atlantic, was recorded from *Callorhynchus milii* in New Zealand (Manter, 1954). The cestodarian genus *Gyrocotyle* includes several species, all from chimaeroid fishes. Four monogenetic trematodes are known from these fishes: *Calicotyle affinis* Scott, 1911; *C. kroyeri* Diesing, 1850; *Chimaericola leptogaster* (Leuckart, 1830) Brinkmann, 1942, from *Chimaera monstrosa* in the North Atlantic; and *Callorhynchicola branchialis* Brinkmann, 1952, from *Callorhynchus callorhynchus* off the coast of Chile (Latitude 41° S). These Monogenea are so unique that Brinkmann (1952a, p. 96) has placed them in a new superfamily, Chimaericoloidea. They are, to date, the only two species known in the family Chimaericolidae Brinkmann, 1942.

---

*Studies from the Department of Zoology, University of Nebraska, No. 276.

The two species described below were sent to the author by Dr. Robert A. Wardle, University of Manitoba, who had received the material from the University of Capetown, South Africa. They had been collected from *Callorhynchus capensis* Dumeril. One is believed to be a new species of *Callorhynchicola* and to be the same as a specimen collected by the author from *Callorhynchus milii* Bory in New Zealand. The other species belongs to *Squalonchocotyle*, a genus hitherto known only from Selachians.

Superfamily CHIMAERICOLOIDEA Brinkmann, 1952

Family Chimaericolidae Brinkmann, 1942

Callorhynchicola multitesticulatus n.sp.

Figs. 1-5

Hosts: Callorhynchus capensis Dumeril, elephant fish;
Capetown, South Africa (type host and locality)
Callorhynchus milii Bory, elephant fish;
Wellington, New Zealand.

Location: gill chamber

Type specimens: U. S. Nat. Mus. Helminthol. Collections Nos. 37445-37446.

Description (Based on 2 mature and 3 immature specimens): Body of adult divided into a rather broad anterior portion containing all the reproductive organs, and a long, narrow, stalk-like region with the relatively small haptor at the posterior end. Immature specimens only slightly widened anteriorly with no clear demarkation between main body and stalk. Total length of type specimen 24.7 mm; main body 10 mm long by 5.8 mm wide; "stalk" 14.7 mm long by 0.312 to 0.850 mm in width. Body corrugated by transverse rings most conspicuous on "stalk;" edges of rings pointing in anterior direction (Fig. 2). Haptor 0.803 mm long by 0.390 mm in greatest width; with 8 claspers in two alternating rows. Claspers somewhat smaller at one end (anterior?); size 0.148 to 0.195 mm in width by 0.094 to 0.150 mm in length. Each clasper consisting of a muscular bowl and three curved sclerites; one median and two lateral (Fig. 3). One pair of broad-based, recurved hooks on haptor (Fig. 4), close together between the first two claspers on right side of body; length of hook 0.08 mm. Oral sucker simple, very weakly developed in adult but more evident in immature specimens; pharynx 0.234 mm long by 0.156 mm wide; intestinal ceca with lateral branches reaching to lateral edges of main body, extending into the "stalk" all the way to the haptor; unbranched in the "stalk."

Genital pore median, 0.903 mm from anterior end (in 24.7 mm specimen). Two vaginal pores, ventral, about halfway between midline and body sides, about ½ distance from atrial pore to beginning of vitellaria in adult specimens, but only about ¼ this distance in a subadult specimen. Testes about 125 in number, rounded to slightly irregular, close together, in a rather short, intercecal area at posterior end of main body. Seminal vesicle a slightly sinuous tube leading in midbody line directly to base of the short cylindrical cirrus opening through the genital atrium. Genital spines lacking.

One ovary on each side of midline immediately anterior to testes; testes in contact with ovary posteriorly and laterally. Each ovary a set of slender tubes extending more or less laterally and branching near their tips. Ovaries slightly unequal in size. Vitelline glands in sides of body from near posterior end of testes to about 2.15 mm from anterior end of body (in 24.7 mm specimen). Vaginae not observed in adult except in sections. Seminal receptacle lacking. Uterus filling most of main body, with lateral extensions. The uterus could be interpreted as sac-like and multilobed, with lobes separated by stroma-like cellular strands of tissue which may form partial partitions even in the lateral lobes themselves. A longitudinal, dorso-ventral partition divides the uterus almost wholly into right and left halves, each of which has branches or lobes reaching almost to the sides of the body and frequently forked near the end. In fact, the possibility of two uteri could not be ruled out by study of the material available. Near the anterior end of the uterus, this longitudinal septum appears to be only ventral and here the dorsal portion of the uterus has every appearance of a median stem with lateral branches. Brinkmann (1952) interprets this unique uterus as saccular and "septate with pouches between the septae." Eggs have only a very thin membrane. Largest eggs measured 116 to 129 by 65 to 70 μ. Embryos evidently hatch before eggs are laid or immediately after. They grow rapidly and are almost fully developed in anterior regions of the uterus. About ⅓ of the body of the embryo forms a haptor with 16 larval hooklets.

The excretory system was not observed.

The name *multitesticulatus* indicates the numerous testes.

Discussion: Brinkmann (1952b) named the superfamily Chimaeri-

EXPLANATION OF PLATE

All figures, except Figure 9, were made with the aid of a camera lucida. The projected scale is in mms. All the figures of *Squalonchocotyle* are from African material except Fig. 8, which is from a New Zealand specimen.

Abbreviations: *at,* atrial pore; *ce,* intestinal cecum; *gic,* genito-intestinal canal; *od,* oviduct; *ov,* ovary; *t,* testis; *ut,* uterus; *va,* vagina; *vd,* vas deferens; *vp,* vaginal pore; *yd,* yolk duct.

Fig. 1. *Callorhynchicola multitesticulatus.* Ventral view.

Fig. 2. Portion of body stalk of *C. multitesticulatus* showing annulations with anteriorly directed edges.

Fig. 3. Haptoral sucker of *C. multitesticulatus* showing sclerites. The aperture is dotted.

Fig. 4. Haptoral hook of *C. multitesticulatus.*

Fig. 5. Longitudinal section through a well developed egg in the uterus of *C. multitesticulatus.* Six of 16 larval hooks on the haptor are seen.

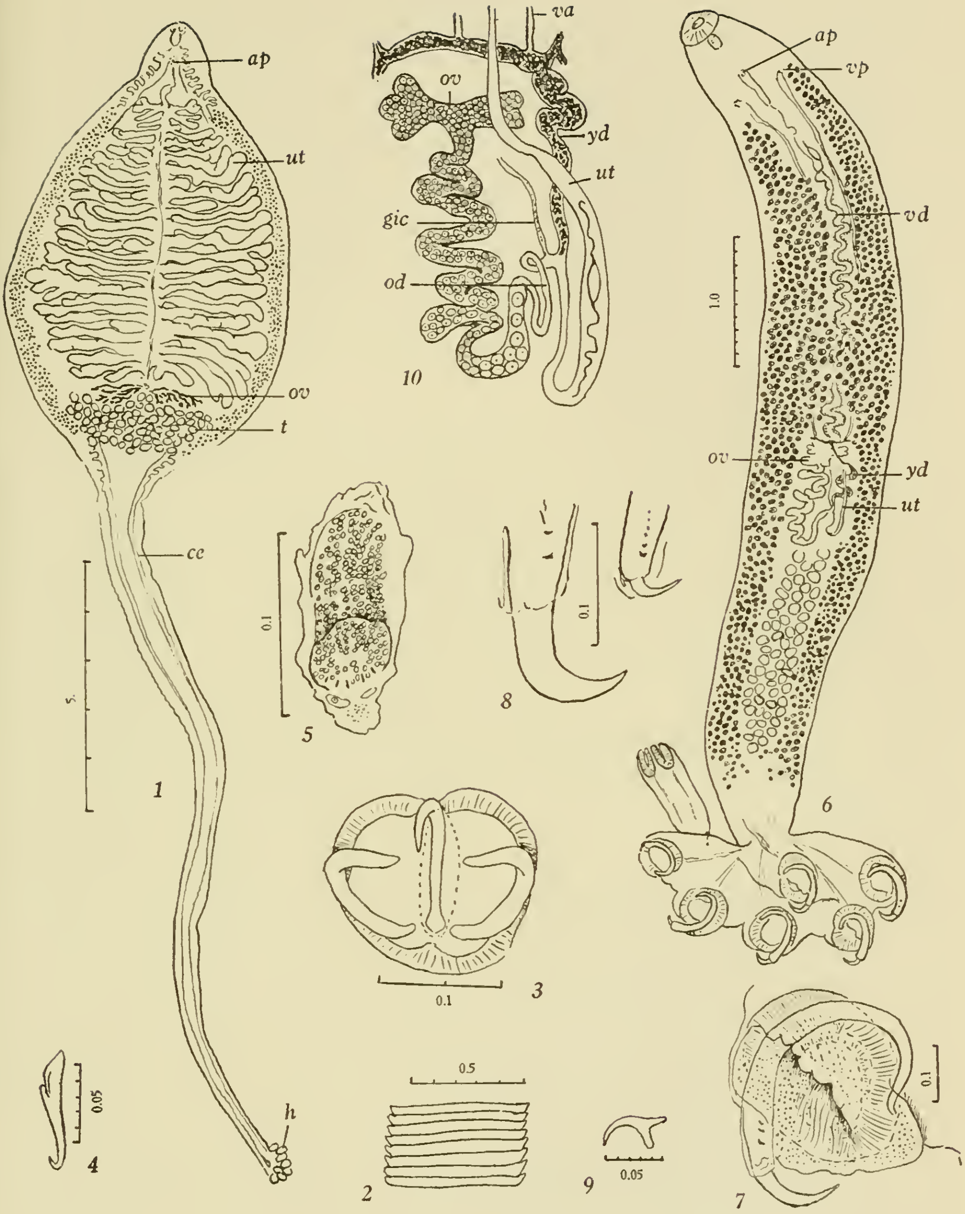
Fig. 6. *Squalonchocotyle callorhynchi.* Ventral view.

Fig. 7. Haptoral sucker of *S. callorhynchi* showing flanged aperture, papillated surface, and sclerite.

Fig. 8. Tips of the two sizes of sclerites of *S. callorhynchi.* From a single specimen.

Fig. 9. Appendix hook of *S. callorhynchi.*

Fig. 10. Diagram of ovary and adjacent organs of *S. callorhynchi.*


ap
ut
ov
t
cc
.5
h
1
va
ov
yd
ut
gic
od
10
ap
vp
vd
1.0
ov
yd
ut
6
0.1
5
0.1
8
0.1
3
0.05
4
0.5
2
0.05
9
0.1
7

coloidea for the family Chimaericolidae Brinkmann, 1942. This family includes only two genera and, until now, two species: *Chimaericola leptogaster* (Leuckart, 1830) Brinkmann, 1942, from the gills of *Chimaera monstrosa* in the North Atlantic and *Callorhynchicola branchialis* Brinkmann, 1952, from the gills of *Callorhynchus callorhynchus* (Linn.), the elephant fish, from the coast of Chile. *C. multitesticulatus* is very similar to *C. branchialis,* differing chiefly in possessing about 125 rather than about 20 testes. Eggs appear to be significantly smaller than the 170 by 70 μ size in *C. branchialis*; branches of the uterus are more distinct; the vitellaria do not extend posterior to the testes but do extend a little further anteriorly; the oral sucker is more distinct; and the haptoral clamps have a more muscular bowl. Haptoral hooks were not described for *C. branchialis.*

Two specimens, identified as *C. multitesticulatus*, were collected by the author from the gills of *Callorhynchus milii* from New Zealand. Both of these were broken off near the haptor, which was not found. They agreed with the South African specimens in number of testes, distribution of vitellaria, and egg size. The uterine branches or lobes were larger and more regular; many of the older embryos in the uterus were free of egg membranes and even more mature than in the South African specimens. Until better material can be studied, the New Zealand form is considered the same as the one from South Africa.

The hosts (*Callorhynchus*) from New Zealand and from Chile were from almost identical latitudes and probably near the South African latitude.

Superfamily POLYSTOMATOIDEA Price, 1936

Family Hexabothriidae Price, 1942

Squalonchocotyle callorhynchi n.sp.

Figs. 6-10

Hosts: *Callorhynchus capensis* Dumeril
Callorhynchus milii Bory

Location: gills

Localities: South Africa (type locality) and New Zealand

Type specimens: U.S. Nat. Mus. Helminthol. Collections Nos. 37447-37448.

Description (based on 4 specimens from Africa and 5 from New Zealand): Length of body 4.662 to 8.170 mm, maximum width 0.774 to 1.505 mm. Haptor 1.290 to 2.940 by 0.795 to 1.290 mm. Oral sucker wider than long, 0.210 to 0.312 by 0.296 to 0.366 mm. Preoral membrane lacking or very slightly developed; inner surface of sucker with very prominent papillae. Suckers of haptor with membranous flange; inner surface with very evident papillae and also some parallel ridges. Sclerites of anterior pair of suckers somewhat smaller than other two pairs. Hooks of sclerites with rather abrupt curve; hooks of anterior pair of sclerites much smaller than those of other sclerites (Fig. 8), this difference being even greater than the difference in size of sclerite (Fig. 8). Length of large sclerites disregarding curvature, 0.343 to 0.538 mm; length of smaller sclerites, 0.319 to 0.444 mm. Appendix 0.702 to 1.720 mm long; with a pair of elongate suckers 0.156 to 0.351 mm in length. Hookets of appendix remarkably constant in size, 57 to 61 μ in length (usually 57 to 59 μ), with fairly short subequal roots (Fig. 9).

Pharynx spherical or subspherical, 0.078 to 0.098 mm in diameter; esophagus and ceca with lateral branches, inconspicuous and well concealed by vitellaria, entering the appendix and the haptor.

Atrial pore median, about $\frac{1}{9}$ to $\frac{1}{11}$ body length from anterior end of body. Vaginal pores a short distance posterior to atrial pore, about halfway between midline and sides of body. Testes numerous, about 50 to 65 in number, close together in posterior third of body. Vas deferens glandular, sinuous, in midline to base of cirrus; cirrus cylindrical, somewhat wider in its anterior portion. Ovary beginning as a lobed structure near midbody, becoming a spirally coiled tube extending backward to testicular field, then bending forward to a point about $\frac{1}{3}$ the distance back to its base, where it narrows to form the oviduct (Fig. 10). Oviduct sinuous, receiving the common yolk duct, then, as the uterus, forming a short posterior loop before extending forward, ventral to vas deferens, to the genital atrium. Genito-intestinal canal present, relatively long and usually sinuous among the loops of the ovary, extending anteriorly, conspicuous when filled with yolk cells. Seminal receptacle lacking. Vitelline follicles distinct, filling most of body from just posterior to the vaginal pores to near posterior end of body but not quite reaching the haptor and not entering appendix. The common yolk duct arising at anterior edge of ovary and relatively long (Fig. 10). Vaginae straight and parallel to each other, entering transverse yolk duct separately near anterior edge of ovary. Eggs spindle-shaped, 0.148 to 0.203 by 0.056 to 0.074 mm, with a long polar filament at each end. Length of filament variable but, unless broken off or clearly abnormal, at least several times the length of the egg. Eggs not connected by their filaments.

Excretory pores near edges of body slightly anterior to the atrial pore.

Discussion: The status of the generic name *Squalonchocotyle* Cerfontaine, 1899, is disputed and much in doubt. It is pre-dated by *Erpocotyle* Beneden and Hesse, 1863, and Price (1942), although noting that *E. laevis*, the type of the genus, could not be identified from its original description, concluded from circumstantial evidence (identity of host species, locality and distribution of vitellaria) that *S. vulgaris* is a synonym of *E. laevis*. In that case, the name *Squalonchocotyle* is a synonym of *Erpocotyle*. Sproston (1946, p. 361) and Brinkmann (1952, p. 80) disagree with this conclusion and consider *Erpocotyle laevis* as "gen. and sp. inq." or *nomen nudum*. They retain the well defined *Squalonchocotyle* of Cerfontaine. *Erpocotyle* might eventually be established as the valid name for this genus, but the long usage of *Squalonchocotyle* and its retention by Sproston and Brinkmann lead to its use here. The extension of vitellaria into the appendix, although not indicated by early descriptions, does appear to be a valid generic character as proposed by Price. The genus *Neoerpocotyle* Price, 1942, includes species with vitellaria extending into the appendix.

S. callorhynchi differs from most species of the genus in lacking a seminal receptacle. Brinkmann (1942, p. 90) reports this organ lacking in *S. abbreviata* (Olsson, 1876) Cerfontaine, 1899, although Dollfus (1937) shows it present in that species. *S. abbreviata* differs from *S. callorhynchi* in the more anterior extent of vitellaria, the very short genito-intestinal canal, non-papillated oral sucker, vaginal pores near midbody line, and appendix hooks 75 μ long (rather than about 57 μ).

S. canis Cerfontaine, 1899, appears to be the most closely related species. It agrees in such characters as body size, papillated oral sucker and haptoral suckers, and flange around the opening of the haptoral suckers. However, the vaginal pores are at about the same level as the atrial pore, a seminal receptacle is present (Cerfontaine 1899, p. 444, p. 450), the egg is about 100 μ in length rather than nearly 200 μ, and the appendix hook has a more abrupt curve. *C. canis* is from *Galeus canis* off the coast of France.

S. torpedinis is not very completely described. As compared with *S. callorhynchi*, it has a much larger oral sucker and short vaginae.

Squalonchocotyle antarctica Hughes, 1928, was described from *Mustelus antarcticus* at Port Philip Bay, Australia. Its range can be extended to New Zealand, as I have collected two specimens from the same host there. It is very different from *S. callorhynchi* in its conspicuous preoral flange, lateral vaginal pores, conspicuous intestinal ceca, and shorter filaments on the egg. The following details can be added to Hughes' description: The inner surface of the oral cavity is papillate; the haptoral suckers have conspicuous ridges but either lack papillae or have only a few, faint and widely scattered. Haptoral hooks have spines along the inner edge for about half their length. Appendix hooks are 52 to 54 μ long. A seminal receptacle is present; eggs are about 166 to 194 μ long, egg filaments to about the same length as the egg.

SUMMARY

Two new species of Monogenea are described from the elephant fish, *Callorhynchus capensis*, from South Africa. These are *Callorhynchicola multitesticulatus* (family Chimaericolidae) and *Squalonchocotyle callorhynchi* (family Hexabothriidae).

Both species are also reported from *Callorhynchus milii* in New Zealand.

S. antarctica Hughes, 1928, formerly known from *Mustelus antarcticus* in Australia, is reported from that same host in New Zealand.

LITERATURE CITED

BRINKMANN, A.

1942. On *Octobothrium leptogaster* F. S. Leuckart. Goteborgs K. Vetensk.-och. Vitterhets-Samh. Handl., 6. F., s.B, 2 (3): 29 pp., 11 figs.

1952a. Fish trematodes from Norwegian waters. Univ. Bergen Aarbok 1952. Naturv. rekke Nr. 1, 134 pp., 50 figs.

1952b. Some Chilean monogenetic trematodes. Repts. Lund Univ. Chile Exped. 1948-1949.6. Lunds Univ. Aarssk. N.F. Avd. 2, 47 (11): 1-26.

CERFONTAINE, PAUL

1899. Les Onchocotylinae (Contribution à l'étude des Octocotylides. 5.) Arch. Biol. 16 (3): 345-478, 4 pls.

DOLLFUS, ROBERT-PH.

1937. Parasitologia Mauritanica helmintha (III). Trématodes de sélaciens et de chéloniens. Bull. Com. Etudes Hist. et Scient. Afrique Occident. Français. 19 (4): 397-519.

MANTER, HAROLD W.

1954. Some digenetic trematodes from fishes of New Zealand. Trans. Roy. Soc. N.Z., 82 (2): 475-568.

PRICE, EMMETT W.
1942. North American monogenetic trematodes. V. The Family Hexabothriidae, n.n. (Polystomatoidea). Proc. Helm. Soc. Wash., 9 (2): 39-56.

SPROSTON, NORA G.
1946. A synopsis of the monogenetic trematodes. Trans. Zool. Soc. London. 25 (4): 185-600.

THE ROLE OF BATS IN THE TRANSMISSION OF RABIES

By

CHARLES R. SCHROEDER

San Diego Zoological Gardens

Three recent reports have brought to us an entirely new concept concerning the transmission of rabies virus. Courter, 1954, in his paper "Bat Rabies," reviews two of the reports; first, the findings of the Tampa Regional Laboratory of the Florida State Board of Health, identifying the Florida yellow bat (*Dasypterus floridanus*) and the seminole bat (*Lasirus seminola*), both species insectivorous, as vectors of rabies in June, 1953; and, second, that of Witte, Pennsylvania State Department of Health, who in September, 1953, reported rabies in an insectivorous bat, species unknown, in Carlisle, Pennsylvania. Enright, 1954, University of California, reported the isolation of rabies virus from a Mexican Freetail bat in California.

Public health officials have dealt with many unexplained outbreaks of rabies and have felt that they must involve some unknown vector in which a latent carrier state exists. The reports of Pawan (1936), Verteuil and Urich (1936), Gilyard (1945), Johnson (1948), Schroeder (1952), and the review by Malaga-Alba (1954), indicate quite clearly and conclusively that vampire bats have been justifiably incriminated as disseminators of rabies virus to cattle and other domesticated animals and to man for more than half a century.

The animal vectors of rabies virus for man in order of importance are: the dog, fox, jackal, wolf, skunk, coyote, raccoon, vampire bat, cat, mongoose, genet and horse. We can use almost the same order for animals other than man, except that the vampire bat would hold first or second position. Practical methods for the control of migration of the domestic dog are available, but they are not and will not be followed in the U. S. A. If the dog were declared legally a domestic animal, the Department of Agriculture could set up a vigorous government supervised program for the control of traffic and migration of dogs which would quickly bring an end to our dog-transmitted rabies problem. For many unrelated reasons, dog owners and kennel clubs are not in accord with this proposal. Bats, however, present quite a different problem and there are no simple methods for either area extermination or migration prevention.

In July, 1950, the author had occasion to investigate serious cattle losses in an agricultural area in and adjacent to La Ceiba, Honduras. The losses far exceeded those usually caused by snake bite, chronic infectious diseases and nutritional inadequacies. The successful management of extensive banana plantations—the property of the Standard Fruit Company of New Orleans—was dependent on the maintenance of adequate sources of milk and other dairy products and meat for the field workers. Cattle losses therefore seriously interfered with banana production. The causes of death were variously attributed to metal poisoning, plant spray poisoning, tick fever, anaplasmosis, pasteurellosis, brucellosis, listeriosis, bovine encephalitis, infectious bulbar paralysis (Aujesky's disease), and botulism. Brain tissue had been sent to the Virus and Rickettsial Laboratories of the Communicable Disease Center, Montgomery, Alabama, and rabies virus had been isolated. The author discussed these findings with Harold Johnson at the Rockefeller Institute for Medical Research, New York City, preliminary to making the field investigation, and it was tentatively agreed that the cause of death might very well be "Derriengue"—vampire bat-transmitted paralytic rabies. Ten animals were examined within a five day period, July 13-18, 1950, at La Ceiba. Brain tissues from six of seven specimens were positive for inclusion bodies from direct impressions of Ammon's horn using Seller's stain, and proved to be positive by mouse inoculation. Postmortem changes were too far advanced to use tissues from three other cases. Vampire bats identified as *Desmodus rotundus murinus*, Wagner, were present in large numbers in the area, retreating to hollow Ceiba trees, old buildings, and palm trees during the daylight hours. Of fifty bat brains collected in neutral glycerine, all were negative on mouse inoculation. However, cattle losses were most abundant where the bat population was greatest, especially along the river courses. Potential virus sources, other than bats, were not apparent. By animal inoculation and by serological and cultural means, other infectious diseases were ruled out. Gross postmortem findings were essentially negative; blood smears did illustrate occasional blood parasites—*Anaplasma* and *Babesia*. All cattle were remarkably free of gross parasitism.

Of the family Desmodontidae, the single species *Desmodus rotundus murinus*, Wagner (Figs. 1-3), was involved in the writer's experience in Honduras. It is strictly hemophagous and colonial with no tail or tail membrane. It lives in caves, buildings and hollow trees for the most part, but may also seek shelter in thatched roofs or any other secluded and darkened area. Its diet consists of one or two mammalian blood feedings each night. The daytime retreat can easily be discovered by locating large accumulations of bloody droppings under the roosting area. The bat approaches its blood source after sundown, often coming down to the ground, approaching its victim, climbing up the leg of the animal spider fashion without detection, and attaching itself to the hair in a sheltered area on the neck where it cannot be easily dislodged by movement of either head or tail. With the upper chisel-like incisors it scoops out skin, causing capillary bleeding, and laps blood, often until it is too full to fly. It then drops to the ground and makes its way to a nearby shelter to digest the meal. It may return before morning to feed a second time on the same victim, often at the same wound site, and may consume up to 30cc of blood in a single feeding. Its specialized twenty teeth, including functionless premolars and molars, narrow its diet to blood (Fig. 4). According to Pawan's observations in Trinidad, the gestation period is probably approximately three months. The female bears a single young, occasionally two, which matures in a year or less. It is stated that the bat's saliva contains an anticoagulant which permits free flow of capillary blood at the site of the inflicted wound. Some observers have noted erratic daylight flight with fighting between bats in mid air and have assumed that such bats, especially those that aggressively attack animals, are rabid and are in the furious stage. These phenomena were not seen in Honduras. The life span is unknown, but Pawan (1936) succeeded in keeping a captive vampire bat alive for five years. The vampire bat has been shown to be a transmitter of yellow fever and *Trypansoma cruzi*—Chagas disease—in addition to rabies. Investigators in Brazil, Venezuela and Trinidad have demonstrated that the virus of rabies may appear in the vampire bat, artificially infected, seven days after subcutaneous injection, and that the bat may remain symptom free for long periods. In individual cases it was shown that a symptom free bat was capable of transmitting viable virus for five and a half months, and under usual circumstances may transmit virus from one to five and a half months.

Hurst and Pawan (1936) believe that there are six forms of rabies seen in bats:

1. Furious form followed by paralysis and death.
2. Paralysis, not preceded by a furious form, with death.
3. Furious form with recovery.
4. Furious form followed immediately by death.
5. Sudden death with no symptoms.
6. Symptom free carrier.

However, the usual course seen in bats experimentally infected closely follows that of other mammalian hosts, which is

1. Period of incubation.
2. Prodromal or invasive stage.
3. Period of excitement (furious form).
4. Paralysis of an ascending type.
5. Death.

In man it is reported that the early symptoms of rabies following bat bite are a burning or tingling sensation at the site of the wound, followed in five to seven days by ascending paralysis and death. In cattle there is progressive ascending paralysis with early loss of sensory reflexes. There are licking paroxysms and the temperature may be elevated. Paralysis starts in the hind quarters, causing knuckling over at the fetlock and a drifting walk, with complete paralysis by the end of the third day. The eyes are sunken, with an anxious expression, the ears constantly flopping, the head usually turned to the right. The animal is prostrate with flaccid paralysis on the fourth day but conscious to the last, with death due to respiratory failure on the fifth day.

Rabies is a preventable disease. Prevention practices did not change much from the time of Pasteur until Johnson, Koprowski and Cox (1948) led the way with the preparation of a chick embryo modified live virus vaccine. Johnson had isolated a strain of virus from the brain of a child from a family named Flury, at Macon, Georgia, and directly carried the Flury virus strain in day-old chicks by intracerebral inoculation at the Rockefeller laboratories. Koprowski secured from Johnson frozen samples of chick brain bearing rabies which had been serially passed in excess of one hundred twenty times, and promptly inoculated intracerebrally developing chicken embryos. He soon discovered that all tissues of the embryo supported the virus. Whereas this virus source would not permit the preparation of an inactivated vaccine, the virus strain was avirulent, would not induce rabies by any usual method of inoculation, and was highly immunogenic since a single injection produced complete immunity. This type of vaccine was a great advance over the older types prepared from nerve tissue—brain and spinal cords—from the rabbit, horse, calf, sheep, and goat. Historically, it has been shown that there is a rather high incidence of post-vaccinal paralysis when nerve tissue vaccines are used, regardless of the method used to inactivate the virus—phenol, chloroform, merthiolate, ultra violet radiation, or just desiccation. The cause of paralysis following the injection of nerve tissue has not been conclusively proven. One school of thought is that myelin, a common antigen in all mammalian nerve tissues, injected in volume at the right interval forms antimyelin antibody. The resulting antigen-antibody reaction brings about varying degrees of paralysis and occasionally causes death. In one kennel, carefully studied, the incidence of paralysis was four in one hundred. In man in the city of Los Angeles the incidence is one in six hundred. Not a single post-vaccinal reaction has been reported following the use of chicken embryo vaccines. Because it was impractical to distribute a chick embryo live virus vaccine in a frozen state, and since it was unstable in the fluid state, it has been prepared as a dry product—dried from the frozen state and sealed in vacuo.

TABLE I

IDENTITY TEST OF VIRUS ISOLATION FROM CATTLE BRAINS FROM LA CEIBA, HONDURAS

Mortality ratio of guinea pigs challenged with dilutions of street virus—deaths/total

	NYC strain		Honduras strain			
	1:5	1:5	1:20	1:80	1:320	1:1280
Immunized	0/14	0/14				
Controls	10/10	6/10	6/8	8/8	8/8	5/8

The virus isolated from cattle in the Honduras area was shown to be indistinguishable immunologically from a New York dog salivary gland street-virus strain (Table I). It was therefore proposed that an attempt be made to immunize cattle in a vampire bat rabies epidemic area, using as antigen chicken-embryo-adapted and modified live virus vaccine. Thousands of cattle in Guatemala, Mexico, Honduras, Costa Rica and Nicaragua have now been successfully immunized. This form of vaccine has given complete protection without a report of a single vaccinated animal coming down with rabies from any source. Currently the dose of Flury-strain chick-embryo rabies live-virus vaccine is 15cc of a 20% suspension injected intramuscularly (Table II).

TABLE 2

Mortality Ratio of Cattle Vaccinated with Avianized Rabies Vaccine and Challenged Five Months Later with Street Rabies Virus

Live virus chick embryo vaccine			Virus Dilution*		
Dose	Route of		Deaths/total**		
(ml.)	administration	1:20	1:40	1:80	1:160
7.5	subcutaneous	9/10	7/9	7/10	7/10
15.0	subcutaneous	9/10	9/10	8/9	8/10
7.5	intramuscular	6/11	4/9	6/11	4/10
15.0	intramuscular	4/10	3/11	2/10	1/9

*Challenge—1 ml. street rabies virus in each masseter muscle. This is a severe challenge far exceeding field exposure.

**Recorded forty-eight days after challenge inoculation.

In 1948 Johnson reported that from an historical standpoint "Derriengue" or vampire bat paralytic rabies has been known in Mexico for a minimum of thirty seven years and possibly longer. He showed by cross neutralization, complement fixation, and protection tests, that the virus he recovered in Mexico from vampire bats and from cattle was rabies.

In May, 1945, the San Diego Zoo lost a long-time resident, an adult female Masai giraffe carrying a 5 months calf. The symptoms were typical of encephalitis. Howard Ball, M. D., Pathologist and member of the Research Committee of the Zoological Hospital and Biological Research Institute of the Zoological Society of San Diego, conducted an autopsy. He sent specimens of brain tissue in glycerine to Edwin Linette, M. D., State Virus Laboratory, California State Department of Health, Berkeley. The findings of that laboratory are recorded in the Bulletin of the Pan American Sanitary Bureau, WHO, Volume 27, No. 4. Rabies virus was isolated. The source of infection remains unknown. Dogs and other small animals could not possibly have reached the giraffe through the woven wire fence. At the time there was no history of rodent transmitted rabies in the San Diego area. Infected rats have never been demonstrated in Balboa Park. It is known, however, that nectar-eating bats had appeared in San Diego at about that time, described by Lawrence M. Huey, Curator, San Diego Natural History Museum, as on "adventurous flights" from the mainland of Mexico to southern California. Many areas in Mexico harbor vampire bats from which rabies virus has regularly been demonstrated. It is known that nectar-eaters and other bats in southern California and Mexico are colonial, and that, although it would be unusual, they might migrate great distances. One cannot assume but can admit the possibility of transmission of rabies from the infested vampire to another species of bat which could conceivably have migrated to the San Diego area and have attacked the giraffe. The degree of susceptibility of giraffes to rabies is not known, but we may assume that it is similar to that of the domestic cow. Cattle mortality due to rabies is high and rabies is declared by some workers to be the main cause of cattle deaths in Mexico, Central and South America as far south as Argentina.

In the order Chiroptera there are more than two thousand species, the greatest number being in the tropics. There are sixteen genera and more than sixty five species represented in the United States. The insect eaters consume from a half to their full weight in insects a day and consequently have considerable economic value in agriculture. It is hoped that bat banding, although now carried on only in a small way, may lead to a better understanding of bat migratory habits.

Until they are proved rabies free, we must admit the possibility of latent rabies infection in all species of bats; and with this in mind, all cases of rabies in which a virus source is unknown should be promptly and carefully investigated.

LITERATURE CITED

COURTER, R. D.
1954. Bat Rabies. U. S. Public Health Rept. 69:9.

ENRIGHT, JOHN
1954. Personal communication.

GILYARD, R. T.
1945. Bat Transmitted Paralytic Rabies. Cornell Vet. 35:195-209. (July)

HURST, E. W. and J. L. PAWAN
1931. An Outbreak of Rabies in Trinidad without history of Bites, and with the Symptoms of Acute Ascending Myelitis. Lancet. 221:622-628.
1936. A Further Account of the Trinidad Outbreak of Acute Rabic Myelitis: History of the Experimental Disease. Jour. Path. & Bact. 35:301-303.

JOHNSON, H. N.
1948. Derriengue: Vampire Bat Rabies in Mexico. Amer. Jour. Hyg. 47:189-204. (March)

KOPROWSKI, H. and H. R. COX
1948. Studies on Chick Embryo Adapted Rabies Virus. I. Culture Characteristics and Pathogenicity. Jour. Immunol. 60:533-554.

MALAGA-ALBA, AURELIO
1954. Vampire Bat as a Carrier of Rabies. Amer. Jour. Pub. Health. 44:909.

PAWAN, J. L.
1936. The Transmission of Paralytic Rabies in Trinidad by the Vampire Bat *(Desmodus rotundus murinus* Wagner, 1840). Ann. Trop. Med. and Parasit. 30:101-130. (April 3)

SCHROEDER, C. R.
1952. Rabies in Central and South America. Proc. Ann. Meet., Vet. Med. Assoc. 1952:411-412.

VERTEUIL, E. DE and F. W. URICH
1936. The Study and Control of Paralytic Rabies Transmitted by Bats in Trinidad, British West Indies. Trans. Roy. Soc. Trop. Med. and Hyg. 29:317-347. (January 25)

Fig. 1. *D. rotundus murinus* (Ernest P. Walker, National Zoological Park).
Illustrating size and position when moving.

Fig. 2. *D. rotundus murinus* (Panamerican Sanitary Bureau, Dr. Aurelio Malaga-Alba). Illustrating the thumb.

Fig. 3. *D. rotundus murinus* (Ernest P. Walker, National Zoological Park).
Typical hanging position assumed when resting.

Fig. 4. *D. rotundus murinus* (Panamerican Sanitary Bureau, Dr. Aurelio Malaga-Alba). Mature mouth. Central chisel-like upper incisors adapted for painless blood letting.

Figure 1

Figure 2

Figure 3

Figure 4

VARIATIONS AND ADAPTATIONS OF THE RODENTS OF THE NORTH RIM OF THE GRAND CANYON, ARIZONA

By

Floyd E. Durham

Allan Hancock Foundation

The Kaibab Plateau, a high, isolated dome in northern Arizona, is bounded by the Grand Canyon of the Colorado River on the south and east, by canyons and ravines on the west, and by high desert on the north, as well as to the eastward and westward (Map 1). The higher part of the Plateau is an isolated unit of Transition and Canadian forest, an island at whose margins strike waves of desert winds. The zone of transition between Sonoran vegetation and heavy timber is narrow, especially on the North Rim of the Grand Canyon. This intermediate strip is where the ranges of most of the forest dwelling mammals meet the ranges of the desert mammals. Few kinds cross this zone.

Within the confines of this secluded forest there evolved the endemic Kaibab squirrel, well known to mammalogists and to the casual visitors of the Grand Canyon National Park. The powerful factors of isolation and selection which produced this striking pattern of black underparts and white tail in the squirrel presumably influenced the other rodents there. In order to study these variations, I made arrangements for limited collecting on the North Rim of the Grand Canyon (Map 2), particularly in the wild, unfrequented western area of the Park, during one month of early summer in 1947 and again in 1949. Thirteen species of rodents were observed, collected and studied (Table 3). Variations within the populations of the North Rim, as well as differences between these rodents and those of areas not far distant, show certain responses of the animals of the North Rim to the environment and illustrate basic rules of ecological variation.

It was through the generosity of Captain Allan Hancock that I was able to spend two months collecting on the North Rim. Dr. Harold C. Bryant, then superintendant of Grand Canyon National Park, negotiated the special permits, arranged for cabins at several collecting stations and acted as guide through much of the wilderness country over which Captain Hancock had previously flown the reconnaissance party. Grand Canyon rangers and naturalists generously contributed information on roads, collecting stations, water holes and weather. I am indebted also to Dr. John S. Garth, of the Hancock Foundation, who arranged and led the trip in 1947 and thereafter encouraged me in this project. Dr. William V. Mayer of the Biology Department, University of Southern California, kindly read the manuscript and offered helpful suggestions.

ACCOUNTS OF SPECIES

Spermophilus variegatus grammurus (Say)

Habitat: Rock squirrels were found among rocks, on cliffs and in sparse vegetation at the edge of the Canyon where insolation is high. They are not widely distributed on the North Rim. Wary animals were seen at Dutton Point (Map 2) and four adults were trapped at Muav Saddle. In contrast to the exposed Sonoran environment of these two places is a cool, shady, leafy canyon just north of Swamp Point where one juvenile squirrel, possibly in migration, was shot.

Color: Available for comparison with the rock squirrels from the North Rim are one adult from southeast Arizona, typical of the pale subspecies *grammurus*, and two adults from Zion National Park, Utah. The latter animals appear to be dark enough on head and posterior back to belong to the subspecies *utah*. The specimens from the North Rim are nearly as dark as those from Zion National Park and much darker than the above mentioned one from southeast Arizona. I agree with Howell (1938, p. 146) that those from the Kaibab Plateau are nearer *S. v. utah*, but because Kelson (1951, p. 31) and Durrant (1952, p. 121) considered specimens even as dark as those from Zion National Park to be *grammurus*, and Hall and Kelson (1952, p. 346) so considered the single specimen

(161566BS) they examined from the Kaibab Plateau, I have assigned those from the North Rim to *grammurus*.

Size: From an examination of the available body and skull measurements, it seems that the subspecies *utah* and *grammurus* are too nearly alike in size to be separated on this basis. Those from the North Rim (Table 3) are large and equal or exceed the average measurements for both *utah* and *grammurus* from adjacent areas. There appears to be a cline of decreasing relative length of tail from southeastern Colorado (where the tail is 82 per cent of head-body length) to Nevada (where the tail is 73 per cent for males and 71 per cent for females). In this character, the rock squirrels from the North Rim (74 and 71 per cent for males and females, respectively) agree with those from Nevada.

Sexual dimorphism: Males usually have slightly larger skulls, longer hind feet and greater head-body length than females, but weigh less. Hall (1946, p. 310) found females to be 97.5 per cent as long as males, but 107 per cent as heavy. My corresponding figures for the specimens from Muav Saddle are 94.5 and 105.

Both females from the North Rim were suckling young but neither showed evidence of a second pregnancy for the season.

More collecting needs to be done to determine the kinds and ranges of these rock squirrels. For example, Durrant (1952, p. 482) wrote, "*Citellus* [=*Spermophilus*] *variegatus utah* . . . is known also from Idaho . . ." but I find no record of its occurrence in that state. Also he (*op. cit.*, p. 119) gave the northern limit of the range of *S. v. grammurus* along the Nevada-Utah boundary as 37½° N, whereas Hall (1946, p. 311) gave it as 40° N.

Spermophilus lateralis lateralis (Say)

Habitat: Golden mantled ground squirrels were common at many stations on the North Rim, particularly in meadows and in forested areas near open water. They did not go as far into the dry forest as did the chipmunks nor were they observed or taken on the very rim of the Canyon. They were most abundant at Swamp Lake, where six adults were taken. One of these was caught in a gopher trap set in a tunnel of the mountain pocket gopher. The subspecies *S. l. lateralis*, to which Howell (1938, p. 192) assigned this isolated population on the Kaibab Plateau, occurs widely in Colorado, and its range extends westward along the Uinta Mountains in Utah and thence southward along the High Central Plateau to southwest Utah.

Size: Specimens obtained from the North Rim, particularly those from Swamp Lake, are large. In most mass measurements of animal and skull, the North Rim specimens are as large as or larger than the average of the topotypes of *S. l. lateralis.* They also average larger than those listed from Utah (Durrant, 1952, p. 132). Those from the margin of the Kaibab Plateau are somewhat smaller; e.g., an adult female from Jacob Lake, near the periphery of this population, had worn teeth, was suckling young and had a head-body length of only 173 mm. Squirrels of this size from the North Rim were immature, with unworn teeth and juvenile pelage.

The tail of the North Rim specimens is short, 48.5 and 46 per cent of head-body length for males and females, respectively, against averages from Howell (1938, p. 193) of 51 and 53.5 per cent for squirrels from Colorado and New Mexico. In this character of relatively short tails (usually less than half head-body length), the North Rim population resembles the subspecies *chrysodeirus* more than *lateralis.* From the measurements of Davis (1939, p. 203) and those of Hall (1946, p. 322) of the subspecies *trepidus*, it appears that an adaptive cline of decreasing size and increasing length of tail extends southward from Idaho into Nevada. The short tails and large size of these squirrels on the Kaibab Plateau are in agreement with Allen's Rule and Bergmann's Rule, respectively, that shorter than average appendages and larger bodies appear to the northward and at higher altitudes.

Comparative weights from other populations of the subspecies *lateralis* are lacking, but Hall (*op. cit.*) gave the weights of 181 and 199 grams as averages for ten males and ten females, respectively, of *S. l. chrysodeirus*, the linear measurements of which correspond closely with those of *lateralis* of the Kaibab population.

Sexual dimorphism: I found the females of the North Rim heavier than the males (averages of 208 and 185 gr., respectively). This is in agreement with statements from Hall (*op. cit.*) but not from Hatt (see Howell, *op. cit.*). Males have larger hind feet. Although one was a subadult, the two males taken on the North Rim had hind feet 45 mm long, whereas 44 mm is the maximum foot length for the females and 42.4 mm is the average. Tails of the two males average 90.5 mm in length against 85 mm for the females, and 48.5 and 46 per cent of head-body length, respectively. Of the fifteen adults I took on the North Rim, only one was a male. I cannot explain the reason for this uneven taking of sexes (Linsdale, 1938, p. 178).

Color and molt: Adults molt during June and July. At that time it is not uncommon to take in the same trap line one specimen in bright new pelage and another in faded, worn pelage (Hall, 1946, p. 319). Furthermore, the faded pelage of the one obtained from the juniper-pinyon belt at Jacob Lake near the north edge of the Kaibab Plateau was no paler than the one in worn pelage taken from Robber's Roost in aspen country, North Rim. Regardless of sex, subadults (probably yearlings) apparently start molting first and have their new coat by July 15. Most adult females have only a small area of new hair on the forehead by July 1, although one female suckling young was in new pelage on June 29.

Eutamias minimus consobrinus (Allen)

Habitat: Only three least chipmunks were taken on the North Rim and all these were from Tipover Spring where the Transition forest consists of yellow pine, spruce and fir. In the field I could not distinguish between them and the more numerous Say chipmunks (see below) taken in the same trap line.

Size: Although the three specimens taken are subadults, they equal or exceed in every skull and body measurement except total length and length of tail the maximum measurements given for specimens from Utah (Howell, 1929, p. 47 and Durrant, 1952, p. 133 and 154). The skull measurements are 3 to 8 per cent larger, the length of head-body 5.8 per cent larger; but the tail is actually and relatively shorter, averaging 76.5 per cent of head-body length against 82.5 per cent for specimens from Utah (Howell, *op. cit.*). The hind feet are large but in the usual proportion (28 per cent or slightly more) to length of head-body. The tails and feet of these subadults may not be fully developed.

These young specimens of *E. m. consobrinus* are about the size of large individuals of the subspecies *operarius* from the opposite side of the Colorado River, between whose ranges there is thought to be no intermingling. They are also near the size of the smallest Say chipmunks of the North Rim and were distinguished from the two dwarfed adults of that species from the Walhalla Plateau only by the use of minimum lengths for the Say chipmunks, i.e., head-body 120 mm, skull 33.5 mm (Johnson, 1943, p. 71), and hind foot 33 mm. The maximum corresponding measurements of the *minimus* from the North Rim are: 112, 32.3 and 32 mm. These specimens verify the statement of Johnson (*op. cit.*, p. 79) concerning the great variability of the least chipmunk in the Rocky Mountain region.

Eutamias umbrinus adsitus Allen

Habitat: The Say chipmunk is the most common one on the North Rim and it occurs widely throughout the timbered areas of pine, fir and aspen. None were taken at the edge of the Rim nor below it. The population on Powell Plateau is probably isolated, as none were observed at Muav Saddle, the most likely avenue of entrance.

Color: The specimens show considerable variation in color other than that resulting from age and wear. In the eastern part of the North Rim the underparts of adults and immatures are grayish white, while in the western part the underparts are almost pure white (Howell, 1929, p. 93) with hairs, at least on the throat, white to the base. Variations in pigmentation of tail margin are evident, the color ranging from the expected pale buff to cinnamon, as in the least chipmunk. The resemblance to the latter has been pointed out in the account of that species.

Size: Although Howell (*op. cit.*) considered the colony on the Kaibab Plateau nearly typical, I found the specimens of the North Rim particularly large in length of head-body, hind foot and nasals (see Table 3). Even the males, which average smaller than the females, are as large as the largest topotypes (Howell, *op. cit.*).

Eutamias dorsalis utahensis Merriam

Habitat: Cliff chipmunks were observed and taken only at Muav Saddle and vicinity, below the canyon rim. Several were observed running over the high, vertical cliffs at the foot of the trail from Swamp Point. Two of the wary animals were trapped in this Upper Sonoran environment. A third was obtained from the shady, wooded slope of Saddle Canyon, which is lower Transition (Bailey, 1931, p. 92). All three were subadult females without embryos.

Color: The throat is creamy white and the underparts are grayish. The specimens from the North Rim have more conspicuous striping on the head and body and brighter cinnamon on the sides, legs and head than have the *E. dorsalis* from the South Rim in the Hancock Collection.

Size: These three specimens, although not fully grown, are large and exceed in length of head-body, hind foot and nasals and in breadth of cranium the averages of adult topotypes (Howell, 1929, p. 134).

Tamiasciurus hudsonicus dixiensis Hardy

Habitat: That chickarees were rather common in the Canadian forest of the North Rim was indicated by the mounds of shucked cones, the tree nests and the noisy chatter. However, only two were shot (at Tipover Spring) and a third was picked up on the road (near Robber's Roost where they were common, as they also were at Bright Angel Ranger Station). These three specimens, taken in late June and early July, are in various stages of molt, one specimen still retaining from its winter pelage the conspicuous ear tufts, gray sides, and heavy hair on the hind feet.

Color and size: This group of chickarees, isolated on the Kaibab Plateau, was formerly assigned to the small, gray subspecies *fremonti* of Colorado. Available data indicate that the specimens of the North Rim are too large, have nasals too long and pelage too dark for *fremonti.* In size they compare favorably with those of the large chickarees of the subspecies *mogollonensis* of the highlands of central Arizona, including the San Francisco Mountains, from which they are separated not only by the Grand Canyon but also by stretches of desert; but the lack of a bright yellow-rufous dorsum indicates only distant relationship. In size (length of head-body, length of hind foot, length and breadth of skull and length of nasals) and in dorsal coloration (Hardy, 1942, p. 87) they agree with *dixiensis* of the High Central Plateau of southern Utah.

The form from the North Rim may prove to be a new subspecies but until more specimens are available it seems best to assign it to *dixiensis*, with which it shows close geographic, morphologic and chromatic affinities. The relationship of the populations of large chickarees on the High Central Plateau, the Kaibab Plateau, and the San Francisco Mountains is yet to be worked out.

Thomomys bottae boreorarius Durham

Habitat: The Botta pocket gopher was found for the first time on the North Rim in 1947 (Durham, 1952, p. 498). This is the only pocket gopher found at Swamp Point, Muav Saddle and Powell Plateau, whereas the northern pocket gopher is common and widespread in boreal areas of the Kaibab Plateau. The Botta pocket gopher occurs sparingly and sporadically in the shallow, stony soil at or near the margin of the coniferous forest. By July those individuals occupying the hardest, shallowest soils became relatively inactive, and two days often elapsed before an animal would traverse its tunnels to spring a trap or close a burrow opening. The northern pocket gopher, in the deeper, moister soil of the forest, was still active and readily trapped at this season.

Botta pocket gophers were obtained at the following localities: (1) Swamp Point where the soil is thin, drainage excessive and chaparral dominant; (2) Muav Saddle where the soil is shallow and stony and contains but little moisture in early summer, the exposure to insolation is maximum and the vegetation is limited to Upper Sonoran chaparral by the up-canyon and up-wall drafts from the hot deserts and valleys to the westward and below; (3) Saddle Canyon, north of Muav Saddle, where insolation is reduced because of the north exposure, where the hot desert winds are deflected overhead, where some alluvium has accumulated and seepage from highlands supplies some soil moisture, and where scattered pines grow in the chaparral; and (4) the northeastern part of Powell Plateau, which is typical Transition Zone with a good stand of yellow pine. Two Botta pocket gophers were taken at the latter station although the environment seemed more appropriate for the northern pocket gopher.

Color: Botta pocket gophers from Muav Saddle and Swamp Point are buffy golden; those from Saddle Canyon are buffy gray; those from Powell Plateau are darker than either, tending to rufous brown. In general the brightest buff pocket gophers are found in environments of high insolation and thin stony soil; the grayer animals in less exposed places which contain some alluvium; and the browner animals at the margin of the forest where the soil is deeper and moister.

Size and sexual dimorphism: As the smallest individuals were taken from the stoniest soil, sexual dimorphism in size on the North Rim seems to increase with depth of soil and ease of excavation.

Age and sex ratios: Of the eighteen specimens of the Botta pocket gopher taken, six were immature; and of the twelve adults, only two were males. The low percentage of adult males of both the Botta pocket gopher (18.2) and the northern pocket gopher (16.1) is unexplainable. The percentage of immature specimens taken in the two species is 36.1 and 11.4, respectively. The difference in ratios of the two age groups in the two species suggests differences in breeding cycles. It may be that the Botta pocket gopher, adapted to warm climates, bears young late in the summer and/or early in the spring, so that the young are mobile by early summer; whereas the northern pocket gopher, adapted to the short summer season of high mountain areas, may have young late in the spring and possibly then only one litter per year, so that there would be but few mobile young in early summer.

Temperature and humidity, with the resulting flora, appear to be factors in the distribution of pocket gophers in the Grand Canyon. In 1947 maximum and minimum temperatures were taken for the few days spent at each of the several collecting stations. Standing alone these few data have but little significance; but they agree with the temperature gradient for July obtained from the three official weather stations in the Grand Canyon National Park.

TABLE 1

Average daily temperatures for the month (from weather stations) or fractional part (from field data) of July, 1947. Names of official weather stations are in capital letters. Areas of occurrence of the Botta pocket gopher are boxed.

Station	*Elevation*	*Temperature* *Min.*	 *Max.*	 *Av.*
INNER CANYON	2400 ft.	76°	106°	91°F.
Swamp Point	7523	55	93	76
Muav Saddle	6717	59	83	71
Powell Plateau	7650	56	83	70
SOUTH RIM	6900	54	85	69
NORTH RIM	8250	45	79	62
Tipover Spring	8200	39	79	59

The similarity of temperatures at the three collecting stations on the North Rim where Botta pocket gophers were taken and that of the South Rim where this animal is common, is evident. The hot air moving up the canyon and the canyon wall produces Sonoran vegetation and gives higher local midday temperatures than obtain otherwise at the given altitude. This is especially well illustrated in the maximum temperature for Swamp Point, which is in the path of the hot air currents. The Botta pocket gopher, the only one on the South Rim, is now known to occur on the North Rim at certain places where the environment is suitable. It is assumed to occur over much of Powell Plateau and possibly on such arid points as the tip of Walhalla Plateau.

The Botta pocket gopher of the North Rim is similar to the subspecies *absonus* to the northeastward in the small size, reduced sexual dimorphism and conservative skull characters. In color, the grayest of the series from Saddle Canyon of the North Rim compares favorably with the average *absonus*. A close genetic linkage between these two subspecies seems reasonable because the intervening land is probably inhabited by Botta pocket gophers. The surprising similarity in general coloration and markings between the typical *boreorarius* and the subspecies *fulvus* taken on the opposite side of the Grand Canyon cannot be explained so easily. Genetic differences in skull characters make these two subspecies readily separable. Further discussion of the similarity in color pattern between the pocket gophers on the two sides of the Grand Canyon is to be found in the account of the northern pocket gopher.

Thomomys talpoides kaibabensis Goldman

Habitat: The northern pocket gopher is the common one of the North Rim and occurs widely over the Kaibab Plateau. It is found in the deep soils of the mountain meadows and in the forests of pine, fir and aspen, where it attains a large size; and it may be found also on adjacent ridges in stony soils which support only thin timber.

Size: The most obvious environmental response of this pocket gopher is the adjustment of body size to the depth and texture of soil. Clines of decreasing size from easily tilled, deep soils to shallow, stony soils can be easily demonstrated in a given valley or from the west end of the North Rim to the east end. For example, the largest specimen is from the deep alluvium of Swamp Lake (the most westerly station for the species) and the smallest adults are from the stony soil of Walhalla Plateau (the most easterly station). About midway between these two stations, on a ridge of shallow, stony soil, two immature northern pocket gophers were taken. Because they were unusually pale and had small ears these two specimens passed for Botta pocket gophers until their skulls had been cleaned and examined. A series of average northern pocket gophers were taken a few rods away in a typical boreal environment.

The population of the Kaibab Plateau was formerly assigned to *fossor* but later Goldman (1938, p. 333) renamed it *kaibabensis*. Judging from the thirty-one adults which I took on the North Rim, I think the average size is much smaller than that given in the original description of the subspecies. In head-body length, my males and females average 159 mm and 155 mm, respectively, whereas those few selected specimens out of eighteen available from De Motte Park are particularly large (type male, 180 mm and average of four topotype females, 164 mm). My largest specimen, a female, measured 162 mm. As will be pointed out in subsequent accounts, there is a geographic relationship between the boreal mammals of the Kaibab Plateau and those of the High Central Plateau of Utah. I think the relationship is closer than Goldman anticipated, for he wrote (1938, p. 335) of the subspecies in southern Utah, ". . . *parowanensis* is more closely allied to *kaibabensis* than to any other known form, but the smaller size and cranial features pointed out are separative." Having no comparative material I cannot judge the cranial differences, but the head-body measurements of my specimens (159 mm and 155 mm for males and females, respectively) agree rather closely with Goldman's (*op. cit.*) lengths of 159 mm and 148 mm for *parowanensis.*

Sexual dimorphism: On the North Rim the animals from resistant soils are not only smaller, but the sexes are nearer the same size, females averaging 97 per cent as large as males whereas in De Motte Park they are 91 per cent as large.

Color: The most distinctive color character of the northern pocket gopher of the North Rim is the white markings on the ventral side, particularly anteriorly. The chin and openings to the cheek pouches are white. Occasionally one has a white pectoral or a white inguinal spot or a bold, white "V" on the chest.

The character of white ventral markings was mentioned in the original description (Bailey, 1915, p. 111; ". . . chin usually, and spot on breast sometimes, white . . .") of *T. fossor*, the kind to which the North Rim form was originally assigned. In the original description of *T. t. kaibabensis* (Goldman, *op. cit.*) mention was made not of the white ventral spots but rather of anterior white fleckings (presumably on the dorsum; see Warren, 1942, p. 164) which the author considered an erratic factor. This flecking does not appear in my specimens from the North Rim. Goldman (*op. cit.*) noted a close relationship between *kaibabensis* and *fossor* but suggested that "a new group alignment should be based on more complete studies than I have made."

The character, white ventral markings, is characteristic of the subspecies *durranti* (Kelson, 1949, p. 143) in southeastern Utah, but the recognized ranges of both *durranti* and *fossor* lie on the opposite side of the Colorado River from that of *kaibabensis*. It seems probable that the size character of *kaibabensis* has been over-estimated and that the white ventral markings of the subspecies have been ignored by most writers. A reconsideration of the size factor would decrease the assumed gap between *kaibabensis* and *parowanensis*, and the size- and pattern-gap between *kaibabensis* and both *durranti* and *fossor*.

Goldman apparently ruled out white spotting as a genetic factor. Is this character then an environmental one? If we say no, we will have to explain why similar patterns of white spotting occur in both the Botta and the northern pocket gophers on opposite sides of the Grand Canyon. Furthermore, a study of Table 3 reveals an unexpected similarity in size (except for length of tail and ear) between the Botta pocket gophers and the northern pocket gophers of the North Rim. It seems to me that there is some environmental basis for this convergent evolution.

Peromyscus crinitus stephensi Mearns

Habitat: A single specimen of the canyon mouse was taken on a ledge just over the Rim at Point Honan, 7950 ft. elevation. This is apparently a new record for this species on the North Rim. This mouse of the Sonoran Life Zone (Bailey, 1935, p. 18) occurs sparingly at such high elevations (Hall, 1946, p. 504). Bailey (1931, p. 161) made two questionable references to its abundance in the Grand Canyon. The second reference was to Merriam's (1890, p. 62) discussion of *Hesperomys* [*Peromyscus*] *eremicus* which Bailey apparently confused with *P. crinitus*. Perhaps his first reference also concerns *eremicus*.

Size and color: Judging from the single specimen available, the canyon mouse from the North Rim may be assigned to *stephensi*, the designation for those in the Grand Canyon north of the Colorado River. The specimen resembles this subspecies in gray color, short head-body length (77 mm), and unusually long tail (121 per cent of head-body length). Osgood (1909, p. 232) and others give the Grand Canyon as an area of intergradation for the canyon mouse. It is therefore not surprising to find that this specimen from the North Rim resembles both the race *doutti* on the same side of the Colorado River in southeast Utah and *auripectus* (Durrant, 1952, p. 303) on the opposite side of the River in long hind foot, a faint pectoral spot, heavily-haired tail and large skull, i.e., in length of nasals, zygomatic breadth and breadth of brain case. The hairs of the tail are approximately 2 mm, 4 mm, and 8 mm long at the base, the middle and the distal parts of the tail, respectively.

Peromyscus maniculatus rufinus (Merriam)

Habitat: The deer mouse is the common white-footed mouse of the North Rim and occurs in a variety of habitats from barren cliffs along the Rim to dense Canadian forests. It was taken at every station except Swamp Point, Muav Saddle and Powell Spring. It probably occurs at these places also, although the brush mouse was the dominant white-footed mouse at the latter two stations.

Population fluctuation: Normally the deer mouse occurs in considerable numbers in such areas, but 1947 was a lean year and only four adults were obtained in a month of trapping on the North Rim. The mouse was common in 1949 when enough more were obtained to make a series of seventeen adult males and fifteen adult females. This fluctuation in population of *Peromyscus* agrees with Kelson (1951, p. 79) who reported the species scarce in eastern Utah in 1946 but abundant in August, 1948. Also, Quick (1953, p. 257) stated, "During the fall of 1947, populations of . . . *Peromyscus* were low [in British Columbia]. In the following autumn, 1948, [*Peromyscus*] made marked advances . . . and the natives . . . called it a 'mouse year.' "

Size and sexual dimorphism: From external measurements it is evident that the sexes of the deer mouse on the North Rim are almost identical in size of appendages (i.e., length of tail, hind foot and ear). In length of head-body the females are 4.35 per cent longer than the males, and their weights (corrected for embryos) are correspondingly heavier. The skulls of the males are slightly larger than those of the females. The tail and hind foot of the specimens from the North Rim are slightly longer than those of the topotypes from the San Francisco Mountains (Merriam, 1890, p. 65) but the skulls of the two populations appear identical in size (Osgood, 1909, p. 263). However, Durrant (1952, p. 312) for Utah and Warren (1942, p. 199) for Colorado list a smaller size for this mouse and their measurements agree with those obtained from a series collected by G. P. Ashcraft, formerly of the Hancock Foundation, on the South Rim of the Grand Canyon. Averages for this series, consisting of 18 males and 8 females, are 145, 153; 61, 63; 20.3, 21; 16, 17; skull: greatest length, 24.9, 25.6; zygomatic breadth, 12.5, 12.8; breadth of cranium, 11.6, 11.9; length of nasals, 10.2, 10.6, respectively. There is little difference in skull size in these various populations, but in length of head-body both those from the San Francisco Mountains and those from the North Rim exceed other populations by 6 mm.

Peromyscus boylii rowleyi (Allen)

Habitat: The brush mouse occurs sparingly on the North Rim. Only three adults were trapped, one in the cabin at Muav Saddle and the other two, along with five immature specimens, from rock cliffs near

Powell Spring. Apparently they occur in certain habitats on the North Rim where the deer mouse is rare or absent.

Size: These adults are considerably larger than the topotypes from Utah (Osgood, 1909, p. 145) which are similar in size to others from Utah (Durrant, 1952, p. 320), and those from Colorado and New Mexico (Warren, 1942, p. 205, and Bailey, 1931, p. 154, respectively). These from the North Rim are even larger than those large specimens from southeast Nevada which were thought by Hall (1946, p. 519) to be merely individual and geographic variants. The North Rim form is slightly larger than the Hancock series of four adult males and three adult females from the South Rim. More specimens are needed from the North Rim, but apparently the population there is unique in having (1) large size (head-body length of adults, 101 mm or longer) and (2) long rostrum as expressed in (A) actual measurements of greatest length of skull, (B) length of nasals, and (C) relative lengths, i.e., ratio of nasals to greatest length of skull and ratio of nasals to basilar length. In the males of the North Rim the nasals are 41.3 per cent of greatest length of skull whereas the averages for the larger sex from the South Rim, from Nevada (Hall, *op. cit.*), from Southern California and from Utah (Durrant, *op. cit.*) are 40, 39, 39, and 37.3 per cent, respectively. In the males of the North Rim the nasals are 56.6 per cent of the basilar length, whereas in the above populations the percentage is 53.8, 51.6, 51.9 and 49.7, respectively. In length of head-body and size of skull and in relative lengths of nasals to greatest and basilar lengths of skull, the population of the North Rim agrees with those of the two large mice *P. b. attwateri* of Texas and *P. b. artemesiae* of Wyoming.

Comparisons: Because the brush mouse *P. b. rowleyi* of the North Rim has an unusually long nose, the specimens were carefully examined to be sure that they were not *P. nasutus*, the long-nosed deer mouse. The actual and relative length of nasals of the males of the brush mouse from the North Rim exceed the maximum measurements for the long-nosed deer mouse in Colorado and New Mexico. To my knowledge, *P. nasutus* does not occur westward and northward of the Colorado River.

The *P. b. rowleyi* of the North Rim differ from the Hancock series taken in Los Angeles vicinity in having darker dorsal pelage, less buff on sides, longer rostrum and nasals, and shorter premaxillaries. Premaxillaries in the population from the North Rim extend posteriorly to the zygomatic branch of the maxillary but not as far as the proximal end of the nasals. Topotypes of *P. nasutus griseus* from New Mexico (in the Los Angeles County Museum) have premaxillaries which extend farther posteriorly than do the nasals, which may prove to be a distinguishing character between *boylii* and *nasutus.* Certainly "length of nose" in this particular population fails to be a criterion. The *boylii* of the North Rim lack the globular bullae of *P. truei.* I have taken no *truei* or *nasutus* in the Grand Canyon but Bailey (1935, p. 18) reported the former "all through the Grand Canyon country, mainly in Upper Sonoran Zone" and made no mention of *nasutus.*

Neotoma cinerea acraia (Elliot)

Habitat: Bushy-tailed wood rats appeared to be uncommon on the North Rim. They were wary and the catch was low even where the animals seemed to be concentrated. Evidence of their presence was most abundant on rocky ledges just over the rim of the canyon where one specimen was taken from a barren, weathered cliff on Point Honan and two specimens (one subadult) came from a steep, rocky slope almost covered with dense chaparral near Point Imperial. A young male was unexpectedly trapped on Walhalla Plateau near Snowshoe Cabin under a log on the bank of a small valley. There was no runway, tunnel, nest or rock outcrop in sight. One sly adult was seen by day in an abandoned cabin on Swamp Point but it could not be lured into a trap even in several nights of trying. Signs of this species were also noted on a rocky ledge near the Harvey Camp stables.

Color: The young male from Walhalla Plateau was acquiring its adult pelage which seems unusually pale for this area as well as for this species. Buff shows brightly on face, sides, shoulders and hips. The lumbar region is pale gray, and there is a broad, midventral white stripe, the hairs of which are white to the base. The tail is only slightly bicolor with a faint, yellow-tinged, gray dorsal stripe. The short lateral and ventral hairs of the tail are white. Such a pelage seems more appropriate for an animal living in the Lower Sonoran Zone, e.g., in the Painted Desert across the Colorado River. However, the absence of sphenopalatine vacuities distinguishes this specimen from the bushy-tailed wood rats (*N. c. arizonae*) in the desert to the southeast. Hall (1931, p. 6) stated that the color of pelage in these rodents seems particularly responsive to climatic conditions. Two pale specimens, one of *N. c. acraia* (Kelson, 1951, p. 94) and one of *N. c. arizonae* (Durrant, 1952, p. 352) were reported from Utah. My pale specimen from the North Rim may be an extreme color variant of the high montane population but is more probably a migrant from the Sonoran Life Zone of the wall of the canyon up to this high plateau valley. My other specimens from the

North Rim have a dark gray dorsum and face, a tail much darker than the Hancock specimens from the southern Sierra Nevada, California, and the buff reduced in intensity and limited to a fringe along the sides.

Size: Of the two females taken on the North Rim in early July, one had three 5 mm embryos and the other was in an early stage of pregnancy. The former was considered a subadult, but the latter was fully grown, as was the male, which had 15 mm testes. Comparing these latter two from the North Rim with adults from the southern margin of the range of *N. c. acraia,* Mt. Whitney (Hooper, 1940, p. 417) and Charleston Mt. (Burt, 1934, p. 421), we find that they are larger and the sexual dimorphism is greater; e.g., the North Rim female is 96 per cent, 93.5 per cent and 72.5 per cent as large as the North Rim male in length of head-body, basilar length of skull and weight, respectively.

Microtus longicaudus baileyi Goldman

Habitat: Most of the long-tailed meadow mice from the North Rim were trapped in moist meadows near lakes, streams and springs, but two specimens were taken on a dry forest ridge one-half mile from open water. Nowhere were they found abundant. I considered them scarce in 1947 when only two were obtained in four nights of trapping at Tipover Spring, a likely habitat, although seven were taken in one rainy night at Swamp Lake. Two years later none were taken in a night of otherwise good trapping at Swamp Lake, and they then seemed more common in other localities. Apparently their degree of abundance in a given locality may vary widely from year to year.

Size: In the long-tailed (*longicaudus*) group of meadow mice the tail usually exceeds one-half the length of head-body. The tails of these meadow mice from the North Rim, as well as those from southeast Utah, average less than one-half (46 per cent) head-body length and, in those populations near the limits of their distribution to the southward, the tails are even shorter. It is evident that a cline of decreasing length of tail in this species (Table 2) occurs from north to south (Map 1).

TABLE 2

Subspecies	*Locality*	*Elevation*	*Latitude*	*Tail/Head-Body*
mordax	Sawtooth Mts., Idaho	7000′	44°N	57 per cent
mordax	Elko Co., Nev.	6500′	42	51 per cent
latus	Toiyabe Mts., Nev.	8500′	39	50 per cent
alticola	Mts. of SE Utah	9000±′	38½±	49 per cent
baileyi	North Rim, Ariz.	8000′	36+	46 per cent
alticola	San Francisco Mts., Ariz.	8200′	35½	45 per cent
leucophaeus	Graham Mt., Ariz.	??	32½	40 per cent

The relative length of tail to length of head-body for certain subspecies and populations of *Microtus longicaudus* as obtained from published measurements.

Because the altitudes are all relatively high it is assumed that the environments (including temperature) are similar for all these stations. Therefore, in consideration of surface-volume relationships, the tails of the southern populations should be as long as or longer than the tails of the northern populations in order for length of tail to be an adaptive character. This is an exception to Allen's Rule.

Sexual dimorphism: The males and females on the North Rim are nearly identical in size (Kellogg, 1922, p. 281) except that the skulls of the males are slightly (1 to 2½ per cent) larger. It was difficult to decide which individuals were adult. One pregnant female was classed as immature because of her subadult pelage and small size.

Color: The dorsal pelage of one juvenile was unusually reddish.

SUMMARY

The measurements (Table 3) of the rodents of the North Rim as compared with measurements of types, topotypes and series of the same subspecies from adjacent regions show that most of the nonfossorial rodents (i.e., rock squirrels, golden-mantled ground squirrels, least chipmunks, chickarees, deer mice and bushy-tailed wood rats) of the North Rim are as large (head-body length) as or larger than the average (or sometimes than the maximum) from adjacent areas. Even the deer mouse, which occurs on both sides of the Colorado River, is noticeably larger on the North Rim than on the South Rim. Although some of these rodents were available to me only in small series, the overall concept of size is that of "large." These animals have correspondingly larger skulls, as shown (Table 3) by length of skull and breadth of brain case. The weight of the animals gives further evidence of their superior size whenever comparative data are available from other collectors.

TABLE 3

Average Measurements of Rodents Taken on the North Rim

Linear measurements in millimeters, weights in grams (weight of all pregnant females corrected for embryos). Where only subadults were available they are indicated with an asterisk (*). The dagger (†) indicates basilar length of skull.

	Number and sex of specimens	Total length	Length of tail	Length of hind foot	Ear from crown	Ear from notch	Weight in grams	Greatest length of skull	Zygomatic breadth	Breadth of cranium	Interorbital constriction	Length of nasals
Spermophilus v. grammurus	2 ♂	490	209	61.5	21.5	31	655	60	36.7	24.5	15	21.8
	2 ♀	453	188	58.5	20	29	670	59.3	37	24.5	14.2	21.4
Spermophilus l. lateralis	1 ♂	275	90	45	16	23	185	—	—	—	—	—
	14 ♀	271	85	42.4	15.8	22.5	208.4	44	27.7	20.3	—	15.5

Eutamias m. consobrinus	1 ♂*	187	80	30	12	16	41	31	17.3	15.2	—	10
	2 ♀*	197.5	85.5	31.5	11	17	55.5	32.1	18	16	—	10.7
Eutamias u. adsitus	12 ♂	218	92	34	14	19.6	61	35.3	19.3	16	8.5	11.4
	8 ♀	227	98	34	14	19	68	35.7	19.5	16.2	8.4	11.5
Eutamias d. utahensis	—	—	—	—	—	—	—	—	—	—	—	—
	3 ♀*	226	99	34	16	22	56	35.1	19.6	16.7	7.9	11.2
Tamiasciurus h. dixiensis	2 ♂	340	132	54	22	29	273	48.9	28.2	21.1	—	15.4
	1 ♀	322	130	51	22	29	250	—	—	—	—	15
Thomomys b. boreorarius	2 ♂	221	68.5	29.5	4	4.5	122	33.1†	23	19.8	6.4	13.3
	10 ♀	203	62.3	27.6	3.8	4.3	90.3	31 †	20.8	17.8	6.3	11.7
Thomomys t. kaibabensis	5 ♂	220	61	29.6	7.1	8.4	122	33 †	22	17	6	14.7
	26 ♀	215	60	28.7	7.4	8.2	106	31.7†	20.8	16.4	6.1	13.5
Peromyscus c. stephensi	1 ♂	170	93	21	19	21	15	24.7	12.3	12.3	4.3	9.7
	—	—	—	—	—	—	—	—	—	—	—	—
Peromyscus m. rufinus	17 ♂	162	70	20.3	16	18.5	21.3	25.5	13.1	12	—	10.3
	15 ♀	166	70	20.4	16.5	18.4	22.7	25.3	12.7	12	—	10.2
Peromyscus b. rowleyi	2 ♂	210	109	23	18.5	20.5	26.5	28.8	14.2	12	—	11.9
	1 ♀	194	93	23	18	20	23	26.8	13.5	11.4	—	10.5
Neotoma c. acraia	1 ♂	400	182	45	32	34	325	44.4†	27.4	18	5.6	19.9
	1 ♀	375	165	41	29	33	235	41.4†	25.4	17.5	5.5	19.5
Microtus l. baileyi	5 ♂	178	56	21	12	16	44	28.2	15.8	13	3.6	8.4
	6 ♀	178	55.5	21.3	11.5	15	41	27.7	15	12.9	3.7	8.4

The large size of the animals on the North Rim is in agreement with Bergmann's Rule of larger animals in colder environments. The size of the pocket gophers on the North Rim, however, is correlated not so much with temperature as with compaction of soil and altitude. On the North Rim the relatively small Botta pocket gopher seems to be approaching its limits of toleration of high altitude and compaction of soil. Although the northern pocket gophers found in the center of the Kaibab Plateau where the soil is deep and the temperature low, are unusually large, those taken on the North Rim, not far from the rim of the Canyon (temperature somewhat higher), show a decline in size. However, this decline is probably based on tolerance of range margin (minimum altitude and maximum compaction of soil) (Miller, 1952, p. 442).

Because most of the nonfossorial rodents in this boreal environment are larger than average, one might expect relatively shorter than average appendages (Allen's Rule). This is true of the tail of the golden-mantled ground squirrel, the least chipmunk and the long-tailed meadow mouse, but the tail of the Say chipmunk and of the canyon mouse is longer than the average. The length of nasals, an indication of the length of rostrum or nose, is also greater in least chipmunks, chickarees, canyon mice, brush mice, bushy-tailed wood rats and long-tailed meadow mice. The longer nasals at least partly account for the greater length of skull found in some of these animals. Of these long-nosed rodents, the brush mouse is unique in that the rostrum is so long that the animal might be mistaken for the long-nosed mouse. Possibly this exaggerated appendage is an adaptation for food getting and air warming by a nonhibernating animal active in a cold climate. A longer than average hind foot appears in rock squirrels, Say chipmunks and canyon mice.

Considering the short tails of the population of long-tailed meadow mice, we find this character adaptive to the high mountain environment of the Kaibab Plateau. Nevertheless, on examining a series of mountain top populations of meadow mice from Idaho to Arizona we find the unusual correlation of decreasing length of tail with decreasing latitude. This exception to Allen's Rule is also found on the Pacific Coast where, in this same species, the subspecies *Microtus longicaudus abditus* in Oregon has the longest tail (73 per cent of head-body length) and the subspecies *M. l. bernardinus* in Southern California has the shortest tail (52 per cent of head-body length). Because the rules of Bergmann, Allen and Gloger deal with adaptive characters, the cline of decreasing length of tail to the southward seems to be an example of a fixed random character.

Males are larger than females in the rock squirrel, bushy-tailed wood rat and both species of pocket gophers. However, the females of the rock squirrel weigh more than the males—a possible adaptation to reproduction and/or hibernation. Females are larger than males in the Say chipmunk and deer mouse, except that in the latter the males have larger skulls.

The limited trapping done below the Rim in the Sonoran Life Zone indicated that desert mammals tend to move into the boreal zone more than boreal mammals into arid places. The reason for the appearance of the rock squirrel and the cliff chipmunk, both immature, in lower Transition seems to be population pressure. The Botta pocket gopher on Powell Plateau seemed out of place in the pine forest but apparently no competition was being offered there by the northern pocket gopher. The Botta pocket gopher and the bushy-tailed wood rat seemed as versatile as any of the other rodents in occupying both desert and boreal habitats. The ubiquitous deer mouse seemed to shun the arid Muav Saddle and vicinity—the brush mouse was taken there. Although the canyon mouse was taken at an unusually high altitude for the species, it was still in its Sonoran Life Zone.

Possible close genetic relationship between species occupying both North and South Rims has been pointed out in the discussion of the size of the least chipmunk, of the white patches on the Botta pocket gopher, and of the short tail of the long-tailed meadow mouse.

Rodents of the North Rim support Gloger's Rule of adaptive coloration. The Kaibab squirrel, with limited range in the high, cold, moist forest, shows areas of dense melanins. Those rodents with wide ecological tolerances and more extensive ranges (e.g., the rock squirrel of the North Rim) tend to be paler than one might expect. This paleness, presumably affected by the nearness and potency of the extensive deserts, is particularly pronounced in certain juvenile pelages of the mountain pocket gopher and the bushy-tailed wood rat. The young of the long-tailed meadow mouse appear to be as dark as the adults, and one immature specimen from the Canadian forest has a definitely reddish dorsum. Immature pelages may be indicative of ancestral environments, whereas adult pelages seem to reflect the present local environment of the particular animal.

Paleness resulting from fading and wear of pelage of such sun-loving animals as the rock squirrel and the golden-mantled ground squirrel is the result of exposure to intense insolation. Such seasonal variation appears not to detract from the animal's protective coloration on pale soils and dead tree trunks.

The Botta pocket gopher shows high adaptation of color to local conditions of soil color and humidity, and possibly even to light intensity (see description of color under the account of species).

The relationship between the rodents of the North Rim and the South Rim of the Grand Canyon presents perplexing problems. Is the barrier between these two areas an impassable chasm or altitudinal difference (about 1000 feet), or a combination of the two? Durrant (1952, p. 515) correlated the degree of separation of juxtaposed populations further up the Colorado River with the relative size of the canyon.

Obviously, all the ground squirrels as well as all the tree squirrels, all the meadow mice, and all the pocket gophers are genetically related if we go back far enough on the generic tree. The relationship between certain subspecific variations seems indefinite and appears to be the product of the environment, even when the character seems to be nonadaptive; e.g., the white patches on the ventral surface of the pocket gophers and the short tail of the meadow mouse.

Conclusions

The rodent fauna of the North Rim is fairly typical of that of the Kaibab Plateau. All these animals show certain relationships to those of the South Rim, the San Francisco Mountains, and the other highlands of Arizona, but the boreal rodents of the North Rim have their nearest relatives on the High Central Plateau of Utah. A chain of highlands from the core of the Rocky Mountains in Colorado forms a route of migration westward into Utah via the Uinta Mountains and thence southward along the High Central Plateau almost to the southern border of Utah. Up to this point a continuous forest of yellow pine gives a high montane environment similar to that of the Kaibab Plateau, from which it is separated by some fifty miles of arid Kaiparowits Canyon Lands. This desert area is occupied by animals such as the ground squirrel, Botta pocket gopher, and deer mouse, not greatly unlike those from the arid margins of both the High Central Plateau of Utah and the Kaibab Plateau of Arizona; but the montane rodents, such as the chickaree, northern pocket gopher and bushy-tailed wood rat, are absent from the Kaiparowits area.

To account for the near relationship between the montane rodents of the Kaibab Plateau and those of the High Central Plateau of Utah, it is postulated that in the glacial periods of the Pleistocene the cold wet climate allowed the yellow pine forest to grow in what is now the Kaiparowits area. The montane rodents then descended to the lower levels and their distribution was continuous from the High Central Plateau to the Kaibab Plateau. During the warmer, arid, interglacial periods of the Pleistocene, the intervening forest disappeared and the montane rodents were forced to ascend to the higher mountains. Thus the continuity of population was periodically broken and the Kaibab animals were isolated, as they are now in the Recent epoch. This isolation by the Grand Canyon of the Colorado River and by the adjacent deserts has been so effective since the last Ice Age that the montane rodents of the Kaibab Plateau are ideally stranded for speciation.

It seems possible that during the Ice Ages the yellow pine forests and the montane rodents were continuous from Utah southward into Arizona (e.g., on the San Francisco Mountains, Mogollon Plateau and other highlands of east-central Arizona). Because of their more southerly latitudes and the rapid development of the canyon of the Colorado River, the highlands of central Arizona must have been cut off from the Kaibab Plateau at an earlier period than the Kaibab Plateau was cut off from the High Central Plateau of Utah. The result has been the later and closer genetic connection between the boreal rodents of the Kaibab Plateau and those of the mountains of southern Utah.

LITERATURE CITED

Bailey, V.

1900. Revision of American Voles of the Genus *Microtus*. North Amer. Fauna. 17:1-88.
1915. Revision of the Pocket Gophers of the Genus *Thomomys*. North Amer. Fauna. 39:1-136.
1931. Mammals of New Mexico. North Amer. Fauna. 53:1-412.
1935. Mammals of the Grand Canyon Region. Grand Canyon Nat. Hist. Assoc., Nat. Hist. Bull. 1:1-42.

Burt, W. B.

1934. The Mammals of Southern Nevada. Trans. San Diego Soc. Nat. Hist. 7:375-427.

Davis, W. B.

1939. The Recent Mammals of Idaho. Caxton Printers Ltd., Caldwell, Idaho. 400 pp.

Durham, F. E.

1952. A new Pocket Gopher from the North Rim of the Grand Canyon, Arizona. Jour. Mammal. 33:498-499.

Durrant, S. D.

1952. Mammals of Utah. Kansas Univ. Pubs. Mus. Nat. Hist. 6:1-549.

Goldman, E. A.

1938. New Pocket Gophers of the Genus *Thomomys* from Arizona and Utah. Jour. Washington Acad. Sci. 28:333-343.
1947. The Pocket Gophers (Genus *Thomomys*) of Arizona. North Amer. Fauna. 59:1-39.

Hall, E. R.

1931. Critical Comments on Mammals from Utah, with Descriptions of new Forms from Utah, Nevada and Washington. Univ. Calif. Pubs. Zool. 37:1-13.

1946. Mammals of Nevada. California Univ. Press, Berkeley. xi,710 pp.

Hall, E. R. and K. R. Kelson

1952. Comments on the Taxonomy and Geographical Distribution of some North American Rodents. Kansas Univ. Pubs. Mus. Nat. Hist. 5:343-371.

Hardy, R.

1942. Three new Rodents from Southern Utah. Proc. Biol. Soc. Washington. 55:87-92.

Hooper, E. T.

1940. Geographic Variation in Bushy-tailed Wood Rats. Univ. Calif. Pubs. Zool. 42:407-424.

Howell, A. H.

1929. Revision of the American Chipmunks (Genus *Tamias* and *Eutamias*). North Amer. Fauna. 52:1-157.

1938. Revision of the North American Ground Squirrels, with a Classification of the North American Sciuridae. North Amer. Fauna. 56:1-256.

Johnson, D. H.

1943. Systematic Review of the Chipmunks (Genus *Eutamias*) of California. Univ. Calif. Pubs. Zool. 48:63-148.

Kellogg, R.

1922. A Synopsis of the *Microtus mordax* Group of Meadow Mice in California. Univ. Calif. Pubs. Zool. 21:275-302.

Kelson, K. R.

1949. A new Pocket Gopher from Southeastern Utah. Proc. Biol. Soc. Washington. 62:143-146.

1951. Speciation in Rodents of the Colorado River Drainage. Utah Univ. Biol. ser. 11:1-125.

1952. Comments on the Taxonomy and Geographic Distribution of some North American woodrats (Genus *Neotoma*). Kansas Univ. Pubs. Mus. Nat. Hist. 5:233-242.

Linsdale, J. M.

1938. Environmental Responses of Vertebrates in the Great Basin. Amer. Midland Nat. 19:1-206.

Merriam, C. H.

1890. Results of a Biological Survey of the San Francisco Mountain Region and Desert of the Little Colorado, Arizona. North Amer. Fauna. 3:1-136.

Miller, M. A.

1952. Size Characteristics of the Sacramento Valley Pocket Gopher (*Thomomys bottae navus* Merriam). Jour. Mammal. 33:442-456.

Osgood, W. H.

1909. Revision of the Mice of the American Genus *Peromyscus*. North Amer. Fauna. 28:1-285.

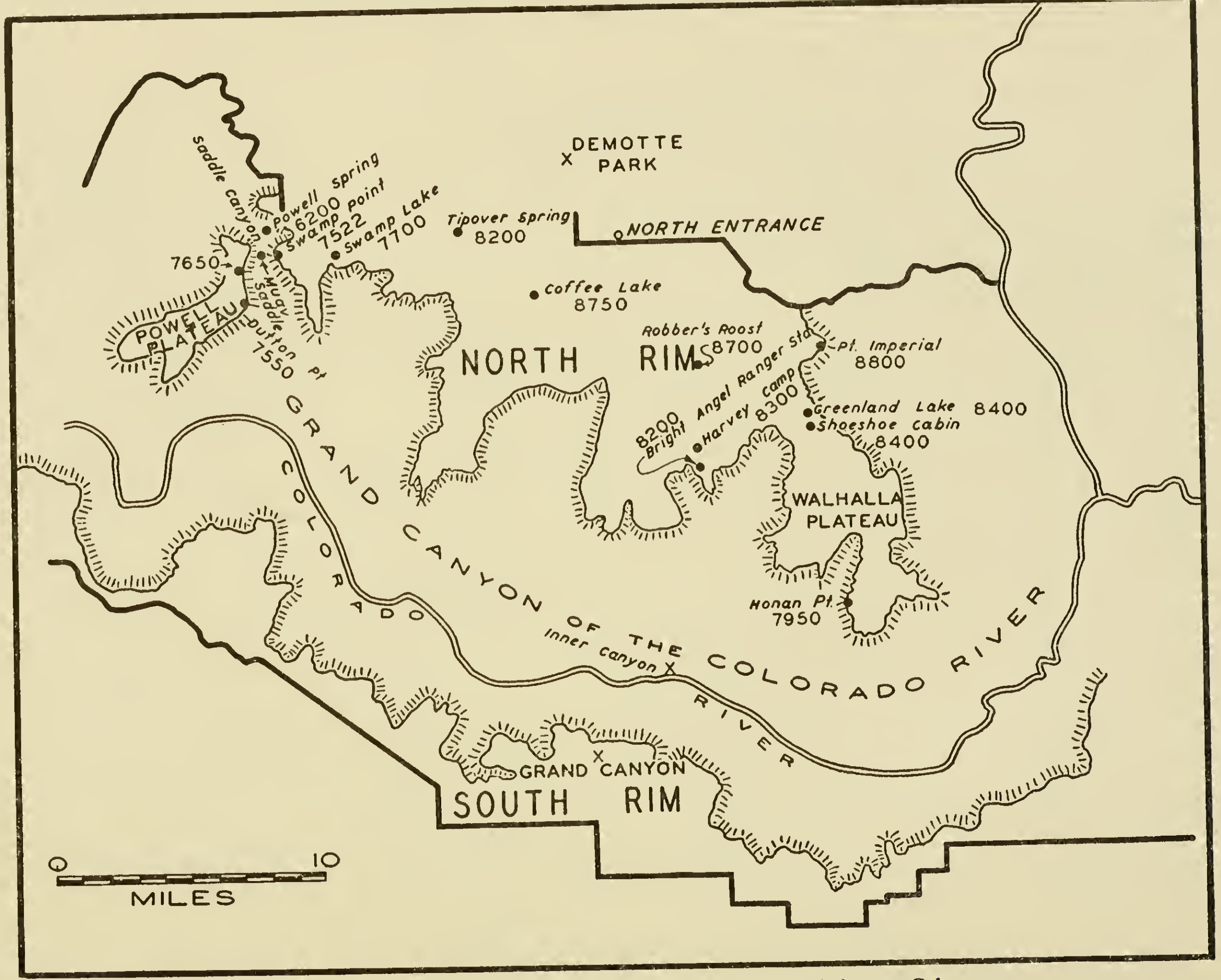
Quick, H. F.

1953. Occurrence of Porcupine Quills in Carnivorous Mammals. Jour. Mammal. 34:256-259.

Warren, E. R.

1942. The Mammals of Colorado, their Habits and Distribution. Okla. Univ. Press, Norman, Okla. xviii,330 pp.

MAP 1. The Colorado Plateau and the contained Kaibab Plateau and neighboring highlands, plus certain adjacent mountains significant in the distribution of rodents.



Map 2. Part of the Grand Canyon National Park, Arizona. Collecting stations, with elevations in feet, are indicated by black dots.

MARINE ALGAL FLORA OF THE CARIBBEAN AND ITS EXTENSION INTO NEIGHBORING SEAS

By

Wm. Randolph Taylor

University of Michigan

Studies of the marine algae of the Caribbean Sea and contiguous areas have developed slowly. Our earliest substantial knowledge of the region came from the records of Cuban algae published by Montagne (1842) ; J. G. Agardh added a few Mexican species (1847) but W. H. Harvey's reports of Florida algae (1852-58) served best of all to characterize the flora of the region. Outstanding for the elaborateness of their collections is the famous survey of Guadeloupe algae by Mazé and Schramm (1870-77). The identification of these Guadeloupe collections by the Crouans is more notable for the acuteness with which they distinguish between samples than for their appreciation of natural species limits. A great number of names of algae from distant seas were incorrectly applied to Guadeloupe plants, and many new species were described on insufficient evidence. These were mistakes easily excused when one remembers the relatively primitive state of phycological taxonomy at that time. Murray (1888-89) incorporated many new station records throughout the Caribbean area, but, depending largely on the work of Mazé and Schramm, portrayed a West Indian flora with more endemic species than was justified, and distorted the relationships of the flora by these doubtful names when he prepared his phytogeographical tables. Nevertheless, a close reading of Murray's lists makes the character of the flora clear in its general features and most common genera. Since that time, careful studies on the Virgin Islands algae by Børgesen (1913-20), on those of Bermuda, the Bahamas, Jamaica, and Puerto Rico by Collins and by Howe have clarified many features. Less detailed lists have come from several other careful observers, and the time appears ripe for a fresh look at the Caribbean flora.

In the last 30 years thousands of specimens from almost all sections of this region have passed through my hands. Hundreds of station records have been established, bridging many long gaps between earlier records and extending other ranges north and south beyond what had been known. There remain hundreds of species which have been reported only once or twice. Perhaps a third to a half of these are really rare or even endemic species whose ranges we will at some distant date be able to define with confidence. One-half to two-thirds are probably old, ill-described species which will never be fully verified and accepted. However, in all these thousands of specimens very few indeed have seemed to me to be any other than well defined and recognized plants. There is very little encouragement for the anticipation of discoveries of many new species, or rediscoveries of ill-described species (except among the more minute forms) which would give them a place in the well-understood flora.

It is, nevertheless, clear that the Caribbean marine flora is an exceedingly rich one. It might be thought that elimination of early and ill-described species names would cut the list down to a very modest size, but this is not the case. After we set aside over 330 species too ill-known to delimit precisely, we still have (exclusive of Myxophyceae, diatoms, flagellates, and the like) some 790 well defined species known in the flora; and numerous species in the smaller categories like Acrochaetium, Streblonema, and the endophytic Chlorophyceae will be added in time to this. Not all of the 790 species are common ones. Some are known from but one or two reports, although these appear to be reliable.

However, it is not these rarities which determine the facies of the flora, but rather the more obvious species such as come in from general correspondents. Eventually one will be able to tabulate the rarities as well as the commoner things; but as they stand now, to count them equally with the others would unduly stress the vegetation of the few places where expert phycologists have made detailed collections. If we examine the distribution of species known from at least 5 major islands or countries, we have some assurance that our sample is meaningful. Admittedly incompletely representing the flora, it does represent the vast bulk and most distinctive parts of it. In discussing the Caribbean flora and its ranges we will stress particularly these commoner species. One must note here that the distributions of some species in latitude on the

American and on the European coasts by no means necessarily correspond. A good example is *Dictyota dichotoma*, which in America reaches 35° N.L. but in Europe extends at least 23° farther north, into decidedly colder water. It is the American strains of these species which concern us, and their American distribution, not the similar, but not necessarily physiologically identical, European representatives.

It is customary to think of our western tropical Atlantic algal flora as typified by what appears in the Caribbean. However, the Caribbean Sea lies far north of the Equator. Its highly complex shoreline, with a host of islands and reefs, favors a rich algal flora, which focusses attention on it. The very brief northward extension of this flora to 30° N.L. in Florida and 32° N.L. in the Bermudas is not unexpected, for the Gulf Stream, flowing through the Straits of Florida, favors just such an extension. The almost total disappearance of the flora in the Gulf of Mexico as one goes north and northwest is one of impoverishment, and not of replacement by a temperate flora. Muddy shorelines and large injections of fresh water, rather than the somewhat lowered temperatures of winter, seem to be the chief reasons for this. The type of algal vegetation does not show any distinctive change as we go southeast across the Equator. Allowing for our less adequate exploration of the coast, it is seen to retain the same character far toward the southern boundary of Brazil. Extensive regions are probably so affected by the discharges from the Orinoco, the Amazon, and other great rivers that they are nearly sterile, and other regions with muddy shores are similarly unproductive. Where we have collections in the Guianas and northeastern Brazil, we find no change of character, no incursion of a new and more equatorial tropical element, in spite of the northwestwardly tending South Equatorial Current. Furthermore, perhaps aided by the southerly Brazil Current, the same type of flora extends many hundreds of kilometers farther to the south, and only when we reach southern Brazil do new elements begin to appear. Not until we reach Uruguay at about 35° S.L. do the new elements dominate, though they still do not altogether replace species typical of the Caribbean.

A general chart (Table 1) shows many of the features of the Caribbean flora. The number of species in each class which we may accept as well established appears in the first column of numbers, and the second column shows the species that have been reported enough times to give us a clue to their probable range. In the third column this is broken down for each algal class into four categories, depending on whether the alga is limited to the Caribbean in American waters, ranges northward, ranges southward, or is wide-spread in both directions from the Carib-

TABLE 1

Algal class	Established species, total	Same, 5 or more stations	Number in range group	Per cent of algal class	Per cent of total frequently reported species (317)		
Chlorophyceae	213	92	27	12.6	8.5	Caribbean	Strictly
			11	5.1	3.4		and Northern
			32	15.0	10.0		and Southern
			22	10.3	7.0		and Widespread
Phaeophyceae	109	53	10	9.1	3.1	Caribbean	Strictly
			3	2.7	1.0		and Northern
			25	23.0	8.0		and Southern
			15	13.7	4.7		and Widespread
Rhodophyceae	468	172	53	11.3	16.6	Caribbean	Strictly
			21	4.5	6.6		and Northern
			48	10.2	15.1		and Southern
			50	10.7	16.0		and Widespread
	790	317	317	—	100		

bean. Some 790 species are well-known entities, contrasting with about 330 which are ill-supported either taxonomically or geographically and do not enter into our tables. Known synonyms are excluded. Of this 790, less than half, or 317 species, have been found in at least five places (countries or major islands), the discrepancy being greatest among the Rhodophyceae, where there are many small species, with only 172 out of the 468 species collected in as many as five places.

If we consider now how many better known species of the total in each algal class range north or south from the Caribbean, we find the analysis in the first percentage column. Altogether, 43 per cent of the Chlorophyceae are known from five stations or more. Of these, 27 species are apparently strictly Caribbean, and this is 12.6 per cent of all the Chlorophyceae known from the region, or 8.5 per cent of all adequately reported species. Of the Chlorophyceae, the distribution of 57 per cent is not well enough known to make it wise to consider them in the analysis. The other range groups and algal classes can be compared in the same way. This first percentage column shows that all algal groups range less to the north than to the south, but as the data are clouded by the many species about which we know too little, the second table based on commoner species offers a better analysis. The last percentage column is valid and does show what proportion each range group contributes to the total flora of more frequently reported species. Quite as we would expect, the Rhodophyceae contribute most, but of the Rhodophyceae those which range northwards are much fewer (6.6 per cent) than those with southward tendencies (15.1 ~~and 16.0~~ per cent ~~respectively~~). In the Phaeophyceae, the strictly Caribbean species are relatively much fewer (3.1 per cent) than the species with southern tendencies (8.0 and 4.7 per cent), and it is curious that so very few (1.0 per cent) have northward tendencies.

TABLE 2

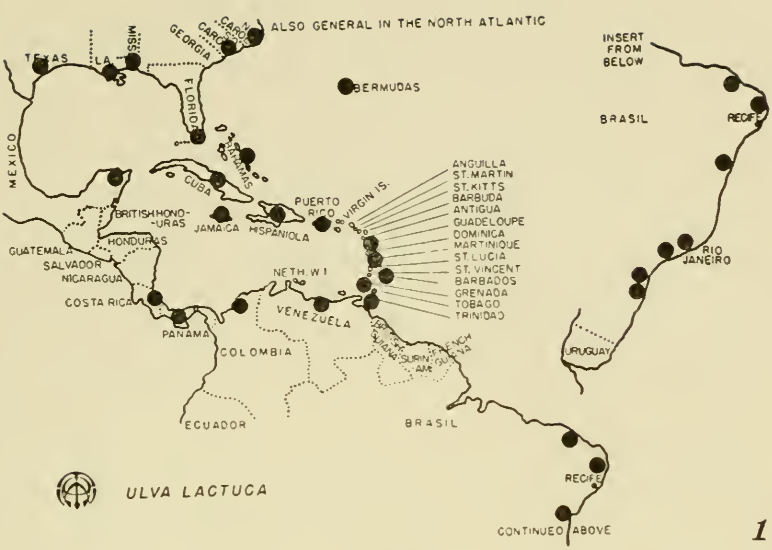
	Chlorophyceae	*Phaeophyceae*	*Rhodophyceae*	*All Groups*
Strictly Caribbean	29.3	18.8	30.8	28.4
Caribbean and Northern	12.0	5.7	12.2	11.0
Caribbean and Southern	34.8	47.2	27.9	33.1
Widespread North and South	23.9	28.3	29.1	27.5

Percentage of each range type in the several algal classes, based on well-known species (317) each reported from 5 or more stations.

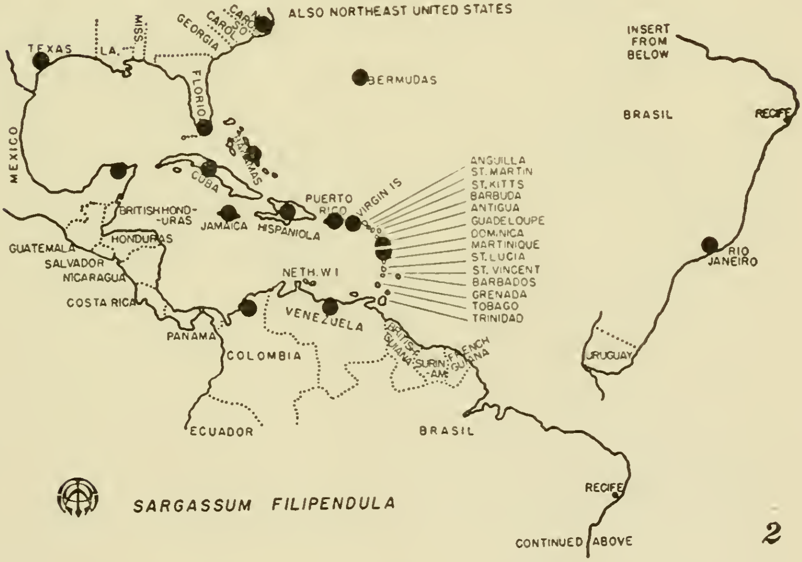
The second table shows the flora of species well known from five or more stations where the percentages relate the number in each range type to the total better known species of individual algal classes, not the whole flora. This really expresses the proportions of the important species and their range trends. The group of species which occurs in the Caribbean but ranges to the northward is hardly more than a third as large as any of the others. The strictly Caribbean contingent is about as large as the Caribbean and southern, or the widespread group (which will include the most cosmopolitan species). Specifically, applying the principle of comparing the distribution ranges of better known species, we find by Table 2 that only 11.0 per cent of the species extend beyond Florida into the Carolinas, hardly a thousand kilometers from the rich tropical flora of the Florida Keys. Remember that we are considering a relatively well-explored region. By contrast, the southern extension of the flora to Brazil involves three times as many, or over 33 per cent of the species, and the best known parts of the coast of Brazil are in the vicinity of Rio de Janeiro, over 5000 kilometers away from the Caribbean. In fact, the group which has an extended southern range is larger than the ubiquitous group of algae, many cosmopolitan, which range both north and south, and which constitute about 27.5 per cent of the Caribbean flora. It is also larger than the strictly Caribbean fraction, which is about 27.9 per cent. If we go into more detail and examine the individual algal classes, we find that the smallest, the Phaeophyceae, is the most extreme in these respects, for only 5.7 per cent of the Caribbean species range northward while nearly eight times as many, or 47.2 per cent, range southward, as against less than three times as many in either Chlorophyceae or Rhodophyceae.

Many examples of species with distinctive ranges on the American coasts could have been provided from each of the groups of larger marine algae, but two examples of each range type are a sufficient sample. Of those which range widely from the Caribbean both northward and southward along the American coast, we select from the Chlorophyceae *Ulva lactuca*, known from the Magellan Strait to the subarctic waters of Newfoundland and nearly cosmopolitan. The map of Fig. 1 shows the available records. Reports in the literature of this species are particularly suspect, but the occurrences in our range seem well substantiated. For comparison note *Sargassum filipendula*, shown in the map of Fig. 2. This is not a cosmopolitan species, though it ranges widely on the eastern American coasts, being quite distinct in its northern range but less easily delimited when one has southern collections. It reaches to south-central Brazil.

More restrictively, we may consider two species which, while widespread in the Caribbean, seem only to range northward. One, *Aegira*

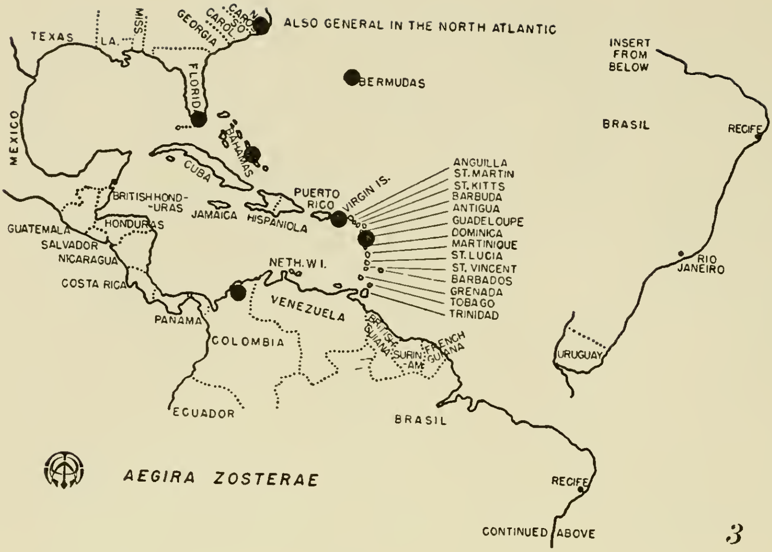


1

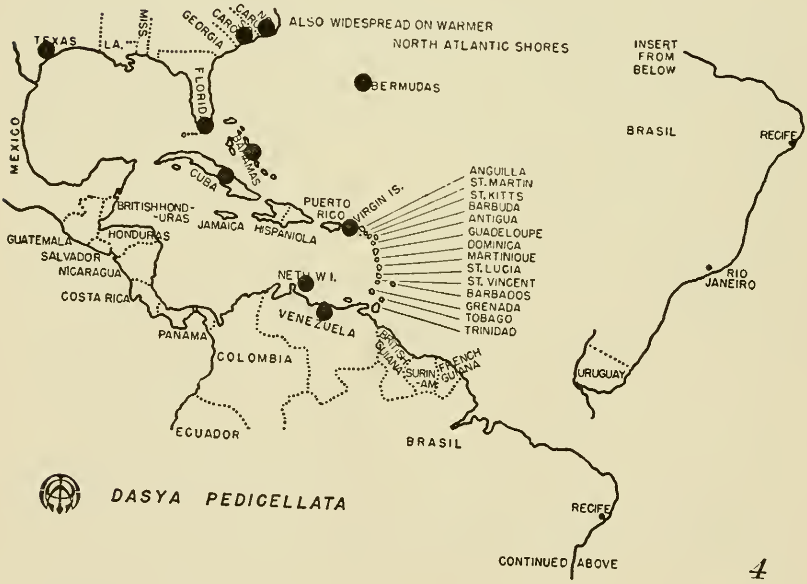


2

Text-figs. 1, 2. Caribbean algae with a wide range in the Americas.

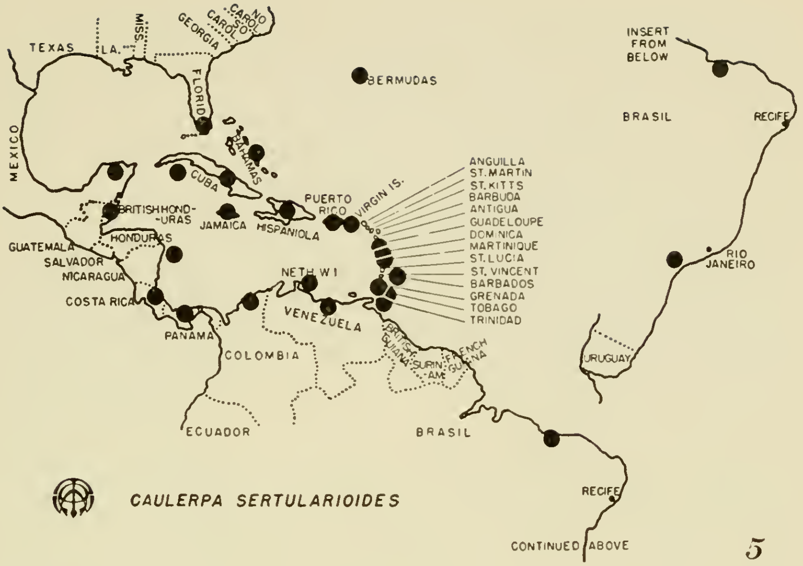


3

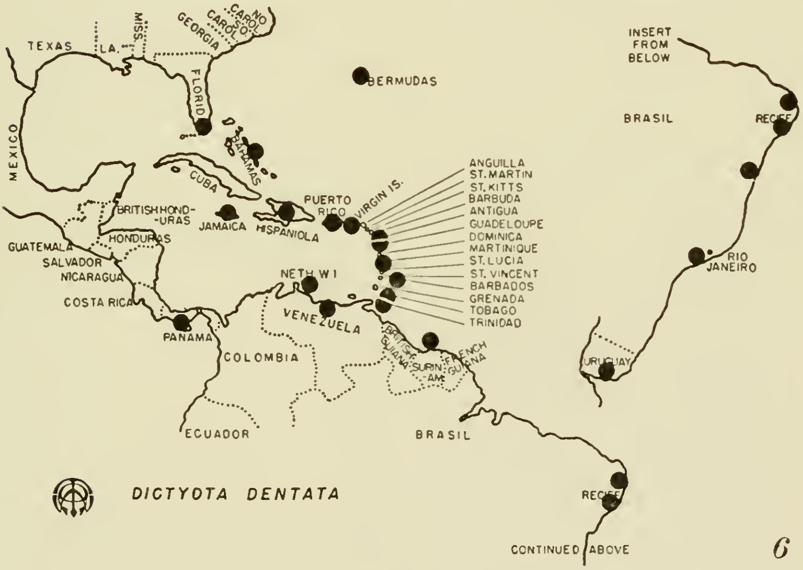


4

Text-figs. 3, 4. Caribbean algae with a northward range in the Americas.



5



6

Text-figs. 5, 6. Caribbean algae with a southward range in the Americas.

7

8

Text-figs. 7, 8. Caribbean algae which are restricted to the Caribbean Sea and floristically similar Florida, Bahamas, and Bermuda.

zosterae, mapped in Fig. 3, ranges from Guadeloupe and Colombia to the northeastern United States and Canada, and to the western European coasts. Of Rhodophyceae, *Dasya pedicellata*, appearing in Fig. 4, ranges from the Virgin Islands and Venezuela to the northeastern United States but not into Canada.

Conversely, as examples of species which range southward from the Caribbean, we select from the Chlorophyceae the common *Caulerpa sertularioides,* which, as Fig. 5 shows, ranges from Florida and Bermuda, but not the Carolinas, to south-central Brazil. It is to be remembered that the Florida and Bermuda floras are almost exclusively tropical in their assortment of species. Of the Phaeophyceae, *Dictyota dentata*, an equally distinct species, shown in Fig. 6, ranges from Florida and Bermuda to Uruguay.

Species which are, so far as we know at the present time, limited to the Caribbean and the phytogeographically similar Bermuda and Florida areas are represented from the Chlorophyceae by *Cymopolia barbata.* This plant, as Fig. 7 shows, ranges from Puerto Rico through the Greater Antilles only, to Mexico, Florida and Bermuda, and is as yet not known from the Central or South American mainland. Of the Rhodophyceae, *Herposiphonia secunda*, Fig. 8, ranges from Barbados and Grenada and the Venezuelan mainland to Florida and Bermuda.

In short, then, the Caribbean flora deserves this name only because the Caribbean Sea is the area of its greatest known luxuriance and diversity. It extends but a little way north, as even 1000 kilometers to the north less than 12 per cent of the Caribbean forms remain; contrariwise, 3000 or 40000 kilometers east and south of the easternmost Caribbean a third of the flora is of the Caribbean type. The conclusion is readily made that the Caribbean flora is actually a west or American Atlantic tropical flora which, in spite of the Brazil current and the North Equatorial current, extends down the Brazilian coast to Rio de Janeiro, with few replacements. By the time Uruguay is reached at 35° S.L., a south temperate element has replaced many of the Caribbean species and the aspect of the flora has changed fundamentally.

Comparison with areas far afield is, in the present state of algal literature, of doubtful value. However, for the Canary Islands, corresponding in latitude to Florida, we have a list by Bϕrgesen (1925-30), who knows the West Indies, showing a few species in common, but many more which differ. The Cape Verde Islands, corresponding in latitude to the southern Caribbean, have a very much higher proportion of pantropical algae also found in our area, types which Feldmann has listed (1946) in his careful comparison of the algae of the islands of the eastern Atlantic. One concludes that the rich Caribbean flora has a high proportion of pantropical and subtropical algae, some relation to the eastern Atlantic, less than has earlier been suggested to the floras of the Indian and Pacific Oceans, and a marked individuality of its own.

LITERATURE CITED

AGARDH, J. G.

1847. Nya Alger från Mexico. Öfveıs. Kongl. Svenska Akad. Fördhandl. 4:5-17.

BØRGESEN, F.

1913-20. The Marine Algae of the Danish West Indies. I. Chlorophyceae, Phaeophyceae. Dansk Bot. Arkiv. 1(4):1-158 [+2], figs. 1-126, map, 1913; 2(2):1-66 [+2], figs. 127-170, 1914. II Rhodophyceae, with Addenda. *Ibid.* 3(1):1-504, figs. 1-435, 1915-1920.

1925-30. Marine Algae from the Canary Islands. I. Chlorophyceae. Kgl. Danske Vidensk. Selsk., Biol. Med. 5(3):1-123, figs. 1-49, 1925. II. Phaeophyceae. *Ibid.* 6(2):1-112, figs. 1-37, 1926. III. Rhodophyceae. Part I. *Ibid.* 6(6):1-97, figs. 1-49, 1927. Part 2. *Ibid.* 8(1):1-97, figs. 1-31, pl. 1-4, 1929. Part 3. *Ibid.* 9(1):1-159, figs. 1-60, 1930.

FELDMANN, J.

1946. La Flore Marine des Iles Atlantides. Mém. Soc. Biogéogr. 8:395-435.

HARVEY, W. H.

1852-58. Nereis Boreali-Americana. Part I, Melanospermeae. Smithsonian Contrib. Knowl. 3(4):1-150, pl. 1-12, 1852. Part II, Rhodospermeae. *Ibid.* 5(5):1-258, pl. 13-36, 1853. Part III, Chlorospermeae (including suppl.) *Ibid.* 10:ii + 1-140, pl. 37-50, 1858.

MAZÉ, H. ET A. SCHRAMM

1870-77. Essai de Classification des Algues de la Guadeloupe. 2^e édition [Actually the third edition]. xix + 283 + iii pp. Basse-Terre, Guadeloupe.

MONTAGNE, G.

1842. Botanique.—Plantes Cellulaires (Algae). *In* Ramon de la Sagra, Histoire Physique, Politique et Naturelle de l'Ile de Cuba. x + 104 pp., 5 pl. [1838-1842]. Paris.

MURRAY, G.

1888-89. Catalogue of the Marine Algae of the West Indian Region. Jour. Bot., British & For. 26:193-196, 237-243, 303-307, 331-338, 358-363; 27:237-242, 257-262, 298-305.

A PRELIMINARY WORKING KEY TO THE LIVING SPECIES OF *DERMATOLITHON*

By

E. Yale Dawson

Allan Hancock Foundation

Before the outset of the Hancock expeditions, the vast Pacific Coast of Mexico had never been visited by a student of the marine plants. To be sure, collections had been obtained, more or less incidentally, by botanists of other specialties, and a few reports existed in the literature; but to a great extent the algae of the thousands of miles of shoreline, both insular and continental, remained unexplored. The marine vegetation of the off-shore waters was almost totally unknown.

Dr. William Randolph Taylor was the first algologist to visit this region, and through his efforts on the Hancock Expeditions of 1934 and 1939 a splendid collection was made and subsequently reported upon in 1945.

In 1940 Captain Hancock directed the Velero III into the Gulf of California, and, Dr. Taylor being otherwise engaged at the time, the writer was privileged to begin his algological investigations in that fascinating area. Subsequent expeditions under Hancock Foundation auspices to various parts of the Mexican coast have resulted in the assembly at the University of Southern California of the world's outstanding seaweed collection from that region. Publication on studies of this immense collection, which now numbers several tens of thousands of specimens, was begun by the writer in 1944 and has continued up to the present. The most recent general contribution to the Pacific Mexican algal flora (Dawson 1954) dealt with the order Cryptonemiales, but did not include the crustose members of the Corallinaceae because of the excessively time-consuming difficulties of interpreting the literature and of preparing suitable materials for study. Furthermore, it was found that for some of the genera of these calcareous plants one needed to resort essentially to monographic studies in order to arrive at a satisfactory interpretation of the individual Mexican collections. Such a difficulty was encountered in the relatively obscure genus *Dermatolithon* and has led, preparatory to the treatment of the several Mexican species, to the following provisional working key.

The genus *Dermatolithon* Foslie has recently been discussed by Mason (1953), but she dealt specifically only with two of its Pacific North American members and made no effort to relate them to the various other species of this poorly documented assemblage. Inasmuch as the literature is so scanty on many of these plants and the distinctions between them are so unsatisfactorily recorded, it appears to be worthwhile to present a working key to the species as currently recognized in the literature, as a means of pointing out the characters by which they are supposed to be distinguished. In doing this, the writer realizes that we have as yet little knowledge of the relative stability or taxonomic worth of the various characters used in this synopsis. It is presented with the hope that workers in the various regions where these plants occur may study them more carefully and record those pertinent data which may ultimately aid in clarifying the circumscriptions of the natural species.

1\. Plants growing upon stones, pebbles or mollusk shells . . . 2

1\. Plants growing epiphytically upon other algae 11

  2\. Thalli relatively thin, mostly of 5 or fewer cell layers; conceptacles emergent, hemispherical 3

  2\. Thalli relatively thick, of 7 or more cell layers; conceptacles sometimes prominently elevated, sometimes not . . 7

3\. Thalli with more or less extensive monostromatic margins; perithallium of 1 to 4 or more layers, or of similar, superimposed layers (crusts); hypothallium cells of more or less variable length 4

3\. Monostromatic margins limited; perithallium mostly 1 to 3 cells thick, the cells of variable length; hypothallium cells of more or less uniform length (45-60 μ), only occasionally to 90 μ long; crusts superimposed. . . . *D. veleroae* Dawson (1944)
Type locality: Gulf of California

4. Perithallium scantily developed; crusts superimposed and individualized by the presence of a cortical cell layer on each, but all contributing to the formation of conceptacles 5

4. Perithallium usually of 1 to 4 layers in middle parts; crusts neither markedly superimposed nor the layers individualized as above 6

5. Conceptacles 150 to 400 μ in diameter, convex, not becoming deformed . . . *D. geometricum* (Lemoine) comb. nov. = *Lithophyllum (Dermatolithon?) geometricum* Lemoine (1929a) Type locality: Canary Islands

5. Conceptacles 400 to 500 μ in diameter, convex but becoming deformed . . . *D. prototypum* (Foslie) Foslie (1909) var. *prototypum* = *Lithothamnion prototypum* Foslie (1897) Type locality: West Indies

6. Thalli 75 to 300 μ thick; perithallium cells mostly 18 to 35 μ long; tetrasporangial conceptacles 220 to 400 μ in diameter, smaller than carposporic conceptacles . . . *D. hapalidioides* (Crouan et Crouan) Foslie (1900a) = *Melobesia hapalidioides* Crouan et Crouan (1867) Type locality: France

6. Thalli 1 mm thick or less; perithallium cells mostly 8 to 12 μ long; tetrasporangial conceptacles 250 to 500 μ in diameter . . . *D. rasile* (Foslie) Foslie (1909) = *Lithophyllum (Dermatolithon) rasile* Foslie (1907) Type locality: Tahiti

7. Surface of crust irregular, warty or papillate 9

7. Surface of crust more or less smooth; hypothallium cells very variable in length 8

8. Perithallium cells 6 to 15 μ long; tetrasporangial conceptacles 120 to 250 μ in diameter, sub-hemispherical . . . . *D. conspectum* (Foslie) Foslie (1909) = *Lithophyllum (Dermatolithon) conspectum* Foslie (1907a) Type locality: Tierra del Fuego

8. Perithallium cells 10 to 35 μ long; conceptacles 150 to 200 μ in diameter, not prominently elevated . . . . *D. saxicolum* (Lemoine) Setchell and Mason (1943) = *Lithophyllum (Dermatolithon) saxicolum* Lemoine (1929) Type locality: Cocos Island, Costa Rica

9. Thalli 1 to 2 mm thick, not extensively superimposed; hypothallium cells mostly 25 to 60 μ long 10

9. Thalli 50 to 225 μ thick, the crusts much superimposed . . . *D. papillosum* (Hauck) Foslie (1909) var. *papillosum* = *Lithothamnion papillosum* Zanardini ex Hauck (1885) Type locality: Adriatic Sea
    10. Thalli producing warty excrescences; tetrasporangial conceptacles 300 to 400 μ in outside diameter; plants growing on shells . . . *D. polycephalum* (Foslie) Foslie (1909) = *Lithophyllum polycephalum* Foslie (1905) Type locality: Cape Verde Islands
    10. Thalli uneven, usually assuming the form of the substrate but without warty excrescences; tetrasporangial conceptacles 400 to 600 μ in outside diameter, sometimes overgrown; plants growing on calcareous pebbles . . . . *D. bermudense* (Foslie and Howe) Foslie (1909) = *Lithophyllum bermudense* Foslie and Howe (1906) Type locality: Bermuda

11. Thalli with more or less extensive monostromatic areas, at least around the margins; perithallium usually of four or fewer layers in mid-parts 12
11. Thalli polystromatic throughout, or up to the thallus edges; perithallium of 5 to many layers in mid-parts 17
    12. Thalli mammillate, the surface provided with warty protuberances; conceptacles little elevated . . . *D. papillosum* var. *cystoseirae* (Hauck) Lemoine (1924) = *Melobesia cystosirae* Hauck (1885) Type locality: Adriatic Sea
    12. Thallus more or less smooth, without warty protuberances 13

13. Crusts overlapping and superimposed; monostromatic parts extensive; conceptacles little elevated . . . *D. prototypum* var. *udoteae* (Foslie) comb. nov. = *Goniolithon udoteae* Foslie (1901a) Type locality: West Indies
13. Crusts not extensively superimposed; conceptacles protruding, hemispherical to subconical 14
    14. Thalli commonly over 120 μ thick, at least in older parts, the perithallium of 1 to several cell layers 15
    14. Thalli usually less than 120 μ thick even in older parts, the perithallium little developed; hypothallium cells short, 25 to 60 μ long; tetrasporangial conceptacles 300 to 350 μ in outside diameter . . . . *D. canescens* (Foslie) Foslie (1909) = *Melobesia (Heteroderma) canescens* Foslie (1900) Type locality: Japan

15. Hypothallium cells long, mostly 60 to 115 μ; tetrasporangial conceptacles 200 to 320 μ in diameter . . . . *D. ascripticium* (Foslie) Setchell and Mason (1943) = *Lithophyllum pustulatum* f. *ascripticia* Foslie (1907) Type locality: California, U.S.A.

15. Hypothallium cells shorter, mostly 30 to 65 μ long; tetrasporangial conceptacles mostly over 320 μ in diameter 16

    16. Asexual conceptacles 200 to 600 μ in outside diameter, with tetrasporangia or bisporangia[1] . . . . *D. pustulatum* (Lamouroux) Foslie (1900a) = *Melobesia pustulata* Lamouroux (1816) Type locality: Europe

    16. Asexual conceptacles mostly 300 to 450 μ in outside diameter, mainly with bisporangia . . . . *D. litorale* (Suneson) Hamel et Lemoine (1953) = *Lithophyllum litorale* Suneson (1943) Type locality: Sweden

17. Thalli completely encasing extensive parts of host algae; hypothallium cells usually 54 to 90 μ long, seldom less than 54 μ long; conceptacles convex and more or less prominent . . . . *D. polyclonum* (Foslie) Foslie (1909) = *Lithophyllum (Dermatolithon) polyclonum* Foslie (1905) Type locality: West Indies

17. Thalli encrusting or partially encasing host algae: hypothallium cells often less than 50 μ long 18

    18. Conceptacles immersed or only slightly prominent . . . 19

    18. Conceptacles forming "very low, small warts;" epiphytic on *Carpophyllum* in New Zealand . . . . *D. carpophylli* (Heydrich) Foslie (1909) = *Melobesia carpophylli* Heydrich (1893) Type locality: New Zealand

19. Hypothallium cells 18 to 30 μ long, not particularly variable in length in different parts of the thallus; conceptacles 200 to 250 μ in diameter, 125 μ high; plants growing on *Gelidium* . . . . *D. tumidulum* (Foslie) Foslie (1909) = *Lithophyllum tumidulum* Foslie (1901) Type locality: Japan

19. Hypothallium cells mostly over 30 μ long, very variable in length in different parts of thallus 20

    20. Hypothallium cells 10 to 50 μ long; tetrasporangial conceptacles 90 to 150 μ in diameter; plants growing on *Laminaria* . . . . *D. crouanii* (Foslie) Hamel et Lemoine (1953) = *Lithophyllum crouani* Foslie (1898) Type locality: France

---

[1] *Dermatolithon macrocarpum* (Rosanoff) Foslie is now generally considered to be a bisporic form of *D. pustulatum*.

20. Hypothallium cells 15 to 100 μ long; tetrasporangial conceptacles over 150 μ in inside diameter 21

21. Tetrasporangial conceptacles 200 to 350 μ in inside diameter; epithallium cells rectangular, periclinally flattened; plants growing on various algae . . . . *D. dispar* (Foslie) Foslie (1909) = *Lithophyllum tumidulum* f. *dispar* Foslie (1907a) Type locality: California, U.S.A.

21. Tetrasporangial conceptacles 150 to 200 μ in inside diameter; epithallium cells more or less triangular, not appreciably flattened periclinally; plants usually growing on *Corallina* . . . . *D. corallinae* (Crouan et Crouan) Foslie ex Bϕrgesen (1902) = *Melobesia corallinae* Crouan et Crouan (1867) Type locality: France

LITERATURE CITED

Bϕrgesen, F.
1902. The Marine Algae of the Faeröes. *In* Botany of the Faeröes. Copenhagen. II: 339-532, text-figs. 51-110.

Crouan, P. L. et H. M. Crouan
1867. Florule du Finistère. x + 262 pp., 32 pls. Paris, Brest.

Dawson, E. Y.
1944. The Marine Algae of the Gulf of California. Allan Hancock Pac. Exped. 3(10): 189-453, 47 pls.
1954. Marine Red Algae of Pacific Mexico. Part 2. Cryptonemiales (cont.) *Ibid.* 17(2):241-397, 44 pls.

Foslie, M.
1897. On some Lithothamia. Norske Vidensk. Selsk. Skr. 1897(1): 1-20.
1898. Some New or Critical Lithothamnia. *Ibid.* 1898(6): 1-19.
1900. Five New Calcareous Algae. *Ibid.* 1900(3): 1-6.
1900a. Revised Systematical Survey of the Melobesieae. *Ibid.* 1900(5): 1-22.
1900b. Remarks on Melobesiae in Herbarium Crouan. *Ibid.* 1899(7): 1-16.
1901. New forms of Lithothamnia. *Ibid.* 1901(3): 1-6.
1901a. New Melobesiae. *Ibid.* 1900(6): 1-24.
1905. Den botaniske Samling. Norske Vidensk. Selsk. Aarsberet. 1904: 15-18.
1907. Algologiske Notiser III. Norske Vidensk. Selsk. Skr. 1906(8): 1-34.
1907a. Algologiske Notiser IV. *Ibid.* 1908(6): 1-30.
1909. Algologiske Notiser VI. *Ibid.* 1909(2): 1-63.

Foslie, M. and M. A. Howe
1906. New American Coralline Algae. Bull. New York Bot. Gard. 4(13): 128-136, pls. 80-93.

Hamel, G. et Mme P. Lemoine
1953. Corallinacées de France et d'Afrique du Nord. Arch. Mus. Natl. d'Hist. Nat., Paris. vii, 1:17-136, 23 pls.

Hauck, F.
1885. Die Meeresalgen Deutschlands und Oesterreichs. xxiv + 575 pp., 5 pls., 236 text-figs. Leipzig.

HEYDRICH, F.
1893. Vier neue Florideen von Neu-Seeland. Ber. Deut. Bot. Gesell. 11:75-79, pl. 22.

LAMOUROUX, J. V. F.
1816. Histoire des Polypiers Coralligenes flexibles, vulgairement nommés Zoophytes. lxxxiv + 560 pp., 19 pls. Caen.

LEMOINE, MME. P.
1924. Corallinacées du Maroc. I. Bull. Soc. Sci. Nat. Maroc. 4(5-6):113-134, pls. 3-4.
1929. Les Corallinacées de l'Archipel des Galapagos et du Golfe de Panama. Arch. Mus. Natl. d'Hist. Nat., Paris. vi,4:37-88, 4 pls., 35 text-figs.
1929a. Fam. 6. Corallinaceae, pp. 19-72, *In* F. Børgesen, Marine Algae from the Canary Islands . . . III. Rhodophyceae, Part II, Cryptonemiales, Gigartinales and Rhodymeniales. Danske Vidensk. Selsk., Biol. Meddel. 8(1): 1-97, text-figs. 6-27, 4 pls.

MASON, LUCILE R.
1953. The Crustaceous Coralline Algae of the Pacific Coast of the United States, Canada, and Alaska. Univ. Calif. Pubs. Bot. 26(4): 313-390, pls. 27-46.

SETCHELL, W. A. AND LUCILE R. MASON
1943. New or little known Crustaceous Corallines of Pacific North America. Proc. Nat. Acad. Sci. 29: 92-97.

SUNESON, S.
1943. The Structure, Life-History and Taxonomy of the Swedish Corallinaceae. Lunds Univ.Årsskr. N.F., Avd. 2, 39(9): 1-66, 9 pls.

TAYLOR, W. R.
1945. Pacific Marine Algae of the Allan Hancock expeditions to the Galapagos Islands. Allan Hancock Pac. Exped. 12, 528 pp., 110 pls.

STRUCTURE AND EVOLUTION OF THE SEA GRASS COMMUNITIES *POSIDONIA* AND *CYMODOCEA* IN THE SOUTHEASTERN MEDITERRANEAN

By

Anwar Abdel Aleem

Associate Professor of Oceanography
University of Alexandria
and
Fulbright Scholar at the Hancock Foundation

The ecology of marine littoral environments has received considerably more attention than that of submerged areas. Information on the biocoenoses of submerged habitats formerly came largely from the study of material brought up by the dredge. Recent developments in underwater equipment, however, have made possible much more adequate studies of the ocean bottom. During the past few years, the writer (Aleem, 1951) has undertaken a study of the algal and phanerogamic communities inhabiting the sublittoral region along the Egyptian Mediterranean coast. Material was collected mostly by diving, using a face mask and respiration tube; notes were recorded underwater on plexiglass slates. A preliminary report on the ecology and distribution of the seagrass communities is presented in this paper.

The only previous detailed account on the ecology of these Mediterranean marine phanerogams appears to be that made by Molinier and Picard (1952) on the Coasts of France.

The two distinct phanerogamic communities of *Posidonia oceanica* Delile and *Cymodocea nodosa* Ascherson possess, along the Mediterranean Coast of Egypt, dissimilar ecological characteristics. The former inhabits exposed localities on open shores and at the head of bays, and is sensitive to temperature and salinity variations; while the latter community thrives mostly in sheltered bays, harbors, and lagoons, where calm water prevails, and thus tolerates a wider range of temperature and salinity changes. *Posidonia oceanica,* moreover, favors a rocky substratum covered with clean sand, with constant aeration and renewal of water by winds and currents. *Cymodocea nodosa,* on the other hand, grows on muddy sand and tolerates organic pollution in its environment. Under favorable conditions, both communities form prairies on the sea bottom comparable to grass prairies on land. Despite the marked differences in their ecology, there are some localities at which a certain degree of competition exists between the two communities and where the ecological factors affecting the growth of one are modified by the presence of the other. Abu Qir, near Alexandria, is one such locality where extensive observations on the two communities in question were made.

Along the shores of Alexandria and further to the west, a shallow water belt 8 to 10 meters deep and running parallel to the shore, is occupied either by *Posidonia* or *Cymodocea,* depending upon the nature of the bottom and the degree of agitation of the water. A second belt, exclusively of *Posidonia*, lies in deeper water, usually at 20 or more meters below the surface. Surrounding these two beds are vast growths of *Cystoseira fimbriata*, *Halimeda tuna*, *Caulerpa prolifera*, or lithothamnia, again depending upon the nature of the bottom. *Posidonia* leaves, rhizomes, and balls formed of macerated tissues of *Posidonia* mixed with sand particles, are cast along the shore in scattered heaps which also occasionally contain *Cystoseira* and *Sargassum*, particularly in winter. The deep-water *Posidonia* beds extend along the coast of the Libyan Desert west of Alexandria, and are most abundant at Burg El Arab, where the shore is of coarse white sand, completely devoid of fixed algae. In the Delta region, between Rashid and Ras-el-Bar, *Posidonia oceanica* is scarce, while *Cymodocea* is more frequent because of the deposition of mud particles brought up by the river. From Port Said east to El Arish, *Posidonia oceanica* is abundant only at the few rocky places between the two ports.

THE *POSIDONIA-CYMODOCEA* COMPLEX AT ABU QIR

Abu Qir suburb, about 25 kilometers east of Alexandria, lies on a small peninsula, with the Citadel forming the head of an arrow which separates the calm, sandy bay of Abu Qir on the east from the open rocky shore to the west. Prairies of *Cymodocea nodosa* grow in the shallow water of the bay, where organic decomposition, especially in summer, produces H_2S in the substratum. *Posidonia oceanica* flourishes on the rocky open coast. As the littoral rocks here are almost flat, the littoral algal belts are broad and distinct, despite the low amplitude of tides (30-50 cm).

The area studied (fig. 1) covers roughly 10,000 sq. m. and is for the most part submerged. The rocky ridge, extending for about 60 meters into the sea and separating it into two distinct subregions, is broken in the middle by a channel through which a strong current flows from the east. A region of submerged rocks and islets extends parallel with the coast, a short distance out from the end of the ridge. The subregion west of the ridge is the deeper and more exposed to currents and waves; that to the east is shallower and more protected, and is referred to as the "lagoon." Little seasonal variation has been found in the chief algal and phanerogamic communities of these regions. As the greater part of the work was done during the summer, the profiles presented here are those for the months of June and July.

The ridge (figs. 1-2) is splashed by waves during rough weather, forming on the higher parts of the rocks a "spray zone" occupied mainly by blue green algae. In the small rock-pools and small ditches on the ridge, where the water remains unchanged for longer periods and temperature and salinity variations are prominent, a special algal flora grows, composed mainly of blue greens, *Enteromorpha compressa* and *Polysiphonia phleborhiza*. On the rather abruptly sloping side of the ridge to the west, the algal communities are arranged in well-defined descending belts, described below. Some of these belts, it will be noted, disappear with the advent of hot weather.

THE LITTORAL REGION:

1. Blue green-belt. This is formed chiefly by *Rivularia polyotis* and *Brachytrichia balani*, intermingled with *Lyngbya*. Near the shore, where the vegetation is subject to continuous splashing by waves, grows *Cladophora* sp., higher on the ridge than the blue greens but receiving a greater amount of spray. This place is usually occupied by *Nemalion helminthoides* during the spring, but it disappears early in June.

2. *Scytosiphon lomentaria.* This species occupies the zone just below the blue greens, in an uninterrupted belt, and, like *Nemalion*, disappears completely in summer. Its place is taken by *Enteromorpha compressa*, young growths of *Padina*, and *Polysiphonia phleborhiza*, particularly when the substratum is covered with sand and shell fragments.

3. *Laurencia papillosa.* This extends from the mean water level down to some 20 cm below the surface and remains throughout the year, shedding its branches in later summer. Heavy masses of *Jania rubens* cover it during the summer.

THE UPPER SUBLITTORAL REGION:

4. *Cystoseira-Sargassum.* This characteristic belt occupies the space on the ridge from below the *Laurencia* down to 80 cm. It is better developed and wider on ledges subject to wave action, especially at the distal end of the ridge facing the open sea and on the borders of the channel intersecting the ridge. *Cystoseira crinita* (?) and *Sargassum linifolium* are the two chief species in this community, which also harbors a number of epiphytes such as *Ectocarpus*, *Ceramium*, and *Polysiphonia* spp. *Jania rubens* forms a carpet over the substratum and occurs also as an epiphyte on other algae.

5. *Halopteris filicina—Padina pavonia.* These two species grow in a well developed community attaining a considerable size, especially on the flat sandy bottom between the ridge and the *Posidonia-Cymodocea* boundary toward the shore, in relatively calm water (fig. 2). As *Halopteris* can tolerate more agitated water, it extends along the ridge all the way below the *Cystoseira-Sargassum* community, at a depth exceeding 1 meter. Older growths of *Halopteris* and *Padina* form good substrates for a large number of epiphytic algae.

6. *Caulerpa prolifera.* This species occupies a unique position. Not only does it almost always form the boundary between *Posidonia* and *Cymodocea* (fig. 1) but it also grows in patches among the *Cymodocea* and between the *Cymodocea* and the shore. *Dasycladus clavaeformis* also grows in the latter habitat, but only in small patches on stones covered with muddy sand.

Of particular interest are several submerged grottos occurring at different levels along this coast. The occurrence of such grottos below the present sea level (fig. 4) is a good indication of the subsidence which took place along the coast of Alexandria in historical times. This is indicated by the presence of a belt of islets running parallel to the coast, at a short distance from the latter; these were once a part of the shore itself. The algae inhabiting these grottos share with those dwelling in the rock-crevices the common characteristic of being shade-algae (Sciaphiles). The composition of such a community is modified by the degree of exposure to wave and surf action. Three types of grottos distinguished at Abu Qir are listed below, with their characteristic flora.

1. Strongly exposed grottos. These are ordinarily open to the northwest and are washed by strong and continuous waves. The platform under which they are found is usually covered with calcareous algae and *Pterocladia capillacea*, while the roof is inhabited by suspended *Cladophora pellucida*. In addition to sponges and hydroids, the following algae are found on the sides and inner walls: *Botryocladia botryoides*, *Valonia utricularis*, *Rhodophyllis bifida*, and *Phyllophora nervosa*. *Rhodymenia ardissoni* and *Cryptonemia lomation* are also frequently found.

2. Moderately exposed grottos. The platforms covering these grottos are usually covered with the same *Cystoseira-Sargassum* community as one finds on the ridge. *Cladophoropsis zollingeri* forms a narrow belt at the base of this community (fig. 4). In the grottos are found algal groups dominated by *Dictyopteris membranacea* and/or *Taonia atomaria*, associated with *Dictyota dichotoma*, *D. linearis*, *Udotea petiolata*, *Amphiroa beauvoisii*, *Lithothamnion lichenoides*, *Pseudolithophyllum expansum*, and *Peyssonnelia*. Some of the species found in the strongly exposed grottos are also present here, but less abundantly. The floors are usually covered with *Caulerpa prolifera*, *Halopithys pinastroides*, and *Dasycladus clavaeformis*.

3. Calm-water grottos. Boring animals play an important role in forming these small grottos, several of which are found on the lagoon side of the ridge. They are inhabited chiefly by *Codium* spp., *Ulva lactuca*, *Hypnea musciformis*, *Spyridia filamentosa*, *Halimeda tuna*, *Cordylecladia erecta*, and *Peyssonnelia polymorpha*. *Asparagopsis delilei* is frequent in summer. *Udotea petiolata* and *Valonia macrophysa* are sometimes found and, less frequently, *Digenea simplex* and *Chrysimenia ventricosa*.

Extending along the ridge at about a depth of one meter and sloping gently to the west to about 1.5 to 2 meters, is a living *Posidonia*-Reef (figs. 2-3), formed by the accumulation of years of dead rhizomes of *Posidonia*, together with sand grains, calcareous tubes of worms, crustose algae, dead shells of animals, all resulting in an elevation of the substratum. The surface of the reef is occupied by living *Posidonia* whose leaves attain a length of 50 to 80 cm, reaching the surface of the water near the ridge. It forms a triangle with its base oriented toward the north, facing the onshore currents and acting as a buffer against them. This form is evidently determined by the currents and waves, as the maximum development occurs where they are strongest. Toward the shore the development of *Posidonia* is at a minimum and competition with *Cymodocea* is great. A strong current flowing from the east through the channel intersecting the ridge has apparently caused the *Posidonia* community to extend west along its direction of flow, thus producing a bulge on the western side of the triangle.

Apart from modifying the intensity of the current, the *Posidonia* leaves also act as a trap for floating algae and organic debris, which are deposited on the leeward side of the reef. There, the calm water and accumulated organic debris make conditions favorable for the establishment of *Cymodocea nodosa*, in a rough triangle next to that formed by *Posidonia* but with its maximum development toward the shore, where relative calm prevails. The substratum is of muddy sand, and the slope toward the open sea is greater than that of the *Posidonia*-Reef. In its maximum development toward the shore, *Cymodocea* grows at a depth of approximately 3 meters; at its distal end, the depth is 8 meters. The leaves of *Cymodocea nodosa* attain a length of 150 cm or more; but its rhizomes are thin and unable to build up a reef similar to that built by *Posidonia.* The boundary between these two great sea-grass communities is occupied by *Caulerpa prolifera*, as previously noted.

Cymodocea encroaches upon *Posidonia* from different directions. It establishes itself in depressions and gullies resulting from the destruction or erosion of certain parts of the reef from the action of stones, animals, marine fungi, or other agents. These depressions become filled with sand and are occupied not only by *Cymodocea*, but also by *Caulerpa* and other algae such as *Halopteris*, *Sargassum*, *Cystoseira*, and *Padina*, whose ramified stolons help to bind the sand in place.

Cymodocea has also established itself in a narrow belt running from north to south, parallel to the *Caulerpa*-community (fig. 1) and occupying the distal edge of the *Posidonia*-Reef. The intervening space between *Cymodocea* and *Caulerpa* is inhabited by degenerating *Posidonia*, which apparently has been choked by the long dense leaves of *Cymodocea.* A close examination shows that long cracks form as a result of the erosion of the sandy substratum by water movements, causing the collapse of the edge of the reef. These cracks eventually are colonized by *Cymodocea.*

From the observations made at Abu Qir, it appears that the *Cymodocea*-community in the area back of the *Posidonia*-Reef owes its existence largely to the latter's role in modifying the currents. Another factor is the accumulation of dead *Posidonia* leaves, detached algae, and other sediments in the lee of the reef. In this sense, a phenomenon comparable to that of ecological succession in land plants may be ascribed to these sea-grasses. The ecological factors which produce this succession may be summarized as follows:

1. The direction and strength of currents and waves, which determine the shape of the area occupied by *Posidonia* on rocky shores.

2. The ability of *Posidonia* rhizomes to raise the substratum and eventually build up a reef.

3. The failure of *Cymodocea* to do the same, or to grow under the influence of strong currents.

4. The action of the *Posidonia* leaves as a buffer against the intensity of the current, creating behind the reef calm conditions similar to those in lagoons.

5. The inability of *Posidonia* leaves to grow continuously above water, causing the growth of the reef to stop at a certain minimum height below sea level.

6. The action of *Caulerpa prolifera* and other algae in binding the substratum back of the reef, thus paving the way for *Cymodocea.*

7. *Cymodocea* encroachments on *Posidonia*, by occupying depressions and gullies formed by erosion or by biological factors.

The lagoon shown in fig. 1 is protected to the west by the ridge and to the north by emerged and submerged rocks. The water flowing between these rocks creates a current directed toward the channel intersecting the ridge; and the areas lying under the influence of this current are largely inhabited by *Posidonia oceanica.* Toward the shore, the lagoon is much shallower (20 to 50 cm), the water is little disturbed, and the temperature much higher, as much as 5°C in summer, than in the open sea. Here *Cymodocea nodosa* grows in patches among tropical algal communities.

The most conspicuous algal community in the lagoon, especially in the shallow coastal region, is one dominated by *Acanthophora delilei* and *Spyridia aculeata. Asparagopsis delilei* is abundant during the spring. Branches of *Acanthophora* reach a height of 50 cm; and *Padina pavonia, Hydroclathrus clathratus*, and *Colpomenia sinuosa*, found usually as separate individuals or in small patches, also attain considerable size. Of particular interest is *Laurencia paniculata*, which grows on rocks covered with sand and shell debris, at a depth of about one meter, and is covered in summer by dense growths of *Jania rubens* and *Dictyota* *linearis.* The more muddy places are covered with a mat of the blue green algae *Microcoleus chthonoplastes* and *Lyngbya.* Occasionally there are small patches of *Dasycladus clavaeformis*, and *Ulva lactuca* with its characteristic epiphytic brown alga *Myrionema strangulans. Cystoseira, Halimeda tuna, Valonia macrophysa*, and *Udotea petiolata* occur less frequently, the last three usually in concealed places. *Caulerpa prolifera* grows abundantly between the *Cymodocea* patches. *Derbesia tenuissima* and *Ceramium gracillimum* var. *byssoideum* are found as epiphytes on the older fronds of *Padina.* The wet sand of the shore sometimes displays a brown color due mainly to diatoms and to the peridinian *Exuviaella marina.*

The flora and fauna inhabiting the crevices and grottos on the lagoon-side of the ridge differ markedly from those in the grottos to the west. Of interest is the gradual replacement, in these grottos, of the calm water algae by more open sea flora, as one proceeds to the open sea.

On the whole, the lagoon vegetation is dense and easily detached from the substratum, which is composed mainly of sandy mud. Fig. 5 shows the distribution of the common algae and sea grasses in the lagoon.

STRUCTURE OF THE *POSIDONIA* AND *CYMODOCEA* COMMUNITIES

The Posidonia Community

A dense and diverse flora of algae finds shelter as epiphytes on leaves and rhizomes of *Posidonia.* Light is an important factor governing the distribution of these algae. Species growing on the rhizomes or between them are usually shade-algae that thrive under the reduced light conditions created by the overlying thick canopy of leaves. The algae growing on the upper parts of the leaves are those most adapted to the prevailing light in their environment. The algae of this community may thus be classified into (a) epiphytes on rhizomes in shallow water and in deep water; (b) epiphytes on leaves in shallow water and in deep water.

Whether dead or alive, the rhizomes of *Posidonia* provide a good substrate for a number of the larger algae. In relatively shallow water, particularly when the leaves are dense as at Abu Qir, the following algae are invariably found as epiphytes on the rhizomes.

BROWN ALGAE:

Padina pavonia
Dictyopteris membranacea
Hydroclathrus clathratus
Cladostephus verticillatus
Ectocarpus spp.
Halopteris filicina
Colpomenia sinuosa
Nereia filiformis
Sphacelaria pennata
Cystoseira fimbriata

GREEN ALGAE:

Cladophora prolifera
Dasycladus clavaeformis
Valonia utricularis
Bryopsis spp.
Ulva rigida
Codium dichotomum
Halimeda tuna
Cladophora pellucida
Udotea petiolata
Halicystis parvula
Ulva lactuca
Chaetomorpha sp.
Caulerpa prolifera

RED ALGAE:

Peyssonnelia rubra
Pseudolithophyllum expansum
Mesophyllum lichenoides
Griffithsia opuntioides
Pterocladia capillacea
Halopithys pinastroides
Botryocladia botryoides
Laurencia pinnatifida
Falkenbergia hillebrandii
Grateloupia filicina
Callithamnion granulatum
Peyssonnelia squamaria
Melobesia farinosa
Neomonospora furcellata
Gelidium spp.
Champia parvula
Rytiphloea tinctoria
Laurencia obtusa
Heterosiphonia wurdemanni
Rhodymenia ardissoni
Gigartina acicularis
Jania rubens

Padina and *Halopteris* are especially abundant where the leaves of *Posidonia* are not so dense. They can even grow on stones washed on to the *Posidonia*-Reef and in places where parts of the reef are eroded. *Dictyopteris*, on the other hand, requires more shade and is more abundant in deeper prairies, or where dense leaves are found. At Abu Qir the *Dictyopteris* from the center of the *Posidonia*-Reef attains a considerable length, some fronds measuring over 60 cm in length.

The algal flora associated with *Posidonia* in deep water is less abundant and is mainly dominated by calcareous algae such as *Pseudolithophyllum* and *Lithothamnion*.

Some of the algae mentioned carry secondary epiphytes, mostly microscopic red and blue-green algae, which are not listed here.

The fauna associated with the rhizomes of *Posidonia* is no less important than the algae. Cirriped worms secrete their calcareous tubes there, while a diverse fauna of holothurians, chitins, and polychaetes find shelter on the sand deposited over the rhizomes. The *Posidonia* biotype also shelters echinoderms in abundance, as well as several sponges and hydroids.

The upper third of the *Posidonia* leaf is usually the part colonized by epiphytes, which show a periodic development according to season, being most abundant during the spring. In the early winter the young developing leaves become readily colonized by the brown algae *Ascocyclus orbicularis*, on top of which grows *Giraudya sphacelarioides*. With the advent of spring several microscopic forms attach themselves to the leaves, amongst which members of the Melobesiaceae, *Acrochaetium*, *Ectocarpus* and *Polysiphonia* become dominant.

The following epiphytes have been identified on *Posidonia* leaves at Abu Qir in late spring:

GREEN ALGAE:
Ulvella setchelli
Ulva rigida
Endoderma viride
Cladophora spp.
Enteromorpha linza
Phaeophila dendroides

BROWN ALGAE:
Ascocyclus orbicularis
Hydroclathrus clathratus
Colpomenia sinuosa
Ectocarpus mitchelli
Giraudya sphacelarioides
Scytosiphon lomentaria
Castagnea mediterranea
Ectocarpus irregularis

RED ALGAE:
Acrochaetium virgatulum
Erythrotrichia carnea
Falkenbergia hillebrandii
Dasya sp.
Melobesia farinosa
Callithamnion corymbosum
Ceramium tenuissimum
Jania rubens
Amphiroa beauvoisii
Acrochaetium secundatum
Erythrocladia subintegra
Laurencia obtusa
Lithophyllum pustulatum
Melobesia lejolisii
Polysiphonia spp.
Hypnea musciformis
Acrosorium uncinatum

Castagnea becomes a dominant epiphyte in the late spring and fronds of this plant up to 20 cm in length are found in many places at Alexandria. Under such heavy loads of epiphytes, the leaves of *Posidonia* drop off during the autumn and new leaves sprout in winter.

Another interesting observation concerning these epiphytes was made at Asafra rock in Alexandria where *Posidonia* grows in a wide area from just below low water level down to a depth of several meters. The *Posidonia*-Reef thus formed slopes gently into the sea. The epiphytic algae in this community vary both in quantity and quality during the spring as one proceeds away from the shore. Close to the shore the Melobesiaceae together with *Ascocyclus* and *Giraudya* are abundant. At a distance of about 10 meters from the shore where the depth is about one meter, *Ectocarpus mitchelli* and *Enteromorpha linza* are dominant. Further away from shore and in deeper water, the dominant algae is *Castagnea*. Probably this differential colonization of the distal ends of the *Posidonia* leaves is connected with the light distribution at such depths.

THE CYMODOCEA COMMUNITY

Unlike those of *Posidonia,* the rhizomes of *Cymodocea* are thin and afford no strong support for larger algae, which may explain the paucity of the latter in the community. Occasionally, however, one meets with individuals of *Hypnea musciformis* or some calcareous crusts of Melobesiaceae. *Caulerpa prolifera* grows in the substratum supporting the *Cymodocea* and this important alga, together with other sand-binding species such as *Pterosiphonia pennata*, is one of the first forms in the cycle of substratum colonization by *Cymodocea.*

As previously mentioned, *Cymodocea nodosa* tolerates organic pollution in its environment. The amount of organic matter in the substratum seems to affect the balance between shoot and rhizome systems in exact accord with the observations made by Molinier and Picard (1952, p. 162). The *Cymodocea* growing near the Citadel where there is much organic matter has the rhizome and root system much more developed than the leaves. The *Cymodocea* prairies shown in Fig. 1 develop leaves exceeding 150 cm in length but have reduced rhizome and root systems. This well-developed leaf system enables plants growing in a substratum relatively poor in organic content to compensate for this shortage through carbon assimilation.

Whether in shallow or deep water, only the upper parts of the leaves carry epiphytic algae, which differ in quantity and quality according to the depth of water above them. The epiphytes on the leaves are more numerous in shallow water and include several of the more tolerant algae which occur on *Posidonia. Cymodocea* leaves in calm, shallow water, particularly in the spring, carry also a heavy load of diatoms composed chiefly of *Licmophora* spp., *Climacosphenia* and *Grammatophora*, most of which are colonial forms growing in long chains. The following are the more important epiphytes on *Cymodocea* from shallow water:

Chondria tenuissima (abundant)
Polysiphonia variegata (common)
Ectocarpus irregularis
Ectocarpus mitchelli
Acrochaetium spp.
Colpomenia sinuosa
Hydroclathrus clathratus
Hypnea musciformis
Spyridia filamentosa
Dasya arbuscula
Ceramium tenuissimum
Cladophora spp.
Enteromorpha compressa
Blue green algae

In deep water the epiphytes are scarce. Occasionally one meets with *Ectocarpus confervoides*, *Acrochaetium*, *Colpomenia*, and *Hydroclathrus* in the *Cymodocea* prairies at Abu Qir.

THE CYCLE OF DEVELOPMENT OF *POSIDONIA* AND *CYMODOCEA*

The initial groups preceding the establishment of either *Posidonia* or *Cymodocea* are composed largely of algae and diatoms. The latter help to pave the substratum for the instalment of the seagrasses by accumulating sand and organic sediments and building a consistent covering in which the roots and rhizomes of the grasses ramify. The algae entering into this succession differ according to whether the situation is exposed or calm. Ordinarily forms like *Enteromorpha*, *Ulva*, *Padina*, *Halopteris*, *Cystoseira*, *Sargassum*, *Dasycladus*, *Jania*, and *Caulerpa prolifera* play an important part. The latter species almost always precedes *Cymodocea.*

Concerning the biological cycle of development of *Posidonia* and *Cymodocea* in the northern Mediterranean, Molinier and Picard (1952, p. 209) distinguish the following three modalities:

*Prairies in exposed superficial modes.** In this type, *Cymodocea* installs itself first on sand moderately enriched with organic sediments. *Posidonia* invades such a formation initially as small separate rhizomes and later eliminates *Cymodocea.* Eventually *Posidonia* builds up a reef which raises the substratum, making it more subject to erosion, and *Posidonia* thus gradually degenerates. Waves further wash away the sediments and erode the reef. *Cymodocea* again re-installs itself in the "intermats" thus formed.

Prairies in calm superficial modes. The sand containing much organic sediment in this mode is very favorable for the growth of *Cymodocea,* which eventually becomes dense. It is invaded by *Posidonia* and ultimately eliminated by its successor, which then builds up a reef. This reef disturbs the equilibrium between organic and inorganic sediments and leads to the deposition of more mud. *Posidonia* then disappears and another dense covering of *Cymodocea* follows.

Prairies in calm deep modes. Starting from sand containing a certain amount of organic matter, *Cymodocea* readily establishes itself and is followed by *Posidonia*, which attains a maximum prosperity in this mode. Under exceptional circumstances such as interference by man, the destruction of *Posidonia* leads to its replacement by *Cymodocea.* The authors give only a tentative scheme for this mode. One must not, however, ignore the influence of deep currents in this mode, and it is difficult to suppose that *Cymodocea* forms the initial stage.

---

*The term "mode" is that of the writers; it implies variations in the composition of the water, and its degree of turbulence in the sense of De Beauchamp, 1914 (cf. Feldmann, 1951, p. 321).

It appears that in almost all cases the instalment of *Posidonia* is preceded by that of *Cymodocea* in the three modalities just listed. My observations on the Egyptian coast, especially at Abu Qir, lend little support to this view. For example, *Cymodocea* prairies on the east side of the Citadel in Abu Qir Bay, a superficial calm mode with much organic sediment, have been in place since my first visit in 1943, having been neither eliminated nor encroached upon by *Posidonia,* which grows more toward the open sea. This is true also with respect to strongly exposed modes where *Posidonia* rarely, if ever, has been replaced by *Cymodocea,* unless one assumes the interference of serious topographic changes that alter the modality itself, which would be very exceptional. It is true that in certain *moderately exposed* modes such as those found at the back of rocks or barriers facing a strong current or as a result of special configurations of the shore line itself, competition between *Cymodocea* and *Posidonia* takes place and the latter might eventually eliminate the former. Molinier and Picard give a good example of this (1952, p. 167) and I have noted such cases frequently at Alexandria.

I have already stressed that the vast prairies of *Cymodocea* on the western side of the Ridge at Abu Qir owe their existence to the special conditions created by the *Posidonia*-Reef. In other words, *Cymodocea* comes as a direct result of the growth of this reef. This particular *Cymodocea* has also been *in situ* for a very long time. Under no circumstances has *Posidonia* been found in this community. Aside from the peripheral parts near the shore, where the two grasses meet, each of them has attained a state of stability. On the other hand, the transgression of *Cymodocea* upon the neighboring *Posidonia* takes place only in the gullies and depressions on the *Posidonia*-Reef, as previously described, and it cannot grow on the same level as *Posidonia.* All these invasions occur after the reef has been established. Molinier and Picard seem to be aware of these facts and have also observed "formation lagunaire" (p. 230) at the back of *Posidonia* reefs.

SUMMARY AND CONCLUSIONS

A detailed study of the submerged algal and phanerogamic communities inhabiting the sea area at Abu Qir, near Alexandria, has resulted in the conclusions which may be summarized as follows:

EXPOSED MODES:

1. *Posidonia oceanica* forms extensive "prairies" on the exposed sea area lying west of the Ridge at Abu Qir.

2. Its spread is largely determined by the current regime (intensity and direction of flow).
3. *Posidonia* builds up a reef through the accumulation of new rhizomes added every year, thus producing an elevation of the substratum upon which it grows. Inorganic sediments (sand particles), crustose algae living on the rhizomes, sea urchins and other animal debris further contribute to the growth of the *Posidonia*-Reef.
4. The leaves of *Posidonia* act as a buffer for the water currents flowing over them, thus creating at the back of the *Posidonia*-Reef calm conditions similar to lagoon formations created by coral reefs.
5. Organic sediments accumulate in the calm mode thus created, enriching the substratum and rendering it favorable for the growth of *Cymodocea*, which tolerates more organic matter than *Posidonia.*
6. *Caulerpa prolifera* occupies the boundary between the *Posidonia* and *Cymodocea* and plays an important part in the succession leading to the instalment of *Cymodocea.*
7. Other algae like *Cystoseira*, *Sargassum*, *Halopteris*, *Padina* and *Jania* contribute to the succession leading to the instalment of *Posidonia.*
8. Transgression of *Cymodocea* upon *Posidonia* takes place in gullies and depressions formed in the *Posidonia*-Reef as a result of erosion by physical or biological factors. Prior to the instalment of *Cymodocea* in these gullies, the latter are filled with sand particles.
9. A state of stability is attained between the *Posidonia* prairies growing in the exposed mode and forming a reef and those of *Cymodocea* growing at its back. The balance between the two is maintained primarily by the direction and intensity of currents, which in turn affect the rate of sedimentation of organic and inorganic particles. Unless this equilibrium is disturbed by abnormal climatic changes, by physical factors leading to erosion of the *Posidonia*-Reef, or by changes in the topography of the coast, e.g., as a result of subsidence, the two communities in question grow in close proximity to each other for a very long time.

CALM MODES:

10. *Cymodocea nodosa* flourishes in calm modes such as those found to the east of the Citadel at Abu Qir and reach a "climax" in such modes. Successive stages leading to the establishment of this community are formed by algae, chiefly *Caulerpa. Posidonia* does not compete with *Cymodocea* in these calm modes.

MODERATELY EXPOSED MODES:

11. Competition between *Posidonia* and *Cymodocea* is great in such modes and the former ultimately eliminates the latter. This occurs in shallow water near the shore and also at the back of projecting rocks facing a water current.

THE LAGOON:

12. *Posidonia* grows in the outer northern side of the lagoon at Abu Qir, subject to the currents, while *Cymodocea* occupies the inshore calm part, together with tropical algae which reach maximum prosperity there.

STRUCTURE OF THE POSIDONIA AND CYMODOCEA COMMUNITIES:

13. A dense and diverse flora of algae finds shelter as epiphytes on the leaves and rhizomes of *Posidonia*. Light is an important factor affecting the distribution of these algae. Epiphytes on the leaves differ also in quantity and quality according to season and depth below the surface. Some of these epiphytes follow a certain succession in colonizing the leaves of this grass.
14. Epiphytes on rhizomes of *Cymodocea* are scarce; those on leaves are more abundant in shallow than in deep water.

LITERATURE CITED

ALEEM, A. A.
1951. Algues marines de profondeur des environs d'Alexandrie (Egypte). Bull. Soc. Bot. France. 98:249-252.

FELDMANN, J.
1951. Ecology of marine algae. *In* Smith, Gilbert, ed. Manual of Phycology. Chronica Botanica. 27:1-375.

MOLINIER, R. ET J. PICARD
1952. Recherches sur les Herbiers de Phanerogames marines du littoral mediterranneen français. Ann. Inst. Océan. Paris. 27:157-234.
1953. Notes biologiques à propos d'un voyage d'étude sur les Côtes de Sicile. *Ibid.* 28:163-188.

Fig. 1

Chart showing the distribution of *Posidonia oceanica* and *Cymodocea nodosa* in the sea area to the west of the rocky Ridge at Abu Qir, Alexandria, together with the chief algal communities. The numbers on the chart show depth in meters below sea level.

Fig. 2

Transect A-B on Plate 1, passing through the *Posidonia*-Reef and showing the algal communities above and below sea level. Only a small part of the *Cymodocea* prairies is shown at the back of the Reef. For practical purposes the horizontal and vertical distances are not represented to the same scale.

Fig. 3

Transect C-D on Plate 1, representing a horizontal distance of 40 meters to the west of the Ridge and showing littoral and sublittoral algal communities, the *Posidonia*-Reef, the *Cymodocea* prairies and the intervening *Caulerpa prolifera* belt. Again the horizontal and vertical distances are drawn to different scales. Legends as in Fig. 1.

Fig. 4

Profile of a moderately exposed grotto below sea level at Abu Qir, showing the distribution of the common algae and animals inhabiting the grotto and the overlying platform.

Fig. 5

Distribution of algal and phanerogamic communities in the lagoon lying to the east of the Ridge at Abu Qir.

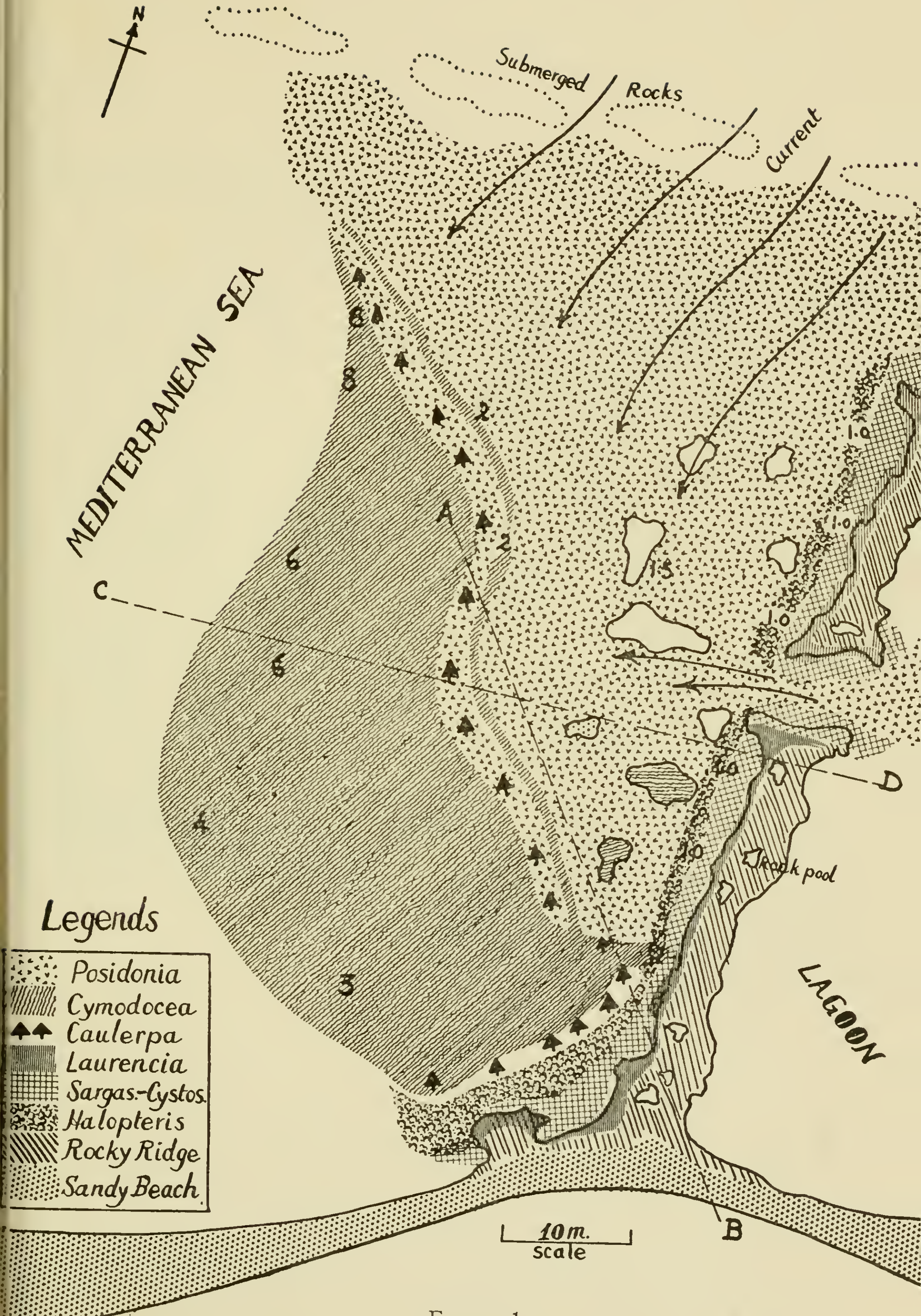

N
Submerged Rocks
Current
MEDITERRANEAN SEA
LAGOON
A
B
C
D
8
8
2
2
6
5
4
3
15
1.0
1.0
1.0
1.0
10
10
Rock pool
Legends
Posidonia
Cymodocea
Caulerpa
Laurencia
Sargas.-Cystos.
Halopteris
Rocky Ridge
Sandy Beach
10 m.
scale

FIGURE 1

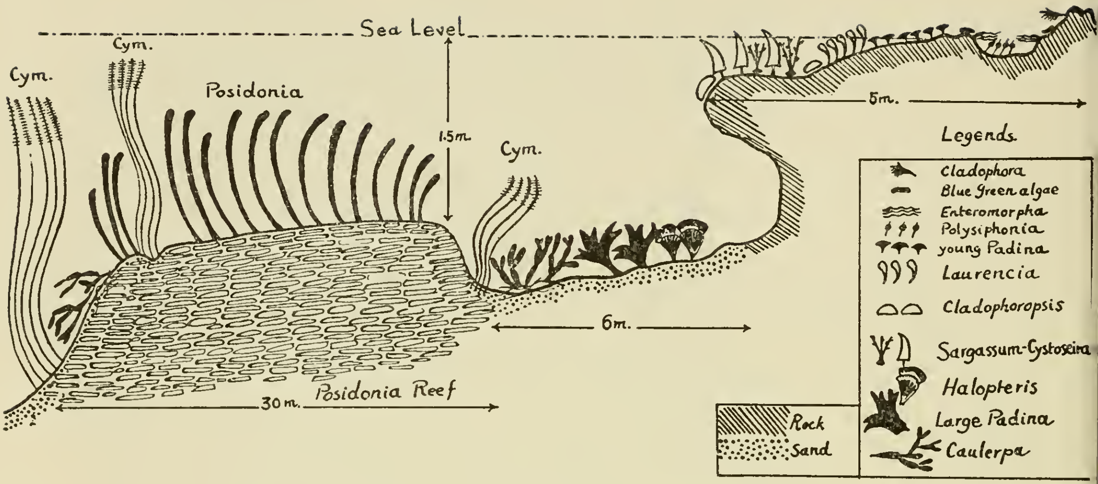


FIGURE 2

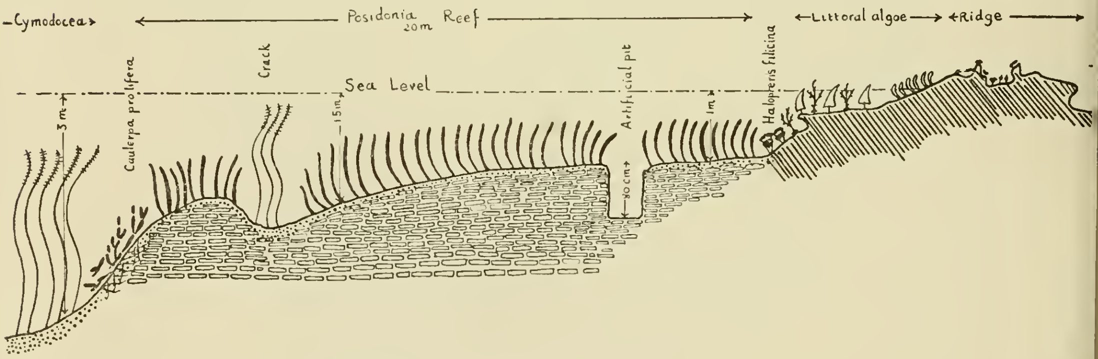


FIGURE 3

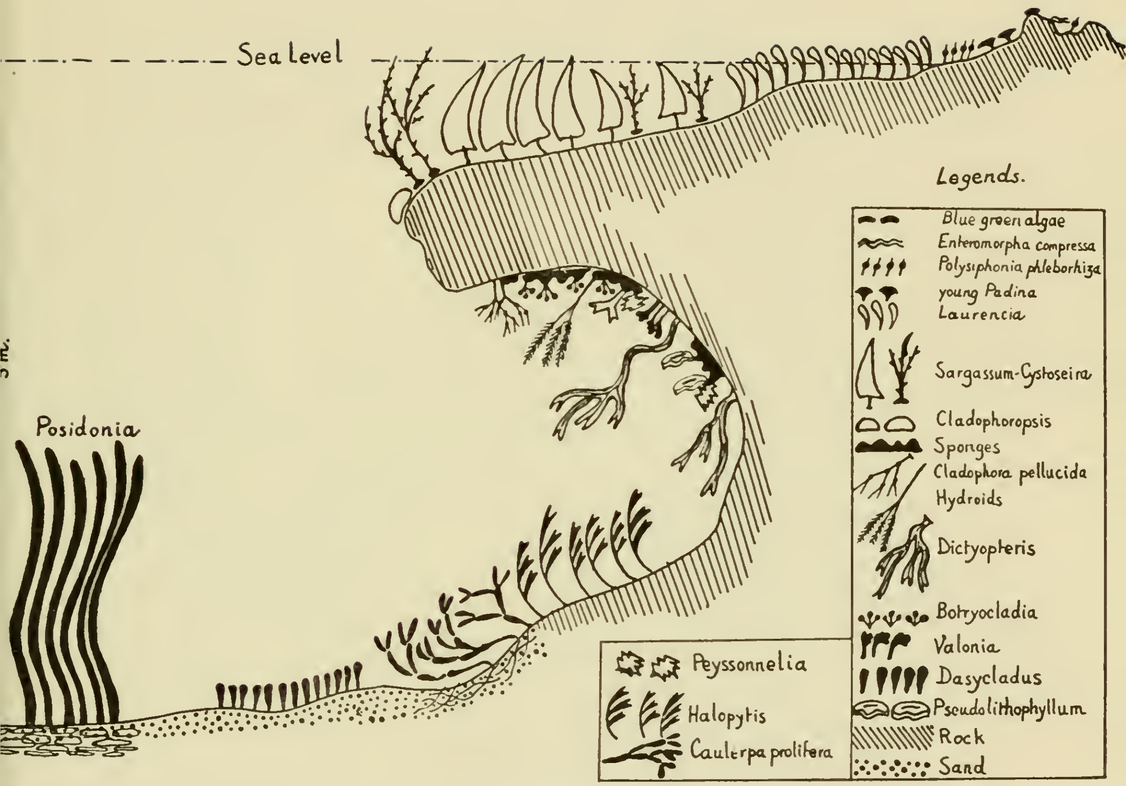

Sea level
Posidonia
Legends.
Blue green algae
Enteromorpha compressa
Polysiphonia phleborhiza
young Padina
Laurencia
Sargassum-Cystoseira
Cladophoropsis
Sponges
Cladophora pellucida
Hydroids
Dictyopteris
Botryocladia
Valonia
Dasycladus
Pseudolithophyllum
Rock
Sand
Peyssonnelia
Halopytis
Caulerpa prolifera

FIGURE 4

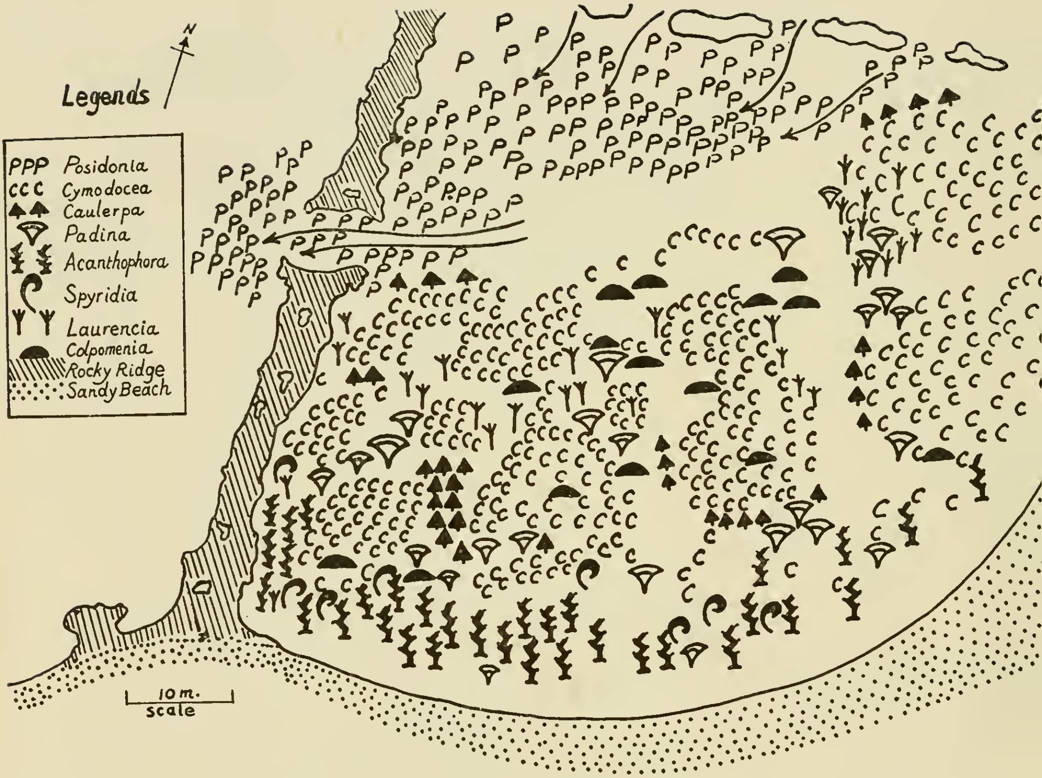

N
Legends
PPP Posidonia
CCC Cymodocea
Caulerpa
Padina
Acanthophora
Spyridia
Laurencia
Colpomenia
Rocky Ridge
Sandy Beach
10 m.
scale

FIGURE 5

NUTRIENT BUDGETS IN THE OCEAN

By

K. O. Emery,[1] Wilson L. Orr,[2] and S. C. Rittenberg[3]

University of Southern California

INTRODUCTION

Nitrogen, phosphorus, and silicon are among the most important to living organisms of the more than four dozen elements known to be present in sea water. These elements, the nutrients, together with carbon, hydrogen, oxygen, and minor quantities of other elements, are required for development and growth of plants, which in turn serve as the food base for all animal life. Because of their biological significance, nitrogen, phosphorus, and silicon have been examined more thoroughly than most of the other elements; yet there remain large uncertainties in the quantitative measures of their distribution and utilization.

The general cycle of nutrients involves their introduction into the ocean by rivers and rain, their conversion into organic matter by plants, their partial regeneration in the water, their loss to the sediments by deposition, plus some return to the land and atmosphere by various mechanisms. If steady state conditions exist in the ocean, the annual loss of nutrients must be balanced by addition of new supplies; otherwise, the concentration in the water would increase or decrease, eventually leading to greater or lesser abundance of life. Construction of a budget involves chemical, biological, and geological information having

---

[1] Geology Department.

[2] Chemistry Section, Allan Hancock Foundation.

[3] Bacteriology Department.

varying degrees of uncertainty. Although the required data are not as precise as desired, it is believed that an attempt to set up a quantitative budget of nutrients is worthwhile for pointing up discrepancies in data and areas in which more work is needed.

NITROGEN

The geochemical cycle of nitrogen includes the atmosphere, as well as the lithosphere and hydrosphere to which the cycles of phosphorus and silicon are essentially confined. In fact, nearly all of the earth's nitrogen is in the atmosphere, where it totals 386 x 10^{13} metric tons (Rankama and Sahama, 1950, p. 305). Sedimentary rocks and the hydrosphere contain 7.7 x 10^{13} and 2.3 x 10^{13} tons of nitrogen, respectively. The total, about 396 x 10^{13} tons, is more than 100 times the total amount that has been weathered from igneous rocks during the geological past; therefore most of the nitrogen is presumed either to have been released directly into the atmosphere by volcanic activity or is a remnant of the original atmosphere (Rankama and Sahama, 1950, p. 575; Goldschmidt, 1954, p. 443).

In the ocean nitrogen occurs as molecular nitrogen, nitrate, nitrite, ammonia, and dissolved and particulate organic matter. Although molecular nitrogen is dominant (2.2 x 10^{13} tons), its apparent saturation at atmospheric pressure in water from all depths (Rakestraw and Emmel, 1938; Hamm and Thompson, 1941) means that its concentration is virtually independent of chemical and biological activity in the water. The quantities of nitrate, nitrite, and ammonia-nitrogen were estimated from concentration-depth curves for the Pacific, Atlantic, and Indian Oceans (Sverdrup, Johnson, and Fleming, 1942, pp. 242-244) by appropriately weighting for volumes of water in 1000 m depth zones. The averages are 30, 0.1, and 0.5 μg-a/L, respectively. For the whole ocean, with its volume of 1.37 x 10^{21} L, the total is about 5.8 x 10^{11} tons, of which nitrate-nitrogen by itself constitutes 5.7 x 10^{11} tons. To this must be added 3.4 x 10^{11} tons of nitrogen computed from Krogh's (1934) estimate of 0.244 mg/L of nitrogen in dissolved organic matter in the ocean. These values total 9.2 x 10^{11} tons, a quantity that may be called the nitrogen reserve of the ocean (Table 1). To this should be added the nitrogen in the standing crop of organic matter, an extremely uncertain quantity owing to the difficulty of collecting the smaller forms and to the variations in abundance with depth, season, latitude, and other factors. Rough estimates expressed by Vinogradov (1953, p. 131) and by Hutchinson (1953) correspond to *n* x 10^9 tons of nitrogen in the standing crop, an order of magnitude less than a value computed from scant measurements presented by Cooper (1937). The two recent estimates are two to three orders of magnitude less than the total of other constituents of the oceanic reserve and thus may be neglected in this discussion.

The annual use of nitrogen by phytoplankton can be calculated from the annual production of organic matter. The most recent figure for organic production, that of Steeman-Nielsen (1954), is 42 gm carbon/m^2/year, a value based upon carbon-14 uptake under laboratory conditions. This is only about 1/10th of the estimates prepared by Trask (1939) and Riley (1944) that were derived from oxygen production under laboratory conditions, supported by field evidence based on oxygen gain and nutrient depletion in the photosynthetic layer of the ocean. Until the present uncertainty is resolved, an intermediate value of 150 gm/m^2/year will be used in the following computations. With a 0.18 ratio of nitrogen to carbon in plankton (Sverdrup, Johnson, and Fleming, 1942, p. 929), 150 grams of carbon assimilated annually per square meter corresponds to about 9.6×10^9 tons of nitrogen uptake for the whole ocean (an area of 3.61×10^{14} m^2) per year. The quantity of nitrogen used by the plants is, thus, about 1% of the total reserve in the ocean; however, it is probable that the circulation of the ocean water is not so rapid that as much as 1% of the water comes within the photosynthetic zone each year. Sources of nitrogen other than the general oceanic reserve must therefore be available.

The sources of new supply of nitrogen to the ocean are the land and atmosphere from which fixed nitrogen is carried by rivers and rain. Clarke (1924, pp. 63, 120) reported that of the 2.735×10^9 tons of dissolved substances annually carried to the ocean, 0.90% is nitrate, corresponding to 5.5×10^6 tons of nitrogen per year. The amount of nitrogen carried to the sea in dissolved organic matter is less well known. Clarke (1924, pp. 110, 119) and Hutchinson (1944) accepted John Murray's average organic content of river water as 10% of the dissolved solids. The average nitrogen content of the organic matter may be expected to be less than 7.6%, which is the nitrogen content of dry marine plankton (Sverdrup, Johnson, and Fleming, 1942, p. 929). Studies of Birge and Juday (1934) on lake waters gave an average of 3%. The latter figure, which was accepted by Hutchinson in his calculations, appears to be the best estimate now available and on this basis 8.2×10^6 tons of dissolved organic nitrogen are carried annually to the ocean. Direct analysis for organic nitrogen in the Mississippi River, 0.35 mg/L (Riley, 1937), and the mixed river waters of Los Angeles Metropolitan Water District, 0.28 mg/L, lend support to the above figure. If these are typical of river waters, the average, 0.32 mg/L, would correspond to 8.4 x 10^6 tons of dissolved organic nitrogen contributed by rivers to the ocean each year. The ammonia-nitrogen of river water is very uncertain, but may be the same order of magnitude as nitrate-nitrogen (Conway, 1942, Note to Table 5), or about 5.5 x 10^6 tons per year. Summing the nitrate, organic, and ammonia-nitrogen, the total dissolved nitrogen transported to the ocean each year by rivers is 19 x 10^6 tons.

Fixed nitrogen is also contributed directly to the ocean in rain. Much lower concentrations of total nitrogen appear to be present in rain water falling on oceanic islands than on continental areas (Clarke, 1924, p. 55). The average of the scanty measurements from islands is 0.20 mg/L (Eriksson, 1952). If this value is a good average for the 297 x 10^{15} L of rain water falling on the ocean, the total contribution of fixed nitrogen by rain is 59 x 10^6 tons annually. Only a negligible percentage of the fixed nitrogen in the rain can have been derived directly from the ocean because of the low concentration in the surface sea water (Hutchinson, 1944; Eriksson, 1952). On the basis of these estimates the total nitrogen contributed by rivers and rain is 78 x 10^6 tons, or only 0.8% of the annual use by phytoplankton. The only remaining source for new growth is nitrogen regenerated during the life and after the death of the plants, and this must be the chief source. Riley (1951) estimated that 90% of the organic matter annually produced is regenerated in the upper 200 m.

Organic debris falling from the surface serves as food for many scavengers living in the water and on the bottom so that little debris becomes buried in an unaltered condition. The fact that some organic matter, though altered, escapes complete oxidation during burial is shown by its presence deep in the sediments and in sedimentary rocks. Trask (1939) reported that nearshore sediments contain about 2.5% organic matter and pelagic sediments about 1%, and Kuenen (1941) estimated the average speed of oceanic sedimentation to be 1 cm of solid material in 6000 years. Assuming that nearshore sediments are deposited 40 times as fast as pelagic ones (Trask, 1939), using an average ratio of nitrogen to organic matter in sediments of 0.05, weighting the nearshore and pelagic sediments by area (74,000,000 km^2 for nearshore sediments and 287,000,000 km^2 for pelagic sediments), and subtracting 50% for losses of nitrogen during diagenesis (Emery and Rittenberg, 1952), we find that about 8.6 x 10^6 tons of nitrogen is permanently deposited annually. This is an order of magnitude less than the 78 x 10^6 tons of annual contribution by rivers and rain. The lack of correspondence of these figures indicates that other losses such as denitrification must be important. If a steady state be assumed and if the values for contribution and loss are reasonably accurate, then the difference, which may be attributed to denitrification, amounts to 70 x 10^6 tons annually. This is only five-millionths of the molecular nitrogen dissolved in the oceans. The circulation of ocean water is undoubtedly sufficiently rapid to prevent supersaturation at depth even with this magnitude of denitrification.

Bacterial denitrification is an anaerobic process and consequently it should occur only in inshore sediments. Unless anaerobic micro-environments can exist in the water column or unless chemical denitrification takes place in the sea, then no more and probably considerably less than 8.6 x 10^6 tons of molecular nitrogen should be formed annually: a quantity equal to the nitrogen returned to the water from the sediment. Taking the lower value for denitrification, the annual loss of nitrogen is considerably less than the calculated contribution by rivers and rain. If steady state conditions exist, one or more of the estimates must be in error and, considering the meager data available, our estimates for the nitrogen content of rain water over the ocean and those for ammonia and organic nitrogen content of river water are all subject to question.

PHOSPHORUS

An average concentration of 2.4 μg-a/L throughout the whole volume of the ocean, derived from the phosphate-depth curves of the oceans (Sverdrup, Johnson, and Fleming, 1942, p. 241), yields a total of 1.1 x 10^{11} tons of phosphorus. To this must be added phosphorus in dissolved organic matter. From the data of Redfield, Smith, and Ketchum (1937) it appears probable that phosphorus in dissolved organic matter of near-surface waters is about 7% of the phosphate-phosphorus. Preliminary studies by E. D. Goldberg (personal communication) suggest that approximately the same ratio may also be valid for deep waters. On the basis of this ratio, there are 0.1 x 10^{11} tons of organic phosphorus in the oceans, making a total of 1.2 x 10^{11} tons of all phosphorus dissolved in the ocean water (Table 1).

Annual use of phosphorus amounts to 1.3 x 10^9 tons as computed from the compromise of 150 grams carbon per square meter annual assimilation and a weight ratio of 0.024 for phosphorus to carbon in plankton (Sverdrup, Johnson, and Fleming, 1942, p. 929). The ratio of annual use to oceanic reserve is 1%, the same as for nitrogen, and it is again doubtful that circulation is rapid enough to bring 1% of the water within the photosynthetic zone for extraction of phosphorus by phytoplankton.

Phosphorus, unlike nitrogen, is brought to the ocean only by rivers. The best value available for the concentration of phosphate-phosphorus in river water is probably that computed by Hutchinson (1952) from Clarke's data, 0.07 mg/L. For the 27.2 x 10^{15} L (Clarke, 1924, p. 63)[1] of river water annually reaching the ocean, this concentration corresponds to an annual contribution of phosphate-phosphorus of 1.9 x 10^6 tons. To this should be added the phosphate contained in dissolved organic matter. Assuming that the dissolved organic matter of rivers and the ocean have the same phosphorus to nitrogen ratio, the phosphorus contributed in dissolved organic matter of rivers is 0.3 x 10^6 tons annually. The total, 2.2 x 10^6 tons, is about 0.2% of the annual use and it is evident that, like nitrogen, most of the needed phosphorus must be regenerated and re-used. In addition to its dissolved form, much of the phosphorus contributed to the ocean is in the form of mineral grains and of ions adsorbed on solids (Carritt and Goodgal, 1954). Analyses of phosphorus in river-borne sediments are not abundant, but the average for fine-grained Colorado River sediments trapped in Lake Mead is 0.074% (Gould, 1953, p. 178) and for the Mississippi River delta 0.079% (Clarke, 1924, p. 509). The total annual tonnage of suspended matter contributed to the ocean by rivers is 16 x 10^9 tons, as computed from Conway's (1942) average for suspended matter in rivers, 0.6 gm/L. From Twenhofel's (1932) ratio of dissolved to suspended load for eastern United States rivers the tonnage is 5 x 10^9, and from Kuenen's (1950, p. 233) estimate of 12 km^3 per year it is 24 x 10^9. Using the middle value (neglecting deposition on deltas), with the average percentage of phosphorus in river suspended sediment, the annual contribution of phosphorus is 12 x 10^6 tons. The total dissolved and inorganic suspended phosphorus contributed by rivers is 14 x 10^6 tons.

The phosphorus content of pelagic sediments averages about 0.072% on the basis of 87 samples from the North Atlantic (Correns, 1939) and 25 from the Pacific Ocean (Revelle, 1944). For 52 near-shore terrigenous muds Clarke (1924, p. 518) gave an average value of 0.092% phosphorus, nearly the same as the average of 0.094% for three basin cores off southern California. Areas of phosphorite, a rich authigenic phosphorus deposit, may be neglected in view of their small extent. Considering the area and rate of deposition of the sediments in the same way as was done for nitrogen, we find that a total of 13 x 10^6 tons of phos-

---

[1] Wüst (Sverdrup, Johnson, and Fleming, 1942, p. 120) estimated runoff at 37 x 10^{15} L. If his value were used our estimate of nutrients carried by rivers would be increased 37%.

phorus is deposited annually. This is very nearly the same as the calculated contribution from rivers.

SILICON

The geochemical cycle of silicon also has its uncertainties. Few data are available for computing an average silicon content of phytoplankton; moreover, the silicon in sediments is so great, owing to the abundance of silicate minerals, that the contribution by organisms is not determinable by ordinary chemical analysis of sediments.

Following the method used for nitrogen and phosphorus, the total dissolved silicon content of the ocean was found to be 4.0 x 10^{12} tons on the basis of an average concentration of 105 μg-a/L, taken from silicate-depth curves of Sverdrup, Johnson, and Fleming (1942, p. 245). According to Clarke (1924, p. 119) SiO_2 averages 11.67% of the 2.735 x 10^9 tons of dissolved solids carried by rivers to the ocean annually. Thus, the annual contribution of dissolved silicon is 150 x 10^6 tons. The annual increment for dissolved silicon is about 0.004% of the total oceanic reserve, roughly approximating the 0.009% for nitrogen and 0.002% for phosphorus. Using an average of 26% silicon (Clarke, 1924, p. 518; Gould, 1953, p. 168) in the 16 x 10^9 tons of suspended sediment of rivers, we find that 4150 x 10^6 tons of silicon are contributed to the ocean annually in the form of mineral grains. The total annual contribution of dissolved and suspended silicon is thus 4300 x 10^6 tons.

The approximate rate of deposition of all forms of silicon can be computed from Clarke's (1924, pp. 516, 518) values of SiO_2 in nearshore sediment, 57%, and in pelagic sediment weighted for type and area, 49%. Using these percentages, the areas of nearshore and pelagic sediments, and the estimated rates of deposition of these sediments, computation shows that about 3800 x 10^6 tons of silicon are deposited annually. As was shown for phosphorus, the annual supply of silicon is approximately the same as the annual loss to the bottom.

TABLE 1

NUTRIENT BUDGET

Millions of Metric Tons

	Nitrogen	*Phosphorus*	*Silicon*
Reserve in ocean	920,000	120,000	4,000,000
Annual use by phytoplankton	9,600	1,300	....
Annual contribution by rivers (dissolved)	19	2	150
(suspended)	0	12	4,150
by rain	59	0	0
Annual loss to sediments	9	13	3,800

CONCLUSIONS

Fixed nitrogen and phosphorus in their various forms are present in the ocean in quantities amounting to 100 times their estimated annual use by phytoplankton. The annual use by phytoplankton, however, far exceeds the annual contribution to the ocean of nitrogen and phosphorus. Accordingly, the major proportion of the nutrients used by phytoplankton must be regenerated from organic debris settling through the photosynthetic zone. Though most of the regeneration occurs in and just below the photosynthetic zone, some occurs at greater depths and even within bottom sediments. This has led to the accumulation of large nutrient reserves at depths too great for depletion by photosynthesis.

It is of interest that the renewal times (or the number of years that would be required for dissolved nutrients in rivers, plus rain in the case of nitrogen, to build up the nutrients dissolved in the ocean water to their present concentrations in the absence of withdrawal) are similar: 12,000, 60,000, and 27,000 years for nitrogen, phosphorus, and silicon, respectively. All are close to the renewal time for the water itself, 50,000 years (volume of ocean divided by annual volume of river flow). For phosphorus, which has the longest renewal time, desorption of phosphate ions on clays carried by rivers to the ocean would reduce the required time. Similarly, solution of minerals may reduce the renewal time for phosphorus and silicon. Nitrogen, with the shortest renewal time, would be completely transferred from the atmosphere to the ocean in only fifty million years if denitrification did not recycle much of it back to the atmosphere. The brevity of these renewal times and the character of the geological record, suggesting that the total life in the ocean has been more or less constant over long periods, indicate that steady state conditions exist.

Under steady state conditions as much nitrogen, phosphorus, and silicon must be deposited annually in sediments, or otherwise lost from the ocean, as are contributed to the ocean from non-marine sources. Total fixed nitrogen is contributed in far greater quantity than is lost to sediments (Table 1) ; we attribute this difference to denitrification. On the other hand, both phosphorus and silicon are brought to the ocean and deposited on its floor in approximate balance. Because the contribution of each is dominantly in the form of mineral grains, the percentages of phosphorus and silicon in the ocean bottom sediments are not materially different from their percentages in stream-borne sediment. In summary, we conclude that nitrogen, phosphorus, and silicon exist in steady state conditions. Bruyevitch (1953), on the basis of similar calculations for the Pacific Ocean only, also concluded that a steady state probably exists with respect to silicon.

It must be admitted that the writers did not expect that the computations would so closely support their belief in a steady state in view of the incomplete source data. Values given in Table 1 still must be accepted with caution. For example, because of lack of data the standing crop was not considered in computing the reserves of nutrients in the ocean. In addition, contribution of nutrients from juvenile waters and loss of nutrients to the land in the form of blown sea salts, guano, and marine products of commerce were ignored because the quantities involved are insignificant. Taking all known uncertainties into consideration, it is believed that the estimates for oceanic reserves are correct to within a factor of 2, but the other estimates are correct only to within an order of magnitude. Certainly, one of the prime tasks of geochemistry is to obtain more exact information on the distribution of these and other elements in the earth's surface zones. When more widespread and precise analyses are available, the budgets can be recomputed and given more credence. Until then, the budgets outlined in this article should be taken no more seriously than as rough guides.

LITERATURE CITED

Birge, E. A. and C. Juday
1934. Particulate and dissolved organic matter in inland lakes. Ecol. Monogr. 4:440-474.

Bruyevitch, S. B.
1953. Geochemistry of silicon in the ocean. Izvestiia Akad. Nauk SSSR. Ser. Geol. 4:67-79.

Carritt, D. E. and S. Goodgal
1954. Sorption reaction and some ecological implications. Deep-sea Res. 1:224-243.

Clarke, F. W.
1924. The data of geochemistry. U. S. Geol. Survey Bull. 770, 841 pp.

Conway, E. J.
1942. Mean geochemical data in relation to oceanic evolution. Proc. Roy. Irish Acad. Sec. B. 48:119-159.

Cooper, L. H. N.
1937. The nitrogen cycle in the sea. Jour. Mar. Biol. Assoc. 22:183-204.

Correns, C. W.
1939. Pelagic sediments of the North Atlantic Ocean. *In* Recent Marine Sediments. Thos. Murby & Co., Tulsa. pp. 373-395.

Emery, K. O. and S. C. Rittenberg
1952. Early diagenesis of California basin sediments in relation to origin of oil. Bull. Amer. Assoc. Petrol. Geol. 36:735-806.

ERIKSSON, E.
1952. Composition of atmospheric precipitation. Tellus. 4:215-232.

GOLDSCHMIDT, V. M.
1954. Geochemistry. Clarendon Press, Oxford. 730 pp.

GOULD, H. R.
1953. Lake Mead sedimentation. Univ. Southern Calif. Doctorate Dissertation in Geology. 333 pp.

HAMM, R. E. AND T. G. THOMPSON
1941. Dissolved nitrogen in the sea water of the northeast Pacific with notes on the total carbon dioxide and the dissolved oxygen. Jour. Mar. Res. 4:11-27.

HUTCHINSON, G. E.
1944. Nitrogen in the biogeochemistry of the atmosphere. Amer. Scientist. 32:178-195.
1952. The biogeochemistry of phosphorus. *In* The Biology of Phosphorus. Michigan State College Press. pp. 1-35.
1953. The biochemistry of the terrestrial atmosphere. *In* The Earth as a Planet. Univ. of Chicago Press. pp. 371-433.

KROGH, A.
1934. Conditions of life at great depths in the ocean. Ecol. Monogr. 4:430-439.

KUENEN, P. H.
1941. Geochemical calculations concerning the total mass of sediments in the earth. Amer. Jour. Sci. 239:161-190.
1950. Marine Geology. Wiley and Sons, N. Y. 268 pp.

RAKESTRAW, N. W. AND V.M. EMMEL
1938. The ratio of dissolved oxygen to nitrogen in some Atlantic waters. Jour. Mar. Res. 1:207-216.

RANKAMA, K. AND T. G. SAHAMA
1950. Geochemistry. Univ. of Chicago Press. 912 pp.

REDFIELD, A., H. SMITH AND B. KETCHUM
1937. The cycle of phosphorus in the Gulf of Maine. Biol. Bull. 73:421-443.

REVELLE, R. R.
1944. Marine bottom samples collected in the Pacific Ocean by the Carnegie on its seventh cruise. Carnegie Inst. of Washington Pub. 556. 196 pp.

RILEY, G. A.
1937. The significance of the Mississippi River drainage for biological conditions in the northern Gulf of Mexico. Jour. Mar. Res. 1:60-74.
1944. The carbon metabolism and photosynthetic efficiency of the earth as a whole. Amer. Scientist. 32:129-134.
1951. Oxygen, phosphate, and nitrate in the Atlantic Ocean. Bull. Bingham Oceanog. Coll. 13, 126 pp.

STEEMAN-NIELSEN, E.
1954. On organic production in the oceans. Jour. du Conseil International pour l'Exploration de la Mer. 19:309-328.

SVERDRUP, H. U., M. W. JOHNSON AND R. H. FLEMING
1942. The Oceans. Prentice-Hall, N. Y. 1087 pp.

TRASK, P. D.

1939. Organic content of recent marine sediments. *In* Recent Marine Sediments. Thos. Murby & Co., Tulsa. pp. 428-453.

TWENHOFEL, W. H.

1932. Treatise on Sedimentation. Williams and Wilkins Co., Baltimore. 926 pp.

VINOGRADOV, A. P.

1953. The Elementary Composition of Marine Organisms. Sears Found. for Mar. Res. Mem. 2, 647 pp.

THE PLEISTOCENE HISTORY OF THE CHANNEL ISLAND REGION, SOUTHERN CALIFORNIA

By

Thomas Clements

Hancock Professor of Geology, University of Southern California

INTRODUCTION

The Channel Island region of southern California, as the term is used in the present paper, includes the continental shelf area south of the Santa Barbara coast line and west of the Los Angeles-San Diego coast line, and extending offshore approximately 150 land miles. There are two groups of islands in the area: the northern or Santa Barbara channel islands, and the southern group. The first consists of Anacapa, Santa Cruz, Santa Rosa, and San Miguel; the second consists of San Clemente, Santa Catalina, Santa Barbara, and San Nicolas. To the latter group should be added the Palos Verdes Hills, which, although not now an island, have been an island in the recent geologic past. There are also a few shallow submarine banks which likewise have been islands during the time under consideration. Tanner Bank and Cortes Bank, lying approximately 150 land miles west of San Diego and at depths of less than 50 fathoms, are examples of these.

The sea floor is by no means the conventional gently-sloping, relatively featureless continental shelf of some parts of the world. It consists of high ridges and deep troughs, the latter having depths of 3,000 to 6,000 feet below sea level, and in many cases being bounded on one side or another by steep scarps. The islands surmount the crests of the ridges and rise to heights of as much as 8,000 feet above the bottoms of the troughs. Canyons gash the ridges, and the bottoms of some of the troughs appear to have been leveled off by the sediments accumulating in them. The topography and relief of the region have been likened to the topography and relief of Death Valley and vicinity (Shepard and Emery, 1941).

The deciphering of the Pleistocene history of the Channel Island region involves many problems, and as yet the evidence at hand is too meager to permit the satisfactory solution of many of them. Nevertheless, certain facts have come to light as the result of research carried on in the area by many geologists and oceanographers over a long period of years, and it is possible at this time to suggest, at least for some of the problems, answers that probably are not far from the truth.

The types of evidence used in the solution of the problems are varied. There is first the direct geologic evidence from the rocks exposed on the islands and on the mainland adjacent to the area. A somewhat less easily obtained type of geologic evidence is that from the sea floor, as brought up in dredge, snapper, and core barrel. The physiographic features of the region tell something of its history in the not too distant past: the wave-cut terraces, the sea cliffs, the submarine valleys, the submarine banks. Fossils tell their part of the story: the dwarfed elephants of the northern islands; the fossil plants; the shells on the uplifted terraces.

PREVIOUS WORK

Attention was first called to the contrasting topographies of Santa Catalina and San Clemente islands by Cooper as early as 1863 (in Whitney, 1865, pp. 184-85). Lawson (1893) made a reconnaissance of the islands and the shore of the mainland before the turn of the century, and developed the idea of different histories for the two islands mentioned. He discussed this again in a later paper (1934). Smith (1897), while first agreeing with Lawson's conclusions, later argued against the idea of Santa Catalina's having differed from the other islands in its history (1933).

The geology of the various islands has been discussed by a number of writers: San Nicolas by Bowers (1890) and later by Kemnitzer (1936); Santa Catalina by Smith (1897), with a later paper on the metamorphic rocks by Woodford (1924); San Clemente by Smith (1898); Santa Rosa by Kew (1927), by Moody (1935), and by Seymour (unpublished); Santa Cruz by Bremner (1932), and Rand (1931); San Miguel by Bremner (1933); Santa Barbara by Kemnitzer (unpublished); and Anacapa by Yates (1890). The Palos Verdes Hills have been studied by a number of men, among whom Arnold (1903), Kew (1926), and Woodring and associates (1935, 1946) should be mentioned.

The geology of the shore area of the mainland adjacent to the Channel Island region has been studied by more men than it is possible to mention here. Reference has been made to papers and larger works by Lawson (1893, 1934), Grant and Gale (1931), Reed (1933), Davis (1933), Reed and Hollister (1936), and Bailey (1943).

The submarine canyons off the coast have attracted the attention of many workers, of whom Shepard is probably the best known. A portion of the paper by Shepard and Emery (1941, pp. 51-108) and of the former's book (Shepard, 1948, pp. 207-250), together with a paper by Crowell (1952) and a reply by Shepard (1952), give the most complete discussions of the subject to date.

In recent years, growing in part out of the submarine canyon study, more and more attention has been given to the collecting of sediment samples from the sea floor of the Channel Island region, and to the submarine geology of the area. This work has been done largely by Scripps Institution of Oceanography, the Navy Electronics Laboratory, and the Allan Hancock Foundation of the University of Southern California. Dr. K. O. Emery, of the last-named institution, has been a leader in this field, and his papers (1945, *et seq.*), as well as papers by Trask (1931), Revelle and Shepard (1939), Clements and Dana (1944) and many others, have been used freely in the present study.

The fossil elephants of the northern islands were described by Stock (1935), who also discussed the Pleistocene fauna of Rancho La Brea (1930). The fossil plants of Santa Cruz Island were studied by Chaney and Mason (1934). Woodring determined the age of the shells from the lower terraces on Palos Verdes Hills (Woodring, 1935).

ACKNOWLEDGMENTS

The author wishes to acknowledge his indebtedness to Captain Allan Hancock and Chancellor Rufus B. von KleinSmid of the University of Southern California for making the study possible. He also is grateful to Dr. K. O. Emery of the Department of Geology and the Allan Hancock Foundation of the same institution for helpful discussion and criticism.

TOPOGRAPHIC FEATURES

The most striking topographic features of the Channel Island Region are the wave-cut terraces so beautifully shown on the Palos Verdes Hills and on all the present islands with the exception of Santa Catalina Island, on which they are obscure. On Palos Verdes Hills there are 13 main terraces and two minor ones, the highest being 1325 feet above sea level, and the lowest 150 feet above (Woodring, 1935). Smith (1898) recorded 23 terraces on San Clemente Island, although Lawson (1893) listed only 19. The highest of these is 1,500 feet above sea level, with those higher than 1,320 feet rather indistinct. San Nicolas and Santa Barbara islands are distinctly terraced, but being at present only 890 and 635 feet above sea level respectively, they must have been completely submerged when the higher terraces were being cut on the other islands.

The terraces on the northern group of islands have been less intensively studied than those of the southern group, although all the islands show obvious terracing. The highest recorded on Santa Cruz Island is at 750 feet above sea level (Bremner, 1932). Since the summit of Anacapa, which has an elevation of 930 feet above sea level, is a wave-cut surface, it is logical to believe that all the northern islands were submerged at least to that level, and probably to the highest level recorded on any of the islands. Certainly Anacapa and San Miguel were completely submerged, and Santa Cruz and Santa Rosa greatly reduced in size at the time of the cutting of the highest terraces.

Only on Santa Catalina Island is there a question regarding the presence of wave-cut terraces. Lawson (1893) declared that no terraces existed, and that this and the evident stream-cut topography indicated a very different history for this island from that of San Clemente or Palos Verdes Hills. In other words, he believed that Santa Catalina Island had been emergent while the others had been submergent. Smith seemed more or less in agreement with this in his earlier paper (1897), although he pointed out some possible terracing. In a later paper (1933), however, he came out vigorously for the idea that Santa Catalina had been subjected to the same wave action as the others, and stated that because of its more resistant rocks, the terraces developed were not as striking in appearance as on other islands. Shepard, Grant, and Dietz (1939) upheld Lawson's view.

During World War II, the United States Army Engineer Corps made new topographic maps of Santa Catalina Island on a scale of 1:25,000, and with a contour interval of 50 feet. Carefully constructed profiles at several places suggest terraces at a number of elevations (Clements, 1948), with the highest at approximately 1,400 feet above sea level. A study of aerial photographs of the island, furnished through the courtesy of the Army Engineers, corroborates the presence of the terraces. However, the terraces appear to be more highly dissected than those on the other islands, suggesting the possibility of their having been cut at an earlier date. On the other hand, this appearance may be the result of their being less well developed because of the presence of more resistant rock, as suggested by Smith. It is the opinion of the present writer that the latter is the case.

Another striking feature of the topography of the region is the submarine canyons mentioned above and discussed by so many writers. Shepard has probably done more actual research on the canyons than any other person, and it is his opinion that they are of fluviatile origin, cut under subaerial conditions when the landmass was emergent (Shepard, in Shepard and Emery, 1941, pp. 109-158, and Shepard, 1948, pp. 207-250). A number of other writers, of whom Crowell (1952) is the most recent, have tried to explain the canyons by submarine erosion of one type or another, calling particularly on turbidity currents as the agent.

The chief obstacle to the acceptance of fluviatile origin seems to be the amount of emergence or lowering of sea level that would have been required for the canyon cutting, in some cases (as the Monterey Bay canyon) amounting to several thousand feet. And yet geologists apparently accept without question the Pleistocene age of wave-cut, marine terraces as high as 1,325 feet above present sea level (Woodring, 1935).

The principal reason for this anomaly probably is that the commonly accepted figure for the lowering of sea level during the most extensive glaciation is from 350 to 400 feet (Flint, 1947, p. 427). This figure has been arrived at by calculations based on assumptions of the thickness, areal extent, and contemporaneity of the ice sheets, as well as on the further assumption that sea floor and continental platforms remained relatively quiet during the time the ice sheets were at their maximum. The figure obviously could be in error by several hundred per cent; nevertheless, it has influenced the thinking of a great many geologists.

Shepard's earlier concept was that the submarine canyons were cut during the Pleistocene when sea level was lowered or the land uplifted (or both) by a total of 2,000 to 3,000 feet or perhaps more (*op. cit.*). More recently he has modified his original view (Shepard, 1952), and now concedes that the deeper parts may have been cut by processes of subaerial erosion during a time of emergence earlier than the Pleistocene, and kept open by turbidity currents, and that only the upper parts were cut as the result of Pleistocene lowering of sea level. Even this would require more than the accepted 350 to 400 feet of lowering, and he suggests relative movement of as much as a thousand feet. Regardless of the amount of lowering involved, it is the opinion of the present author that Shepard presents convincing evidence for the fluviatile origin of the submarine canyons.

SEDIMENTS OF THE SEA FLOOR

Rounded pebbles and cobbles have been dredged from the sea floor at several places. One of these localities was on what appears to be a submarine terrace extending six miles southeast of Santa Catalina Island, at a depth of 900 feet (Clements and Dana, 1944). From the shape and degree of rounding of the fragments it was concluded that they represented a beach deposit, formed when Santa Catalina stood 900 feet higher or sea level was 900 feet lower. Although a possible upper Pleistocene age was postulated, it could as readily be assigned to any other part of the Pleistocene.

Material of similar characteristics and probably also of beach origin was dredged from Cortes Bank at a depth of 300 feet (Clements, 1945), and a ridge extending northwesterly from Tanner Bank yielded like sediment from a depth of 2,862 feet (Emery and Shepard, 1945). Thus the sediments, like the terraces and submarine canyons, suggest wide fluctuations of sea level during the relatively recent geologic past.

FOSSILS

In attempting to work out the distribution of sea and land in the Pleistocene, fossils of various kinds—mammals, plants, and invertebrates—have been found very useful. Fossil elephants have been described from Santa Cruz, Santa Rosa, and San Miguel Islands by Stock (1935). These elephants are closely related to those found on the mainland at such localities as Rancho La Brea (Stock, 1930) and Centinela Park (Clements, 1937), and thus indicate a land connection between the northern group of islands and the mainland during the Pleistocene. However, the elephants are dwarfed, the dwarfing being more pronounced in those of Santa Rosa than those of San Miguel, which lies farther offshore (Stock, 1935). The dwarfing is similar to that shown by the fossil elephants of the island of Malta, and is believed to be the result here, as there, of island environment. The indication is that the islands were connected with the mainland during early Pleistocene time, and were again separated later in the Pleistocene with sufficient time for dwarfing of the elephants before their final extinction, which occurred earlier on San Miguel than on Santa Rosa.

Fossil plants are known from terrace deposits on Santa Cruz Island, and have been studied by Chaney and Mason (1934). They consist of logs and fruiting structures, and represent nine species, three being conifers and the rest dicotyledons. All are still living in California, the modern forest most closely approximating the assemblage occurring at Fort Bragg, 440 miles to the northwest. At the latter locality the temperature is considerably lower and the rainfall greater than on Santa Cruz Island today, indicating that similar conditions prevailed on the island when the plants grew there. It is concluded by the above-mentioned writers that this was during one of the glacial ages of the Pleistocene.

Still further evidence is given by the invertebrate fossils found on the terraces of Palos Verdes Hills (Woodring, 1935). Fossil marine shells occur on nine of the 13 main terraces, the highest being on the twelfth terrace at 1,215 feet above sea level. These are generally tide-pool and rock-cliff species, living today. However, the fossils from the lowest (youngest) terrace were determined by Woodring (*ibid.*) to be of Palos Verdes (late Pleistocene) age. This is confirmed by a recent Carbon 14 determination on one of the shells collected by Woodring, which gives the age as "older than 30,000 years" (Kulp, *et al.*, 1952). The indication is that the terraces were cut during the Pleistocene, and probably during late Pleistocene, although it is conceivable that they may be of more than one generation of terrace cutting.

GEOLOGICAL HISTORY OF THE REGION

It is seen from the foregoing that there are two widely divergent sets of conditions to be met in attempting to work out the Pleistocene history of the Channel Island region. If the submarine canyons were cut by normal stream processes, the land must have risen or sea level have been lowered by at least 1,000 feet and possibly as much as 2,000 to 3,000 feet. On the other hand, the terracing of Palos Verdes Hills and San Clemente Island, and possibly of Santa Catalina Island, requires a rise of sea level or a sinking of the sea floor and mainland by 1,325 to 1,500 feet. And following this there has been a return of sea level to its present position. The net movement to be accounted for is a minimum of approximately 2,500 feet and a maximum of 4,500 feet.

It is possible, of course, as has been suggested, that part of the submarine canyon cutting took place in the Pliocene, or perhaps even earlier

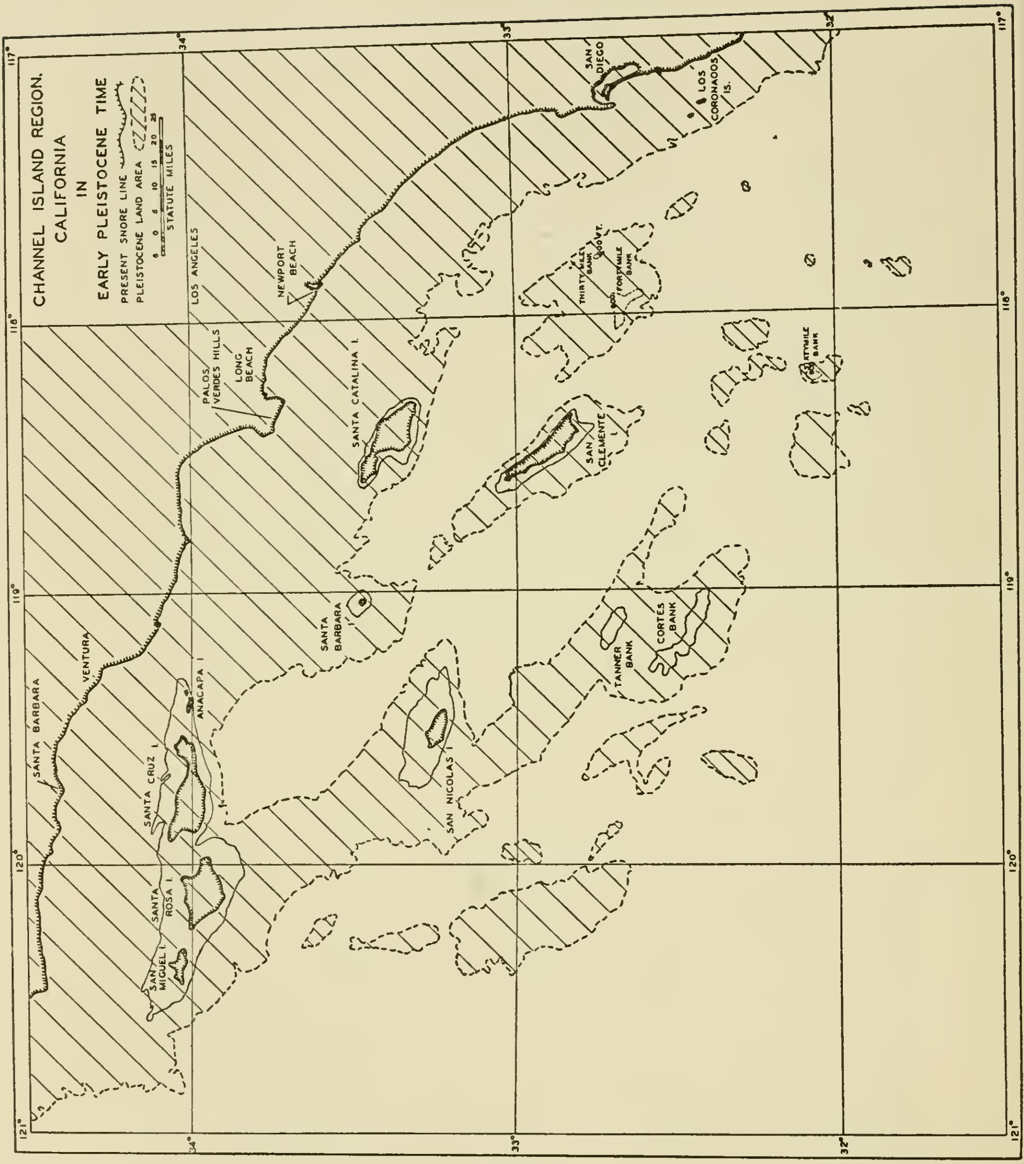

CHANNEL ISLAND REGION.
CALIFORNIA
IN
EARLY PLEISTOCENE TIME
PRESENT SNORE LINE
PLEISTOCENE LAND AREA
5 0 5 10 15 20 25
STATUTE MILES
117°
118°
119°
120°
121°
34°
33°
32°
LOS ANGELES
NEWPORT BEACH
PALOS VERDES HILLS
LONG BEACH
SAN DIEGO
LOS CORONADOS IS.
SANTA CATALINA I.
THIRTY MILE BANK
600 FT.
FORTY MILE BANK
SAN CLEMENTE I.
SANTA BARBARA
SANTA BARBARA
VENTURA
ANACAPA I.
SANTA CRUZ I.
SANTA ROSA I.
SAN MIGUEL I.
SAN NICOLAS I.
TANNER BANK
CORTES BANK

FIGURE 1

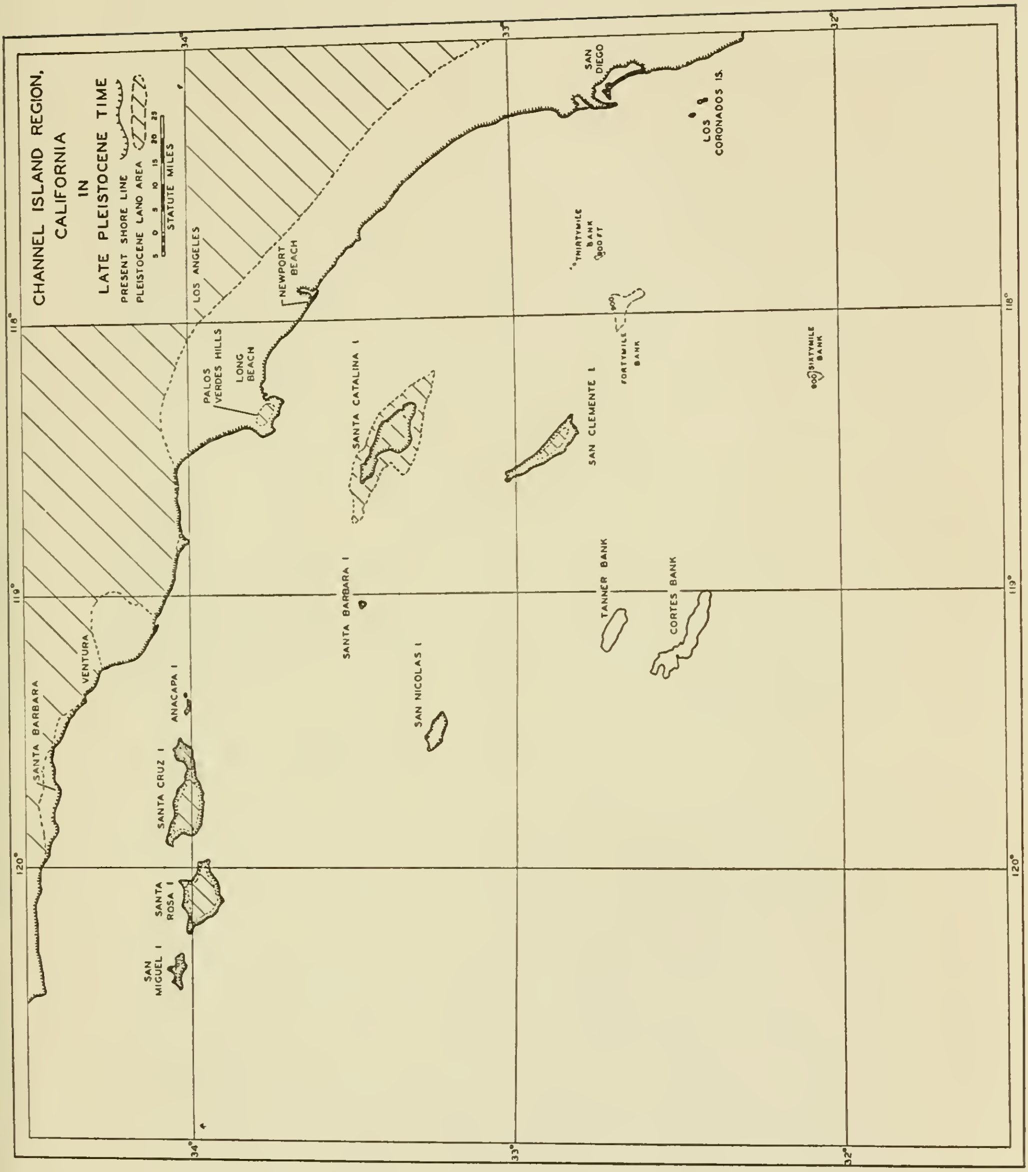

CHANNEL ISLAND REGION, CALIFORNIA IN LATE PLEISTOCENE TIME
PRESENT SHORE LINE
PLEISTOCENE LAND AREA
5 0 5 10 15 20 25
STATUTE MILES
34°
33°
32°
118°
119°
120°
LOS ANGELES
NEWPORT BEACH
PALOS VERDES HILLS
LONG BEACH
SAN DIEGO
LOS CORONADOS IS.
THIRTYMILE BANK 900 FT
FORTYMILE BANK
SIXTYMILE BANK
SANTA CATALINA I
SAN CLEMENTE I
SANTA BARBARA I
SAN NICOLAS I
TANNER BANK
CORTES BANK
SANTA BARBARA
VENTURA
ANACAPA I
SANTA CRUZ I
SANTA ROSA I
SAN MIGUEL I

Figure 2

in the Tertiary. However, the great thickness of marine Pliocene known to exist in the Los Angeles and Ventura basins, and the fact that rocks containing marine Pliocene fossils have been dredged up offshore indicate that the region was submergent rather than emergent in the Pliocene. It does not seem logical that canyons cut earlier than Pliocene would remain open during an epoch of submergence and deposition.

It is the present writer's opinion that the first great lowering of sea level (perhaps accompanied by actual uplift of the land) that initiated the cutting of the submarine canyons came in early Pleistocene time, concurrently with and as the result of the accumulation of glacial ice on the continents in the Nebraskan glacial age. The effective lowering of sea level amounted to approximately 3,000 feet, and converted the Channel Island region into a great archipelago with long southeasterly-extending peninsulas and fringes of islands 150 miles off the present shore (see Plate I). Between the peninsulas, gulfs or bays occupied the present deep basins, and some of the shallower basins such as Santa Monica and the one between Palos Verdes Hills and Santa Catalina Island were altogether landlocked and probably contained lakes.

The greatly increased gradients of all streams and the greater rainfall as the climatic belts were forced to the south by the advancing ice sheets increased the cutting power of the streams immensely. Existing channels were extended across the newly exposed land surface, and were rapidly deepened, and new channels that never reached back as far as the present shoreline were developed.

It was at this time, in all probability, that the elephants, moving south before the advancing cold, wandered onto the peninsula formed by the present northern group of islands, as well as occupying the Los Angeles area. And it was probably at this time, too, that the more northerly forest flourished on this same peninsula.

Whether or not a similar emergence, of the same or smaller magnitude, occurred during the Kansan and Illinoian glacial ages, the record does not indicate. An inundation of the region occurred, however, at some time later than the above-mentioned emergence. This must have been in part from the return of water to the sea from the melting of the glaciers, but actual rise of sea level was accompanied or followed shortly by a lowering of the coastal area by perhaps as much as 1,500 feet.

This brought about the reduction of the northern peninsula to a chain of islands smaller than at present, with the drowning of parts of the Ventura and the Los Angeles coastal plain areas. Likewise, Palos Verdes Hills and San Clemente were reduced to small islands, and San

Nicolas and Santa Barbara Islands were completely submerged (see Plate II). Santa Catalina Island may have remained high, a considerably larger island than at present, although if the somewhat obscure terraces have been properly interpreted in the earlier pages of this paper, it was partially submerged like the others.

Presumably it was during this inundation that dwarfing of the elephants on the northern islands occurred, and the highest terraces were cut on Palos Verdes, San Clemente, and Santa Catalina. This probably was not later than the early part of late Pleistocene (Palos Verdes age), perhaps during the Sangamon interglacial.

As the Wisconsin ice sheets developed, sea level again fell, probably accompanied once more by actual rise of the land. During intervals of stillstand in the general emergence, the numerous terraces were cut and remain as mute witnesses to the presence of the former shorelines. The Palos Verdes (late Pleistocene) fossils from the lowest terrace indicate that the withdrawal of the sea was also accomplished in late Pleistocene time, before the end of the Wisconsin glacial age.

With the melting of the Wisconsin ice sheets, the beginning of which is variously estimated at from 11,000 to 25,000 years ago, and which is presumed to be still in progress, sea level should again be rising. On the other hand, the Channel Island region itself may also be rising. Recent seismic activity in the area (Clements and Emery, 1947) indicates certainly that it is by no means quiescent. Whether or not the region is rising faster than sea level can be answered only in the future.

LITERATURE CITED

ARNOLD, R.

1903. The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California. Calif. Acad. Sci. Mem. vol. 3, 420 pp.

BAILEY, T. L.

1943. Late Pleistocene Coast Range orogenesis in southern California. Geol. Soc. America. Bull. vol. 54, pp. 1549-1568.

BOWERS, S.

1890. San Nicolas Island. Calif. State Min. Bur. Ann. Report No. 9, pp. 57-61.

BREMNER, C. ST. J.

1932. Geology of Santa Cruz Island, Santa Barbara County, California. Santa Barbara Mus. Nat. Hist. Occas. Paper 1, 33 pp.

1933. Geology of San Miguel Island, Santa Barbara County, California. Santa Barbara Mus. Nat. Hist. Occas. Paper 2, 23 pp.

CHANEY, R. W. AND H. L. MASON

1934. A Pleistocene flora from Santa Cruz Island, California. *In* Studies of the Pleistocene Paleobotany of California. Carnegie Inst. Washington. Pub. No. 415 (Contrib. Paleontology), pp. 1-24.

CLEMENTS, T.

1937. A new Pleistocene vertebrate locality in southern California. Geol. Soc. America, Proc. for 1936, p. 298 (abstract).

1945. Notes on the geology of Cortes and Tanner Banks off southern California. Proc. 25th Anniversary Founding of the Graduate School, Univ. Southern California, pp. 154-155.

1948. Terraces on Santa Catalina Island, California. Geol. Soc. America. Bull. vol. 59, p. 1368 (abstract).

CLEMENTS, T. AND S. W. DANA

1944. Geologic significance of a coarse marine sediment from near Santa Catalina Island, California. Jour. Geol. vol. 52, pp. 351-354.

CLEMENTS, T. AND K. O. EMERY

1947. Seismic activity and topography of the sea floor off southern California. Seis. Soc. America. Bull. vol. 37, pp. 307-313.

CROWELL, J. C.

1952. Submarine canyons bordering central and southern California. Jour. Geol. vol. 60, pp. 58-83.

DAVIS, W. M.

1933. Glacial epochs of the Santa Monica Mountains, California. Geol. Soc. America. Bull. vol. 44, pp. 1041-1133.

EMERY, K. O. AND F. P. SHEPARD

1945. Lithology of the sea floor off southern California. Geol. Soc. America. Bull. vol. 56, pp. 431-478.

FLINT, R. F.

1947. Glacial geology and the Pleistocene Epoch. N. Y., John Wiley & Sons, xviii, 589 pp.

GRANT, U. S., IV AND H. R. GALE

1931. Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions. San Diego Soc. Nat. Hist. Mem. vol. 1, 1036 pp.

KEMNITZER, L. E.

1936. The geology of San Nicolas Island, California. American Assn. Pet. Geol. Bull. vol. 20, p. 1519 (abstract).

KEW, W. S. W.

1926. Geologic and physiographic features of the San Pedro Hills, Los Angeles County, California. Oil Bull. vol. 12, pp. 513-518, 590.

1927. Geologic sketch of Santa Rosa Island, Santa Barbara County, California. Geol. Soc. America. Bull. vol. 38, pp. 645-653.

KULP, J. L., L. E. TRYON, W. R. ECKELMAN, AND W. A. SNELL

1952. Lamont natural radiocarbon measurements, II. Science, vol. 116, new ser., pp. 409-414.

LAWSON, A. C.

1893. The post-Pliocene diastrophism of the coast of southern California. Univ. Calif. Pubs. Geol. vol. 1, pp. 115-160.

1934. The continental shelf off the coast of California. Natl. Res. Council. Bull. vol. 8, pt. 2, no. 44.

MOODY, G. B.

1935. The geology of Santa Rosa Island, California. American Assn. Pet. Geol. Bull. vol. 19, p. 136 (abstract).

RAND, W. W.

1931. Preliminary report of the geology of Santa Cruz Island, Santa Barbara County, California. Mining in California, Report 27, State Mineralogist, pp. 214-219.

REED, R. D.

1933. Geology of California. Tulsa, American Assn. Pet. Geol., 355 pp.

REED, R. D. AND J. S. HOLLISTER

1936. Structural evolution of southern California. Tulsa, American Assn. Pet. Geol., 157 pp.

REVELLE, R. R. D. AND F. P. SHEPARD

1939. Sediments off the California coast. *In* Recent Marine Sediments. Tulsa, American Assn. Pet. Geol., pp. 245-282.

SHEPARD, F. P.

1948. Submarine geology. N. Y., Harper and Brothers, xvi, 348 pp.

1952. Composite origin of submarine canyons. Jour. Geol. vol. 60, pp. 84-96.

SHEPARD, F. P. AND K. O. EMERY

1941. Submarine topography off the California coast: canyons and tectonic interpretation. Geol. Soc. America. Spec. Paper 31, 171 pp.

SHEPARD, F. P., U. S. GRANT IV, AND R. S. DIETZ

1939. The emergence of (Santa) Catalina Island. American Jour. Sci., vol. 237, pp. 651-655.

SMITH, W. S. T.

1897. The geology of Santa Catalina Island. Calif. Acad. Sci., Proc. ser. 3, Geol. vol. 1, pp. 1-71.

1898. A geological sketch of San Clemente Island. U. S. Geol. Survey. Ann. Report 18, pt. 2, pp. 459-496.

1933. Marine terraces on Santa Catalina Island. American Jour. Sci., 5th ser. vol. 25, pp. 123-136.

STOCK, C.

1930. Rancho La Brea: a record of Pleistocene life in California. Los Angeles Mus. Pub. 1 (Science ser. 1), 84 pp.

1935. Exiled elephants of the Channel Islands, California. Sci. Monthly, vol. 41, pp. 205-214.

TRASK, P. D.

1931. Sedimentation in the Channel Island region, California. Econ. Geol. vol. 26, pp. 24-43.

WHITNEY, J. D.

1865. Report of progress and Synopsis of the Field-work, from 1860 to 1864. Geol. Survey California. Geol., vol. 1, 498 pp.

WOODFORD, A. O.

1924. The Catalina metamorphic facies of the Franciscan series. Univ. Calif. Pubs. Geol. vol. 15, pp. 49-68.

WOODRING, W. P.

1935. Fossils from the marine Pleistocene terraces of the San Pedro Hills, California. American Jour. Sci., 5th ser. vol. 29, pp. 292-305.

WOODRING, W. P., M. N. BRAMLETTE AND W. S. W. KEW

1946. Geology and paleontology of Palos Verdes Hills, California. U. S. Geol. Survey, Prof. Paper 207, 145 pp.

YATES, L. G.

1890. Notes on the geology and scenery of the islands forming the southerly line of the Santa Barbara channel. American Geol. vol. 5, pp. 43-52.

INDEX OF SCIENTIFIC NAMES

Plate references are printed in bold face.