THE IMPORTANCE OF RESIDENCE TIME OF WATER IN COASTAL MARINE COMMUNITIES

A Research Proposal

Submitted to

Bureau of Planning (Coastal Zone Management)

Government of Guam

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The Marine Laboratory

University of Guam

Principal Investigator: Dr. Charles Birkeland

OBJECTIVES:

Land-management practices influence the amount of nutrient runoff and sedimentation from land into coastal bays and coral reefs. Nutrient runoff and sedimentation are known to have a great influence on the marine communities (Randall and Birkeland 1978). However, the factors of nutrient runoff and sedimentation are not enough to explain the whole effect of land-management practices on marine communities. Communities at the north ends of Tumon and Agana Bays appear to react differently to nutrient runoff than do communities in the south ends of these bays and marine communities in Pago Bay appear to react differently to runoff than to those in Tumon and Agana Bays. I believe that the current patterns produce different residence times for waters in different areas and length of residence time is the major cause of differences in reaction of the marine communities to nutrient input from terrestrial run-off. If the input of nutrients stimulates an increase in productivity of phytoplankton in an area of strong unidirectional currents, then the phytoplankton community will be gone from the area before a large enough standing crop is built up to support the higher trophic levels in the area. If the waters in the area have a high residence time, then the increased productivity in the phytoplankton will produce a buildup in biomass large enough to have a marked influence on the higher trophic levels in the area.

A better understanding of the influence of residence time of the water will provide us with a better understanding of the relative sensitivities of different regions to disturbance from urban development and will allow us to predict effects of constructions that change current patterns, such as breakwaters.

MOTIVATION:

Recent studies of high islands and low islands (atolls) were under-taken to determine the importance of terrestrial runoff of nutrients to

the nearshore benthic and planktonic communities. It was found that terrestrial runoff from heavy rainfall was an important factor, but not sufficient to explain everything. For example, Kosrae and Ponape are both high islands in the Carolines; both are surrounded by waters with very high nutrient contents and potentially high productivity of phytoplankton (Cowan and Clayshulte 1980), but Ponape has a great number of suspension feeders and a chronic problem with Acanthaster while Kosrae apparently does not. The reason for this may be that Kosrae is surrounded by fringing reefs, and although the waters are very productive and the phytoplankton is increasing rapidly, the waters are carried away before a large biomass can accumulate. In contrast, Ponape is encircled by a barrier reef and the nutrient-rich water is probably in the lagoon long enough to build up a substantial standing crop.

A similar explanation may account for why the fisheries are more productive near Okinawa than Taiwan although the upwelling occurs near southern Taiwan, a long distance upstream of Okinawa. Although the rate of production is great off Taiwan, the standing crop of plankton has not had time to build up enough until water in the Kuroshio Current passes Okinawa. If there was no major unidirectional current, Taiwan might have the greater region of fisheries where the upwelling occurs.

The concept of the importance of residence time of the water in allowing a buildup of standing crop may also explain the strange situation in those atolls of the Tuamotu that are entirely enclosed and no passes exist. With no water exchange, the waters of these atoll lagoons have even lower nutrient contents than the surrounding clear tropical oligotrophic waters of the open ocean (Sournia and Ricard 1976) and yet there is a large biomass of phytoplankton (Sournia and Ricard 1976) and an extrordinarily

rich biomass of suspension feeders. For example, the lagoon contained an estimated 340 tons of Arca (a mussel-like bivalve) and the main industry of the lagoon was harvesting of the mother-of-pearl oyster Pinctada margaritifera for jewelry (Richard, Salvat and Millous 1979). The large standing crop of phytoplankton and benthos in a nutrient-depleted pool of water may possibly be explained with the same classic explanation of rich tropical rain forests on nutrient-poor lateritic soils and rich coral reefs as oases in nutrient-poor tropical western ocean waters, i.e., rapid turnover and retention of nutrients in the standing crop. This can occur only if the system can remain cohesive.

I hypothesize that the most important factor in all of the above examples (terrestrial runoff from high islands, upwelling along coasts, and production in landlocked atoll lagoons) is residence time of the water. I also hypothesize that residence time of the water is a major factor in explaining why Acanthaster outbreaks originated on two occasions at the north ends of Tumon and Agana Bays and did not originate near Pago Bay, although plumes of terrestrial runoff are frequently observed running out of Pago Bay after heavy rains. I propose to examine the current patterns, nutrient content of the waters, pelagic and demersal plankton abundance and composition, and structure of benthic communities at the northern and southern ends of Tumon, Agana and Pago Bays.

The value of this study to applied science is that a greater understanding of causal factors in the nature of benthic marine communities will allow some understanding of the relative sensitivities of different regions to disturbance from urban development, allow a prediction of recovery rates of natural communities, and allow us to predict effects of constructions that change current patterns, such as breakwaters. The

value of this study to basic science is that it will help explain the nature of pelagic and benthic communities around different high islands and atolls and also the local distribution of origins of Acanthaster outbreaks.

SPECIFIC GOALS:

To test the hypothesis that residence time of the water has a strong influence on the standing crops of plankton and benthos, I will determine whether there is a positive rank correlation between residence time of water (as determined by measurements of current velocities and patterns) and the standing crops of plankton and benthos. Specifically, I predict that the north ends of Tumon and Agana Bays have longer residence times of water, higher standing crops of plankton (pelagic and demersal), and greater rates of biomass accumulation in the benthos than do Pago Bay and the south ends of Tuman and Agana Bays. The source of this prediction is that Acanthaster outbreaks have apparently originated on two occasions at the north ends of these bays and I suggest that phytoplankton blooms of sufficient magnitude to provide an adequate food supply for the larvae of Acanthaster must have occurred here and not at the other sites under study. Since terrestrial runoff occurs at all the sites, the areas at the north ends of Tumon and Agana Bays must differ in some other way; greater residence time of the water might be the difference that is the causal factor.

METHODS:

Once a month, I will obtain samples of: current patterns and velocities at 1-m and 5-m depths offshore along the reef front and in surface waters on the reef flat through eight-hour periods, NO_3-N, NO_2-N and PO_4-P contents of the water, replicate pelagic and demersal plankton samples, and growth rate of benthic biomass at six stations (north and

south Tumon, Agana and Pago Bays). During the year I will obtain descriptive data on the composition of the benthic communities.

Current patterns and velocities will be measured at 1-m and 5-m depths offshore along the reef front with the drogues and methods described in Birkeland (1980). Surface currents on the reef flat will be followed with dye. Water samples will be collected by opening and closing polyethylene sampling bottles underwater at the sampling stations. The sample bottles will then be placed in an ice chest and transported to freezer in the Water Resources Research Center (WRRC) at the University of Guam. The WRRC will be subcontracted to analyze the water samples for NO_3-N, NO_2-N, and PO_4-P by the methods of Strickland and Parsons (1968) as was done in previous projects (Randall and Birkeland 1978). Salinity will be measured in the field with an American Optical Corporation refractometer. Pelagic plankton tows will be collected in replicate and analyzed with the equipment and methods described in Smalley, Best and Birkeland (1980). Demersal plankton will be sampled with traps that have already been constructed with the basic design described in Hobson and Chess (1979). Rate of biomass accumulation in the benthic communities will be determined by the dry weights accumulated on plexiglass settling plates at each of the stations; the method and equipment will be the same as used by Birkeland (1977). Replicates of each of the above samples will be taken once a month at each of six stations, one each at the north and south ends of Tumon, Agana and Pago Bays.

Data on the composition and structure of the benthic communities at each of the stations will be acquired during the year. Surface cover by plants and animal taxa will be sampled by tallying points contacting intersecting lines on gridded quadrats. Corals will also be sampled with

the point-quarter method and density, percent cover, and frequency of occurrence will be calculated as described in Birkeland et al. (1976).

REFERENCES CITED:

Birkeland, C. 1977. The importance of rate of biomass accumulation in early successional stages of benthic communities to the survival of coral recruits. Proceedings, Third International Coral Reef Symposium. 1. Biology:15-21.

Birkeland, C. (ed.). 1980. Marine biological survey of northern Ponape Lagoon. Univ. Guam Mar. Lab. Tech. Rept. No. 62. 102 p.

Birkeland, C., R. T. Tsuda, R. H. Randall, S. S. Amesbury, and F. Cushing. 1976. Limited current and underwater biological surveys of a proposed sewer outfall site on Malakal Island, Palau. Univ. Guam Mar. Lab. Tech. Rept. No. 25. 59 p.

Cowan, P. A., and R. N. Clayshulte. 1980. Marine baseline water quality of the Trust Territory of the Pacific Islands. Univ. Guam WRRC Tech. Rept. No. 14. 116 p.

Hobson, E. S., and J. R. Chess. 1979. Zooplankters that emerge from the lagoon floor at night at Kure and Midway Atolls. Hawaii. Fishery Bulletin 77(1):275-280.

Randall, R. H., and C. Birkeland. 1978. Guam's reefs and beaches. Part II. Sedimentation studies of Fouha Bay and Ylig Bay. Univ. Guam Mar. Lab. Tech. Rept. No. 47. 77 p.

Richard, G., B. Salvat and O. Millous. 1979. Mollusques et faune benthique du lagon de Takapoto. Journal de la Societé des Océanistes 35(62):59-68.

Smalley, T., B. Best and C. Birkeland. 1980. Fish eggs and fish larvae. Pages 67-76. In C. Birkeland (ed.), Marine Biological survey of northern Ponape Lagoon. Univ. Guam Mar. Lab. Tech. Rept. No. 62. 102 p.

Sournia, A., and M. Ricard. 1976. Données sur l'Hydrologie et la Productivité du Lagon d'un Atoll Fermé (Takapoto, Isles Tuamoto). Vie Milieu 26(2), ser. B:243-279.

Strickland, J. D. H., and T. R. Parsons. 1968. A practical handbook of seawater analysis. Fisheries Res. Bd. Canada Bull. 167:1-311.

BUDGET

A. SALARIES AND WAGES

Name or Position	No. of Months	Cost Per Person
Graduate Student Assistant (20 hrs per week for one year at $5.20/hr).....	12	$ 5,406.00
Fringe benefits (above x .0613).....		331.39
	TOTAL S & W	$ 5,737.39

B. PERMANENT EQUIPMENT — Total Equipment — $ 0

C. EXPENDABLE SUPPLIES — Total Supplies — $ 400.00

(floresceine dye for current studies, Plexiglass for settling plates, ice for transporting chemical samples, plastic specimen bottles for plankton samples, buckets, construction blocks, plastic-coated wire, etc.)

D. TRAVEL — Total Travel — $ 0

E. PUBLICATION COSTS — Total Publications — $ 700.00

F. OTHER COSTS

Subcontract to Water Resources Research Center for chemical analysis of seawater samples	$ 1,600.00
Boat time (1 out of 6 days per month at $100 per day)	$ 1,200.00
Total Other Costs	$ 2,800.00

G. TOTAL DIRECT COSTS (A through F) — $ 9,637.39

H. INDIRECT COSTS - % of Total Direct Costs (G)

Less Equipment (B) Research on campus 31.30% of $5,737.39

TOTAL INDIRECT COSTS: $ 1,795.80

TOTAL REQUESTED BUDGET (G + H): $11,433.19

MATCHING FUNDS FROM UNIVERSITY OF GUAM

A. SALARIES AND WAGES

Name or Position	No. of Months	Cost Per Per
Associate Professor	20% of time (8 hrs per week) for 12 months	$ 4,908.80

B. PERMANENT EQUIPMENT

All permanent equipment will be supplied by the University of Guam (e.g., plankton net, 6 demersal plankton traps, freezer chests, dive gear, boat and boating equipment, transect tape, quadrats, microscope, etc.).

F. OTHER COSTS

Boat time (4 out of 6 days per month at $100 per day)	$ 4,800.00
TOTAL MATCHING FUNDS	$ 9,708.80

CONTRIBUTOR	AMOUNT	%
BUDGET REQUESTED FROM SEA GRANT	$11,433.19	54.1%
MATCHING FUNDS FROM UNIVERSITY OF GUAM	$ 9,708.80*	45.9%

*Plus all permanent equipment

CURRICULUM VITAE

CHARLES EVANS BIRKELAND

PERSONAL:

Birthdate and Place: October 4, 1942; Manhattan, Kansas

Marital Status: Married

EDUCATION:

1965 B.S. (Zoology) University of Illinois
1968 M.S. (Zoology) University of Washington
1970 Ph.D. (Zoology) University of Washington

PROFESSIONAL SOCIETIES:

Ecological Society of America
American Society of Naturalists

POSITIONS:

May 1970	Visiting Scientist, National Aeronautics and Space Administration (NASA) Tektite II Program, St. John, U. S. Virgin Islands.
August 1970-November 1973	Research Associate, Environmental Protection Agency Contract to Smithsonian Tropical Research Institute for research on effects of oil pollution on tropical shore communities.
July 1973-August 1973	Guest Instructor, Coral Reef Ecology Course, Fairleigh Dickinson University, West Indies Laboratory, St. Croix, U. S. Virgin Islands.
Fall 1973	Instructor, Introductory Biology Course, Florida State University, Canal Zone.
December 1973-July 1975	Research Associate, Environmental Sciences Program Smithsonian Tropical Research Institute.
Summer of 1974, 1976	Visiting Associate Professor, Natural History of Marine Invertebrates Course, Zoology 330, University of Washington.
June 1978	Visiting Scientist, National Oceanic and Atmospheric Administration (NOAA) Manned Undersea Science and

Technology Office's Underwater Laboratory System-I (NULS-I), St. Croix, U. S. Virgin Islands.

Fall 1975-Present — Associate Professor, Marine Science, University of Guam Marine Laboratory.

GRANTS:

1968-1970 — Ecology Training Grant Fellowship for Dissertation Research. National Science Foundation (NSF).

1970 — Pilot Grant to Study the Structure and Dynamics of Temperate and Tropical Rock Wall Communities in Costa Rica. Organization of Tropical Studies (OTS) funded by NSF.

1970 — Funds for studies on predation by fish and invertebrates carried out with the Tektite II project in the U. S. Virgin Islands. National Aeronautics and Space Administration (NASA) and NSF.

1970 — Survey of Communities in Panama and Experiments with Oil. U. S. Environmental Protection Agency. Office of Research and Development. Environmental Research Laboratory. ($79,772 with A. A. Reimer and J. R. Young)

1975 — A study on the effects of thermal effluent on the coral reef community at Tanguisson. Guam Power Authority (GPA). ($7,000)

1976 — The effects of thermal effluents of the Tanguisson Power Plant on the Establishment and Development of the Adjacent Reef Community and the Predicted Effect of Reducing the Discharge Temperature Rise. GPA. ($14,800)

1977 — Guam's Reefs and Beaches II. Regional Studies. Guam Office of Coastal Zone Managment. ($19,263 with R. H. Randall, R. T. Tsuda and S. S. Amesbury)

1977 — Studies on Benthic Community Structure and Species Morphology Comparisons Between Taiwan and Guam in Relation to Temperature, Upwelling and Fish Grazing. Division of International Programs, NSF. ($22,939 with R. H. Randall, J. E. Randall and L. G. Eldredge)

1978 — Biological Limiting Factors in Ocean Thermal Energy Conversions. Guam Energy Office (GEO). ($7,550)

1978 — Three Methods of Coral Transplantion for the Purpose of Reestablishing a Coral Community in the Thermal Effluent Area at the Tanguisson Power Plant. ($27,816.07 with R. H. Randall)

PUBLICATIONS IN REFEREED SCIENCE JOURNALS;

1968 Mauzey, K. P., C. Birkeland and P. K. Dayton. Feeding behavior of asteroids and escape responses of their prey in the Puget Sound Region. Ecology 49:603-619.

1971 Birkeland, C., and F.-S. Chia. Recruitment risk, growth, age and predation in populations of the sand dollar, *Dendraster excentricus*. J. Exp. Mar. Biol. Ecol. 6:265-278.

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1971 Birkeland, C., F.-S. Chia and R. Strathmann. Development, Substratum selection, delay of metamorphosis and growth in the sea star *Mediaster aequalis* Stimpson. Biol. Bull. 141:99-108.

1974 Birkeland, C. The effect of wave action on the population dynamics of *Gorgonia ventalina* Linnaeus. Studies in Tropical Oceanography Miami 12:115-126.

1974 Spight, T. M., C. Birkeland and A. Lyons. Life histories of large and small Murexes (Prosobranchia: Muricidae). Mar. Biol. 24(3):229-242.

1974 Birkeland, C. Interactions between a sea pen and seven of its predators. Ecol. Monogr. 44(2):211-232.

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1979 Glynn, P. W., G. M. Wellington and C. Birkeland. Coral reef growth in the Galápagos:Limitation by sea urchins. Science 203 (4375):47-49.

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1971 Birkeland, C., and B. D. Gregory. Feeding behavior of a tropical predator *Cyphoma gibbosum* Linnaeus, pp. 58-69. In "Tektite 2, Scientists in the sea" J. W. Miller, J. G. VanDerwalker and R. A. Waller (editors). U. S. Department of the Interior, Washington, D. C.

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1977 University of Guam Marine Laboratory (17 authors). Marine enviornmental baseline report, Commercial Port, Apra Harbor, Guam. University of Guam Marine Laboratory Technical Report No. 34. 96 p.

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1978 Birkeland, C., and S. Neudecker. A comparative study of adaptive radiation of chaetodontid foraging patterns. West Indies Laboratory of Fairleigh Dickinson University Report 78-1. 27 p.

PUBLISHED ABSTRACTS FROM FORMAL PAPERS PRESENTED AT MEETINGS:

1969 Reciprocal interactions between a sea pen and its complex of predators. Amer. Zool. (presented at 1969 AAAS meetings).

1971 Grazing pressure in benthic communities on the Caribbean and Pacific Coasts of Panama. Bull. of the Ecol. Soc. of Amer. 52(4):50. (presented at 1971 AAAS meetings)

1973 Community dynamics on the Caribbean and Eastern Pacific Coasts of Panama. Proceedings of the Association of Island Marine Laboratories 10:16. (presented at 1973 AIMLC meetings)

1975 Grazing and productivity as confounding factors in the development of benthic marine communities. Proceedings of the Association of Island Marine Laboratories 11:20. (presented at 1975 AIMLC meeting)

1978 A stable system of predation on a holothurian by four asteroids and their top predator. Proceedings of the International Conferenc on Echinoderm Biology 3:9.

1978 An experiment on the role of historical chance in the distribution of population of Dendraster excentricus. Proceedings of International Conference on Echinoderm Biology 3:10.