No. 17 May 15, 1953

ATOLL RESEARCH BULLETIN

17. *Handbook for Atoll Research (Second Preliminary Edition)*

edited by F. R. Fosberg and Marie-Helene Sachet

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences—National Research Council

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ACKNOWLEDGEMENT

It is a pleasure to commend the far-sighted policy of the Office of Naval Research, with its emphasis on basic research, as a result of which a grant has made possible the continuation of the Coral Atoll Program of the Pacific Science Board.

It is of interest to note, historically, that much of the fundamental information on atolls of the Pacific was gathered by the U. S. Navy's South Pacific Exploring Expedition, over one hundred years ago, under the command of Captain Charles Wilkes. The continuing nature of such scientific interest by the Navy is shown by the support for the Pacific Science Board's research programs, CIMA, SIM, and ICCP, during the past six years. The Coral Atoll Program is a part of SIM.

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Correspondence concerning the Atoll Research Bulletin should be addressed to the above

c/o Pacific Science Board
National Research Council
2101 Constitution Avenue, N. W.
Washington 25, D. C., U. S. A.

PREFACE TO SECOND PRELIMINARY EDITION

The "Preliminary trial edition" of this Handbook, issued in May, 1951, was unfinished, as some of the manuscripts had not come in by the deadline. The intention was to distribute only the few copies needed at that time and to issue the finished book when all the material was ready. Since there was much delay in this, it was thought best to allow the authors a chance to revise their sections in light of subsequent experience and criticism, and to re-edit the whole book. This has been done, with the result that several chapters have been replaced entirely, others reorganized, and several new sections added. In this edition there has been little editing of the content of manuscripts, but mostly correction of punctuation and ambiguity of expression. Differences in style and differences of opinion on certain techniques and scientific points are those of the authors. Such differences of opinion merely reflect the fact that not everything is positively settled about coral atolls. In such cases, as well as in anything else, experience of users pointing one way or the other, or which could in any manner contribute to an improvement of the Handbook, should be brought to the attention of the editors. Any such notes will be kept on file until such time as a final edition of the Handbook is written.

The editors and the Pacific Science Board again wish to express their thanks to all who have contributed to this edition.

INTRODUCTION [TO PRELIMINARY TRIAL EDITION]

by F. R. Fosberg

One of the projects recommended by the Honolulu Symposium* on Coral Atoll Research was the preparation of a Handbook on Atoll Research, for use by future Atoll Project expeditions, as well as by other parties and individuals who might be in a position to make observations of interest to the Project.

Obviously, it was too late to produce such a handbook in finished shape in time for this summer's expedition to the Gilbert Islands. It was felt, though, that as much information as possible should be placed in the hands of those taking part in this expedition, and that this might be produced in the form of a preliminary trial edition of the handbook. Use of this during one season would doubtless bring out the spots where it most needed amplification or revision. The present mimeographed series of essays is the result of an attempt to carry this out.

A tentative outline was prepared and the sections were given to various workers whose specialties or experience qualified them to write preliminary discussions on short notice, and they were requested to write what they could in a very short time. It is to the great credit of those asked to cooperate that their contributions came in so promptly and so adequately covered the subjects treated.

The contributions have been edited only for minor details of punctuation, spelling, and grammar. Where my own experience has suggested that anything might be added with benefit to the user, since there was not time to correspond with the authors, additions have been made in square brackets thus: [....--Ed.]

It must be emphasized that both the topics covered and the essays here presented are tentative and preliminary. The Handbook, in its ultimate form, will depend, for its quality and adequacy, on suggestions, corrections, and criticisms evoked from readers and users by this preliminary version. All such suggestions will be welcomed and should be submitted in writing to the Pacific Science Board, Washington, D. C., or Honolulu.

Although it was decided at Honolulu that Mr. E. H. Bryan, Jr., should prepare the Handbook, it was felt that it would be unfair to ask him to meet the deadline necessary for this preliminary edition, and that since Miss M. H. Sachet was in the employ of the Pacific Science Board, working on the bibliography for the Atoll Project, she could logically be assigned the editing of this draft. Thus, much of the necessary detail will be taken care of in the task of editing the final Handbook.

I wish to extend the sincere thanks of the editor and of the Pacific Science Board to all who have so willingly given their time and written the sections that follow.

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* Organized by the Pacific Science Board of the National Research Council, with the cooperation of various Honolulu scientists, and held at the University of Hawaii on February 5 and 6, 1951.

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Chapter 1 -- Geography

INTRODUCTION TO THE GEOGRAPHY OF ATOLLS

by E. H. Bryan, Jr.

The study of atolls, being sponsored by the Pacific Science Board of the National Research Council, has two broad objectives. The first is to investigate total environmental interrelationships on atolls. The second is to apply the knowledge gained from such studies to improve the wellbeing of persons living upon atolls. At its best, an atoll presents a harsh environment in which to live. Numerous atolls are inhabited, and several, particularly in the Gilbert Islands Colony, are overpopulated, which adds to the difficulty. These atoll studies are being made in cooperation with a project of the South Pacific Commission to improve human conditions on atolls.

This handbook presents suggestions for various types of investigation on atolls. By way of introduction, I have been asked to summarize some general aspects of the subject: What is an atoll? What is the range of physical form? Where are atolls found? What are some of the theories of their formation? What general observations are needed concerning atolls?

WHAT IS AN ATOLL?

A "coral reef" is an accumulation of limestone principally derived from skeletons of marine animals and plants, especially corals, foraminifera, mollusks, echinoderms, and red and green algae. These may or may not be in their original location or position of growth. The structure extends from the sea bottom near or quite to the surface. Changes in sea level or elevation of the sea bottom may cause it to protrude above the present level of the ocean.

Reefs occur chiefly as fringing reefs, barrier reefs, and atolls. In addition, there may be reef structures which do not fall into any one of these categories.

Fringing reefs are platforms of reef which extend out a relatively short distance from the shores of both high and low islands, even continents. Such reefs are not at uniform depths below sea level and may be cut by channels, especially opposite the mouths of streams, for reef organisms do not develop in fresh or silty water.

Barrier reefs lie at a greater distance from shore, with relatively deep water between. The Great Barrier Reef, for example, lies up to 90 miles off the coast of Australia, with soundings of 20 fathoms in the intervening channel. Barrier reefs may be cut by channels, and there may be islets upon them, but the proximity to other land, which usually is high, distinguishes them from atolls. The barrier reef around the Truk group illustrates this point. Although the reef resembles an atoll rim, Truk is <u>not</u> an atoll because of the high islands within its lagoon.

An atoll is a physiographic structure, composed of reef, broken reef rock, and sand, rising abruptly from the ocean, and typically enclosing a shallow lagoon, which does not contain "high" islands. The popular conception is that an atoll rim is circular. This seldom is the case. More frequently it is angular or elliptical. There is great range of size, shape, and form. Some atolls are completely submerged, with no dry land. At the other extreme we find "raised atolls", the reef rim of which is raised to a considerable height above sea level, enclosing a dry lagoon basin. Every intermediate form can be found. Some atolls have a great number of distinct islets (Kwajalein has about 95), and numerous entrances or channels. On some atolls the islets may be connected by ridges of sand, with few lagoon entrances. The next form in this sequence (which I call the "doughnut") has a continuous ring of land surrounding the lagoon, which may vary from very salt (Sydney Island) to quite fresh (Swains Island), depending chiefly upon the rainfall and the permeability of the material of which the atoll is composed. The size of the enclosed lagoon becomes smaller and smaller, in our series, until we reach the "pancake" with no lagoon. On the "pancake" island the marginal rim and enclosed basin may be distinct (as in Baker or Jarvis Islands) or the island may be quite flat (Howland), or so covered with trees that the basin is not apparent (Vostok or Flint). The highest part of such islands generally is just behind the windward beach, and rarely exceeds about 20 to 30 feet, usually much less. Any greater height would require an uplift of the land, as is the case on Fais, Nauru, and Ocean Islands.

The question is, when does an atoll cease to be one? The point is academic. One has to make his own definition, depending upon the circumstances. It was decided at an atoll symposium, held in Washington, D. C. and Honolulu, in 1951, that, for the purpose of our studies, we would include non-elevated limestone structures, with dry land, with or without a lagoon, which were not associated with high land. We would exclude elevated atolls (reaching a height of more than 20 feet or so), sunken atolls (without dry land), barrier reefs surrounding high islands (such as Truk), and reef structures on fringing shelves or platforms adjacent to land masses (such as the Great Barrier Reef, the islands in the Bay of Batavia, Java, and the like.)

DISTRIBUTION OF ATOLLS

The writer has undertaken to compile a list of known atolls for the Pacific Science Board. To date these number about 400. They are located chiefly in the Pacific and Indian oceans, most of them between the Tropics. The ones furthest north are Kure and Midway, at the northwestern end of the Hawaiian chain (28° 25' North). Those furthest south (excepting Pelsart Island and Middleton and Elizabeth Reefs) are Oeno and Ducie (24°40' S.). The greatest concentration is in the Central Pacific: Equatorial, Northern Cook, Tokelau and Phoenix (together 35); Ellice (9), Gilbert (16), Marshall (33), Caroline (40), and isolated in the Northwest Pacific (3), a total of 136. The Tuamotu archipelago contains 75, with 4 more to the east and 7 to the west of it. There are 5 in the Hawaiian chain; 8 in Fiji (not counting a host of small circular reefs without land); 27 between Fiji and Australia, chiefly in the Coral Sea; 6 north of the Solomon Islands; 6 in the Louisiades; 20 near the Admiralty Islands; 9 northwest of Australia; 15 in Indonesia; 41 in the central Indian Ocean (Laccadive 13, Maldive 22, and Chagos 6); and 26 in the western Indian Ocean. Only one has been recognized in the Atlantic (Rocas Reef, off Brazil). There are 25 potential atolls in the Caribbean Sea, but whether or not they are comparable with those in the Pacific and Indian Ocean is in dispute.

If we follow the custom of the taxonomist, the type locality of atolls would be the Maldive Islands, where the native name atollon is used to designate the reef rings found there. These differ in structural detail from "typical" atolls in the Pacific.

ACCEPTED IDEAS REGARDING REEFS AND ATOLLS

Harold T. Stearns (1946) has listed various factors which now are generally accepted by geologists. They are:

"1. Reef building corals thrive only at moderate depths, usually less than 200 feet below sea level in warm, fairly clear ocean water.

2. Nullipores [coralline algae] bind corals together and make a reef possible. In some places nullipore reefs exist nearly free of corals.

3. Sea level was lowered about 300 feet during the Pleistocene by the abstraction of water for the ice caps. If all the ice on earth were melted today, sea water would rise about 150 feet.

4. Changes in the configuration of the ocean basins and consequent changes of sea level have occured since Miocene time to an undetermined extent.

5. The Sialic (continental) islands bordering Australasia [including Melanesia and western Micronesia] are underlain by folded rocks.

6. No folded rocks are exposed in the Simatic (oceanic) islands [Polynesia, except perhaps Tonga and New Zealand] except for slight warping which occurs locally, usually in calderas.

7. Emerged reefs of Tertiary age are exposed in many islands.

8. Coral atolls are not generally formed by growth upward from crater and caldera rims.

9. Coral atolls rest on basements of volcanic or other non-coralliferous rock.

10. Barrier and fringing reefs require shelves built with their own talus, antecedent platforms or shelves of some other origin, or gently shelving shores of any origin.

11. The growth of corals is relatively rapid under favorable conditions, variously reported from 20 to 90 feet in 1,000 years.

12. Very rapid submergence may drown a reef.

13. Reefs at sea level are killed by emergence.

14. Coral reefs grow most rapidly at their outer edges in the breaker zone where the food and oxygen supply is greatest.

15. The lagoons of atolls are not caused by submarine solution."

[Evidence for some solution of limestone in the intertidal zone recently has been pointed out.]

Dr. Stearns proceeds to examine the various theories which have been proposed to explain the formation of reefs and atolls, and to develop some modifications of his own. He points out that the shelves and platforms upon which reefs have grown have been built by volcanism, sedimentation, or diastrophism, or out by marine or subaerial erosion. Examples of all can be found, he says, and "the origin of many shelves can be determined by study of the geology of the adjacent land, but much drilling and geophysical work is needed to determine the origin of submerged platforms."

THEORIES FOR THE FORMATION OF ATOLLS

It is not the object of this summary to discuss the relative merits of the various theories for the formation of atolls which have been proposed. A brief listing of the principal theories is given chiefly to suggest the kinds of observations which need to be made.

In 1928, William M. Davis' monumental work on coral reefs was published. This summarized the theories for reefs and atolls to that date. Many detailed observations on the subject have been made since then, and the resulting ideas should be outlined to bring the subject up to date. One of the more recent summaries, which presents a relatively unprejudiced comparison, is "The problem of coral reefs," by Harry S. Ladd and J. I. Tracey, Jr., (1949). Another recent summary is given by Ph. H. Kuenen in his "Marine geology," (1950). During the past 20 years, several other valuable contributions have been published (see bibliography, below.). Contributions are being made at an accelerated rate.

In order of presentation, the principal theories have been:

1. In 1821, A. von Chamisso proposed a theory for atolls based on the natural growth of corals around the edge of submerged banks, observing that massive corals grow best around the seaward edge of reefs, while those within are killed or stunted.

2. Charles Darwin's famous "subsidence theory" was published in 1842. It suggested that fringing reefs growing around a sinking volcanic island would build up around their outer edge to form a barrier reef, and that an atoll would result when the enclosed island had sunk entirely and its summit, probably buried by coral debris, was submerged beneath the lagoon. This theory was supported and expanded by James D. Dana and favored by Davis.

3. Carl Semper (1863), working in Palau, suggested that reefs were formed by outgrowth on a rising foundation, and that the lagoon of an atoll was formed by solution of the enclosed living reef.

4. Discovery of submerged elevations in the sea prompted Sir John Murray (1880) to go back to von Chamisso's original idea that atolls formed by the upgrowth of corals around the edge of still-standing, aggraded submarine banks. Similar ideas were held by J. J. Rein, H. B. Guppy, and F. Wood Jones. W. J. L. Wharton suggested that the foundations could have been completely truncated by erosion, or incompletely truncated.

5. In 1910 (and later), R. A. Daly developed his "glacial control theory," which supposed that during the glacial period, when sea level was lowered by the removal of sea water to form glaciers, platforms were formed, around the edges of which reefs were built up in the warmer seas as sealevel rose, following the melting of the glaciers. Up growth kept pace with rise of sealevel, forming the present barrier reefs and atolls.

6. In 1928, W. M. Davis amassed a tremendous amount of evidence in support of a combined subsidence and glacial control theory, in which inhibition of coral growth by lowered temperatures in the marginal belts of the coral seas during glacial times played a great part. He favored a modified subsidence theory which did not involve regional subsidence of the sea bottom but individual subsidence of islands separately.

7. J. F. F. Umbgrove (1939 and 1947), unable to find evidence to support the glacial control theory in his studies of the reefs of Indonesia, described evidence for crustal movements during the Pleistocene. He stated that elevated reefs in that area were formed in late Tertiary or early Pleistocene, then uplifted and eroded. He noted that other reefs could be explained by Darwin's subsidence theory.

8. J. E. Hoffmeister and H. S. Ladd (1944) presented evidence for the antecedent-platform theory. This was based chiefly on studies in Tonga and Fiji, where there is land movement due to folding. It suggests that volcanic cinder cones are eroded to a depth of about 150 feet below sea level, and then the resulting platforms are built up by non-coralliferous deposits until reef-building corals can commence their growth, chiefly around the periphery. This theory obviates both subsidence and glacial control. Later studies in Micronesia, particularly as a result of deep drilling on Bikini atoll, have caused these authors to modify or broaden their ideas.

9. In 1945 and 1946, Harold T. Stearns suggested that great eustatic shifts of sea level occured during Pliocene and Pleistocene time, as a result of changes in the configuration of ocean basins. On sialic (continental) islands, he said, reefs formed on rising foundations, caused by folds. On simatic (oceanic) islands of the central Pacific block, they developed on subsiding islands. The appropriate hypothesis was used in each case.

10. In 1947, Ph. H. Kuenen, elaborating Davis' ideas, combined the two chief theories into a "glacially controlled subsidence theory," suggesting that preglacial reefs were cut down to glacial sea level by chemical means, and that reefs grew around the edge of such platforms.

Summary: It will be noted that the important theories fall into two main groups: those that involve a relative change of level between land and sea, and those which do not. Of the former group, some favor a rising foundation, others a sinking foundation, and others a sinking and later rising sea. The chief argument in the other camp seems to be how the foundation was formed and how it became a suitable habitat for the growth of reef organisms. There is good evidence that the sea shifted its level during the glacial period, and doubtless in previous eras. It is also known that oceanic islands can settle as well as be built up, and that other islands, which are remnants of a more ancient land mass, can move up and down with the folding of their foundations.

The trend seems to be for geologists to cease their feuding and to agree that one theory can account for the formation of reefs and atolls in one region, while those in another region may have another explanation, even a combination of theories. Professor Kuenen states that he is in complete agreement with the statement of Hoffmeister and Ladd (1935) that "Probably no single reef theory will explain all reefs. Certainly, recognition of the complexity of the problem is essential to its solution. It does not belong within the realm of any one subject, but requires the attention of scientists of many fields, each contributing his share."

DETAILED FEATURES OF ATOLLS

Careful studies of atolls, such as those recently made at Bikini, are much needed. They show that "an atoll is a composite reef made up of a number of distinctive reef types - windward reefs, leeward reefs, and lagoon reefs. Most of these are zoned relative to prevailing winds and currents. Organic growth, erosion, and deposition of sediment influence each of these zones, but in each the balance of forces operating at the present time may be roughly appraised. Some reef zones appear to be making headway against the sea, others appear to be essentially in a state of equilibrium, while still others are being eroded. Organic growth is the source of all the materials that make up an atoll. Some of the skeletons of the reef-building organisms remain in position of growth after death, but a much larger proportion are broken up by physical and organic agencies to form sediments that are deposited on the seaward slopes or in the lagoons. So long as organisms live on an atoll, it continues to grow, but it grows mainly by the accumulation of classic sediments." (Ladd, Tracey, Wells, and Emery, 1950.)

The above abstract summarizes the kind of study needed for more atolls. It scrutinizes an atoll zone by zone: the Lithothamnion ridge, the coral-algal zone, the reef flat, the beach; submarine cliffs, eroded edge, boulder ramparts; various parts of the lagoon, including the coral knolls. It attempts to evaluate the balance of forces operating on an atoll, which have produced these formations.

TYPES OF INVESTIGATIONS NEEDED

Ladd and Tracey (1949) suggest the following promising fields in atoll investigation.

1. "Island geology. Reef-encircled islands of all types should be mapped geologically." This raised the need for adequate base maps of convenient scale and considerable accuracy. In cataloging the known atolls, the writer has noted that but few atolls, outside of Micronesia, are mapped or charted in any detail, or with any accuracy. The use of the aerial photograph, so widely used in the Pacific during World War II, should be of tremendous value in this connection.

2. "Reef studies. Additional ecological studies such as those carried out on the Great Barrier and at Bikini on organic productivity of reefs are needed."

3. "Lagoon studies. Mapping and coring of lagoon sediments yield data that are of great value in the interpretation of elevated limestones and of the cores and cuttings obtained from drilling. When such information is combined with data obtained from dredging on the outer reef slopes, it is possible to make sound paleoecological interpretations and to determine the significance of the several types of limestone that occur in reef areas." Study is needed also of the internal constitution of the numerous coral knolls rising from the lagoon floor.

4. Submarine geology. More details are needed regarding the structure of seamounts, discovered in considerable number in the Pacific. "Dredging and additional coring of these structures should give more clues to their origin and, perhaps, their age. Specifically, it is essential to learn if they have a hard rim with a central depression now filled with sediment; to determine if the coating of recent sediments is thick, and if it contains pebbles of hard rock suggesting an origin of wave erosion."

"Studies of isolated banks in the coral seas at 300 - 1,000 feet below sea level would give needed data on the types of sediments that accumulate and the kinds of organisms that live in reef areas at depths below the limit of reef coral growth."

5. Island foundations. More drilling and geophysical investigations are needed.

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Other subjects in need of investigation include:

How do climatic factors tend to modify atolls? These include wind direction and velocity, force of tropical storms, temperature, and rainfall.

What is the effect upon reefs and atolls of ocean currents, tsunami and other large waves, water temperature and salinity?

What are the geographic names in use by the native inhabitants for islets and localities on atolls?

How has man modified atolls? He is known to have removed sand and guano, dredged reefs and cut channels into lagoon basins. What has been the effect of these? He has made large withdrawals of ground water, dug pits for cultivation, removed the natural vegetation.

Items to note regarding human inhabitants include: the number of persons and their areal distribution; land utilization, including areas used for residences, crops, exploitation of the lagoon, and the like.

The general observations, listed above, together with the specific directions presented in the pages which follow, should help to make possible a study of total environmental interrelations on atolls, and result in improved conditions for those who make atolls and reef islands their home.

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Chapter 2 -- Meteorology

NOTES ON THE COLLECTION OF METEOROLOGICAL INFORMATION ON TROPICAL ISLANDS

by Luna B. Leopold

There is considerable truth to the general belief that meteorological records must have considerable length to be useful for hydrologic and climatic work. On the other hand there are some areas of the world where meteorological information is so meager that a relatively small volume of observational data taken by a careful observer can be very useful for several purposes. The accompanying notes describe very briefly the kinds of information a scientist can easily gather in connection with other work. Emphasis is placed on observations of simple nature requiring the minimum of instrumentation, and on data which may prove useful for the interpretation of biologic and ecologic data.

Rainfall

The mean annual rainfall over the open ocean is very poorly known over great areas of the world. Observations taken near the seashore in a location essentially free of orographic influence approximates closely the rainfall of the open ocean. The main difficulty is to choose a location which is free from orographic effects. On an island sufficiently small it is desirable to measure rainfall near both the leeward and windward shore, as well as on a topographic high. On an atoll, observations at three such points might be made without undue trouble in connection with other work. If measurements cannot be made at more than one location, at least a series of observations should be taken at the base camp and the location should be described with care.

To measure rainfall nearly any kind of a container can be quite satisfactory though a standard gage is eight inches in diameter. It has been shown that even cylinders of one inch diameter generally approximate the catch in the standard gage. A very satisfactory gage may be made out of a large size tin can, approximately four inches in diameter and nine inches tall. If a large can is not available a standard tin can holding about two cups may be used.

The can should be set on a post so that the open end stands 24 inches above the ground. The open end should be approximately horizontal. From the open end of the can a cone, sloping up and outward at 45°, should not intersect any obstruction such as a tree or house. As the above description implies, the most representative rain reading is obtained in a location as exposed as possible despite our intuitive feeling that a gage should be protected from the wind.

The gage should be read about the same time every day, preferably in the morning at approximately 7 o'clock. A stick may be calibrated with pencil marks to show the depth of water in the can. The depth should be expressed in inches on the area exposed on the open end of the can. If a bucket is used which converges to smaller diameter at the bottom than at the top, it is clear that the actual inches in the bottom of the can will be too large. If a glass jar is used in which the open diameter is somewhat smaller than the diameter at the base, the inches of depth in the jar will give too small a reading. The calibrated stick can be easily made to give the proper reading.

If the gage cannot be read once a day the reading should be taken at uniform intervals of a week or a month, in which case a few drops of oil should be put in the can to reduce the evaporation.

Wind Direction

Wind direction should be observed at a relatively open place and should be recorded to at least 8 points on the compass and preferably 16. Because there is a diurnal change of wind direction as a result of land and sea breezes, wind direction should be recorded both in the morning and evening.

Wind direction measurement is facilitated by the construction of a simple vane which can be made out of a stick and flattened tin can tacked on the end. A nail should be driven in the stick so that it goes through the center of gravity of the vane. Such a simple vane can be constructed in a few minutes and mounted on the top of a post, the height of which should be theoretically 18 feet, but in practice need not be that high. If the vane is 8 feet above the ground it will be quite satisfactory. If such a vane is installed near the base camp and as many as 4 readings a day can be taken, a much better picture of the land and sea breeze may be obtained.

Wind speed may be estimated by the use of the following scale:

Table 1 -- Beaufort Wind Scale for Observations on Land Stations

Force	Explanatory title	Specification for use	Miles per hour
0	Calm	Smoke rises vertically	1
1	Light air	Direction of wind shown by smoke drift, not by wind vanes	1-3
2	Light breeze	Wind felt on face; leaves rustle; ordinary vane moved by wind	4-7
3	Gentle breeze	Leaves and small twigs in constant motion; wind extends light flag	8-12
4	Moderate breeze	Raises dust and loose paper; small branches are moved	13-18
5	Fresh breeze	Small trees in leaf begin to sway; wavelets formed on inland waters	19-24
6	Strong breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	25-31
7	High wind	Whole trees in motion; inconvenience felt when walking against wind	32-38
8	Fresh gale	Breaks twigs off trees, generally impedes progress	39-46
9	Strong gale	Slight structural damage occurs (chimney pots and slates removed)	47-54
10	Whole gale	Seldom experienced inland; trees uprooted; considerable structural damage occurs	55-63
11	Storm	Very rarely experienced; accompanied by widespread damage	64-75
12	Hurricane		75

Temperature

A thermometer for measuring air temperature should be hung so as to be well ventilated and constantly in the shade. Readings should be made at the same hour each day, preferably in the morning if only one observation is made each day. It is observed that when one becomes acclimated to the tropics he becomes increasingly sensitive to small changes in the temperatures. Therefore, at the time of the temperature reading it would be of interest to note, even subjectively, the observed impression of the relative warmth of the day, using such terms as excessively hot, hot, warm, cool or very cool. The maximum temperature of the day will generally occur approximately at 2 P. M. and the minimum temperature at about 5:30 A. M. If two readings a day are possible they should be made at these times.

Measurements of dew are very desirable because data on dew are meager. Estimates of the amount of dew may be made by walking through a patch of grass or by shaking the leaves of a bush. Amount of dew should be recorded as heavy, medium, light or none. Estimates of dew should be made at the same time the temperature readings are made in the morning.

Water Temperature

At least weekly records should be made of the temperature of the ocean in a relatively exposed spot, not in a lagoon. Because ocean temperature changes are relatively small the ocean temperature should be read to the closest half degree F. or quarter degree centigrade. Observations should include a description of the place where ocean temperatures are made.

Wind Direction Aloft

The direction of winds aloft may be estimated by observing the direction of movement of different levels of clouds. Clouds may be classified in three classes; fair weather cumulus or trade wind cumulus are considered low clouds. Their height is generally about 2,000 feet and their tops may be 4,000 to 8,000 feet. Their direction should be estimated separately from clouds of other heights. Middle clouds in the tropics generally occur at 14,000 to 20,000 feet and may be identified by their relatively thin appearance. The most common type in the tropics are alto-cumulus which may be identified by their resemblances to tradewind cumulus except they are arranged in some linear or repetitive pattern. Alto-cumulus are often described as small lambs-wool clouds.

The high clouds are cirrus clouds which generally occur above elevations of 30,000 feet. They are generally identified by their wisp-like pattern, and the common mares-tail clouds are of the cirrus type. A record of the direction of movement of these three levels of clouds is more important than the speed of the clouds.

Diurnal changes in cloudiness should be noted, particularly the repetitive patterns such as afternoon thunderstorms and sea-breeze clouds caused by the meeting of trade wind and sea breeze.

Chapter 3 -- Geology

GEOLOGIC STUDIES OF ATOLLS

by J. W. Wells

The significant features of atolls are the reefs, lagoon, and islands. The reef is the primary structure; the lagoon is enclosed by it; and the islands are transient features of secondary importance.

The following outline of geologic features of atolls gives an idea of the data and materials to be collected and studied.

I. Reefs.

A. Seaward Reefs.

1. Windward.

2. Leeward.

Relations to prevailing winds and currents. Passes. Algal ridges. Width of flats. Distribution and zonation of coral genera and species, and other hermatypic organisms over the reef. Outer slopes: surge channels and steepness of slopes. Correlation of reef types with classification of Ladd, Hoffmeister, and Tracey. Distribution, origin, and condition of niggerheads and rubble. Traverses and profiles to implement data.

B. Lagoon reefs.

Width of flats and development with relation to size and strength of lagoon waves. Lagoon margins and slopes. Source of sediment on flat and slope. Zonation of corals.

C. Coral knolls.

Pattern of distribution. Any relation to reefs and passes?

II. Lagoon.

Depth. Nature of bottom sediments. Coral zonation on slopes and over bottom.

III. Islands.

Distribution. Beaches. Boulder ridges. [Depressions - Ed.] Beach conglomerates and sandstones. Island sandstone. Dune ridges. Phosphate deposits.

IV. Processes.

A. Degradational. Effects of normal waves, swells, and local currents. Degradational beaches. Effects of typhoons: frequency; destruction of islands. Evidence of exposed beach conglomerates, sandstones, and island sandstones, bearing on former islands. Development of rubble tracts on lagoon and seaward reefs. Development of new islands subsequent to typhoon destruction.

B. Aggradational. Movement of sediment over reefs into lagoon. Tidal deltas. Building of beaches. Source and composition of wind-transported particles and development of dune ridges.

C. Uplift and eustatic changes. Evidence of these?

Data on all these points are important in the general problem of the origin and natural history of atolls, as well as the more specific problem of the recent history and relative development of a particular atoll. Well documented collections of corals and other hermatypic organisms are significant in the problem of the geographic distribution of the Indo-Pacific hermatypic fauna.

COLLECTING GEOLOGICAL DATA

by Martin Russell

Many features of importance to the geologist will be seen by observers whose main interest may not be geology. Because geologists need more information on atoll composition, structure, and development, the non-geologist could make valuable contributions to the geological sciences if he would record observations about easily recognized features as he pursues his own particular scientific interest. Examples of the significant geological features of atolls have been described in one form or another. But, like words in a dictionary, though they may be known, they have little significance until they are fitted intelligently into a coherent story, by a writer in the case of words, by an intelligent observer and scientist in the case of geological features. If you would record what you see, you could, with little effort, do much to help the geologist.

A knowledge of certain basic features of an atoll is necessary in almost any field of atoll research. The chapter "Introduction to the Geography of Atolls" should make clear the names of these features, which become obvious to anyone after a few days on an atoll. Once understood, they should be freely used for orientation in making notes.

I. Reefs
   A. Seaward reefs
      1. Windward
      2. Leeward
   B. Lagoon reefs
   C. Coral knolls

II. Lagoon

III. Islands
   A. Seaward beach
   B. Lagoon beach
   C. Inland surface

A notebook and pencil should be carried at all times and if a large-scale base map is available it may be used to record the location of the features described. The following are the features to be seen that deserve a few lines of description in your notebook. One should not hesitate to report descriptions if similar features are observed in two or more locations. Some of the <u>names</u> of the features and the <u>characteristics</u> which should be noted are underlined.

REEFS. The growth, extent, and form of the reefs depend to a large degree on the winds and water currents passing over them. The observer should start out on a reef an hour or more before low tide, noting <u>width</u>, which ranges from a few tens of yards to a mile or more. Commonly there is a distinct <u>zonation</u>. On windward reefs there may be a reddish tinged algal (or "Lithothamnion") ridge a foot or more higher than the reef flat, upon which the waves break; note the steepness of the outer slope and the surge channels running perpendicular to the reef front through which the sea rushes forward then back with each wave. Step carefully here for the reef may be very cavernous or honeycombed and a false step or slip would result in a nasty fall or an unexpected bath. Immediately shoreward of the reef front may be a pavement-like flat covered with mossy algae, close inspection of which may disclose multitudes of tiny sand-grain sized, cream-colored Foraminifera. The calcareous shells, or tests, of these animals are swept back over the reef to form a considerable portion of the beach sands and loose floor of the reef and lagoon. Note their concentration in different sandy deposits throughout the atoll. Between the reef front and the shore may be many different reef environments which should be noted: isolated coral growths separated by waist-deep, sandy bottomed water; shallow sandy areas; rough coral flats; and isolated channels or areas of deeper water. Note the different types of coral growth which commonly are restricted in distinct areas (delicately branching colonies, solid smooth heads, bluish palmate colonies, etc.)

On the leeward reefs, the picture may be much different, zonation may not be distinct, the reefs are commonly much narrower, and individual coral and algal forms may be more delicate and varied. Note the distribution and condition of reef blocks (negro heads) torn from the reef edge by tropic storms and cast upon the reef flat.

Anywhere on the reefs may occur sand or rock groins, platform-like structures which stand clearly above the level of the general reef flat. Any measurements of their height (above the general reef flat, in feet) and notes on their distribution, and orientation would be a valuable aid in determining the extent of geologic uplift and/or change in sea level.

Most atolls have distinct breaks or passes in the continuity of the reef ring. Distinguish whether these are clearly breaks with no reef growth or merely parts of the reef over which the water is deep enough for navigation.

On parts of the reef, commonly near islands, some currents form sand bars, and spits curving away from islands. Be sure to note, if possible, any difference in their size, shape, or location from those shown on any map you may have.

The reefs on the lagoon side may exhibit different forms around the atoll depending on the size and strength of waves generated within the lagoon. It is generally found that lagoon reefs on the windward side of the atoll (but leeward of their reef or island) are less developed than lagoon reefs on the opposite side where the waves generated by winds sweeping across the lagoon are sufficient to encourage extensive coral growth. Here again any zonation of reef type, observable features of the reef margins, slopes and character of sediments should be noted.

Should you be fortunate enough to fly over the atoll and its lagoon watch for coral knolls, which are masses of coral that grow to within a few feet or tens of feet of the surface of the water. Note their size, shape, relative numbers, and pattern of distribution if any. Note in what relation to passes, islands, or abrupt change in direction of the reef ring these knolls occur.

ISLANDS. Beachrock, a common feature of the intertidal zone, generally dips (angle between a horizontal plane and the layered surface of the rock) toward the open water, a reasonably definite indication of the slope of the beach sands from which the beachrock was formed. It follows that should you record beachrock dipping toward the island instead of the open water, that there has been a shifting of the islands (by storms, currents, wind, etc.). In some places on the reef ring, the existence and even outlines of former islands can be inferred from lines of beachrock, now submerged, out on the open reef and between present islands. A feature generally found only on the seaward beaches of leeward islands is the boulder rampart.* Immediately above the intertidal zone there may extend a mass of water-worn and rounded boulders. A cross section of this mass perpendicular to the shore may show two, three, or four "steps" or ridges. These are formed during the infrequent but particularly severe storms.

Other island features of note include a) mangrove swamps containing brackish water; b) guano, a light gray, powdery material filling crevices or encrusting rocks; from action of bird droppings or calcareous rocks; c) layers of cemented phosphatic sandstone, commonly 4 to 10 inches thick, formed from action of bird droppings on calcareous rocks, but occurring only a few inches beneath the humus mat of *Pisonia grandis* forest; d) any unusual depressions; e) wind-formed sand dunes or irregular ridges; and f) the depth and thickness of any hard, cemented layer encouraged in excavations on islands. Because calcium carbonate (limestone) is the only material deposited by the reef-building organisms, the occurrence of any other rock material (hard, soft, or loose) is of especial interest (pumice, for example).

In describing the sands, rocks, gravel, and so forth, it is well to remember that four types of organisms are responsible for about 95% of the reef and island material on atolls. These are 1) hard or massive coralline algae (reef flats, reef front); 2) coral (colonies on reef flats, coral knolls); 3) segmented algae (the lagoon); and 4) Foraminifera (reef flat, lagoon).

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* This is termed a boulder ridge or a beach ridge by some workers. There are several other uses of the term "rampart", especially the application to a ridge lying on the reef flat, with water behind it, by those who have studied the Great Barrier Reef islands, Australia. -- Ed.

BEACHROCK

by K. O. Emery

Beachrock occurs around many islands of the Atlantic, Pacific, and Indian Oceans and even on the shores of some of the large lakes of the western United States. At Bikini Atoll, in the Marshall Islands, it covers perhaps 15 percent of the beach area, exhibiting no marked preference for seaward or lagoonward sides. It is practically restricted to the intertidal zone. Except for cementing calcite, it is the same in composition as the loose beach material that adjoins or overlies it: corals, Foraminifera, echinoid spines, shells, and calcareous algae. Usually, the grain size is also similar to that of the beach material, and, just as in the beach, the sand grains in the beachrock form alternating coarse and fine-grained laminae from 1/16 to 1 inch thick. These laminae, as well as the surface of the beachrock, have, in places, the same slope toward the water as does the surface of the loose beach sand; where the beaches are of cobbles, the beachrock is apt to exhibit a similar composition.

In some areas the beachrock is collected and used as flagstones, building stones, and grave markers. It may form discontinuously, but certainly some of it in Kwajalein Atoll is of very recent origin, because of the inclusion of a Coca Cola bottle, shell cases, and other wartime debris.

Although there are numerous published references to the presence of beachrock, little is known of the mechanics of its formation. One theory requires humic acids carried by rainwater to dissolve calcium carbonate from the interior of islands and to deposit it again when the water seeps out through the beach. Another relates it to unknown biochemical processes. A few physical-chemical measurements made in a loose sand beach at Bikini showed that the interstitial sea water a few feet below the surface was acid enough to dissolve calcium carbonate, whereas that near the surface was alkaline enough to cause precipitation. Upward capillary movement of interstitial water is known to exist from studies of other beaches. It is supposed that the water-bearing calcium bicarbonate in solution rises close to the surface, where the higher pH, higher daytime temperature, and high evaporation cause loss of carbon dioxide [CO_2] and precipitation of calcium carbonate as cement. The accuracy of this theory is not yet known; it is hoped that more data can be secured in other investigations. Measurements of CO_2, alkalinity, pH, temperature, chlorinity, and calcium ion should be made on interstitial beach water at several depths over a 24-hour period to test this suggestion. Methods for some of these analyses are given by Doax Cox in connection with studies of ground water (see Chapter 4). Moreover, an attempt should be made to observe, if possible, an area where beachrock is being actively formed. Perhaps this would be indicated by weak incipient cementation.

Once deposited, the beachrock soon begins to be destroyed. Abrasion wears and polishes it to a shiny surface, often with flutings, and it also develops deep cylindrical pot holes. Wave action undermines it. Solution by sea water, charged with CO_2 from respiration of animals and plants at night dissolves some of the beachrock, forming shallow flat-bottomed solution basins that eventually join and deepen to develop a jagged surface.

SUBMARINE GEOLOGY

by K. O. Emery

Little is known of certain phases of the topography of coral atolls and still less is known of the distribution and types of their sediments. It would be highly desirable to obtain soundings and samples from atolls of the Gilbert, Caroline, and other island groups for comparison with the northern Marshalls, which have become relatively well known as a result of recent studies. Among the more important problems that can be attacked with makeshift equipment are the following:

1. Steepness of outer slopes. In the northern Marshalls the edge of the leeward reefs is very steep, locally vertical, to depths of 100 to 200 feet. Most of the windward reef, however, is bordered by a slope of about 45° to a depth of 20 to 30 feet, beyond which a terrace may locally extend several hundred yards to depths of 40 to 50 feet. The greatest width is within broad lagoonward indentations of the reef. The terrace probably marks the position of an old reef level, the geographical distribution of which is unknown. Soundings can be made during times of low waves from aboard a skiff, using a light line marked in feet and weighted at the end with a 5-pound piece of scrap iron or a rock. For the steep leeward reef, distance out from the reef can best be determined by paying out another marked line that is attached to the reef, taking a sounding at each distance interval of 2 to 5 feet. For the seaward terrace, distance from the reef can best be estimated.

2. Lagoon terrace. In the northern Marshalls the seaward terrace has its counterpart in a lagoon terrace that is several hundred yards wide, particularly within seaward projections of the reef. Its depth is 50 to 60 feet. Sounding profiles across it can be obtained in the same manner as for the seaward terrace, but under easier wave conditions.

3. Coral masses. Scattered about the lagoons of the northern Marshalls are roughly conical coral knolls that range from less than 100 feet to more than a mile in diameter. They rise from any depth of the lagoon floor, and their tops may be at any depth, including sea level. At Canton and Johnston Islands, however, instead of conical coral knolls, there are elongate ridges that divide the lagoons into compartments. It would be of interest to know the geographical distribution of the two forms of coral growth of the lagoons, their composition, and details of their shapes. Such investigations may be conducted by simple sounding operations and by observation with a face mask or glass viewing box.

4. Lagoonal sediments. In the northern Marshalls the sediments of the lagoon are arranged in a series of concentric belts. In water deeper than 180 feet the sediments consist chiefly of small Foraminifera. In shallower depths, enough sunlight reaches the bottom to permit growth of a calcareous green alga, <u>Halimeda</u>. This plant grows faster than the small Foraminifera, so at depths less than 180 feet it is dominant, completely masking the Foraminifera. Within a mile or two of the shore or reef and at depths of less than about 100 feet the <u>Halimeda</u> itself is masked by detrital calcium carbonate mostly of fine sand size, carried by currents from shore

or from the reef. Along the shore the sandy beaches consist largely of Foraminifera again, but the types are different from those of the deep water. They have their origin in the sand mantle of the reef flat. Most of them are discoid or flattened forms and are 1 to 3 mm in diameter. Coral is concentrated in knolls and thickets at any depth, and is of various types. The fine sand is the most rapidly deposited of the sediments. The small maximum depth of small lagoons is probably a result of the rapid filling that takes place when the belt of fine sand reaches to or near the middle of the lagoon. Profiles of bottom samples across the lagoons of atolls in other areas of the Pacific would provide welcome new information. Such samples can be obtained with simple equipment. For example, a useful dredge can be made by attaching the bail of a stout bucket to a line with a 5 to 10 pound weight tied a foot or so above the bucket so that the lip of the bucket can cut into the sediment when dragged for a short distance across the bottom. A portion of the sample should be dried and placed in a cloth or paper bag labeled with the depth and position. The dredge can also be used to obtain samples from the upper part of the outer slope, thus providing more information on the differences between lagoonal and seaward sediments.

The great scarcity of information on submarine geology of atolls makes every new fact of great value in interpreting the composition and history of coral reefs.

USE OF HAND LEVEL AND BRUNTON COMPASS FOR DETERMINING AND MAPPING MINOR TOPOGRAPHY

by C. K. Wentworth

In the absence of surveying instruments and without precise methods, useful mapping of small details can be achieved and made more useful by attention to certain principles and practices. If a hand level (with sighting mirror) is available it should be checked against the ocean horizon from the beach for gross errors. The observer's height to the eyes should be measured, and this value used. If horizontal distances per shot are not over 50 feet, successive hand levelling will give fairly accurate differences if care is used to mark or identify successive points. Even without a hand level, fair estimates can be made in places very near sea level if the ocean horizon can be seen and projected.

When climbing a fairly steep bluff, differences of level can be measured within 2 or 3 feet in a hundred with a hand level, and for more gentle slopes and lower features results within 15 or 10 per cent by hand level will have greater validity than an off-hand guess, and should be so described in notes. Level lines of more than 50 feet per shot can be run by hand level but will be open to question unless checked and unless the observer has unusual skill and describes the precautions taken. Two short pieces of glass tube with 25 or 50 feet of rubber tube will make a more reliable levelling apparatus for projecting long shots (see that air bubbles are eliminated).

A sighting compass such as the Brunton, commonly used by geologists and which includes a clinometer, is useful in many ways and can provide a part of the control needed in making a fairly reliable sketch map. Nearly the same results can be obtained with any compass having sighting points or a square box and with a two- or three-inch needle that swings freely. Distances can be paced on smooth ground with fair consistency if the observer makes a sustained effort to calibrate his pace. For somewhat more accurate yet rough-and-ready quadrats, or traverses, a cord or rope with 10-foot knots or paint marks is convenient and often faster than a metal tape, even if the latter be available. Calibrate the markings occasionally if the cord gets wet.

In using the compass, whether using the mirror at eye level, or viewing the needle from above, keep the box level and the needle free. Check the readings with yourself or other observers; form your own judgment as to whether your readings are reliable to 1 degree, or are in doubt up to 4 or 5 degrees. The latter may need some remedy in instrument or procedure. If the Brunton compass is used for dip or slope measurements, it should be so held that the axis of the pivot is normal to the direction of steepest slope and the sighting line should be either directly up or down that slope, or just at right-angles to it.

Regardless of what instruments or devices are used, the accuracy and utility of a map is based on use of lengths and directions of lines and of angles and triangles arranged to make the map a firm, small-scale replica of the features on the ground. The larger the map, the more it needs reference to a single long line, to one or more strong triangles, or to a well-defined grid of some sort. Any of these is preferable to a non-planned locating of minor features successively to each other. Any such sketch maps or sections should be made clear as notes by giving scale, compass directions and a legend or code of symbols; even the observer himself may forget.

DESCRIBING SIZE GRADES OF BEACH AND OTHER SEDIMENTARY MATERIALS

by C. K. Wentworth

Lacking special equipment or the services of a specialist, the range of coarseness of sedimentary accumulations can be described for the record by systematic use of simple devices. The following scale of grade terms conforms to most general usage:

Size in inches	Size in mm.	Name of material -	of grains
			boulders
10	256		
		gravel	cobbles
2.5	64		
		fine gravel	pebbles
1/12	2		
		very coarse sand	grains
1/25	1		
		coarse sand	"
1/50	1/2		
		medium sand	"
1/100	1/4		
		fine sand	"
1/200	1/8		
		very fine sand	"
1/400	1/16		
		silt	"
1/6400	1/256		
		clay	"

For extensive work sieves are necessary; it will, however, be very useful if casual observations are made specific and consistent with the above terms. For larger sizes, one can select and lay out samples showing approximately the above limits for more ready visualization in making detailed notes. Intermediate and smaller sizes can be laid on a grid background of quadrille paper for rough estimation megascopically or under a magnifier. Any essay of this sort is greatly superior to snap guesses which tend to become stereotyped without valid basis. Proportions are best stated by weights or volumes reduced to percentages (even when only estimated).

Chapter 4 -- Hydrology

AIMS AND TECHNIQUES FOR GROUND-WATER INVESTIGATION

by Doak C. Cox

Critical Factors:

The aim of a ground-water investigation on the islands of an atoll is to indicate the quantity and quality of ground water available, and the variation in both in space and time, as a basis for determining the effectiveness of the ground water as an ecological control. Generally, the fresh ground water will be found to rest on sea water. On Arno the permeability of the reef platform was so high that the fresh water body probably behaved according to the Ghyben-Herzberg principle that the ratio of the depth of fresh water below sea level to the head, or height of the water-table above sea level, is the difference between the specific gravities of the fresh and salt water. Ascertaining the generality of this principle should be one of the purposes of ground-water investigation. The mean head is the most convenient index, though an imperfect one, to the quantity of ground-water. Chlorinity, hardness and density are convenient indices to the quality. It is the job of the hydrologist to relate the magnitudes and variability of these indices to the magnitude and variation of the causative factors. On Arno the relations were worked out with considerable intensity but almost entirely for one island only. A more extensive treatment seems desirable now, but will be attained with difficulty so far as the head is concerned because the head can be usefully approximated only by rather intensive investigation. Salinity is easily investigated extensively, however, and on a dry island will have more interesting variability than on Arno. It is the salinity, moreover, that is most important as an ecological factor. More emphasis on the salinity than was made on Arno thus seems justifiable.

Measuring Points:

Ground-water may be measured and sampled at any land surface depression in the land surface that penetrates the water table; in natural ponds, or in artificial retting pits, taro pits, or wells. On Arno artificial pits were comparatively plentiful but on drier islands where the ground-water will be of poorer quality they will probably be scarcer. Where the land surface is less than 3 or 4 feet above sea level, as it is in much of the interior part of atoll islets, it is simple and quick to dig pits to the water-table. Such pits should be small, a foot or so in diameter, to avoid capacity effects, and it would be best to excavate such small pits on the side of the large excavations also, rather than using the large pits themselves for water-level readings. Where the ground surface is higher it will be more expeditious to drive or drill small diameter wells. Cheap drive pipe and well points will penetrate sand but will break at joints when driven in coral limestone or beach rock. Drive pipe with special joints might be satisfactory, but simple wells can be driven to hard rock by excavating with a soil auger inside a $1\frac{1}{2}$" pipe, using hand drilling with a rock bit and a small sledge inside the pipe for breaking up boulders. The coral conglomerate and harder rock will not require casing so that when the pipe is driven through the sand layer the hole can be extended as needed with the hand drill and soil auger alone. Water levels in such holes may be measured by lowering a stick or tape a measured distance into the hole and noting the level to which it is wetted. Samples can be withdrawn by suction through a rubber tube or by lowering an elongate cup.

Measurements:

The head is difficult to obtain with sufficient accuracy because of low water-table gradients and because of variation in sea level and well water level. Useable estimates of mean head require averaging of tidal variation and accurate leveling by telescopic level, transit, or alidade. Brunton or hand leveling is not good enough. Leveling could be probably done satisfactorily with a long (100 ft.?) rubber tube with glass tube ends, filled with water (and no bubbles) and a pocket tape or rule or two. Determination of tidal variation in a well is easiest done by a recording gage, but can be done very simply and well by observing frequently over at least a 24-hour period. Determination of tidal fluctuation in ocean is easiest and best done by recording gage of Coast & Geodetic Survey portable type. The use of the gage is described in a Manual of Tide Observations, U. S. Coast & Geodetic Survey Spec. Pub. 196, 1941. This gage fits a 4-in. standpipe which must be at least 6 feet longer than expectable tidal fluctuation. Plastic pipe, very light-weight, now available, would probably meet this need admirably. Without a recording gage frequent observations over at least a 24-hour period will suffice, but the water levels observed must have wind-waves damped out. Observations can be made in a partly submerged, vertical 2" plastic tube plugged at the bottom with a rubber stopper containing orifices from 1/8" to 1/2" depending on ratio of wave height to tide range. Or observations can be made by mercury manometer of the suction in a gallon jug partly filled with water and connected with the ocean by rubber tube filled with water. Suction recorded in height of mercury can be reduced to height of water level in jug above temporary sea level. The rubber tube furnishes the damping. (Wentworth: Wash. Acad. Sci. Jour., vol. 26, p. 347, 1936.) Mean head as measured above a single day's ocean tide level will be subject to a considerable error owing to long period tides, only partly compensated by adjustment of ground-water level.

Salinity measurement is treated in a separate section.

Analysis of Head:

In space, the mean head will increase with the width of the island, with the distance from the shores, with the permeability, and with the rainfall. The estimation of the mean rainfall is treated in a separate section. It will be nearly constant over an atoll. Measurements of head should be combined with observations of the size of the islands, with the positions of the measurements on the islands, and with whatever observations are possible on the distribution of rocks of varying permeabilities in the island, to permit analysis of the effects of these independent variables on the head. It should be noted that the head measured at any time or even over the longest period of observation permitted on an expedition will not be the mean head. Estimation of the mean head will depend on knowledge of the variability of the head and correction for it. The variability in head with time is caused by variation of recharge of the ground water body caused by variation in rainfall, variation in the rate of withdrawal (of minor importance on atoll islands), variation in barometric pressure (results negligible on atoll islands), and variation in the rate of discharge caused by variation in sea level. Rainfall measurement is treated in the section on gathering weather data. Rainfall correlation with head has not yet been done for the Arno data, so no tested rules of procedure can be laid down.

The correlation made must include recognition that the rainfall of a given interval of time has an effect on the head not only during that or the first succeeding interval, but also for a number of intervals, the effect presumably dying out in according to an exponential decay law.

Before analyzing the rainfall effects on heads, it will generally be easiest to correct the observed heads for tidal effects through a tidal analysis or at least to obtain a mean for at least a day. Methods of analyzing the tidal fluctuations are given in a separate section. The parameters obtained from the tidal analysis will again be found to vary with the size of the island, the distance from the shores, and the permeability.

It should be pointed out here that the damping of tidal fluctuations is a function of their period. Fluctuations with periods of two weeks or more pass across ground-water bodies in small islands almost undamped, and as they commonly have amplitudes of at least several tenths of a foot, heads not corrected for them may differ very materially from true mean heads. Without fairly intensive tidal analysis the best head measurements are subject to errors large in proportion to the heads themselves.

Analysis of Salinity:

The salts in the ground-water are derived (1) from solution of salt crystals in the air or at the ground surface by the rain, (2) from the solution of minerals in the ground by the ground-water, and (3) from the mixing of the fresh ground-water with the sea-water in which it is in contact at the bottom edge of the fresh water body.

The salts in the air and on the ground surface are derived from the evaporation of the sea-water spray. They should, therefore, show the same balance of composition as the sea-water. The chloride content of the water collected in natural or artificial rain-catchment structures may be used as an index of the total salts so dissolved. Density may be similarly used but with less precision, particularly in the low salinity range. The salts derived from mixture of salt water with the fresh water in the rocks should again show the same balance. The difference between the chloride content of the ground-water and that of the usual rain-catch water will provide a good index to the degree of this mixture. The degree of mixture will depend on the thickness of the ground-water body and on the amount of fluctuation of the head, and therefore, like the head and its fluctuation, on the amount of rainfall and its variability, and the size of the island, the distance of the point of observation from the coasts, and the permeability. Thus, the salinity alone will indicate the same set of conditions as the head, and the salinity is much easier to measure. On Arno the rainfall was so great that except on very narrow islands or within a few hundred feet of the shore the chloride contents were so small that differences from the chloride content in rain water were not significant. On drier atolls, larger islands should show interesting variations in chloride content to their centers. The technique for determining the chloride content of water is described in a separate section.

The degree of solution of the rocks is also of very great interest from the standpoint of its importance in physiographic processes. The rocks of the atolls are almost entirely limestone or perhaps limestone and dolomite. The hardness of the water, its content of calcium and magnesium ions, is an index to the importance of this solution, but the hardness attributable to sea water admixture must be subtracted. It seems a logical assumption that the hardness attributable to sea water admixture should be proportional to the chloride content. The ratio of hardness to chloride content should, therefore, be determined for the sea water and for the ground water.

The hardness attributable to rock solution is therefore

$$H_S = H_G - Cl_G \left(\frac{H_O}{Cl_O}\right)$$

Where the H's are hardness concentrations

Cl's are chloride concentrations

and the subscripts

S indicates the concentration resulting from rock solution

G indicates total concentration in the ground-water

O indicates concentration in ocean water

H_O/Cl_O will be about 1/4 or 1/3

A simple and accurate method of hardness determination is given in the section on salinity determination, which also includes a discussion of calcium hardness determination (analysis of calcium ion concentration alone) which should be interesting in studying the relative amounts of dolomite and limestone available for solution.

Ecologic Controls:

The study of atoll ground water is interesting not only on its own account but because it provides certain ecologic controls on vegetation and man. Taro culture is almost certainly controlled by the distribution of fresh ground water. Breadfruit is apparently so controlled on Arno. Influence of salinity on other economic plants may be found. Mangroves and some other plants require ground-water in a very brackish range. The extension of recognition of salinity controls, and the investigation of their effect on the pattern of cultural adjustment of man to the various islands and on individual islands, constitute the chief reasons for support of ground-water work on Pacific Science Board projects.

TECHNIQUES FOR SALINITY DETERMINATION

by Doak C. Cox

Chlorides:

As discussed in the section on ground-water investigation, the saline constituent of chief interest is the chloride ion. The determination of chloride ion concentration depends on titration with silver nitrate solution using potassium chromate as an indicator. Chloride concentrations encountered on an atoll may range from less than 10 parts per million to nearly 20,000 parts per million. In analyzing this very large range it will be helpful to have two concentrations of silver nitrate. The following reagents and equipment will permit analysis of at least 100 samples in high and 100 samples in low Cl^- range:

1 pint $AgNO_3$ soln. (1 ml. = 1 mg. Cl^-) (4.791 g. per liter soln.) in dark bottle.

1 pint $AgNO_3$ soln. (1 ml. = 10 mg. Cl^-) (47.91 g. per liter soln.) in dark bottle.

2 oz. K_2CrO_4 soln.; part in 1 oz. dropper bottle.

2 pipettes, 5 ml. cap., graduated to 1/10 ml.

2 casseroles, porcelain, 100 ml. cap.

2 glass stirring rods.

The reagents can be made up in any chemical laboratory, and the equipment is available at any chemical supply house. Keep $AgNO_3$ soln. in dark to inhibit deterioration. The procedure is as follows:

1. Determine range of Cl^- content by hydrometer (see discussion later) or by taste, or by testing first as if high range.

Range	Taste	Use $AgNO_3$ soln.
0-200	None	1 ml. = 1 mg. Cl^-
200-2,000	Flat or brackish	1 ml. = 10 mg. Cl^-
2000-20,000	salty	dilute sample (see step 2) and use $AgNO_3$ 1 ml. = 10 mg. Cl^-

2. Measure 25 ml. of sample in graduated cylinder and transfer to casserole. To avoid excessive use of $AgNO_3$ soln. dilute samples containing more than 2,000 ppm. Cl^- as follows: Measure 2.5 ml. sample with pipette (do not use this pipette for $AgNO_3$ solns.). Transfer to graduate. Dilute to 25 ml. with distilled or rain water. Use this diluted sample for test. If rain water is used it must be tested for Cl^- and a correction made as indicated in step 6.

3. Add 5 drops K_2CrO_4, stir. Soln. will turn bright yellow.

4. Fill pipette above zero mark with appropriate $AgNO_3$ soln. Drain to zero mark, controlling flow with finger at top of pipette. Add $AgNO_3$ slowly from pipette to sample in casserole, with continual stirring. Clear yellow soln. will become turbid, very turbid if high chloride. Each drop of $AgNO_3$ will make a brick red flash in the soln. in the casserole, which will disappear on stirring. As the end point is approached the red flashes will become larger and more persistent. The end point is reached when the whole soln. in the casserole acquires a faint permanent red tinge. It is sometimes helpful to pour only about 23 to 24 ml. of the sample into the casserole at the start, titrate quickly past the endpoint, then add the remainder of the sample, reversing the endpoint, and titrate to the endpoint with care.

5. Read the amount of $AgNO_3$ soln. used from the pipette.

6. Compute the chloride content as follows:

With dilute $AgNO_3$	With concentrated $AgNO_3$
(1 ml. $AgNO_3$ soln. = 1 mg. Cl^-)	(1 ml. $AgNO_3$ soln. = 10 mg. Cl^-)

for 25 ml. sample

ppm. Cl^- = ml. $AgNO_3$ soln. x 40	ppm. Cl^- = ml. $AgNO_3$ soln. x 400

limit of accuracy, equivalent of 1 drop $AgNo_3$ soln.

Approx. 1.3 ppm.	Approx. 13 ppm.

With 1 to 10 dilution

Determine Cl^- ppm. in test sample with concentrated $AgNO_3$ as above.

Cl^- ppm. of original = 10 (Cl^- ppm. of test sample) - 9 (Cl^- ppm. of diluent water). Limit of accuracy approx. 130 ppm.

Chloride may be reported as NaCl as follows: Chlorides as ppm.

NaCl = 1.649 ppm. Cl^-

Total hardness:

As discussed in the section on ground-water, the hardness of the water is a key to the amount of limestone it has dissolved. The following simple and accurate method for the determination of hardness depends on titration with an organic agent which sequesters calcium and magnesium ions, in an alkaline soln. using an organic indicator. Total hardness is usually expressed as parts of $CaCO_3$ per million, both Mg^{++} and Ca^{++} being treated as if they were Ca^{++} and combined with CO_3^{--}. Total hardness encountered on an atoll may range from less than 10 to nearly 7,000 ppm. $CaCO_3$. As in chloride determination, two concentrations of the titrating reagent will be convenient. The following reagents will permit analysis of at least 100 samples in high and 100 samples in low range.

1 pint hardness titrating solution. (1 ml. = 1 mg. $CaCO_3$)

1 pint hardness titrating solution. (1 ml. = 10 mg. $CaCO_3$)

2 oz. hardness buffer reagent. (1 oz. in dropper bottle)

1 oz. hardness indicator. (in dropper bottle)

pHydrion paper will be useful in checking pH in buffering.

The buffer reagent, indicator, and dilute titrating solution may be obtained from W. H. & L. D. Betz, Philadelphia 24, Pa. For instructions for making all reagents see Betz and Noll, (Am. Water Works Assn. Jour., Vol. 42, p. 49, 1950). Equipment necessary is same as for chloride determination. Use pipette used in dilutions for hardness titrating soln. or carry a third pipette.

The procedure is as follows:

1. Determine range of hardness. In general, hardness as $CaCO_3$ will be in same range as Cl^- content except for sea water, which will have about 1/3 or 1/4 as much hardness as Cl^- content.

2. Measure 25 ml. sample as in chloride determination. Dilute if necessary as in chloride determination.

3. Add 5 drops buffer reagent and stir. Solution should have pH of 8 or 9. Add 2 or 3 drops of hardness indicator and stir. Soln. will turn red.

4. Titrate with hardness titrating soln. in same manner as in titrating with $AgNO_3$ soln. for Cl^- determination. As endpoint is approached solution will start changing from red to blue. Endpoint is reached with final discharge of red.

5. Read the amount of titrating soln. used. Add a drop more to the evaporating dish to ascertain that there is no further color change.

6. Compute total hardness as follows:

<u>With dilute hardness titrating soln.</u>	<u>With concentrated hardness titrating soln.</u>
(1 ml. = 1 mg. $CaCO_3$)	(1 ml. = 10 mg. $CaCO_3$)
Hardness, as ppm. $CaCO_3$ = ml. titrating soln. x 40	Hardness, as ppm. $CaCO_3$ = ml. titrating soln. x 400
Limit of accuracy approx. 1.3 ppm.	Limit accuracy approx. 13 ppm.

<u>With 1 to 10 dilution</u>

determine $CaCO_3$ ppm. in test sample with concentrated titrating soln. as above.

Hardness as $CaCO_3$ ppm. of original = 10 ($CaCO_3$ ppm. in test sample)
-9 ($CaCO_3$ ppm. in diluent water)

Limit of accuracy approx. 130 ppm.

Calcium hardness:

In the above method there is no separation of Ca^{++} and Mg^{++} ions. They are lumped and the results computed as if they were Ca^{++}. With the use of a different indicator and sodium hydroxide for pH control, calcium alone may be determined with the same titrating solutions as used in total hardness determination. The indicator, a solid, is available from Betz in 50 gm. bottles with a measuring dipper. Equipment is the same as for total hardness determination. About 8 oz. of NaOH 1.0 N are required.

The procedure is as follows:

1. Determine range. Probably 1/4 to 1/2 total hardness.

2. Measure 25 ml. sample as above. Dilute if necessary.

3. Add 1 ml. NaOH 1.0 N and stir. Add 1/2 dipper of calcium indicator and stir. Solution will turn salmon-pink.

4. Titrate with hardness titrating solution as above. Solution will turn purple as endpoint is approached. Endpoint is final change to orchid.-purple.

5. Read titrating soln. used as above.

6. Compute Ca hardness as $CaCO_3$ in same manner as computing total hardness as $CaCO_3$. Compute calcium ion if desired as follows:

$Ca^{++} = .400$ Ca hardness as $CaCO_3$.

Compute magnesium ion if desired as follows:

Mg hardness as $CaCO_3$ = (total hardness as $CaCO_3$) - (Ca^{++} as $CaCO_3$)

$Mg^{++} = .243$ (Mg hardness as $CaCO_3$)

Calcium and magnesium hardness were not differentiated on Arno because the materials for this method could not be procured in time.

Total salinity:

In ocean water the ratio of the chloride content to the total salinity is nearly constant.

$$\frac{Cl^-}{\text{total salinity}} = .55$$ (Sverdrup, Johnson, Fleming, The Oceans, p. 166, 1942)

The chlorinity is thus a convenient index to total salinity in any water diluted from the sea water if diluent has roughly the same balance of salt as sea water. This will not be the case if there is much $CaCO_3$ dissolved from the rocks in the water. In sea water or its dilutions, density also is a very convenient index to total salinity. Densities may be measured by hydrometers.

A set of three, as manufactured by G. M. Manufacturing Co. for the Coast and Geodetic Survey, with ranges 0.996 to 1.011, 1.010 to 1.021, and 1.020 to 1.030, covers the range of sea water to distilled water in most temperature ranges. A convenient cup for use with the hydrometers is available from Mercer Glassworks, 725 Broadway, New York 3, N. Y. The temperature of the water must be measured to 1° C., as a temperature correction is critical. Tables for the temperature correction to densities and density to salinity reduction are given in the Manual of Tide Observations, U. S. Coast and Geodetic Survey Spec. Pub. 196, 1941. Density measurements were not made on Arno because the one hydrometer carried broke.

TECHNIQUES OF TIDAL ANALYSIS

by Doak C. Cox

Introduction:

As is further discussed in the section on ground-water investigations, the study of the head of a ground-water body in an atoll island must include some sort of analysis of the tidal fluctuations of both the water-table and sea level. Simple averaging of a day's water levels will suffice for some purposes. For others, a more intensive analysis is required. The tide fluctuation in a ground-water body is itself a key to conditions in the rocks. A study of this fluctuation depends upon separation and individual analysis of tidal components of different periods, because the periods affect the changes in the tides as they progress from the ocean through the rocks. The techniques discussed here have not been published yet, but have been applied to a number of problems (Cox and Munk, Hawn. Acad. Sci. Proc. 1951, in preparation).

Analysis of tidal components:

Many tidal components of different periods go to make up the tide. Several have periods near 24 hours or near 12 hours, the diurnal and semidiurnal components respectively. The separation of the individual components in either diurnal or semidiurnal group requires a long tide record, but the separation of diurnal from semidiurnal components can be made fairly simply from a short tide record, as short as a day. These components are analyzed and expressed as if their periods were exactly 24 and 12 hours respectively.

The procedure is as follows:

1. From tide records, choose a period of an integral multiple of 24 hours for which records are available for ocean and wells to be compared.

2. List water levels for each station, as measured from any datum, for half hour intervals starting with the time of the period of the analysis ($t = 0^h$). If the original records are discontinuous, plot them up so that half hour readings may be interpolated.

3. Make two tables of 24 columns each, for diurnal and semidiurnal components respectively of each record. Enter readings for hourly periods (for $t = 0.0$, $t = 1.0^h$, $t = 2.0^h$, etc.) in the diurnal table and readings for half-hourly periods (for $t = 0.0^h$, $t = 0.5^h$, $t = 1.0^h$, etc.) in the semidiurnal table. Set first 24 readings in a row across the columns in each table. If there are more than 24 readings put the next 24 in a second row beneath the first, etc. Readings should complete the last row.

4. Add algebraically each column and obtain a mean. This will give 24 mean values for each table.

5. Add these 24 values and divide by 24 to obtain a general mean for each table. Subtract this general mean from the individual means to obtain departures. For example the 24 departures for the diurnal tide in Hilo Bay, Hawaii for a day beginning at 1/24/51, 0:00 are:

+.450, -.251, -.951, -1.501, -1.751, -1.751, -1.451, -.851, -.251, +.249, +.549, +.649, +.599, +.399, +.199, +.049, -.051, -.001, +.249, +.649, +.949, +1.219, +1.249, +1.149. These values are analyzed on the attached sample form.

6. Prepare a form like the sample for each component for each station. Multiply the first twelve of the above departures by 100 with the signs shown in the twelve corresponding columns of row d of the form, and enter the products in row 1. Enter in the twelve columns of row 2 the products of the second twelve of the departures multiplied by 100 with the signs shown in row e. Example: the 13th departure is +.599. Column 0, row e is (-). +.599 X(-100) = -59.9. Enter -59.9 in column 0, row 2.

7. Add algebraically row 1 and row 2, entering sums in row 3.

8. Transfer numbers in columns 7 to 11 inclusive of row 3 to columns 1 to 5 inclusive of row 4, but in reverse order (column 7, row 3 goes to column 5, row 4) entering original signs (top) and also reversed signs (bottom).

9. Add columns 1 to 5 inclusive of rows 3 and 4 using original (top) signs and enter sums in row 5. Add columns 1 to 5 inclusive of rows 3 and 4 using new (bottom) signs in row 4 and enter in row 6.

10. Multiply figures in row 5 by corresponding figures in row b and enter products vertically in column 0, rows 4 to 8 inclusive (Column 1, row 5 times column 1, row b goes to column 0, row 4). Multiply figures in row 6, columns 1 to 5, by corresponding figures in row c, and enter products vertically in column 6, rows 4 to 8 inclusive.

11. Add rows 3 to 8 in column 0 and enter sum in row 9. Add rows 3 to 8 in column 6 and enter sum in row 9.

12. Divide figure in column 0 row 9 by 1200 to obtain "p".

Divide figure in column 6 row 9 by 1200 to obtain "q".

13. Compute the amplitude of the component, $A = \sqrt{p^2 \quad q^2}$.

A will be in feet if the original water levels were in feet.

14. Compute the cotangent of the phase angle of the component, cot $\alpha = p/q$. Use trigonometric tables to determine α in degrees. The cotangent will not discriminate between two values of α, 180° apart. Actual discrimination may be made by inspection of the record or by trial when both components have been analyzed for a station as described below. If t_h = A is the time when the height of the component in question reaches a maximum, measured in hours after zero time of the observations, α in degrees = 360t/T,

where T is the period of the component in hours.

15. When both diurnal and semidiurnal components have been analyzed for a station, compute the tide and compare with the actual tide for a check.

Let A_1 = diurnal amplitude; α_1 = diurnal phase angle in degrees.

A_2 = Semidiurnal amplitude; α_2 = semidiurnal phase angle in degrees.

t = time after zero time of observations.

h = height of water at any time above chosen datum.

$\bar{h}$ = mean height of water above that datum. (Step 5 mean if above original datum)

$$h = \bar{h} + A_1 \cos.(15t - \alpha_1) + A_2 \cos.(30t - \alpha_2)$$

Because of the approximations involved in using only one diurnal, and one semi-diurnal component, this equation cannot be used to extrapolate the tide fluctuation beyond the period of observation. However, comparison may be made of equations at different stations for the same period.

Comparison of ocean and well tides:

The tides in a ground-water body whose discharge is controlled by sea level will, at any well, bear certain constant relations to ocean tide. Using the same symbols as above and the additional subscripts O for ocean coefficients and W for coefficients at a given well: A_{1W}/A_{1O} and A_{2W}/A_{2O} the damping ratios of diurnal and semidiurnal components, and $\alpha_{1W} - \alpha_{1O}$ and $\alpha_{2W} - \alpha_{2O}$ the phase lags for the two components will all be constants. Any of these may be used as parameters of the conditions between the shore and the well. The damping ratios have a constant relation to the phase lags and phase lag values may be computed from them for comparison. Furthermore, the phase lags for the two components are related through the periods of the components, and a value of a single parameter describing the whole tidal difference may be computed from them. If L = phase lag in degrees.

$$L_1 = \alpha_{1W} - \alpha_{1O} = \frac{180}{\pi M} \log\left(\frac{A_{1O}}{A_{1W}}\right)$$

$$L_2 = \alpha_{2W} - \alpha_{2O} = \frac{180}{\pi M} \log\left(\frac{A_{2O}}{A_{2W}}\right)$$

Where $1/M = \log_e 10 = 2.303$

$$\frac{180}{\pi M} = 131.9$$

logs are to base 10

Let C = the tidal difference in units of $\sqrt{\text{hrs}}$.

$$C = \frac{L}{\sqrt{T}} \cdot \frac{\sqrt{\pi}}{180}$$

Where T = period of component in hours

$$\sqrt{T_1} = \sqrt{24} = 4.899; \quad \sqrt{T_2} = \sqrt{12} = 3.464; \quad \frac{\sqrt{\pi}}{180} = 0.09847$$

$$C = \frac{L_1}{4.899} = \frac{L_2}{3.464}$$

Comparison of tidal difference constants for different wells:

The exact way in which the constant "C" is controlled by the conditions between the well and the coast is not known. "C" is inversely proportional to the square root of the permeability and directly proportional to the square root of the porosity. It is also proportional to a distance which is apparently some function of the distance from the ocean to the well. If there is an impermeable layer at a depth small compared with the distance from shore to well, it may be inversely proportional to that depth.

Because of the present inadequacy of theory, quantitative study of permeability variation indicated by variation in tidal difference constants is impossible or unsafe. It is obvious, however, that if two wells are at equal distances from the shore, the depth to an impermeable layer, if present, is equal and the porosity is roughly equal, and if they still have very different tidal difference constants, the permeability is higher between the shore and the well with the lowest constant.

Determining tidal corrections for single head readings:

Once the tidal difference constant for a given well is determined, the mean head can be computed from a single head measurement for any time at which tides are still known in the ocean so that a new component analysis can be made for a short period of ocean tides including the time of the single measurement of well head. If A_O' and α_O' are ocean coefficients from the new analysis, A_W/A_O and $\alpha_W - \alpha_O$ are the constants already derived, and h_W is the single head measurement, the mean head

$$\bar{h}_W = h_W - A'_{10}\,(A_{1W}/A_{10})\cos.\left[15t - \alpha'_{10} - (\alpha_{1W} - \alpha_{10})\right]$$
$$- A'_{20}\,(A_{2W}/A_{20})\cos.\left[30t - \alpha'_{20} - (\alpha_{2W} - \alpha_{20})\right]$$

Extrapolation for long term tides:

The tidal difference constant "C" should be constant for tides for any period. If the tides are measured or can be predicted for a long period for the ocean, so that long period components can be analyzed, long period corrections to mean heads can be determined for wells whose tidal fluctuations are correlated with those of the ocean by solving for L and A_1/A_2 with C known, using the proper long period T in the previous equations.

TIDAL COMPONENT ANALYSIS

STATION: Hilo   to : 0:00

DATES: 1/24/51   TIDE COMPONENT: Diurnal

Column		0	1	2	3	4	5	6	7	8	9	10	11
Row	a	0	15	30	45	60	75	90	75	60	45	30	15
	b		.966	.866	.707	.500	.259						
	c		.259	.500	.707	.866	.966						
	d	+	+	+	+	+	+	+	−	−	−	−	−
	e	−	−	−	−	−	−	−	+	+	+	+	+
	1	+45.0	-25.1	-95.1	-150.1	-175.1	-175.1	-145.1	+35.1	+25.1	-24.9	-54.9	-64.9
	2	-59.9	-39.9	-19.9	-4.9	+5.1	+0.1	-24.9	+64.9	+94.9	+121.9	+124.9	+114.9
	3	-14.9	-65.0	-115.0	-155.0	-170.0	-175.0	-170.0	+150.0	+120.0	+97.0	+70.0	+50.0
	4	-14.5	±50.0	±70.0	±97.0	±120.0	±150.0	-29.8					
	5	-39.0	-15.0	-45.0	-58.0	-50.0	-25.0	-92.5					
	6	-41.0	-115.0	-185.0	-252.0	-290.0	-325.0	-170.0					
	7	-25.0						-251.0					
	8	-6.5						-314.0					
	9	-140.9						-1035.3					

$p = \dfrac{-140.9}{\quad} \quad -0.118$

$q = \dfrac{-1035.3}{\quad} \quad -0.863$

$A = \sqrt{p^2 + q^2} = \sqrt{.013924 \quad 744769}$

$= \sqrt{.758693} \quad 0.871$

$\cot \alpha = \dfrac{p}{q} = \dfrac{-0.118}{-0.863} = +0.137$

$\alpha = 82° \; 12'$

Chapter 5 -- Soil Science

SUGGESTIONS FOR STUDYING ATOLL SOILS

by Earl L. Stone, Jr.

A. Objectives:

The purposes of studying the soil vary according to the aims of the investigator but recognition of alternate or subsidiary objectives may aid him in getting the most from his study. Common objectives -- which overlap to some extent -- are:

1. For knowledge of soils *per se* as natural bodies, their kinds and distribution and how these are affected by climate, geological materials, vegetation, topography and age.

2. There are obvious relationships between soil and vegetation. Very commonly the soil decidedly influences the distribution and competitive abilities of both macro- and microflora and of the fauna.

3. In a larger sense the soil is part of a comprehensive ecological view. Even in general terms, a "feeling" for the historical development of the land surface and soil, their response to natural processes and cataclysms, and the influences of both primitive and recent mankind provide a perspective or frame of reference for other investigation.

4. Agricultural development and, to a lesser extent, a detailed understanding of contemporary or paleoagriculture obviously depend on knowledge of soils.

5. The study of soils often has geological, hydrological and archeological implications. Soil texture, moisture relationships, profile age or inferred typhoon history are obvious examples. Indications of man's former activities are occasionally revealed as are some of the natural limitations on his use of land.

These objectives are stated in general terms. The significance of some aspects is greatly altered by the youthful nature of the atoll soils. From the meager reports all appear to be lithosols and regosols, their characteristics still dominated largely by parent material and time of development; none of them are mature soils in the usual sense of the term. For this reason the amateur student should be quick to lay aside his textbook generalities about soil profiles and development when they fail to fit field observations.

B. General methods of study:

There is a popular notion, unfortunately shared by too many naturalists, that the important and concealed properties of the soil are somehow revealed by means of a "soil test." It should be clearly understood that knowledge of the soil starts in the field; without comprehensive information on their natural occurrence, laboratory analysis of samples is at best limited in applicability and may be useless or misleading. Usually we are concerned with three general types of information:

1. Knowledge of the kind of profiles and their distribution: The kinds of profiles are distinguished by differences in parent material, drainage and degree of development. These usually involve description of soil texture, structure, color, depth, etc. Fortunately, in the simple environment of the atoll there are relatively few combinations of these factors.

(a) Parent materials, for the most part, are from corals, mollusks, calcareous algae, foraminifera, etc., usually in mixture. These are largely composed of calcium and magnesium carbonates with very small amounts of other materials. Their physical nature -- gravel, sand, etc., -- and consolidation, is important; identity of the class of organisms may be also inasmuch as it influences chemical compositions.

Phosphatic materials are usually readily recognized by their brown color. Such deposits are often cemented but loose sands also occur. Wave working and redeposition of such deposits or even local washing from them may influence surrounding areas and such admixture should be looked for. Guano deposits are of obvious significance.

The presence of other kinds of parent material is not probable but the possibility must be kept in mind. The occurrence of basalt fragments in the Rose Atoll reef presumably explains Lipman's analytical results of soil material from there and entirely vitiates his conclusions. Ships ballast, and soil transported for garden by colonials or natives -- as on Funafuti, Jaluit and elsewhere -- may locally influence the soil.*

(b) Soil drainage is in part inferred from topographic position, groundwater level, etc., and confirmed by profile examination. Because of their coarseness most atoll soils are well-drained and peats formed under conditions of extremely poor drainage are easily recognized. Between these, however, may be soils of progressively poorer drainage which cannot be characterized by any single feature. Water level, soil moisture content, character of the surface soil and deeper layers compared with those of obviously well-drained soils, etc., provide evidence for the classification of drainage levels.

(c) Degree of development is a relative term since most atoll soils are youthful. The horizons that can be distinguished are described as to sequence and character, that is, texture, depth, color, etc. Most well-drained atoll soils appear to be simple and shallow, consisting of a horizon of organic incorporation (A_1), say, 4 to 10 inches deep which passes through a more or less narrow transitional zone into relatively unaltered parent material (C horizon). The upper portion of the C may be slightly weathered and stained with organic matter and tongues of the A_1 may penetrate into it. Upon Arno atoll the depth, color and organic content of the A_1 usually increased in passing from the shores to the wide interiors; this sequence is related to both time of development and character of the vegetation.

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* Floating pumice

Particular attention should be given to evidence of erosion, deposition, buried horizons, etc., which may otherwise be misinterpreted. Buried profiles are relatively easy to distinguish for accumulation of an appreciable organic horizon is a surface phenomenon. Their occurrence at depth is obviously related to further deposition by storm waves, blow sand, etc. Soils receiving continual small surface additions as wind-blown or washed on sand, may develop a deep A_1 horizon fairly rapidly and to a degree simulate an older soil.

It should be borne in mind that many islands have been long inhabited and thus occasional profile anomalies caused by man's digging can be expected. On Arno the pits dug for sanding walks occasionally intersect former pits which were filled with rubbish before being closed; these now appear as extraordinarily deep A_1 horizons. Hog rooting can cause widespread disturbance of the upper few inches of the soil.

The character of the surface horizons, drainage level, salinity and texture (sandy or stony) largely determine the more obvious soil-plant relationships. These elements can be studied as separate variables or as properties associated with soil groups. For classification it will be found that most of the "normal" profiles can be referred to a few groups or soil types. Within each of these will be a certain amount of deviation about the "modal" or "type" profile and in fact some of the types may intergrade. Having fixed upon recognizable units these can be mapped to show distribution, or used to describe areas or study their relation to other features. Recurring associations of different soils (or soils and land types) which are hopelessly intermingled can be described and mapped as <u>complexes</u>. Thus, on Arno the stony land formed on the beach rampart could not be satisfactorily separated into units of different age and development although generally it became progressively more youthful towards the sea; accordingly, it was mapped simply as a stony land complex although this is admittedly unsatisfactory for vegetational studies.

2. <u>Other field observations</u>: These will vary with the purposes of the investigator. Presumably vegetation, plant development or agricultural use will be recorded as a matter of routine. Degree of rock weathering, soil fauna and extent of their activity, evidence of land clearing and trash burning, evidence of old house sites or disturbance and inferred land history are other observations that must be made on the spot. To some extent qualitative observations of soil moisture, such as depth of wetting or drying, unusual wetness, as at the capillary fringe, etc., may be useful although the coarse texture and uniform color of the lower horizons limits the accuracy of such determinations.

Depth of rooting and root distribution, particularly in relation to groundwater and its salinity appear to be very significant for vegetation. Fosberg and Cox suggest that groundwater salinity is probably the feature controlling development of the breadfruit. By way of contrast, coconut roots seem to readily penetrate from the soil upward into heaps of sodden decaying coconut husks on the surface. Root nodules and legumes may be inconspicuous, fragile or distant from the root crown so their absence should not be inferred from superficial observations.

As soils, special materials such as peat, phosphate and guano may have little genetic significance but increase the limited range of habitat variations over which a given species or vegetational type can be studied. Thus, coconut and pandanus may grow successfully on the low-humic, seemingly dry recent dunes as well as in the highly organic soils of the interior and in fresh water peats where there is no competition for moisture. Rock porosity and the presence of fissures must be considered when studying moisture relations of cobbly soils or those shallow over consolidated rock.

3. Analytical procedures and sampling:

(a) Field analytical techniques are limited to pH and soil or groundwater salinity. Determinations of nutrient availability, etc., by the usual field "kits" are eseentially meaningless. Soil moisture could be determined with reasonable accuracy by drying to an air-dry condition and weighing, but other physical analyses require specialized equipment or "briefing."

By using indicators pH can be determined easily in the field. Reaction probably has little general significance, since most soils are calcareous. Poorly drained soils, peats, and phosphatic soils should be tested in the field, however, since a wide range in pH is possible and, moreover, the reaction of peat samples may change materially upon drying.

The most rapid means of measuring salinity of the groundwater and soil extracts is with a conductivity bridge but the cost and possibility of instrument failure remote from repair facilities must be considered. Chloride titration with silver nitrate is an accurate method adaptable to field use. Fosberg's hydrometer method, with temperature correction, provides a rapid means of determining groundwater salinity in the field although of only moderate precision.

(b) It is unnecessary to mention the laboratory analyses here but the investigator would do well to make tentative arrangements for analysis of the samples before they are taken. Otherwise, he may have more or less than can be examined. As already implied, if the laboratory analyses are to be worthwhile the samples must be taken with reasonable care from well described profiles. In general, samples should be taken from a known depth but within recognized horizons, dried at air temperature without contamination, enclosed in tight durable containers and well labeled.

It is well to describe the profile thoroughly prior to sampling. The samples are taken as representative of horizons or portions of a horizon and usually are composites of several inches of depth, e.g. 0-6 inches, 6-11 inches, 14-20 inches, etc. Samples should be at least 100 grams in weight and 300 to 400 grams is preferable. In taking a sample from a given depth range equal amounts of soil must be taken from each part of the range if the sample is to be truly representative. The number of samples and width of the range can be modified to fit circumstances. Transitional zones should be excluded or sampled separately. With the simple profiles found on

Arno two to four samples per profile, often covering a six-inch range, were found adequate. Roots, stones, excess gravel, etc., are usually excluded when sampling since only the finer fraction (less than 2 mm.) is used for analysis. With very stony or gravelly soils some estimate should be made of the amount of the excluded matter, preferably by weighing, if analytical results are to be compared with other soils. Thus, 30% organic matter in the 2 mm. fraction of a very gravelly soil may be no more significant than 10 or 15% in a uniform sand.

The sample should be spread out and air-dried as soon as convenient; in long periods of wet weather gentle artificial heat may be necessary but this should be at a minimum. The most suitable container for field collection and shipment are small canvas bags made for the purpose. Paper bags disintegrate when wet and are likely to burst in shipment; however, extra-heavy 3 or 5 pound paper bags can be used double and tightly packed for shipping. Cylindrical, waxed cardboard icecream containers are satisfactory but are very bulky even when empty.

Samples for study of microorganisms must be taken and handled with a special regard for contamination.

All samples entering the country must pass through the USDA Division of Foreign Plants quarantine. If necessary samples may be shipped directly to the Inspection House, Bureau of Entomology and Plant Quarantine, Washington, D. C., enclosing list of samples and a copy of the covering letter; the originals of both should be sent to Dr. H. S. Dean of the above division and bureau. A much better procedure will be to write Dr. Dean and work out arrangements in advance of shipment; this will facilitate entry and delivery. If microbiological studies are intended this should be stated so the samples will not be fumigated.

C. Field procedure:

Possibly the primary intent of field work will be to recognize and define classes of soil so their relationship to each other and to other features may be observed. Classes, which may or may not correspond to soil types recognized elsewhere, are established by recognizing the modal profiles and a permissible range about each. The field procedure is thus somewhat as follows:

1. Know the general geography of the island being studied. Locate profile pits, topographic features and type lines on maps or sketches.

2. Observe the origin and geomorphology of the area studied, e.g. lagoon or sea beach origin, dune ridge, beach rampart, basin, etc.

3. Examine soil profiles in excavations.

(a) Before attempting serious description look at a number of profile exposures -- sand pits, wave-cut dunes, etc., and shovel holes -- for a general notion of the soils.

(b) Dig or, better, have dug a few to several profile pits to penetrate well into unaltered material. When in doubt, dig deeper.

(c) Describe these profiles in detail, preferably with a methodical recording of depth, texture, structure, color, etc., of each recognizable horizon.

(d) Tentatively establish classes and examine as many more profiles as necessary to clearly define their modal profiles and limits. This is less burdensome than may appear for the number of classes on an atoll will be few and some limits will be fixed sharply by the considerations of 2 above.

(e) Sample profiles representative of major soil types or otherwise significant profiles. These may be chosen to represent a sequence of development, drainage level, etc. If desired, map the types established under (d) for an accurate picture of soil distribution.

Despite the above it should be understood that step-by-step instructions for studying soils have the same limited usefulness as they would for, say, making love. In both instances there is a high degree of individual variation and, in any event, if intuition or previous experience is lacking, the case is probably hopeless.

D. <u>Miscellaneous</u>:

1. The USDA Soil Survey Manual currently in press sould be referred to for definition of terms and units.

2. The tools and equipment for the study of soils in the field are simple:

a. A soil auger may be useful occasionally but a shovel or spade of some sort is essential; a long bladed tiling spade is useful since a slice will expose the entire upper profile.

b. With the pH kit should be included dilute hydrochloric acid and extra supplies of acid and indicators.

c. Containers for samples.

d. For intensive field work a set of Munsell soil color charts is useful but for most purposes accurate color determinations can be made on the dried samples upon arrival at the laboratory.

e. Additional equipment is necessary for moisture or salinity determinations.

f. Paper on which to spread samples for air-drying, labels, wrapping materials, etc.

Chapter 6 -- Botany

DIRECTIONS FOR STUDYING VEGETATION AND FLORA

by F. R. Fosberg

I. Vegetation

Basically, atoll vegetation is relatively simple in structure, composition, and arrangement. The several types may conveniently be arranged in a series from halo-xerophytic to mesophytic. This series does not represent a single succession, though its members must certainly, in various combinations, form parts of a number of successions in different situations. Observations are not yet available over a sufficient period or in enough detail to enable one to more than guess at what developmental relations actually exist, or how nearly in equilibrium are the main types of vegetation.

The gross arrangement of types from atoll to atoll corresponds very well with the general climates of the atolls, and the more detailed arrangement on an atoll seems to be correlated with variations in salinity of ground-water. Other factors being equal, the more halophytic communities will probably be peripheral, especially on the seaward edges of the islets, while the mesophytic ones will be central, and better developed on wider islets.

Climatically, the driest atolls are those in the equatorial belt of calms and those near the tropic of cancer. They have vegetation approaching true desert, in the most extreme cases with no trees at all. The wettest atolls are those few degrees north of the equator or some degrees south of it. Some of them have lush jungle, sometimes of enormous trees with a dense canopy, with a good development of epiphytes.

Composition varies both with climate and with distance from larger land masses. Generally, the wetter islands have the larger floras, and the floras decrease from west to east, culminating in the barren Clipperton, which perhaps had no indigenous land plants. This seems to be, more than anything else, a matter of distance from sources of colonists. At best, the composition of atoll vegetation is very poor in species.

Briefly characterized, the commoner plant communities, arranged from driest to wettest, are:

1. Open stand of *Sesuvium portulacastrum* on saline flats.

2. Grassland of *Lepturus repens*, *Thuarea involuta*, and *Fimbristylis cymosa*, often pure stands of one or the other, rarely extensive, rarely with scattered trees. (Christmas I., Pokak, etc.)

3. Open beach or sand flat communities of *Triumfetta procumbens*, *Boerhavia*, *Ipomoea pes-caprae*, *Portulaca lutea*, etc.

4. Weed communities on cleared or disturbed ground, mostly resulting from human activity and composed of both introduced and native species.

5. Dwarf scrub of Sida fallax, Heliotropium anomalum, etc.

6. Mat of Vigna marina or Ipomoea pes-caprae on flat ground, successional after disturbance.

7. Thick mat of Wedelia biflora or of Wedelia and Ipomoea pes-caprae, on flat cleared ground, successional after disturbance.

8. Scaevola frutescens fringe at top of seaward beaches, merging into dense Scaevola or mixed scrub on narrower islets and sand-spits.

9. Scrubby forest of Messerschmidia argentea, Pandanus tectorius, Guettarda speciosa, Cordia subcordata, etc., behind Scaevola fringe.

10. Sonneratia caseolaris stands on tidally submerged lagoon beaches or reef-rock flats.

11. Mangrove swamps of Rhizophora with openings to lagoon or occupying shallow edges of lagoons.

12. Pemphis acidula thickets on dry reef-rock flats.

13. Mangrove depressions, rock-lined, with clear brackish water.

14. Mixed forest with Messerschmidia argentea, Guettarda speciosa, Intsia bijuga, Pipturus argenteus, Pisonia grandis, Ochrosia oppositifolia, Soulamea amara, Ficus, Eugenia, Pandanus, etc., richer in composition in the western atolls, attenuated toward the east, merging gradually, on the one hand with the scrub forest (#9) and on the other with the Pisonia forest (#16). Any of the components may assume dominance or even occur locally in pure stands.

15. Coconut plantations, with sparse understory of Pandanus, Guettarda, Premna obtusifolia, Morinda citrifolia, etc., the luxuriance depending upon the rainfall, the stature upon how recently the undergrowth was cleared out of the plantation.

16. Pisonia forest, originally of huge trees with dense closed canopy, perhaps the most mesophytic of natural types.

17. Ochrosia oppositifolia forest, usually pure stand.

18. Coconut-breadfruit forest, a tall dense forest with closed canopy, perhaps the most mesophytic man-induced type. Either component may occur alone locally.

19. Mesophytic swamp, with Intsia bijuga, Pemphis acidula, Ochrosia oppositifolia, and various other trees, growing in wet depressions, either muddy or with clear water.

20. Open fresh or brackish marsh, with Cyperus javanicus, etc.

21. Artificial marshes for taro-culture, with Cyrtosperma chamissonis, Colocasia esculenta, Saccharum officinarum and and other planted species.

These are the most noticeable groups of communities on the average run of Pacific atolls. There are many variations of these, intermediate stages, and seemingly distinct local types. Toward the west, in the Melanesian and East Indian regions, the vegetation is certainly much richer, but there seems to be almost no recorded information on it.

The problems presented by atoll vegetation are many. Good descriptions of the structure and composition of atoll communities are practically lacking. Nothing is known of its relationship with atoll soils. Actual patterns need to be mapped. An attempt must be made to reconstruct the original forest of present day coconut plantations. Correlations with ground-water conditions, with the several soil series, phosphate hard-pan, with sand, rubble, beach rock, and reef-rock must be made. Developmental or successional relations between the communities must be worked out. Effects of hurricanes and typhoons must be clarified.

The basic tasks that must be accomplished first, and that are best tackled first by the Atoll Program expeditions are the description of the gross structure and physiognomy, the recording of composition, and the mapping of the local distribution of the communities. Any further observations are all to the good, but these basic tasks must be done before any more detailed work can be of much significance.

If any correspondence can be established between patterns, incidence of salt spray, ground-water salinity, and soil patterns, it should be regarded as an important accomplishment.

If the communities listed above can be established as recurrent and sufficiently homogeneous to be of significance by the observations of several independent observers, a standard scheme for mapping them can be worked out. Eventually their distribution through the Pacific can be plotted and the present impression of a correlation with major climatic belts can be placed on a firmer and more objective basis.

Specific observations should be made on selected sites representative of the communities listed above, and of any others discovered, as follows: average height of dominant layer, slope of canopy surface toward sea and correlation of this with wind direction, number of layers and their definiteness, composition of each, relative abundance and evenness of distribution of commoner species, density of canopy and of other layers, substratum amount of disturbance by humans, abundance of sea-birds, presence of guano, presence of a raw-humus layer on ground, underlain or not by a hard-pan, presence or absence of weeds, indications of chlorosis of any species, either native or introduced, which species seem to be reproducing themselves in the vegetation, which not, which only in openings, any obvious invaders, presence and abundance of epiphytes, lianas.

Plenty of photographs should be made, and accompanied by notes on their exact locations and the nature of the subject matter.

One of the most intriguing sets of problems on which observations may readily be made is that concerning the colonization, by plants, of newly formed land--sand spits, gravel bars, etc. Which plants are the pioneers, how their seeds reach these habitats, conditions under which germination takes place, the order in which species are added to the communities, percentage composition at different stages in the development of the communities, and many related facts can be observed by anyone, and will contribute to an understanding of this process of colonization by plants. Collection should be made of seeds found on beach-drift, with accurate data on localities, abundance and whether or not similar seeds were seen germinating.

II. Plant Collecting on Coral Atolls

Preparation of herbarium specimens on coral atolls presents few special problems, other than those normally encountered in tropical lowland regions. Perhaps the principal difference is the abundance of fleshy plants that dry slowly. With modern methods and sufficient time, there is no reason for failing to secure excellent specimens with very little trouble.

The principal difficulties encountered in tropical collecting lie in getting the material dried rapidly enough to avoid disarticulation and molding, plus the unwieldy nature of some of the material, especially the fruits of some species.

Adoption of the following techniques should eliminate these difficulties and make collecting only a normally laborious task. A list of recommended equipment appears as part IV. of this chapter.

1. For ordinary herbaceous, shrub, or tree material:

Material should be gathered directly into folds of newsprint carried in a simple portfolio or field press. A vasculum is practically useless. The specimens should be placed in the field press immediately after being uprooted or cut, as some of them will wilt very readily. Wilted material is likely to be worse than useless. Extra specimens of delicate flowers should be taken and carefully pressed between small folds of newsprint, blotting paper, or cellophane, and these included in the folder with the plant. The press should be kept strapped tightly whenever specimens are not actually being inserted.

In selecting examples or parts of the plants for pressing, the fact should be borne in mind that the purpose of the preparation is to represent the particular local population that is being sampled. Between the pieces collected and the notes that accompany them, it should be possible to describe the plant and to know its range of variation. This means collecting vegetative, flowering, and fruiting material, if available, herbaceous plants with roots or rhizomes, and enough specimens to show the range of variation. Duplicates enough to deposit in several herbaria should be taken. Collectors on Atoll Program expeditions should secure a full set of specimens for the U. S. National Herbarium, one for the B. P. Bishop Museum, one to be submitted for identification, besides whatever the collector wishes to retain for himself or his institution.

After the material has been in press for some hours, long enough to have lost any springiness, a solution of equal parts formaldehyde, alcohol, and water should be applied with a small paint or varnish brush. If the plants are delicate, the solution may be brushed on the outside of the folder, otherwise directly on the plant. This kills the tissues immediately, prevents disarticulation and mold, and renders even fleshy plants easy to dry. They may be restrapped for some hours or overnight, to allow the formalin to penetrate thoroughly before they are dried. If it is not convenient to dry them at once after this, they may be tied in tight bundles and kept for several weeks with no damage before drying. This is often a great convenience, as it permits doing all the drying at a central base camp where much better facilities may be set up.

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Drying should always be done by artificial heat. As a source of heat electricity is the best, but is rarely available on atolls. If it should be available, several porcelain sockets screwed onto a board, provided with strong light bulbs or coils from reflector type bathroom heaters make a good heating element. If not, kerosene is next best. Small flat-wick stoves, such as the Harper "Beatrice", or ordinary lanterns, if enough are used, are practical means of burning kerosene. Round-wick Perfection-type stoves, if small enough to be portable, are good, but must be equipped with a spreader, or plate of sheet metal, to keep the heat from being concentrated on one spot and causing a fire. Portable gasoline stoves may be used, but are dangerous.

The heating element should be put in a box just wide enough for the ends of the press to rest on its sides. The top should be covered with wire netting to prevent straps from falling in and causing fires. The box should be open along the sides at the bottom to let in air, and should be about thirty inches high, to keep the plants far enough from the heat and to be of a convenient height for working.

If corrugated cardboard ventilators are used, they may be alternated directly with the newsprint folders containing the plants, building up a stack up to two feet high, which is then strapped between two stiff press frames or boards, the straps being tightened as tightly as possible to apply pressure while drying is taking place. If the much superior corrugated aluminum ventilators are used, the folder should be placed between two felt driers (blotters), and these alternated with the aluminum sheets, and tied into a press the same as described above. The press, strapped up, should then be laid on the heat box with the side down so that the corrugations conduct the heated air vertically up through the press, evaporating off the moisture absorbed by the driers.

For most atoll plants, the press should be heated about forty-eight hours. During this time it is best to turn it over a number of times, and if the straps loosen they should be tightened. Then it should be opened and each specimen examined, felt with the finger-tips to see if it is dry and crisp to the touch. The dry ones are removed, the rest strapped up again, and dried some more.

Adequate notes are absolutely essential, if the specimens are to be of any value. These are best written in a stiff-covered bound notebook, in a numbered series, with a number to correspond with each specimen and its duplicates. This number is written, preferably in soft pencil, on the newsprint folder, identically for each duplicate. Numbers should be large and easily seen. It is best to use one single series during the whole lifetime of a collector. This avoids confusion. Any separate fruit or seed specimens should bear the same number as the herbarium specimen from the same tree.

Information recorded should include notes on the habitat, place and abundance in vegetation, substratum in which it is growing; descriptions of any features that may not show in the dried specimen, such as habit of growth, size, color of flowers and other parts, waxy bloom, shape and consistency of fleshy fruits, odor of flowers and other parts, if any; vernacular name and native uses, recorded directly from native informants or observation in connection with the actual specimen collected, not taken from books or hearsay, are of great interest.

After the plants are dry and removed from the press, they should be tied tightly in bundles about three inches thick between stiff cardboards the size of the folders. As long as these bundles are kept tightly tied, the specimens can be handled with little fear of damage. For storage or shipment the bundles should be wrapped in tar-paper or other waterproof paper, with a small handful of para-dichlorbenzene or napthalene in each. For shipping by freight these should be packed tightly in substantial wooden packing cases. They may be shipped by parcel post in cardboard cartons of the type that canned goods come in, those for no. 10, no. 2 1/2, or for tall evaporated milk cans being about the right size. If time is available it is well to arrange the folders in numerical order, all those of one number being slipped inside one folder, and the range of numbers in each bundle should be indicated on the outside of the package.

Although there are no quarantine regulations against herbarium material, it is always best to secure a permit to import specimens from the U. S. Bureau of Entomology and Plant Quarantine, or to ship the material to an institution that has such a permit. It is also well to take advantage of any facilities for fumigation of material to destroy insects that might damage the specimens.

2. Special instructions for difficult genera which may be encountered, or those needing peculiar techniques:

a. Pandanus. For species likely to be found on atolls, a single representative leaf, folded several times so that it will fit in the press, with two or three phalanges or segments of the fruiting head, preferably taken from the middle rather than the ends of the head. These should be dipped in the formaldehyde mixture, then put in small gauze or cloth bags with a label inside, bearing the number. The bags must be spread out and dried thoroughly before storing. If bags are not available, the phalanges may be wrapped in a package of newsprint, but this is likely to tear open. A photograph of the tree and one of a fruiting head are valuable additions to the specimen. Ripe fruits should be selected if possible; if not, the fact that they are immature should be noted. Staminate panicles may be dried as with any other plant.

b. Portulaca. These should, if possible, be collected in the morning while the flowers are open. It is essential to count the number of stamens in the flowers, and note it down, as it is difficult to open them up after they are dried. Secure the tubers in tuberous-rooted species. Formaldehyde is especially necessary for Portulaca, as it is very fleshy and continues to grow while being dried, otherwise. Instead of formaldehyde, the plants may be dipped, momentarily, in boiling water.

c. Barringtonia, Ochrosia, Cerbera, and others with large fruits. The fruits should be collected separately, but from the same tree as the rest of the specimen, treated with formaldehyde, dried, and placed in a gauze bag with a label bearing the number. Especial note should be made of the way the fruit is attached, its position, color, texture, etc.

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d. Coconut. There is no satisfactory way for routine collecting of coconut palms. A photograph of the tree, with a section from the center of the rachis of a leaf, with two or three pinnae attached and folded, and notes, is about the best that is usually practical. A branch of a flowering inflorescence is a welcome addition if it is easily available.

e. Sesuvium. It is of interest to know if the leaves are glossy or dull, the color of the stems and the flowers, if the leaves are terete or flattened, held erect or horizontal.

f. Cyrtosperma and similar aroids. Search should be made for flowering plants, and if they are available, the flowering stalk should be collected, well doused with formaldehyde solution, one side split off. The stalk may be split to facilitate drying, also the petiole of the leaf, of which only one-half is necessary. Careful notes should be made as to how the blade is held on the petiole (erect, pendent, etc.), glaucousness, prickliness, gloss, color of spathe, petiole, etc. Photographs are valuable and easy to make.

g. Breadfruit. An average leaf or branch tip with at least one leaf, with a sketch of the shape of the fruit and a piece of its rind, and seeds if any, are sufficient. If staminate aments are available they should be included.

3. Mosses, liverworts, lichens:

These may be pressed as with any other plant, or merely collected in paper bags, numbered and allowed to dry.

4. Freshwater algae, diatoms, etc.

Most of these may be collected by spreading out the scum, or the slimy or leathery mass, on newsprint, placing this in the sun, weighted down with stones, and allowing it to dry. (See special section below.)

5. Fungi:

Parasitic forms without fleshy fruiting bodies are preserved by pressing and drying the host, as described for vascular plants. Hard, woody or indurate fruiting bodies are simply placed in paper bags. (For other forms requiring special techniques, see sections below.)

6. Wood specimens:

The nature of specimens or samples of wood to be collected depends upon the sort of information desired from them. Microscopic structure can be determined from a very small piece of wood, while full engineering tests demand large logs which are ordinarily impractical to collect on an ordinary expedition. Although a few general directions may be given here, if any extensive investigation of timber properties is intended, previous correspondence should be had with the laboratory which is to do the testing. Wood-testing, particularly of so-called "engineering properties", is an expensive procedure, and, unless previous arrangements have been made to have the tests made or unless funds are certainly available, much effort is likely to be wasted.

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Size of samples collected will, undoubtedly, be determined by the practical matter of available transportation. If it is not practical to collect samples of more than a few ounces weight, structural properties based on microscopic examination, and macroscopic physical characteristics determined by inspecion are all that can be determined. The fact that should be borne in mind is that characteristics of wood from the trunk of a tree differ significantly from those of branch wood. Trunk wood should always be selected, preferably from clear portions of the trunk, free from knots, bends, diseased or injured wood, or worm-holes. If a very small piece, only, can be collected, then a portion of heart-wood, midway between the center and the sap-wood should be taken. A better sample is a plank-shaped or pie-shaped section, at least an inch thick and a foot long, running in width from the center to the outside of the tree-trunk. Seasoning of such small pieces does not usually cause difficulties, but they should be exposed to dry air on all sides, or turned frequently.

Density is a property of wood from which estimates or approximations of certain other valuable properties may be obtained. If there is serious interest in the economic properties of woods, the minimum test that is of value is a measurement of the density. Dimensions of minimum samples for determination of density are contained in the following quotation, which is from a letter from the Director of the Forest Products Laboratory of the U. S. Forest Service dated March 13, 1953:

"The minimum sample size for specific gravity and shrinkage determinations depends upon the diameter of the log, the presence of knots or other defects, characteristics of grain, and the like. In general it is preferable to obtain sample sections from living trees that are freshly cut in order to be sure that they stay green during transit and to minimize stain and decay. Only heartwood of dead timber would be sound. It is desirable to secure sections from a reasonably uniform height in the tree, say 10 to 16 feet above the ground (for better comparison among species and with data in Tech. Bull. 479 where samples ordinarily represent the 8 to 16 foot height). The section should preferably represent the full cross section except in large trees where shipping costs of a full section become excessive. It is difficult to lay down hard and fast rules but, in general, if the diameter is 12 inches or more a section 12 to 15 inches in length should suffice. For trees smaller than 12 inches in diameter we would prefer longer sections, say 18 inches in length down to about 8-inch diameter, and not less than 2 feet in length if less than 8 inches in diameter. The ends of the tree sections should be coated promptly after the section is cut, preferably with not less than 2 coats of aluminum paint or a heavy coating of asphalt paint. If coating cannot be applied the sections should be increased in length to provide not less than a 6-inch cut off at each end upon arrival at the Laboratory.

While such provisions may appear somewhat rigorous, we have seen many instances where sample sections were of little use because of drying, checking, and decay when proper precautions were not taken, and the results of tests on such material are, to say the least, subject to a great deal of question."

III. Directions for Collecting Information on Varieties of Economic Plants

A number of the most important economic plants in the atoll groups have proliferated into series of horticultural varieties. Of these very little is known, and what is known is not adequately backed up by specimens. More information should be collected, and an expedition where an anthropologist is present provides an ideal opportunity to do this. His co-operation should be sought and made use of, both in dealing with the natives and in cross-checking information. The results should be of equal interest to him and to the botanist.

Brief directions as to what is needed for the principal groups of plants follow:

1. Pandanus. Varieties differ in size and shape of fruiting head, sculpturing of distal end of phalanges, number and arrangements of styles, size and fleshiness of base, juiciness, sweetness, flavor, and irritating qualities of flesh, prickliness of leaves, toughness, pliability, and other weaving qualities of leaves. The first half dozen of these features will be shown by the herbarium specimens. The features of the flesh must be found by trying them, and by asking the natives' opinions. The natives must be consulted as to utilitarian qualities of leaves, also on use made of fruits. These may be eaten raw or used in several preserved forms. Native names should be secured, as well as any information available on origin of the varieties, how propagated, whether they come true from seed, etc. All of this information should be carefully associated with specimens.

2. Coconut. Varieties differ in size, shape, color of nuts, number in a cluster, flavor of water, thickness of meat, edibility of husks, and perhaps other characters. Very little is known of these varieties. Considerable instruction will be needed from the natives before any understanding will be gained. It is of especial interest to know if these are really characters of fixed varieties, or if they are merely characters that segregate independently. Do the characters have names, or the individual trees, or general types of trees, or actual varieties? What are the differences in uses of each? Origin?

3. Cyrtosperma. The tangible differences here are in color and prickliness of petioles and peduncles. Perhaps there are differences in edible qualities, or cultural characteristics. Botanical specimens with notes will show prickliness and color. These must be correlated, if possible, with other features. Names. Origins. Seasons. Do not confuse with Alocasia.

4. Colocasia. Taro varieties differ in stature, number of leaves fully open, shape of blade, color of petiole, veins, and blade, color and arrangement of tubers, edible qualities, cultural characteristics. Names. Origins. Seasons.

5. Alocasia. Possibly two varieties or species, one with green petioles, the other with purple. Differ in stature. Possibly varieties within these, differing in edible qualities. Determine if actually eaten, if any way to prepare to get rid of acrid qualities, under what circumstances eaten, if actually cultivated, names, origins. Do not taste.

6. Breadfruit. Many varieties, in two main series, differing in being seedless or with seeds. Varieties differ in leaf outline, size, shape, and surface of fruit; edible qualities, whether can be eaten raw, or only cooked, flavor; season of bearing, if fruit is preserved in any way for off-season. Evidence particularly desirable as to whether seed trees are ever fertilized by pollen from seedless, whether two species were originally present, one entire leafed and seedy, other incised leafed and seedless, now mixed by hybridization. Origin of varieties. Names. Place in economy of natives.

7. Tacca. Careful watch should be made for varietal differences. Extent of use and modes of preparation, as well as whether actually planted or cultivated should be determined.

8. Other economic plants. Notes should be taken, with specimens, indicating cultivation or use of any species of plants that in any way enter into the native culture, past or present. This should preferably be done in close cooperation with an anthropologist. Information gained locally, either from native informants or from missionaries or other white residents should be carefully verified from independent sources before being accepted as fact.

IV. List of Equipment for Collecting Plants on a Coral Atoll

1. 200 corrugated aluminum sheets or "ventilators", 12 x 17 inches. The corrugations should not be over 1 cm. wide, and must run transversally rather than longitudinally.

2. 400 felt driers or "blotters", sheets of deadening felt 12 x 17 inches. (If aluminum ventilators are not available, 500 hard finish double-faced corrugated cardboard sheets, 12 x 17 inches, will do in place of both driers and ventilators.)

3. Newsprint, folded into quires 17 x 12 inches, or newspapers with the folded end torn off so as to make quires of this size. Enough for 1500 or 2000 folders should be enough for a season on an atoll, depending, of course, on the number of duplicates to be collected. An atoll may be expected to have between 75 and 150 species, some of which will have to be collected more than once.

4. 100 sheets of stiff cardboard, 12 x 17 inches, for tying bundles.

5. Several cones of the heaviest butcher's twine.

6. A roll of waterproof paper.

7. Five pairs of wooden press frames or boards, 12 x 17 inches.

8. Five pairs of 9 foot two-inch webbing trunk straps.

9. Five pairs of 12 x 17 inch sheets of beaver-board or other very heavy cardboard for field presses.

10. Five pairs of oilcloth envelopes just large enough to slip the sheets of beaver-board inside of, with a flap and snaps.

11. Five pairs of four or six-foot, one-inch webbing trunk straps.

12. Two gallons 40% commercial formaldehyde.

13. Two gallons of 95% ethyl alcohol.

14. Three 1-inch or 1 1/2-inch paint brushes.

15. Ten lbs. para-dichlorbenzene.

16. 10 yards of gauze.

17. 100 medium sized paper bags.

18. Three Harper "Beatrice" flat-wick kerosene stoves, or equivalent, or six ordinary kerosene barnyard lanterns. Extra wicks.

19. Coleman lantern, extra mantles and generator.

20. Two sixteen-inch or eighteen-inch Collins machetes.

21. Two pairs small clippers.

22. Two boy scout knives.

23. 200 shipping tags.

24. Five bottles insect repellent.

25. Record books, fountain pen, steel pens, permanent ink (Parker 51 pen and ink are good, as the ink dries very rapidly), blotters.

26. Soft pencils.

27. Small chest or foot-locker with lock in good order, for notebooks and other valuables.

28. Piece of chick wire 2 x 6 feet.

29. 5 yards of white muslin.

30. Waterproof matchbox or lighter that works.

31. 2 or more 1 or 2 gallon tins with spouts, for kerosene and gasoline, for filling stoves and lanterns.

32. One drum of kerosene.

33. One drum of white (unleaded) gasoline, to be used for cooking as well as for light.

SUGGESTIONS FOR COLLECTING FUNGI

by Donald P. Rogers

Fungi parasitic on leaves or other plant parts are almost entirely unrecorded from atolls. Many of these occur as or in leaf-spots; the fungus fructification may be a superficial pustule or an embedded fruiting chamber (perithecium or pycnidium), often surrounded by a dead or discolored area of the leaf. The distinction between infected leaves and those merely damaged by insects or mechanical injury is not always easy in the field. Often close inspection by a hand-lens is necessary to reveal the fructification; and even then the ostiole of a pycnidium may appear as no more than a brownish, or blackish fleck in a discolored area. Other parasites, the sooty molds, may form wide-spread blackish incrustations. Occasionally a fungus (such as the downy mildew on Boerhavia) causes marked distortion of the host. All parasites on herbaceous plant-parts are treated as the host alone would be-- that is, pressed, preferably along with sufficient host material to confirm the identification of the latter. Parasitized woody parts are dried without pressing. Slabs cut from a stem will dry more quickly than sections of the entire stem, and since the fungus fructifications are not apt to be deep, are just as useful as larger pieces. Where there can be any question of the identify of the host, material sufficient for identification should be pressed to accompany woody specimens.

Although the specific identity of the substrata of non-parasitic fungi is of less importance, it should wherever possible be noted. Such fungi occur on soil (but not so commonly as in temperate regions), on dung, and on dead plant material, including worked wood and fiber. Standing trees or stumps, fallen logs (a rich and interesting source of fungi), accumulations of dead vegetation on the ground and especially in trash-pits—all serve as substrata for saprobic fungi and should be examined. Fungi are apt to be present although not visible in soils and humus of the first shrub-zone of the upper beach, of forested areas and of the wet pits planted to Cyrtosperma and banana; samples of soil, and of dung, thoroughly dried and wrapped so as to minimize contamination, can serve as a source of cultures of such fungi as mucors and water-molds even after months or years.

Myxomycetes. The fructifications resemble minute puffballs or stalked globes or eggs, or may be sessile and effused. They are extremely fragile; and although usable specimens may be kept in paper packets, the usual and better practice is to wedge or pin portions of their substratum into the tray of a penny match-box or similar small box. Myxomycetes are found on decaying plant debris and on stumps and logs, or sometimes on sound trees or wood where they have migrated to fruit.

Phycomycetes. Most forms will be invisible and must be isolated by culture methods from dung or soil samples. One is known as a systemic parasite of Boerhavia; other such downy mildews may be found. Glaziella forms hollow red fleshy fructifications, up to 2 inches across, in trash on the ground. If it is found, the exact color of living specimens should be noted. A piece of printed paper, such as a cigarette package, will serve as a color-standard.

Ascomycetes. Many leaf-spot fungi belong here. In addition, some saprobes will be found. Cup-fungi occur on soil or dead wood, and may occur also on dead herbage. They are firm enough to be dried readily. Pyrenomycetes, hard-fleshy to woody or carbonaceous growths, sometimes bright-colored but often coal-black, develop especially on dead wood. Some are minute and mammiform; many are embedded in the substratum, with only the ostiole or beak of the perithecium protruding; others form encrusting layers or large nodular to club- or antler-like growths. Readily dried.

Basidiomycetes. For the satisfactory identification of most Hymenomycetes (those Basidiomycetes with exposed fruiting surfaces) a spore-print is of considerable use, although for most it is not of critical importance. To secure a spore-print the fruiting-body should be placed, fertile (usually lower) surface down, on a piece of white paper, and unless the atmosphere is nearly saturated, covered with something such as an inverted tumbler or empty can that will prevent drying out of the specimen before spores have been deposited. If black paper is available, such as that in which photographic film is packed, a part of the specimens may be placed over white paper and part over black. The color of the spores can be learned (and should be noted from the fresh print) from the deposit on white paper; the black will show whether spores have been shed. A microscope slide will do as well as the paper. The spore-print is dried and filed with the specimen. If the weather is very wet, or if only a single specimen of a fleshy fungus is available, spore-printing may destroy the specimen, and it is then better to do without the print. Twenty-four hours should be time enough to secure a good print, if the material is going to yield one at all.

Most larger fungi, including nearly all Basidiomycetes, should be wrapped when gathered in pieces of newspaper, one collection to a packet. As soon as possible the packets should be opened and the specimens spread for drying, on a flat roof, table, or sandy area, if the atmosphere will dry the material, or above an artificial source of heat if that is necessary. Fleshy specimens need quick drying; woody ones are useful even if conditions for preparation are poor.

The jelly-fungi (Tremellales) may be ear-like and hairy on the sterile surface (Auricularia), jelly-like and translucent (Tremella), or only a mucous or gelatinous layer on a dead log (Sebacina). Spore-prints are desirable, but the basidia that produce the spores are of greater importance for subsequent study, and if the specimen is held a day for a spore-print and then too slowly dried the basidia may nearly all have discharged their spores and disintegrated by the time drying is complete. It is often better, therefore, to dry a part of a collection at once, and to use only a part for a spore-print. If the collection is small, or a choice must be made, it is better to secure immediate drying. If the heat is not so great as to kill the fungus by cooking, a well-dried specimen can often be revived months later and spores secured.

The genus Septobasidium produces lichen-like growths on living plant parts, usually twigs or smooth bark. A very interesting lavender-gray species has been found on Pandanus in the Marshalls; one should be sought on Citrus twigs. The fungus is usually felt-like in texture, and under the lens may show three layers in section-- a continuous basal layer in contact with the bark, a layer of pillars and air-spaces, and a continous fruiting surface-- all in a thickness of one or two millimeters. It is parasitic on scale-insects which in turn parasitize the host-plant; and any collection of Septobasidium therefore presents a triple problem in biogeography--that of the host-plant, the insect, and the fungus. This should be dried like any similar fungus; specimens in preservative are also desirable.

Thelephoraceae (and some Fungi Imperfecti which resemble them) and Hydnaceae may form films or sheets closely applied to the substratum (resupinate), or may be reflexed or occasionally free or even stalked. The last family is characterized by a tuberculate or toothed fruiting-surface, and the other groups by a more or less even one. Even the most delicate ones, which appear almost mold-like, are worth collecting; these should not be spore-printed unless quick drying is possible, or unless a part of the collection can be dried at once and a part sacrificed for the print. Unless the fructifications are stipitate, all should be collected with a slab or generous fragment of the substratum.

Polyporaceae may be shelf-like and leathery, fleshy, or woody, or may be resupinate like some of the groups earlier listed; all have a fruiting surface marked by pores. They are easily dried; the resupinate ones should be printed if possible, even if this necessitates first moistening the fructification or soaking the attached substratum.

Polyporaceae may be shelf-like and leathery, fleshy, or woody, or may be resupinate like some of the groups earlier listed; all have a fruiting surface marked by pores. They are easily dried; the resupinate ones should be printed if possible, even if this necessitates first moistening the fructification or soaking the attached substratum.

Agaricaceae, the gill-fungi, will be found both on dead wood and on the soil. Some are extremely fleshy and decay very very quickly, and for these the preparation of specimens will be a race between the drier and the processes of decay. The smaller, less fleshy species will retain their form and texture fairly well; but specimens of the larger species are usually worthless unless accompanied by notes showing color, attachment of gills to cap, and presence or absence of a ring around the stalk and a cup for membrane at the base. Color-notes are desirable for all. It is also desirable to make a median longitudinal section of one or two before drying.

Gasteromycetes, the puffballs and stinkhorns, will probably be rarely found, but are of considerable interest. Puffballs are worthless except for food unless the spore-mass within has taken on its characteristic deep color. Stinkhorns, which may have a simple columnar receptacle covered at the tip with a sticky greenish spore-mass, or may have a number of free or interwoven arms, are greatly sought by carrion flies, and may have to be sprinkled with formaldehyde before drying or put at once in preservative.

Rusts and smuts are rare on atoll plants. If found they should be treated like leaf-spots.

Lichens. As is generally known, these are compound structures composed of a weft of fungus threads in which are embedded algal cells. In moist areas they are quite common on trunks of trees--either crust-like forms or rosettes; rock-incrusting species are not usual on atolls. Lichens are apt to be whitish or grayish when dry; rain or artificial soaking usually shows up the green component and shows them to be lichens rather than simply fungi. Specimens dry readily, and ordinarily are not much damaged by remaining moist for some time. They should be collected whenever found.

Whether many of the atoll plants are mycorrhizal is not known; information on this point would be of importance not only to mycologists but also to the ecological understanding of the vegetation. If soil fungi are found it would be well to note whether they are associated with particular plant species. If they are, or perhaps in any case, portions of the absorbing tips of roots, held in preservative, should provide data on the mycorrhizal or non-mycorrhizal nature of the plants.

COLLECTION OF SOIL SAMPLES FOR THE RECOVERY OF AQUATIC PHYCOMYCETES

by F. K. Sparrow

Equipment needed: Tablespoon; wide-mouthed jar of 70% ethyl alcohol; 2 oz. cardboard cylindrical drug cartons, $2\frac{1}{2}$" high by $1\frac{1}{2}$" in diameter; tape (adhesive or scotch).

Collection method: Scrape away topmost inch of soil, fill carton with soil, using spoon, tape carton shut, pencil collection data on box, sterilize spoon in alcohol.

It is better to collect only dry soils.

Collection data: Locality, depth, any special features such as proximity to beach, tide line, etc., date, collector.

INSTRUCTIONS FOR COLLECTING ALGAE

by Maxwell S. Doty

Algal forms of three categories should be sought in particular:

1. Algae that are prospectively important in the structure of reefs, in the filling of lagoons or in contributing to the sand of which the non-volcanic islands are formed;

2. Algae of use to the natives;

3. Soil algae that contribute to the binding of the sand, humus formation, or nitrogen fixation.

Algae of the first category should be sought on the reef, encrusting coelenterates and rocks, or waving free in the water or on lagoon bottoms. Algae of the second group are to be obtained with the aid of local guidance as to names and uses. The algae of the last category appear as strands, scums and crusts that vary from elusive stains to tar-like crusts of various colors or black. They appear on sand, dead wood or in pools, both on dry land and in the water. Labels indicating, in these respects, the roles of the different algae collected will greatly enhance the value of the collection.

There are two methods of preservation recommended. The simplest is drying the algae in the shade in clumps or spread on paper or leaves. Drying will be hastened by the elevated temperatures above a heater (e. g. Coleman lantern). When dry or nearly so, the algae should be wrapped with their labels in bundles and packed so as to prevent crushing. The second and better method for field use is "pickling" in ten per cent formalin in water, ten per cent sea water formalin being used for marine forms. "Alcoholic specimens" are good.

It is feasible to set aside a can of four per cent formalin to which, in the course of other work, the different kinds can be added, as found, until it is felt that a representative collection from the area has been obtained. Most phycologists working in the Central Pacific recently have sealed their specimens in tin cans with a can sealer, as in the process of home canning. This method is greatly superior to older field methods, as it avoids breakage and leakage, and identifying marks painted or scratched on the can are permanent. Algal herbarium specimens mounted on herbarium sheets or mica are, of course, most welcomed.

Preserved algae may be shipped mixed with other preserved materials such as fish or invertebrates, but take measures to prevent the rock-line corallines from crushing the more fragile forms. It is desirable but not essential that the algal collections be kept separate. Again: The value of a collection will be inestimably enhanced if labels will include information relative to the roles outlined in the first paragraph above, or information which will show critical consideration of distribution.

SUGGESTIONS FOR COLLECTING MODERN AND FOSSIL CALCAREOUS ALGAE

by
J. Harlan Johnson

Calcareous algae are those seaweeds that deposit lime within and around their tissues. They are of interest and importance because they assist in the formation of coral reefs and often contribute appreciably to the formation of limestones.

In the course of geologic time, some members of most of the major groups of algae have developed the ability to secrete or deposit calcium carbonate. In connection with studies of tropical reefs, however, only two groups are important, the red coralline algae and the green Codiaceae, (represented by Halimeda) and Dasycladaceae, (represented by Cymopolia and and Acetabularia).

The red coralline algae include both crustose and articulated types. In general the crustose corallines are important on reefs and on reef limestones. They form the Lithothamnion Ridge, (which is usually constructed mainly by a few species of the genus Porolithon), and play an important part in binding together the various organic elements of the reef. They may contribute appreciably to the mass of the reef. Halimeda species, the most important calcareous green algae, grow in the lagoons, on the reef flat, and sometimes on the reef face. They may develop banks or meadows over large areas, especially on lagoon bottoms. Some bottom samples from the lagoons at Bikini, Saipan, and Palau show that Halimeda remains are the principal constituent of the sediment. In some places, Halimeda fragments contribute to the sand and beach rock.

Collecting Modern Algae

The massive, branching, encrusting, and nodular forms of the crustose corallines need relatively little attention. After the specimens are collected, they should be soaked in fresh water for several hours or overnight. Then all extraneous material, especially worms, sponges, and other animals, should be picked out. The specimens should then be washed carefully in fresh water and allowed to dry for several days, until they have bleached white and until any enclosed animal remains have ceased to smell. They should be wrapped well and packed carefully in strong containers for shipping. The large, highly branching forms are heavy and very brittle, so they require careful packing with paper, shredded paper, cotton or straw.

If it is desired to preserve the color or the associated organisms or both, the specimens should be "pickled" in a solution composed of 90% sea water and 10% formalin and packed in containers. Since crustose algae are both heavy and brittle, only one or two specimens should be put in a container, and they should be packed so as to fill it. If specimens are packed too loosely or too many to a container, crushed and broken material will result. For the same reason, crustose algae should not be packed with articulated corallines, Halimeda, or noncalcareous algae.

Articulated coralline algae are very fragile. Specimens should be washed or soaked in fresh water to remove all salts. Then they should be placed on blotters or newspapers and allowed to dry slowly (not in sun) for several days or a week. Specimens should be wrapped carefully in tissue paper and packed in shallow boxes or trays, padded with cotton or soft paper. These boxes should be packed in strong containers for shipping.

Halimeda, Dasycladaceae, and other calcareous green algae usually contain more moisture and organic matter than the calcareous red algae. They are also commonly fragile. After the specimens have been soaked and carefully washed in fresh water, they should be spread out on blotters or newspapers and allowed to dry slowly, possibly for several weeks.

During that time the specimens should be turned over every day or two. Care must be taken to prevent mold or mildew, which can permanently discolor or even destroy specimens. The dried specimens are fragile and need to be packed carefully.

Fossil Algae

Fossil algae are best known from fragments scattered through limestones, especially limestones containing corals and large Foraminifera. Nodular masses and large crusts may form large lenses or beds of limestone. Sometimes algal material may weather out of chalky or marly beds. In most cases the algal fragments are firmly imbedded in the rock and samples of the limestone should be collected. Take material as little weathered as possible.

To identify the algae, thin sections are necessary. This means that fairly large specimens (3 x 4 inches or larger) or several small specimens should be taken as samples.

Calcareous algae are also known to weather free from marly or tuffaceous deposits; more attention should be paid to obtaining such material, as it may supply the best-preserved specimens. Loose specimens, which may be studied in their entirety and by means of oriented thin sections, are ideal for comparative systematic studies but are difficult to obtain--so they are worth searching for and collecting carefully. They should be wrapped in tissue paper or cotton and put in vials or small boxes. They can be cleaned and freed of matrix in the laboratory.

Desirable Field Data

It will greatly help the specialist who studies the specimens if the collector will label the material carefully as to locality and will supply notes on distribution, ecological association, and depth of water.

Chapter 7 - Zoology

SUGGESTIONS AS TO COLLECTING LAND VERTEBRATES ON CORAL ATOLLS

by J. T. Marshall, Jr.

Each member of the party should be provided with a copy of "A field collector's manual in natural history" publication 3766 of the Smithsonian Institution, Washington, D. C. This concise pocket book gives complete instructions for collecting and preserving all types of animals.

The Field Notebook

Preferably loose-leaf, of medium size, the field notebook is much more important than the specimens. In it are recorded observations on the behavior, feeding methods, habitat, breeding activity of the various animals.

Species Accounts: Keep the records for each species in a series of pages devoted to that species alone. Memory is treacherous, and to be of value, these observations should be written down in the field while you are watching the animal.

Catalogue of Specimens: The catalogue duplicates the information on the specimen label, and is the place where additional information (for which there may not be enough room on the label itself) such as coloration, stomach contents, parasites found, slides prepared, condition of gonads, amount of fat, habitat, time of collecting is entered. Number each specimen in serial order, in the order in which they are collected, using the same consecutive series of numbers for all the vertebrates. Each number then is unique for the particular specimen, and this number appears both on the specimen label and in the catalogue.

Label: Labels will be provided by the Smithsonian Institution. They should be of tough paper which will not go to pieces in liquid, and should be written upon clearly with Higgins Eternal Fountain-pen Ink. For any vertebrate specimen, the information which must appear on this label is

exact locality
date
your signature
your catalogue number

In addition, for birds, the sex, as determined by opening the body cavity and examining the gonads, must be entered; for mammals, in addition to the sex, the following measurements must appear, and to save space, you can merely put the numerals down in this order, in millimeters: total length, tail length, hind foot, ear. In addition, for all vertebrates, put as much of the further information as stated above under catalog for which there may be room. A strong label, the "skull tag" bearing your initials, cat. number, sex, is tied to the mammal skull.

The Specimens

With the bookkeeping methods well in mind, let us now turn to the actual preservation of the specimens.

Reptiles and amphibians: Don't neglect the nocturnal species. They may easily be found by their eye-shine, seen when you hold the flashlight near the level of your eyes. A head flashlight is a great convenience. These animals are easily caught by hand while they are active, or when uncovered in their hiding places. For the shy forms, a noose of leader or grass at the end of a long stick is an efficient collecting device. Tie a label on one hind leg, slice open the body wall and big muscle masses in a few places to permit penetration of the preservative, and place in 70% ethyl alcohol. Alcohol can usually be obtained from Navy hospitals. Spike or change the alcohol before shipping home. Record coloration in the catalogue, for these animals fade.

Birds: These can often be obtained from the natives, who have various methods of snaring them. It is not absolutely necessary to take a shotgun along to collect birds, as the forms found on atolls are pretty widely distributed and well known from the standpoint of specimens. They are practically unknown as regards behavior, annual cycle, etc. You can make a good skin of a bird shot with a small bore rifle, as long as it is not hit in the head. Powdered arsenic, dry sand, cotton and scissors and forceps are needed in preparation. Liberally sprinkle sand all over the bird while skinning, so that blood and juices may not soil the feathers. The process of bird skinning in a nut-shell is this: make an incision lengthwise of the belly from about the middle of the breast muscle to the cloaca. Lift the skin away from this opening and turn the skin completely inside-out, thus removing it from the carcass, and cutting it away from any attachments to the carcass in the following order:

Cut each leg from under the skin at the knee; cut the tail through the caudal vertebrae, again under the skin, as you expose this area in turning the skin inside-out; cut the wing through the humerus, pull out the ears, cut the eyelids between the skin and skull; cut out the back of the skull and roof of the mouth. Do not cut off the bill. You now have the skin inside-out, with the bill, skull, wings, feet and tail all attached by the skin. Clean off all meat, brains, fat, and if very fat soak in gasoline or scrape and keep sprinkling with sand. (Gasoline-soaked skins easily fluff out and dry if held up in a brisk wind.) Now turn the skin right-side-out again and from the ventral incision, fill each eye with a ball of cotton. (Sprinkle arsenic on the skin before turning right-side out.) Put a stick wrapped with cotton into the neck, and anchor the sharpened end of this stick in the base of the upper mandible. Roll up a piece of cotton the size of the carcass and put it into the skin, with the neck stick ventral to it - thus the neck stick runs along the throat, and we have left a hollow space at the back of the neck into which the neck feathers can find their proper alignment. Sew up the incision, cross the feet and tie the label around both at the point where they cross. Wrap in cotton until dry. The object of this preparation is to have a specimen resembling the dead bird, which will be well filled out with cotton so as to reveal the plumage and coloration, and from which measurements of the bill, wings, tail and feet may be taken. This requires that the bill should be closed in a natural fashion. For large birds, it is necessary to skin out the muscles of the wing. This can be done by turning the wing skin inside out as far out as the wrist. This of course involves stripping the secondary feathers off the ulna, but is a justifiable procedure as long as you are certain to pull these feathers back along the ulna to their original locations when you turn the wing right-side out again.

The sex determination appearing on the bird label should be based on an examination of the gonads, which lie at the anteroventral portion of the kidneys, near the adrenals. Two oval white or yellowish bodies with tiny tubules showing through the transparent covering, which has a smooth surface, indicate a male. In the female, there is usually only the one gonad, on the left, and it is granular and irregular in shape, owing to the presence of numerous ova.

Mammals: Again, it is well to bear in mind, especially if you are restricted as to luggage, that it is not absolutely necessary to have traps. The little Polynesian rats, and the larger house rats can readily be taken as follows: break open a fresh coconut and lay it at the edge of a pile of coconut husks, or a rock wall, or a rotten log. Sit quietly with a stick and club the rats on the back as they come out to eat the coconut meat. The natives can get you many in this way, though they make the mistake of hitting them on the head, thus ruining the skull for scientific study. The skinning method is similar to that used for the birds with this important difference: the four measurements must be taken before skinning, and the entire undamaged skull must be removed from the skin, the brains blown out through the foramen magnum, and a skull tag attached to the skull. The tail bones also are entirely slipped out of the tail skin, to be replaced with a long wire carefully wrapped with long-fibered cotton of just the right thickness to get all the way back to the tip of the tail. After dusting the skin with arsenic and turning it right-side out again, it is filled with a cylindrical piece of cotton, pointed into the snout, and wires wrapped with cotton are thrust into the four feet. These four wires and the inner end of the tail wire lie between the skin and the stuffing, on the ventral side of the animal. After sewing up the incision and tieing the label on the hind foot, the rat is pinned down on a board, with the soles of the feet down.

Problems of Interest on Atolls

Large series of the rodents and lizards should be preserved. Look for signs of the introduction of house rats, and determine if they are eating the green coconuts. Apparently the Polynesian rat does not eat the nuts on the tree. Among the reptiles, the skinks are of particular interest for they are apt to show polymorphism (within the same species) and you are likely to observe different proportions of the various color phases on different islets of the same atoll. You may even find in the skink genus *Emoia* that two closely related forms, differing markedly in color replace each other about the atoll (apparently not occurring together upon any one islet). Exceedingly valuable data will accrue from a brisk survey of *every* islet of the atoll, whereby you collect representative samples of such a species and note the environmental conditions under which each form flourishes as well as the conditions upon islets where neither is found. Thus one might be permitted to evaluate the possible role of natural selection in bringing about such strange distributional patterns. In other words, environmental conditions about an atoll may not be as uniform, from the standpoint of land vertebrate habitats, as one might suppose. Striking irregularities in distribution may be disclosed by such a canvass of the entire vegetated land area of the atoll--vastly worth-while even though brief. For birds, the items of interest are a determination of the breeding period for each species. (On Ascension Island, the sooty terns are now known to breed every 9 1/2 months, year in, year out!). Also observe and record location of colonies, time of activity, whether flocking or solitary, behavior in general. The most valuable observations accrue from continuous or daily observations of the same individual or group.

Parasites

After going such a long distance to get your specimens, it is rather too bad if you do not take full advantage of all the information that they may yield, before they are preserved. It is worth the trouble, therefore, to take along a microscope and look for rectal and caecal protozoa, and for intestinal helminths. These are easy to find, for if they occur at all, they are usually swarming. For instance, a drop of liquid which a lizard exudes from his cloaca when handled, may be just a living mass of flagellates. The same applies to the caeca of birds and of rats. Take along a stock bottle of Bouin's fixative, and a supply of round coverslips, and vials into which they just fit, round papers, the size of the covers. Smear the fluid from the rectum or caecum on one side of the cover slip and immediately (before it begins to dry) float it face down upon the surface of the Bouin's solution. After a half hour or so, transfer it to 50% alcohol, then to 70% alc. in the vial. On top of the series of covers all coming from one vertebrate specimen, put a paper label bearing your catalogue number for that particular vertebrate, and the organ from which the smear was made. It is of great scientific interest to do the same for the protozoa living in the hind gut of termites. Keep a vial of the termites in alcohol with a catalogue number corresponding to that on the label for the coverslip preparations, so they may be identified.

Roundworms are killed in hot 70% alcohol (this makes them straighten out) to which is later added a little glycerine, if handy. Flatworms should be placed in Bouin's fixative overnight, then placed a few minutes in 50% alcohol, then stored in 70% alcohol. If time and space are very limited it is possible to get good results by just leaving these cover smears and flatworms in the Bouin's, but it is preferable to store in alcohol after killing in the Bouin's.

Ectoparasites: Mites, ticks, lice, fleas, hippoboscids, and other external parasites are only collected efficiently in conjunction with collection of their hosts. Mites which infest lizards are automatically preserved with their hosts in alcohol, but, because they may drop off, the lizards should, at least at first, be placed in separate receptacles of alcohol, separating the species and localities. When the alcohol is changed any mites that have dropped off may be picked up with a medicine dropper and placed in a vial with a label. Wrapping bird and mammal skins in a thin layer of cotton while they are drying will serve to gather many of the ectoparasites, which leave the host as it dries. They do not live long, especially if the skins are dried in the presence of paradichlorbenzene or napthalene, and when they leave the skin they usually lodge in the layer of cotton. Rats, which usually have fleas, may be left for a short while in a jar with paradichlorbenzene crystals or a few drops of gasoline or ether. The fleas will be killed and either remain in the hair of the rat or fall to the bottom of the jar. All of these parasites may be preserved in alcohol. Like the helminths, they should be kept in a separate vial corresponding to each host specimen, as proclaimed by a slip of paper in the vial, which bears your catalogue number of the vertebrate host, as well as the location or organ where the parasite was found.

SUGGESTIONS FOR COLLECTING TERRESTRIAL INVERTEBRATES ON PACIFIC ISLANDS

by Robert L. Usinger

Introduction. The best general advice on collecting terrestrial invertebrates is to look everywhere, collect everything, preserve it carefully, and label it adequately. This comprehensive statement is especially true for the little-known islands of the Pacific where even the commonest invertebrates may prove to be of exceptional interest. The following remarks are intended to provide detailed information on specific points in collecting. It may appear that a disproportionate amount of time is devoted to the insects, but the collector will find that this is the largest group of terrestrial arthropods, both in species and individuals.

Collecting. The various methods of collecting may best be discussed separately, though in actual practice the procedures are carried on almost simultaneously. The most obvious method of collecting insects is with a net. Flying insects are encountered in greatest numbers when the sun is shining. Sweeping and beating vegetation is possibly the second most important method of collecting. In this connection a sturdy net bag is essential, or a canvas sheet, or an inverted umbrella can be placed beneath vegetation and the limbs can be beaten with a heavy stick. Beating and sweeping yield large numbers of inconspicuous insects which would be completely overlooked by other methods of collecting. The third type of collecting which should not be neglected is ground collecting under stones and logs, on roots, and in leafmold.

In addition to the above-mentioned types of collecting, which are perhaps the most important, there are numerous specialized methods that need to be mentioned. Aquatic collecting is one of these. Specimens should be sought for in ponds, taro patches, wells, cisterns, tree holes, opened coconuts, bases of leaves and fronds of Pandanus, palms and various epiphytes, and in protected coves on coral reefs or even in the open ocean. Mosquito larvae (or better still, pupae) should be collected with a net or dipper and kept alive until the adults emerge. Light collecting is another specialized, but sometimes very profitable, method. Insects are usually attracted to lights in greatest numbers on evenings when there is no moon and when the atmosphere is relatively humid. Electric lights may be used, preferably with a white background, or a Coleman lantern is satisfactory. In places where a Coleman lantern is used, care should be taken to provide white gasoline. Wood-boring insects may be collected by beating dead or dying branches of trees or by gathering such branches and rearing the larvae out in closed containers. A rich fauna will be found under loose bark and in rotting wood. Equally productive are decaying breadfruit and rotted pandanus fruit as well as other fruits which have fallen to the ground. An entirely different type of life will be found in animal carcasses and dung. Ectoparasites of man and animals should not be overlooked. These are found on the animals or in some cases in the beds or nests. Plant-feeding caterpillars including leaf miners should be reared by collecting the infested parts of the plants and placing them in cardboard or tin boxes. Additional food must be provided from time to time. This type of rearing is also very productive of parasites which might otherwise be overlooked completely. To complete the coverage of the insect fauna, close attention should be paid to small insects which occur on the leaves and flowers of plants. These include scale insects, thrips, aphids and microscopic plant-feeding mites. The latter may only be visible under the magnification provided by a small hand lens.

Other terrestrial invertebrates include the land snails and fresh-water snails, earthworms and leeches, nematodes and planarians, Crustacea and other arthropods such as millipedes, centipedes, spiders, pseudoscorpions, etc. All of these will be encountered in the course of the various types of collecting mentioned above for insects, and especially in ground collecting, bark collecting, and aquatic collecting.

Two highly specialized types of collecting should be mentioned for the sake of completeness, though they should not be undertaken except under the direction of a specialist. The first of these is plankton collecting of Protozoa, rotifers, etc. A plankton net is necessary for this type of collecting. The other, and most specialized type of collecting is the search for endoparasites, and for blood flukes of man and animals. (See section by Marshall).

<u>Preparation and Preservation of Material</u>. It is obviously useless to collect material unless it is to be cared for in such a way that it will serve some useful purpose. The preparation and preservation of terrestrial arthropods is especially important in the tropics. The following generalizations may assist the non-specialist, though it is recognized that special techniques may be devised to fit unusual situations. The commonest method of killing insects is with a cyanide jar. Material killed in this way should be protected in the jar by means of tissue paper, and should be removed from the jar before specimens become damaged by rubbing or by accumulated moisture on the sides of the jar. Bees, wasps, true bugs (except aquatics), flies, mosquitoes, lacewings, many Orthoptera, moths and butterflies, dragonflies and damselflies, crane flies, and other fragile insects too numerous to mention should be killed in this way. Such insects should be curated at the end of the day's collecting. Failure to do this will result in stiffening of the appendages and excessive breakage. The moths and butterflies, dragonflies, damsel flies, and crane flies should be folded individually in paper triangles or envelopes. This prevents rubbing and is the only satisfactory way to preserve such fragile insects. The remaining types of insects killed in cyanide should be spread out on layers of cellucotton in cigar boxes or other safe boxes for shipping. The cellucotton layers should be double between each layer of insects so that specimens will not be damaged when they are removed layer by layer for mounting. Specialists may wish to pin a few of the most fragile specimens such as small gnats and micro-Lepidoptera. If it is desired to do this, minute pins should be used and a regulation insect box with tight-fitting cover should be used to store the specimens. Small Hemiptera and perhaps some other insects may be glued to small paper points and stored in this same way, but this is only recommended in cases where pinned material can be cared for properly in the field.

All of the other groups of insects and most other terrestrial invertebrates should be collected in 70% ethyl alcohol. Small procaine vials, used by dentists in most parts of the world, may be found convenient for collecting the smaller invertebrates, but some large vials and bottles will also be needed. Land snails, which are such a characteristic feature of many Pacific islands, are better collected in water and transferred to alcohol after a few hours. This results in an expanding of the soft parts and greatly facilitates later study.

Labeling is of the greatest importance and should be done at the time the material is prepared. Because of the large numbers of specimens, it is best to label the material as fully as possible and make sure that these data accompany the specimens. The exact locality should be given in every case, together with the date and name of collector. Ecological data should be added whenever possible. Elaborate cross-reference systems, including index numbers and field notebooks, are to be discouraged because of the danger of loss of one or another of the essential elements in such a system.

Storage and shipping. Numerous hazards are likely to beset the collector in the field, the most important of which are mold, cockroaches, ants, and rats. To avoid such hazards, material should be kept in tight boxes and not allowed to remain out on tables overnight. In some cases it is necessary to hang spreading boards or exposed specimens from the ceiling by strings, and cover the strings with sticky material or protect tables by treating the legs with a DDT solution. Usually it will suffice to finish all curating in a single evening and place the material in tight boxes. Mold is an ever present menace and should be guarded against by storing material in a hot locker or in glassine bags provided with silica gel.

Specimens should be shipped to a museum or home base at the earliest possible time. Specimens may be shipped in the original boxes in which they have been layered by adding naphthalene (which keeps out museum pests and seems to prevent mold), or by adding silica gel crystals. In either case the boxes must be wrapped carefully, and preferably with water-proof wrapping because of the hazards of rain and salt water in Pacific island transport. Alcohol vials should either be full or a cotton plug should be inserted to prevent damage due to the action of bubbles. Vials should be wrapped separately in paper and then mailed in rigid cartons.

Equipment List.

Collapsible net, e. g. fish-landing net, or other (preferably with nylon bag)
Cyanide bottles (several sizes--Alka Seltzer bottles with a cork top are a useful size, and smaller jars of plastic material are valuable because they are unbreakable)
Procaine vials and larger bottles
70% ethyl alcohol (this may be available locally at medical supply depots)
Paper envelopes or cellophane envelopes, glassine bags
Silica gel
Naphthalene
Cellucotton
Cigar boxes, or other wooden boxes, unless air-tight containers are available, in which case silica gel is absolutely essential to prevent mold and rotting

Insect box and pins, including minute pins (only if handled with great care)
Coleman lantern and white gasoline
Hand lens, forceps, scissors
Barking tool (crowbar, screwdriver, or heavy knife)
Small tins or pill boxes for rearing
Cotton

Conclusion. Finally, it is a good guiding principle to concentrate on small forms, because these are so often overlooked. It is also axiomatic in good collecting to take a series; one specimen of a new species is not enough and excess specimens can easily be thrown away. The opportunity to collect on a remote island may not come again for many years, if ever.

A useful reference for general collecting technique is the pamphlet by Oman and Cushman (U. S. Department of Agriculture, Miscellaneous Publication No. 601, Washington, D. C., 1946. Price 15 cents). This small pamphlet includes illustrations of the common orders of insects, as well as specific instructions for collecting and preserving insects.

Most of the above-mentioned equipment can be obtained from supply houses any place in the continental United States. One of the best known sources of such equipment is Ward's Natural Science Establishment, 302 Goodman Street, North Rochester, New York.

THE BERLESE METHOD OF COLLECTING SMALL INSECTS AND OTHER ANIMALS FROM LEAFMOLD, SOIL, MOSS, OR OTHER SIMILAR MATERIALS

by Joseph P.E. Morrison

The apparatus consists essentially of a funnel supported in an upright position with a shallow fine mesh screen-bottomed tray, at the top, to hold the sample of leafmold, and so forth, within the rim of the funnel, and a homeopathic vial half-full of preserving fluid attached (outside) to the neck of the funnel, below, to catch the insect and other specimens that fall out of the sample.

The material such as leafmold is dried by the gentle application of heat from above. If direct sunshine is insufficient, or the humidity too high, or the material is to continue overnight, as is usual, a small light bulb (25 or 30 watt) under a conical shade is used to direct heat onto the top of the sample.

The screen on which the sample is spread in a layer one or two inches thick should be about 20 mesh to the inch. The inside of the funnel and neck must be smooth inside, so that the specimens falling onto the steep slope will not catch anywhere on projections, but end up in or on the preserving fluid in the vial.

Many of the small insects, mites, and so forth, so collected, may be floating on the 70% alcohol used as a preservative. A drop or two of ether, added when the vial containing specimens is removed from the apparatus to be labelled and stoppered, will readily permit the floating specimens to sink into the fluid, so they will not be lost or destroyed around the cork or stopper. After labelling the vials completely, they are set aside, all sorting of specimens being done in the home laboratory.

COLLECTING MOLLUSKS ON AND AROUND ATOLLS

by Joseph P. E. Morrison

In order to obtain the greatest scientific benefit from any specimens collected, the place and/or zone or region of the atoll must be carefully recorded. In mollusks, as in most other animals, one finds different species in the different habitats or environments in, on, and around an atoll. Marine shells may sometimes be collected in good condition, abundance, and in great variety from beach drift along or just above the high tide line. In the absence of time and equipment available to collect living marine specimens, and prepare or preserve them, the collection of drift material, particularly of the smaller species, makes a very valuable contribution.

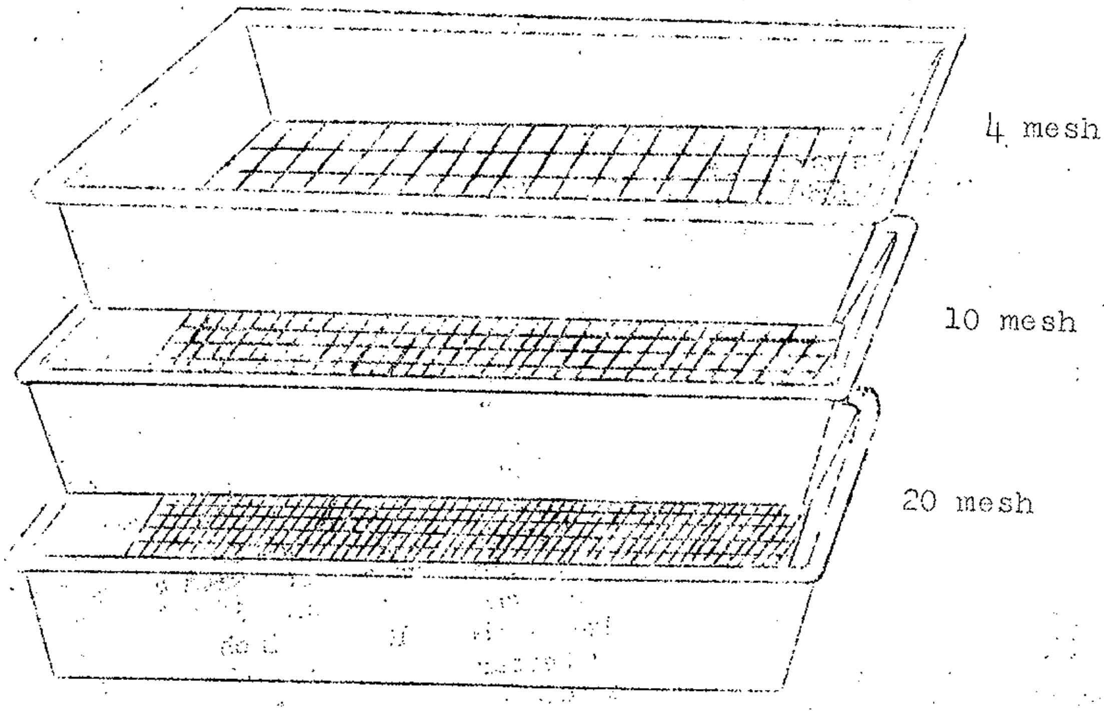
In the absence of preservative, the smaller species may be dried thoroughly, then packed in newspaper, and sealed in boxes or cans for later cleaning. Iron stain on mollusks shells, from rusting of tin can containers is to be avoided; when packing material in cans, wrap well with several layers of newspapers, etc., between the shells and cans. Field cleaning of marine mollusks taken alive may be accomplished by killing and cleaning them in jars of fresh water. Specimens from different localities should always be kept separate to maintain the locality records. A change and washing in fresh water once or twice a day, every day until the shells are clean (that is, do not smell too much) is necessary for this method. If left too long without changing, the acids of decay will etch the shells, leaving them poor and chalky in appearance.

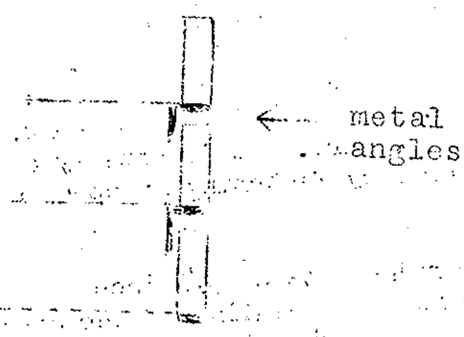
Certain small marine (and fresh water) species may be collected in numbers in a minimum of time by vigorously washing or shaking them off rocks or plants in a bucket full of water. The water, if muddy in the bucket, may be cleared of mud and floating plant material by repeated filling and pouring off the top 3/4 of the water. The bottom residue containing snails is then poured out of the bucket (through) on to cheese cloth or field screens or a dip net, and dried or preserved. Pulmonate fresh water snails (that float when disturbed) may be recovered in this process by pouring all water out of the bucket through cheese cloth or whatever other fine strainer may be available.

The smaller land species of mollusks are usually the only types found upon atolls. These may be collected in numbers by taking quart size or larger samples of leaf mold or other detritus where ever these small snails are seen in abundance in the leaf mold or on or in the soil surface immediately under the leaves, etc. The mass of large samples may be greatly reduced after drying by screening the leaves, larger rock fragments, sticks, etc., out through screen of 4 or 6 mesh to the inch. The fine material containing the smaller land snails may then be dried and sacked or boxed for later separation, at the museum, of these minute land species. Excessive dust may be screened out through mesh as fine as 20 mesh to the inch. Caution: Ordinary window screen (16 mesh to the inch) may pass most of the fine species with the dust. If there is excessive sand or foram sand or rock in the sample, the sample may perhaps be concentrated, after drying, by water separation. In this water separation, the sample is put in a bucket or jar of water, the rock fragments sink, and the minute snails, etc., are skimmed off the surface, thoroughly dried again, then packed. Drift along fresh water lakes and streams, as well as on ocean beaches, is sorted by nature in this fashion; all the species of snails may not float, so check the residue before it is discarded.

Particular attention should be given to the recording of exact data on the habitat zonation probable on all atolls. The zones expected will probably include: the windward reef edge (surf beaten); the lee reef edge, reef flats, or reef pools of shallow water at low tide; channels through the reef or between islands; island shores; the shallow margin of the lagoon; and the deepest waters of the lagoon. On island shores zonation should be recorded in relation to the distance inland from shore as well as the type of dominant plant cover or habitat. In the lagoons of atolls zonation may be present along the inner reef edge, the inner shelf of the atoll ring (up to 5 fathoms?) and the general lagoon bottom. Shoals or "coral heads" upraised from the lagoon floor may be particularly interesting in fauna, if facilities are available for such collecting. Even one person in a small row boat or canoe can reach the lagoon bottom fauna by dredging. A practical small dredge for work by one person should have a frame with an opening of about 5 x 12 inches, and a bag about 18 inches in length. If a launch and other equipment is available, a dredge of about 10 x 20 inch frame, and a 30 inch long bag will obtain bigger and better samples from the lagoon bottoms. This is about the maximum sized drag-dredge that it is practical to use without power winches. The frame of a dredge may be made of any readily available metals such as bar or strap iron. If all parts are galvanized it will last longer in salt water, and will not rot out the cloth dredge bags by rusting in such a short time. The outward flare of the dredge frame is not always necessary; a simple plate, with inner edge beveled, will work well on most occasions. The dredge bag is made of netting of "chalk line" cotton cord with 1 inch mesh. If special dredge netting is not readily available, burlap sacking can be used; this will retain even the smallest snail shells. The bag will last longer if it is wired onto the frame with copper or monel wire. It is usually advisable to protect the net bag from rocks and coral by fastening an open ended sleeve of canvas to the frame around the bag.

The dredge line of 3/4 inch or 1 inch rope (large enough to provide a good grip for hand hauling of the dredge) is securely attached to only the longer of the two triangle halter frames. The short one is tied to the longer (arrows in diagram) only with two turns of marline cord or string. This cord will break, and release the dredge from obstructions, before the line breaks. Usually this is a sufficiently effective device, even on coral bottoms. If the dredge "hands up," backing up on the line and pulling in the reverse direction should clear it. About three times as much line as the depth of water is the proper amount to use for this type of dredging. The speed of dragging should be slow enough so as not to pull the dredge off the bottom or have it only skip along. With experience one may judge even the type of bottom the dredge is moving over, by the simple method of holding one hand on the dredge rope and feeling the vibrations from the dredge.

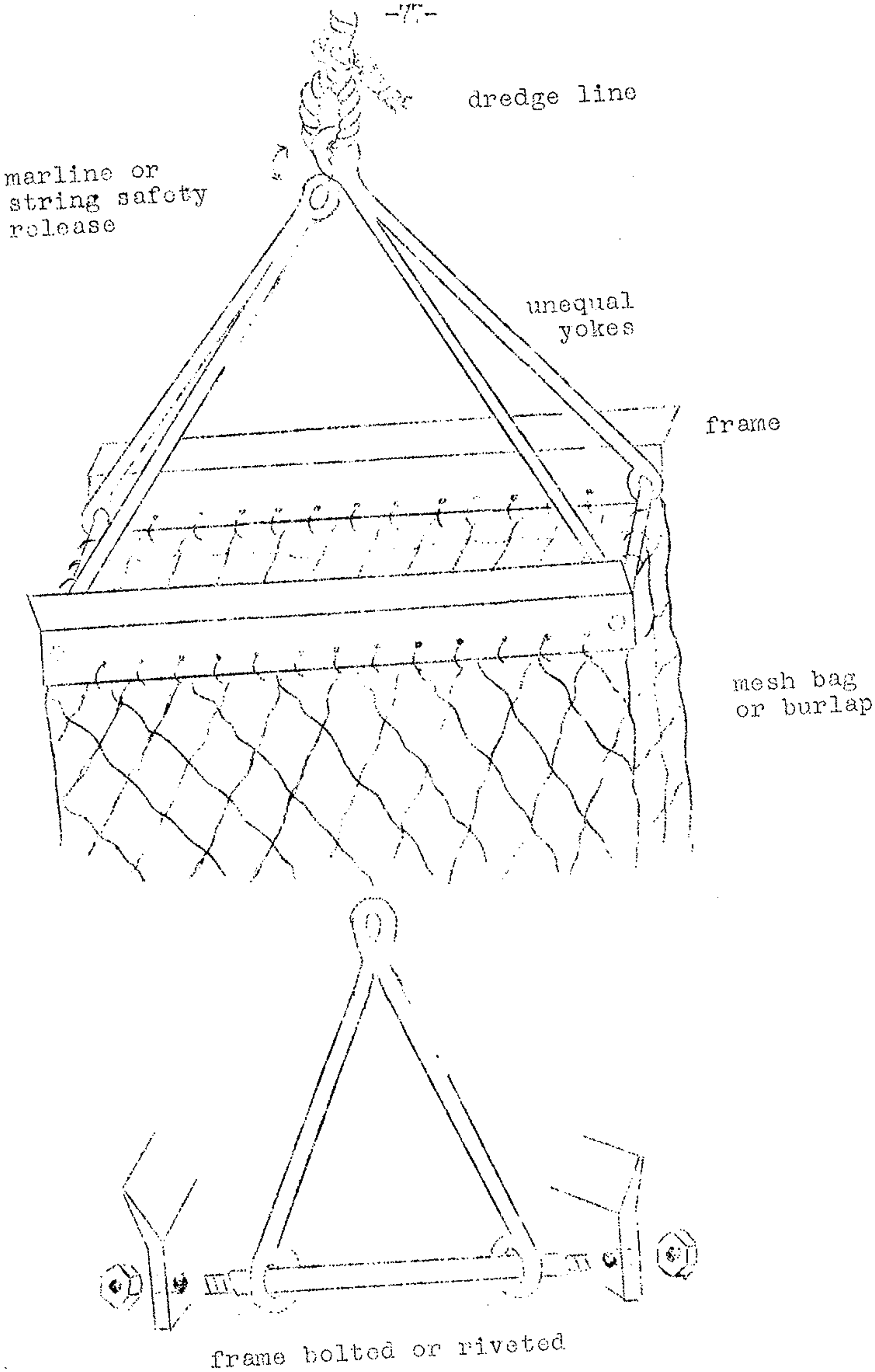




metal frame nesting

wood frame nesting

F I E L D   S C R E E N S



A PRACTICAL DREDGE

METHODS OF COLLECTING MARINE INVERTEBRATES ON CORAL ATOLLS

by Robert W. Hiatt

INTRODUCTION

While it would be presumptuous to inform a fellow marine zoologist about collecting methods along our continental coasts it is certainly justifiable when coral atolls are concerned, for such collecting is very different and requires special information and experience. I trust that our several years of experience in collecting on coral reefs will serve to introduce the uninitiated to the problems and their methods of solution, so that his preparation for and handling of work in the field will be greatly facilitated. A check-list of equipment appears in the section on "Instructions for Marine Ecological Work on Coral Atolls." The first portion of this section of the Handbook concerns ways and means of collecting; a second portion is devoted to methods of preservation.

ASSEMBLING EQUIPMENT

Emphasis should be placed upon the selection of special equipment for the special collecting tasks ahead. Both clothing and equipment should be selected for its utility, not merely because it is the most readily available. Moreover, wherever possible, carry out all the critical stages of preparation personally. Remember that you will be a long way from any source of additional equipment once you reach an atoll -- in fact, so far that you cannot expect supplementary shipments of forgotten material. Obviously, another person never cares quite so much about the material as you would, nor would they know precisely what use was to be made of the tools.

SAFETY MEASURES IN THE FIELD

Because medical care is frequently unavailable, perhaps for weeks, it is important to be even more cautious than would normally be necessary. Certain safety rules should be kept in mind. These are:

1. Never collect alone in boats, when using diving gear, on rough slippery shores, or while swimming.

2. Exercise care in handling poisonous or venomous species, e.g., certain echinoderms, coelenterates, annelids and fishes. Avoid handling all sea urchins having slender, long spines, starfishes having sharp spines (_Acanthaster_), stinging corals (_Millepora_) and other corals if an allergic reaction is noticed, medusae and siphonophores, annelids with long whitish setae (_Eurythoe_), and scorpaenid fishes.

3. Treat cuts and scratches immediately with an antiseptic and merthiolate. Recurrent wetting hinders healing.

4. Keep a weather eye on sizeable sharks in the neighborhood. These ubiquitous creatures are curious and often come close to you, possibly because their eyesight is poor. Our experience shows them to be more frightened of you than you are of them, once they see you. It is often stated that if this is true, their fright knows no bounds.

5. Give moray eels a rather wide berth. They will not attack a wader or a swimmer unless the person inadvertently steps alongside their shelter or thrusts his hand into a hole which he has not examined previously. Morays are usually easily seen by a person wearing a face mask or using a glass-bottom box.

6. While collecting on reefs it will be found desirable to wear a shirt, long trousers, wading shoes, and heavy cloth or leather gloves.

FIELD NOTES

Getting back with the animals in good condition is only one part of the job. For purposes of modern taxonomy, for ecology, or even for obtaining further specimens to carry on certain work, collecting is meaningless without at least minimal data. The marine zoologist is handicapped in his note-taking because it is impossible to write field notes while in the water. Consequently, he must make his collections in a systematic manner so that a single set of notes will suffice for a number of animals. In all cases field notes should be written as soon as the worker reaches the shore. When collections are made in quadrats with code numbers, and in certain species of corals within the quadrats, note-taking can be kept to a minimum. Well-planned field procedures can do much to reduce copious note-taking for the vast number of species living on coral reefs.

For many species of invertebrates colors and color patterns are of taxonomic significance. In such cases reference should be made to Ridgway's, Color Standards and Nomenclature (1912).

METHODS OF COLLECTING

Unlike continental shores, where collecting can be accomplished on exposed surfaces as the tide recedes, coral reefs offer very little intertidal area so that collecting in general is accomplished only under water. Thus, specialized underwater equipment is needed. A brief account of such equipment follows.

Underwater Equipment

Glass-bottom boxes

These may be made or purchased as desired. They are perhaps the least useful of all underwater collecting devices because (1) the observer's field of view is highly restricted, (2) one hand is required to hold the box, thus leaving only one hand free for collecting maneuvers, and (3) the collector is restricted to very shallow water. I recommend against this piece of equipment.

Face mask

Face masks of many types are inexpensive and readily available. Their chief advantages are (1) the observer's field of view is limited only by the turbidity of the water, (2) both hands are free for collecting maneuvers, and (3) the collector is not restricted to shallow water. He may be restricted in depth of collecting by his skin-diving ability, but he is restricted in observations only

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by the turbidity of the water. In clear tropical waters it is often possible to see clearly to a depth of two hundred feet.

In shallow water the collector may wear wading shoes, but in deeper water where diving is essential or where considerable distance is to be traversed, swim fins are useful. With them one can propel himself entirely with the feet, leaving the hands free to carry equipment or for collecting. With a little practice a person can dive 15 to 20 feet. Experienced skin-divers can collect at 50 or 60 foot depths. This outfit supplemented by a collecting bag and inner tube float has proved highly satisfactory.

Self-contained diving gear

Both oxygen and compressed air diving equipment are available. Since the advantages and disadvantages are held in common, both types will be considered together. The chief advantage of this type of gear is the extended period of submergence permitted while observing or collecting. With oxygen equipment submersion periods up to two hours are possible at a depth of 25 feet, while compressed air outfits will maintain a person at this depth for only about twenty minutes. The chief disadvantage of such equipment for atoll work is the necessity of transporting tanks of oxygen or air. Far less oxygen is needed than compressed air, so less shipping space is involved with the oxygen type. However, the increased safety of the compressed air type makes it more desirable if shipping is no problem.

Pump-type diving gear

If adequate personnel and shipping space is available the pump-type diving gear is quite useful and probably the safest. However, a minimum of two persons above for each person submerged is necessary, thus virtually eliminating such equipment from consideration in atoll work. The submerged observer is also restricted in his movements because of the attached air hose and line. The greater depths accessible and the longer periods of submersion are the chief advantages.

Collecting on Different Types of Substrata

The Coral reef

Methods of collecting fishes on coral reefs are detailed in another section of this Handbook. It should be noted at this point that cephalopods are also killed by rotenone and should be collected along with the fish.

Invertebrates on coral reefs may be collected in a variety of ways. Perhaps the most important method is the collecting of living or dead coral heads or porous coral boulders for their entrapped invertebrate fauna. These coral heads and boulders should be carried to shore and there broken apart with a geology pick or similar instrument. In interstices of the branching heads and in burrows in the solid heads will be found a multitude of animal types. Crustaceans, molluscs, polychaete worms, bryozoans, tunicates, sipunculids, hydroids, echinoderms, sponges, nemerteans and small fishes are easily and efficiently collected in this manner. Indeed, if this method is not used, a large proportion of the species present will be missed. Moreover, such a method lends itself admirably to collecting in transect quadrats. Studies on biotic interaction in specific coral head biocoenoses are also facilitated by employing this method.

Many species of gastropod molluscs, particularly of the families Strombidae, Cypraeidae, Conidae, Muricidae, Fasciolariidae, and Buccinidae are found on rock or coral rubble between coral heads. A host of species will also be found in burrows or crevices in the reef rock. Many boulders, particularly near shore can be over-turned to reveal the motile species which seclude themselves beneath it and the attached species which grow on the lower surface. Species of Tridacnidae will be found occasionally either attached to or lying free on the reef rock. Near the outer reef edge the collecting becomes more difficult because of the rougher nature of the coral and nullipore growth. Here echinoids will be found secluded deeply in holes where only a pry-bar can be used effectively to expose them. Boring species of tridacnid clams can also be extricated in this manner from their attached positions deep in coral heads. Usually the outer reef edge area is rather weakly consolidated so that large sections of it can be fragmented with a pry-bar. Oftentimes this reveals a host of species, particularly crustaceans, ophiuroids, and gastropods which may not be collected elsewhere.

Collecting in sand and mud

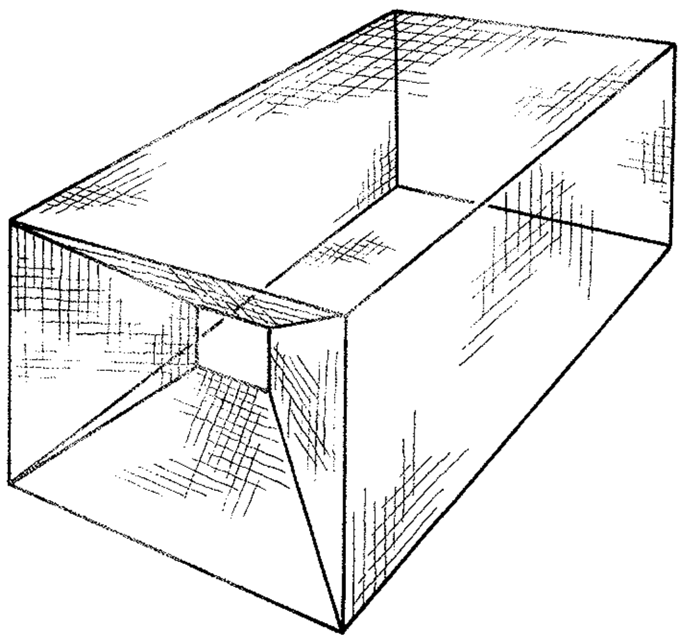
Most animals in sand or mud are either burrowers or exist just below the surface making them relatively difficult to see and collect. Perhaps the most successful method of collecting under these conditions is to become acquainted with the habits of the animals. For example, many gastropods live just under the surface in sandy areas and carry on most of their activity of moving about at night. If the sandy area is not disturbed too greatly by wave motion it is frequently possible the next day to observe through a face mask the slightly excavated trail in the sand which marks their most recent movements. By diving down and scraping your hand through the top layer of the sand, marked by a slight elevation at the end of the trail, you can collect the gastropod. These sand trails made by subsurface movements of gastropods are ubiquitous in sandy regions of atolls. Members of the families Terebridae, Conidae, Olividae, Mitridae, Alectrionidae, and Cerithiidae are common in such locations.

Among the echinoderms cake urchins and heart urchins are often abundant just beneath the surface of the sand. The animals usually disturb the normal appearance of the sand above them, thus marking their position. Probing and digging in the sand at that location will expose the specimen. Holothurians frequently lie just below the surface of the sand, and they may be found and exposed in the manner described for the echinoids.

Many species are true burrowers, making permanent burrows which are easily seen. These animals are usually so deep in the sand that it is not feasible to extricate them without special equipment. Such equipment consists of a shallow box with a wire screen bottom into which the sand or mud may be shoveled and strained. Many species of pelecypods, crustaceans, polychaetes, and echinoderms will be gathered in this and in no other fashion.

Use of traps, nets, dredges

Certain species of invertebrates, particularly the larger crustaceans and those inhabiting depths not available to the average skin-diver, can be collected only by traps, nets or dredges. Such species as stomatopods, palinurids, scyllarids, portunids, etc., may be taken much more efficiently in suitable traps than in any other manner. It is often impossible to secure suitable traps from native fishermen, so considerable thought should be placed on constructing wire take-down type traps which weigh but little and occupy only a small space. The trap should be constructed somewhat along the lines of the accompanying diagram.



Fish make excellent bait for such a trap. Baited traps such as this will also attract moray eels, so frequent inspection of the trap may prevent the loss of valuable specimens to the eels.

With the exception of small dip nets very little use can be made of seines for invertebrates. The field collector is advised against taking large nets where space is limited.

The naturalist's dredge is a most useful tool if a power boat is available to haul it. Usually such a boat is not available, so make inquiries before you send such equipment into the field. Native sailing canoes are not very suitable for dredging.

Plankton nets

Much has been written about collecting plankton from both qualitative and quantitative standpoints. The field man is advised to investigate suitable nets for the purpose intended. A letter to the Secretary of the American Society of Limnology and Oceanography will make available the literature on plankton sampling issued by the Society.

METHODS OF PRESERVATION

Perhaps the most important point to remember in preserving specimens in the tropics is that bacterial and physiological decomposition is accelerated by the high temperatures, thus more attention must be given to methods of immediate preservation.

Preservatives

FORMALIN is perhaps the most useful liquid for keeping animals temporarily, but not for preserving them permanently. It has greatest utility in that a much smaller volume of liquid need be carried, thus, it is very important for the atoll worker. If no restriction is placed on the amount of collecting gear which may be taken, more ethyl alcohol and less formalin is desirable. There are two principal objections to formalin. First, while it is a very useful provisional fluid for many animals which are not contractile, and especially for those which contain no lime spicules, skeletons, or shells, it will attack the calcareous portions of animals containing such and dissolve them or cause them to lose brilliancy, or both because of the free acids in the fluid. Substantial relief from the free acids may be achieved by neutralizing the formalin with an excess of either sodium carbonate or lithium carbonate. Usually it is sufficient if an excess of the salt be kept as a sediment in the stock jar or barrel of formalin. Second, unless specimens are transferred to alcohol after two or three years they begin to disintegrate.

Preservation of different types of animals should be accomplished with different concentrations of formalin. With large and relatively impervious animals such as fish, large crustaceans and cephalopods under tropical conditions it is necessary to use up to 30 per cent formalin. If refrigeration is available they should be preserved under refrigerated conditions. In any case injections of formalin into the body cavities and into thick muscular areas should be made. For smaller animals the normal concentration should be approximately 10 per cent formalin, while soft or gelatinous animals should be preserved in 2 to 5 per cent formalin, the general rule being that the softer the animal, the weaker the formalin.

With formalin, as with other preservatives, only one, or at any rate only a very few, objects should be put into the same receptacle at the same time, and there must be a good amount of fluid in proportion to the animal matter present. Either fresh or salt water may be used in making the solutions. The sea water solution often preserves the transparency of gelatinous bodies better than the other. For certain flaccid animals the hardening accomplished by formalin is advantageous.

ALCOHOL, ethyl preferred, is without doubt the most indispensable liquid for permanent preservation. Fully denatured alcohol is to be avoided because of the deleterious effect of the denaturants on specimens. In certain instances alcohol is required for the initial preservation, so a small amount is essential in the field. In most instances, except where anesthetizing is necessary, specimens may be dropped directly into 70 per cent alcohol. Certain soft-bodied forms such as jellyfishes must be first placed in 50 per cent alcohol and after 6 hours or longer placed in 70 per cent. The alcohol must be diluted with fresh water, as a white precipitate usually appears and covers the specimen if sea water is used.

Specimens which possess calcareous shells, spicules or other structures of a similar nature, should if possible be placed directly in alcohol, since the acid formalin may seriously damage the specimens even within a short time. It is not necessary to use alcohol in concentrations in excess of 70 per cent, indeed, it may be harmful to do so. The effect of both formalin and alcohol is to a considerable extent to replace the water of the tissues and thus prevent bacterial decomposition. The removal of the water not only prevents decomposition but at the same time stiffens the tissues. Alcohol at 70 per cent accomplishes this replacement most efficiently. Regardless of whether formalin or alcohol is used the colors will fade eventually.

Anesthetizing reagents

MAGNESIUM SULPHATE, commercial grade, is perhaps the most useful and least expensive of all the narcotizing reagents. Animals to be narcotized should be carried to the laboratory in sufficient sea water to keep them alive, then placed in a pan with sea water barely covering them. Crystals of magnesium sulphate should be added roughly in concentration of one tablespoon per quart of sea water. As narcotizing progresses more reagent may be added. This method works well for gastropods, echinoderms, sipunculids and echiuroids.

CHLORAL HYDRATE, commercial grade, is useful in a very weak solution, from 0.1 to 0.2 of 1 per cent in sea water, for narcotizing forms difficult to pick off of algae or madreporarian beads.

CHLORETONE is useful in weak aqueous solutions for narcotizing small forms.

ALCOHOLIZED SEA WATER is also a useful anesthetic for quieting small marine species, particularly the worms. Care should be taken not to put many individuals together during the process as a copious secretion of mucous results in an inextricable entanglement of the worms, thus rendering the specimens useless.

Transportation of specimens

There are a number of points to remember from the standpoint of returning specimens to the laboratory and from there back to the institutions where they will be handled.

1. Don't crowd your collecting containers in the field.

2. Don't place antagonistic species together in the same container, e.g., large carnivores with small species, crabs with soft-bodied types, etc.

3. Only animals taken at a particular station should be placed in one container.

4. Carefully segregate mucous secreters from other specimens in the field, as the entanglements caused often result in worthless specimens.

5. If specimens are to be returned to the laboratory alive, suffocation must be avoided by (a) having only a small number in each container and by (b) having a minimum of water plus a good deal of algae for cover. Aeration may be supplied by an Oxy-bomb outfit obtainable from

   A. Daigger & Co.
   159 West Kinzie Street
   Chicago 11, Illinois

6. Avoid leaving containers in the sun.

7. If specimens are returned to your institution in metal cans, they should be opened immediately upon arrival, and the specimens should be transferred to 70 per cent alcohol in glass storage jars.

Notes on preservation of particular animal groups

PORIFERA should never be preserved in formalin as the tissue degenerates at once, leaving only the skeleton which may also be in poor shape. Drop the specimen into 70 per cent alcohol immediately and renew alcohol when it becomes discolored. Horny sponges may be dried by first washing them in fresh water for a few hours, then they should be placed in 70 per cent alcohol for a day or so, and then placed in the sun to dry. Sponges treated this way will not have an offensive odor. For best taxonomic results a small piece of the sponge should be cut off and dropped into Bouin's fixative.

COELENTERATA provide a variety of situations which must be dealt with individually. Corals, including the madrepores, millepores and other hydrozoan types with stony skeletons should be broken from their attachments as carefully as possible. If a piece of a large coral head is taken, it should be obtained in a typical part of the head and should contain exposures in as many planes as possible. If the atoll is in a rainy belt all that need be done is to place the corals in the sun on a slightly elevated structure where drainage is good and where no vegetation will touch them. Alternate wetting and drying, accompanied by frequent turning of the specimen, will soon clean and bleach it. Where rainfall is slight and undependable, immerse the corals in containers of fresh or tepid sea water until the tissues disintegrate. Wash them well and place them in the sun to dry. Labels, especially temporary ones, during the rotting and bleaching period, should be on heavy tough paper and attached with stainless steel wire.

Anemones and hydroids should be covered with sea water to which a small amount of magnesium sulphate has been added. When they have expanded completely and are fully narcotized, transfer them to formalin.

The soft-bodied siphonophores and scyphozoans may be immersed directly in approximately 5 per cent formalin. This results in highly contracted tentacles, but this does not impair the specimens for taxonomic study.

NEMERTEANS present great difficulties because of the highly contractile body and danger of fragmentation. It is best to place them alone in a sizeable container of sea water to which chloral hydrate is added. Allow them to remain there for about 12 hours, then drain off the narcotizing solution and replace it with 70 per cent alcohol.

SIPUNCULIDS may be narcotized with chloral hydrate in sea water until the tentacles are expanded. Often it is necessary to wait until the proboscis is extended, then seize the body with one hand and with a pair of forceps seize the extremity of the proboscis to keep the tentacle extended, then immerse the animal into 10 per cent formalin or 70 per cent alcohol until it dies.

BRYOZOANS are somewhat resistant to anesthetics but some extension of the zooecia may be preserved by narcotizing slowly with 70 per cent alcohol added to sea water. Preserve in 70 per cent alcohol or in 5 per cent formalin.

POLYCHAETE worms are difficult to preserve properly in the field in the best taxonomic condition. If they are not completely narcotized at fixing, they will contract greatly, twist out of shape and frequently will fragment. Narcotizing may be accomplished by separating the worms into finger bowls with just enough sea water to cover them. Then add alcohol slowly and let them stand for several hours. Just before they are completely immobilized place them in 5 per cent formalin to which a little glycerine is added.

MOLLUSKS present special problems because some are shelled while others are not.

The shelled gastropods are identified by shell characters only, thus it is unnecessary to preserve the soft parts unless they are needed for special study. The chief problem is to remove the soft parts from the shells without damaging the structure or brilliance of the shell. I have found it most satisfactory to place the living shelled gastropods into a container of sand so oriented that the rotting fleshy material will drain from the shell into the sand. The bottom of the container should be perforated so that all decaying material can drain or be leached out of the container. The container should be placed on the ground so that ants can enter the decaying shells and hasten the removal of organic substance. Remember to cover the container sufficiently well to prevent the entrance of land hermit crabs which will be attracted to the area. If the hermits are able to enter the containers you will soon find that many beach-worn shells have been traded for your prize specimens which now decorate the abdomens of these ubiquitous robbers. When most of the decaying material is out of the shells, after a month or more in the container, they may be washed in water, labeled and packed away.

Tectibranchs and nudibranchs should be anesthetized using chloral hydrate or magnesium sulphate. When they appear immobile preservation may be made with alcohol or formalin. Large specimens should be injected with preservative.

Pelecypods, except for certain boring species (<u>Teredo</u>, <u>Bankia</u>, <u>Rocellaria</u>, etc.) are identified by shell characters so the soft parts may be discarded.

In both shelled gastropods and shelled pelecypods some specimens have brilliant clean shells (sand-dwellers) and the shells of others are more or less encrusted with other organisms, especially calcareous algae. It is virtually impossible to make shiny shells from these latter specimens, and indeed, for taxonomic purposes they should be left in their natural condition. The cleaning of such shells has little to do with scientific endeavor so the methods are omitted here.

Cephalopods can be dropped into 10 per cent formalin after the body cavity has been injected with preservative. No particular problems will be encountered with this group.

CRUSTACEANS present individual problems in fixation, but in general all should be preserved in 70 per cent alcohol to which glycerine is added in a ratio of 1 part to 10. The greatest danger in preserving crustaceans is the loss of appendages. Glycerine will help in this regard by maintaining some flexibility in the arthrodial membranes.

Shrimps except for snapping shrimps (<u>Crangonidae</u>) can be preserved without narcotizing in alcohol and glycerine or formalin and glycerine. Snapping shrimps are prone to autotomize [detach - Ed.] the large chela, especially if they are dropped directly into the fixative or are crowded with other specimens. Unfortunately some taxonomic characters are based on the morphology of the large cheliped. If shrimps of more than one species are crowded together and many autotomize their chelae, a near hopeless confusion results in matching shrimps with cast appendages. I find it preferable to permit them to die in fresh water or tepid sea water with but one type in a container. Under field conditions this is difficult to do, but if a sufficient number of small vials are taken along it can be accomplished.

Many anomurans and brachyurans will autotomize appendages if stimulated too strongly with the fixative. The impermeability of the integument prevents rapid penetration and death, thus the prolonged thrashing about often results in mutilated specimens. It is best to put them into fresh water or leave them exposed to air until they die. Land crabs (Cardisoma, Geograpsus, Coenobita, Birgus, etc.) present special problems because exposure will not kill them and fresh water is not particularly effective. The only suitable method is to drop them into formalin. Fortunately, they do not autotomize the appendages readily. Large specimens should be injected with preservative. Where it is necessary to transport many preserved specimens in a common container, each specimen should be protected by wrapping it adequately in cheesecloth which is tied securely with string. Whenever possible, flex the appendages so that the tied animal will be compact. I find it best to preserve hermit crabs in their shells so as to have precise information as to the shell occupied. Oftentimes both the crab and its shell will require identification by specialists. Most specimens can be pulled from the shell rather easily following preservation.

Barnacles must be pried from their attachments and preserved in 10 per cent formalin. It is not necessary to relax them first as taxonomic determinations are made from the valves. Wet preservation is superior to drying because it insures the safekeeping of the valves until they are cleaned for use by the taxonomist.

Smaller crustaceans such as ostracods, copepods, amphipods, isopods, stomatopods, etc., should be dropped directly into 70 per cent alcohol or 5 per cent formalin.

ECHINODERMS present a variety of problems of preservation. The hard-shelled echinoids may be dropped directly into 10 per cent formalin. Large specimens should be punctured through the peristomial membrane to insure internal preservation. After a day or two they may be placed in a shady spot to dry. The sun will bleach the colors rapidly if the specimens are not shaded.

Asteroids and ophiuroids may best be handled by anesthetizing with $MgSO_4$ in a pan with sea water barely covering the specimen. When the asteroids have flattened out remove them to another pan of 70 per cent alcohol or 10 per cent formalin. After two or three days in the fixative they may be dried in the shade. Ophiuroids must be handled with extreme care as the arms are readily autotomized. Do not crowd them in containers in the field and place them in $MgSO_4$ solution as soon as possible. When the arms no longer react to touch arrange them all parallel to one arm so that a comet-shaped form results. Remove the narcotizing solution and replace it with 10 per cent formalin or 70 per cent alcohol. After two days lay them out in the shade to dry.

Holothurians require more care than other echinoderms, because they have soft and highly contractile bodies and all are furnished with tentacles which contract or retire within the body on contact with a reagent. Moreover, certain species are prone to expel their viscera shortly after being immersed in the preservative or anesthetic. While this behavior does not impair the use of the specimen taxonomically, it is unsatisfactory in many other ways. Allow the animals to relax and expand in a pan of sea water to which $MgSO_4$ is added. After a few hours of such treatment many species will become narcotized with their tentacles expanded. They should be injected with 70 per cent alcohol, wrapped in cheesecloth, and tied, and dropped into 70 per cent alcohol. Never leave sea cucumbers in formalin for any length of time because the acids will quickly destroy the tiny calcareous cutaneous spicules so important for correct identification. Thin-walled apodous species must be handled carefully to avoid fragmentation. The tentacles cannot be inverted within the body so complete relaxation is unnecessary, indeed, it is usually to be avoided since many of these species are several feet in length. It is best to place them in a shallow pan containing 50 per cent alcohol. When killed they should be transferred to 70 per cent.

Crinoids have a tendency to fragment regardless of their treatment, but this can be minimized by immersing the animal in 90 per cent alcohol, then violently shake the vessel to hasten death. Usually the field collector has no suitable containers for transporting these animals to the institutional laboratory in wet preservative. I have found it useful to hang the specimen in a shaded place to dry after it has been in preservative a few days. They must be packed separately in rigid boxes for transport.

LOWER CHORDATES may usually be dropped directly into 10 per cent formalin. However, if the specimens are wanted for microscopic structure the investigator should consult a guide book on animal micrology. If time and facilities permit it is better to narcotize cephalochordates and tunicates with chloral hydrate and enteropneusts with alcoholized sea water.

DIRECTIONS FOR COLLECTING, PRESERVING, AND SHIPPING FISHES

by Leonard P. Schultz

COLLECTING FISHES

The usual methods of collecting fishes are baited hook and line, trolling, spearing, dredging, trawling, attracting them to the surface with a light at night, and using various nets and beach seines. Poisoning is the most important method for shallow water fishes of ocean reefs. Powdered cubé or derris root with a five percentum of rotenone content or rotenone in concentrated form is best.

Collecting by Means of Fish Poisons on Coral Atolls*

Thirty-five minutes before the tide reached its lowest point, the dry powdered root was placed in buckets or any suitable container and mixed with water to a thick chocolate malted milk consistency, allowing about 20 minutes for one man to mix 25 pounds. By squeezing and stirring with the hands, as water was gradually added the powder soon formed a thick mud. Ten minutes before low water, the distribution of the mixture began. The stupefying of a great variety of fishes with rotenone was most successful at the lowest stage of water.

The success of this operation depended on determining the strength of the currents and depth of water. A little of the mixture was tossed into the water, and the direction of movement of the small, light brownish cloud, watched. After several such tests, assistants, each with a bucket or two of the mud, were stationed in the water and the distribution began. In water 4 to 5 feet deep, with a slow current, the mud was thrown out permitting the little soft pellets to dissolve as they settled toward the bottom, forming a light brownish cloud. Twenty-five pounds of the dry powder formed a cloud about 100 to 150 feet long by 50 to 75 feet wide. It was highly effective if it took 10 minutes to pass any one point in water above 80° F. When used at lower temperatures the fishes must be exposed for a longer time. Usually a part of a bucket of the mud was reserved to strengthen the cloud after it had traveled a few hundred feet. This precaution was advisable, since the currents did not always behave as predicted.

Shallow Water Reef. -- It was learned through experience which shallow water habitats (to a depth of ten feet) were suitable for collecting fish with rotenone. An area with an abundant growth of coral heads in about 3 to 4 feet of water, down to ten feet in pools, with narrow to wide channels between the various kinds of corals, and a wind blowing the surface water more or less shoreward, was the most ideal situation.

Many kinds of fishes in the areas treated floated for a few minutes, then sank to the bottom. Some were picked up while they were violently swimming more or less in circles. A greater quantity of fish appeared at the surface than were recovered immediately. Those that drifted ashore were recovered but those that got over deep water were often lost.

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* Schultz, COPEIA, no. 2, pp. 94-98, 1948.

Immediately after introducing the rotenone, recovery of the fish started, but it was inadvisable to enter the area in which the treated water would flow, since that drove the unaffected fishes away. As soon as the water cleared, those fishes that settled to the bottom were collected. Two or three men continually wandered over the treated area, picking up the specimens in fine-meshed, bobbinet dipnets, 14 or 15 inches in diameter and 25 to 30 inches deep, with a 4 or 5-foot-long lightweight wooden handle.

As the water-laden cloud of rotenone drifted onward for a thousand feet or more, it spread out, gradually becoming so diluted that it lost its effectiveness. When the water appeared as a light, tan-colored cloud, it was most effective since it retained its stupefying properties yet was not so much concentrated as to be detectable by most fishes. Sharks, apparently able to detect small amounts of the rotenone in the water, left the area until the cloud had passed. They then returned to feed on the sick and dead fish, sometimes becoming troublesome. With only one or two 3 to 6-foot-long sharks feeding on the sick fish, the skin diver can keep watch of them. However, when two or three of these voracious creatures become too bold, as on one or two occasions, the ichthyologists left the water.

The searching for the demobilized fishes was done by means of a face mask covering eyes and nose, swim fins on the feet, and a dipnet. With a face mask, both hands were free to devote to picking up fishes, some of which were rather slippery. A canvas glove as an aid for holding slippery fish was used on one hand when necessary. Some of the fishes affected appeared lifeless, but when touched were found to be very much alive and quickly moved away unless caught in the dipnet. Those fishes too small to pick up with the fingers were, with a little practice, lifted from the bottom by inducing upward currents through rapid movement of the hands or feet. A fish, thus suspended for a few moments, was scooped up in the dipnet. Desirable fishes frequently swam into the crevices of the corals and erected their spines, making their removal difficult. With clear vision through the face mask, these, too, were collected.

A rubber boat, tied to one of the coral heads, served as a base from which to work and was an added safety in case someone ran into trouble under the rugged conditions. This boat held the preserving tank, and other gear. Three good swimmers picked up enough fish to keep one man busy preserving the specimens in the rubber boat.

Those fishes first to be affected by the rotenone were the damsel, cardinal, butterfly, surgeon, and puffers; others such as needlefish, halfbeaks, goatfishes, gobies, jacks, threadfins, and mullets were a little slower in reacting to the treated water. The burrowing fishes, namely, eels, appeared last, probably because it took longer for the rotenone to diffuse into their habitats. Fish continued to appear for over 6 hours after treatment; eels were recovered that came out 8 hours after the cloud had passed their burrow.

Care was exercised in picking up supposedly dead spiny fishes, and especially moray eels, since they may inflict serious wounds. Scorpion fishes, siganids, and other venomous species, even the stinging corals and jelly fishes, were treated with respect.

The snake eels often appeared with about 6 to 12 inches of their head section above the bottom. They were grabbed firmly and quickly, then the remaining 2 or 3 feet of their bodies were pulled out. A light touch or a miss when grabbed usually caused the eel to withdraw into its burrow and the specimen was lost.

The rotenone appeared to affect the fishes by constricting the capillaries of the gills, depriving them of an adequate oxygen supply. They leave their hiding places for more oxygen, thus exposing themselves under a weakened condition and simplifying their capture.

Shallow tidal pools that trap fish at low tide are simple to work, but the use of rotenone in the ocean surf on the ocean reef of a coral atoll requires special technique.

Lithothamnium Ridge: -- The outer margin of an atoll rim on the ocean side usually consists of the slightly raised pink to red colored lithothamnium ridge contrasting beautifully with the deep blue ocean beyond. It is dissected by rugged surge-channels, and deep pools often 20 feet deep directly connected with the ocean. This ridge, creviced and pitted with holes, is about a foot or two higher than the flat part of the reef farther inward. At extremely low tides it is exposed except as the surf crashes over it, then some of the water is forced back over the flat part of the reef, flowing seaward again through the surge-channels.

Some of the surge-channels, extending for a hundred feet or more back into the solid reef, are more or less roofed over or with perforations large and small through which the water may pour or spurt on the incoming surge of a wave. They are lined with rich green and red algae, blue, red, yellow and green corals, and a host of brilliantly colored fishes live in these clear waters.

Rotenone was used successfully along the lithothamnium ridge in the ocean surf. The "mud" was administered a few minutes after the low point of the tidal cycle. An area was selected where pools occurred but which were not completely connected with the surge-channels. These pools were desirable as settling basins for the sick and dying fishes. The area between two or three surge-channels, where the waves flow inward across the ridge was the place where we placed the rotenone mixture. Big handfuls of the thick mud were thrown out as far as possible into the backwash of a wave. The next moment the oncoming breaker churned the water into foam and carried the water-laden cloud of rotenone inward, spreading it over the area and into the numerous crevices, then it flowed out the surge-channels. Soon the rotenone cloud was distributed along the ocean edge of the reef, and some was brought back again over the lithothamnium ridge. The continual surging inward of the water brought in the sick fish. Men were stationed along the surge-channels to take fishes that were being swept out to sea and perhaps lost. After the pools and channels cleared, the bottoms were searched for fishes by the skin divers.

Deep-water Use of Rotenone: -- Two ichthyologists who were excellent swimmers and skin divers, successfully carried on several deep-water poisonings of fishes with the powdered root. They mixed in the usual manner about 35 pounds of the substance, then placed 5 to 10 pounds of the "mud" in desert water bags. Equipped with standard United States Navy shallow water diving outfits they took the rotenone to the bottom, distributing it around coral growths. Down below with the usual dipnets, they recovered fishes, bringing them to a man at the surface, who preserved the specimens. This deep-water work was necessary to obtain a more complete picture of the fish fauna of Bikini and the change in kinds of fishes at various depths in the lagoon. Several fish species occurring over the shallower parts of the reefs normally are not found at depths below 10 or 20 feet, whereas some kinds below that depth are not taken near the surface.

Collecting With a Light at Night

A bright light suspended from a small ship at night at the surface of the sea attracts to it myriads of nocturnal organisms -- crustaceans, worms, squid, octopi, and numerous species of fishes. Silversides, small wrasse, round herring, the pelagic stages of goatfishes, surgeon fishes, puffers, lizard and file fishes dart in and out of the field of illumination. Large flying fishes, a foot or two long, come swimming or flying toward the light at night. Down below a few feet, larger predaceous fishes can be seen rushing about feeding on the abundant animal life. Eager collectors gathered above this light on a platform, with fine-meshed dipnets scooped up the animals, and preserved them for future study.

PRESERVATION OF FISHES

In general, the following rule should be applied: Preserve all fish that come into the net or are taken by other means. Do not throw away small specimens because there are many species of fish of which the adults do not reach an inch in total length. Large numbers of specimens of each kind are very desirable. One hundred specimens of a single species are often not too many and in some cases are not enough.

Formalin Preservation: -- Formalin preservation is recommended instead of alcoholic preservation. The fish should be dropped alive (if possible) into a solution of formalin made up by mixing one part of commercial formalin with nine parts of water [fresh or salt- -Ed.] This solution is of sufficient strength to preserve small fish up to five inches in length, in about three days, but larger specimens should be left in it for a greater length of time, depending upon their size. Fish which are allowed to die before being preserved are paled and distorted and hence are of less value. All specimens over three inches in length should be slit in the belly with a sharp knife or scissors or they should be injected with formalin. This allows the preservative to enter the body cavity and keep the contents from spoiling. In addition to this, very large fish, a foot or more in length, should be injected about every two inches into the muscle tissue and left in formalin from five to seven days, or more. After that time, if it is desired, they can be transferred to water for one or two days, and the formalin washed out, and then placed in seventy-five percent alcohol. One should never crowd the fish in the containers like sardines in a can. If it is desired to leave the specimens in formalin indefinitely, they may be transferred to a weaker solution, made up as follows: One part formalin to fifteen or eighteen parts of water, to which has been added two teaspoonsful of borax to each gallon of preservative. This weaker formalin solution is usually of sufficient strength to preserve the fish indefinitely if the container is closed tightly. Always fill the containers full of liquid.

Alcoholic Preservation: -- Drop the fish alive (if possible) into thirty-five percent alcohol and in about six hours they should be placed in seventy-five percent alcohol. If the specimens are at all crowded, the alcohol should be poured off and fresh seventy-five percent alcohol added the next day. If they become soft, then another change of alcohol should be made, using seventy-five percent again. In general, formalin preservation is best at the start and should be used instead of alcoholic preservation because formalin hardens the specimens. However, after the fish have been in formalin about a week, they should be transferred to seventy-five percent alcohol, after thoroughly washing the formalin out, because the acid in the formalin has a tendency to soften the bones, unless it is neutralized (as by adding borax - see above).

Salt Preservation: -- If neither formalin nor alcohol is available, fishes may be preserved in salt. The fish should first be soaked in a saturated brine solution and when thoroughly impregnated, they should then be packed in dry salt for shipment. As with the other methods of preservation, the abdominal cavity should be opened to allow the salt solution to enter freely. It may be necessary to open the intestinal tract of those fishes that feed heavily on vegetation and remove the vegetable matter accumulated therein.

Skinning Large Fish: -- Fish too large for preservation in available containers should not be thrown away but should be skinned as one would skin a rabbit. Make a slit along the abdomen and remove the skin and flesh from the body, but leave all of the fins in place and the head attached to the skin. This skin can then be placed in formalin or alcohol, or it may be salted. It is best to remove most of the fat and all flesh from the skin. For moderately large fish, it might be well to leave the vertebral column intact.

Labels: -- Labels, giving all essential data, should be placed in the jar with the fish when collected. Accurate information about the locality is as valuable as the fish, for specimens without proper data are of little scientific value. These labels should have the following data: Exact locality, with reference to a town or island commonly appearing on maps; dat e; collector; and any other information that seems pertinent, such as depth of water, method of capture, ecological data, etc.

The labels should be written with a soft lead pencil on a special type of paper furnished by the U. S. National Museum, or on any pure linen ledger paper. Do not use ordinary paper, because it will disintegrate in the liquid. Do not use ink or indelible pencil, as these wash off the label. Large fish may have tags tied onto them, preferably through the lower jaw, with all essential data written on the tag, or a number may be used and the data recorded under the identical number in a notebook.

Wrapping Fish for Shipment: -- After thorough preservation, fish may be wrapped for shipment in the following manner: Place the small fish in a stack (as cordwood is piled), with their heads outward, so that the tails are protected, and then wrap them in cloth, with the ends secured firmly, tied up with string, or sewed. Be sure to protect all the fins. Tie each package firmly but not so tightly that the strings will cut into the fish. All containers should be completely filled with packages of fish, or the excess space filled with excelsior or dry grass. Do not use paper as it softens and dissolves in the liquid and does not fill the spaces. After the container is completely filled, then nearly all of the excess liquid may be poured off, leaving the contents of the container wet. Be sure the container is sealed to prevent evaporation. If a metal can is used, the top should be soldered on. Shipment may be made by mail or express or other means. If the material is to be sent "Collect", please let us know prior to shipment, so that arrangements can be made to take care of the transportation charges.

Precautions: -- 1. During preservation, fill all containers completely full of preservative so that there is a minimum of air-space in the container. If the fish are allowed to shake around in the jar, their fins will be frayed out and the rays and scales will become worn off, thus greatly reducing the value of the specimens.

2. Never overcrowd the fish in the containers, because overcrowding causes the fish to be hardened in distorted shapes and also they are very likely to spoil for lack of enough preservative (this is particularly true of soft-bodied fish such as suckers and of fish collected in the tropics).

3. All fish over three inches in length, especially soft-bodied fish, should have a small slit made in the belly. The slit should penetrate into the abdominal cavity. It is best to inject all fish over one foot in length, filling the body cavity with preservative.

4. As a rule, fish should be left in the preservative for at least one week, depending on their size, before being wrapped for shipment.

5. Always place a label, with the essential data, in each jar or package of fish. Be certain that you have linen ledger paper for labels as this does not go to pieces in liquid preservatives. Do not use a label covered with starch, as this comes off in water.

COLLECTING SEROLOGICAL SAMPLES

by Alan Boyden*

I. Introduction

The Serological Museum is an agency for developing the subject of comparative serology on a world-wide basis. It is dedicated to a simple principle, viz., that the proteins of the bodies of organisms are as representative of them as any of their other constituent parts, and are fully as worth of collection, preservation and comparison as their skins and skeletons. The data of comparative serology have significance for the study of the biochemical evolution of proteins, for systematics, and for medicine.

Suitable methods for the serological study of proteins and other antigens are now available. The great and continuing need is for a truly representative collection of the blood sera of animals, supplemented by other tissue proteins as they become available. The following suggestions in regard to collecting procedures may make it possible to save the sera of animals being collected, or to collect sera especially when the opportunities make it possible.

II. Directions in regard to collecting procedures.

The details in regard to collecting animal bloods will vary with the kinds of animals collected and with the equipment and experience of the collectors. Accordingly there are described the procedures which could be used: (1) where the equipment is minimum (2) where the equipment permits the simplest procedures for collecting fluid sera (3) where the standard serological laboratory equipment is available. In each case use the best procedure possible.

A. Collecting without any special equipment for obtaining and handling fluid sera.
Filter paper--standard grades not hardened--may be used to soak up the blood of animals collected in the field. These soaked papers must be kept from contact with all other samples at all times. They should be dried in air (but protected from sunlight or excessive heat and from visitation by insects) then packed in wax or other protective paper and kept dry. The identification and other data may be written on the filter paper in pencil.

If no filter paper is available at the moment--any absorbent paper will do--towelling paper for example or even a piece of clean absorbent cloth.

1. Terrestrial animals--birds, mammals, reptiles, amphibia, etc.
   a. Birds and mammals
   Small birds and mammals being skinned. Soak up the blood or serum as it is liberated from the surface of the carcass. Then open the thorax, cut the heart and soak up the blood from it on the filter paper.
   For larger animals (about 5 lbs. body weight or larger) the blood may be obtained in larger quantity from wounds as well as from the carcass and heart chamber.

* Director, The Serological Museum, Rutgers University.

b. Reptiles and Amphibia
Blood may be obtained from these by cutting into the heart chamber, as for small birds and mammals. If the specimens are to be kept with as little damage as possible, a small incision into the heart will release some of the blood.

2. Aquatic animals
a. Fish
Live fish will bleed from the haemal artery if the tails are cut off. This blood can be drained onto filter paper as before. Dead specimens will supply blood or serum from the heart if it is exposed and opened.

b. Crustaceae; Crabs and Lobsters
Remove the joined appendages. Blood will drain from the bases of these and can be soaked up on the filter paper. In the case of lobsters, crayfishes or shrimp, an incision in the mid ventral membranes at the junction of cephalothorax and abdomen will yield a good supply.

c. Mollusca; Snails and Clams, etc.
The larger snails can be bled by bringing them back to camp and propping them up off the ground with the aperture down. When the animal protrudes from the shell, jab the foot with a knife, making repeated large cuts. The blood may be expelled rapidly.
For the clams, the shells should be opened and the water in the mantle cavity released. Then cut the foot and allow to drain onto the filter paper.

B. Collecting with containers--(glass or metal jars or even paper cups) so that fluid samples may be obtained. The procedures here differ from the procedures described under "A" in that fluid blood is obtained from live animals mostly, and collected in clean containers. Such blood should be kept in a cool place--but never frozen--until clotting has occurred. From this clotted blood, the serum will be expressed, which process may continue for several hours or over night. The watery serum may be separated from the clot in one of several ways:

Pour off into another container, getting as clear serum as possible. If this serum is approximately 5 ml. or more it may be preserved with formalin (see remarks on preservation). If less than this amount, it may be soaked up on filter paper and dried as described in A.

If the amount of blood and serum is quite small, the serum may be soaked up on the filter paper directly from the container holding the clot. The expression of serum from the clot may be hastened by loosening the clotted blood from the sides of the containers or cutting the clot into sectors. In case of Crustacean bloods which jell but do not express serum, the jell should be squeezed with cloth or even with the filter paper if no cloth is available. The serum can thus be expelled from the jell under pressure.

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C. Collecting with availability of standard serological equipment: syringes and needles, centrifuge and centrifuge tubes, serum bottles, refrigerator, etc.
Fluid blood may be obtained by collecting from wounds, or by heart puncture with syringe and needle. Blood is allowed to clot and to stand in a cool place for several hours or overnight. Centrifuge and pour off serum. Recentrifuge and collect the clear serum. Add preservative and store in serum bottles.

III. <u>General directions in regard to sizes of samples, preservation, etc.</u>

1. Filter paper samples
From small specimens only very small samples will be obtainable. Thus for a mouse, or sparrow-sized bird--one piece of filter paper, 2" x 4" will give plenty of room for the writing of the name on the paper and for the blood. For larger specimens up to the equivalent of a square foot of soaked filter paper is desired.

2. Fluid samples.
   a. <u>Size</u>
   These may vary in size from 5 cc. up to 100 cc. or more.

   b. <u>Preservative</u>
   The standard field preservative is formalin.
   Ordinary commercial formalin (35-40% content of formaldehyde) can be used. Prepare a 2 percent solution of formalin by taking 2 cc. of formalin and adding to 98 cc. of fresh or distilled water. Add this 2 percent formalin to the serum in the proportion of one part of 2 percent formalin to nine parts of serum.
   The volumes may be approximated if no measuring apparatus is available.

   c. <u>Pooling of samples</u>
   The fluid blood of several small animals may be pooled together and treated as one sample. This should be done however <u>only</u> where the specimens clearly belong to the same species (or subspecies if known).

   d. <u>Records</u>
   The record for each sample should include the following information:--
   Scientific Name:
   Date of Collection:
   Collector and Institution:
   Place of Collection:
   Sample from one specimen or pooled:
   Treatment of Sample--especially preservative used and amount:

e. Shipment
Filter paper samples may be sent first class as ordinary letter mail. Fluid samples preserved with formalin should be carefully packed and shipped by air mail or surface mail to:

Serological Museum
Rutgers University
New Brunswick, New Jersey
U. S. A.

Suitable filter paper, glassware, shipping containers, etc. will be supplied where needed.

f. Acknowledgment
The samples contributed to the Serological Museum will be made available to competent serologists for studies in comparative serology. When scientific reports are published, full acknowledgment will be made to the collector and his institution for the aid given.

Chapter 8 -- Marine Ecology

INSTRUCTIONS FOR MARINE ECOLOGICAL WORK ON CORAL ATOLLS

by Robert W. Hiatt

INTRODUCTION

These instructions are designed for studies of only a few months' duration and to cover the most important ecological features in a manner which permits comparison of atoll communities. The studies outlined may be made with a minimum of equipment and personnel, for only on rare occasions would an ecologist have an opportunity to take all the equipment and have all the assistance required to do a more intensive job. These instructions are, therefore, pointed toward meeting the problem of working in the field in the most practical manner possible with a minimum of equipment and assistance. Methods of collecting on coral reefs and of preserving animal species are discussed in separate sections of this handbook.

CHECK-LIST OF ESSENTIAL EQUIPMENT

Clothing

- Canvas gloves (1 pair for each two weeks in the field)
- Canvas wading shoes (1 pair for each three weeks in the field)
- Swim trunks (several pairs)
- T-shirts or other shirts (to be worn both in and out of the water)
- Hat with good sun visor
- Heavy shoes for hiking
- Other suitable clothes for travel and casual wear

Drugs and first aid material

- First aid kit (include ready-made bandages, gauze, adhesive tape, merthiolate, sulpha salve, and antibiotics)
- Aspirin
- Chlorine tablets for purifying drinking water
- Sun-burn preventative

Collecting equipment

- Inner tube and canvas float
- Face masks (at least two)
- Swim fins
- Geology pick or similar instrument
- Pinch bar, small
- Swimming bag (canvas body, fish net bottom and heavy zippered top opening)
- Canvas buckets
- Dip nets ($\frac{1}{2}$ inch stretch mesh; 1 foot in diameter)
- Shovel, short-handled
- Cord, coil of small diameter cord or rope
- Hunting knife and scabard
- Kerosene mantle-type lanterns (take spare generators and alcohol for starting them)

Collecting equipment, (cont'd)

Flashlight (plenty of spare batteries and spare bulb)
Glass-bottom box (not essential if proficient with a face mask)
Shielded thermometers (three)
Portable tide guage (very useful, especially where tidal data are lacking)
Small framed mirror etched with carborundum
Rotenone, freshly ground cubé root (Fish-tox, a wettable preparation from Standard Supply Distributors, Wenatchee, Washington, is preferable
Hand leveling instrument
Metal rule, six foot

Preserving materials and equipment

Metal gallon and two gallon cans of non-corrosible material (make use of empty food cans temporarily in the field)
Formalin, five to ten gallons, preferably in small containers
Alcohol and glycerine (5%), two or three gallons
Magnesium sulphate, ten pounds
Chloretone, small bottle
Cheesecloth for wrapping specimens, two bolts
String for tying labels and specimens, one skein
Parchment paper for labels
Heavy manilla labels, 1" x 2"
Stainless steel leader wire for tying labels to coral specimens
Pliers, with cutter blades
Vials, homeopathic, one gross each of 1, 2 and 8 dram
Corks for vials
India ink and pens
Bakelite top bottles, 4 dram (for salinity samples)
Hypodermic syringe, 50 cc., and needle, 18 ga.

Field laboratory equipment

Reference books on taxonomy (see annotated list)
Long forceps
Dissecting instruments
Dividers
Foot rule, metric
Glass slides and coverslips
Syracuse watch glasses
Stacking dishes
Data books
Blank cards, several hundred
Pencils

INITIAL SURVEY OF REEFS

Land area on atolls is small but reef area is extensive and variable in composition. Since growth characteristics of coral species are closely linked to environmental conditions, especially as regards movement of water, it is to be assumed that a great variety of kinds of coral reefs, sand and muck flats, and gravel or boulder shores will be present. Naturally the complete ecology of an atoll would not be understood without analyzing the interaction in and between each marine biotope. However, the time, distance from research centers, and limited personnel involved preclude such a complete study. The investigator must, therefore, size up the entire reef and shore area so that intelligent selection can be made of working areas.

Listed below on a priority basis are a few things to consider as criteria for selecting a special section of the reef or shore for investigation.

1. The area should be typical of a large proportion of the reefs and shores of the atoll. This means that minimally a section or sections would have to be selected from both the sea and lagoon reefs and across the island from shore to shore.

2. Extremely wide reefs should be avoided unless they are distinctly typical. Usually the same zonation may be found in narrower reefs, thus facilitating the collection of data in a briefer period of time.

3. The areas selected should be relatively free from heavy waves during periods when collections and observations are to be made.

4. The study areas should be as close to the base camp as practicable. Usually this is not entirely possible because of the differences in the sea and lagoon reefs. If the two study areas must be some distance apart, the base camp should be nearest the study area on the sea reef, because transportation along the sea reef about an atoll is often impossible, whereas native canoe transportation in the lagoon is feasible.

THE TRANSECT METHOD

Its Value

The ecological transect seems to provide the best working procedure for the study of coral reef areas. Not only is it possible by such concentration in area to secure a better qualitative picture but it is the only method by which a quantitative analysis may be made. The latter point is significant in that most invertebrates closely inhabit certain coral species and these coral species are zoned across the reef flat and down the sloping reef edges. Moreover, the fishes are tied ecologically to particular facies in the reef biotope and such relationships are best illustrated by treatment of data gathered from particular quadrats within the transect. Any other means of collecting data will fall short of the critical analyses made possible by the transect method. It is desirable, once the collections and observations in the transects have been made, to make general observations on other reefs and shores for purposes of general comparisons with the more detailed data. In this way a better understanding of similarities and differences from one region to another will be secured.

Procedure in Laying Out Transects

From a point at the upper edge of the beach where the terrestrial flora meets the sand or rocks, lay out a line down the beach and across the reef to its outer edge. Place markers at equal intervals along this line. These may be at 50, 100 or 200 foot intervals, but keep them equal. Use sticks well propped up by rocks, or use piles of rocks for markers. Now move horizontally from this line 50 or 100 feet and place similar markers along a similar line. This will segregate the beach and reef area into square or rectangular quadrats of equal area. Give each quadrat a code number in your notes. All collections and observations should be made within these quadrats and the specimens should be labeled as to the quadrat in which they were taken.

Collecting Data

Physical and chemical data

Temperature readings and samples of water for salinity determinations must be taken in each quadrat during both high and low water, and during morning and afternoon periods in order to measure the limits of variation. If especially low tides occur, every effort should be made to get temperature and salinity data. Tidepools in the intertidal zone should be visited for such collections approximately hourly on especially warm days.

TEMPERATURE readings should be taken in each quadrat with a shielded thermometer held at the upper level of the coral heads. During low tides this may be done by wading, but often at high tide the readings must be taken while swimming. In the latter case the best method is to wear a face mask, lower yourself to the coral and hold there, with one hand grasping the coral and the other holding the thermometer in place. After a half to one minute read the thermometer in place. For recording in the water one may use a small framed mirror, the face of which has been etched with carborundum so that a lead pencil will mark it. Use an ordinary pencil wrapped with electricians rubber tape. Tie the mirror and pencil onto the inner tube float which should always be tied to the observer with a short rope. The code numbers for the quadrats can be written on the mirror before entering the water, then only the thermometer reading need be recorded while swimming or wading. For the quadrat which includes the outer edge of the reef and the descending reef slope, a surface reading should be taken with the thermometer held about two feet below the surface. A deeper reading down the slope should be taken because it will represent the closest to oceanic or mid-lagoon conditions that the investigator will be able to get on the transect. The simplest way is to skin-dive down as far as you can, hold onto a rock or coral head with one hand and hold the thermometer in the other. Read the temperature after a half to one minute at that level. With a little practice one should be able to lower himself fifteen to twenty feet for this purpose.

SALINITY samples should be collected concurrently with the temperature records. The volume of sea water collected depends upon the method used to determine salinity. Experience has shown that the Wheatstone Bridge and similar electro-chemical indicators are not suitable for work in the field under conditions met on atolls, since the high humidity soon shorts out the mechanism.

However, it is often desirable to know something of the characteristics of the water while in the field. The only suitable method for making these determinations is the silver nitrate titration method, so take along sufficient 0.5 Molar Ag NO_3, 5% potassium chromate, and the necessary glassware to make a few determinations in the field. Use 25 or 50 cc. medicine bottles with bakelite screw tops for the water samples. Place labels containing the date, tide and quadrat code number in the bottle before entering the water. These bottles may be packed in small compact containers and returned to your institutional laboratory for titration later.

OXYGEN and HYDROGEN ION concentrations need not be recorded in ecological studies on coral reefs, since they are without significant variation.

PHYSIOGRAPHIC features such as levels of reef rock and tops of coral growths in certain instances are significant in relating coral zonation to environmental factors. These data may be determined by establishing an arbitrary bench mark, if an official one is not present, and mapping the contours with a hand-leveling instrument and a jury-rigged surveyor's staff. In certain localities tidal records will be unavailable, and in other localities such records as are available are grossly inaccurate. In order to establish the tidal information desired, and incidentally to refer the bench mark used in ascertaining the reef contours to tidal data, it is desirable to construct and take along a portable tide guage. The type described by Wentworth (Jour. Washington Acad. Sci., 1936, 26(9): 347-352) has proved simple to construct, easy to operate and sufficiently accurate.

Biological data

FISH are collected adequately only by the use of rotenone or Fish-tox. (See instructions for collecting fish.) Rotenone may be obtained in ground, powdered form in a concentration of about 5% at almost any firm, manufacturing insecticides. If the powdered form is to be used, it must be freshly ground and used in a few weeks. Fish-tox is more satisfactory for longer periods in the field. Two persons can poison an area of about 7,500 to 10,000 square feet and do a fair job of picking up the fish. A smaller area is preferable. Do not poison the area if the tide is too low, as most of the fish found in the quadrat when the tide is higher will have gone over the edge of the reef. It is best to poison about mid-tide as it is receding. This will leave adequate depth of water and the force of the waves and the surge will be subsiding rather than increasing, factors of great importance in picking up the dead and dying fish.

The fish should be collected quadrat by quadrat, taken back to the field laboratory and processed, and those not preserved or used otherwise should be returned to the water where they will be quickly devoured. An important point to have in mind is that the natives will be greatly interested in this phenomenal method of collecting fish. Great care should be taken not to poison fish indiscriminately or too near human habitation, because native subsistence depends to a great extent on the reef fishes and you must maintain happy public relations with them. Always give the natives edible fish which you do not wish to keep for later study. Local native customs will dictate how the distribution of fish will be made.

Invertebrates should be collected or noted quadrat by quadrat also. Instructions for collecting in particular types of marine environments and for special groups of animals will be found in another section of this handbook.

ANALYSIS OF DATA

Physical and chemical data

All physical and chemical data should be analyzed and presented in the usual acceptable manner, keeping in mind that comparisons and correlations will provide the most useful data for interpretation of biological phenomena. Raw data should always be tabulated and included in an appendix to any report. Graphic means of presentation are usually best for summary analyses in the main body of the report.

Fauna and flora

Two considerations should be prominent in handling these data. First, the animals present should be identified with accuracy, preferably checked at least by leading taxonomic specialists. Second, their ecological relationships should be described.

The first consideration does not require elaboration, except to say that specimens should be preserved for identification in the best manner possible under field conditions.

Collections made as quantitatively as possible in quadrats described in a transect naturally lend themselves to analysis in a number of ways. Quantitative and qualitative patterns of distribution by phylogenetic groups and by species may be made in relation to physiographic features, physical and chemical aspects of the environment and special biocoenoses within the general coral reef biotope. Zonation horizontally and vertically is readily designated. Biological phenomena on lagoon reefs may be compared directly with sea reefs, and various exposures of reefs on which such transects are made may be readily compared for a better understanding of factors underlying distribution and abundance of reef species.

Useful Field References

Generally speaking, positive identification in the field is difficult and should not be a prime objective of the investigator. However, it is desirable, where possible, to make tentative determinations. Unfortunately, the Pacific region is singularly lacking in faunal and floral handbooks, so recourse must be made to original taxonomic papers. The following list is highly selected for field use and omits monographic works or less extensive works which would not prove practicable to carry into or use in the field.

Fish

Hiyama, Y. 1943. Poisonous fishes of the South Seas. (In Japanese). 136 pp.

Illustrations are excellent and valuable in dealing with fishermen. A translation is available, but it is not needed.

Schultz, L. P. 1943. Fishes of the Phoenix and Samoan Islands collected in 1939 during the expedition of the U.S.S. "Bushnell". Smithsonian Institution Bull. 180: 316 pp.

Currently a basic work for any taxonomic study. Has good keys which incorporate descriptions of the fishes. Does not cover certain large groups such as the scarids, lutjanids, and serranids, and other literature should be used for them.

Smith, J.L.B. 1949. The sea fishes of Southern Africa. Central News Agency, South Africa, 550 pp.

Beautifully illustrated and contains a key to all species listed. While it covers many fishes not found in the Central Pacific, it is nevertheless invaluable to an investigator not well-versed in Central Pacific forms.

Tinker, S. W. 1944. Hawaiian fishes. Tongg, Honolulu, 404 pp.

Illustrations make this useful in dealing with fishermen.

Umali, A. F. 1950. Key to the families of common commercial fishes in the Philippines. Research Report 21, U. S. Fish and Wildlife Service, U. S. Dept. of Interior, 47 pp.

This key to the families should prove very useful to an investigator not familiar with Central Pacific forms.

Weber, M. W. C. and L. F. de Beaufort. 1911-1940. The fishes of the Indo-Australian Archipelago. Vol. I- IX, E. J. Brill, Leiden.

This series of nine volumes serves to supplement Schultz in regions west of Samoa. It is considered basic, although its keys and descriptions are not always adequate.

Invertebrates

<u>Echinodermata</u>

Clark, H. L. 1914. Hawaiian and other Pacific Echini. Mus. Comp. Zool., Mem. 46(1): 1-78.

__________ 1917. Ibid., 46(2): 79-283.

The most concise account of Pacific Echini. Mortensen's monograph is recent and more complete, but is hardly a field reference.

Clark, A. H. 1949. Ophiuroidea of the Hawaiian Islands. B. P. Bishop Mus., Bull. 195: 133 pp.

Includes many widespread Indo-Pacific species.

Fisher, W. K. 1907. The holothurians of the Hawaiian Islands. U. S. Nat. Mus., Proc. 32 (1555): 637-748.

Includes many widespread Indo-Pacific species (except apodous holothurians).

Fisher, W. K. 1919. Starfishes of the Philippine seas and adjacent waters. U. S. Nat. Mus., Bull. 100(3): 712 pp.

The best general account of widespread Indo-Pacific species.

Mollusca

Hatai, K. 1941. Recent marine shell bearing Mollusca of the South Seas islands. Inst. Geol. and Paleon., Tohuku Imp. Univ., Sendai, Japan. One vol. and atlas of plates.

Fine illustrations for field identification but quite incomplete. Other volumes are to follow.

Hirase, S. 1936. A collection of Japanese shells. 5th ed. Matsumura Sanshodo, Tokyo, 217 pp.

An excellent treatise with photos in color of many common gastropods and pelecypods of the Indo-Pacific area. The nomenclature should be checked with specialists.

Robson, G. C. 1929. A monograph of the recent Cephalopoda. Part I. Octopodinae. British Museum, London.

__________ 1932. Ibid., Part II. Octopoda. (except Octopodinae). Op. cit.

This is the best treatment of the Octopoda. Unfortunately there is no similar treatise available for the Decapoda.

Arthropoda

Kemp, Stanley 1913. An account of the Crustacea Stomatopoda of the Indo-Pacific region. Indian Mus., Mem. 4: 217 pp.

Most useful taxonomic account of Indo-Pacific stomatopods.

Miyake, S. 1943. Studies on the crab-shaped Anomura of Nippon and adjacent waters. Dept. Agric., Kyushu Imp. Univ., Jour. 7(3): 49-158.

Excellent account of many of the porcellanid crabs of the Indo-Pacific.

Pilsbury, H. A. 1916. The sessile barnacles. U. S. Nat. Mus., Bull. 93: 1-366.

Sakai, Fune. 1936. Studies on the crabs of Japan. I. Dromiacea. Zool. Inst., Tokyo Univ. Lit. Sci., Sci. Rep. (B) 3(supp. 1): 66 pp.

__________ 1937. Ibid., II. Oxystomata. Op. cit. (suppl. 2): 67-192.

__________ 1938. Ibid., III. Brachygnatha, Oxyrhyncha. Yokendo, Ltd., Tokyo, 193-364 pp.

__________ 1939. Ibid., IV. Brachygnatha, Brachyrhyncha. Op. cit., 365-741 pp.

These volumes are the most useful in identifying crabs in the Central Pacific area.

Chapter 9 -- Anthropology

ANTHROPOLOGY AND CORAL ATOLL FIELD RESEARCH

by Alexander Spoehr

I. Introduction. The examination in the field of the relationship between man and his atoll environment can be focussed on the man (including his culture) term, or on the environment term in this relationship. In either case, it is understood that the relationship between the two terms is the important thing, but as a matter of field procedure it may be necessary first to concentrate on the terms themselves and then investigate the nature of their relationship. In the organization of the work of an ecological field team the anthropologist will necessarily play a primary role when the nature of the cultural adaptation of man to his environment is under consideration. When the focus of interest shifts to the ways in which man's presence has affected the environment, the anthropologist will play a supporting though nevertheless essential role in assisting his colleagues in understanding the factors involved in man's behavior in altering his environment.

In the ecological approach to the anthropology of coral atolls, it is a reflection of the immaturity of our science that we do not yet know those specific questions to ask whose investigation will bring us greatest returns. One phase of atoll research necessarily revolves around formulation of future problems for empirical investigation. This is true of any vigorous discipline, of course, but in human ecology we are still not very far from our starting point.

However, we can delineate the framework within which anthropological fieldwork on coral atolls should proceed. It is my feeling that such field observation should (a) Focus on the present rather than the aboriginal past at the inception of any period of field observation, (b) As the work progresses, elucidate processes involved rather than static patterns, which may mean dredging up as much relevant historical data as possible, (c) Operate with a set of problems suitable for comparative investigation, for in atoll research comparison must be substituted very largely for experiment.

II. Problem areas. Rather than attempt to outline a series of questions applicable primarily to a given atoll, it is perhaps preferable to indicate a number of problem areas within which field research will be fruitful. It should be emphasized that field research should in the end center on relationships rather than terms alone -- as on the relationship of technology to the amount and characteristics of natural resources rather than technology alone or resources alone. Problem areas follow:

A. Population size and density in relation to food resources, given a particular type of technology. In view of the probable future population pressure on atoll resources generally, this forms an important field of investigation, which leads naturally to diet and nutrition studies.

B. Technology in relation to the amount and character of natural resources available and used. Description of tools, in the familiar context of material culture studies, are not as important in this connection as the determination of the over-all characteristics of the technology under examination--skills in relation to technical processes; time and energy expended in particular technical processes in relation to productivity, the total tool system, etc. There is also a need for re-orienting studies of technology to the modern scene rather than to the aboriginal past.

C. Technology, economic organization and utilized resources. Here it may be possible to consider economics under the conventional headings of production, distribution, exchange, and consumption to determine how the organization of human activities in these areas is related to the technology, and to the utilized resources. On the other hand, an entirely different approach may be more useful. Fieldwork in economics is very time-consuming, however, a factor that must be taken into account. An important question is the mechanics of social control of atoll resources in relation to the organization of production, distribution, and consumption.

D. Social organization in relation to technology, economics, and utilized resources. Some of the most productive field research in American Indian social organization has utilized an ecological approach, such as the work done by Steward in the Great Basin, and by Hallowell and others among Algonkin hunting groups in the northeast. Comparable results should be obtained when a similar approach is applied to the study of the social structures of atoll peoples. In this regard, it is important to determine the essential differences in social organization between populations on atolls differing in the abundance and variety of their resources. As a preliminary hypothesis, it is suggested that stratification, elaboration of the functions of corporate kinship groups and complexity of local organization will be more highly developed on atolls with abundant resources than on those with scarce resources. Hypotheses of this sort need to be formulated and tested.

III. Planning. A fundamental problem in the planning of atoll field research is the need for selection of the kinds of data to be collected in order that a relatively brief period of fieldwork be of maximum value. It is suggested that the anthropologist who is able to spend only several months on an atoll concentrate his work on a few problems rather than to diffuse his effort more widely. The type of problem envisaged by an ecological approach demands the examination of functional relationships between variable factors. This type of problem requires more than superficial observation and there is a real danger that the fieldworker may diffuse his effort to the detriment of his over-all results. There is a distinct need for concentration of effort on a limited number of objectives.

SUGGESTIONS FOR INVESTIGATING THE CULTURE OF ATOLL PEOPLES

by Leonard Mason

The following suggestions for investigating the culture of an atoll people are based upon work already accomplished at Arno Atoll in the southern Marshalls. They are outlined here as a guide to the kinds of information which have already been collected for one atoll group. It is hoped that in other atoll studies the same kind of information may be collected by other workers in order to provide some common basis for comparison of atoll cultures. It is recognized, of course, that some subject matter suggested here may not be emphasized at all in other cultural situations, and that some subject matter not included here may be important to concentrate upon elsewhere.

I have found it convenient to group my suggestions in the following organization because investigation of man-land relationships focusses the investigator's attention upon economic activities in which material culture, social culture, and land tenure are frequently so interrelated that this kind of division of subject matter is a difficult one to follow. I have chosen to group my suggestions, therefore, into five categories, not all of which have equal importance for an ecological study, but all of which relate directly to it: (1) population inventory, (2) economic activities, (3) land tenure, (4) social and political organization, and (5) movement of people.

1: Population inventory.

An inventory of the population is essential. How intensive or extensive this inventory will be depends upon the time and assistance available to the field investigator. At Arno, I tried to complete a card file for the entire atoll, a population of under 1,000. This was not feasible in the time available, and the populations of only four communities in the atoll were processed, about 450 people. For each individual we sought and received, usually with very little difficulty, certain personal history data which were recorded during the interview upon a 5 x 8 card form previously prepared for that purpose.* This information included the following: (1) age, (2) sex, (3) residence at the time of the interview (noted by name and location of the land-holding on which the residence was located), (4) ethnic origin (whether all-Marshallese or mixed with Gilbertese, Japanese, or Caucasian), (5) birthplace, (6) identity and birthplace of parents (useful information for determining the degree of immigration), (7) children (with their names, ages, sex, and present residence, plus fact of adoption where pertinent), (8) educational background (number of years and type of school, for evaluation of effect of formal education on the man-land relationship), and (9) specific awareness of the world outside the atoll (visits or residences at other atolls and other Pacific regions, and the reasons and dates of same). A photograph was taken of every individual interviewed for purposes of cross-checking photographic data later in the identification of particular individuals pictured in various economic activities.

Additional information was secured in these interviews as to (1) clan affiliation, (2) social rank or status, (3) change of residence with adoption or marriage, and (4) religious membership. Some of this material has a direct bearing on the economic relationship of man to land, but much of it serves rather to aid the anthropologist in further understanding the composition of the community.

* See sample card A, p. 115

Analysis of these data provides helpful clues in the determination of trends in the changing relationship between populations and natural resources over a period of years. Shifts in population away, from, or onto the atoll in recent generations, as indicated by individual ancestry records, obviously may have some effect on the actual utilization of an atoll's resources. The longer-term trends in population growth have to be determined with the aid of official records or early estimates by travellers and others, where such written records exist. Factors contributing to changes in the size of population could often be detected in interviews with older islanders, when information was given about infant mortality, diseases, foreign medical aid, immigration or emigration for a number of reasons, and disasters, such as typhoons, drouths, and warfare.

2. Economic activities:

The investigation of economic activities was organized along two lines: (1) subsistence, which has to do largely with the direct utilization of atoll resources to meet the demands of daily living, such as the acquisition and preparation of food, the construction of housing and canoes, the preparation of fibers and other materials for handicraft used locally, and (2) commercial, which has to do with introduced economic activities, such as copra and handicraft production for sale to traders, wage labor, and the importation of trade goods to supplement local products. In both cases, studies were made of the kinds and quantities of local resources and imported items that were used, of the techniques and apparatus employed, of the work organization (by individual effort or cooperative labor of a family, a lineage, a household, or a community), of the distribution and use of the products manufactured or prepared or of the money derived from commercial activities. Special attention was given to the amount of work accomplished, the time expended, the individuals involved and their relationship to each other, and the location of the activity.

Following this section is a copy of a project proposal for anthropological investigation of Arnoese economy during the summer of 1951 by Mr. Harry Uyehara (graduate student at the University of Hawaii, under my direction). This project emphasized the collection of certain quantitative data to supplement material gained the previous summer. This project was part of the Coral Atoll Program sponsored by the Pacific Science Board and the Office of Naval Research.

To supplement the notes recorded on economic activities, an extensive photographic record was obtained at Arno, with pictures of food preparation, handicraft production, etc., in black-and-white and color stills, and in color movies for those activities better described by the cinema medium. Such a photographic record proves to be very worthwhile in checking some field notes where for reasons of haste or misunderstanding, notes are incomplete or confused.

In the analysis of economic activities, special interest should be directed toward the relative importance of commercial activities through the years, and the trend today toward greater dependence of island populations on participation in the world economy. Special inquiries were made in the field about the historical development of certain commercial enterprises, with notes about significant changes brought about in the man-land relationship. Estimates were also attempted as to the possible effect of other changes as contemplated by the people or the administration for future years.

3. Land tenure:

Closely related to the preceding topic is, of course, land tenure and associated matters, and especially so in atoll regions where scarcity of land frequently heightens anxiety about land ownership and use rights. At Arno, land maps drawn to a scale of about 1:5000 were produced for several islands (all islands in the atoll could not be surveyed in the limited time). For this mapping, hand-compass for directions, and pacing for distances proved to be accurate enough for our purposes. Generally, it was easiest to lay in the single main street first, then tie in both ocean and lagoon beaches which roughly paralleled the street. Paths and trails from the beaches provided convenient traverse lines to the street. All cultural facilities, such as dwellings, cook-huts, copra driers, latrines, pig-pens, wells, boat-houses, cisterns, public buildings, cemeteries, paths and trails were indicated on the map to scale. (A photographic inventory of these facilities provides a convenient check-list for identification and comparison of types.)

Finally, with the aid of community officials and local landowners, the boundaries of each land-holding were traced from ocean to lagoon and tied into the street. In general, where the terrain had been cleared, the actual boundaries were followed (with notes on the type of markers employed). In some cases, however, where brushing of the area required too much time and labor, only the general location of the boundaries was indicated. Notes were made on the names of individual land-holdings, of persons associated with the land as owners, and of persons holding only a use right to the land. Inheritance of land parcels was traced back for several generations, in representative cases, and related to genealogies of the lineages concerned. Disputes about boundaries or about title to land-holdings were recorded during the field mapping, to be followed up later by interviews with interested parties to determine more precisely the present methods of dealing with land problems.

Information was collected in interviews on the rights and obligations of various categories of persons associated with land-holdings, about changes in attitude regarding these rights and obligations, and about the interrelationships of land tenure patterns and other aspects of the economic system. Special attention was devoted to the actual relationship of people to their land in daily practice, the use made of the land, the products derived from the land, and the potential hardship to be suffered if their interests in the land were either reduced or completely voided.

Fishing areas, in the Marshalls, are relatively free and available for use by all Marshallese. In atolls elsewhere in the Pacific where fishing areas are regarded as properties to be owned and safeguarded, a more detailed investigation of this subject would obviously be called for.

4. Social and political organization:

In the investigation of social and political organization as it pertains especially to the man-land relationship, attention was given to the data under three general headings: (1) kinship groupings, (2) territorial groupings, and (3) systems of rank. With regard to each of these, land ties were found to be a vital element.

For kinship groupings, data were collected on the nuclear family, the lineage, and the clan, as pertinent social units; for territorial groupings, attention was centered on the household, the hamlet, the island community (village), the district, and the atoll. In both cases, notes were taken on the composition of the groupings (together with significant variations permitted in the culture), the organization of the members, leadership, the relation of each grouping to others of both types (kinship and territorial), and obligations of members to each other (especially those involving exchanges or transfers of property of any kind). Trends were investigated as to the respective positions of each type of grouping within the total community, particularly the increasing importance attached to territorial units as compared with kinship units, and the possible effects of such trends upon the man-land relationship.

In investigating systems of rank, both social and political, data were sought about the respective importance of such factors as birth, wealth, personality, education, etc. Notes were taken on the actual composition and organization of certain rank hierarchies as they existed within the atoll population, on the function and relative importance of each rank, and on the relationship of each rank to the exploitation and distribution of natural resources.

5. Movement of people:

Finally, attention was devoted to the movement of people, within the atoll (from land-holding to land-holding, and from island to island) and between Arno Atoll and other atolls and islands in the Marshalls. Frequency of travel was noted, as were also the purpose, persons involved, type of craft utilized, and various factors affecting time of travel and duration of trips. Through interviews and actual observation, daily, seasonal, and annual patterns of movement were established, especially as these related to the exploitation of natural resources. An attempt was made to note significant differences in such exploitation, since contacts between Arno and other atolls have become more frequent in recent years.

SAMPLE CARD A.

<u>recto</u>

ARNO ATOLL CENSUS, SUMMER 1951 No.

Name________________________________Residence________________________
Island Household

Sex____Age____Race_________Clan____________Atoll of birth________________

Mother______________Mother's birthplace____________Mother's clan_________

Father______________Father's birthplace____________Father's clan_________

Adopted?_________By whom?_______________Change of residence?___________

Married?_____Spouse______________Clan___________Date_______Place________

Spouse's mother______________________Spouse's father____________________

Change of residence at marriage____

Religion________________Education________________Where?________________

Occupation__________________________Class or social status_______________

Atolls visited: (German)___________________(Japanese)______________________

(American)____

<u>verso</u>

Children:_____________________Age__Sex____Residence____________________
(Living)

____

____

____

____

____

____

Children:____
(Dead)

____

Spouse deceased?_____When?____Divorced?____When?_____Why?_______________

Remarried?____Date_____Place_____________Change of residence?____________

Spouse________________Clan___________Residence before marriage__________

A QUANTITATIVE STUDY OF CERTAIN ASPECTS OF THE MAN-LAND RELATIONSHIP IN MARSHALLESE ECONOMY AT ARNO ISLAND

by Leonard Mason and Harry Uyehara

Quantitative data for the fiscal year 1949-50 were obtained* for atoll production of copra at Arno (by district and by season, sales value and weight, and distribution of money income) and for atoll importation of trade goods (by district and by season, sales value and, in the case of food supplies, specific itemization). Further quantitative studies had been intended, at Arno Island only, with special reference to individual and family participation in copra production, in preparation and consumption of food, in movement of persons within the atoll and between atolls, and in the distribution and use of other economic goods derived from the natural environment. Time, however, did not permit.

A feeling that generalizations about these activities, as based upon personal observation by the investigator or upon statements and estimates by Marshallese informants, were frequently too vague or unreliable, resulted from two conditions. The first was the great individual variation in work activity as noted in the few test studies on a quantitative basis that were attempted. The second was the unconcern on the part of the majority of Marshallese, in recalling past behavior, about the accuracy of numbers of hours expended, numbers of people involved, and amounts of work produced.

These are conditions, of course, which are not peculiar to the Marshallese situation. Other anthropologists working with other groups in the Pacific and in other parts of the world, have noted the same methodological difficulties among nonliterate peoples. Nonetheless, the value of quantitative data which can be obtained under controlled conditions with statistically reliable techniques is never doubted.

It was proposed, therefore, that an anthropologist (in this case, Mr. Harry Uyehara) conduct an intensive quantitative study of certain aspects of the man-land relationship in Marshallese economics at Arno Island during the summer of 1951. This study was an extension of the 1950 field work referred to above, and utilized the materials already collected and analyzed. The results of the 1950 and 1951 field projects will eventually be integrated with other studies undertaken at Arno Atoll within the framework of the Coral Atoll Program for the better understanding of the Arnoese and their ecological relationship with other components of the total atoll environment.

In 1950 Arno Island, with a land area of 0.66 square miles or 422.4 acres, supported 201 persons who were combined in various numbers (ranging from 1 to 15, averaging 6) in 30 households. The island was divided into 63 land parcels, each averaging 6.72 acres and with boundaries from lagoon to ocean shores; only 30 of these parcels were actually occupied in 1950. The remaining 33 were either more or less abandoned although ownership and use rights were kept alive, or associated with parcels then occupied.

* by Mason in 1950.

In obtaining quantitative data for statistical treatment, 12 of the 30 households were selected by random sampling, thus 4 from each of three strata based upon size of household. After an inventory of economic resources available to each of these 12 households made by the anthropologist, with special attention to numbers and kinds of economic plants, animals, and fishing areas, building facilities and household goods, and personal effects, he checked each household daily during one month,and later for one week for a detailed quantitative report on a number of economic activities as listed below. A number of simple questionnaire forms were prepared in English and in Marshallese on which each household group recorded numbers, amounts, and times involved in production, distribution, and consumption of economic goods.*

The anthropologist lived at intervals of one to two weeks in several of these 12 households, reviewing daily the reports of the other 11, checking for accuracy wherever possible, filling in more complete information through interview with members of each household, and further instructing Marshallese assistants in a more reliable reporting of economic activities. The difficultie of employing questionnaires, among an essentially untutored people are realized, but it is believed that the carefully conceived forms were feasible in this case, since most Marshallese at Arno Island are literate in their own language, and many have become accustomed to reckoning in numbers and by weight through their transactions over half a century with foreign traders and tax collectors.

Within the three-month period, the anthropologist became acquainted with each household; providing thus a better basis for evaluation of the daily reports, and had adequate opportunity to take his own observations on economic activities of the people. The three summer months, roughly from mid-June to mid-September, coincide with the main breadfruit season, the most productive period of the year in terms of food. The results of the study have primary value for this season of the year; similar studies should be carried out at other seasons for a more complete understanding of the year-round relationship between Arnoese and their natural environment.

Subjects for Quantitative Study

The following subjects were basic in the daily reports from each of the households selected for this study. In general, the questions to be answered were:

How much work is accomplished?
Where is the work undertaken?
How many persons are involved?
Who are they? What is their social status?
How much time is consumed in each activity?
How much leisure time remains? How is it spent?

1. Food collection and preparation:

Kinds and amounts of food materials assembled (plant, animal, marine, store); time consumed in different stages of preparation; artifacts and accessories required; persons employed; location of activities.

* See sample cards attached (B and C, pp. 119 and 120)

2. Food distribution and consumption:

Food exchanges (raw, cooked, store); persons involved in exchanges; their relationships; quantities and kinds of food exchanged; occasions for exchange; quantities and variety of food consumed by individuals; number of meals, times, and composition of eating groups; visitors at mealtime, their relationship with host; their treatment by host; foods consumed by visitors.

3. Copra production:

Number and size of nuts husked; weight of meat cut from nuts and dried; weight of copra sacked and stored; weight and value of copra sold to trader; location of each activity; time involved; persons employed; distribution of income from sale of copra.

4. Production of artifacts and handicraft:

Amounts and kinds of raw materials collected, prepared, and processed; types of articles produced; value of articles sold to trader; use of articles retained; ownership in relation to producer; location of each activity; persons employed; time involved.

5. Clothing production, laundry, and repair:

Items of clothing produced or bought; value and quantity of clothing; materials employed in laundry and repair; time involved in work; persons employed; location of each activity.

6. Construction and repair of housing and water transport:

Quantities of raw materials for use in construction of housing units or canoes and boats; processing of raw materials (time consumed, persons employed, location of activity); ownership and use of completed structures and craft.

7. Weather conditions and events competing with economic activities:

Frequency and duration of weather conditions impeding work progress; Sundays and holidays; festivals and visiting; recreation and other leisure-time activities; frequency of these, degree of disruption of work program, persons involved.

8. Movement of persons.

Travel from one land-holding to another; from Arno Island to other islands in the atoll; from Arno Island to other atolls; kinds of transport used; occasions for travel; length of journeys; duration of stay; persons involved.

9. Participation in money economy:

Receipts of money; source of income; distribution of income; purchases and other transactions requiring money; persons involved.

SAMPLE CARD B.

INVENTORY OF LANDHOLDING - Arno Project - 1951

Name____________________ Informant____________ Lot No.______

Iroij____________________ Iroij erik__________ Alab__________

Ri jerbal____

Occupants____

Buildings____

Sail canoes__________ Paddle canoes____________ Bicycles__________

Other transport____________________________________

Land acreage____________________

Pigs____________ Chickens________ Ducks__________ Others________

Breadfruit________ Coconut_________ Pandanus_________ Banana________

Papaya____________ Mangrove_________ Others____________________

Taro______________ Arrowroot______________ Sweet potato__________

Cisterns____________________ Wells__________________________

Household effects____________________________________

Money____

SAMPLE CARD C.

QUANTITATIVE SURVEY - ARNO ATOLL PROJECT - 1951

Household________________ Informant________________ Date____________

1. How much food was eaten here today?

   Morning:________________________________

   Noon:________________________________

   Evening:________________________________

2. How much of this food was prepared before today?________________

3. How much food was prepared here today, but was not eaten today?____________

4. Who helped to make the food today?________________________

5. Where did the food come from that was eaten or prepared today?____________

   ____

6. Who ate the food here today?________________________

   ____

7. How much food was sent to people elsewhere?________________

* * * * * * * * * * *

8. What work was done on houses or canoes today?________________

9. Who did the work?________________ When?________________

10. What materials were used?________________________

11. Where did the materials come from?________________________

   ____

* * * * * * * * * * *

12. How much money was earned by people here today?________________

13. How was the money earned?________________________

14. Who worked for the money?____________ Who received the money?____________

15. How much money was spent here today?_____ To whom was the money paid?________

16. For what was the money spent?________________________

   ________________ Who spent it?________________

* * * * * * * * * * *

17. How many coconuts were collected today for husking?________ Where?________

   Who did the work?________________________

(Sample Card C - Cont'd)

18. How many coconuts were husked today?__________ Who did the work?__________

19. How many coconuts were cut today?__________ Who did the work?__________

20. How many bags of dried copra were sacked today?_____ Who did the work?_______

21. How many bags of copra were sold today?________ To whom?__________

22. Who sold the copra?______________ How much money was received?__________

How was the money divided?______________________________

* * * * * * * * * * *

23. What new clothing do you have here today?______________________

24. What clothing was washed here today?______________________

25. What clothing was ironed here today?______________________

26. What clothing was mended here today?______________________

* * * * * * * * * * *

27. What handicraft was made here today?______________________

28. Where did the materials come from?______________________

29. Who did the work?____________ Who owns the finished products now?__________

30. Where is the handicraft now?______________________

* * * * * * * * * * *

31. How much water was used here today? For what purpose?

Cistern:______________________________
Well:______________________________
Lagoon:______________________________

* * * * * * * * * * *

32. What work was stopped today because of bad weather, or for other reasons?____

33. What other things did you do today besides work?______________________

34. Whom did you visit today?__________ Where?__________ When?__________

35. Did anyone from here leave today for another place: house, island, or atoll?_

How did he travel?______________ Where did he go?______________

How long will he be gone?____________ Where did he go?______________

36. Did anyone arrive today to stay here awhile?______________________

How did he travel?______________ Where did he come from?__________

When was he here the last time?__________ Why did he come?__________

INVESTIGATION OF MATERIAL CULTURE

by K. P. Emory

In the determination of what in the culture is due to the particular environment of the atoll being studied, and what due to the cultural influences brought to the island, historically, it will be necessary to record details of structure and technique in the material culture, native terms, and what the people themselves have to say about origins.

For content and terminology of material culture investigations on an atoll one should have at hand Dr. Buck's "Material Culture of Kapingamarangi", Bishop Museum bulletin 200, designed to set a pattern for such recordings. What has been known of canoes is summarized by Hornell, "Canoes of Oceania," Bishop Museum special publication 27, vol. 1, pp. 345-361. Time would be saved by having a copy of this and simply noting anything different, new or additional.

Of special importance to record step by step in every detail is the preparation of pandanus flour, pandanus preserve, breadfruit preserve, preparations of arrow-root, etc. A photograph record of these in color as well as in black and white would give us material comparable to that we now have from the Marshalls and from Kapingamarangi. Always inquire what the ancient methods were like, - if they differed from the present and how and why.

An effort should be made to collect shell or stone adzes, ancient fish hooks and ornaments that the people may have found. Adults and children could be encouraged to hunt for them during the stay of the expedition.

For the island of Onotoa, in the Gilberts, it would be interesting to know if they also made the coconut fibre armor and if any now living know the techniques. Also, do they know how the shark's teeth were bored to be lashed to weapons. Tamana, next atoll south, seems to be the island mentioned as the homeland of the Kapingamarangi people. If so, it was once inhabited by Polynesians. Is there trace of an early occupation of Onotoa by Polynesians?

Arthur Grimble's, "The Migration of a Pandanus People," Journal of the Polynesian Society, Memoirs no. 12 (1933-1934) is our main source for the Gilberts, revealing how little we know of them.

Chapter 10 - Miscellaneous

HINTS ON TROPICAL PHOTOGRAPHY

by C. J. Lathrop

Fear and uncertainty are the photographer's worst enemies when it comes to photography in the tropics. The photographer who comes from a temperate zone into the warm humid tropics finds his formulas and calculations, based upon temperate conditions, upset. Temperatures in the tropics are generally no hotter than summer in many places in the United States, and the other factor, humidity, may be just as high. New York when it is summer and in the "90's" can be just as humid and hot as most tropical localities in the Pacific, but, of course, not as continuously.

Selection of film (black and white)

If you plan to use a miniature or 35mm size film in your work be sure to select a film of the finest grain available. Either (Eastman) PANATOMIC X or (Ansco) FINOPAN are excellent. While it is true that these films are rated as slow films the results in enlargement will more than compensate for the loss of speed. I enlarge all my shots to 8"x10" and without exception they are better shots than 4"x5" shots on fast (100-125 speed) film. Insist on all film being tropical-packed. If your film is ordered or purchased in Honolulu it will be tropical-packed. (KODAK HAWAII LTD.) For cameras using ordinary roll films my selection would be (Eastman) VERICHROME.

Care of film and equipment in the field

Two conditions that are not favorable to films are heat and moisture. If your film is tropical-packed the problem of moisture, before the package is opened is not a factor for consideration. After the tropical package is opened and the film loaded in the camera the best thing to do is use it up as soon as possible. The film should not be returned directly to the tropical package. (In most cases the tropical package is a screw type metal can.) All film must be desiccated before it is resealed in the tropical can.

Desiccating is a simple process whereby the moisture that the film has picked up after leaving the tropical container is absorbed by a desiccating agent. Common dried rice may be used but silica gel is easier to handle and can be re-used again and again. A large friction top or screw top can or jar is used as the desiccating container. The dried silica gel is placed in the bottom of the container. The film should never come in contact with the silica gel. One should purchase a chamois skin bag for the film to be placed in while desiccating. An indicator should be put in the container. These indicators change color when the moisture content increases to a danger level. When the air is dry the indicator will be blue, as the moisture increases the color will change to a pink. As an easy way of remembering the color, Red means Danger. The indicator should be in the container at least 4 hours before a reading is taken, as the moisture in the air will turn the indicator pink before the silica gel has time to pick up the moisture. The film may be resealed in the tropical cans after being in the desiccating can for 48 hours (and the indicator is blue).

To reactivate the silica gel it must be heated in an oven at about 300° to 400° F for 30 minutes. Some times it is done by placing the silica gel in a metal can or container and securing the can over the gasoline lantern during the evening. After the light is turned out the silica gel is placed in a container with a screw or friction top. The top is not put in placed tightly, as, on cooling, the container would collapse with the contraction of the air within, forming a vacuum. WARNING: Do not put the plastic indicator plugs in the hot silica gel or in the oven as they melt at a low temperature.

In resealing the tropical film containers after desiccating I find the SCOTCH MASKING TAPE 3/4" that is used by auto painters to be excellent. Adhesive tape can be used but electrical tape (black) is not satisfactory.

Cameras should be fitted in cases and packed in moisture tight cans when not in use. The metal parts should be treated with wax. I find that transparent (clear) Esquire shoe polish is ideal for this use. I have experienced no film discoloration from fumes with this preparation. Some types have an objectionable compound that will spoil Kodachrome due to the volatile chemical content, even though used sparingly. Clean your lenses frequently with a lense brush or tissue. As a fungus inhibitor, a small wad of cotton is placed in a glass in the camera case or can and a small amount of formalin added. The formalin gas in many cases will keep your camera free from mold and fungus. This may be done several nights a week with the camera empty (no film).

For processing the film in the field I find that the early morning is the best time as the temperature is at its lowest point. Eastman Kodak has produced tropical developer, tropical hardener, and tropical fixer that give a fine grained, fog-free negative at temperatures up to 95°F.

HINTS ON LIVING ON A BOAT

by J. E. Randall, Jr.

Living on a small vessel, either when underway or while in port, presents problems quite new to the uninitiated. Some of these problems are concerned with the operation and maintenance of the vessel and will not be considered here. Others, however, are personal or individual in nature and arise largely from the closeness of the association of all persons on the vessel and the necessity for a strict, scheduled sort of an existence.

The following, in brief, are suggestions for the carrying out of a cruise on a small vessel. Some of these suggestions may not be pertinent if a large boat is utilized.

One, and only one, man should be chosen as captain of the vessel. He should be capable and experienced. He should be placed in a position of total responsibility for the operation of the vessel. He will make all important decisions which concern the vessel or its disposition at sea, and such decisions should not be disputed.

The stowing of gear before departure should receive very careful thought and planning. All items which could become detached when the boat is in motion should be lashed securely. Canned goods or any items which could be damaged by contact with salt water should be stowed in a place which is known to be dry or should be wrapped in waterproof or water repellent bags. It would be wise to place all extra clothing and bedding in such bags even when it does not seem likely that they will get wet. Also noteworthy of mention is the covering of mattresses with zippered plastic covers.

All items of equipment necessary to the handling of a vessel must be kept consistently in the same place. This is especially true of things like tools which will often be needed in a hurry and at some unexpected time. This point is sufficiently important to warrant explanation to all members of the crew at a time before the vessel has set sail.

When underway, a strict schedule should be enforced as to the duties which must be performed. The delegation of duties must be carried out before the vessel has left port. With the exception of the cook, every man should stand watch if capable. The duration of the time at the helm should be talked over and decided upon beforehand and provision should be made for a rotation in time so that one man will not have watch at the same period or periods every day.

Great care must be taken to see that vital jobs like the winding of chronometers, inspection of engines and other items of equipment are executed at the correct time each day. One man should be held responsible for each task of this nature throughout the voyage.

The greatest danger at sea is falling overboard. All steps should be taken to minimize such a hazard. An adequate railing should be erected all around the vessel. Life rings should be readily accessible and never lashed in such a manner as to delay their prompt procurement. Water lights should be available. These are waterproof lights which should be thrown overboard at night with the life ring. They contain a mercury switch and become lighted when floating vertically in the water. They serve the purpose of guiding a person to the life ring and, in turn, enable the vessel to locate the person who has fallen overboard.

It may be wise to trail a sturdy line astern which a person can try to grasp if he has fallen overboard. Such a procedure is vital if a person is standing watch alone. In heavy weather the helmsman should always fasten a short line from himself to the boat.

Fire hazard on a boat is a very real danger. This is accentuated if a gasoline engine is used or if gasoline is stored anywhere on the boat. Certain safety regulations concerning the location of tanks, etc. must be met by all boats with gasoline engines, but a hazard still exists. If gasoline is stored on the boat the fittings on the lines should be inspected every day. Such fittings have a way of coming loose from vibration and this results in a dripping of gasoline into the bilge. It is just this sort of thing which causes the disastrous explosions on power boats so often read about in news items. No gasoline-burning stoves or lanterns should ever be used on a boat. Other potential sources for a fire at sea often exist in butane, kerosene or alcohol stoves, kerosene lanterns, electrical wiring, and smoking. No one should attempt to light a stove or lantern without proper instructions. Electric wiring should be frequently inspected. Smoking should be eliminated. Since this is practically impossible to achieve, the best alternative is to designate a specific safe place on the boat for smoking.

Every vessel must be equipped with a specified number of fire extinguishers. These should be inspected before departure. CO_2 fire extinguishers are superior to the pyrene type, and at least one of these should be on board and very accessible. A very desirable type of fire extinguisher to have is a built in CO_2 system in the engine room which operates automatically when a certain high temperature is reached.

The restricted use of fresh-water by all members of the crew must be emphasized. Unless a very large supply is present, water should be utilized only for drinking, cooking, shaving, and limited washing purposes. It may be necessary to wash clothes and dishes in salt water. Ordinary soap under such conditions is useless. Salt water soap, in general, is not too good. A detergent such as Dreft seems to be the best agent for washing with salt water. An emergency water supply should be maintained in a tank separate from the regular water line. Inspection of water tanks for possible leaks should be made periodically.

The scourge of any cruise is seasickness. In a rough sea and in a small vessel very few persons are completely free of nauseous sensations. Each individual usually finds a set of conditions which best alleviates his distressing symptoms. Generally, if sickness has come on while below in a confining cabin, going on deck in fresh air is very helpful. A recent drug, dramamine, has proven to be amazingly effective in preventing seasickness. It must be taken before sickness ensues or it is not effective. If a person knows that he is very prone to sickness at sea he should take dramamine a half hour before departure, and continue dosage every six hours. The drug has a pronounced somnolent effect. For this reason, the dosage recommended by the physician may be experimentally lessened so that the minimum amount necessary to prevent sickness is obtained. Dramamine can be procured only by doctor's prescription; it is considered very dangerous to persons with low blood pressure.

Sleeping in a vessel which is underway is an art in itself, especially in rough weather. Most individuals will sleep only intermittently during their first few nights at sea, but gradually will adapt themselves to the unusual motion. Narrow bunks are often preferable and the sides of the bunks should be equipped with bunk boards or some similar arrangements to prevent the sleeping individual from falling out. The sides of the bunks should be well-padded with extra bedding.

A cruise at sea, especially if it is a long one and on a small vessel, presents an environment of close quarters and unpleasant living conditions which is usually quite unexpected to those who have not experienced it before. And the knowledge that there is no escape from this environment until the cruise is terminated may make these conditions even more difficult. It therefore behooves all members of the crew to make constant effort to be congenial, to do at least their share of the work, and to be as considerate as possible of their fellow crew members.

There are a few points worthy of mention regarding living on a vessel which is lying at anchor or tied to a dock. First, there are often very distracting noises which arise from movements of the vessel against fenders on a dock or alternate tightening and slackening of mooring or anchor lines. Many of these noises can be eliminated, and effort should be made to do so before turning in. A breast anchor can be taken out from the side of the vessel away from the dock and pulling in on this line will prevent contact with the dock. On anchor or mooring lines pieces of elastic cord or inner tube can be incorporated to reduce the sudden jarring effects which the boat transmits to the lines. This saves wear on lines as well as eliminating the noises which occur when the lines tighten on boat fittings.

Adequate ventilation presents another problem. Frequently one can create a current of air through the boat by erecting a funneling arrangement on the back side of hatches facing the wind. An elevated hatch cover may serve the purpose or a more elaborate affair may be constructed from a large piece of canvas.

Usually there is no provision for preventing the entrance of flies, mosquitoes, or other insects into a boat. Pieces of mosquito netting over hatches and the cutting of round pieces of screen wire to fit into port holes will help materially. Aerosol bombs should be on hand as well, however.

Since space on a boat is so limited, cooking or bathroom odors are generally a source of annoyance. Airwick is a big help.

While in port and in hot weather, decks tend to leak due to the drying out and consequent opening up of deck seams. The best preventative is the wetting of decks at least once a day. Salt water should be used for this, for constant wetting with fresh-water promotes dry rot in a vessel.

HINTS ON LIVING UNDER RESTRICTED CAMP CONDITIONS

C. K. Wentworth

Small groups of people living in remote places with limited supplies, communication and transport often become acutely aware of differences in tastes and habits between individuals. While possibly confronted by less potential danger than a party in a small boat, a small land party has nearly equal need for a single leader who must make final decisions on camp disposition and major procedures. The writer has been as guilty as any in failing to recognize those of his own habits that were or might have been noisome or distracting to others. The text below is an attempt to suggest possible varieties of offense. Each must, of course, be weighed in the balance between its importance to the individual or the work of the expedition and its possible discomfort to other members.

The camp menu must depend on wise planning, successful transport, preservation, and preparation, often under difficult conditions. At the best it will be a kind of average in taste with little support for individual whim. If you have a small whim and will balance the needed transport and care against some small personal sacrifice in another direction, by all means make your own provision. But don't expect to pilfer the group supply to satisfy your own improvidence. If you have a large whim that involves transport don't go on such a trip. Individual tastes must in some degree be met by rotation, both in the menu and perhaps in the preparation itself. If you can't give and take in eating what other people adore, or what the existing larder provides, at least keep quiet about it. The camp leader may have to ration certain supplies and may have to invade private supplies of drugs and similar articles in emergency. Persons requiring special drugs should make adequate provision. It may not be superfluous to enjoin orderly, perhaps assigned or rotated care for wood and water supply, stoves, and lamps, outside the obvious need for such handling of cooking and k.p. duties.

A good bit of fussiness is needed in care and placing of both personal effects and group articles, flashlights, matches, perhaps firearms and the rest of the gear that may have been brought along. Some people are more gifted at this than others; the less gifted should at least help up to the point where the more zealous fusser is clearly a nuisance.

Differences in taste for ventilation and other sleeping conditions may be met by little choice, but a bit of negotiation can be a wise medium between suffering in an explosive mood and exploding in an endless tirade. People who snore may not be able to do much about it, but should be willing to accept the serious testimony of their fellows and accept such segregation as conditions permit.

Personal laundering, caring for specimens, dressing and preserving of organic materials, can be slightly or quite obnoxious to others of the party. While continuing necessary operations, try to be aware of such possibility and make any adjustment that is feasible. The practices of your craft, even those approved in this manual, may _ad nauseam_ seem silly to someone in another craft; a great deal of fine interchange can take place but try not to let the operations get rubbed in on the other fellow because of your own enthusiastic inattention.

Turn about with him as much as possible in operations that are within your own capacity, when you are in camp and he is not, and the like. On the other hand it must be borne in mind that these activities even if disagreeable, are the work of the expedition and the reason for it, and that tolerance of them may augment the success of the enterprise.

Some of us talk too much, at times, others in compensation are reticent to the point of impeding group success. Neither extreme is best. The heavy talkers can be very boring, I have many times been told! But the quiet person owes it to his fellows to leave adequate daily word which way he went and about how long he might be gone; in such situations it is of concern perhaps for his own safety. Also some sharing of knowledge of home addresses and location of valuable or emergency articles in equipment is an obligation in the group interest. Some things can be needed in a hurry, with or without categorical permission.

Recreation has its place even on a hard-working expedition, but should yield priority to work around the available light, and to sleep. Noisy game playing can be an unwarranted intrusion at times. Singing and whistling may be among the N freedoms but in long doses may also be far less inspiring to the hearers than to the producers. A balance may have to be struck between cheer leaders and joy killers.