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EFFECTS OF UNDERWATER DEMOLITION ON THE ENVIRONMENT IN A SMALL TROPICAL MARINE COVE

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Naval Underwater Systems Center
Newport, Rhode Island

11 December 1972

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Effects of Underwater Demolition on the Environment in a Small Tropical Marine Cove

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NAVAL UNDERWATER SYSTEMS CENTER

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13. ABSTRACT
Construction in a small cove on Cross Cay, a small island located off eastern Puerto Rico, necessitated the use of 4000 lb of explosives to (1) clear a beach area for use as an access road and (2) remove underwater and awash coral heads and boulders to create a boat lane. In order to assess the impact of the blasting on the environment, acoustic-pressure levels and the effect of the demolition on marine life were measured. Three separate charges were positioned so that a large portion of the energy was dissipated skyward. As a result of the precautions taken to minimize the damage to the environment, at a distance of 350 yd from the demolition area, the largest of the three blasts produced a pressure level of only 9.15 $lbf/in.^2$, considerably less than expected. Air-bladdered fish that were suspended in cages 175 and 350 yd from the center of the demolition area remained alive and healthy. Damage to the environment was heaviest in the immediate area of the explosions, where a number of fish were killed. However, 2 hours after the last explosion, small schools of fish were observed in the cove.

Details of illustrations in this document may be better studied on microfiche.

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INTRODUCTION

Cross Cay, a small island located east of Roosevelt Roads, Puerto Rico (figure 1), is used by the U. S. Navy as an aerial practice facility. Construction on the island necessitated blasting to (1) clear a beach area for a vehicle-access route into the interior of the island and (2) remove large coral heads and volcanic boulders in a shallow cove, thereby creating a 30-yd-wide boat lane.

In June 1971, the Navy's Underwater Demolition Team (UDT) 21 surveyed the west cove of the island in order to determine the extent of blasting required to accomplish objectives (1) and (2), above, and to ascertain the types of marine life present. The survey found that the bottom of the cove was composed mainly of outcroppings of volcanic rock intermingled with dead coral heads.[1] Extending from the beach, the bottom of the cove is shallow (1 to 15 ft) for approximately 70 yd and then drops off sharply to approximately 60 ft (figure 2). Very little evidence of marine life (attached or swimming) was noted within the cove; beyond the cove, where the bottom drops off sharply, an increase in both attached forms and reef fish was observed.[1]

This study (1) assessed the impact of the blasting on marine life within the cove and offshore and (2) measured the underwater pressure levels created by the blasting. The assessment,[1] prepared before the construction began, indicated that, because of the relatively small amount of life observed in the cove, the danger to living creatures would be minimal. Furthermore, since most of the marine life (attached forms and fish) beyond the cove are found close to the ocean floor, the assessment[1] predicted that the shadow effect created by the steep slope would protect them from the main force of the shock waves from the blasting (figure 3). The results of this study demonstrated that these predictions were essentially correct.

METHODS

DEMOLITION

Four thousand pounds of C-4 explosives* in watertight 40-lb satchels were attached to the coral heads and boulders and their fuses were connected. A single blast detonated by remote radio telemetry was planned. However, as a result of problems with the fuses, three separate blasts were required: two were detonated by radio telemetry and the last by manually igniting the fuses. The three blasts occurred over a 3-hour period.

PRESSURE LEVEL

Three hydrophones (Atlantic Research LC-10) designed for blast measurement were bottom-mounted at selected locations near the blast site and cabled ashore to a seven-track, battery-operated tape recorder (Electronic Specialty). Since the shore location was considered unsafe for attended operation, the recorder was started well before and stopped following each explosion. The recorder contained approximately 1 hour of recording tape.

Hydrophones 1 and 2 were placed approximately 150 yd from the blast center and hydrophone 3 was about 350 yd away (figure 1). Hydrophone 1, located at a known position near shore, was used to confirm the positions of hydrophones 2 and 3 by means of signal-arrival times, as recorded by the tape recorder. The difference in arrival times between hydrophones 1 and 3 was 105 milliseconds. See figures 4A and 4B, respectively, for the sensitivity responses of the three hydrophones and for the tape recorder record and reproduce response levels.

Signals to the tape recorder were routed through a control panel containing three attenuators, one for each hydrophone. As a precaution against signal overload, the attenuators were set at 30 dB. Three of the seven tracks on the tape were used to record the signals from the hydrophones, three were coupled to the attenuators, and one was used for voice. To provide calibration signals, which would be recorded prior to the blasting, a portable, battery-operated calibration oscillator was placed at the recording site. The recorded tape was analyzed in the laboratory on a Sanborn recorder.

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*C-4 explosive is 1.34 times more powerful than TNT on a weight-to-weight basis.

BIOLOGY

A variety of live, healthy organisms were placed in cages that were positioned at 200, 400, and 600 yd, along a line running offshore, from the demolition area. The specially constructed cages, which measured 2 ft on each side, were square, covered with chicken wire, and equipped with hinged tops (figure 5). The cages were suspended 15 ft below the surface by using 55-gal oil drums as buoys. One-hundred-fifty-lb cement anchors kept the cages in position. The anchors and buoys were connected to the cages by 1/2-in. nylon line.

To capture test animals, a local bottom-fish trap and six minnow traps were baited and placed in the cove. After 2 days in the water, neither type had captured a single organism. Therefore, fish were captured by hook and line and kept in cages suspended from the operations boat. In addition, divers hand-picked benthic animals that were also used as test samples.

To update the earlier site survey,[1] the marine life was again surveyed on the day before the demolition. A marline was run from the beach out 150 yd into 60-ft-deep water. Approximately every 25 yd along this line, the type and relative abundance of organisms were noted and photographed (figure 6). Water visibility was estimated to be 25 to 35 yd.

RESULTS

DEMOLITION

At 1210 (local time), 400 lb of C-4 explosives in the water and approximately 1370 lb on the beach were detonated. This explosion cleared the hillside close to the beach for use as a vehicle-access road (figure 7). Then the operations boat, which was about 2000 yd offshore, returned to a point about 50 yd from the cove to repair the fuses and make observations. Visibility under the surface was very limited according to the UDT divers, the only personnel allowed in the water.

The second explosion, only 40 to 60 lb of explosives, occurred at 1407. While the operations boat maintained station offshore, outboard motor boats were used to transport personnel to the cove to repair and then ignite the fuses. The third and most powerful explosion, approximately 2170 lb of C-4, occurred at 1500.

All the underwater explosives were detonated in shallow water so that much of the energy was vented skyward. Moreover, the placement of the explosives ensured that the major force of the blasts was directed shoreward.

PRESSURE LEVEL

The quality of the acoustic data from the first explosion was not suitable for any subsequent meaningful analysis. The second explosion was not recorded because the tape recorder ran out of tape and could not be reloaded before the explosives were detonated. However, the pressure levels resulting from the third explosion, by far the most powerful, were recorded.

Hydrophone 1, which was positioned very close to the center of the blast area, became overloaded and could not be used as a reliable acoustic-pressure indicator. Therefore, it was used only to confirm the positions of the other two hydrophones. The peak level of the signal from the third blast was compared to the recorded calibration level. The measured signal at hydrophone 3 (350 yd from the blast center) was 216 dB//1μPa or 9.15 lbf/in.^{2}.* The level at hydrophone 2 (150 yd away) was 212 dB//1μPa or 5.77 lbf/in.^{2}. These results indicate that hydrophone 2 either was positioned in a bottom depression or was defective.

BIOLOGY

The observations recorded in reference 2 confirmed the earlier observations[1] that the cove is relatively poor biologically. In general, the biota increased in variety and abundance seaward from the beach into deeper water. In the first 50 yd, only a few small fish, chitons, and sea urchins (Diadema sp. and Lytechinus sp.) were noted. At 50 to 150 yd, an increasing number of reef fish, urchins, and brain and gorgonian coral (sea fans) were observed. Colonies of Staghorn coral (Acropora palmata) and encrusting coral (Millepora complanata) that had very little vertical development were also found. Only one large gastropod was observed in the entire area.

On 4 and 5 May, wind gusts of 30 to 35 knots and strong along-shore currents made it difficult to maintain the cage assemblies at the desired locations. One cage assembly was lost and only the cage from another was retrievable. On 5 May, the day of the demolition, it was only possible to position two cages (see figure 1). Cage 1 was approximately 150 yd from the blast area and cage 2 was about 350 yd away. Cage 3 was suspended from the operations boat about 2000 yd offshore.

*One micropascal, equal to 10^{-5} dynes per square centimeter, has been adopted by NUSC as the standard reference pressure for acoustic measurements in liquids, superseding the microbar (1 dyne per square centimeter). The effect of the change in reference is a translation of 100 dB in level; e.g., 90 dB//1μB = 190 dB//1μPa.

Six healthy active Queen Triggerfish (Balistes vetula) were placed into cages 1 and 2, three fish per cage. In cage 1, the lengths of the fish were 8-3/4, 8-5/8, and 10-3/8 in. In cage 2, the lengths were 9-1/4, 10, and 10-1/2 in. A large snail (conch type) and a sea urchin (Lytechinus, sp.) were also included in cage 1. Cage 3 had a single 11-1/2-in. specimen of a wrass (Halicoeres maculipinna). Inactive or moribund animals were excluded from the experiment.

All the test animals survived the blasts in apparently unscathed condition. Divers observed the fish to be swimming actively with no observable abnormal behavior. Also, the movements of the snail and the sea urchin appeared to be unimpaired.

Following the first blast, when the operations boat returned to the cove, only six dead fish were observed floating on the surface. Where visibility permitted, divers observed dead fish on the bottom. After the second and third blasts, no dead fish were observed on the surface.

Two hours after the last explosion, the turbidity in the cove had cleared sufficiently for an in-water survey. Live sea urchins, chitons, and returning schools of small fish (2 to 4 in.) were seen in the cove. Sixty dead fish, representing 14 families and weighing a total of 25 lb, were collected.[2] Almost all the Acropora colonies were broken off near their bases and the Millepora appeared to have suffered some abrasion. A few colonies near the mouth of the cove were also broken. In general, however, most of the damage was observed close to the demolition area, with damage decreasing seaward. Very little damage was observed in the deeper water outside the mouth of the cove, where only three dead fish were found.

A second visit to the site was made one day after the demolition.[2] As on the previous day, schools of small fish were observed, as well as some larger (longer than 5 in.) fish. The most common of these were wrasses, surgeonfish, triggerfish, damselfish, and parrotfish. All seemed normal in their motions and behavior.

Turbid water was observed drifting westward after each detonation and little or no sediment was noted on the coral in the cove. The absence of silt accumulation and the high flushing rate of the cove, which rendered almost normal transparency within 2 hours after the blasts, were attributed to the strong alongshore current mentioned earlier.

DISCUSSION AND SUMMARY

The entire at-sea operation was completed within 3 days, 3 to 5 May 1972. On the first day, the baited fish traps were set and the demolition charges were prepared. On the second day, the charges were attached and some of the fuses connected; the hydrophones and shore-recording station were positioned; the cages were set out; and the biological survey was conducted. On the third day, the fusing was completed; the test animals were placed in the cages; the explosives were detonated; and a followup survey was made.

The Navy's objectives of clearing a boat lane and creating a vehicle access route on the beach were accomplished, with little environmental damage to marine life, except in the immediate area of the blasts. The prediction of a shadow-zone effect was apparently correct, since, in the deeper water outside the cove, very little damage was noticeable — only three dead fish were found. Within 2 hours after the last and most powerful explosion, schools of fish were observed in that area. On the following day, more fish were in the cove, indicating that the area could be recolonized in a short time. An adequate number of benthic forms remained in the cove indicating that a quick recolonization was possible. It would be interesting to return to the cove to observe the recolonization over lengthening time periods.

Very likely, the low acoustic-pressure levels measured resulted from the explosions venting skyward, thereby dissipating much of their energy upward and creating only a low-pressure shock wave in the water. Therefore, minimal damage occurred at relatively short distances from the center of the demolition area.

Reference 3 concludes that fish will be killed by an overpressure shock wave of 40 to 70 lbf/in.^{2}, when dynamite or similar explosives are used. Under ideal conditions, 2170 lb of C-4 (equivalent to 2908 lb of TNT: 2170 x 1.34) should produce 159 lbf/in.^{2}* 350 yd from the explosion center. However, the measured lbf/in.^{2} at 350 yd was only 9.15 lbf/in.^{2}. The Queen Triggerfish,

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*Overpressure of TNT calculated according to the formula, $p = 13,000/d\sqrt[3]{W}$, where p = pressure in lbf/in.^{2}, w = pounds of explosives, and d = distance in feet (see reference 4, p. 94).

which were used in this experiment, have highly-developed, gas-filled swim bladders and, therefore, are more sensitive to pressure waves than fish without swim bladders. The shock waves encountered by the fish in the cages were apparently below the harmful level. Future experiments, similar to the one described here, should try to use a greater variety of marine life. However, based on the results of the experiment and the observations of the environmental effects of the explosions, it is felt that the proper precautions were taken to keep the damage to the environment to a minimum.

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4. U. S. Navy Diver's Manual, NAVSHIPS 0994-001-9010, Superintendent of Documents, Government Printing Office, Washington, D. C., March 1970 edition.

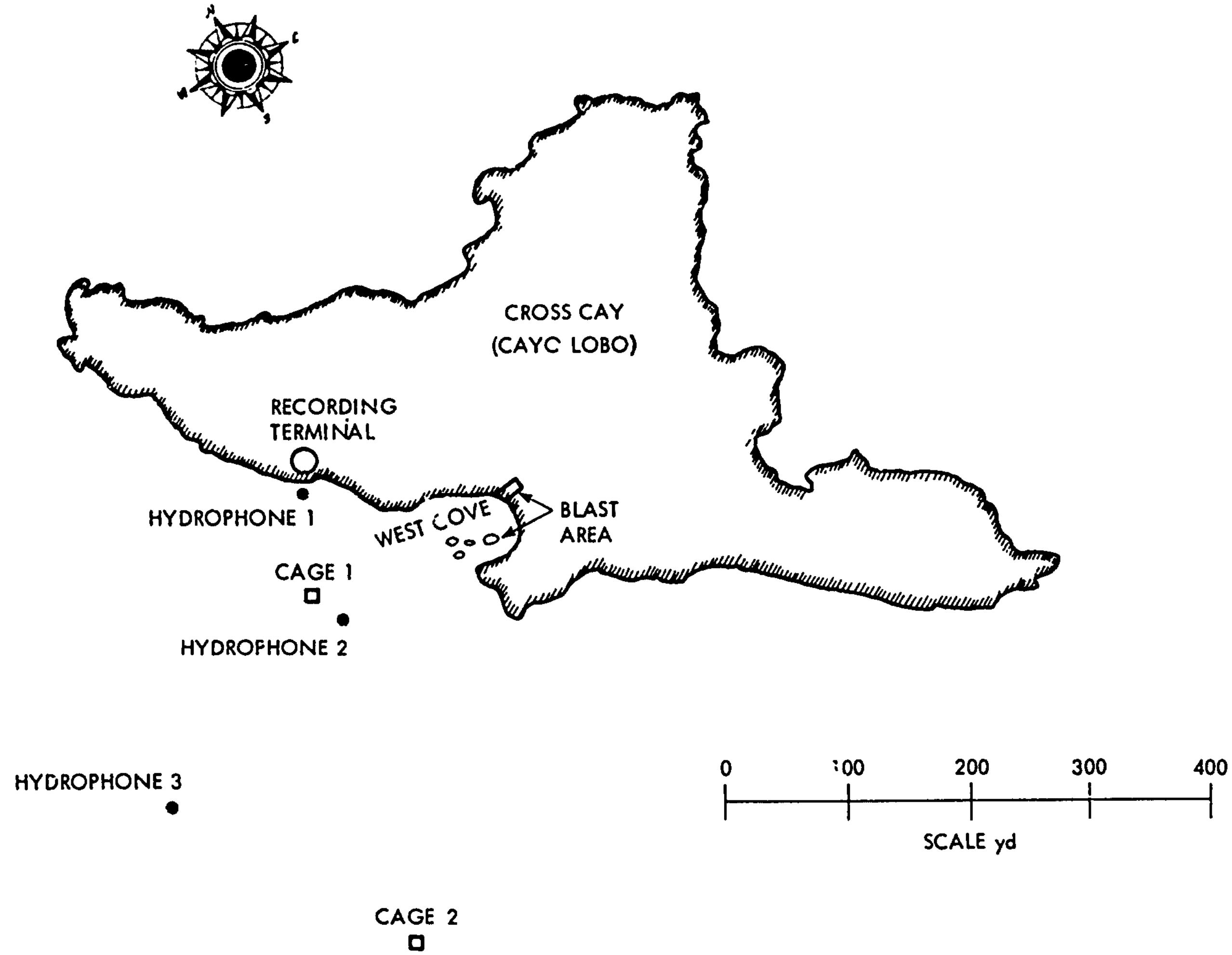

Figure 1. Cross Cay Island and Locations of Hydrophones and Cages

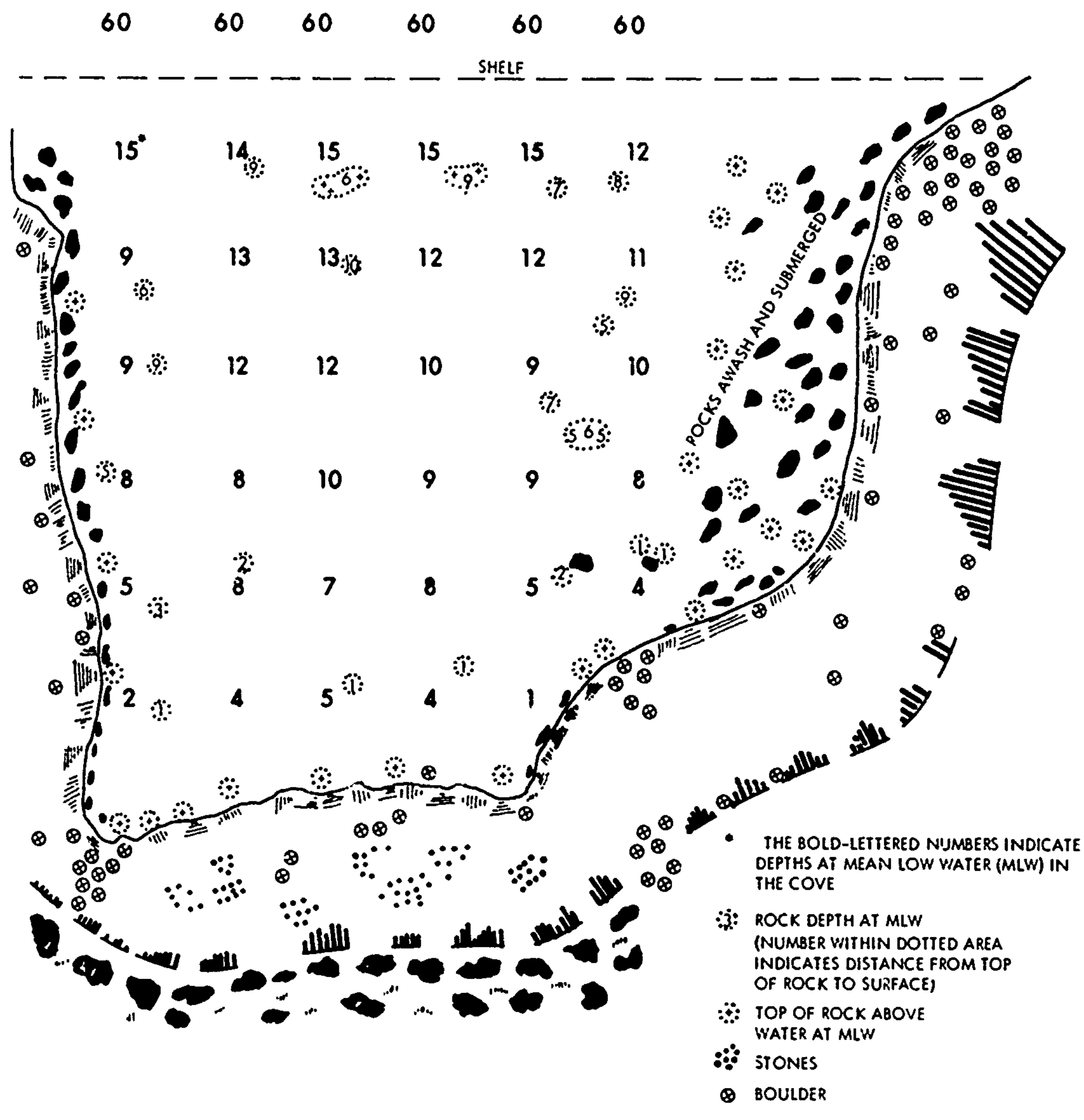

Figure 2. Chart of West Cove, Cross Cay Island

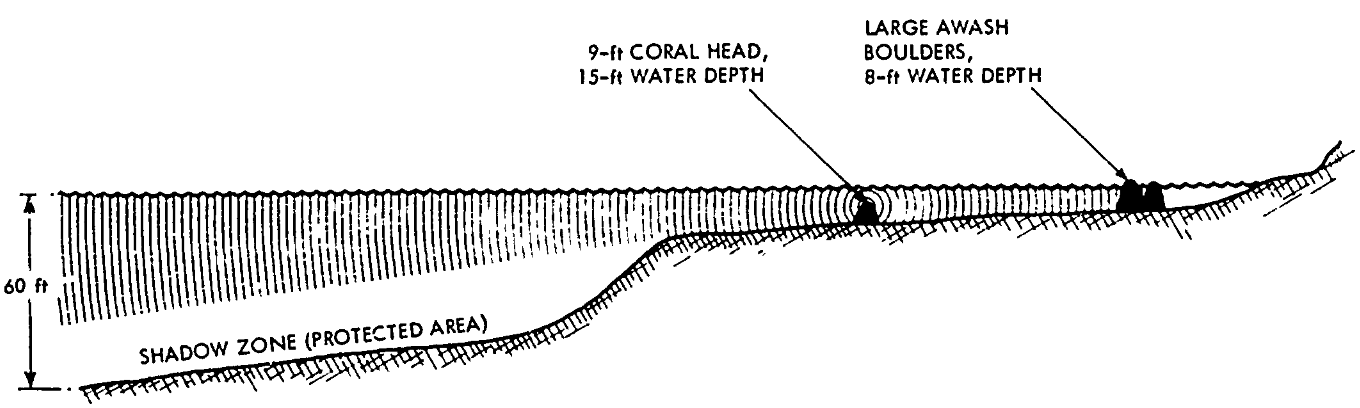

Figure 3. Shadow Zone Created by Blasting in the Cove

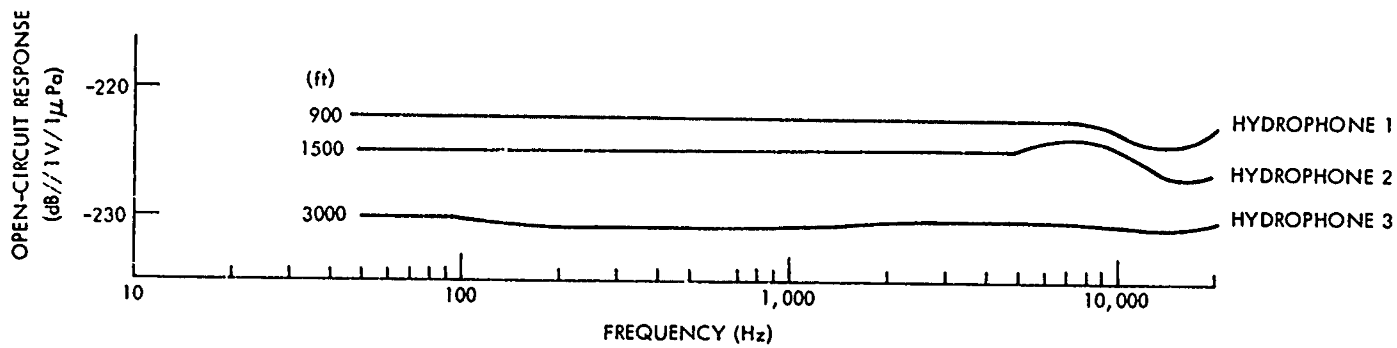

Figure 4A. In-Water Hydrophone Sensitivity

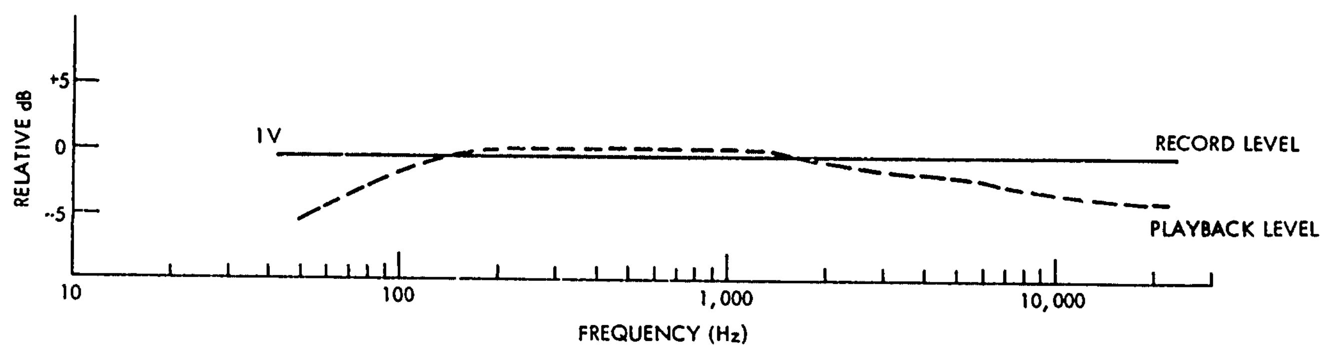

Figure 4B. Tape-Recorder Response

Figure 4. In-Water Hydrophone Sensitivity and Tape-Recorder Response

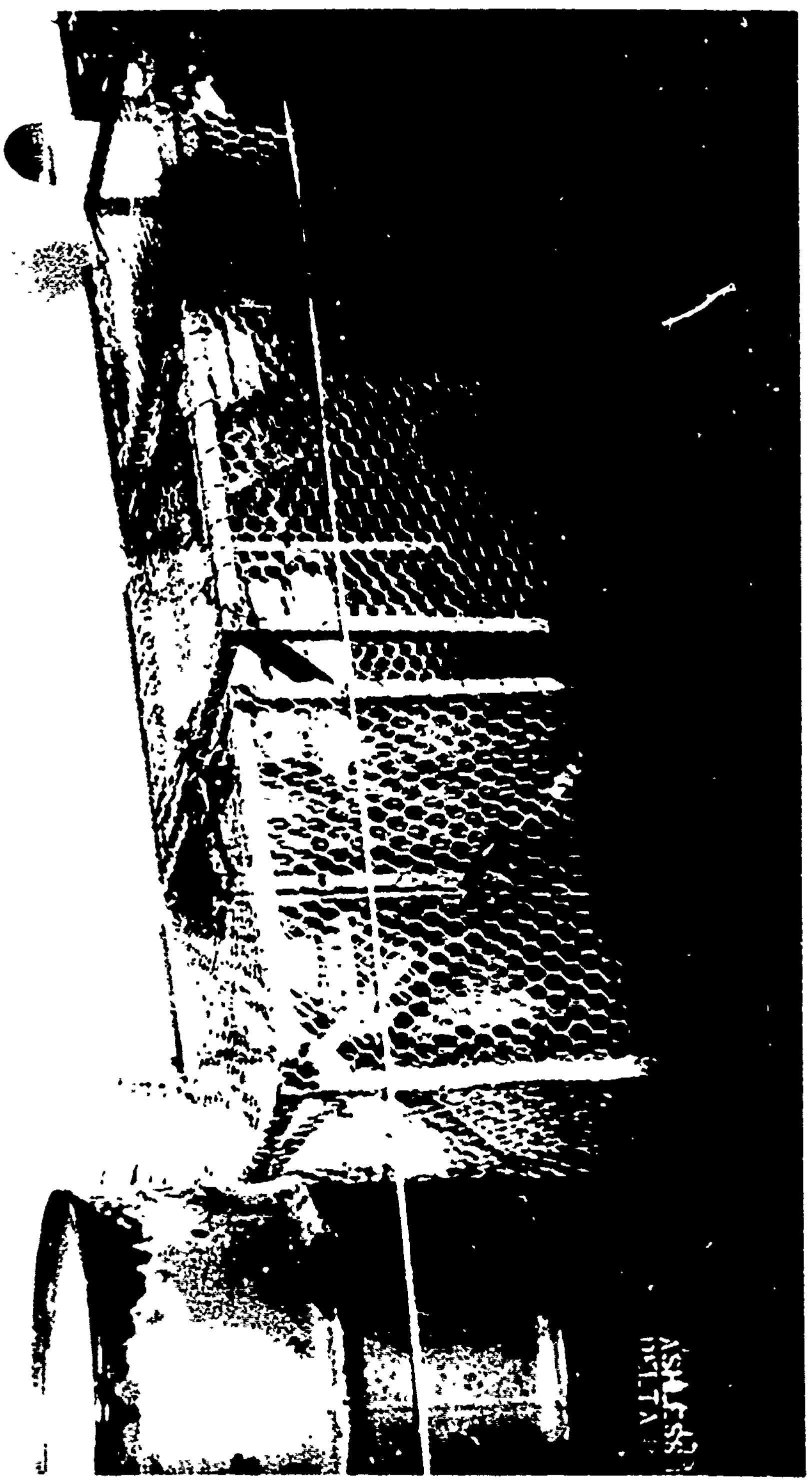

Figure 5. Fish Cages

Figure 6. Photograph of the Bottom (40-ft water depth) 100 yd from the Beach

Figure 7. Effects of the First Blast Showing Cleared Beach Area