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MID-PACIFIC MARINE LABORATORY

Annual Report
for the Period
1 July 1976-30 September 1977

Ernst S. Reese
Victor R. Johnson, Jr.
February, 1979

Work Performed Under Contract
EY-76-C-08-0703

University of Hawaii
Office of Research Administration
Honolulu, Hawaii 96822

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224

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Prepared for the

U. S. Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, Nevada 89114
Under Contract EY-76-C-08-0703

ANNUAL REPORT FOR FISCAL YEAR 1977

INTRODUCTION

This report covers a 15-month period because the end of the federal fiscal year was moved from June 30 to September 30 in 1977. The period from July 1, 1976 to September 30, 1976, is designated as fiscal year 1976T, and the period October 1, 1976 to September 30, 1977, is designated as fiscal year 1977. For the sake of convenience, this 15-month period is treated as one in this report and is designated as fiscal year 1977.

During this period, three persons directed the operations of the laboratory. Dr. Stephen V. Smith, July-December, 1976; Dr. Philip Helfrich, January-May, 1977; and Dr. Ernst S. Reese, June-September 1977. All three are University of Hawaii faculty members, so it was possible to maintain continuity in the direction of the laboratory. No policy changes were initiated during this transitional period and the day to day research activities of the laboratory continued without interruption.

The tables and individual research reports contained in this annual report summarizes the research activities of the laboratory during the 15-month period.

The research supported by the laboratory represents the selection by the Proposal Review Committee from all the research proposals which were received. Announcements of the kinds of research the laboratory would like to support, as outlined in the laboratory's proposal to the Department of Energy, were published in the Atoll Research Bulletin and the Coral Reef Newsletter. As in the past, we continue to receive many more proposals from biologists than from geologists, chemists or oceanographers, and consequently proposals in these areas are given preferential treatment whenever possible.

Although statistics do not tell the whole story, they are nevertheless informative. During fiscal year 1977, 23 research projects were undertaken at Enewetak involving 73 scientists from 19 universities or laboratories, and amounting to approximately 324 person-weeks of scientific effort. The number of scientists involved in a project ranged from 1 to 15, and the duration of projects ranged from 1 to 8 weeks.

In considering the research effort, it should be realized that since the laboratory does not pay the salaries of any of the scientists, the input of dollars into the laboratory in the sense of salaries paid by home institutions represents a very handsome return in matching funds on the operating funds supplied by the Department of Energy.

The Marshall Island Workshop was held at the Lawrence Livermore Laboratory on June 27-29, 1977. During the workshop many suggestions were made concerning the important role MPML would play during Operation Clean-up which was just being initiated by the Defense Nuclear Agency. These suggestions were incorporated in the proposal submitted to the Department of Energy for the operation of the laboratory during the next fiscal year, and many were implemented immediately. The laboratory advised the Joint Task Group Commander on matters such as dangerous and poisonous marine animals, the ecology of atoll environments, the preparation of tide charts, and other matters in which the laboratory has expertise. As a result, MPML developed an excellent working relationship with the Defense Nuclear Agency.

An audio-tape slide show was prepared in order to acquaint diverse groups of governmental officials with the historical background, purpose, current research and future plans for the laboratory. This show has proved to be most effective.

Perhaps the highlight of the fiscal year was the Reef Coral Taxonomy Workshop held at Enewetak, 23 November to 15 December 1976. An international group of 16 coral taxonomists participated. The results of the workshop are being prepared for publication under the editorship of Dr. Judy Lang of the University of Texas.

It is important to note that the research thrust of the laboratory did not change as much as had been planned and hoped for simply because proposals in geology, geochemistry and oceanography were not submitted in spite of efforts to solicit proposals in these areas via announcements. It is one thing to state an intention to initiate a research emphasis in a particular area, but it is another matter to follow through with implementation. The same point must be made with respect to stated policy changes with respect to favoring larger research programs over smaller proposals. These comments are offered as explanations rather than as excuses. Since the laboratory does not pay research salaries, it cannot initiate research itself.

RESEARCH PROJECTS DURING FISCAL YEAR 1977

Research Subject	Number of			
	Pro- jects	Trips	Scien- tists	Person- Weeks
<u>BEHAVIOR</u>				
Reef fishes: sociobiology reproduction, movements	2	3	4	24
Sharks: food habits, home range, ultra-sonic telemetry	1	1	4	32
<u>ECOLOGY</u>				
Corals: growth, reproduction survival	1	2	2	10
Crustacea: population structure	1	2	2	10
Echinoderms: growth, mortality	1	2	1	3
Mice: population demography	1	1	1	2
Mollusca: growth, mortality	1	3	1	5
Rats: population demography, dosimetry	1	1	3	6
Vegetation: succession	1	1	2	6
<u>GEOCHEMISTRY</u>				
Hydrogeochemistry: groundwater	1	3	15	90
Bioerosion	1	2	2	12
<u>OCEANOGRAPHY</u>				
Lagoon circulation	1	1	2	2
Zooplankton: abundance	1	1	2	6
<u>PHYSIOLOGY</u>				
Corals: nervous system	1	1	2	10
Corals: nitrogen uptake	1	1	1	3
Coelenterates: chemical symbiosis	1	1	3	15

Research Subject	Number of			
	Pro- jects	Trips	Scien- tists	Person- weeks
Sharks: hearing and electroreception	1	1	3	15
Sharks: radioisotope uptake	1	1	2	10
Various organisms: nitrogen uptake and release	1	1	2	6
Various organisms: natural products, especially toxins	1	1	3	9
<u>SYSTEMATICS</u>				
Corals: taxonomy workshop	1	1	16	48
TOTALS:	23	31	73	324

(FY 76T) (FY 77)
 (1 July 76-30 Sept. 77)
 (Chronological)

Dates	Investigators	Project
22 June-11 Aug. (1976)	Corwin, Jeffrey, T. Reetz, Wayne P.	1) Hearing in sharks 2) Radioisotope intake histories of sharks
6 July-11 Aug. (1976)	Bullock, T. H. Corwin, Jeffrey T. Reetz, Wayne P. Ebbeson, Sven Lopez, Maria D.	1) The acousticolateralis system in sharks: hearing and electroperception 2) Nervous systems of corals
27 July-18 Aug. (1976)	Marian, Ronald E.	Uptake assimilation, and fate of inorganic nitrogen in <i>Pocillopora</i>
27 July-11 Aug. (1976)	Stimson, John Polacheck, Tom	Reproduction, growth and survival of Enewetak corals
23 Aug.-7 Sept. (1977)		
29 July-13 Aug. (1976)	Buddemeier, Robert Buddemeier, Dorothy	Hydrogeochemistry of Enewetak Atoll
6-28 January (1977)	Coleman, J. H. Dahlstrom, P.	
8-16 June (1977)	Goff, S. K. Groves, G. N. Handschumacher, D. Hart, Allen Jansen, Christopher Keeling, David L. Keeling, Diana L. Matson, Neil McConachie, William Meyers, R. Souza, W. R.	
3-11 August (1976)	Smith, Stephen V. Marsh, James	Lagoon circulation study
17 Aug.-1 Sept. (1976)	Reese, Ernst. S. Boucher, Lisa	1) Behavioral ecology of coral reef fishes
11-26 January (1977)	McDonald, Craig Motta, Phil	2) Population ecology and behavior of coconut crabs
9-24 August (1977)		

Dates	Investigators	Project
14 Sept.-6 Oct. (1976) 6-28 Sept. (1977)	Highsmith, Ray Riggs, Alan	A study of the agents and dynamics of coral bioerosion
21 Sept.-6 Oct. (1976)	Zedler, Paul Louda, Svata	Role of succession in the terrestrial vegetation of an atoll
21 Sept.-6 Oct. (1976)	D'Elia, Christopher Webb, Kenneth L.	The uptake and release of dissolved nitrogen by reef organisms
21-29 September (1976) 13-27 September (1977)	Ebert, Thomas A.	1) Population studies of echinoderms 2) Growth and mortality of sea cucumbers
22-29 September (1976) 15 Feb.-2 Mar. (1977) 13-28 September (1977)	Turk, Ted R.	Patterns in growth and mortality of marine snails
22 Sept.-13 Oct. (1976) 19 July-3 Aug. (1977)	Wenner, Adrian M. Fusaro, Craig Page, Henry M.	An analysis of population structure in Pacific mole crabs
28 Sept.-20 Oct. (1976)	Scheuer, Paul J. Fürstenwerth, Hauke Yunker, Mark	Toxins and biomedical agents of marine organisms
12 Oct.-15 Dec. (1976)	Nelson, Donald R. McKibbin, James N. Tricas, Timothy C. Cooksey, Donna J.	Home range and food habits of Pacific reef sharks (primarily the gray reef shark, <i>Carcharhinus amblyrhynchos</i>)
23 Nov.-15 Dec. (1976)	Lang, Judith Devaney, Dennis Faure, Gerald Jokiel, Paul Kinzie, Robert Lambert, Austin Lang, Lynton Maragos, James Pichon, Michael Randall, Richard Rosen, Brion Stimson, John Vernon, John Wallace, Carden Wells, John Wijsmanbest, M.	A reef coral taxonomy workshop at the Mid-Pacific Marine Laboratory, Enewetak Atoll

Dates	Investigators	Project
11 Mar.-1 Apr. (1977)	Jackson, William B. Vessey, Stephen H.	Ecology of island rat population
15-29 March (1977)	Berry, R. J.	House mice on Enewetak Atoll
12 July-17 Aug. (1977)	Wittle, Karen S. Wittle, L. W.	Chemical relationships between sea anemones and their symbiotic fishes
30 Aug.-21 Sept. (1977)	Alldredge, Alice L. King, James M.	Relative abundance of resident versus oceanic zooplankton over an interisland reef

- Project: Relative abundance of resident versus oceanic zooplankton over an interisland reef
- Investigators: Alice L. Alldredge
James M. King
Biological Sciences Department
University of California
Santa Barbara, California 93106
- Objectives:
1. To determine the relative importance of oceanic vs. demersal zooplankton as a source of organic matter and energy to the reef community.
 2. To determine distribution, density and substrate preferences of demersal zooplankton on an inter-island reef.
 3. To investigate differences in the abundance and types of plankton emerging from under different species of corals.

Zooplankton occurring over coral reefs fall into two major categories; (1) drifting zooplankton originating in oceanic waters, and (2) zooplankton resident to the reef itself. Resident zooplankton include select species of polychaetes, mysids, amphipods, isopods, decapod larvae, shrimp, copepods and other crustaceans not found in oceanic waters surrounding the reef. Many of these resident plankton are demersal (bottom dwelling) forms which hide in bottom sediments or within the framework of the reef during the day but emerge to swim freely in the water column above the reef at night. Little is known about the biology of demersal plankton and previous studies demonstrating net accretion of zooplankton to the reef from oceanic waters have failed to differentiate between oceanic and resident zooplankton.

Twelve, cone-shaped bottom traps (modified from Alldredge, A. L. and J. M. King 1977. *Marine Biology* 41:317-333) were placed on living coral, rubble, sand and reef rock at four locations on the Biotrans transect (Johannes, R. E. *et al.*, 1972. *BioScience* 22:541-543) at Japtan reef. These traps were set on the substrate in the late afternoon and retrieved the following morning. Six to eight replicates of each substrate type were obtained at each location. Emergence traps collected the plankton emerging from $\frac{1}{4}$ m² of substrate. A 30 cm plankton net with flow meter was simultaneously moored near the traps to collect drifting plankton swept across the reef by the strong, unidirectional tidal current. Current speeds and the percent cover of coral, rubble, rock and sand at each location was also determined.

Preliminary Results

The following densities (number emerging / m²) of demersal plankton were found at each location sampled on the Biotrans transect:

Table 1

Taxon	Biotrans tower 1 (up- current)	Biotrans tower 2 (down- current)	100 M down- current from Bio- trans 2	Sand/shingle downcurrent from Bio- trans 2
Copepods	192.0	198.0	186.0	2295.0
Mysids	3.5	8.3	5.5	3.2
Amphipods	10.3	11.7	15.4	12.3
Isopods	9.4	5.5	4.3	21.9
Decapod larvae	76.3	72.0	96.2	151.4
Polychaetes	41.9	59.6	27.1	26.3
Miscellaneous	55.7	42.7	35.0	115.2
Total plankton	389.1	397.8	369.5	2736.0

Our results indicate that demersal plankton are abundant on the Japtan reef flat. This is surprising considering the strong tidal current which flows almost continuously. Behavioral mechanisms may be exhibited by many of the plankters, including swimming near the substrate or in the lees of coral heads, which enable them to be kept from being swept off the reef. Demersal plankton may provide an important food source for nocturnally foraging fishes. The relative contribution to the energy budget of the reef remains to be determined.

- Project: House mice on Enewetak Atoll
- Investigator: R. J. Berry
Royal Free Hospital
School of Medicine
London W. C. 1, England
- Objectives: 1. To trap house mice on various Enewetak Atoll islands.
2. To draw some preliminary conclusions on their relative abundance and population ecology.

Pacific island house mice (*Mus musculus*) occurs on at least three islands of Enewetak Atoll, Japtan, Medren and Enewetak. Since the Marshallese do not distinguish mice from rats (except by size), there is no specific information about the length of time that mice have been present. Several thousand mice were brought to Enewetak and exposed to radiation during the atom test period, then flown to Oak Ridge Natural Laboratory for study (Upton *et al.*, 1960). It is possible that some of these escaped, and founded or contributed to the present populations.

The study reported here involved trapping with Longworth traps for 14 nights (8 on Enewetak, 1 on Japtan, and 5 on Medren). A total of 124 animals were caught on Enewetak (25.0% trap success), 80 on Medren (23.0% success), and none on Japtan. Although a few roof rats were caught on Enewetak and Medren, they did not appear to affect the trapability of the mice. In contrast, over 30 Polynesian rats were caught in the single nights trapping on Japtan, and there was obviously no prospect of collecting a reasonable mouse sample there.

Both Enewetak and Medren harbored substantial mouse populations, particularly in open land with weeds. Most animals on Enewetak were caught on the grassland near the runway of the Aerodrome, and in similar habitats on Medren along the main "road" running parallel to the lagoon. The Medren population appeared denser, judging by the different sex ratio of the samples from the two islands. On Medren equal numbers of males and females were caught, whereas on Enewetak the ratio was 1.84 males to every female. The pattern of trapping on Enewetak and Medren was effectively the same.

The most obvious characteristic of mice from both islands is their small size, smaller than that of the Ponape population, and less than half the size of mice from temperate latitudes (Table 1). The small size of the Enewetak mice is probably an adaptation to constant high temperature. Whether the size response is genetic or phenotypic must remain unknown until some atoll mice are taken and bred in a temperate climate. The haematological characteristics of the atoll mice are similar to those from colder areas (*cf.* Maclean and Lee, 1973) (Table 2).

Besides being small in overall dimensions, the atoll mice have relatively smaller organs (Table 3). It is not surprising that they have a small heart or small amount of brown fat, because both these organs are involved in maintaining body temperature. The size of the spleen is (crudely) a measure of physiological stress. Clearly the Medren population (particularly) is a relaxed one. The significance of the relatively small kidneys is unclear, although kidney size is important in adaptation and survival in wild-living mice generally (Berry and Jakobson, 1975).

There is no doubt that the Medren and Enewetak populations are genetically different. The Enewetak animals all had dark bellies, whereas belly color in the Medren population varied considerably from dark to almost pure white. It is difficult to quantify this almost continuously distributed color variation. Organs were collected for allozyme characterization, which will enable a quantitative genetical comparison to be made of the two populations, and of them both with populations from elsewhere.

Only 5 of the 81 females collected in March 1977 were pregnant. This fact, together with data collected by W. B. Jackson and his collaborators on numerous visits to study the atoll rats and by R. D. Kirkpatrick in March 1969, should enable a reconstruction of the reproductive characteristics of the atoll mice.

Table 1. Body measurements of mature house mice

	♂♂					♀♀					Latitude
	N	Head + body (mm)	Tail (mm)	Hindfoot (mm)	Weight (g)	N	Head + body (mm)	Tail (mm)	Hindfoot (mm)	Weight (g)	
Enewetak	79	76.6	68.2	15.5	9.5	43	75.2	66.5	15.1	8.9	11°N
Medren	38	74.6	67.4	15.7	8.9	38	72.7	66.5	15.4	8.5	11°N
Paauiilo, Hawaii	61	81.6	73.6	17.0	11.9	46	79.9	71.8	16.8	11.4	20°N
Ponape	216	74.7	79.2	-	11.9	(♂♂ + ♀♀ combined for measurements)				12.9	7°N
Malaya	1589 (♂ + ♀)	-	-	-	9.9	-	-	-	-	10.4	3°N
Reigate, England	20	79.0	77.6	17.7	15.6	20	77.6	77.5	17.8	15.2	51°N
Skokholm Is., Whales	69	89.6	84.8	17.2	20.8	59	91.6	85.1	17.3	21.3	52°N
Foula, Shetland Is.	24	97.1	81.2	18.3	23.9	31	98.3	83.7	18.1	26.3	60°N
Macquarie Is., (Sub-Antarctic)	52	89.7	73.5	17.0	15.8	26	(♂♂ + ♀♀ combined)				54°S
Marion Is., (Sub-Antarctic)	49	78.1	79.1	17.7	21.4	43	78.7	78.4	17.8	20.6	47°S

Data from Marshall, 1962; Berry and Tricker, 1969; and unpublished

Table 2. Haematological values in house mice

		Haemoglobin (g/100 ml blood)	Haematocrit (%)
Enewetak	♂♂	18.1	52.7
	♀♀	16.8	49.7
Medren	♂♂	17.2	48.6
	♀♀	16.0	45.7
Paauilo, Hawaii	♂♂	16.4	53.8
	♀♀	16.6	53.5
Marion Is.		18.1	49.5
Berry, Shetland Is.		14.9	48.7
Skokholm		17.1	47.3
Taunton, England		17.3	50.6
Keysborough, Victoria, Australia:			
trapped in winter		17.7	50.0
trapped in summer		16.5	46.4
trapped in summer and kept at 5°C for 32 days		17.3	49.4
Range in 18 inbred mouse strains (Jackson Lab., Bar Harbor)		12.1-15.0	39.5-50.6

Data from Russell, Neufeld and Higgins, 1951; Maclean and Lee, 1973;
Berry and Jakobson, 1975

Table 3. Relative organ weights in wild-caught house mice (mg/g)

	Heart	Left kidney	Spleen	Adrenals	Brown fat
Enewetak					
♂♂	6.40±1.03	6.65±1.03	1.58±0.78	0.38±0.27	2.19±0.77
♀♀	6.49±1.05	6.21±0.83	2.03±1.23	0.49±0.27	2.13±0.86
Medren					
♂♂	5.38±0.52	5.76±0.48	1.08±0.36	0.26±0.08	1.61±0.52
♀♀	5.60±0.85	5.58±0.83	1.16±0.46	0.30±0.11	1.79±0.61
Paauilo, Hawaii					
♂♂	7.59±0.89	7.73±1.21	2.88±1.28	0.55±0.17	4.33±2.00
♀♀	7.69±1.25	6.90±0.91	2.67±0.82	0.62±0.16	4.57±2.01
Marion Is.	9.23	9.29	2.78	0.46	4.46
Macquarie Is.	-	8.99	-	0.55	6.14
Sand, Faroe	6.53	6.82	1.99	0.38	3.82
Berry, Shetland	7.02	6.34	4.01	0.36	5.17
Skokholm	7.49	7.12	4.77	0.32	2.61
Taunton, England	7.20	6.35	1.89	0.39	4.90

Data from Berry, Peters and van Aarde, 1977

Project: Hydrogeochemistry of Enewetak Atoll

Investigator: Robert W. Buddemeier
Department of Oceanography
University of Hawaii
Honolulu, Hawaii 96822

Objective: The overall purpose of the study is an understanding of radionuclide distributions in and the dynamics of their movements through the soil-vegetation-groundwater-lagoon system.

During the past year of this continuing study most of the measurements of tidal response characteristics of the groundwater wells on Enjebi, Runit, Japtan and Medren have been completed. Characterization of the quantity and quality of the groundwater has been extended by *in situ* probing and by laboratory analysis. Rainfall data collection has been continued. Tritium studies of the groundwater have been expanded and a model of the hydrologic system and the groundwater geochemistry is being developed.

Project: The acousticolateralis system in sharks: hearing and electroreception and nervous systems of corals

Investigators: Theodore H. Bullock
 Jeffrey T. Corwin
 Wayne P. Reetz
 Department of Neurosciences
 University of California, San Diego
 La Jolla, California 92093

Sven Ebbeson
 Maria D. Lopez
 Medical Sciences Campus
 University of Puerto Rico
 San Juan, Puerto Rico 00936

- Objectives:
1. To determine if the macula neglecta permit sharks to hear and localize far field sound.
 2. To determine what brain structures receive auditory, vestibular, electroreceptive and lateral line canal organ inputs, whether these structures are different in more advanced and less advanced sharks.
 3. To determine the tuning, filtering, and dynamic properties of the brain structures receiving electroreceptive inputs.
 4. To determine how the colonial nervous system coordinate parts of coral colonies of several species.

A preparation was developed elastically suspending an intact, briefly anesthetized small shark in water, by means of fish hooks and rubber bands, so that it could be stimulated acoustically without the chance for tactile stimulation. Electrodes were also developed that could be inserted through the skin and cartilage to various depths in the brain to record the "evoked potential" following acoustic, photic, electric and tactile stimuli. Black-tip reef sharks and Lemon sharks were the two species studied.

Such responses were studied in hind brain, midbrain and forebrain for acoustic and for electric and photic stimuli. The material including preserved brains, permits localizing the areas of special responsiveness. These are limited parts of the brain and overlap but are distinct in "hot spot" for the three modalities. It also permits statements about the differences in form of response, latency, successive peaks, dynamics with repetition and best stimulus. Tentatively it appears that acoustic stimuli above 100 and below 300 Hz are the most effective in this species and size of shark. Preliminary results bear on the questions of the sound window into the head and the sound-sensitive macula in the ear.

Results confirm the role of the parietal fossa as an acoustic window into the head and tentatively indicate that the inner ear and specifically the macula neglecta are the main sites of acoustic sensitivity in these sharks.

On the coral project we obtained many rolls of cine film of responses of the same colonies of *Palythoa* to controlled electric stimuli of different frequencies. This will permit supplementing our previous material with statements about the degree of consistency of response and the fine details of pattern spread.

- Project: Hearing in sharks and radioisotope intake histories of sharks
- Investigators: Jeffrey T. Corwin
Wayne P. Reetz
Department of Neurosciences
University of California, San Diego
La Jolla, California 92093
- Objectives:
1. Microautoradiographic determination of the rate of sensory cell generation in the ears of blacktip reef sharks.
 2. Determination of the relation between sensory cell age and recently described variations in ultrastructure.
 3. Determination of brain centers receiving input from the macula neglecta.
 4. Analysis of radionuclide activity in the skeletons of sharks with restricted home ranges.
 5. Description of anatomical features of the tiger shark ear and their relation to directional hearing ability.

Juvenile blacktip reef sharks were intravenously injected with a tritiated precursor to DNA and allowed to survive for 1 to 14 days before sacrifice and tissue fixation. The macula neglecta was dissected from one ear of each specimen and microscopically autoradiographed. Preliminary evidence of sensory cell production in the post-embryonic ear has been confirmed. The zone of sensory cell proliferation and the type of cell that gives rise to the new sensory cells have been tentatively identified.

Ears from other blacktip reef sharks collected during this trip were examined with the scanning electron microscope at Scripps. They have provided the information needed for correlation of the autoradiographic results with the results of scanning electron microscopy conducted on dogfish sharks. The combination of those results provide the first firm evidence that a slow turnover of sensory cells in the inner ear can occur throughout an animal's life.

Other ears have been processed through the Bodian method for selective visualization of intraepithelial nerve terminals. This technique demonstrated that the newly produced sensory cells are associated with nerve terminals very soon after their production.

Ears from a tiger shark, *Galeocerdo cuvieri*, a manta ray, *Manta alfredi*; and a Pacific nurse shark, *Ginglymostoma ferrugineum*, were also collected and will be described through scanning electron microscopy.

A portion of the vertebral column was dissected from the large tiger shark and preserved. Samples of the calcified vertebral centra have been analysed for indications of the animal's age and possible radionuclide content. However, the results of autoradiography, gas flow counting, and other analysis methods employed thus far, provide an ambiguous picture.

Project: The uptake and release of dissolved nitrogen by reef organisms

Investigators: Christopher F. D'Elia
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Kenneth L. Webb
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

- Objectives:
1. To determine the rates and direction of hermatypic coral dissolved N fluxes.
 2. To complete work started at Enewetak concerning the importance of *Holothuria atra* in N and P regeneration on the reef flat.

Studies conducted at Enewetak in September, 1976, were initiated on the Symbios Expedition of the R/V Alpha Helix in 1971. These studies were concerned with the quantification of N and P fluxes of reef organisms. It is hoped the results can be incorporated into a computer simulation of the nutrient dynamics of the entire reef.

Short (less than 5 hours) chamber incubations on freshly collected reef flat holothurians were used to determine the relationship between size and nitrogen and phosphorus excretion rates. Generally, body size (W)-metabolic rate (M) relationships can be expressed according to the expression

$$M = KW^b$$

where K and b are constants. Values of b less than 1.0 are typical and signify a decrease in weight-specific body metabolic rate with increasing body size. For oxygen consumption, the value of b is normally approximately 0.75. Table 1 shows the values of K and b calculated collectively for the holothurians *Holothuria atra*, *H. difficilis* and *Actinopyga mauritiana*. While weight-specific release rates for phosphate and total phosphorus fall within the normally expected range, it is somewhat surprising that for ammonia and total nitrogen it is approximately unity. Thus, larger animals regenerate or produce more nitrogen per unit of oxygen consumed or phosphorus produced than smaller animals. When weight-specific metabolic rates calculated are applied to population census data obtained in 1971, it is found that ammonia release by the *H. atra* populations on Symbios transect II (Webb *et al.*, 1975; *Limnol. Oceanog.* 20:198-210) would account for approximately 9% of the net dissolved NH_4^+ -N export. This suggests a significant role for *H. atra* in N regeneration on the reef flat.

Table 1. Constants for use in the expression $M = KW^b$. M will be in ng-atoms N or P · g fresh weight⁻¹·h⁻¹.

	b	K	r (correlation coefficient)	n	Range of weights (w)
NH ₃	1.01	68.1	0.98	30	1.3-970g
Total N	0.94	125.0	0.99	3	40-970g
PO ₄	0.657	3.83	0.71	12	12-125g
Total P	0.810	5.02	0.81	18	12-970g

The role of algal symbionts in coral nutrition has been a subject of controversy. Recently, it has become clear that symbiotic corals remove net amounts of dissolved inorganic N and P from solution even at typically low environmental concentrations. It is difficult to assess the importance of this N and P uptake as organic N and P fluxes of these organisms are not well quantified. Chamber incubations were used to measure fluxes of dissolved total nitrogen, ammonium and nitrate. No significant loss of organic N (as determined by difference between dissolved total nitrogen and inorganic nitrogen flux) by *Pocillopora elegans* was detected, but additional data will be required to confirm this (as the statistical confidence in our total nitrogen flux measurements was poor). The mathematical expression of uptake and kinetic constants obtained for NH₄⁺ uptake by *Pocillopora* spp. were consistent with values determined by Muscatine and D'Elia (ms. submitted) and will not be discussed here. NO₃⁻ uptake by intact coral heads was confirmed. It was independent of light. Corallum with tissue freshly removed did not exhibit such activity; thus, the permease responsible for uptake is present either in the zooxanthellae or coral tissue. Kinetic constants we determined for NO₃⁻ uptake for *Pocillopora elegans* are shown in Table 2. It appears that uptake of dissolved inorganic nitrogen by corals may be important in supplying these organisms with required N.

Table 2

	$\mu\text{moles N} \cdot \text{g atom N}^{-1} \cdot \text{min}^{-1}$	V_{max}^* $\mu\text{moles N} \cdot \text{g chlorophyll}^{-1} \cdot \text{min}^{-1}$
	0.976	7.25
	0.164	6.27
	0.806	3.54
$\bar{X} = 0.649$	5.69	29.9
SE = 0.247	1.11	7.12

* Constants used in the "Michaelis-Menten" expression, $V = V_{\text{max}} (S/K + S)$, where V = uptake rate, V_{max} = maximum uptake rate, S = substrate concentration, and K = half-saturation constant, i.e., that substrate concentration at which uptake is one-half maximum.

- Project: Population studies of echinoderms and growth and mortality of sea cucumbers
- Investigator: Thomas A. Ebert
Department of Biology
San Diego State University
San Diego, California 92182
- Objectives:
1. To collect sea cucumbers which had been tagged in September 1975.
 2. To determine growth rates of plates of the calcareous ring.
 3. To use these calculated growth parameters and a length-frequency distribution to estimate mortality and population turnover.
 4. To gain understanding of the movement of materials through the atoll ecosystem.

Five thousand thirty-one *Holothuria atra* were tagged with tetracycline in September 1975 and returned to a gutter on the seaward side of Ananij (Bruce) Island. In September 1976, 184 were collected, weighed, measured and dissected to remove the calcareous ring. The ring was treated with 5% sodium hypochlorite solution to remove organic material, washed and dried and then examined with ultra-violet light under a dissecting microscope. Only 18 individuals showed clear growth lines although it is believed that all of the individuals dissected had been tagged. Sea cucumbers were very highly concentrated in the areas where they had been released in 1975 but densities were very low in surrounding areas. The recovery of only 10% with a clear mark is believed due to only 10% of the population actually growing at the time of tagging rather than due to mixing of tagged and untagged individuals. It is, of course, impossible to support this contention with the data which were gathered.

In plates of the calcareous ring, length of the glowing image (S_t) was measured as well as length of the extant plate (S_{t+1}) using an ocular micrometer. A regression of S_{t+1} vs. S_t was used to estimate growth parameters of the Brody-Bertalanffy growth equation.

$$K = -\ln (\text{slope})$$

$$S_{\infty} = Y\text{-intercept}/(1\text{-slope})$$

For the plates of the calcareous ring:

$$\bar{K} = 0.106$$

$$S_{\infty} = 8.910 \text{ mm}$$

So: Plate length (mm) = $8.910 (1 - e^{-0.106t})$ with t in units of years

A zero-intercept regression line was estimated from the relationship between total animal length and plate length:

Total length (cm) = $3.66P$ where P is plate length in mm

A length frequency distribution was determined for 610 individuals and the cumulative-% curve compared with the distribution obtained in 1975 using the Kolmogorov-Smirnov test. Maximum difference between the two distributions was 4.9% at the interval 11-12 cm. Significant difference with $\alpha = 0.2$ is 5.5% ($n_1 = 1015$; $n_2 = 610$) so H_0 is not rejected and it is concluded that the size distribution had not changed in one year.

Using the average individual size ($\bar{S}$), K , S_∞ , and minimum size (S_R), it is possible to obtain a preliminary estimate of instantaneous mortality using the equation developed by Beverton and Holt:

$$Z = K(S_\infty - \bar{S}) / (\bar{S} - S_R)$$

$$Z = 0.106(32.653 - 13.995) / (13.995 - 5.5)$$

$$Z = 0.23$$

Mean length of life is also the average length of time it takes the population to replace itself and is equal to $1/Z$ so mean length of life is 4.3 years. Because a constant mortality rate is assumed, 5% of a cohort would still be alive at 13 years.

There is good reason to believe that these are underestimates:

a. The estimate of S_∞ is probably too high because only animals which actually were growing when tagged were included in the analysis. If an animal did not grow at all during the year it would not be included. Consequently there is a bias towards estimating a large S_∞ .

b. *H. atra* appears to be capable of asexual reproduction by transverse fission. This has been reported in the literature and short individuals with large plates in the calcareous ring (the front end of a divided animal?) were found. Two short individuals were also collected which lacked both a ring and tentacles (the posterior part of a divided animal?). Loss of some large individuals would be not by death but by moving from a large size class to two individuals in a small size class by transverse fission.

Accordingly, the estimate of turnover should be taken as a minimum time. Turnover probably takes much longer than this but how much longer is still unclear.

Asexual reproduction by transverse fission is important in this species and an attempt was made to obtain an estimate of the rate of fission by double tagging animals with nylon monofilament at their anterior and posterior ends. This study failed because individuals were able to move the nylon line through the body wall in less than one week.

Size distributions were measured for animals at Ananij Island, in the Quarry on Enewetak Island, and on the reef flat north of the Quarry. Median and maximum sizes were:

<u>Area</u>	<u>Median Length</u>	<u>Maximum Length</u>
Ananij	13.0 cm	20.5 cm
N. of Quarry	13.5	31.5
Quarry	20.5	41.5

To see whether the growth rates are similar in these three localities, animals were tagged with tetracycline and will be collected in 1978.

Loss rates of *H. atra* at Ananij are now estimated to be between 50% and 70% per year with replacement due to asexual reproduction so the loss rates are also the estimates of fission rates. It would appear that the population at Ananij has a short turnover time of only 0.8 to 1.5 years.

A study of sea urchin life histories was initiated with primary emphasis on the slate pencil urchin *Heterocentrotus mamillatus*.

A total of 182 *H. trigonarius* was tagged with tetracycline at the reef edge at Ananij and will be collected in 1978.

The size distribution was negatively skewed. The median test length was 8.9 cm and maximum was 10.6 cm. The smallest individual found was 3.2 cm long. Such a distribution suggests long life and some of the animals may have been present at the last nuclear tests.

Autoradiograms of *H. trigonarius* spines from Ananij show apparent presence of radioactivity throughout the spine rather than concentration in definite zones. Specimens were collected at Enewetak Island and autoradiograms are to be made with spines from Ananij, Enewetak and from *H. mamillatus* spines from Hawaii as a control. The pattern of activity is of interest not only because *H. trigonarius* may be a long lived reservoir of elements tied-up in its skeleton but also because the diffuse pattern of radioactivity suggests that the skeleton is dynamic and may be reworked internally.

Allocation to body parts is important in life history studies and dissections were made of four species:

Species	% of Total Weight					
	N	Body Wall	Lantern	Gut	Gonad	PVF*
<i>Heterocentrotus trigonarius</i>	11	82.7	2.2	0.5	1.5	8.5
<i>Echinometra mathaei</i>	4	64.3	6.4	1.5	1.3	12.5
<i>Echinostrephus asciculatus</i>	5	55.1	7.1	2.0	1.5	16.4
<i>Echinothrix diadema</i>	3	47.4	4.9	1.9	6.1	26.1

* perivisceral fluid

Dry and ash weights were also determined, for example:

Heterocentrotus trigonarius N = 11

	Body Wall %	Lantern %	Gut %	Gonad %	PVF %
water	24.4	37.7	76.9	71.9	95.8
organic	1.1	6.0	19.9	25.1	0.2
salt+bound HOH	1.1	1.5	3.2	3.0	4.0
CaCO ₃	10.3 (T)*	54.8			
	62.1 (S)				

* T = test; S = spines

Allocation of resources within urchins is part of a long term study of the evolution of life histories.

- Project: A study of the agents and dynamics of coral bioerosion
- Investigators: Ray Highsmith
 Alan Riggs
 Department of Zoology
 University of Washington
 Seattle, Washington 98195
- Objectives:
1. To determine the roles of the various burrowing organisms in altering and generating infaunal habitat structure and in excavation and destruction of corals.
 2. To determine what sequential events or processes, starting with the initial availability of a substrate, are instrumental in the ontogeny of the community of burrowing organisms.

A number of time-dependent experiments were set up in June 1976 in order to determine which organisms initially penetrate a freshly exposed surface. In these experiments, Iceland spar calcite crystals (an optically clear form of CaCO_3) and aragonite controls were placed in holes chiseled in *Porites* heads. These experiments were monitored and a new set of such experiments were installed in the quarry and at North Enewetak pinnacle.

Massive corals of the genera *Porites*, *Favia*, *Platygyra*, *Astreopora*, *Goniastrea* and *Oulophyllia* were collected over a depth gradient, measured, photographed and serial sectioned for mapping of bore holes and *Ostreobium* bands. At least one section from each head has now been x-rayed and measurement of annual density bands is in progress.

Burrowers and associated infaunal organisms were collected from these corals and are now being identified but include polychaetes, sponges, bivalves, gastropods, sipunculans, crustaceans, echinoids and nematodes.

Field observations were made on the presence or absence of hapalocarcinid crab burrows and alpheid shrimp grooves in *Goniastrea retiformis*. Of 84 heads, 23 contained crab burrows, 41 had shrimp grooves, and 20 had neither. Only 10 heads contained both crab burrows and shrimp grooves but a preliminary statistical analysis indicates that their distributions are independent of each other ($X^2 = 0.36$, 1 d.f.). The number of crab burrows/head ranged from 1 to 7 with a mean of 2.14.

Sections of microatolls were collected from the Enewetak interisland reef flat for analysis of growth rates and sponge burrowing rates. The remaining parts of the microatolls were returned to their approximate original location to see if and at what rate they would subsequently be transported across the reef flat to the back-reef consolidation zone.

Since organisms present on the surface of a coral skeleton may have an important effect on borers, space competition experiments between coral and red encrusting sponge were set up on *Porites* heads at Sand Island Pinnacle I.

Two *Porites* heads at South Medren Pinnacle were killed with bleach in order to determine the rate at which dead heads are colonized by boring organisms over a three month period.

One prediction of a coral bioerosion model developed is that massive corals with a basal diameter of less than approximately 6 cm suffer greater mortality due to bioerosion than do larger heads. The basal circumference of all massive heads along a transect at North Enewetak Pinnacle was measured. Of 74 heads, the calculated basal diameters ranged from 4.1 to 59.0 cm with only 2 diameters less than 6 cm and one of them was 5.9 cm.

Heads of *Favia* were collected for analysis of bioerosion and growth rates. *Favia pallida* grows more slowly, both linearly and in mass, than the other common massive corals at Enewetak, *Porites lutea* and *Goniastrea retiformis* (in press, J. exp. mar. Biol. Ecol.). *Favia pallida* is also less bored than the other two species.

Porites lutea microatolls were counted and measured along transects from the junk reef (north end of Enewetak Island) to the algal ridge. Microatolls that come loose due to bioerosion or storms are moved by prevailing currents to the edge of the lagoon. Many survive this movement and subsequent growth has resulted in reef formation. The volume of the reef forming along the lagoon edge is approximately 1200 m³.

When the microatolls are dislodged, one to several small pieces of live coral often remain attached to the reef flat, resulting in asexual colony multiplication.

Porites lutea heads on pinnacles and on sand around pinnacles were measured. Significantly more heads on sand are loose and they are significantly larger than attached heads.

Polychaetes and their burrows were collected for SEM analysis of burrowing mechanisms.

The density of *Lithophaga curta* (Bivalvia) in live *Montipora berryi* colonies was measured. Because *L. curta* appears to be limited to *M. berryi* and small *L. curta* occur in the center of *M. berryi* colonies, it is concluded that *L. curta* settles directly on live *M. berryi*. Interestingly, very small *M. berryi* colonies were found in vacant *L. curta* burrows.

Project: Ecology of island rat populations

Investigators: William B. Jackson
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Environmental Studies Center and
Department of Biology
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Bowling Green, Ohio 43403

- Objectives:
1. Morphological and ecological studies of three rodent species.
 2. Banding of sooty terns.

More than 500 rats (*Rattus rattus* and *R. exulans*) were collected and necropsied. Samples were obtained from most of the infested islets at the atoll. Reproduction was at a very low level except in the village area on Japtan. The cleanup and environmental disruption apparently had stimulated breeding activity. Investigations on the interaction of population density, behavior and physiological responses were continued: (a) incisor scars on the backs of the rodents were counted, as were tail scars; (b) internal parasite loads were counted; (c) adrenal weights were determined. Rat populations at the atoll continue to be allopatrically distributed; no evidence of the UH introduction of roof rats to Japtan was found. Palatal ridges were examined and the now completed study demonstrates measures of divergence correlated with relative separation on atoll islets. Dosimeters were placed in a grid pattern on Runit; levels of gamma radiation are now being determined.

Recommendations were made relative to rodent control on Japtan and other areas to be used by returning Enewetak natives.

More than 200 mice (*Mus musculus*) were caught on Medren and Enewetak. Organs were weighed and measured, and the collected blood sera currently are being analyzed. Reproductive rates were low. These island populations are very much smaller in body size than mainland populations and somewhat smaller than those in Hawaii. External morphologic differences will be correlated with serologic patterns.

More than 500 sooty tern young were banded on Sally. The lack of adults incubating eggs reduced our ability to recapture adult banded birds.

Table 1. Summary of autopsy data, Enewetak Atoll, March 1977

Islet	Total Number	Males				Females					Avg. Litter
		No.	Testes		Tubules NV/V	Vaginal Orifice			Preg.		
			Non-scrotal	Scrotal		No.	Imp.	Perf.		Scars	
<i>Rattus rattus</i>											
Ananij	41	22	0	22	0/22	19	3	16	6	1	4.0
Enewetak	31	7	4	3	0/3	24	6	18	8	0	-
Enjebi	45	16	1	15	1/14	29	10	19	9	1	3.0
Medren	71	45	4	41	2/40	26	0	26	16	1	7.0
Runit	49	23	1	22	2/20	26	6	20	10	0	-
Totals	228	113	10	103	5/99	124	25	99	49	3	4.7
<i>Rattus exulans</i>											
Aomon	40	22	0	22	1/21	18	3	15	7	0	-
Bijile	55	28	5	23	0/23	27	11	16	5	0	-
Lojwa	56	31	3	28	3/25	25	13	12	6	0	-
Japtan	81	40	3	37	8/29	41	2	39	14	5	2.8
Japtan (village)	35	13	0	13	6/7	22	0	22	11	9	2.5
Totals	267	134	11	123	18/105	133	29	104	43	14	2.65

Table 2. Distribution of stomach nematodes (*Protostrongylus*) in Enewetak rat populations.

Islet	Total Number	0	1-3	>3	<10	Few (<25)	Moderate (25-50)	Heavy >50
<i>Rattus rattus</i>								
Ananij	38	37	1	0				
Enewetak	17	0	0	0				
Enjebi	45	0	-	-		22	17	6
Medren	45	9	-	-		29	5	2
Runit	46	5				36	4	1
<i>Rattus exulans</i>								
Aomon	37	29	8	1		-	-	-
Bijile	-	-	-	-				
Lojwa	25	6	15	4				
Japtan	32	22	9	1		-	-	-
Japtan (village)	30	23	7	0		-	-	-

Table 3. Distribution of pelage patterns in roof rats at Enewetak Atoll

Islet	Total Number	Agouti/ white cream	Agouti/ gray	Black/ White	Black/ gray
Ananij	41	8	1	0	32
Enewetak	31	29	2	0	0
Enjebi	45	41	4	0	0
Medren	71	60	3	3	5
Runit	49	8	5	0	36

Table 4. Stomach analyses of rat populations at Enewetak Atoll

Islet	Number of stomachs with *					Insect	
	$\geq \frac{1}{2}$ plant	$\geq \frac{1}{2}$ insect	$\geq \frac{1}{2}$ bird	$\geq \frac{1}{2}$ lizard	$\geq \frac{1}{2}$ fish	Fragments	Empty
<i>Rattus exulans</i>							
Sally N = 38	26	11	5	0	0	8	1
Ursula N = 25	13	13	1	1 (animal)	1	3	1
Japtan N = 32	16	12	0	1	0	4	9
Japtan (Village) N = 30	25	6	0	0	0	10	2
<i>Rattus rattus</i>							
Ananij N = 38	37	0	1	2	0	4	0
Enjebi N = 45	42	1	0	0	0	6	2
Medren N = 45	44	1	0	0	0	14	0
Enewetak N = 19	19	0	0	1	2	6	0

* summation of categories exceeds sample size because of multiple entries

Project: A reef coral taxonomy workshop at the Mid-Pacific Marine Laboratory, Enewetak Atoll

Investigators: Judith C. Lang
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Austin, Texas 78712

J. W. Wells (Cornell University), D. M. Devaney (Bishop Museum), P. Jokiel (University of Hawaii), R. A. Kinzie (University of Hawaii), L. S. Land (University of Texas), J. E. Maragos (U. S. Army Corps of Engineers), M. Pichon (James Cook University), R. H. Randall (University of Guam), B. R. Rosen (British Museum), J. E. N. Veron (Australian Institute of Marine Science), C. C. Wallace (Queensland Museum), M. Wijsman-Best (Rijksmuseum), J. Stimson (University of Hawaii) and G. Faure (La Reunion)

- Objectives:
1. To update the MPML Coral Reference Collection with a set of named reef coral species characteristic of each major reef habitat at Enewetak Atoll.
 2. To prepare an Enewetak reef coral field identification guide for general use and a number of taxonomic and ecologic publications.

About 2,500 specimens of coral from 28 different sites around Enewetak Atoll were collected, labelled, cleaned and divided among approximately 170 species of scleractinians and about 5 species of non-scleractinian corals. A complete collection of the best specimens was given to the MPML; and another complete collection was deposited in the Bishop Museum. Remaining replicates were given to the USNM (Washington), the Rijksmuseum van Natuurlijke Historie (Leiden), and the British Museum (London). Fairly detailed habitat and living appearance records were made for most specimens, and some were photographed underwater. Some of the specimens in the MPML and BPBM collections are being photographed to show skeletal characteristics. This collection and data are currently forming the basis of the Enewetak reef coral guide (Lang *et al.*, manuscript in prep.). The specific information recorded for the specimens will be transferred to tape and stored in the Hawaii Coastal Zone Data Bank. After publication of the guide, all original B&W photographic negatives and color transparencies will be deposited in the Bishop Museum.

- Project: Uptake, assimilation and fate of inorganic nitrogen in *Pocillopora*
- Investigator: Ronald E. Marian
Department of Biology
University of California, L. A.
Los Angeles, California 90024
- Objectives:
1. To test the capacity of reef corals for the assimilation of nitrate-N, using direct (isotopic) methodology.
 2. To verify and quantify the translocation of organic nitrogen from zooxanthellae to coral host tissues.

The generally accepted model for "nitrogen recycling" in reef corals includes the zooxanthellae-mediated uptake of dissolved inorganic nitrogen and the translocation of nitrogen in organic form (principally as alanine) to the host tissues. However, this scheme is based on fragmentary and indirect evidence. I therefore applied tracer methodology, using nitrogen-15, to the examination of nitrogen assimilation and translocation in the hermatypic coral *Pocillopora*.

Small heads of *Pocillopora* were collected from shallow areas on the lagoon side of Enewetak Island. These were incubated for various periods under constant illumination in seawater enriched with ^{15}N -labelled NO_3^- . Coral tissues were then homogenized, separated by centrifugation into zooxanthellae and host tissue components, further fractionated by ethanol extraction, and freeze-dried. Samples were returned to UCLA for nitrogen isotopic analysis by optical emission spectrometry.

Zooxanthellae and host tissue fractions showed rapid increases in $^{15}\text{N}/^{14}\text{N}$ ratios during and immediately after 45 minutes of incubation in $^{15}\text{NO}_3^-$, and slow decreases during an eight hour "chase" with unlabelled nitrate. Highest values of isotopic enrichment occurred in the zooxanthellae alcohol-soluble, insoluble, and chloroform-soluble fractions (Figures 1-3). These data provide confirming evidence for the capacity of coral zooxanthellae to take up and reduce nitrate *in vivo*. The greater percentage of total recoverable ^{15}N was found in the host tissue fractions (Figures 6, 7). Since nitrate is not known to enter metabolic pathways in metazoans, any organically-bound ^{15}N in host tissues (other than that due to cross-contamination) may be attributed to assimilation by, and release from, the algal symbionts. During $^{15}\text{NO}_3^-$ incubation, the host fractions accounted for greater than 80% of the total label recovered, suggesting that as much as 80% of the inorganic nitrogen assimilated by zooxanthellae is translocated to the host in organic form. Though this value can only be taken as a first approximation, it does indicate that the rate of nitrogen translocation is in the same range as that previously reported for the translocation of photosynthetically-fixed carbon in *Pocillopora*.

The results suggest that translocated nitrogen is incorporated into host tissue constituents (Figures 4, 5). Whether translocated nitrogen can offset a potential deficit in the coral host's nitrogen balance remains a question for future study. Such internal recycling of available nitrogen may be one possible adaptation allowing reef corals to flourish in a characteristically nutrient-poor environment.

6

7

- Project: Home range and food habits of Pacific reef sharks
(primarily the gray reef shark, *Carcharhinus amblyrhynchos*)
- Investigators: Donald R. Nelson
James N. McKibben
Timothy C. Tricas
Donna J. Cooksey
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California State University
Long Beach, California 90840
- Objectives:
1. To determine home-range dimensions and stabilities by tracking sharks equipped with ultrasonic transmitters.
 2. To evaluate telemetry instrumentation and techniques for applicability under Enewetak conditions.
 3. To investigate social behavior, especially aggression towards divers, in relation to space utilization (e.g., territoriality) and group organization.
 4. To obtain food-habit data from examination of stomach contents.

Telemetry trackings were performed on 12 gray reef sharks, *Carcharhinus amblyrhynchos* (= *C. menisorrhah*), in order to determine home ranges and activity patterns over periods of several days. The sharks were bait attracted and either (1) captured via hook and hand line for internal or external transmitter attachment, or (2) allowed to swallow the transmitter concealed in bait. Intermittent trackings were conducted several times daily during daylight hours, and occasionally at night when sufficient moonlight permitted. Of the 12 trackings initiated, nine were considered successful and three unsuccessful (no contact after first day).

Of the three transmitter-application methods used, self-ingestion in bait proved the best for short multi-day trackings. All six sharks using this method yielded successful trackings (3-5 days). In four cases, transmitter regurgitation occurred (on days 3, 4, 4, and 5) allowing diver recovery (depths, 8-38 m). For longer-term trackings, body-cavity implantation (inserted into coelom via abdominal incision) appeared best. Of three trackings by this method, two were successful (5, 6 days), and one unsuccessful. The dorsal-fin attachment was least successful (1-2 days). The fin mounting may have caused irritation and subsequent abnormal departure from the area of capture.

Home-range dimensions were approximated for each shark as the maximum polygon enclosing all of the position points determined during the trackings. For the nine successful trackings, polygon lengths ranged from

.95 to 4.8 km (mean, 2.8 km), and widths from .30 to 1.8 km (mean, .77 km). Polygon areas ranged from .19 to 3.7 km², with a mean of 1.5 km². Considering the non-continuous nature of the trackings, especially at night, these values are probably underestimations of the actual areas covered by the sharks.

The telemetered sharks exhibited relatively high day-to-day home-range stability and diel-movement repeatability, especially those sharks implanted by self-ingestion. For instance, of the three sharks bait-implanted at the garbage pier (S end Enewetak) during the routine morning dumping, all returned to the immediate or near vicinity of the pier prior to that time on each successive day - while the remainder of the daylight hours were spent in the black-buoy areas of S. Channel (1.5 km W of pier). In the E. Channel area, the two sharks bait-implanted at pole pinnacle (NW of Rex) both returned daily at the same approximate time to the immediate base of the pinnacle - while spending other parts of the day and night as far as 1.5 km away.

Whenever conditions permitted, receiver-equipped divers attempted to intercept and observe the telemetered shark. Of four sharks visually contacted, three were in group association with other gray reef sharks. One adult female (fin mount) was seen on day 2 slowly swimming near the bottom followed closely by three other sharks (sexes undetermined) - a behavior suggestive of courtship. Another adult female (body-cavity implant) was observed within a large pack of gray reef sharks slowly milling about close to the bottom in 20 m depth near the black buoy in S. Channel. The structure of this pack varied from closely spaced parallel individuals to a more-dispersed form, with individuals and sub-groups occasionally separating from or merging with the central pack. On day 3 (November 15, 1000-1130 hours) this pack contained at least 27 individuals. Later that day (1400-1630) up to 33 were counted. On day 4 (0930-1030) the telemetered shark was part of a smaller group in the same area varying between 5 and 10 individuals.

Significant variations were noted in the aggressiveness of gray reef sharks towards divers or boats. On two separate occasions in S. Channel, lone adult females closely approached divers and exhibited agonistic display - a behavior suggesting some form of territorial defense. In neither case had the divers made any "aggressive" moves towards the approaching sharks. These instances were in marked contrast to the behavior of the large S. Channel pack members which paid little attention to divers. Sharks in the central pack showed only mild avoidance of the free divers, never approaching them. Some sharks at the periphery of the pack showed occasional mild interest in the divers, rising about halfway to the surface towards them.

Numerous relatively aggressive individuals were observed in the drop-off area at the center of the mouth of E. Channel. Sharks repeatedly swam up to the drifting boat (no bait) from depths of over 40 m. In one case a group of 17 congregated beneath the boat, following it closely for some distance. The behavior of this group was distinctly different from that of

the S. Channel pack which essentially ignored the boat. Several sharks caught in the mouth of E. Channel showed evidence of reproductive activity. A 157 cm TL female (November 25) bore numerous fresh mating scars. A 140 cm male (November 25) showed clasper erections. A 154 cm female (November 6) contained three nearly full-term pups.

The stomachs of 10 male and 4 female hook-and-line caught gray reef sharks were examined (including three not killed - using "flushing" and "hand-insertion" techniques). All 14 stomachs were empty, suggesting that the baited-hook method is not satisfactory, possibly biased in favor of "hungry" sharks with empty stomachs. In the future, other capture methods should be tried. A blacktip reef shark, *C. melanopterus*, contained one surgeonfish, *Acanthurus triostegus*. A tiger shark, *Galeocerdo cuvieri*, contained one green turtle, *Chelonia mydas*.

- Project: Survey of the coconut crab population on Ikuran Island, including the collection of demographic data AND behavioral ecology of coral reef fishes.
- Investigators: Ernst S. Reese
Philip J. Motta
Craig MacDonald
Lisa Boucher
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- Objectives:
1. To use a tagging-recapture method to estimate the coconut crab population.
 2. To record demographic data while tagging the crabs, and to take notes on the distribution of vegetation.
 3. To make an in-depth study of the behavior of three species of coral feeders on Medren Pinnacle.
 4. To elucidate the anatomical adaptations of the feeding apparatus of butterflyfishes, and to relate this to their feeding behavior on the reef.
 5. To test the duration of residence and reproductive activity of butterfly and damselfishes.
 6. To survey the "Study" and "Reference" reefs to assess recovery from the typhoon of May, 1972.

I. Survey of the Coconut Crab Populations on Ikuran (Glenn) Island

Transects were established which covered approximately half of the island and crossed all available kinds of habitat including both the seaward and lagoon beaches. Beach transects were necessary to capture egg-carrying females which release their mature eggs into the sea. On the first night the transects were searched systematically for four hours and 103 crabs were tagged, measured, weighed and sexed. On the second night more crabs were tagged and recaptures of previously tagged crabs were noted. Wooden stakes were driven into the ground where crabs were captured and tagged and recaptured. The following day these stakes were picked up and the distance along the transects where the stakes occurred was measured. In this way the distribution of the crabs was measured and mapped. Also it was possible to measure the distance travelled by recaptured crabs.

This procedure was repeated on two consecutive nights, one week later. In each case search effort was held as constant as possible. The same people searched the transects and search time was the same.

Using the Lincoln Index on the above data, a population estimate of approximately 1,400 crabs of all sizes and sex was arrived at for the transect area. Since this was approximately half the island, the total crab population was estimated to be about 2,800 crabs. This indicates a slight increase over previous estimates, perhaps 10% in the past five years. This may reflect the more mature nature of the vegetation. The *Pisonia* trees are markedly conspicuous as compared with past years. With relatively fewer coconuts, the rat population appears to have decreased. The coconut crab population size and demographic characteristics remained stable from August, 1976, through January, 1977.

The demographic data show that the sex ratio remains at 50:50, that males are larger than females, that very small crabs are scarce due to their secretive and fossorial habits, and that relatively few females are still in reproductive activity this late in the summer. This substantiates previous data.

Weight data was collected on 60 crabs which will allow us to regress size of crabs on crab weight. Four small crabs, about the size of the ones which were raised from the eggs in 1966-1971, were brought back to HIMB for continued studies on growth rate.

It was confirmed that there is no reproductive activity among coconut crabs in January. We are now quite certain that the population begins reproductive activity in late April or May, depending primarily on the rainfall pattern which determines the amount of food available, and continues into late summer. It peaks in June and July. Very few females are still carrying eggs in August.

Overall, the two two-night surveys were most valuable in arriving at a final statement about the unexploited *Birgus* population on Ikuran Island. It will be interesting to compare these population figures and size class data with past and future data (if it is possible to continue with the work) after the Enewetak people have returned and begin again to harvest the crabs.

II. Behavioral Ecology of Coral Reef Fishes

Ethological studies on the distribution, abundance and social behavior of butterflyfishes, family Chaetodontidae, emphasized three obligate and exclusively coral feeding species, *Chaetodon trifasciatus*, a paired home-ranging species, *Megaprotodon strigangulus*, a solitary territorial species, and *Chaetodon unimaculatus*. Most of the work was done on Medren Pinnacle and on the two study reefs between Medren and Enewetak Islands. Agonistic encounters were filmed and several hours of underwater interaction was described verbally using an underwater tape recorder.

Five pairs of *C. trifasciatus* identified in August 1976 were intact in August 1977, but two pairs had swapped mates. Home range boundaries were nearly the same, excepting that one pair had extended down into the home range of another pair whose home range was now adjusted to include the front edge of the reef formerly not used. These fish avoid contact with other conspecific pairs when they come close to one another at home range boundaries, and apparently remain in their own home range. Home ranges are not defended interspecifically. This species is an obligate coral feeder, feeding exclusively on hard corals.

Similarly three single territorial *M. strigangulus* identified in August 1976 were maintaining their same territories in August 1977. Territories were measured and mapped. This species is strongly territorial, defending its territory against most intruders. It is an obligate coral feeder. A new "soliciting" behavior was observed and described. Portrait pictures were taken of these three fishes. Prints will be made up to illustrate the unique marking patterns on each fish which make individual recognition without tagging possible.

It was possible to recognize 11 individual *Chaetodon unimaculatus* on Medren Pinnacle by noting the distinctive coloration and marking patterns of each fish. Because the individuals could be consistently recognized, it was possible to determine that the *C. unimaculatus* of Medren Pinnacle have a highly structured social organization, unlike any other observed in these fish at different locations. They occur together in highly cohesive groups of three individuals (in one instance a group of four was found) that often forage together over the same core home range of the reef. Though often found singularly, the group will join together in vigorous defense of their home range against intrusion by neighboring groups of conspecifics. A display of raised dorsal spines accompanied by a dark banding coloration of the body is followed by chasing the intruder away. The consistency of this response, and the cohesive nature of the groups observed, suggests that these fish are capable of individual recognition, have a group bonding behavior, and are territorial.

It was found that four genera of corals comprise 95% of the diet of *C. unimaculatus* at Enewetak. Smaller individuals showed a marked preference for encrusting *Montipora* spp., and the larger ones fed primarily on the soft coral *Lobophyton* sp. The feeding data indicated a high degree of diet specialization.

Preliminary observations of *C. unimaculatus* in Kaneohe Bay, Hawaii, indicate that there is no structured social organization and that feeding is less specialized. This lends support to the hypothesis by Reese that, "The social behavior and social organization of butterflyfishes are determined by what they eat, its distribution in space, and hence their space related behavior."

Extensive data was taken by Motta on the feeding behavior of the butterflyfishes, *Chaetodon unimaculatus*, *G. trifasciatus*, *C. auriga* and *C. trifascialis*. Two parameters of feeding were investigated, the mechanics of feeding on the corals, and the types and abundance of various corals available at Enewetak. Particular emphasis was placed on the angle to the horizontal, that the fish assume during feeding.

Several factors may influence where and how and on which corals the fish feed. These include the shape or species of coral, the degree of water movement or surge, and the shape and position of the fish's mouth. It was also thought that at Enewetak with its abundance of piscivorous predators the butterflyfishes might feed in relatively safe places at angles as close to horizontal as possible to facilitate quick escape, or at least angles that permit rapid entry into the reef.

Using underwater photography numerous feeding events by the various butterflyfishes were investigated. Pictures were studied for the angle that the fish fed at, the type of coral being fed on, the shape of the particular coral species, and the location on the coral head that the fish fed on.

The tentative data indicate that the feeding angles are remarkably constant from species to species except for one species, *C. trifascialis*, which had an angle (mean) well below that of the others. This is believed to be related to the coral it feeds almost exclusively on, *Acropora hyacinthus*, which forms large table-like heads. These fish appear to feed heavily on the edges of these tables; an interesting observation in terms of the coral growth as these corals have the greatest growth rates at these edges, and coral shape is suspected to be in part determined by fish grazing. In terms of the predation factor the evidence at this point lends no weight to the hypothesis.

MacDonald concentrated on the reproductive strategies of the damselfishes. He has now gathered data on time of spawning, associated behavior, characteristics of nest sites, and parental care for five species, and is in position to compare these data with co-occurring species in Hawaii.

Surveys of the reefs damaged by the 1972 typhoon showed that in August, 1976, there were only about half as many butterflyfishes on these reefs compared with the population before the typhoon. Visual subjective inspection of the reefs indicated that there was surprisingly little coral recolonization and growth in areas that formerly were luxuriant. In August, 1977, there were about two-thirds the original 1972 numbers of individuals, however, all the species were present. Coral growth was still not as extensive as previously. The distribution and abundance of butterflyfishes which feed exclusively on corals can thus be used as an indicator of the "health" of the reef in terms of coral success. Quantification of reef health in terms of corals is difficult, but it is relatively simple to count the coral feeding species of butterflyfishes.

- Project: Patterns in growth and mortality rates of marine snails.
- Investigator: Ted R. Turk
Biology Department
San Diego State University
San Diego, California 92182
- Objectives:
1. To determine growth and mortality rates of several co-occurring snail species.
 2. To examine the relationship of growth rate to mortality rate.
 3. To examine the relationship of growth and mortality to other factors, such as recruitment rate and food supply.
 4. To examine the differences in life history features between tropical and temperate species.

February 1977

In September, 1976, 512 *Vasum turbinellus* and 454 *Thais aculeata* (previously misidentified as *T. tuberosa*) were marked and released. On this visit 94 marked *Vasum* and 125 marked *Thais* were recaptured. After measuring, these snails were returned again to their original habitat. In addition, another 508 *Vasum*, 247 *Thais*, 410 *Morula granulata*, 591 *Conus ebraeus*, and 279 *Conus sponsalis* were marked and released. Dissections were made of 30-40 of each species to determine shell size-body size relationships, and to estimate size at first reproduction and seasonality of reproduction.

Size distributions for all species and growth data for *Thais* and *Vasum* are presented in the following figures. In comparing the size distributions (Figures 1 & 2) from September 1976 to the present for *Vasum* and *Thais*, growth of both species is evident. Figure 6 is change in size plotted against original size for *Thais* and *Vasum*, showing larger growth increments for *Thais* than for *Vasum*. It is far from clear that there is a relationship between size and growth in these species. However, it is interesting that the growth of *Thais* was found to be compatible with the Brody-von Bertalanffy growth function, using the method of Fabens (1965), while *Vasum* was not. This is because *Vasum* does not show the attenuation of growth at larger sizes that *Thais* does. Thus, *Thais* has more or less determinate growth, while *Vasum* does not.

Figure 7 is the Brody-von Bertalanffy approximation of *Thais* growth (Fabens, 1965). Average maximum size for *Thais* is estimated by this method to be about 29.5mm, which is reasonable. The rate of approach to

maximum size (K in the Brody-von Bertalanffy function) is about 0.47, which is similar to some temperate species (Turk, 1975; Spight, 1972).

Instantaneous mortality rate for *Thais*, with time expressed in years, is estimated to be 0.48, using the method of Beverton and Holt (1956). This represents an average maximum life span of about 5 years, corresponding to a size of about 27mm (Fig. 7). It is obvious from the *Thais* size distribution that some individuals grow larger than this, because of longer life and/or faster growth than average.

The smallest *Thais* found were about 15 mm, or about 18 months in age according to Fig. 7. This indicates that *Thais* had not had successful recruitment for approximately 18 months prior to September, 1976, in the study area. This contradicts somewhat the idea that recruitment in the tropics occurs year-round. Although a Brody-von Bertalanffy growth curve cannot be constructed for *Vasum*, this species' smaller minimum size and slower growth suggest that it has not recruited for about as long as *Thais*.

The size distribution for *Morula granulata* (Fig. 3) is similar to that of *Thais*, no small individuals and a single, quite narrow peak. Like *Thais*, *Morula* is a predator on small gastropods.

The size distributions for *Conus ebraeus* (Fig. 4) and *Conus sponsalis* (Fig. 5) are similar in that they appear to show several size classes. This is especially true of *C. ebraeus*. A determination of whether these peaks represent age classes or are artifacts of measuring techniques will have to await estimates of growth rate and more size information.

Fig. 1. Thais aculeata

Fig. 3. Morula granulata

Fig. 2. Vasum turbinellus

Fig. 4. Conus ebraeus

Fig. 5. Conus sponsalis

Fig. 7. Brody-von Bertalanffy representation of growth of Thais aculeata. Size is opercular length in millimeters.

6. Change in size plotted versus original size for Thais aculeata and Vasum turbinellum, Sept. 76 to Feb. 77. Dimension measured was opercular length.

September 1977

On this trip 160 marked *Thais*, 86 marked *Vasum*, 61 marked *Morula*, 47 marked *Conus ebraeus*, and 25 marked *Conus sponsalis* were found. All of these snails were measured and released again. Marked and released were 294 *Morula*, 498 *C. ebraeus*, 356 *C. sponsalis*, *Drupa morum* (571) and *Drupa ricina* (623). Individuals of various sizes of *Morula granulata*, *Drupa morum*, and *Drupa ricina* were dissected to estimate size at first reproduction and length-weight relationships.

Thais aculeata. Very little growth seems to have occurred in this species from February to September, 1977. Of the 106 observations on growth during this period, only 16 were positive. Mean growth increment was -0.43mm , sd 0.7060 . This indicates shell erosion, besides the little or no growth. Figure 1 shows the size distributions of *Thais* for September 1976, February 1977, and September 1977. No recruitment occurred in this population between February and September, 1977.

Vasum turbinellus. Figure 2 shows growth increment plotted as a function of original size for *Vasum*, for the period February to September 1977. In contrast to previous data, growth could be approximated by the Brody-von Bertalanffy function (Fig. 3), possibly because there were few observations on large individuals. According to this approximation, the largest *Vasum* (c. 45mm) are very old indeed. Recruitment in this species seems uncommon, the smallest individuals (c. 10mm) being about 4 years old.

Morula granulata. Figure 5 shows a fairly strong negative relationship between growth and original size in this species. The Brody-von Bertalanffy representation of *Morula* growth is shown in Figure 3. *Morula* differs from *Thais* and *Vasum* in its small size, rapid growth, and apparent short life, the largest individuals being only 4 or 5 years old. As with most other species, the maximum size of *Morula* estimated by Faben's Brody-von Bertalanffy method is smaller than maximum size observed because it is an average maximum size. Recruitment is expected to be more frequent in *Morula* than in these other species; the smallest individuals are less than one year old. The rapid growth of *Morula* is demonstrated by the fairly large shift to the right of the size distribution from February to September 1977 (Fig. 6).

Conus ebraeus. There appears to be a relationship between growth and original size in this species (Fig. 7). *C. ebraeus* is a fairly rapidly growing species (Fig. 8), although not as much so as *Morula*. The largest individuals are probably over 20 years old; the smallest are about 2 years old. There was some shift in the size distribution from February to September 1977 (Fig. 9).

Conus sponsalis. Individuals of this species do not grow as much as *C. ebraeus* individuals of the same size (compare Figs. 7 and 10). Although the Fabens' method estimates similar sizes for *C. sponsalis* and *C. ebraeus* (Fig. 8), the slower rate of approach (K) to maximum size for *C. sponsalis* explains its smaller average size (Fig. 11). According to this estimate, based on a fairly small number (25) of observations, the smallest *C. sponsalis* are about 8 years old, the largest are over 50. This seems a little high, and the estimate of rate of approach to maximum size is perhaps low. More small individuals appear in the September 1977 size distributions of *C. ebraeus* and *C. sponsalis* than in February 1977. The possibility that this represents recruitment seems slight, especially in light of the relatively old estimated age of the smallest individuals, esp. *C. sponsalis*. A more likely explanation is improved technique for searching for small cones.

Drupa morum and *Drupa ricina*. September 1977 size distributions of these two outer-reef species are shown in Figures 12 and 13, respectively. Like the con-familiar *Thais*, both *Drupa* species have no small individuals, and recruitment probably occurs infrequently. Firmer conclusions about the rate of life of *Drupa* spp. will have to await growth data.

Fig. 1. Size distributions of Thais aculeata.

Fig. 3. Best fits of Brody-von Bertalanffy function to growth observed in Vasum turbinellus and Morula granulata, 2/77 to 9/77.

Fig. 5. Growth as a function of size in Morula granulata, from Feb. to Sept. 1977.

Fig. 4. Size distributions of Vasum turbinellus.

Fig. 6. Size distribution of Morula granulata.

Fig. 10. Growth as a function of size in Conus sponsalis, from Feb. to Sept. 1977.

Fig. 9. Size distributions for Conus ebraeus.

Fig. 11. Conus sponsalis size dis Fig. 12. Size distribution of Drupa morum. Fig. 13. Size distribution for Drupa ricina.

Project: Toxins and biomedical agents of marine organisms

Investigators: Paul J. Scheuer
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 Mark Yunker
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- Objectives:
1. To determine molecular structures of invertebrate constituents which are biologically active in human physiology or which form the basis of inter- and intraspecific communication between marine invertebrates.
 2. To collect *Palythoa tuberculosa*, which is at present the only sizable known source of palytoxin under U. S. jurisdiction.

Collected for later analysis at the University of Hawaii were 50 kg *Palythoa tuberculosa* and approximately 2 kg samples of 14 sponges, 4 soft corals and 2 gorgonians.

On-site screening by thin layer chromatography was carried out in order to avoid collection of animals that would prove uninteresting afterwards.

Underwater photographic equipment was used in order to document collections. Duplicate slides will be supplied to MPML.

- Project: Reproduction, growth and survival of Enewetak corals
- Investigators: John Stimson
 Tom Polacheck
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 University of Hawaii
 Honolulu, Hawaii 96822
- Objectives: 1. To study the reproduction, growth and survival of
 some common corals.
2. To learn how the structure and organization of coral
 communities develops.
3. To determine how shade producing corals alter the
 composition of coral communities.

Thirty-three Pocilloporid and 73 *Acropora* colonies were examined for the release of planulae during new and first quarters; none of the *Acropora* colonies planulated and a smaller percentage of Pocilloporid colonies planulated than in previous summer new and first quartered surveys.

These results suggest that both these genera, but particularly *Acropora*, are seasonal in their reproduction, which according to some of the older literature should not be the case among tropical marine animals (Pearse, 1973). In support of the idea that planulation is seasonal in some species, the percentage of colonies planulating during winter new and first quarter lunar phases (collected during previous visits) are also lower than summer figures for both these groups of corals.

Growth rates for a number of species have been determined from measurements of tagged colonies and from measurements of colonies in photographs of permanent quadrats. Common *Acropora* of shallow water (*A. corymbosa*, *A. humilis* and *A. nasuta*) have annual increments in diameter of about 5-6 cm, regardless of the colonies initial sizes. Colonies of *Pocillopora* in shallow water showed an annual growth in diameter of about 4 cm, apparently unrelated to the initial size of the colonies. A common shallow water *Pocillopora* (*P. verrucosa*) showed a pattern of increased growth in diameter with increasing size of the colonies; these results were from one group of colonies growing on a vertical wall and the pattern of growth may be a function of the position of the colonies, e.g., shading may have had an influence.

Growth in colony size in *Acropora* and *Pocillopora* are being measured at depths from 1-15 m on lagoon pinnacles and patches. The growth increments per year of corals at four depths over this range are statistically indistinguishable. This result may be due to changes in the species composition of each genus with increasing depth, or to some factor which makes the difference between respiration and energy intake (photosynthesis by the zooxanthellae plus ingestion by the polyps)

comparable at different depths. Although species composition changes somewhat with depth the growth forms occurring at the different depths are comparable.

Survival has been measured by rephotographing a large number of permanent quadrats at 6 to 12 month intervals. The cohorts of *Acropora* and *Pocillopora* in each quadrat are of mixed ages. *Acropora* seem to survive better than *Pocillopora* in the quarry of Enewetak Island.

These results and those on reproduction suggest that the genera *Acropora* and *Pocillopora* have contrasting life histories; *Acropora* colonies survive better than *Pocillopora* colonies and reproduce later or less. However survivorship data from So. Medren pinnacle suggests the opposite pattern exists on the pinnacle; *Acropora* which are more abundant on the pinnacle than *Pocillopora*, survived well, and *Pocillopora* survived poorly. This result may be due to the presence on pinnacles of *Acanthaster* which prefer *Acropora* over *Pocillopora*.

Sources of mortality are difficult to determine, but during the last 12 month period one cohort of 30 tagged *Acropora hyacinthus* colonies on a pinnacle were probably all eaten by an *Acanthaster planci* found in the immediate area of their whitened and algae covered skeletons.

The influence of "canopy" forming corals such as *Acropora hyacinthus* (table *Acropora*) on the density and species of understory corals was examined by counting the number and species of corals beneath each table *Acropora* and comparing this with the number and species of corals in nearby unshaded quadrats of 1m^2 . The area of substrate covered by individual table *Acropora* was generally $>1\text{m}^2$. The tops of the tables were between 30 and 80 cm from the substrate depending on the bottom topography. As shown in Table 1 the density of corals beneath table *Acropora* at $<3\text{m}$ depth was much lower than in control areas, and the number of species in the shade was lower than in control areas. The results were similar when the shading table was dead or alive. In the unshaded quadrats, the higher densities were associated with higher numbers of *Acropora* and *Pocillopora*, which seem to be less shade tolerant than other species.

Measurements of the growth of table *Acropora* show they grow faster than other *Acropora* and that growth in diameter per year is constant once the coral has changed from its vasiform to its tabulate form (Table 2). Thus, table *Acropora* could shade ever larger areas of substrate, if their growth continued uninterrupted by storm damage or predation.

Artificial table *Acropora* were put in place on a pinnacle in the atoll lagoon to see how these tables would alter survival and settlement. The artificial tables were cement disks approximately 80 cm in diameter and 4 cm thick, with four re-bar legs which were cast into the cement. These tables mimic the height and size of living tables and it is expected that the shade they create will result in increased mortality of understory corals and/or reduced recruitment of corals, relative to nearby control areas.

Table 1. Frequency of different coral genera and number of species under large table *Acropora* and in adjacent unshaded areas of 1 m².

	Shaded		Unshaded	
	No. of colonies	%	No. of colonies	%
<u>CHANNEL</u>				
<i>Montipora</i>	16	30	12	19
Massive corals	14	26	19	15
<i>Acropora</i>	18	33	70	56
<i>Pocillopora</i>	2	4	22	18
<i>Porites</i>	2	4	22	18
<i>Fungia</i>	1	2	1	1
<i>Pavona</i>	1	2	0	
Total colonies	54		125	
Total area censused	12.1m ²		9.0m ²	
Density of colonies	4.5/m ²		13.9/m ²	
<u>PATCH REEF</u>				
<i>Montipora</i>	2	13	4	7
Massive corals	2	13	3	5
<i>Acropora</i>	2	13	37	63
<i>Pocillopora</i>	0		1	2
<i>Seriatopora</i>	5	31	12	20
<i>Pavona</i>	5	31	1	2
<i>Heliopora</i>			1	2
Total colonies	16		59	
Total area censused	2.8m ²		3	
Density of colonies	5.7		19.7	
<u>CHANNEL AND PATCH REEF COMBINED</u>				
Avg. no. of species		4.75		9.42
Standard deviation		3.33		3.40

Table 2. Growth of individually tagged *Acropora*. Growth was measured as change in geometric mean diameter in 12 months.

	Mean increase in diameter in 12 months (cm)	Standard Deviation (cm)	No. of colonies	Regression of growth/year on <u>initial length</u> slope S_b	
<i>A. hyacinthus</i>	9.41	5.59	25	0.07	.04
<i>A. humilis</i>	2.31	1.70	20	-0.01	.04
<i>A. corymbosa</i>	5.69	5.47	25	-0.21	.07
<i>A. nasuta</i>	4.72	2.59	13	-0.12	.06

- Project: An analysis of population structure in Pacific mole crabs
- Investigators: Adrian M. Wenner
Henry Mark Page
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University of California, Santa Barbara
Marine Science Institute
Santa Barbara, California 93106
- Objectives:
1. To test whether the sex reversal (protandry) hypothesis remains viable for Pacific mole crabs.
 2. To test whether males and females grow at different rates.
 3. To make indirect estimates of the food distribution pattern around the Enewetak Atoll beaches.

Approximately 15,000 Pacific mole crabs (*Hippa pacifica*) were collected. Of these, about 3,000 were gathered from eight sites on six different islets so we could compare those environments with one another. The remainder of the animals were collected from the west Cargo Pier area. Animals were measured, checked for eggs and returned to the beaches while still alive.

Initial samples from a beach do not accurately represent population structure. Our first three samples (total of 923 animals) yielded a sex ratio of less than 30% males. In subsequent samples, however, the percentage of males collected increased in a non-uniform manner. The cumulative percentage of males, though, increased uniformly until we had a 48.3% representation of males by the time we had removed 4,011 animals from the beach.

Animals apparently do not change sex as they grow, rather males and females remain distinct throughout their lives. This conclusion is based on a consideration of the mean minimum size of egg bearing females and the mean size at which males would have become females if sex reversal occurred. A contradiction exists: Animals would begin producing eggs before they had become females, on the average. We also found that males apparently reach a maximum size and cease growth, though they continue molting. This last find has also been obtained by Dr. Randy Haley, of the University of Hawaii, in laboratory cultures.

Since the ocean currents and trade winds have relatively characteristic directions at the atoll, surface waters in the lagoon move in relatively consistent patterns. At each islet beach, the mole crabs provide a "filter array," as they catch the food brought onto that beach. By measuring their egg production, size at onset of sexual maturity, modal size class changes, sex ratio patterns, and "instantaneous" growth rate,

we have been able to assess just which populations at the atoll have been most favored by environmental conditions. In turn, the net set of results provides us with a good notion of how food has become distributed throughout the lagoon, at least in-so-far as it reaches the beach environment. A manuscript dealing with this topic will be prepared.

Project: Chemical relationship between sea anemones and their symbiotic fishes

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Alma, Michigan 48801

Objective: To detect, isolate and identify the nematocyst inhibitory substance in the mucus coating of anemone fish.

An attempt was made to determine whether any immunological relationship exists between anemone fish and host sea anemones. Double diffusion tests were done on slides coated with 1% Noble-agar in phosphate buffer. Diffusion of anemone fish mucus and/or tissue fluids against host anemone mucus and/or homogenized tissue occurred in a humidior at 5°C. Samples were taken from the anemone fish *Amphiron melanopus*, *Amphiron tricinatus* and *Dascyllus trimaculatus* their host anemones, *Physiobrachia douglasi*, *Radianthus simplex* and *Stoichactus giganteum*, respectively. There was no indication of immunological response in any of the tests.

Numerous attempts were made to electrophoretically compare mucus samples from anemone fish and mucus samples from host anemones. It was hypothesized that if a nematocyst inhibiting substance (protein) is transferred from the anemone to the fish or vice versa a similar protein should be found in all mucus samples. Mucus samples from the following fish-anemone pairings were analyzed. *Amphipron tricinatus* - *Radianthus simplex*, *A. chrysopterus* - *Stoichactis giganteum*, *A. chrysopterus* - *R. malu*, *A. tricinatus* - *R. gelan*, *A. melanopus* - *Physiobrachia douglasi*, *A. tricinatus* - *R. ritteri*, *A. periderion* - *R. ritteri*. Also mucus samples from several species of acclimated (living with the host anemone) anemone fish were electrophoretically compared to samples taken from the same fish after 2-14 days deacclimation (living without the host anemone). Again it was hypothesized that an inhibitory substance would be present in the acclimated samples but not in the deacclimated samples. All the electrophoretic tests proved inconclusive mostly due to technical difficulties.

It was tried to detect the presence or absence of an inhibitor in anemone fish and anemone mucus in yet another way. Drops of melted gelatin were allowed to solidify on microscope slides and were then impregnated with various mucus samples. The slides were then touched to tentacles of anemones and the number of discharged nematocysts in the gelatin were counted under the microscope. There was no clear evidence of nematocyst inhibition when test drops containing fish mucus were tested against host or non-host anemones.

Conclusions: It was not possible to detect the presence of a nematocyst inhibitor in the mucus of anemone fish. Observations, however, lead to the belief that even if anemone fish are protected from the stings of anemones due to an inhibitor which the fish receives from the anemone, the relationship is more complicated. The total lack of consistency in anemone response to various tests, e.g., sometimes nematocyst would discharge into control gelatin drops, other-times they would not, may indicate that anemones have more control (nervous) over their responses than previously suspected.

Project: Role of succession in the terrestrial vegetation of an atoll.

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- Objectives:
1. To describe the process of plant secondary succession on the atoll.
 2. To attempt prediction of the future condition of the vegetation under undisturbed conditions and the response of the vegetation to further disturbance.

Quantitative samples of the vegetation were taken on Ananij (Bruce), Jinimi (Clyde), Boken (Irwin), Japtan (David), Jedrol (Rex) and Kidrenan (Keith). Mut (Henry), Ikuren (Glenn) and Enewetak (Fred) were also visited, but no sampling done. In all, 3,588 square meters were sampled for trees and shrubs, 825 meters for seedlings and herbs, 468 meters of tree and shrub cover transects were run, and 1,671 meters of shore transect to record fringing woody vegetation were taken. In addition to these data, wood samples were collected for specific gravity determinations, and a limited number of insects collected.

A major goal of the sampling and observation was to determine the successional status of each of the more abundant species by observing the number and distribution of individuals by size class. To do this trees and shrubs were sampled by diameter size classes, with diameter measured at 50 centimeters above the ground. At the same time the origin (e.g., seedling, branch sprout, base sprout, etc.), of the smaller size classes was noted if it could reasonably be inferred. Data collected in the sample plots was augmented by casual observations and information in the literature.

At a very general level, observations accorded very well with the views of F. R. Fosberg (e.g., Bull. Am. Mus. Nat. Hist. 119:1-76, 1960). *Pisonia grandis* is the single most important species and it dominates the central portions of the least disturbed islands, forming an open woodland with a sparse covering of herbs. Reproduction of *Pisonia* by seeds seems to be rare, despite the occurrence of very high densities of very young seedlings in places. It seems capable of maintaining its dominance by prolific vegetative reproduction through the rooting of fallen and attached branches and logs. Under natural circumstances it would probably have been almost impossible for physical damage to a stand of *Pisonia* to wipe out the species on an island so long as any living woody material remained. Typhoons probably only temporarily open the canopy of the *Pisonia* stands.

Ochrosia oppositifolia is the only other species that might have potential to dominate under undisturbed conditions. This tree is now found on only two islands (J. Lamberson, pers. comm.); but on Japtan a small stand of trees was spreading by the establishment of seeds in closed conditions. In the proper circumstance this might permit it to compete successfully with *Pisonia*. It would be desirable to protect the stands of *Ochrosia* from disturbance to see if this does happen.

The other woody species of the atoll seem to be gradually excluded from the central portions of the islands as *Pisonia* dominance develops. *Guettarda speciosa* is commonly associated with *Pisonia* forest for some time, but seedlings beyond the earliest stages were not observed, and it is our belief that most of the individuals we observed were established as a consequence of human disturbance which opened the canopy and provided bare ground. It may have been largely restricted to the margins at the islands under natural conditions.

Similar remarks apply to *Messerschmidia argentea*. This species is commonly found in the interiors of islands, but seedlings were never observed in closed conditions despite superabundant seed production. The stands of *Messerschmidia* probably date from past disturbance, and will either yield to *Pisonia* or be regenerated by severe storms which scour the soil or deposit new material on it. *Scaevola taccada* is likewise common in the interior but seems only temporary, with a life span even shorter than that of *Messerschmidia*. Both of these species are very abundant on the margins of all the islands, and often are the only woody species found on some of the smaller islets. They are adapted to the invasion of open habitat, and very tolerant to salt spray. Even the longest imaginable period of time without major storms would probably include enough instances of high tides and high winds to insure that vegetation along the margins of the islands would be cut back and thereby prevent the exclusion of these species by competition.

The effect of man's activities over the past 50 years has certainly been to increase the amount of successional replacement. Under natural conditions, the dominance of *Pisonia* and its capacity for vegetative renewal would probably have prevented massive invasions of the woody species adapted to more marginal exposed habitats, though some degree of intermingling probably did occur. It may also account for the relative scarcity of *Ochrosia*, a species that might be expected to increase under closed conditions.

The wonder is that the vegetation has so rapidly returned to a condition approximating its original condition. On the leeward islands, old coconut plantations are now emergent from a *Pisonia* forest, and if not maintained, will probably be nearly gone in a few more decades, though seedling coconut trees were observed. Comparison of present vegetation with sketch maps prepared in the 1950's shows that areas formerly dominated by *Scaevola* and *Messerschmidia* have reverted to *Pisonia* forest in the 1970's. Since seed reproduction is not likely to have been significant, it is probable that *Pisonia* was never wholly eliminated from these areas and has resurged from vegetative propagules. The same remarks probably apply to the coconut plantations which probably were cleared of competing vegetation by hand cutting. This would have allowed the *Pisonia* to persist by continual resprouting.

In summary, it is hypothesized that the species under natural conditions are distributed along a margin to interior gradient that corresponds primarily to gradients in frequency and intensity of disturbance and secondarily to availability of soil water and nutrients. Man's activities have disrupted this pattern by allowing an invasion of disturbance adapted forms into the island interiors.

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