TECHNICAL REPORT

TWO APPLICATIONS OF HYDROACOUSTIC TECHNIQUES TO THE STUDY OF FISH BEHAVIOR AROUND COASTAL POWER GENERATING STATIONS

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Contribution No. 511
College of Fisheries
University of Washington

WASHINGTON SEA GRANT PROGRAM
Division of Marine Resources
University of Washington HG-30
Seattle, Washington 98195

WSG 79-2

November 1979

Support for publication of this manuscript was provided by Grant No. NA79AA-D-00054 from the National Oceanic and Atmospheric Administration to the Washington Sea Grant Program.

Additional copies of this publication may be obtained from Washington Sea Grant Communications, Division of Marine Resources, University of Washington HG-30, Seattle, WA 98195.

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KEY WORDS: thermal effluent; fish distribution; fish abundance; power plant effects.

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PREFACE

As part of the original Sea Grant Program at the University of Washington, several faculty members with engineering or fisheries backgrounds were organized into the Marine Acoustics Program. The goal of the program was to investigate the use of hydroacoustics for the assessment of fishery resources. Subsequently, personnel of the program have made several significant contributions to the development of hydroacoustic resource assessment techniques, including theoretical studies, equipment development, and pioneering applications.

Since the Sea Grant Marine Acoustics Program has become widely recognized as a center of expertise in the area of hydroacoustic resource assessment, personnel of the program are often contacted by other agencies for specific applications. The two studies described in this publication were conducted for Southern California Edison and the State of California Marine Review Committee, under the direction of Sea Grant Marine Acoustics Program personnel and using Sea Grant equipment. The primary objective of both studies was to investigate the usefulness of hydroacoustic techniques for studying fish behavior around power plant cooling water intakes.

The San Onofre study focused on the effects of the discharge; however, the motivation for the study was a concern over the potential relationship between thermal attraction and entrapment in the nearby intake. The purpose of such studies is to develop techniques for understanding fish behavior around these intakes, thus ultimately leading to siting and operational procedures that will minimize the impact of these power plants on fish populations. Since the results of these studies are of general interest, we decided to make them more widely available through this Sea Grant publication.

The two applications of hydroacoustic techniques employ distinctly different approaches. The San Onofre study was more conventional in that the transducers were used in a down-looking mode from a moving vessel. However, several modifications were made in response to the unique environment and objective. The Redondo Beach study used an upward-looking transducer mounted alongside the intake and one mounted alongside a television camera on top of the velocity cap of the intake. Using this fixed location mode, we were able to obtain tremendous detail on the behavior of fish near the intake. Using the transecting mode, on the other hand, we obtained considerable information on the more wide-scale effect of the power plant operation on the fish distribution, especially the

significant effect of the thermal discharge. Both studies demonstrate the advantages and potential of using hydroacoustic techniques for quantitative studies of fish distribution, abundance, and behavior.

PART 1

OBSERVATIONS ON THE BEHAVIOR OF FISH AROUND THE COOLING WATER INTAKE OF THE REDONDO BEACH (CALIFORNIA) GENERATING STATION

R. Thorne
W. Acker
L. Johnson

ABSTRACT

Acoustic techniques were used to study the behavior of fish around the cooling water intake structure of the Southern California Edison Generating Station at Redondo Beach, California. The transducer was positioned on the bottom near the intake and alongside a television camera atop the intake structure. Considerable information was obtained on the diel behavior of fish and on their response to the television camera lights.

INTRODUCTION

Power plants with once-through cooling systems can impact fish populations by entrainment of eggs and larvae and entrapment of larger fish. The magnitude of this impact is greatly affected by the behavior of fish and their interaction with the cooling water intake structure. Unfortunately, most techniques for observation of fish behavior in the vicinity of intakes are very limited.

In July 1976, acoustic techniques were used in a study of fish behavior at the Southern California Edison Generating Station at Redondo Beach, California. The purpose of the application was to investigate the utility of acoustic techniques as an observational tool. Considerable information was obtained on diel variations in fish behavior around the intake and on the response of fish to artificial lighting.

MATERIALS AND METHODS

The acoustic system was basically a standard commercial echo sounder. Although this particular model, a 105-kHz Ross Laboratories 200 A, has been integrated into a research system (Thorne et al. 1972), only the conventional graphic display was used for the analysis. A pulse length of 0.6 msec was used during most of the study. The transducer was connected with the echo sounder by a 400-ft, twisted pair, shielded cable so that it could be readily placed at various locations around the intake. The transducer was nominally 26° full-angle (Figure 1.1) and was used at three locations during the study (Figure 1.2). The first two locations were bottom-mounted, upward-looking at 25 and 15 ft from the intake. In addition, the transducer was mounted on a television camera which was located atop the intake structure (Figure 1.3). The television camera was an Ocean/Eye 1000 A-O-F-I-N. Axis of the transducer and camera were aligned and were capable of 360° pan and tilt. A 500-watt Thallium Iodide lamp with a high-intensity reflector was used for night observation with the camera. Acoustic observations were made at location number 1 from 1120 to 1420, July 20; location 2 from 1435, July 20, to 0855, July 21; and at location 3 from 1010 to 1410, July 21, and 2300, July 21, to 0900, July 22.

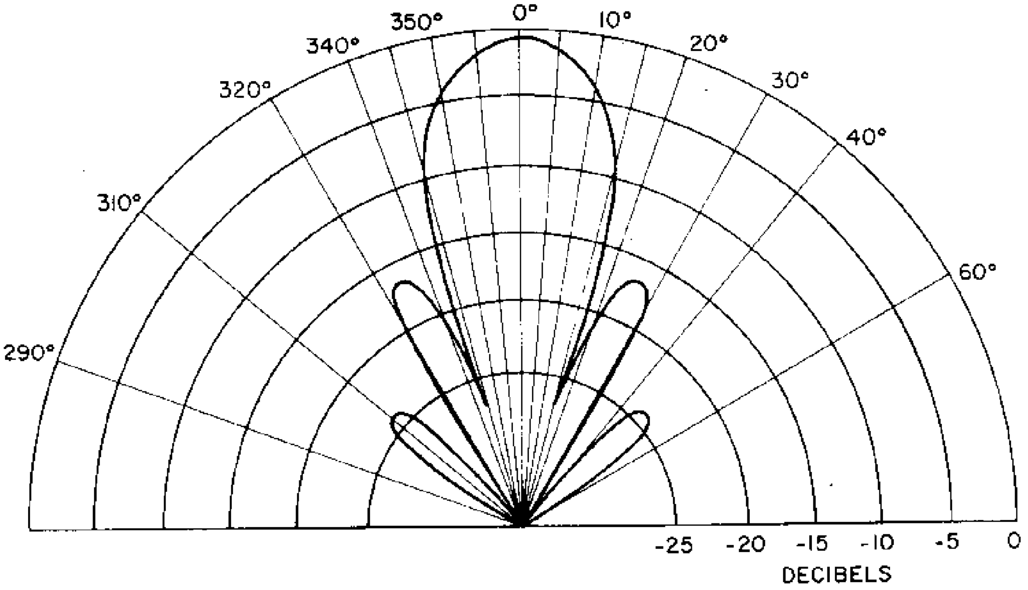

Figure 1.1 Transducer directivity pattern.

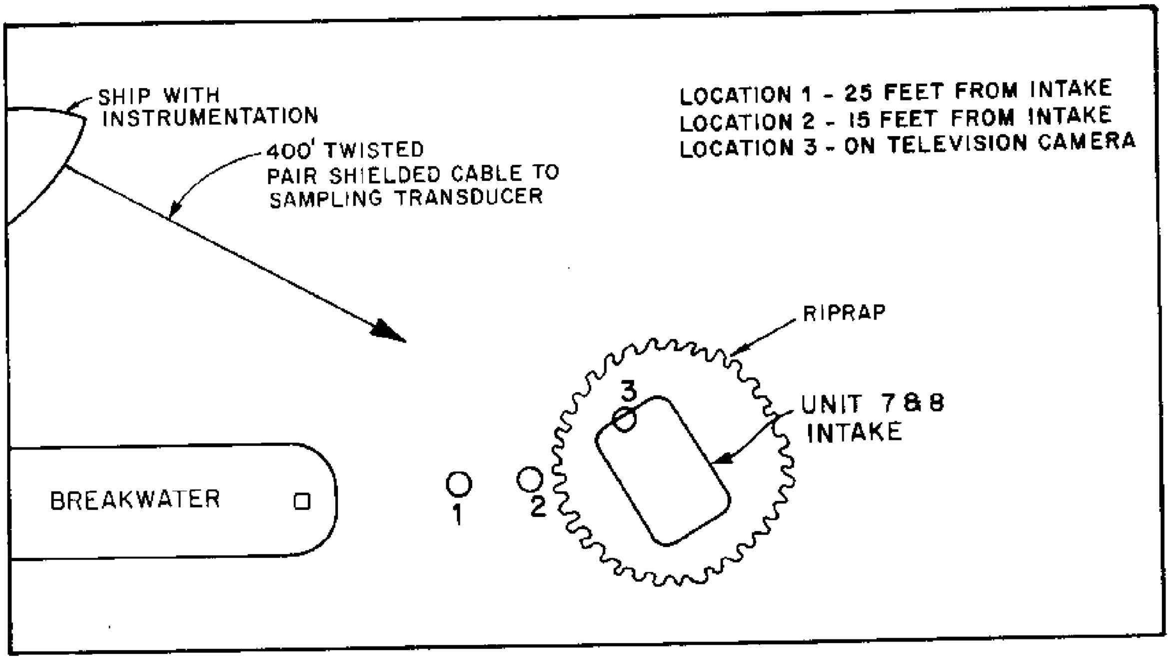

Figure 1.2 Sketch showing transducer locations

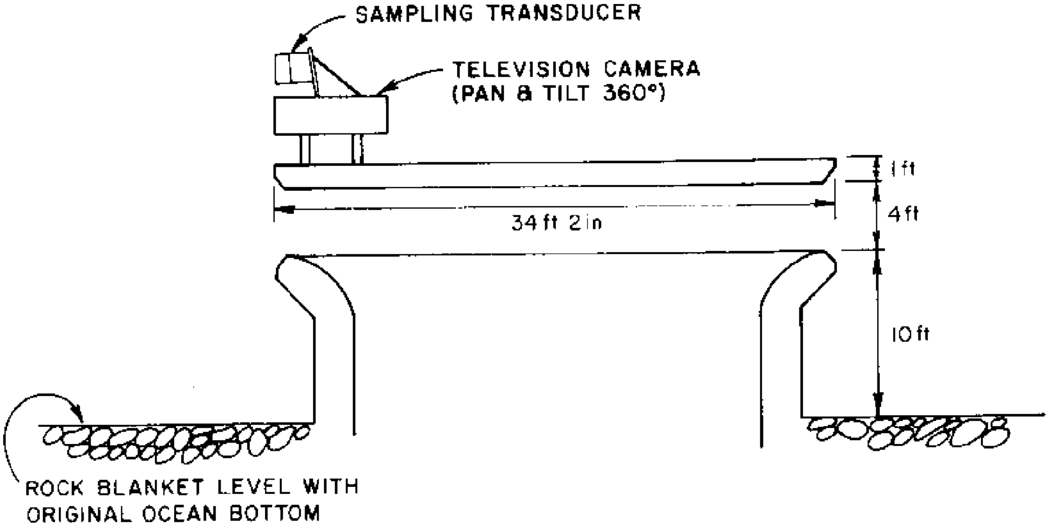

Figure 1.3 Arrangement at location 3 atop the intake structure.

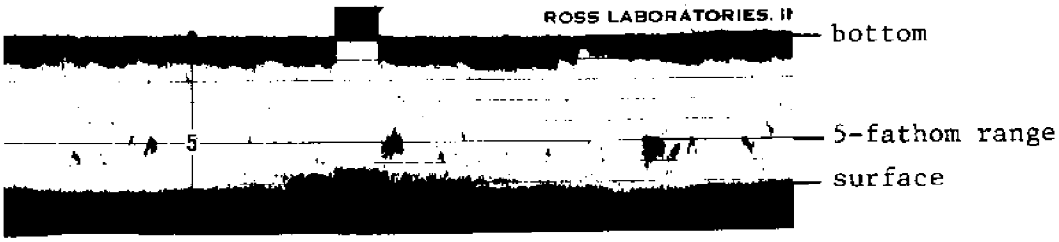

Figure 1.4 Chart recording from location 1, Redondo Beach, 1150-1210, July 20, 1976, showing fish concentration near bottom and occasional schools near surface.

Figure 1.5 Chart recording from location 1, Redondo Beach, 1410-1420, July 20, 1976, showing concentration of fish just above bottom.

RESULTS AND DISCUSSION

Diel Variations in Fish Behavior

The initial recordings taken at location 1 showed high densities of fish very close to the bottom and occasional small schools of fish about 5 fathoms (10 m) above the bottom (Figures 1.4 and 1.5). Often we observed a periodic increase in the vertical extent of the school, followed by a rapid disappearance, as if the school were startled and moved away (Figure 1.5). Dense concentrations of shiner surfperch (*Cymatogaster aggregata*) were observed around and above the intake during this period. Other fish which were occasionally seen on the television monitor included blacksmith (*Chromis punctipinnis*), pile surfperch (*Damalichthys vacca*), senorita (*Oxyjulis californica*), California sheephead (*Pimelometopon pulchrum*), kelp bass (*Paralabrax clathratus*), rainbow surfperch (*Hypsurus caryi*), and jack mackerel (*Trachurus symmetricus*). Similar distribution was observed throughout the afternoon at location 2. However, at dusk

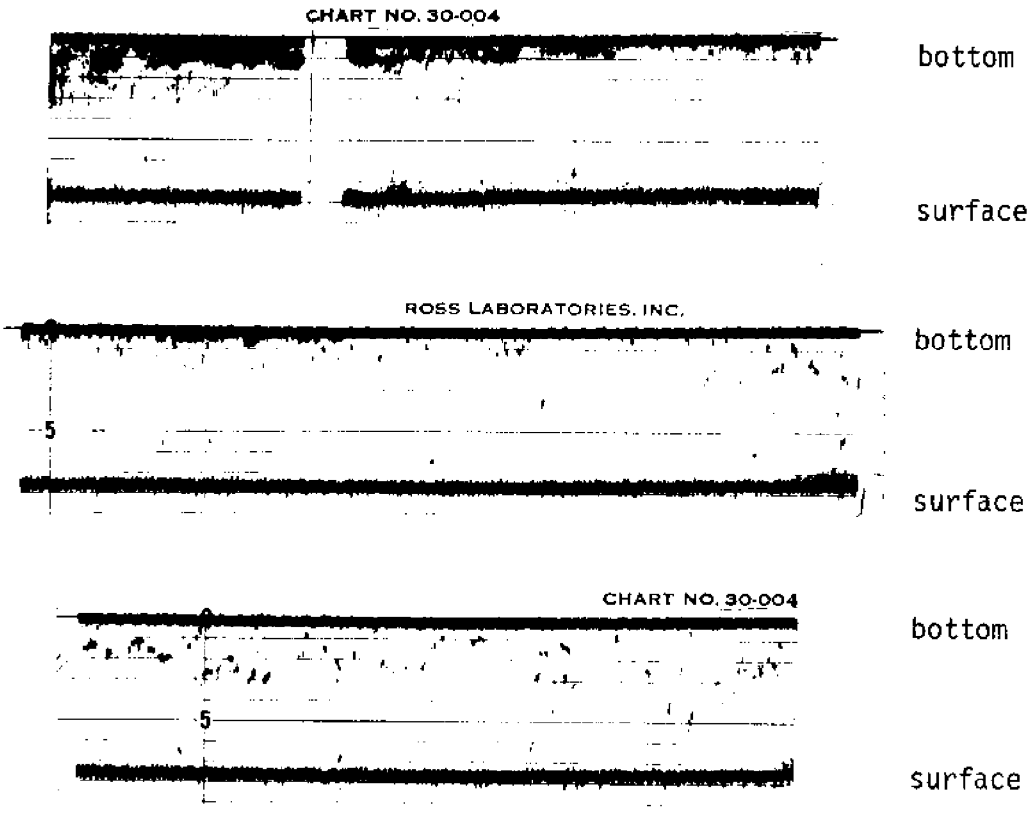

Figure 1.6 Chart recording from location 2, Redondo Beach, 1945-2040, July 20, 1976, showing movement of fish to the bottom and appearance of scattered fish targets in midwater.

the concentration of fish just above the bottom appeared to move down and their acoustic echo merged with that of the bottom (Figure 1.6). Subsequently, scattered targets appeared in midwater. The movement of fish to the bottom corresponds to previous observations on the diel behavior of shiner surfperch, i.e., active in the water column during daylight and quiescent on the bottom at night.

Fish density was generally low throughout the night with most targets within 4 m of the bottom. In the middle of the night we observed a striking change in the appearance of the targets (Figures 1.7 and 1.8). The duration that a single target remained in the acoustic beam began to increase dramatically after 0150, with targets remaining virtually stationary, sometimes for over 10 minutes. After 0430 the durations decreased again, suggesting increased activity as dawn approached.

At dawn, the scattered targets in midwater were replaced with scattered schools. Then a layer of fish appeared to rise off the bottom (Figure 1.9). Shortly afterwards a second layer of fish appeared in midwater (Figure 1.10). This layer gradually merged with the layer on the bottom as the morning progressed (Figure 1.11).

After 0600 sufficient natural light was available for fish observation with the camera. Schools of blacksmith, shiner surfperch, and blue rockfish (*Sebastes mystinus*) and occasional kelp bass and pile surfperch were seen over the cap, but not extending out into the adjacent water column. By 0700 the fish concentrations had spread out into the water around the intake including a large school of jack mackerel and most of the species which had been observed the previous day.

Effects of Artificial Lighting

One of the objectives of the study was to determine whether the television camera lights altered the behavior of the fish around the intake. An indication of the effect of the lights was seen from the acoustic data at location 2 during the first evening when the lights were turned on at 2045. The initial response was a reduction in the number of targets, possibly as a result of the fish moving toward the light (Figure 1.12). Subsequently, the concentration built up to considerably more than the prelight levels. The targets dispersed immediately when the lights were turned off. Several experiments were conducted the next night with the transducer mounted alongside the television camera. The response of the fish to the lights was dramatic (Figure 1.13).

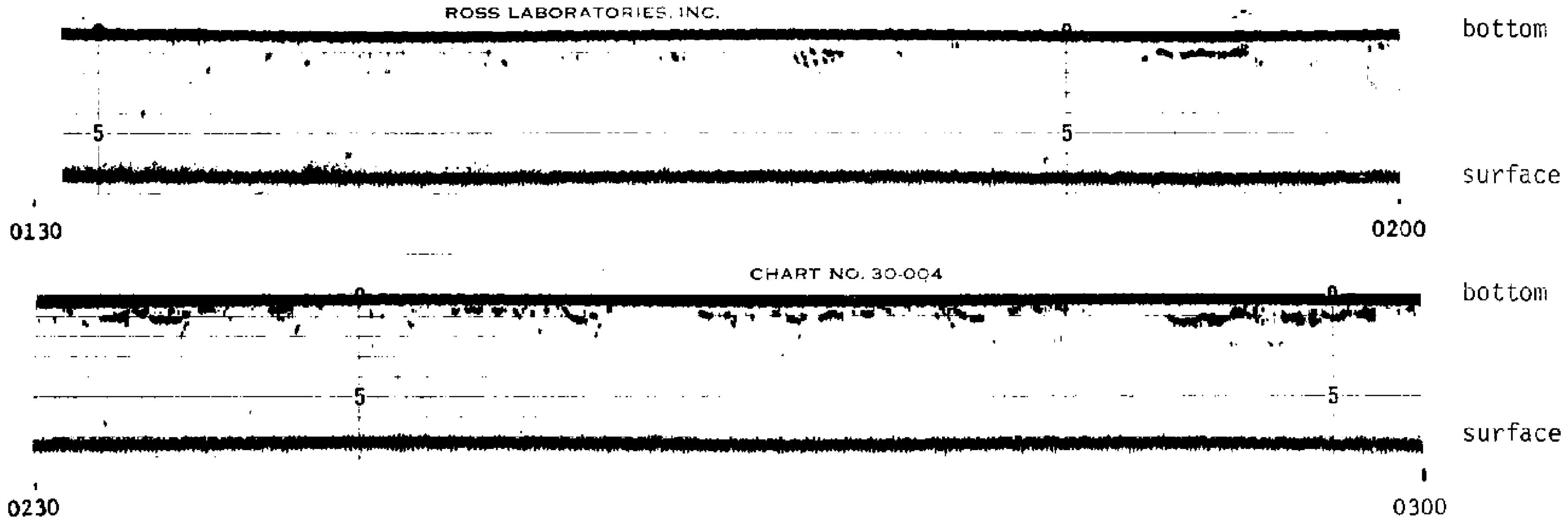

Figure 1.7 Chart recording from location 2, Redondo Beach, 0130-0200 and 0230-0300, July 21, 1976, showing increase in the duration within the acoustic beam for scattered fish targets just above the bottom.

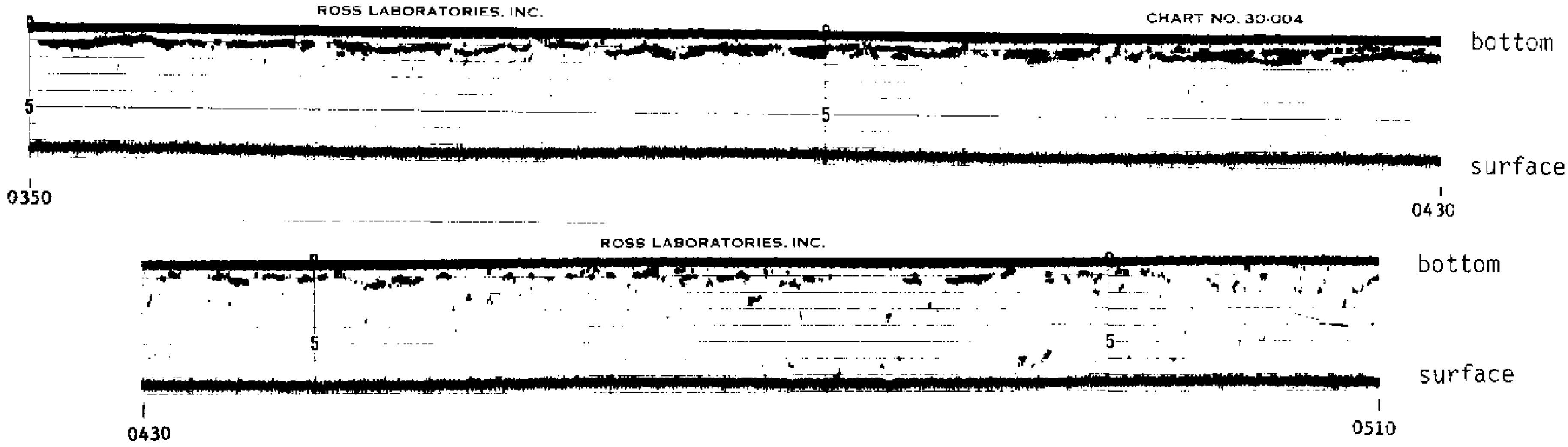

Figure 1.8 Chart recording from location 2, Redondo Beach, 0350-0510, July 21, 1976, showing decrease in the duration within the acoustic beam for scattered fish targets just above the bottom.

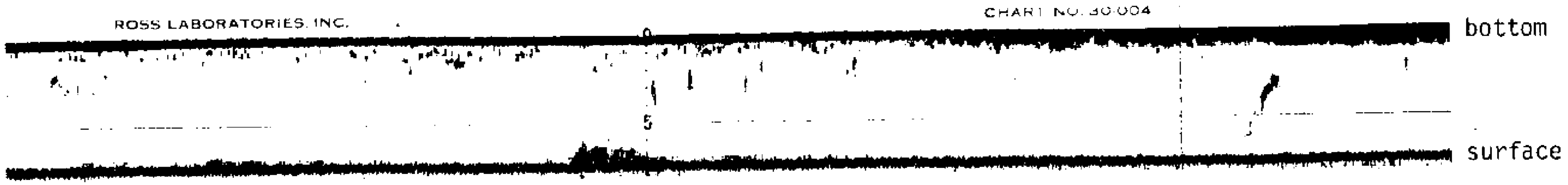

Figure 1.9 Chart recording from location 2, Redondo Beach, 0525-0610, July 21, 1976, showing transition from night to daytime distribution.

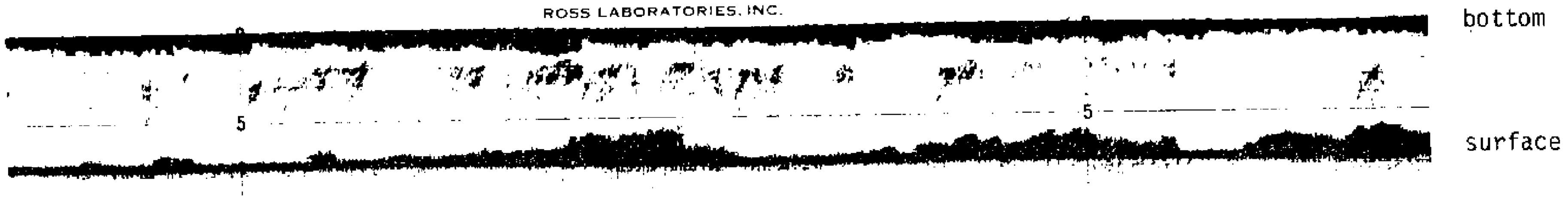

Figure 1.10 Chart recording from location 2, Redondo Beach, 0650-0730, July 21, 1976, showing midwater layer of fish.

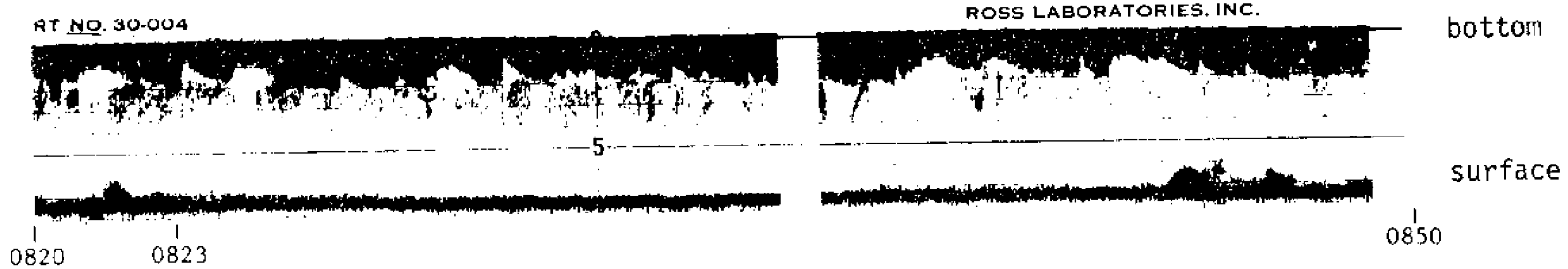

Figure 1.11 Chart recording from location 2, Redondo Beach, 0820-0850, July 21, 1976, showing the merging of the midwater and near bottom fish concentrations.

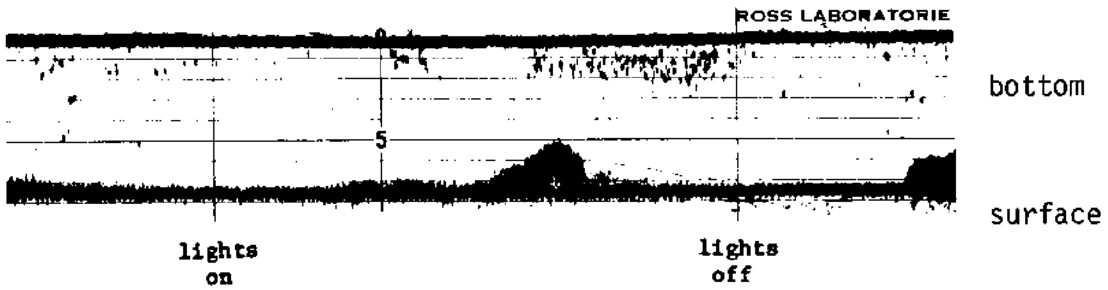

Figure 1.12 Chart recording from location 2, Redondo Beach, 2040-2105, July 20, 1976, showing effects of artificial lighting.

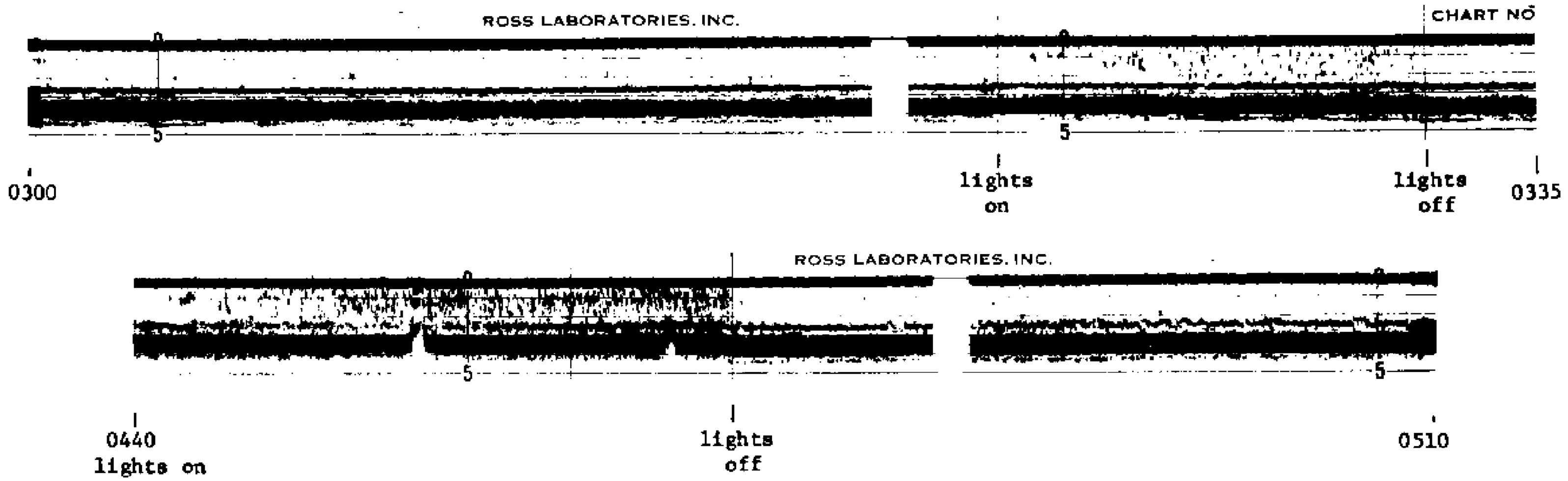

Figure 1.13 Chart recording from location 3 looking down over the edge of the intake, 0300-0335 and 0440-0510, July 22, 1976, showing effects of artificial lighting.

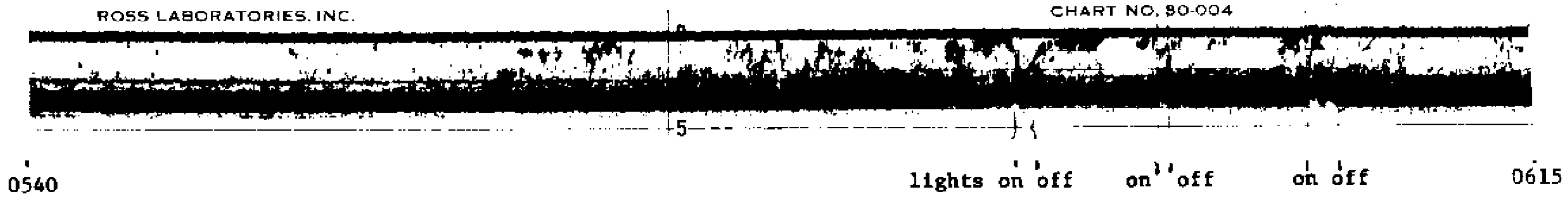

Figure 1.14 Chart recording from location 3 looking down over the edge of the intake, 0540-0615, July 22, 1976.

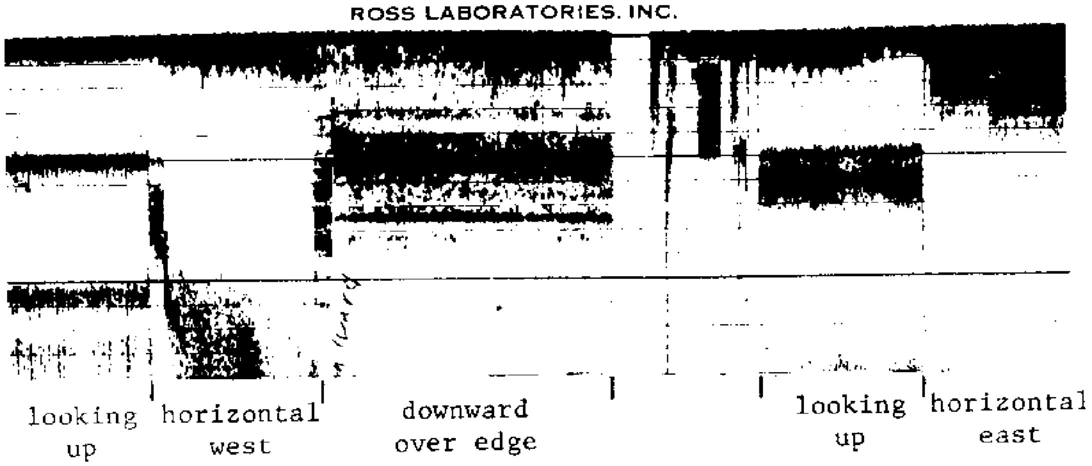

Figure 1.15 Chart recording of various orientations of the transducer at location 3 on TV camera frame, 1335-1400, July 21, 1976.

Generally, the density of targets was very low during darkness, but many targets were rapidly attracted to the lights. Only a few fish could be seen with the camera, and most individuals remained visible for such a short time that they could not be identified. Those which were identified were topsmelt (*Atherinops affinis*). The fish rapidly dispersed when the lights were turned off.

At dawn, fish began to school in midwater around the intake. The camera lights were turned on and off several times, causing a strong reaction of the school even though the ambient light was sufficient for school formation (Figure 1.14). Shiner surfperch and senorita were identified on the television monitor during this time.

Extent of Fish Concentrations around Intake

Large numbers of fish were observed with the television camera around the intake during the day. However, since optical systems have very short range underwater, the extent of the concentrations could not be determined. Acoustic recordings were made in various directions with the transducer monitored on the TV camera frame (Figure 1.15). It is apparent that the fish were closely associated with the intake. The concentration extended only 5-10 ft above the camera level, and a similar distance from the top of the intake horizontally. In other directions, the acoustic range was limited by reflections from the cap structure. The acoustic observations of the extent of fish concentrations around the intake were verified by divers with SCUBA. The divers surveyed along transects which radiated out from the intake and observed the most fish near the intake and over the riprap.

CONCLUSIONS

Several advantages of acoustic techniques were apparent from this study. The sampling power allowed detailed observations of fish behavior over a diel cycle. Only one transducer was used in this study; it was moved to various locations. However, transducer arrays could be used to provide synoptic data from various locations. The acoustic techniques can be applied without disturbing the environment. In this study, the artificial light for the television camera was shown to affect the fish behavior. Similarly, diver observations may affect fish behavior, and capture techniques may impact the fish populations in the limited areas associated with intake studies. Acoustic systems, unlike optical systems, are not limited by turbidity or darkness. This is important in power plant investigations, since lack of visibility is probably a factor in entrapment.

Analysis for this study was limited to examination of the echograms, which are a gross indicator of abundance. However, acoustic techniques for absolute quantification of fish abundance are available and in most cases are more accurate than alternate techniques (Thorne 1977; Saville 1977).

The major disadvantage of acoustic techniques is the lack of direct species identification. Thus, complementary techniques are usually necessary. The development of an optimal combination of techniques is a primary objective of current investigations supported by Southern California Edison.

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PART 2

THE EFFECTS OF THERMAL DISCHARGE ON FISH DISTRIBUTION AND ABUNDANCE IN THE VICINITY OF THE SAN ONOFRE NUCLEAR GENERATING STATION

G. Thomas
R. Thorne
W. Acker

ABSTRACT

The distribution and relative abundance of fish in the water column was investigated prior to, during, and after a shutdown of the San Onofre (Cal.) Nuclear Generating Station. Seven series of acoustic surveys were conducted along transect grids centered at the outfall from fall 1976 to summer 1977. Data on fish abundance were collected with a hydroacoustic system; water temperature data were collected simultaneously using towed temperature sensors; and acoustic fish targets were sampled for species identification using a commercial lampara seiner. The relative fish abundance in the vicinity of San Onofre changed substantially throughout the study period; it was high in the spring and summer and low in the fall and winter, suggesting the expected seasonal pattern in nearshore fish density. However the change in fish density also directly corresponded to the shutdown and resumption of the thermal discharge ($\approx 12^{\circ}$C above ambient). The fact that the decrease in fish density in October 1976 occurred with the cessation of thermal effluent discharge and not with the seasonal decrease in ambient seawater temperature suggested that fish may have been attracted to the thermal effluent. Since ambient temperature seawater effluent was still being discharged during October 1976, the results support the hypothesis that the thermal component of the discharge effluent attracted fish. The lampara net samples suggested that changes in fish density were due to the movement of northern anchovy, queenfish, and white croaker into and out of the study area.

INTRODUCTION

The San Onofre Nuclear Generating Station (SONGS) (Figure 2.1) is owned and operated by the Southern California Edison Company and the San Diego Gas and Electric Company. The Station presently has a single reactor (≈430 MWe output), and two more reactors are under construction (≈2170 MWe added output). As a condition to granting the construction permit, the California Coastal Zone Conservation Commission required that environmental impact studies be conducted offshore of San Onofre. The Commission established the Marine Review Committee to control and implement programs designed to fulfill the Commission's requirements.

At the Committee's request, the University of Washington conducted a systematic study of the fish distribution and seawater temperatures in the vicinity of San Onofre prior to, during, and after a scheduled shutdown of SONGS for refueling. During SONGS operations, the discharge is continuous over a 24-hour period, with a temperature of approximately 12°C above ambient.

The objective of this study was to provide a data base for assessing the effect of the thermal discharge of SONGS Unit 1, and for predicting the effects of SONGS Units 2 and 3 discharge, on the fish distribution around San Onofre. This work involved three phases. The first was to determine the overall distribution of the fish in the area, and whether this distribution was associated with such environmental factors as isobath (nearshore-offshore), substrate (hard or soft bottom), or time period (diel, daily, and seasonal). This phase was accomplished through acoustic surveys. The second part involved the use of simultaneous acoustic-temperature measurements to establish whether the fish distribution displayed associations with water temperature. The third part was to determine the species composition in the study by subsampling the observed acoustic targets with a lampara seine and thereby assess the distribution and relative abundance of fish in the water column.

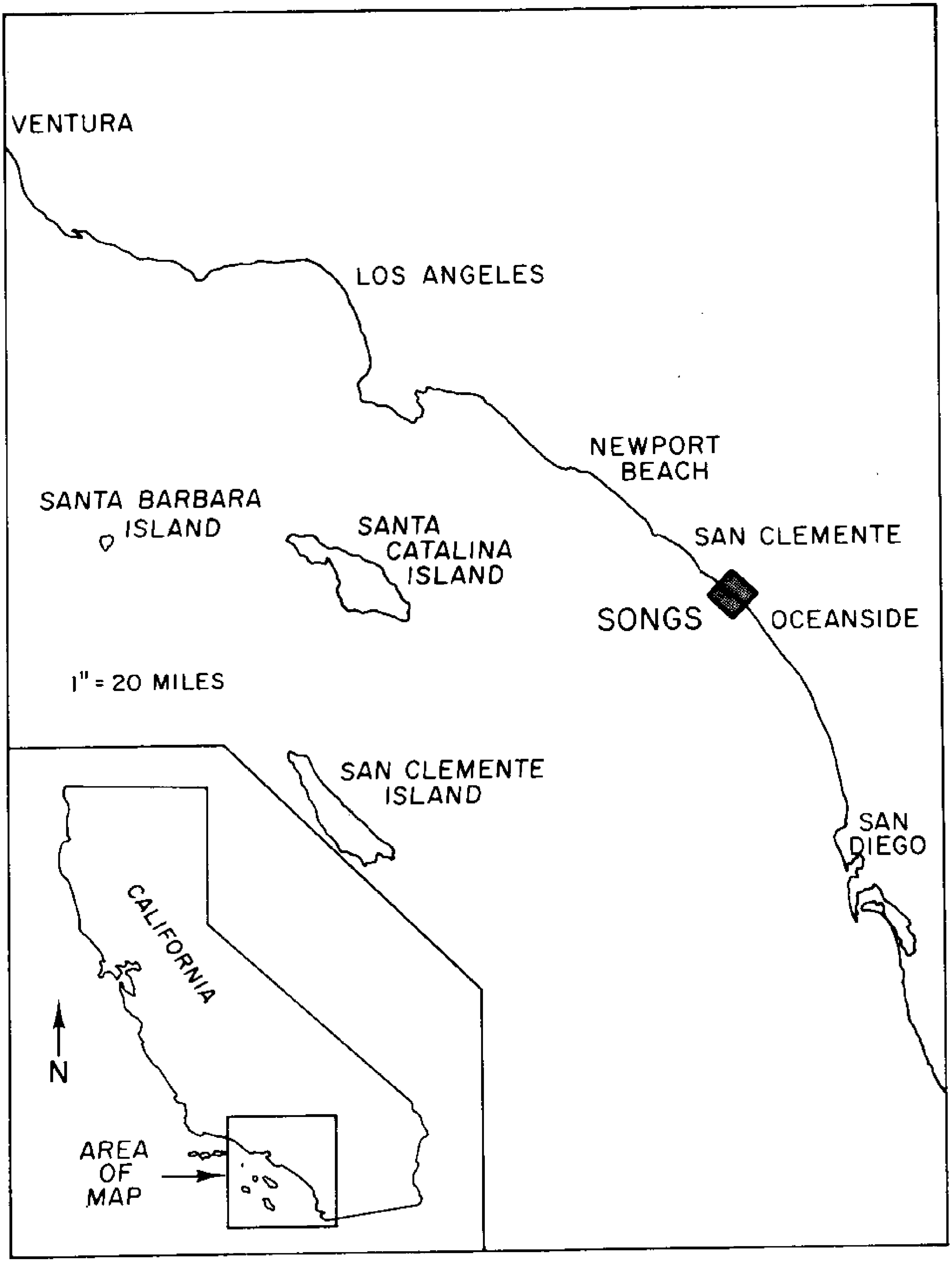

Figure 2.1 Location of the San Onofre Nuclear Generating Station.

METHODS

Data Acquisition Equipment

The hydroacoustic system has been described by Nunnallee (1970). Briefly, the system has a chart recorder to provide output in real time (echograms), and an interface amplifier and magnetic tape recorder to allow data to be stored for later analysis. The echo sounder was a modified Ross 200 A with a source level of about 113 dB (re 1 μbar at 1 m). The pulse width and receiver sensitivity of the echo sounder were adjustable and were set to optimize fish echoes of the SONGS site.

The acoustic transducer had a nominal full angle beam width of 26° at the 6-dB level (referenced to the acoustic axis). This transducer was placed in a Braincon-type 438, 1.3-m V-fin, which was towed with hair-faired, externally armored coaxial cable (Amergraph-type 2J35-RC). The V-fin was towed from a wooden beam protruding from the ship's bow to minimize ship avoidance by near-surface fish.

The temperature measuring system was a modified version of a system developed by the Applied Physics Laboratory to measure temperature versus depth. In this study, data were gathered from temperature and pressure sensors and time-multiplexed through a 1/4-in. tow cable for digital recording on a cassette tape recorder. One pressure (depth) and three temperatures were measured at a rate of 2.5 complete samples per second. The temperature resolution was 0.1°C. The pressure sensor and one temperature sensor were mounted in a V-fin (similar to the one used for the acoustic transducer) that was towed from a wooden beam protruding from the port side of the ship. The V-fin was towed at a depth of 5 m, with the other two temperature sensors placed at 3 m and 1 m.

Survey Technique

Acoustic and temperature data were collected continuously along line transect grids with the 50-ft charter boat *Hustler*. The transect grid designs were varied somewhat in these surveys because of pier construction and to increase replication. However, 3-mile transects were always conducted along the 7-m and 10-m isobaths for comparison purposes between survey periods. The boat's radar was used to navigate and locate the start and end of each transect. Figure 2.2 shows the sampling design with transects of equal distance (1.5 miles) run along isobaths on each side of the discharge area. Eventually, transects at 5-m, 15-m, and 20-m isobaths were added to provide more thorough coverage of the area, with

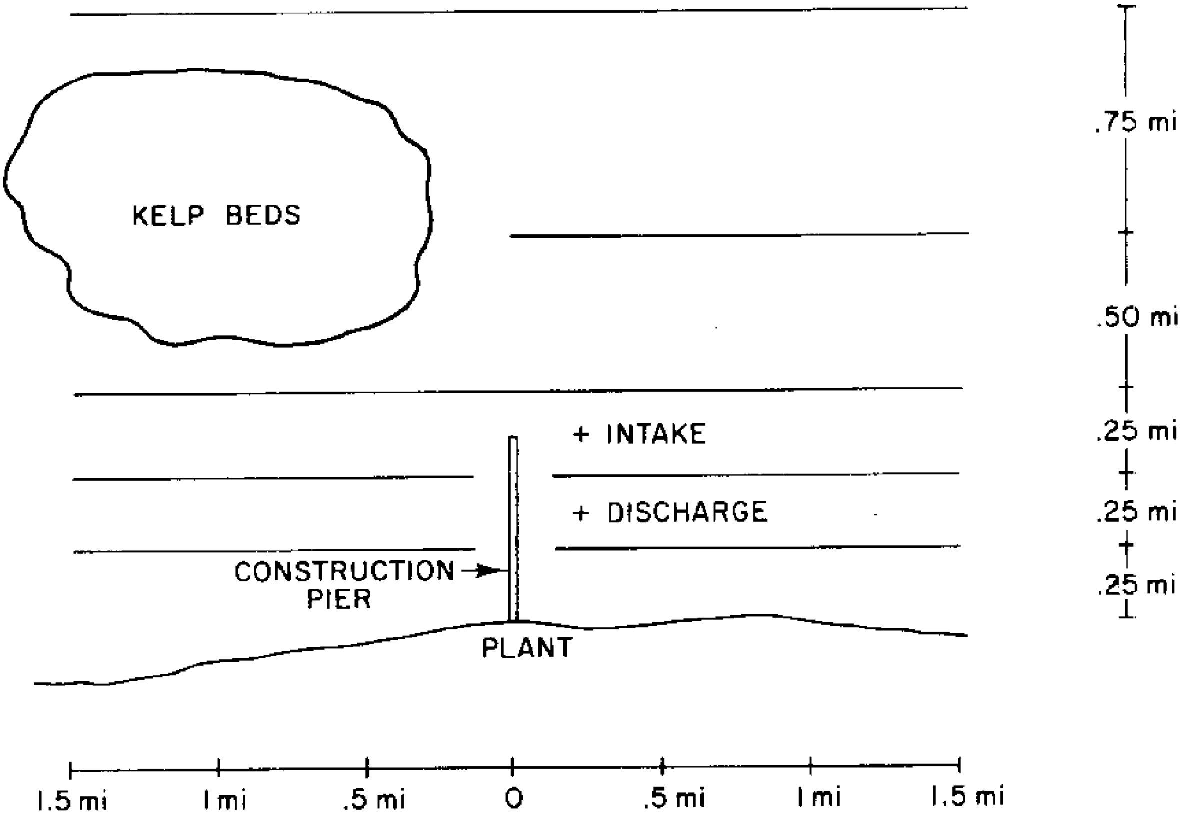

Figure 2.2 Location of acoustic sampling in the vicinity of SONGS.

emphasis on the isobaths near the discharge. Boat speed was maintained at 8 knots ± 1 knot for current and/or wind. Operations were occasionally cancelled due to inclement weather.

Acoustic data were collected in greater detail along a series of short transects run through the outfall area on 2 May 1977; 12 transects were run parallel to shore and 12 perpendicular to shore. Those parallel to shore were run from the pier to 300 m northwest of the outfall. The transects perpendicular to shore were run 300 m in an offshore direction from the outfall. In these series the boat speed was reduced to 4 knots to provide greater detail on fish distribution.

The lampara boat *City of Oceanside* was chartered by Tetra Tech Inc. in order to provide net samples of acoustic targets.

Data Analysis Procedures

The acoustic data were analyzed with digital echo integration system using a PDP 11/45 computer (Thorne, 1977). This system measures and integrates the relative acoustic intensity over preset time and depth intervals. Density values were calculated from the acoustic integration by assuming a target strength of -33 dB/kg. The average temperature (°F), at 1 m and at 5 m, and the average fish density (g/m^2 of surface area) were computed at 1-minute intervals along each transect. All unusual temperature and depth values on the computer output were crosschecked with field notes taken during the original measurements, and erroneous values were deleted. All unusual acoustic values were crosschecked with the echograms, and those due to kelp, surface turbulence, etc. were edited out.

Because the acoustic measurements of fish density were continuous through the study area, determination of far field and near field effects was possible. Far field effects were limited to an area that extended approximately twice the distance of the 1°F thermal plume created by the SONGS Unit 1 discharge of heated water or 1.5 miles up or down coast of the discharge (Marine Advisors, Inc., 1969). Near field effects were determined by examining the fish density measurements in 50 m sections of the transects passing through the SONGS Unit 1 discharge area.

The data were categorized into the following: 1) pre-shutdown, thermal effluent discharge; 2) circulation only, discharge of ambient temperature seawater; 3) shutdown, no discharge; and 4) post-shutdown, thermal effluent discharge.

RESULTS

Far Field Acoustic Observations

Between September 1976 and June 1977, 27 daylight and 10 nighttime acoustic surveys were conducted during the discharge of heated effluent (September, May, and June); 13 daylight and 5 nighttime surveys were conducted during water circulation only, without thermal effluent (October, January, and February); and 3 daylight and 1 nighttime survey were conducted when SONGS Unit 1 was completely shutdown (March).

Extreme patchiness in the fish distribution was often observed. Less patchiness was observed during nighttime surveys, but the harzardous discharge area precluded a large survey effort at night. The major analysis was of the fish density measurements collected during daylight surveys.

TABLE 1. The mean, median, mode, kurtosis, skewness, and variance of fish density values (g/m^2) from the seven acoustic surveys at San Onofre.

Date	Mean	Median	Mode	Kurtosis	Skewness	Variance
September 1976	19.430	5.533	0	96.222	10.001	771.132
October 1976	4.190	0.057	0	238.556	13.124	328.266
January 1977	4.327	0.023	0	97.177	9.374	902.847
February 1977	1.579	0.154	0	121.471	9.551	32.678
March 1977	1.859	0.029	0	54.981	6.673	47.880
May 1977	4.617	0.484	0	464.800	19.650	809.876
June 1977	9.596	1.242	0	86.709	8.351	1081.321

The measurements of fish density were combined for all seven survey periods and the mean, median, mode, kurtosis, skewness, and variance were calculated. The results are shown in Table 1.

These statistics suggested that the distribution of fish density was nonnormal. Therefore, nonparametric statistics and hypothesis testing techniques were employed in the description and analyses of the fish density measurements. Although hypothesis testing with the means and medians gave similar results, the median was used because it is a better distribution-free indicator of central tendency (Siegel, 1956).

Changes in fish density within a day, and between days for each survey period, were examined by comparing the acoustic measurements made on replicate transects. The results of hypothesis testing were: within a day, the fish density measured on the first transect was not different from the second transect ($\alpha = 0.05$); and the fish density measured during a day was not different from other days of that survey period ($\alpha = 0.05$). On our first survey, in September, the density changed substantially between survey days but there were insufficient data collected to test these hypotheses. The September survey was conducted at the end of a period of upwelling (strong offshore winds) which were believed to indirectly affect the fish distribution through shifting the near shore water masses.

Seasonal or operational effects

The fish density in the vicinity of San Onofre changed substantially throughout the study period. The highest fish densities were observed in September, May, and June, when thermal effluent was being discharged from SONGS

Unit I (Mann-Whitney U, $\alpha = 0.001$). The fish densities observed were not highly correlated with ambient water temperatures; because relatively low densities were observed in October when the ambient water temperature was highest (Figure 2.3). The fish density measurements made in March, when the circulation of water through SONGS Unit I was shut down, were not different from the fish density measured during the circulation-only periods of October to February.

Diel effect

The fish density was higher at night during the January to May survey periods. The periods when fish density was not higher at night were the surveys of highest fish density (September and June), and the October survey. These results suggest that the diel effect may be influenced by season. The test statistic values and their levels of significance are given in Table 2.

Substrate effect

The results of tests for difference in the density of fish over hard and soft bottoms displayed a trend similar to the results of the day/night

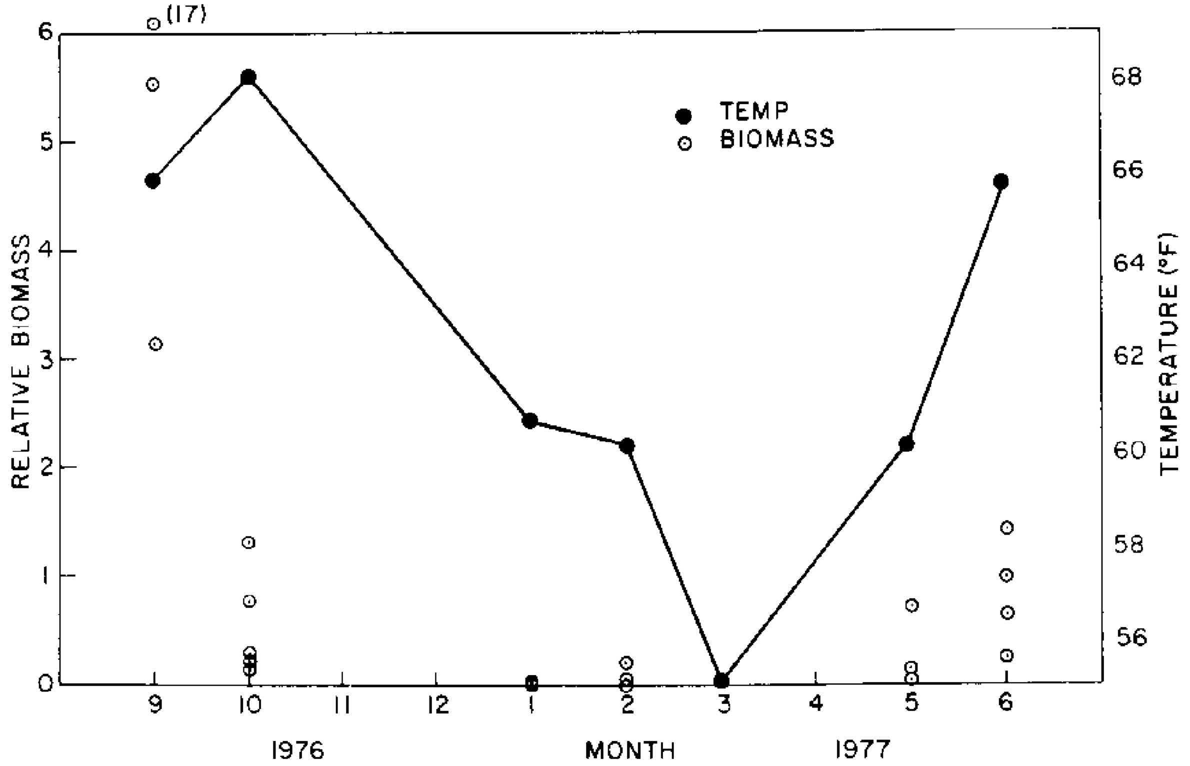

Figure 2.3 Average fish density (g/m^2) and water temperature for each daylight survey from September 1976 through June 1977.

hypothesis testing. The fish density was higher (α = 0.05) over hard bottoms between January and March and was not different during the other survey periods. The test statistics and their levels of significance are given in Table 3.

Current effect

Transects run through the discharge area were examined for far field effects on fish distribution (up to 1.5 miles north or south of discharge area). Aggregations of fish were observed to be associated with the downcurrent side of the outfall area during periods of heated effluent discharge. These aggregations were not always present during the circulation-only and shutdown operations of SONGS Unit 1. The average density of fish on the upcurrent and downcurrent side of the outfall for each of the seven acoustic survey periods is presented in Table 4.

TABLE 2. Values of the Wilcoxon matched pairs signed ranks test statistic (T) and their level of significance for tests of hypotheses of fish density between day and night.

Date	Value of T	Level of significance	Decision for H_o
September 1976	0	0.025	fail to accept (day > night)
October 1976	24	N.S.	fail to reject
January 1977	1	0.025	fail to accept (night > day)
February 1977	0	0.025	fail to accept (night > day)
March 1977	12	0.01	fail to accept (night > day)
May 1977	35	0.025	fail to accept (night > day)
June 1977	114	N.S.	fail to reject

TABLE 3. Values of the Wilcoxon matched pairs signed ranks test statistics (T) and their level of significance for tests of hypotheses of fish density differences between hard and soft substrate.

Date	Value of T	Level of significance	Decision for H_o
September 1976	21	N.S.	fail to reject
October 1976	19	N.S.	fail to reject
January 1977	0	0.025	fail to accept (hard > soft)
February 1977	0	0.025	fail to accept (hard > soft)
March 1977	1	0.025	fail to accept (hard > soft)
May 1977	175.5	N.S.	fail to reject
June 1977	169	N.S.	fail to reject

Near Field Acoustic Observations

Fish were aggregated in all directions around the outfall just outside of the turbulent area during temperature effluent discharge in May. The largest concentration of fish was observed downcurrent from the discharge (Figure 2.4). The lower density of fish at the point of the discharge may have been due to inability to acoustically measure fish because of the turbulence in that area. The concentration of fish was also shown to decrease in the offshore direction from the discharge (Figure 2.5). No transects were run toward shore from the outfall because the waters became too shallow for safe operations.

Species Composition

Thirty-eight lampara net sets were made during the day between January and June 1977. Twenty sets were made during the low-fish-density surveys of January and February, and eighteen sets during the high-fish-density surveys of June.

The species composition changed substantially between the high- and low-fish-density surveys. The species composition, by weight, of the lampara catch was dominated by jacksmelt and shiner perch in January-February, and by queenfish and northern anchovy in June. The percentage of each species, by weight, captured in the lampara seining during these two periods is presented in Table 5.

Lampara net sets were also made near the outfall--two sets in each survey during the January-February and June periods. The species composition near the outfall for the January-February catch (28.7 kg) was 52% queenfish, 19% grunion, 15% white croaker, 8% walleye surfperch, 5% white surfperch and 1% spotfin croaker. The species composition for the June catch (19.8 kg) was 69% queenfish, 8% California pompano, 7% white croaker, 7% spotfin croaker,

TABLE 4. Average fish density (g/m^2 surface) upcurrent and downcurrent from the SONGS Unit I outfall during three operational phases.

Phase	Date	Downcurrent	Upcurrent
Circulation and heated effluent	9/76	27.44	10.81
	5/77	2.08	1.91
	6/77	7.76	4.86
Circulation only	10/76	1.16	0.94
	1/77	1.63	2.89
	2/77	1.90	0.64
Shutdown	3/77	1.08	3.80

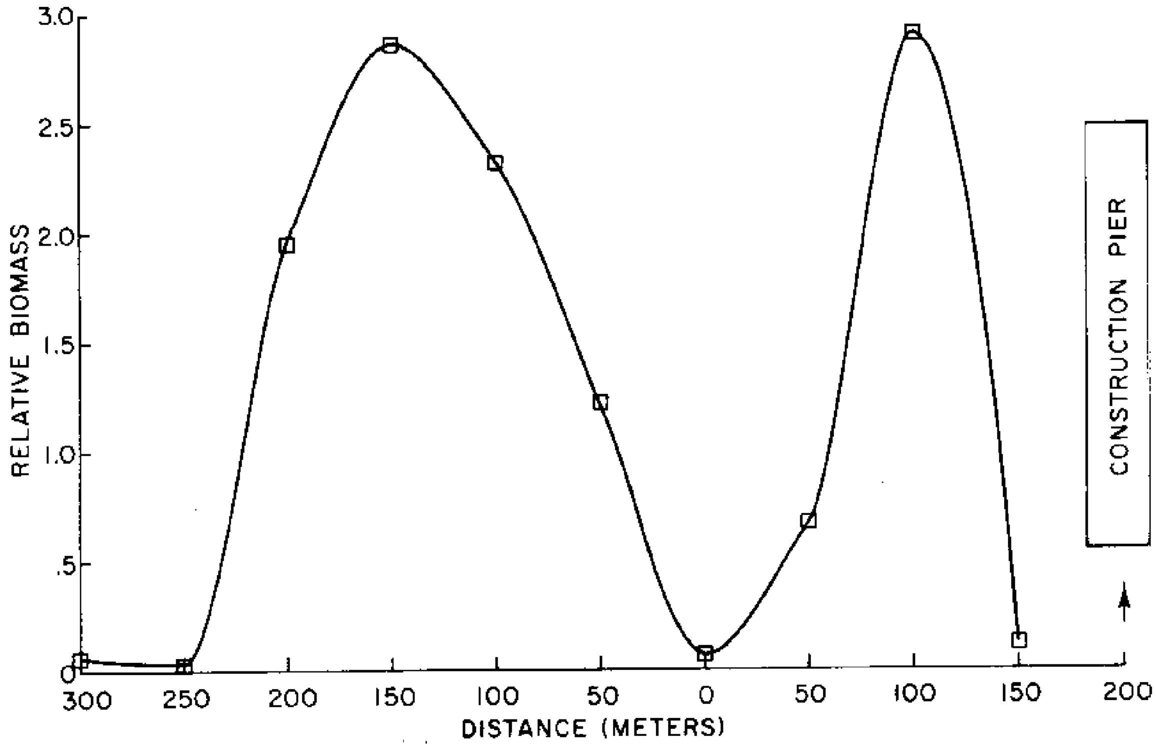

Figure 2.4 Average density of fish (g/m^2) upcurrent and downcurrent from the SONGS Unit I outfall in May 1977.

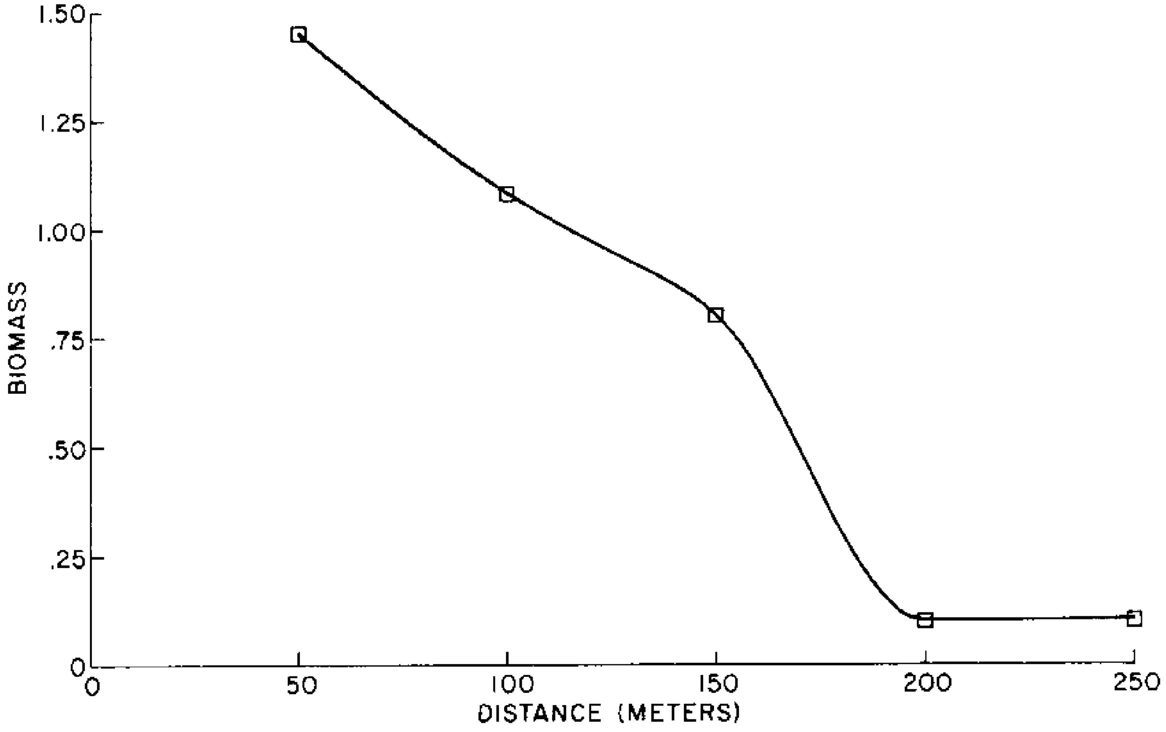

Figure 2.5 Average fish density (g/m^2) offshore from SONGS Unit I discharge in May 1977.

4% white seapearch, 3% walleye surfperch and 2% topsmelt. Bat ray (*Mylibatus californica*) and those species representing less than 1% of the catch by weight are not included in the species composition.

TABLE 5. The percentage and total weight of fish by species captured in lampara seining in January-February and June survery periods. Incidental fish, representing less than 1% of the catch, are not listed.

	Jan-Feb		June	
Species	%	Total Weight, kg	%	Total Weight, kg
Jacksmelt (*Athernopsis californiensis*)	55	211	<1	<1
Shiner perch (*Cymatogaster aggregata*)	18	68	<1	<1
Barracuda (*Syphyraena argentea*)	7	27	<1	<1
White surfperch (*Phanerodon furcatus*)	6	21	<1	<1
Queenfish (*Seriphus politus*)	4	15	44	1516
White croaker (*Genyonemus lineatus*)	4	15	7	250
California pompano (*Peprillus simillima*)	3	13	10	353
Grunion (*Leuresthes tenuis*)	1	2	<1	<1
Topsmelt (*Atherinops affinis*)	1	3	<1	<1
Walleye surfperch (*Hyperprosopun argenteum*)	1	2	<1	28
Northern anchovy (*Engraulis mordax*)	[a]	[a]	35	1193
Chub mackerel (*Scomber japonicus*)	0	0	1	47

[a] present in catch, but not counted or weighed

DISCUSSION

Far Field Effect

Northern anchovy and the sciaenids (queenfish and white croaker) were dominant (86%) during the months of high acoustic density measurements. Atherinids (jacksmelt, grunion, topsmelt) and an embioticid (shiner perch) were dominant (58%) in the surveys of low acoustic density measurements. The simultaneous occurrence of these events suggested that either seasonality and/or the operations of SONGS Unit I influenced changes in the fish community within the study area.

Seasonality undoubtedly explains some of the observed changes in fish abundance and species composition. However, the observation that ambient water temperature was not associated with fish density during October 1976 suggests other factors than just seasonality. Since the changes in fish density observed between the September and October survey corresponded to the cessation of thermal effluent discharge, this suggests that the operations of SONGS Unit I may have affected the fish density and composition.

Near Field Effect

The near field measurements made in May showed large fish concentrations downcurrent from the discharge of heated effluent. Smaller aggregations of fish were also observed just upcurrent and offshore of the outfall. The fish abundance data collected during circulation-only periods suggest that some of this fish concentration may be the result of the warmer water temperatures.

The species composition near the outfall was different from the surrounding study area. Queenfish dominated the near field species composition while northern anchovy or jacksmelt were dominant in the far field. The dominance of queenfish at the outfall suggested that they may prefer the discharge location. Large numbers of queenfish have also been observed to aggregate near the outfall at the Huntington Beach Generating Station (Marine Biological Consultants, Inc., 1973).

The dominance of queenfish near the outfall increased from the January-February to the May survey periods. This increase in queenfish at the outfall may be a result of seasonality and/or the effects of SONGS operations.

The dominant species of fishes observed at the outfall were also those reported to suffer the highest rates of entrapment in the SONGS intake (Tetra Tech., Inc., unpublished, 1977). The intake structure is approximately 150 m offshore from the discharge, which places it well inside the temperature plume created by SONGS operations. Since the fish abundance and species composition observed in this study suggest that the discharge of SONGS Unit I influences both the fish density and distribution, and assuming that fish entrapment is density dependent, it follows that the close proximity of the intake to the discharge may be a major factor influencing fish entrapment.

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