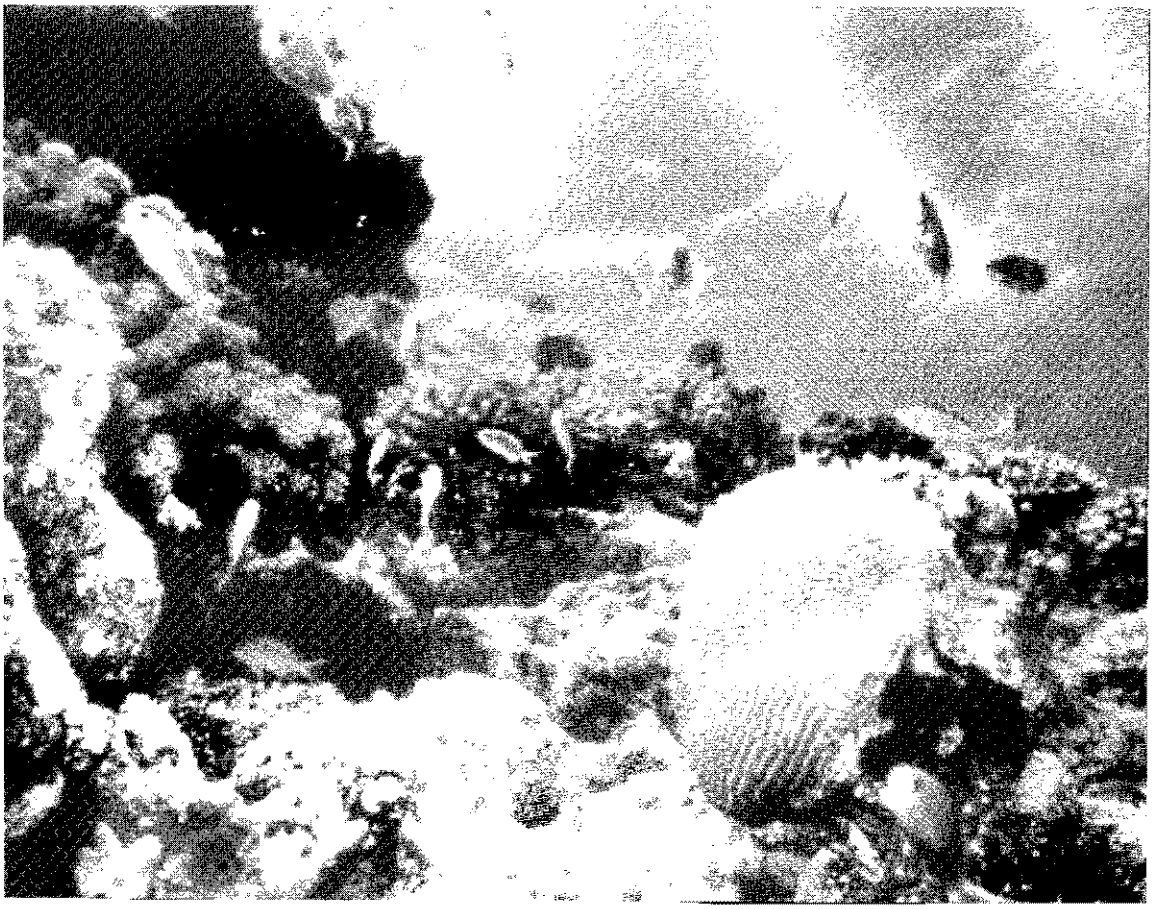

ENVIRONMENTAL MONITORING PROGRAM

by

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Introduction

Pacific Sea Resources (PSR) designed and implemented, in cooperation with the Coastal Resources Management Office of the Northern Marianas, an Environmental Monitoring Program to assess any possible effects of the archaeological recovery activities on the environment of the wreck site. The program provided baseline information on the biota and pertinent physical conditions of the project area, and involved careful observations and monthly reports on the immediate environment of the archaeological operations areas. Employing reliable, simple and replicable methods, the monitoring program focused on the composition and abundance of dominant organisms in Agingan Bay's marine community.

Monitoring personnel consisted of trained individuals familiar with the environment being surveyed. A marine scientist with a Ph.D. in biological oceanography and experience in tropical Pacific environments supervised all aspects of the program. PSR submitted regular reports on all stages of the program to both the Coastal Resources Management Office of the Commonwealth of the Northern Mariana Islands and to the U.S. Army Corps of Engineers. Seven reports were submitted during the ten month period on-site, giving a comprehensive view of the preliminary baseline survey results, materials and methods used during each survey session, and interpretations of environmental impact studies.

Preliminary Baseline Survey

A preliminary baseline survey was conducted to determine the principal biological and physical conditions of the site prior to the onset of recovery operations so that any subsequent impacts of artifact recovery activities could be assessed through follow-up surveys. The scope of this initial survey established the pattern for future surveys: 1) mapping of major gross features of the benthic environment of the salvage area, 2) determination of the composition, distribution and abundance of coral species, 3) counts of reef fish along transect lines placed in survey area, and 4) pertinent physical measurements. Each survey compared two study sites, one a disturbed area due to excavation activities, and one a control area which was undisturbed. Results of this baseline survey, along with results of other surveys taken over the 1987 and 1988 seasons, are described below.

Materials and Methods

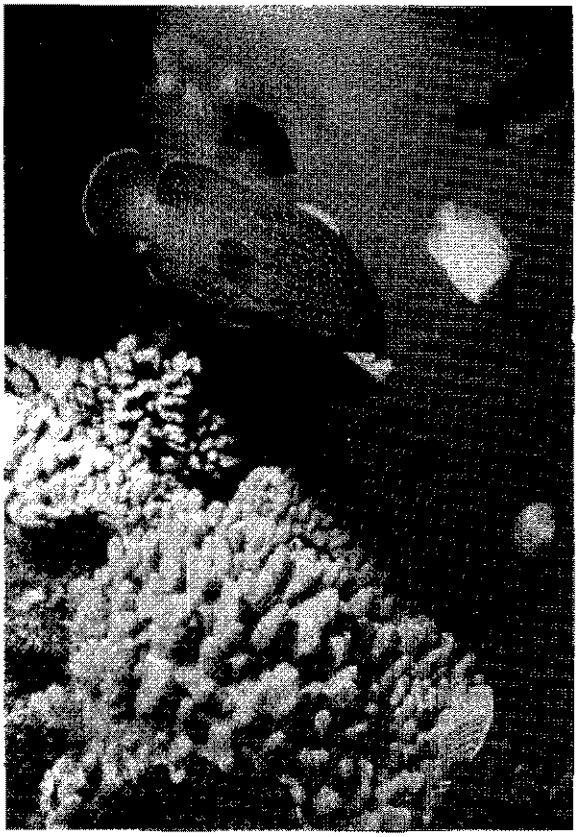
Mapping. Mapping of the survey areas was accomplished with the aid of an Oceano Underwater Acoustic Positioning System. Divers indicated the location and shape of principal underwater features by means of a hand-held transponder which transmitted a continuous record of positions to a computer on board the research vessel. The positions were logged and then transferred to a large-scale, hand-drawn map of the area. This system was supplemented with in situ manual measurements (using grids and transects) of key areas, information from existing charts, and aerial survey data.

Identification and Quantification of Corals. Because of the ecological importance and dominance of corals in tropical reef systems, coral composition and abundance was regularly monitored in areas subjected to archaeological survey and recovery operations and in adjacent, undisturbed areas.

Quantitative assessments of corals were conducted by means of the line transect method described by Loya (1972; 1978). A ten meter line marked off at one meter increments was employed. Coral colonies were identified and quantified on a monthly basis, in replicate transects within the archaeological recovery areas and in the undisturbed control areas, using the following procedure. Any colony which underlay the transect line was identified by species or, in some cases, by genus, and its length intercepted by the line was measured, to the nearest millimeter, with a folding metric rule. Where species identification was not possible in situ, a fragment of the colony was placed in a pre-numbered plastic bag and identified later onboard the research vessel. Identification was accomplished with the aid of Randall and Myers (1983). Small voucher specimens were retained of all species encountered.

Fish Counts. Time limitations and the large number of fish present precluded accurate and thorough accounting of the species and numbers of reef fish in the survey area. Therefore, quantification of fish in the survey sectors was accomplished as follows: upon completion of coral

assessment in each transect, the two survey divers positioned themselves at separate ends of the transect. After remaining motionless for approximately one minute, the divers simultaneously, but independently, sighted along the transect and counted all fish that approached within one meter (horizontally or vertically) of the line in a 60-second period. Because the one-meter distance was estimated, the divers' separate counts were averaged to provide a numerical count for the transect. Independently, we recorded all fish species encountered routinely, as well as those encountered during two survey dives. Surveys and identifications were facilitated by photographing fish in situ with still and video cameras, and with the aid of Amesbury and Myers (1982). Amesbury et. al (1979), Goodson (1985), Randall (1981), and Tinker (1982).



Marine life in Agingan Bay

Other Organisms. Common macroinvertebrates, other than corals, animals and prominent macroalgae were also identified and recorded, but not quantified, during surveys. Invertebrates and algae were identified with the aid of Abbot and Dawson (1978), Colin (1978), Fielding (1985), Melvin (1970), and Segawa (1965).

Physical Measurements. Vertical visibility (light penetration) in the water column was assessed using a weighted Secchi disc lowered from one of the ship's tenders at approximately 1:30 in the afternoon on clear, sunny days. Horizontal visibility at the seabed was determined both in an undisturbed area and in an area in which sediments were being stirred by airlift activities. One survey diver, wearing highly visible white coveralls, was positioned at one end of a line laid out along the bottom (later in the recovery operation this diver held a Secchi disc toward the observer instead of wearing white coveralls). The other survey diver swam along the line until the stationary diver was no longer visible, at that point measuring the distance with a tape measure.

Diver holding Secchi disk

In addition, air temperature, wind speed and direction, barometric pressure, estimates for current speed and direction, and swell and wave height were recorded regularly. Water temperatures at the surface and at a 10 meter depth were measured to 0.5°C with an immersion thermometer. Salinity was recorded to the nearest 0.5 parts per thousand with an A/O hand-held refractometer.

Results

Detailed results of environmental monitoring surveys for the 1987 and 1988 field seasons are presented in Pacific Sea Resources' Reports to the Northern Marianas Government (1987;1988). A summary of principal findings follows.

Mapping. *Figure 1* shows the principal topographic features of the survey area, mapped during the predisturbance survey, and also indicates environmental survey areas for the 1987 field season. There is very little active growth of massive corals on the reef front and seaward slope zones; the abundant presence of dead coral heads on the reef front indicates that much of the reef apparently died at some point in the past, perhaps due to an invasion of Crown-of-Thorns starfish. There is considerable erosion of dead corals. In the seaward slope zone the bottom is relatively smooth with a hard coral floor interrupted by crevices, small faults and isolated coral colonies. The scattered depressions on the bottom are filled with up to one meter of sand and small coral fragments. See also the "Site Description" section of this Report for more detailed information of topographic features of the site.

Prior to removing sediments during archaeological investigations of gullies, large coral debris was hand-carried away from the site. Sand and smaller rubble were then transported seaward primarily by water eductors, and, to a lesser degree, with airlifts. When airlifting was initially employed, a light coating of coarser sediments (up to two centimeters) was noticeable along a section of the lower reef front. However, these deposits were no longer evident two weeks after cessation of airlifting. Finer sediments were carried downstream by currents. The subsequent use of water eductors greatly reduced deposition of sediments outside the excavated gullies.

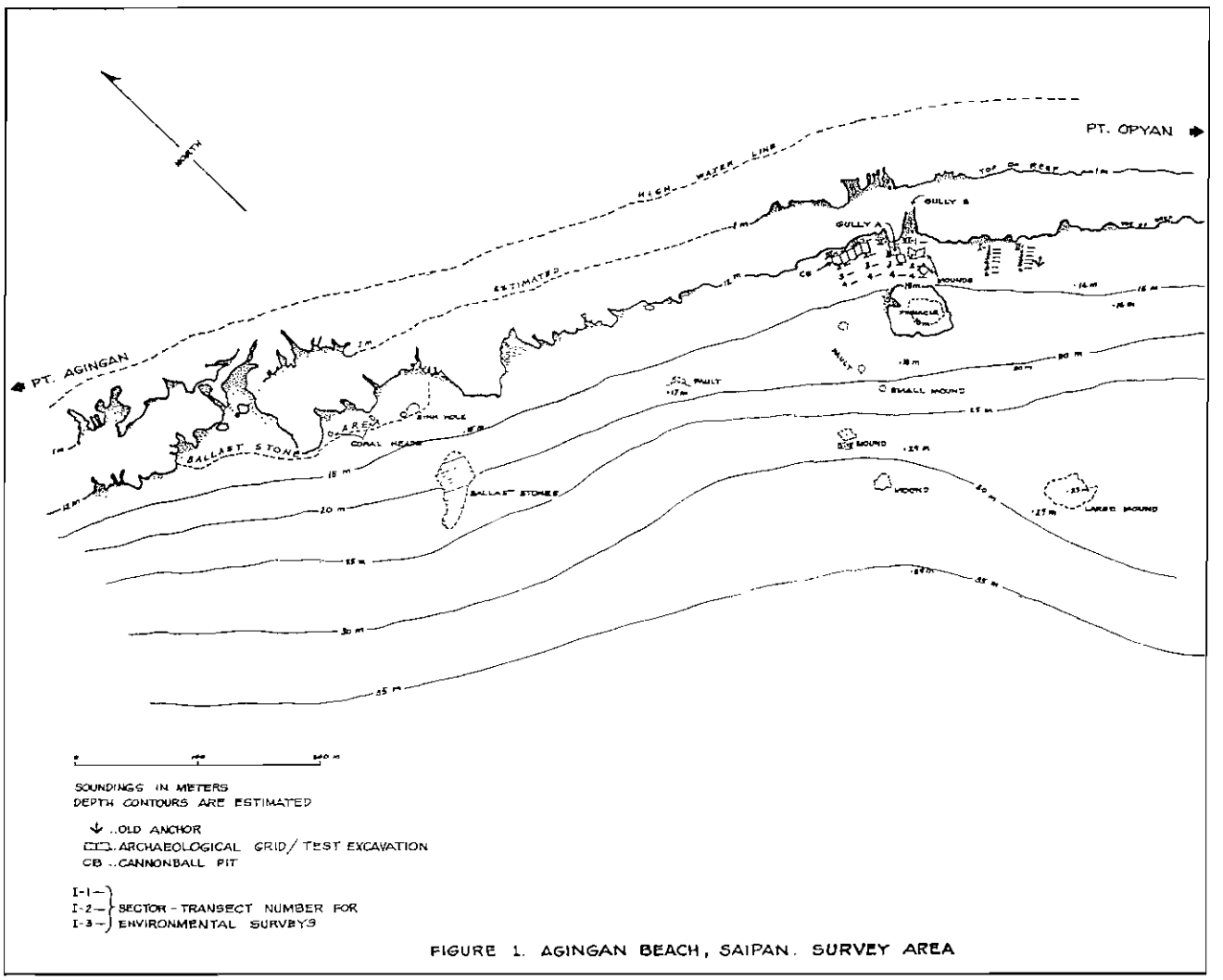


FIGURE 1. AGINGAN BEACH, SAIPAN. SURVEY AREA

Figure 1

Identification and Quantification of Corals. Coral species were overwhelmingly represented by recumbent and encrusting forms growing very close to the sea floor, in both disturbed and control areas. Erect species were rare. Live coral coverage was less than three percent for all transects in all sectors in 1987 surveys, but was approximately six percent in 1988 surveys. Differences in percent coverage between the two different field seasons are not believed to be attributable to coral growth. It is more likely due to the fact that different individuals carried out in situ surveys in the two field seasons.

There was no significant difference in live coral coverage between "disturbed" and "undisturbed" sites during either field season (Table 1). A complete list of corals sighted during the 1987-1988 field seasons at Agingan Bay is provided in Appendix D.

Divers measuring coral in survey area

Table 1. **Percent Live Coral Coverage in Disturbed and Control Sites: Summary of Results**

	Number of Transects Surveyed	Percent Coverage by Living Corals (mean ± Standard Deviation	Significant Difference?
1987 Field Season			
Disturbed Sites	16	2.72 ± 1.42	No
Control Sites	8	2.65 ± 1.11	No
1988 Field Season			
Disturbed Sites	4	6.20 ± 0.79	No
Control Sites	4	6.24 ± 0.06	No

Fish. A total of 74 fish species were sighted and identified in the survey /recovery area during the 1987 and 1988 field seasons (Appendix D). Five species were in the Class Chondrichthyes and the remainder were of the Class Osteichthyes.

The 60-second fish counts taken during transect surveys showed that there were significantly more fish in disturbed transect areas than in undisturbed controls during the 1987 field season but no significant differences during the 1988 field season (Table 2). The higher counts in disturbed areas in 1987 may be attributable to the stirring up of bottom organisms by archaeological activities. Bottom-feeding fish, including ubiquitous goat fish, were attracted to newly uncovered prey organisms. It is not clear why no differences were apparent in 1988.

Table 2. Fish Counts in disturbed and Control Sites: Summary of Results

	Number of Transects Surveyed	Number of Fish Sighted in 60 seconds (mean ± Standard Deviation	Significant Difference?
1987 Field Season			
Disturbed Sites	16	24.8 ± 5.2	Yes
Control Site 1	4	11.0 ± 4.7	Yes
Control Site 2	4	8.7 ± 3.2	Yes
1988 Field Season			
Disturbed Sites	4	29.62 ± 4.43	No
Control Sites	4	32.75 ± 3.34	No

Physical Measurements. Water temperatures at the surface and at 10 meters depth both averaged 28-30°C. Salinity consistently registered 34.5 parts per thousand. Air temperature ranged from 20.5°C at night to 29.5°C at mid-day. Winds generally varied from NE to ESE at 5-15 knots. Swells ranged up to two meters, from a SE or SSE direction. Currents averaged approximately one knot during maximum flow, running longshore and reversing quite unpredictably and rapidly from easterly to westerly directions. The period of maximum currents, of up to three knots, occurred approximately two to five days after new and full moons. Tidal range was less than one meter.

Vertical visibility was clear to the bottom throughout the survey/recovery area, even at deep water sites, with depths up to 75 meters. Horizontal visibility ranged from 33 to 40 meters in undisturbed areas, and from 26 to 38 meters in survey/recovery areas during operations.

Discussion

Environmental Impact. The study areas surveyed indicated that the reef environment had not been highly productive in recent years. The large number of dead, but still intact, coral heads on the reef front suggests that a formerly productive reef suffered major trauma, perhaps severe typhoon damage or a Crown-of-Thorns starfish outbreak, at some point in the relatively recent past and has not yet substantially recovered. The scattered presence of large, healthy branching corals on the reef front, particularly Stylophora, Acropora and Pocillopora, does indicate a satisfactory environment for coral growth. Perhaps the reef is currently undergoing slow recovery.

The paucity of massive corals in the seaward slope zone, where encrusting and recumbent forms are the principal coral species, is probably attributable to the scouring effect of sand and coral debris. The region is exposed to waves and storms from the east and south. Even in relatively calm weather, the surge from prevailing swells can be felt at depths of 15 meters. The constantly abrading effect of moving sediments, comprised principally of dead corals eroding from the reef front, would favor the development of low, creeping coral forms at the expense of erect, branching species. These prostrate species were far less vulnerable to mechanical damage from artifact recovery operations than would be erect, branching forms.

Our surveys of corals in disturbed areas showed that coral abundance, in terms of percent cover, was not significantly different from that of the undisturbed, control areas. The apparent absence of direct impact on coral growth may be attributed to two factors. First, coral productivity and abundance in the reef area in general appeared to be low to begin with, with less than three percent of the bottom covered by live corals win 1987. Second, excavated areas were almost exclusively gullies and crevices filled with overburden and with negligible live coral coverage. These sea floor depressions were common throughout the archaeological survey area, including in the undisturbed control areas.

Based on the underwater visibility assessments, our conclusion is that disturbance of sediments in association with artifact recovery operations would not have a significant adverse impact on the reef's biota. The rapid improvement of visibility upon cessation of sediment removal operations and the moderate to occasionally strong prevailing currents indicated that suspended sediments are dispersed quickly and broadly. In addition, the use of water dredges described earlier in this report, minimized the distance over which sediments were transported. On the other hand, we frequently observed considerable turbidity from natural turbulence, such as waves and storms, in this exposed coastal area.

A more subtle, potentially adverse effect of excavation is the release of nutrients from buried sediments. Resultant algal growth, particularly of filamentous forms, could be detrimental to corals through overgrowth of skeletal materials and subsequent shading and interference with the exchange of vital substances by polyps. We have no information on long-terms, nutrient-related effects of excavation activities, or even of storms, but the harmful results of anthropogenic nutrient introduction into Oahu's Kaneohe Bay are well documented (Smith et al. 1973). We do not believe that our limited excavations in the operations area will have long-lasting harmful consequences, because natural sediment disturbances from storms and wave action appear to be far more substantial.

Our surveys indicated that in 1987 fish counts were 250 percent greater in the disturbed areas than in undisturbed areas. This was probably a temporary situation and attributable to excavation activities which exposed infaunal prey items. All divers noted that even hand fanning of crevices tended to attract bottom-feeders, particularly goatfish, to newly exposed invertebrates.

In the Environmental Monitoring Program (Pacific Sea Resources 1986), we undertook several precautionary measures to minimize potential adverse effects of our operations. Excavations were limited to particularly promising areas as identified by careful and thorough surveys, and sediment removal operations ensured that excavated sediments were redeposited in eroded gullies, and not widely dispersed in areas of active coral growth. Whenever live, erect corals were removed from excavated areas, they were kept as intact as possible and were securely placed in an adjacent undisturbed area.

PSR employed a "soft" mooring system which involved minimal handling of heavy anchors. Once mooring anchors were set in position on the sea floor, the ship was secured to the moor with lines run to the mooring buoys. Whenever the ship got underway, the lines were taken in and the mooring anchors and buoys were left in place.

PSR's handling of human-generated wastes also ensured minimal environmental impact. Sewage was collected in holding tanks which were pumped out periodically at least three miles from shore. In accordance with Coast Guard regulations at the time, garbage and trash were discharged at least 12 miles from shore after removal from plastic containers, and bilge water was discharged only after passing through an oily water separator.

In summary, our surveys indicated that our archaeological recovery operations did not have short term adverse effects on coral or fish populations at the work sites. There was also no evidence that the archaeological survey and recovery operations will have long term harmful consequences on the environment of the wreck recovery area.