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A FIELD EVALUATION ON THE INFLUENCE OF THE RECIRCULATION OF COOLING WATER (A HEAT-TREATMENT OPERATION) ON THE ENTRAPMENT OF FISH AT HUNTINGTON BEACH GENERATING STATION

by

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Technical Report

to
Southern California Edison Company

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1.0 INTRODUCTION

This paper reports on one of a series of field studies for Southern California Edison Company (SCE) proposed by the Fisheries Research Institute (FRI), University of Washington, and the Fish Encounter Studies (FES), Occidental College. A combination inplant entrapment, hydroacoustic, and net sampling survey was conducted between June 21 and July 1, 1979, at the Huntington Beach Generating Station (HBGS).

The objectives of the June 21 to July 1 survey were to simultaneously measure offshore fish density and inplant entrapment before, during, and after a heat treatment. The results were employed to test the hypothesis that the vulnerability of fish to entrapment before, during, and after a heat treatment is the same.

1.1 Background Information

Heat treatments are routinely conducted at SCE generating stations to remove fouling organisms from the inner walls of the cooling water conduit systems. A heat treatment operation is accomplished by partial recirculation of the cooling water which normally passes once through the system. The water is normally recycled for 4 to 6 hrs at temperatures which exceed the lethal limits of fouling organisms. This procedure results in the discharge of higher-than-normal effluent temperatures (with discharge boil temperature exceeding 30°C) and large quantities of fouling organisms. The anticipated response of the fish assemblage to these discharge conditions is one of attraction.

The discharge sites of the majority of existing coastal SCE cooling-water systems are within a 300 m radius area from the intake which has been demonstrated to have higher-than-ambient fish density (Thomas 1979). Also, the fish density within the 300 m area was found to be almost always highest toward the discharge. These observations indicate that the discharge plume under normal operating conditions may be a major factor influencing the distribution and abundance of fish around intakes. This hypothesis was supported by an observed decline in fish abundance offshore of the San Onofre Nuclear Generating Station following the shutdown of heated effluent from the station (Thorne et al. 1979). In view of these observations the heat treatment interval is shown to have some potential for demonstration of the effect of the discharge plume on fish density.

Preliminary observations at HBGS in 1978 indicated that fish abundance may increase during and/or after a heat treatment. Fish entrapment has recently been demonstrated to be density-dependent (Thomas and Johnson, in press). Since the heat treatment may affect fish density, which in turn affects fish entrapment, a field examination of the heat treatment interval was warranted.

The heat treatment procedure used at SCE power plants has not been evaluated with respect to the fish entrapment problem. If it can be demonstrated that fish entrapment increases during a heat treatment, then temporal and spatial information on this event may indicate when the treatments should be conducted to minimize fish loss. A description of such an effect will provide valuable input for the "best technology available" demonstrations by SCE.

2.0 METHODS

The primary objectives of the field survey were to measure simultaneously offshore fish density and inplant fish entrapment. The measurement of offshore fish density involved the coordination between two separate sampling fractions. First, the biomass of fish was estimated by hydroacoustics. Second, as the fish assemblage was being measured acoustically, a net sampling program was conducted in order to subsample a proportion of the acoustic fish targets for species composition. The measurement of fish entrapment involved incapacitating and removing all fish within the cooling water intake system. These techniques were developed in 1978 at Huntington Beach (Thomas et al. 1979).

2.1 Sampling Gear

The acoustic measurement of fish density was made from the 24-ft charter boat Stingray (Fig. 1). An EK 120 Simrad Scientific Sounder was used in conjunction with a 120 kHz transducer with a half-value angle of 9°. The sounder was triggered with a modified Ross 500 SL chart recorder which provided a data collection rate of 8 samples per second. The transducer was placed in a 2-ft Braincon V fin and towed from a bow-mounted boom to reduce the effect of fish avoidance of the boat on the hydroacoustic measurements. The data were recorded on the Ross 500 SL chart recorder for real time analysis and stored on magnetic tape with a TEAC 3440 recorder for subsequent biomass estimation. A block diagram of the data acquisition system is presented in Fig. 2.

Net sampling of acoustic targets was accomplished with a commercial lampara seine. The lampara net corkline measured 85 m at the bunt of the net (Figs. 3 and 4). The bag of the net measured approximately 60 m deep and was constructed from approximately 1.5 cm stretched mesh. The thread of the net (the section around the bag which represents the initial pursing sections) was constructed from heavy material with an approximate mesh size of 3.8 cm. Attached to the sides of the bag were two 148-m corkline wings which tapered into rope leads. A large float was attached to the primary lead rope and the secondary lead rope was fixed to the boat. The retrieval of the rope leads and wings was made with a dual-hydraulic drive system. Once the bag was retrieved the catch was processed manually.

Fig. 1. Acoustic survey boat STINGRAY displaying bow boom-mounted transducer system.

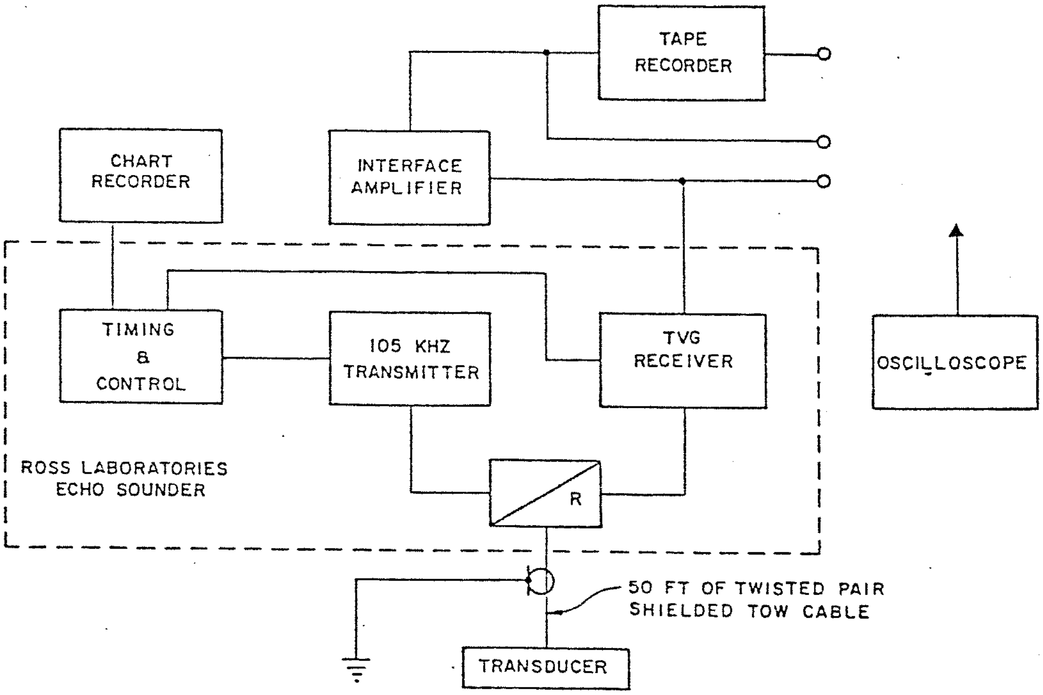
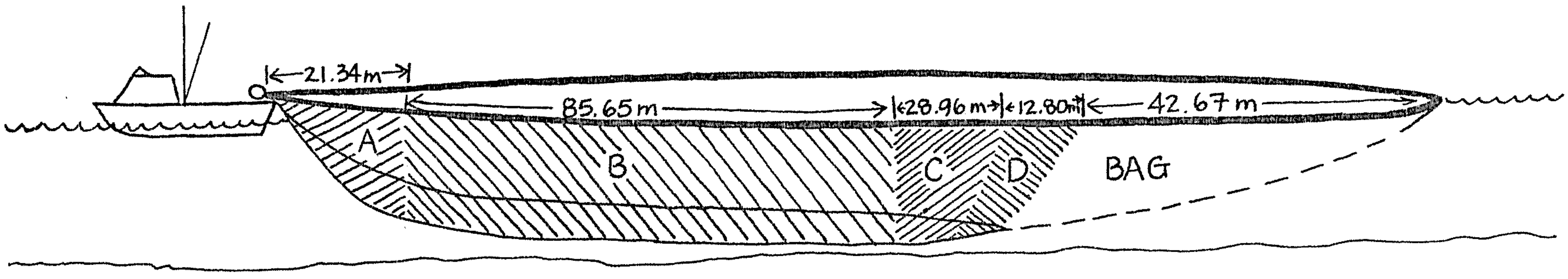


Fig. 2. Block diagram of data acquisition system.



LEGEND

A - 20.32 cm stretch mesh, floats 45.72 cm on center, tapered.

B - 17.78 cm stretch mesh, floats 40.64 cm on center, 30 fathoms vertically.

C - 15.24 cm stretch mesh, floats 35.56 cm on center, 30 fathoms vertically.

D - 3.81 cm stretch mesh, floats 35.56 cm on center.

Bag - 1.59 cm stretch mesh, floats 35.56 cm on center.

Fig. 3. Horizontal view of lampara net.

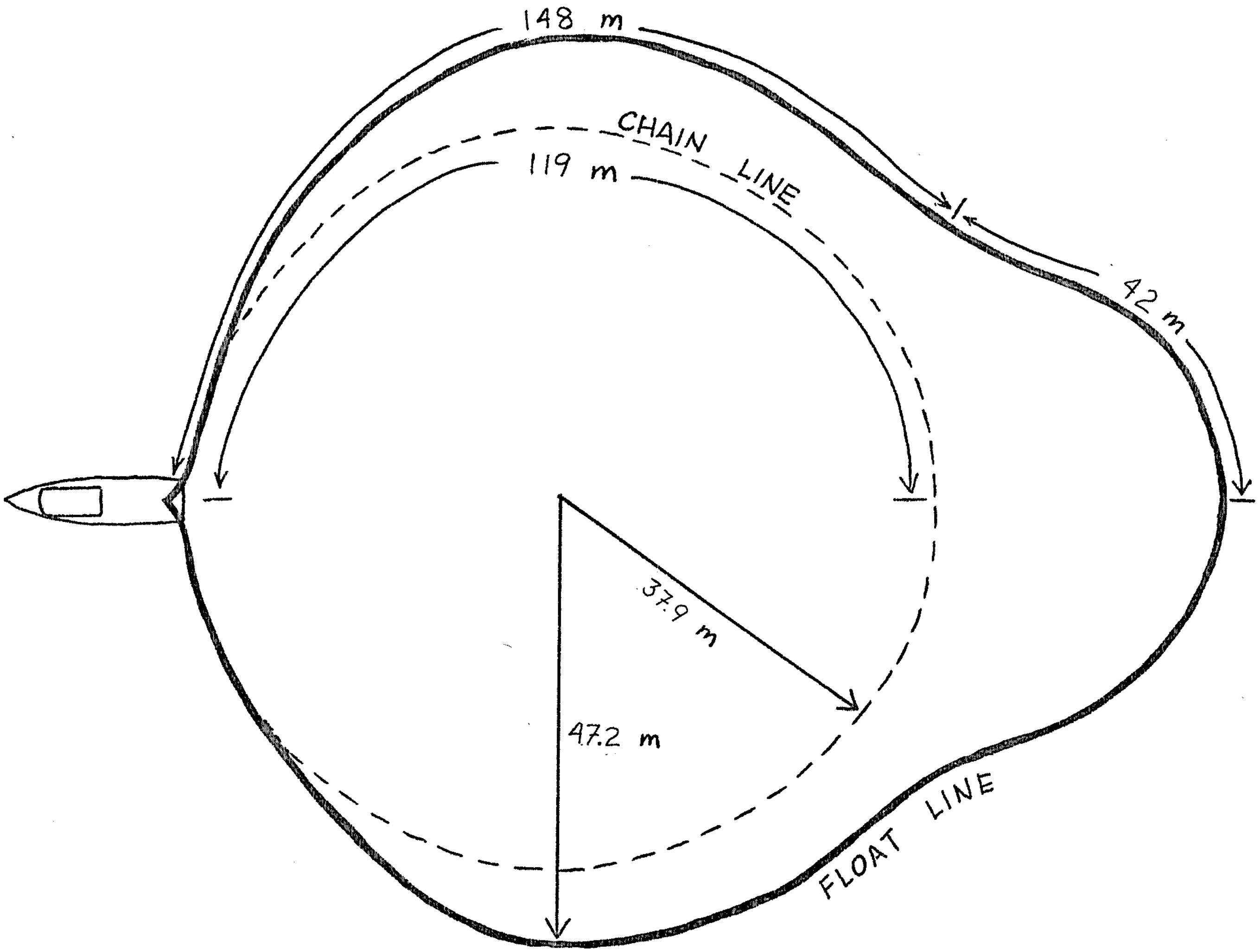


Fig. 4. Top view of lampara net.

2.1.1 Sampling Schedule

Fish entrapment and offshore abundance were synchronously monitored for 5 consecutive nights. A heat treatment was conducted during the third sampling night leaving 2 days of pre- and postsurvey conditions.

A heat treatment operation involves recirculating the cooling water inside the plant in order to increase the water temperature past the tolerance limits of the fouling organisms. The standard procedures of this operation also involve the reversal of flow which results in no-velocity cap as well as reduced flow conditions for part of the operational period. Due to the complexity of this operation we have attempted to describe only its cumulative effect on entrapment, leaving the underlying mechanisms to more specific survey demonstrations, i.e., the reduced flow and velocity cap evaluations. The details of the present heat treatment are presented in the following paragraph.

The heat treatment was conducted between 1900 hr on June 25 and 0400 hr on June 26. The discharge conduit was treated first with the water temperatures elevated to 44°C. At 0000 hr June 26 the flow in the circulating water system was reversed (tunnel swapping) and water temperatures in the intake conduit were elevated to 53°C. At 0330 hr "tunnel swapping" returned the circulating water system to normal flow configuration and water recirculation was discontinued in order to return to normal discharge temperatures. Average ΔT of the discharge boil increase by 6°C during heat treatment operations, from 14° to 20°C.

2.2 Sampling Procedures

Acoustic data were collected on a 600-m crossing transect survey grid and a 3,000-m transect run parallel to the shoreline (Fig. 5). All transects bisected at the intake which provided a uniform sampling effort on each side of the intake. The discharge was approximately 100 m inshore from the intake structure. The 600-m crossing transect grid was run two times per hour, starting at 2330 and repeating at 0030, 0130, 0230, and 0330 each survey night (Fig. 6). The 3,000-m transect was run whenever there was sufficient time between the hourly grid transecting. The boat speed was maintained at approximately 4 knots.

Four to six lampara seine hauls were made in conjunction with the hourly acoustic transect grids on June 25, 26, and 27. An attempt was made to sample all sides of the intake each survey night; however, weather, current, and bottom obstructions often disallowed this kind of effort. The location of each lampara set on the transects was positioned by the deployment of a small lighted surface buoy from the acoustic boat to serve as a mark to set the net around. Time required

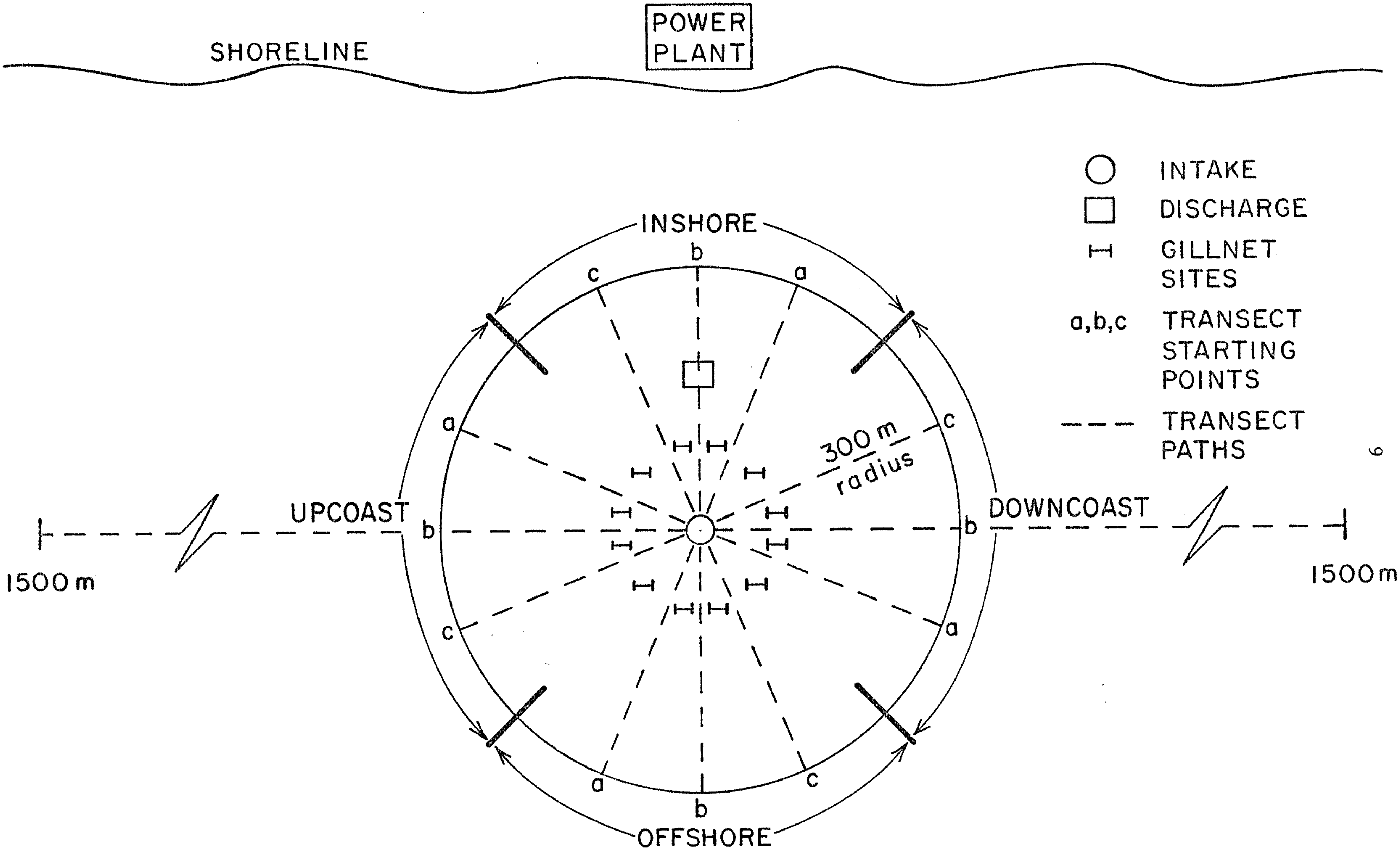


Fig. 5. Schematic of Study Area illustrating stratification into four quadrants (inshore, offshore, upcoast and downcoast) in which the acoustic, lampara and gillnet sampling are allocated. Acoustic transect starting points are randomly selected with the effort being divided equally among strata. Net sampling is allocated by fish density until equally divided among strata. Acoustic sampling is completely replicated whereas net sampling is only partially replicated because of insufficient time.

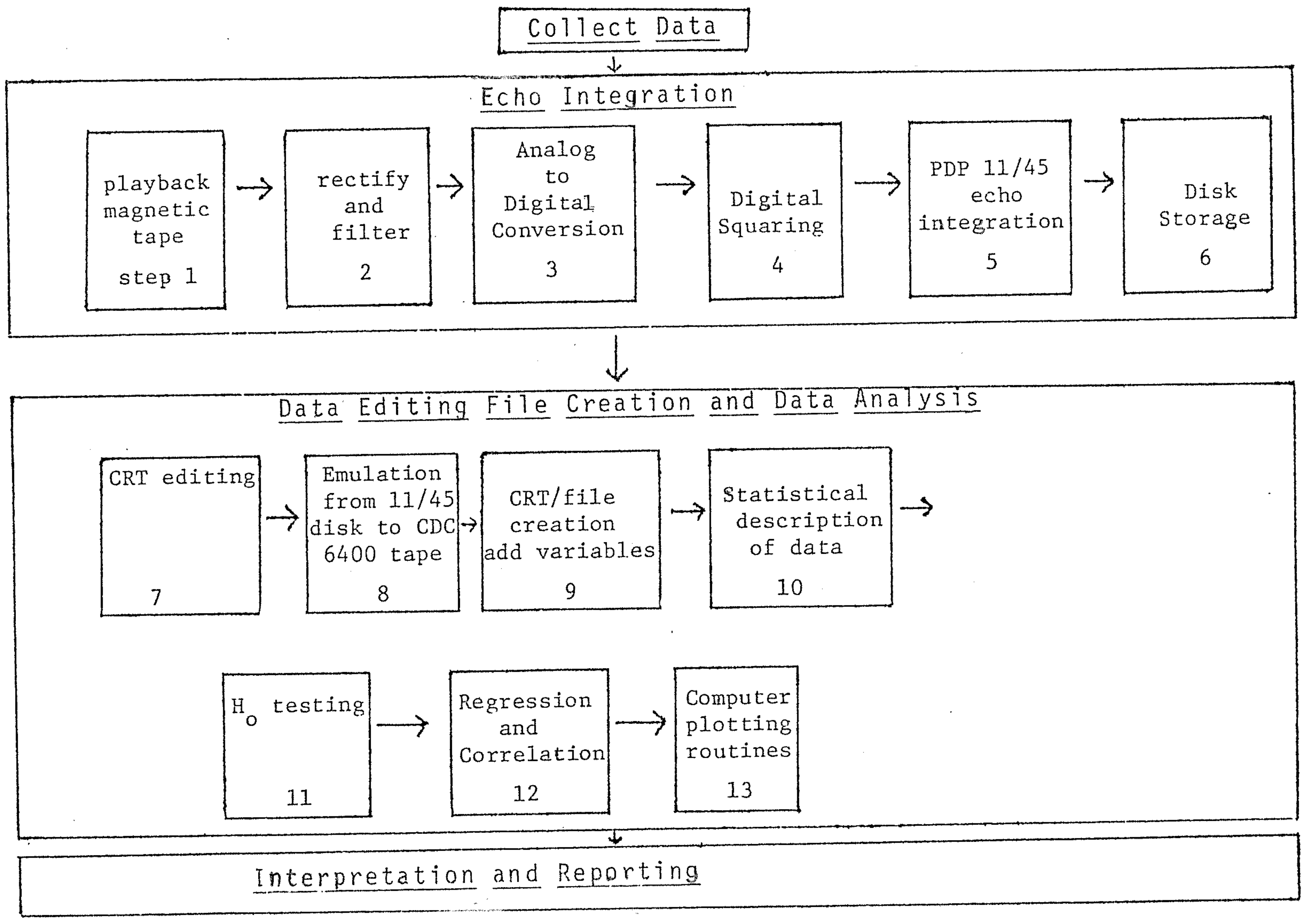


Fig. 6. Block diagram of the reduction, editing, file creation, and statistical analyses of acoustic data.

to surround and purse the light buoy with the lampara seine was approximately 10 min. Large catches, net tears, inclement weather, etc., sometimes reduced the total lampara effort.

The large size of the lampara catches necessitated the following subsampling procedures. First, the total weight of the lampara catch was measured directly. This was accomplished by manually scooping out and weighing the catch with a 1/4 scoop brail after the catch was crowded adequately in the bag of the net. Often the catches were stratified inside the crowded bag, with "greenbait" (anchovy, smelt, butterfish, etc.) on the top stratum (surface) and "brown bait" on the lower stratum (bottom). In any case, strata observed inside the bag were subsampled systematically with equal effort. Up to six 1/4 scoop brails per strata were used to represent the species composition of the total catch. The system for taking these six scoops was to take two at the start, two more when approximately half the fish had been scooped out, and, then the last two scoops in the net. All scoops not saved for subsample purposes were returned to the sea alive. The aliquot of scoops saved was sorted by species as suggested by Paloheimo and Dickie (1963). Fish in the aliquot were weighed and a randomly selected subsample of 100 individuals of each species was measured (standard length). Queenfish and white croaker in the aliquot were stratified prior to measuring lengths into three size groupings which corresponded to age group prior to data recording. The size groupings utilized for queenfish were less than 120 mm, 120-175 mm, and greater than 175 mm; for white croaker, the size groupings were less than 80 mm, 80-140 mm, and greater than 140 mm. These length ranges appeared to correlate well with age 0, 1, and 2+ cohorts of these two species.

The method used to measure entrapment was aimed at reducing the time of residence by the fish in the screenwells, thereby making the rate of entrapment equivalent to that of impingement. Complete clearing of fish from the screenwells was a prerequisite for comparing offshore fish density measurements to entrapment on an hourly basis. This was accomplished by sodium hypochlorite injections.

Chlorine was injected into a screenwell in a sufficient concentration to induce impingement. Impingement resulted from 1) fish swimming downstream in efforts to avoid the noxious stimulant, and 2) partial impairment of swimming capabilities. The injection was made from a 2,000-liter portable chlorine storage tank. The chlorine was metered into the screenwell through reinforced vinyl tubes that were positioned within the dewatering gate slot. The tubes were positioned so that injection occurred about 1 m below the water surface and 1 m above the bottom of the screenwell. Lowflow areas in the screenwells were supplemented with surface injections of chlorine.

At the HBGS injections of 30 gal over a 5-min interval effectively cleared the species of concern from the screenwell. Injections of this dosage resulted in Total Free Chlorine readings at the discharge gate slot averaging 0.56 mg/liter. Chlorine concentrations measured at the gate slot can be expected to decay by as much as 50% before reaching the offshore discharge bubble. Thus, injections of 30 gal chlorine in 5 min probably resulted in discharge concentrations less than the allowed maximum of 0.5 mg/liter.

The amount of chlorine needed per injection to clear fish from the HBGS screenwell was approximately that amount the station normally uses during routine chlorinations. Thus, normal plant chlorinations were cancelled on days chlorine injections were utilized to remove fish from the screenwell.

Water transparency, water temperature, and wind speed were monitored during this survey. Water transparency measurements were obtained by counting the number of rings visible on a grid suspended in the HBGS screenwell. Intake water temperature (^{o}F) measurements were obtained from the HBGS plant operations. Wind speed (mph) measurements were obtained from the Newport Beach Harbor Master operations.

2.3 Data Processing

2.3.1 Hydroacoustic Data Processing

The technique used to convert the acoustic signal into biomass estimates was based on the principle that the acoustic intensity of a signal reflected from fish targets is proportional to the mean individual scattering cross-section of the targets times the number of targets. The scattering cross-section may be expressed for an individual fish or for a given weight of fish. It is usually more convenient to express the scattering properties in terms of fish weight since fish biomass is generally the parameter one desires to estimate, and also it has been shown experimentally that the mean scattering cross-section of an individual fish is approximately proportional to its weight.

Therefore, in order to obtain a biomass estimate from a school of fish, it is necessary to determine the total intensity of the acoustic signal reflected from all the fish. This is done with a procedure called echo integration (Ehrenberg 1973). The scattering properties of fish vary from species to species and with size. However, all swimbladder fishes appear to have similar mean back-scattering strengths as a function of size (Anon. 1978). Acoustic target strength and scattering cross-section are related by

$$TS = 10 \log_{10}\left(\frac{\sigma}{4\pi}\right),$$

A target strength of -33 dB/kg has been used during previous SCE studies to convert acoustic data to biomass estimates. Based on the literature discussed previously and our own experience, this value appears reasonable for swimbladder fishes if the mean length of the fish population is between 10 and 30 cm.

The acoustic data collected at Huntington in 1978 were processed with a digital echo integration system shown in Fig. 7, steps 1 to 5. At "Echo Integration" (step 5) the data are integrated by meter of water column and the relative fish biomass is calculated from the input calibration information. At this step, the minimum horizontal and vertical dimensions of the acoustic sample are determined for the biomass output, the time varied gain (TVG) is corrected to obtain a perfect TVG (electronic TVGs are seldom perfect) with reference to particular depth; and system gain, beam pattern, target strength, etc., are used to standardize the biomass data. Density values at Huntington Beach in 1979 were computed at 20-sec intervals along each transect (approximately 50 m).

At Huntington Beach the water column was shallow enough to transmit at a rapid pulse rate (8 pings/sec) so that an almost continuous volume of water under the transducer was insonified. For purposes of illustration, the sample volume can be considered to be a cone of full angle width about the acoustic axis. In reality, however, it is much more complex. The volume sampled is not only a function of depth but is also dependent upon the interrelationships between depth, fish target strengths, transducer beam pattern, physical properties of the sound transmitted in the presiding oceanic conditions, and the overall gain of and/or power of the echo sounder. These factors were taken into account in the echo integration equation which directly relates echo returns to fish density.

A block diagram (Fig. 7, steps 6-11) illustrates what occurs after the acoustic data were reduced to biomass information and stored on the PDP 11/45 disk. All erroneous data points (bottom and surface reverberation, kelp, air bubbles, etc.) were deleted from the file with the use of a CRT editing routine. The echograms and integration logs were employed to identify measurements which were suspected to contain bottom and/or surface reverberation, etc. The edited data file was then emulated from PDP 11/45 disk space to magnetic tape storage at the University of Washington Academic Computer (CDC 6400). Then, a permanent data file was created for detailed analysis. All pertinent data (water temperature, dates, transect number, species composition, etc.) were time-linked and coded as appropriate.

The echo integration produced measurements of the midwater fish density in g/m^2 surface of each transect. In this manner the average midwater fish density was estimated for each stratum (D_m) of the survey area (inshore, offshore, upcoast, downcoast - Fig. 5).

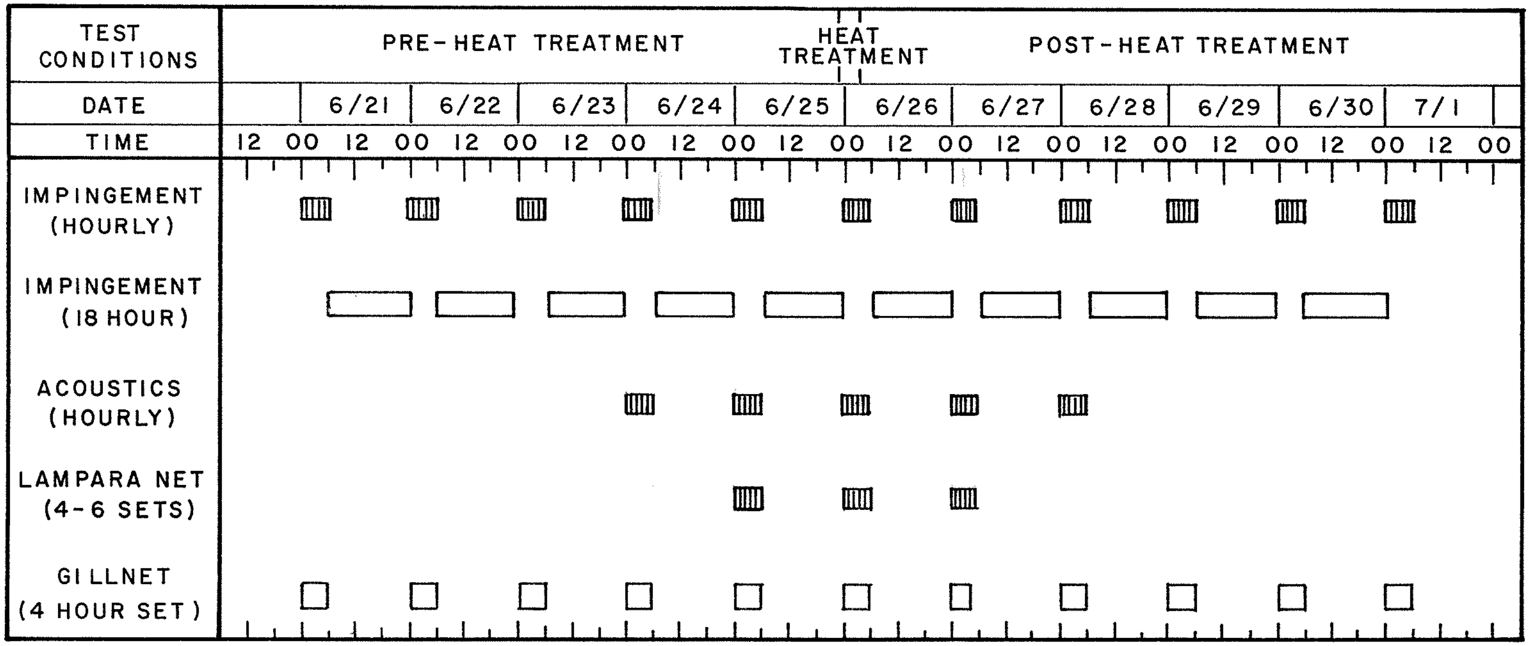


Fig. 7. Sampling intervals of inplant entrapment, offshore acoustics, lampara seine, and gillnet measurements between June 21 and July 1, 1980, at Huntington Beach Generating Station.

The following equation (Cochran 1977) was used to estimate the mid-water fish density (D_m):

$$D_m = \frac{1}{4} \sum_{h=1}^{4} \bar{D}_h$$

n_h = number of transects in stratum h (2)
$\bar{D}_h$ = mean fish density of stratum h
D_{hi} = mean fish density on transect i in stratum h

The number of transects was equal for each stratum, i.e., stratification with proportional allocation. If in every stratum the sample estimate $\bar{D}_h$ is unbiased, the $\bar{D}_h$ is an unbiased estimate of the population mean, D_m (mid-water fish density). Also if the samples are drawn independently in the strata:

$$\text{Var}(\bar{D}_m) = \frac{1}{4} \sum_{h=1}^{4} \text{Var}\ (\bar{D}_h)$$

where Var ($\bar{D}_h$) is the variance over repeated samples from stratum h.

The mean species composition (P_i) and its associated variance Var (P_i) of the lampara catch by day was determined as percent by weight. Therefore, each species component (P_i) was obtained by dividing the total weight of that species (i) in the catch by the total weight of all species in the catch. The species components (P_i's) and their associated variances were computed from the 4 to 6 lampara sets made within a survey day. Since the lampara seine fished the entire water column, in order that the mid-water fish density be expressed in terms of its species composition, $\bar{D}_m$ was expanded to fish density in the entire water volume (D_T) by the constant 1.43. This constant expansion factor was derived from the fact 3 of the 10 m of water volume were not sampled by the acoustics.

$$\text{Therefore, } D_T = 1.43\ \bar{D}_m$$

$$\text{with Var } (D_T) = (1.43)^2 \text{ Var } (\bar{D}_m)$$

The offshore density by species was then computed by the product of D_T and P_i:

$$D_i = D_T\ P_i$$

The variance formula is:

$$\text{Var } D_i = D_T^2 \text{ Var } P_i + P_i^2 \text{ Var } D_T$$

Homogeneous vertical distribution is a major assumption of this technique. The vertical gillnet data are providing information for which species this assumption is weak and techniques for correcting this bias are being investigated.

A limiting factor in this technique is that it requires all the lampara sets of one night to yield one estimate of P_i and its variance. The robustness of applying this nightly value of P_i to the hourly estimates of D_T is now being evaluated. This will largely depend upon the variability in P_i between lampara sets within a night with respect to both time and location. If in fact the spatial variability is low enough it may be possible to use single lampara sets to estimate P_i in the study area owing to the large size of the lampara seine.

The total nighttime fish density D_T (g/m^2 surface) and its species components D_i were expanded to biomass (B_T and B_i's) by the surface of the study area 2.826 x 10^5 m. This was done in order that the total weight of fish entrapped in the plant could be expressed as a proportion of the population (E/B). The ratio E/B was computed in hourly and mean nightly intervals for comparison procedures.

2.3.2 Data Analysis

The major hypothesis addressed in this study was if entrapment vulnerability E/B before, during and after a heat treatment are the same. This hypothesis was examined for three species, the queenfish, white croaker, and northern anchovy, and all species combined.

Nonparametric testing procedures were used exclusively to avoid making assumptions about the underlying distribution of the data (Siegel 1956). The Mann Whitney U and Kruskal-Wallis tests were used for two-sample and k-sample cases, respectively. The Spearman rank correlation coefficient r_s, was used as the nonparametric measure of correlation. The rejection region for all testing procedures was determined using $\alpha = 0.05$.

3.0 RESULTS

3.1 Physical Conditions

Water temperature, tranparency, and wind speed data were examined in order to determine if changes in these physical factors correlated with changes in either entrapment or offshore abundance.

Water transparency, as measured in the screenwell during daylight hours, ranged from 2 to 8 f (Fig. 8). The water transparency values which were initially 3 to 4 f, increased to 7 to 8 f on June 25, the day before the heat treatment. Subsequent to the heat treatment transparency values ranged between 2 and 4 f (Fig. 8).

The ambient seawater temperature (as indicated by measurements taken in the screenwell) ranged from about 59° to 68°F. Temperatures declined gradually during most of the survey, then increased to initial levels during the last 2 survey days (Fig. 8).

The wind speed data examined were collected at the Newport Beach Harbor Patrol Station approximately 6 miles downcoast of the HBGS. These data were utilized because the anemometer at the HBGS was not recording during the survey period. Wind speeds during the interval June 21 to July 1 ranged from 0 to 25 mph. Peak speeds of about 15 mph were generally observed each afternoon (Fig. 9). Wind speeds during the midnight to dawn interval were generally less than 7 mph.

3.2 Common Species (i)

The species composition of fishes observed inplant and in the field was examined. Species which comprised significant percentages of both the inplant and field catches were selected for use in hypothesis testing. These fishes were queenfish (*Seriphus politus*), northern anchovy (*Engraulis mordax*), and white croaker (*Genyonemus lineatus*) (Table 1).

3.3 Length Frequency

The length frequency data for the queenfish, white croaker, and northern anchovy captured inplant, in the lampara seine and in the gillnets were provided by Occidental College for the entire survey. These results may be confounded by daily variation in the population structure because the gillnets sampled for 11 days, the inplant sample represented 5 days, and the lampara sampled only 3 days.

The lampara length frequency of queenfish displayed strong bimodality, at 90 and 130 mm, and suggested the possibility of a third mode at 160 mm (Fig. 10). These mode lengths corresponded to the sizes expected for age 0, 1, and 2+ queenfish and were assumed to be cohorts. The lampara catch was considered the least selective sample, i.e., the best representation of the offshore fish population structure.

The gillnet length frequency of queenfish displayed trimodality at 90, 130, 160 mm, and suggested the presence of greater than 160 mm modes but this may be an artifact of small sample size on the tail of the distribution. The gillnet length frequency data supported the

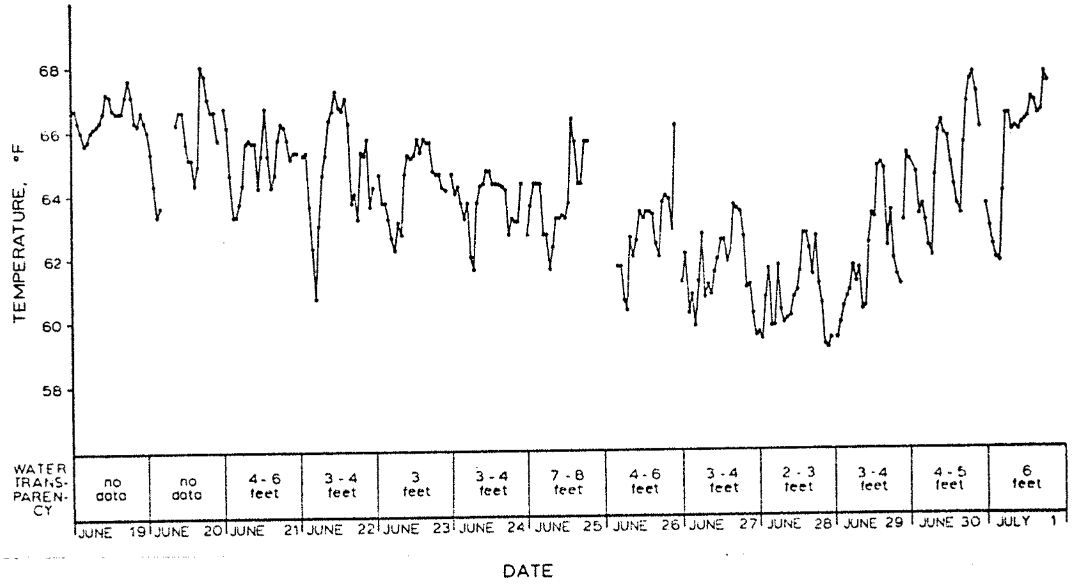


Fig. 8. Intake water temperature (F^{O}) and transparency (ft) at Huntington Beach Generating Station, June 19 - July 1, 1979.

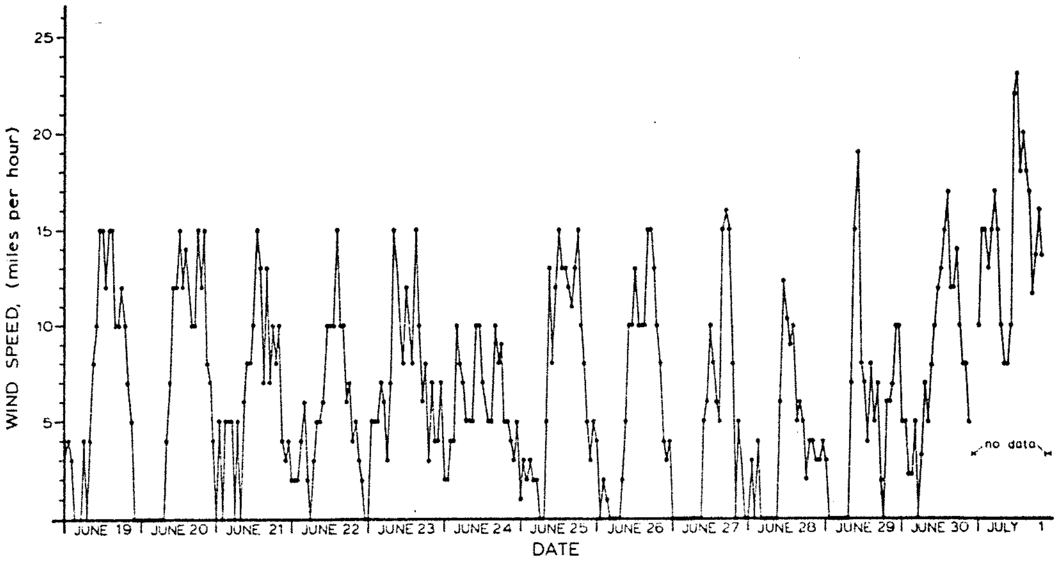


Fig. 9. Wind speed (mph) at Newport Beach Harbor Patrol Station, June 19-July 1, 1979

Table 1. The species composition of fishes caught in-plant and offshore of the Huntington Beach Generating Station, June 21 to July 1, 1979 (ranked by biomass entrapped).

		Entrapment		Lampara catch	
Scientific Name	Common Name	% biomass	% number	% biomass	% number
Seriphus politus	queenfish	58.71	19.46	17.26	3.32
Phanerodon furcatus	white surfperch	8.02	23.41	*	**
Engraulis mordax	northern anchovy	5.37	29.44	31.04	88.49
Hyperprosopon argenteum	walleyed surfperch	6.09	14.07	*	**
Genyonemus lineatus	white croaker	4.27	8.83	42.44	6.37
Peprilus simillimus	Pacific butterfish	1.74	0.94	*	**
Cymatogaster aggregata	shiner surfperch	1.40	2.71	*	**
Anisotremus davidsonii	sargo	1.18	0.03	--	--
Rhinobatos productus	shovelnose guitarfish	1.09	0.01	--	--
Atherinopsis californiensis	jacksmelt	1.06	0.09	*	**
Embiotoca jacksoni	black surfperch	0.97	0.13	--	--
Unidentified teleost		0.93	0.02	--	--
Damalichthys vacca	pile surfperch	0.85	0.05	--	--
Cheilotrema saturnum	black croaker	0.80	0.04	--	--
Paralabrax clathratus	kelp bass	0.68	0.04	*	**
Porichthys notatus	plainfin midshipman	0.48	0.06	*	**
Platyrhinoidis triseriata	thornback ray	0.48	0.01	*	**
Scorpaena guttata	sculpin	0.46	0.02	*	**
Atherinops affinis	topsmelt	0.40	0.15	*	**
Menticirrhus undulatus	California corbina	0.39	0.02	*	**
Urolophus halleri	round stingray	0.38	0.01	--	--
Cynoscion nobilis	white seabass	0.37	--	--	--
Porichthys myriaster	specklefin midshipman	0.29	0.01	*	**
Paralichthys californicus	California halibut	0.29	0.02	*	**
Leptocottus armatus	staghorn sculpin	0.29	0.14	*	**
Myliobatis californica	bat ray	0.26	0.01	*	**
Paralabrax maculatofasciatus	spotted sand bass	0.26	0.01	--	--
Otophidium scrippsi	basketweave cusk-eel	0.25	0.03	*	**
Pleuronichthys verticalis	hornyhead turbot	0.20	0.05	*	**
Unidentified elasmobranch		0.19	--	--	--
Paralabrax nebulifer	barred sand bass	0.14	0.01	*	**
Rhacochilus toxotes	rubberlip surfperch	0.12	0.04	--	--
Chromis punctipinnis	blacksmith	0.11	0.02	--	--
Sebastes auriculatus	brown rockfish	0.10	0.01	--	--
Hypsopsetta guttulata	diamond turbot	0.09	0.01	--	--
Scorpaenichthys marmoratus	cabezon	0.07	--	--	--
Torpedo californica	Pacific electric ray	0.05	--	*	**
Symphurus atricauda	California tonguefish	0.04	0.02	*	**
Synodus lucioceps	California lizardfish	0.04	--	--	--
Parophrys vetulus	English sole	0.03	--	*	**
Medialuna californiensis	halfmoon	0.02	--	--	--
Leuresthes tenuis	California grunion	--	--	*	**
Hypsoblennius sp.	blenny	--	0.02	--	--
Syngnathus sp.	pipefish	--	--	--	--
Citharichthys stigmaeus	speckled sanddab	--	0.01	*	**
Sebastes paucispinis	bocaccio	--	--	--	--
Oxyjulis californica	señorita	--	--	--	--
Pleuronichthys coenosus	C-O turbot	--	--	--	--
Heterostichus rostratus	giant kelpfish	--	--	--	--
Flatfish (unidentified)			--	--	--
Sebastes serranoides	olive rockfish	--	0.01	--	--
Hypsoblennius gilberti	rockpool blenny	--	--	--	--
Sphyraena argentea	California barracuda	--	--	*	**
Sarda chiliensis	Pacific bonito	--	--	*	**
Mustelus californicus	gray smoothhound	--	--	*	**
Alopias vulpinus	common thresher shark	--	--	*	**
Xystreurys liolepis	fantail sole	--	--	*	**
Strongylura exilis	California needlefish	--	--	*	**
Anchoa compressa	deepbody anchovy	--	--	*	**
TOTAL CATCH		636.40 Kg	41,935	1,156.43 Kg	15,172

*Miscellaneous species represented 9.27% of the lampara catch biomass
**Miscellaneous species represented 1.83% of the lampara catch numbers

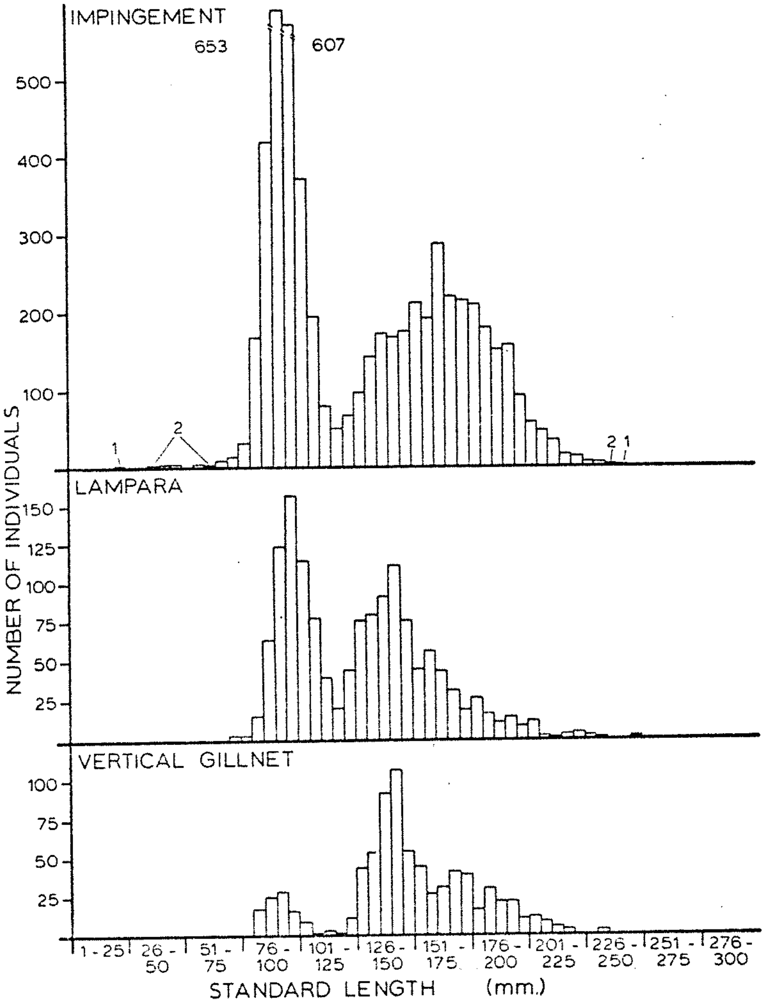


Fig. 10. The length-frequency distribution of queenfish caught inplant and offshore of the Huntington Beach Generating Station, June 21 - July 1, 1979.

decision that the offshore queenfish population was dominated by three cohorts.

The smaller proportion of cohort 0 queenfish in the gillnet catch relative to the lampara suggested low selection of this gear for fish less than 100 mm. The knife-edge selectivity of gillnets for small fish has been widely described in the literature. Reduced selectivity for the larger fish in the queenfish population was probably occurring with the lampara seine because of avoidance, and certainly with the gillnets because of the limited range of mesh sizes employed.

The length frequency of the queenfish entrapped inplant was bimodal. The mode at 130 mm was obscured by the mode at 160 mm. This could mean 1) that only one mode existed at 160 mm, 2) the vulnerability of entrapment for 160 mm queenfish is higher than 130 mm fish, and/or, 3) the offshore abundance of 160 mm queenfish was much higher during the days which the lampara was not fished. The first two explanations are weak because of the existing age/length and size/vulnerability data. However, the third explanation is supported to some extent by the gillnet length frequency data which also suggest the presence of more 160 mm+ fish offshore. Like the entrapment sample, the gillnets were fished during intervals of no lampara sampling. This suggests that significant daily fluctuations in cohort strength can occur and the need for comparisons of simultaneous data only.

The lampara length frequency of white croaker displayed three modes at 60, 110, and 160 mm (Fig. 11). These modes corresponded to sizes expected for ages 0, 1, and 2+ fish. Therefore, the offshore white croaker population was assumed to be composed primarily of three cohorts. The fact that the proportion of cohort 0 in the lampara catch was smaller than cohorts 1 and 2+ suggests the lampara seine is less selective for the smaller white croaker, and/or there is large variation in year class strength.

The gillnet length frequency was also trimodal with modes at 75, 110, and 160 mm and suggested the possibility of another mode at 180 mm. The smaller proportion of mode 1 fish in the gillnet catch and their larger size relative to the lampara suggest a knife-edged selectivity of the gillnet for small white croaker. The gillnet data supported the decision that the offshore population of white croaker was dominated by three cohorts.

The length frequency of the white croaker captured inplant was bimodal with modes at 60 and 110 mm. The larger proportion of age 0 to age 1 cohorts in the entrapment relative to the lampara catch suggested that the smaller white croaker are more vulnerable to entrapment, and/or that the relative abundance of age 0 white croaker offshore was higher than indicated by the lampara catch. The absence of the 160 mm mode, cohort 3, suggested that the vulnerability to entrapment decreases with size for white croaker.

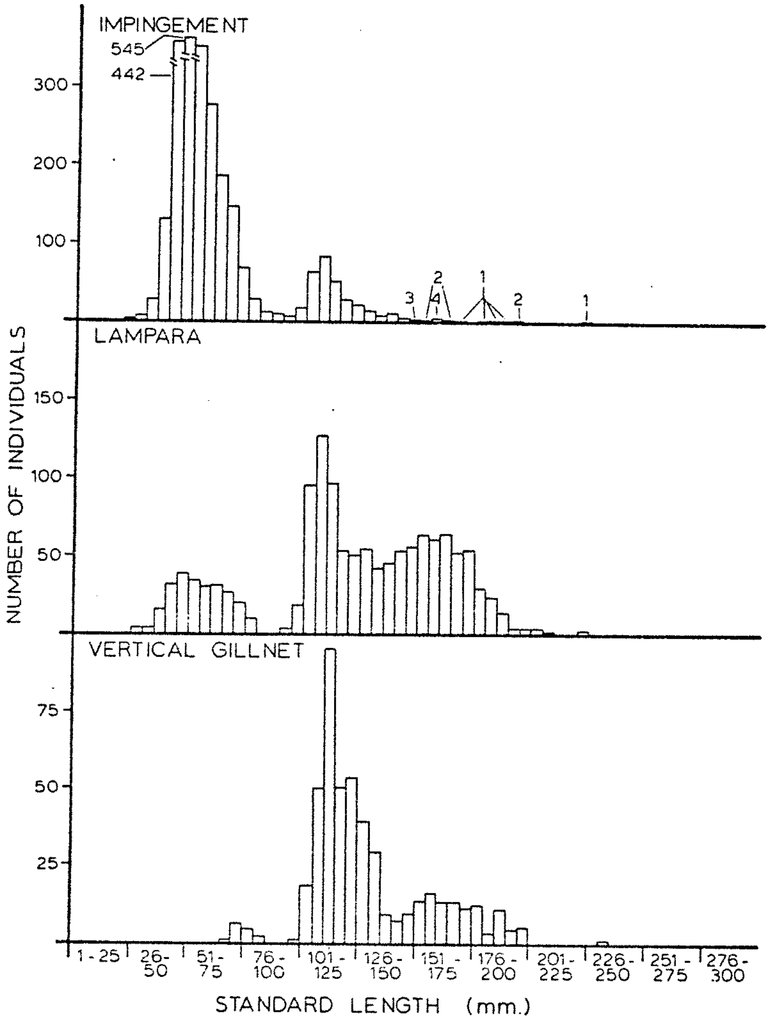


Fig. 11. The length-frequency distribution of white croaker caught inplant and offshore of the Huntington Beach Generating Station, June 21 - July 1, 1979.

The lampara catch of northern anchovy was unimodal at 60 mm (Fig. 12). This length corresponds with age 0 fish. Therefore, the lampara catch suggests the northern anchovy population was composed of one year class of age 0 fish.

The gillnet length frequency was also unimodal, at 110 mm which corresponded to age 1 fish. The disagreement between the gillnet and lampara samples is explained by the inability of the gillnet to capture northern anchovy smaller than observed (knife-edged selectivity) and the small sample size it represents relative to the lampara catch (lampara n = 13,426, gillnet n = 144). The presence of anchovy in the gillnet catch which were larger than observed in the lampara suggests larger anchovy were present in intervals when the lampara seine did not sample, i.e., high daily variability and/or inadequate subsampling of the lampara catch to describe length frequency.

The length frequency of the northern anchovy entrapped within the plant suggested bimodality, with modes at 70 and 110 mm. The presence of the 110 mm mode in the entrapment data supports the suggestion that the lampara was not fished when these fish were present and/or the subsampling did not detect this size class.

In general, the three sampling methods appeared to be capturing fish over the same length range. However, the proportion of the three cohorts was different in each of the sample catches. These results suggested the inplant, lampara, and gillnets to have different selectivity characteristics. Therefore, direct comparisons of total fish entrapment to the offshore catches may be confounded by size-dependent characteristics.

3.4 Fish Entrapment (E)

Hourly entrapment rates (E) observed for queenfish, white croaker, and northern anchovy are shown in Tables 2a, 2b, and 2c, respectively. For all three species the most obvious changes in entrapment rates were the increases that occurred in the last hour of the heat treatment (Fig. 13).

This observation suggested either that the offshore fish density and/or the vulnerability (E/B) of these fishes had changed at the end of the heat treatment.

The hourly rate of entrapment for anchovy was higher during the heat treatment than either before or after the heat treatment (α = 0.01). This observation suggested that the heat treatment either increased the offshore density and/or the vulnerability (E/B) of northern anchovy to entrapment.

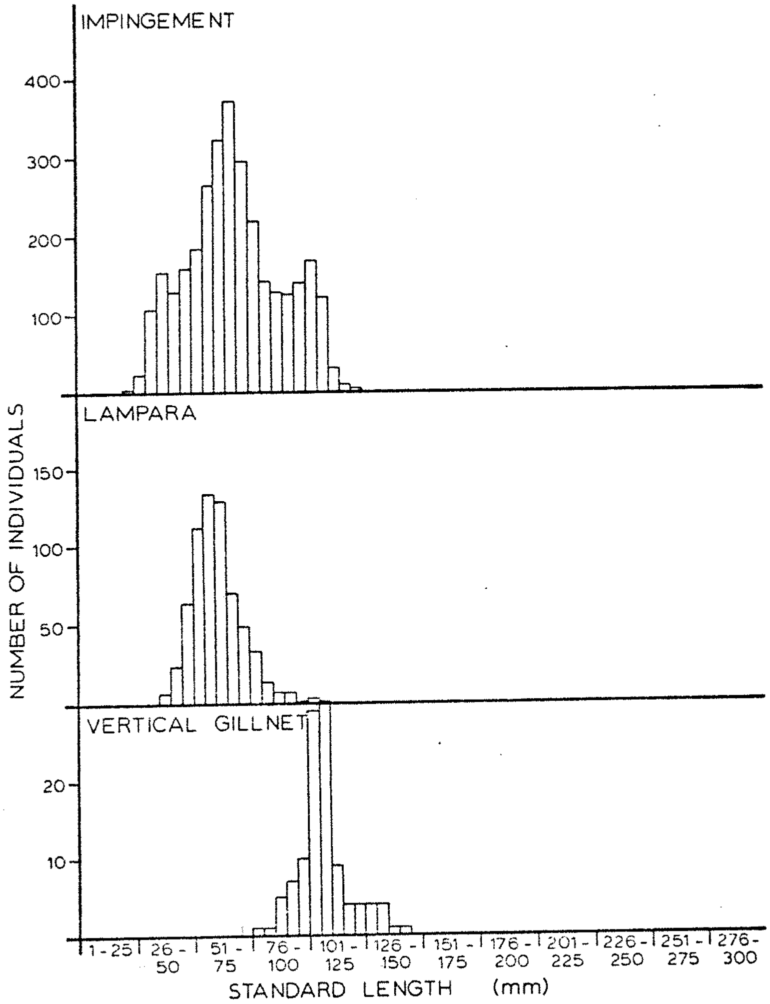


Fig. 12. The length-frequency distribution of northern anchovy caught inplant and offshore of the Huntington Beach Generating Station, June 21 - July 1, 1979.

Table 2a. Hourly entrapment rates observed for *Seriphus politus* during nighttime intervals at the Huntington Beach Generating Station, June 21 - July 1, 1979.

Survey Day	Treatment	Date	Time	#	$\bar{\#}$	E	$\bar{E}$
1		6/21/79	2300	-		-	
	Pre-Heat Treat.		0030	44		1.87	
			0130	121	89.60	4.54	3.06
			0230	119	±33.52	4.50	±1.39
			0330	97		2.67	
			0430	67		1.70	
2		6/22/79	2330	-		-	
	Pre-Heat Treat.		0030	194		9.68	
			0130	78	121.60	3.55	5.06
			0230	128	±43.94	4.52	±2.62
			0330	107		4.21	
			0430	103		3.36	
3		6/23/79	2330	-		-	
	Pre-Heat Treat.		0030	-		-	
			0130	75	186.25	3.53	8.94
			0230	192	±114.30	8.62	±5.83
			0330	342		17.11	
			0430	136		6.50	
4		6/24/79	2330	-		-	
	Pre-Heat Treat.		0030	18		0.92	
			0130	72	110.40	3.74	6.54
			0230	212	±87.41	12.14	±5.21
			0330	195		12.05	
			0430	55		3.84	
5		6/25/79	2330	49		2.11	
	Pre-Heat Treat.		0030	25		0.58	
			0130	9	18.00	0.37	0.71
			0230	9	±16.67	0.44	±0.69
			0330	11		0.47	
			0430	5		0.289	
6		6/26/79	2330	62		2.95	
	Heat Treat.		0030	27		1.75	
			0130	44	195.80	2.08	12.33
			0230	70	±324.77	53.26	±22.89
			0330	776		53.26	
			0430	-		-	

Table 2a. Hourly entrapment rates observed for *Seriphus politus* during nighttime intervals at the Huntington Beach Generating Station, June 21 - July 1, 1979 (cont'd).

Survey Day	Treatment	Date	Time	#	$\bar{\#}$	E	$\bar{E}$
7		6/27/79	2330	421		13.83	
	Post-Heat Treat.		0030	75		3.02	
			0130	78	133.00	3.07	5.47
			0230	71	±141.17	2.14	±4.31
			0330	83		5.63	
			0430	70		5.11	
8		6/28/79	2330	-		-	
	Post-Heat Treat.		0030	-		-	
			0130	60	101.25	4.99	4.63
			0230	164	±49.61	7.12	±1.86
			0330	118		3.18	
			0430	63		3.24	
9		6/29/79	2330	-		-	
	Post-Heat Treat.		0030	-		-	
			0130	184	96.75	6.90	4.11
			0230	103	±63.44	4.79	±2.24
			0330	55		3.02	
			0430	45		1.74	
10		6/30/79	2330	-		-	
	Post-Heat Treat.		0030	-		-	
			0130	56	122.00	2.23	3.82
			0230	150	±52.64	5.31	±1.52
			0330	176		4.95	
			0430	106		2.79	
11		7/01/79	2330	-		-	
	Post-Heat Treat.		0030	-		-	
			0130	6	12.00	0.12	0.46
			0230	16	±4.90	0.85	±0.33
			0330	10		0.26	
			0430	16		0.60	

Table 2b. Hourly entrapment rates observed for *Genyonemus lineatus* during nighttime intervals at the Huntington Beach Generating Station, June 21 - July 1, 1979.

Survey Day	Treatment	Date	Time	#	$\overline{\#}$	kg	$\overline{\overline{\text{kg}}}$
1		6/21/79	2300	-		-	
	Pre-		0030	35		0.09	
	Heat		0130	80	43.60	0.25	0.14
	Treat.		0230	37	±21.18	0.15	±0.07
			0330	41		0.14	
			0430	25		0.09	
2		6/22/79	2330	-		-	
	Pre-		0030	10		0.008	
	Heat		0130	13	32.00	0.06	0.14
	Treat.		0230	68	±23.33	0.33	±0.12
			0330	31		0.16	
			0430	38		0.15	
3		6/23/79	2330	-		-	
	Pre-		0030	-		-	
	Heat		0130	286	165.50	0.98	1.07
	Treat.		0230	217	±109.16	1.20	±0.24
			0330	123		1.31	
			0430	36		0.77	
4		6/24/79	2330	-		-	
	Pre-		0030	9		0.102	
	Heat		0130	31	26.00	0.21	0.21
	Treat.		0230	54	±20.11	0.35	±0.09
			0330	32		0.22	
			0430	4		0.14	
5		6/25/79	2330	4		0.03	
	Pre-		0030	1		0.00	
	Heat		0130	3	3.50	0.24	0.10
	Treat.		0230	4	±2.59	0.04	±0.13
			0330	8		0.28	
			0430	1		0.00	
6		6/26/79	2330	1		0.00	
	Heat		0030	0		0.00	
	Treat.		0130	11	71.60	0.05	0.79
			0230	84	±112.01	0.41	±1.51
			0330	265		3.48	
			0430	-		-	

Table 2b. Hourly entrapment rates observed for *Genyonemus lineatus* during nighttime intervals at the Huntington Beach Generating Station, June 21 - July 1, 1979 (cont'd).

Survey Day	Treatment	Date	Time	#	$\bar{\#}$	kg	$\overline{kg}$
7		6/27/79	2330	49		0.41	
	Post-		0030	43		0.34	
	Heat		0130	53	69.50	0.44	0.47
	Treat.		0230	96	±24.78	0.46	±0.13
			0330	100		0.73	
			0430	76		0.45	
8		6/28/79	2330	-		-	
	Post-		0030	-		-	
	Heat		0130	17	40.50	0.08	0.22
	Treat.		0230	36	±19.23	0.30	±0.09
			0330	63		0.25	
			0430	46		0.23	
9		6/29/79	2330	-		-	
	Post-		0030	-		-	
	Heat		0130	41	24.00	0.63	0.24
	Treat.		0230	14	±11.92	0.07	±0.27
			0330	18		0.06	
			0430	23		0.21	
10		6/30/79	2330	-		-	
	Post-		0030	-		-	
	Heat		0130	20	12.50	0.03	0.04
	Treat.		0230	11	±5.80	0.05	±0.01
			0330	13		0.05	
			0430	6		0.03	
11		7/01/79	2330	-		-	
	Post-		0030	-		-	
	Heat		0130	14	10.75	0.00	0.03
	Treat.		0230	19	±6.95	0.09	±0.03
			0330	5		0.01	
			0430	5		0.01	

Table 2c. Hourly entrapment rates observed for *Engraulis mordax* during nighttime intervals at the Huntington Beach Generating Station, June 21 - July 1, 1979.

Survey Day	Treatment	Date	Time	#	$\overline{\#}$	kg	$\overline{kg}$
1		6/21/79	2300	-		-	
	Pre-Heat Treat.		0030	83		0.76	
			0130	106	78.20	0.67	0.59
			0230	75	±19.69	0.64	±0.17
			0330	76		0.55	
			0430	51		0.31	
2		6/22/79	2330	-		-	
	Pre-Heat Treat.		0030	180		0.84	
			0130	47	80.20	0.22	0.47
			0230	54	±56.12	-	±0.31
			0330	56		0.39	
			0430	64		0.44	
3		6/23/79	2330	-		-	
	Pre-Heat Treat.		0030	-		-	
			0130	115	85.00	0.71	0.45
			0230	101	±30.51	1.20	±0.20
			0330	79		0.42	
			0430	45		0.22	
4		6/24/79	2330	73		0.19	
	Pre-Heat Treat.		0030	17		0.06	
			0130	52	35.40	0.33	0.21
			0230	62	±20.19	0.43	±0.16
			0330	22		0.15	
			0430	24		0.10	
5		6/25/79	2330	34		0.12	
	Pre-Heat Treat.		0030	23		0.05	
			0130	24	38.00	0.06	0.08
			0230	46	±22.08	0.10	±0.03
			0330	79		0.09	
			0430	22		0.06	
6		6/26/79	2330	354		1.02	
	Heat Treat.		0030	550		1.56	
			0130	612	1,169.00	1.63	3.42
			0230	1,477	±1,112.01	4.71	±3.04
			0330	2,852		8.20	
			0430	-		-	

Table 2c. Hourly entrapment rates observed for *Engraulis mordax* during nighttime intervals at the Huntington Beach Generating Station, June 21 - July 1, 1979 (cont'd).

Survey Day	Treatment	Date	Time	#	$\overline{\#}$	kg	$\overline{kg}$
7	Post-Heat Treat.	6/27/79	2330	52	44.00 ±18.57	0.11	0.12 ±0.05
			0030	43		0.15	
			0130	31		0.10	
			0230	73		0.16	
			0330	39		0.16	
			0430	23		0.03	
8	Post-Heat Treat.	6/28/79	2330	-	29.50 ±15.59	-	0.09 ±0.04
			0030	-		-	
			0130	16		0.06	
			0230	52		0.11	
			0330	25		0.13	
			0430	25		0.05	
9	Post-Heat Treat.	6/29/79	2330	-	8.75 ±2.50	-	0.05 ±0.04
			0030	-		-	
			0130	9		0.07	
			0230	6		0.004	
			0330	12		0.10	
			0430	8		0.034	
10	Post-Heat Treat.	6/30/79	2330	-	3.00 ±1.63	-	0.02 ±0.01
			0030	-		-	
			0130	3		0.02	
			0230	1		0.01	
			0330	3		0.02	
			0430	5		0.01	
11	Post-Heat Treat.	7/01/79	2330	-	3.25 ±4.57	-	0.04 ±0.07
			0030	-		-	
			0130	0		0.00	
			0230	10		0.14	
			0330	2		0.02	
			0430	1		0.00	

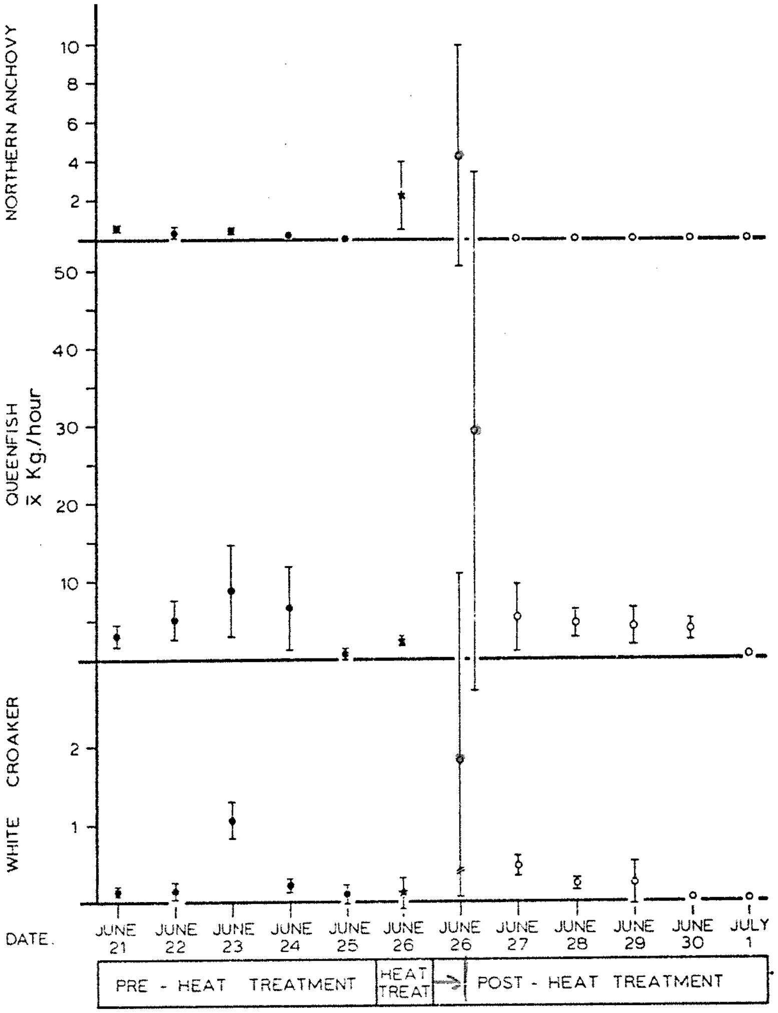


Fig. 13. Mean hourly entrapment rates (± one standard deviation) of queenfish, white croaker, and northern anchovy before (closed circles), during (stars), and after (open circles) a heat treatment conducted June 26, 1979, at the Huntington Beach Generating Station.

Noticeable declines in the entrapment of queenfish and white croaker on June 25 and July 1 appeared to be associated with increased water transparency. Positive correlations (r_s) of 0.88 and 0.82 were computed for mean daily entrapment and water transparency for queenfish and white croaker, respectively ($\alpha = 0.05$). The declines in entrapment observed for queenfish and white croaker during periods of increased transparency indicate that water transparency influences their entrapment rates, assuming that the fish density was stable.

3.5 Offshore Fish Biomass (B_M,B_T)

The biomass of fish (kg) in the total water column within 300 m of the intake structure was determined with hydroacoustic techniques during the nighttime hours, June 24 to June 28 (Table 3).

The mean nightly biomass increased from 1,475 kg to 3,964 kg from June 24 to June 26, the night of the heat treatment. After the heat treatment the mean nightly biomass decreased to 2,677 kg and 1,279 kg on June 27 and 28, respectively. Hypothesis testing of the observed daily changes in total biomass with the hourly measurement data supported these trends. The total biomass increased each day peaking on June 26, the day of the heat treatment, and then decreased each post-heat treatment day (Mann Whitney U, $\alpha = 0.05$).

The hourly estimates of B_T were higher during the heat treatment than either pre- or post-heat treatment (Mann Whitney U, $\alpha = 0.05$). However, pre- and post-treatment densities were not different.

These results indicated that the heat treatment recruited fish into the study area and/or that the fish density along the nearby coastline increased by chance. To aid interpretation of these results the fish densities measured between 0-300 m and 300-1,500 m distances from the intake were compared.

A total of six 3,000-m acoustic transects was run parallel to the shoreline during this survey to examine trends occurring in the fish density outside the 300-m radius study area. The highest far-field fish densities were measured at 0130 and 1130 June 25, prior to and during the heat treatment (Table 4).

Unfortunately, the majority of the far-field density measurements (4/6) were made too close to or during the first morning light (after 0400) for comparison purposes. The value of the mean fish density was larger in the near field area for both the nighttime transects but the density was significantly greater ($\alpha = 0.05$) only just prior to the heat treatment, 0200 June 25 (Figs. 14 and 15).

Table 3. Total offshore fish biomass, B_T (kg), at Huntington Beach, June 24-28, 1979.

Status	Date	Time	B_T	$\bar{B}_T$	Var B_T
Pre-Heat Treat.	6/24/79	0030	1,848	1,475	99,604
		0130	1,427		
		0230	1,548		
		0330	1,076		
	6/25/79	2330	1,603	2,728	1,109,631
		0030	1,767		
		0130	2,830		
		0230	4,088		
		0330	3,352		
During Heat Treat.	6/26/79	2330	4,149	3,964	847,086
		0030	3,393		
		0130	5,022		
		0230	4,545		
		0330	2,711		
Post-Heat Treat.	6/27/79	2330	2,375	2,677	692,239
		0030	1,654		
		0130	2,341		
		0230	3,771		
		0330	3,244		
	6/28/79	2330	1,221	1,279	105,925
		0030	1,480		
		0130	1,463		
		0230	1,498		
		0330	733		

Table 4. Fish densities (g/m^2 surface) in the nearfield (within 300 m), upcoast (300 to 1,500 m NW), and downcoast (300 to 1,500 m SE) areas adjacent to the Huntington Beach Generating Station intake structure, June 24-27, 1979.

		Fish density (g/m^2)				
Date	Hour	Upcoast	Nearfield	Downcoast	H	Level of Significance
6/24	0400	1.837	2.384	1.380	4.54	.1032 NS
6/24	0430	3.019	3.268	2.298	3.73	.1546 NS
6/25	0200	5.946	6.864	4.009	27.89	0 *
6/26	1100	6.791	7.978	7.112	3.57	.1676 NS
6/26	0530	1.890	1.129	1.363	15.38	.0005 *
6/27	0530	1.608	1.582	2.096	.0118	.9941 NS

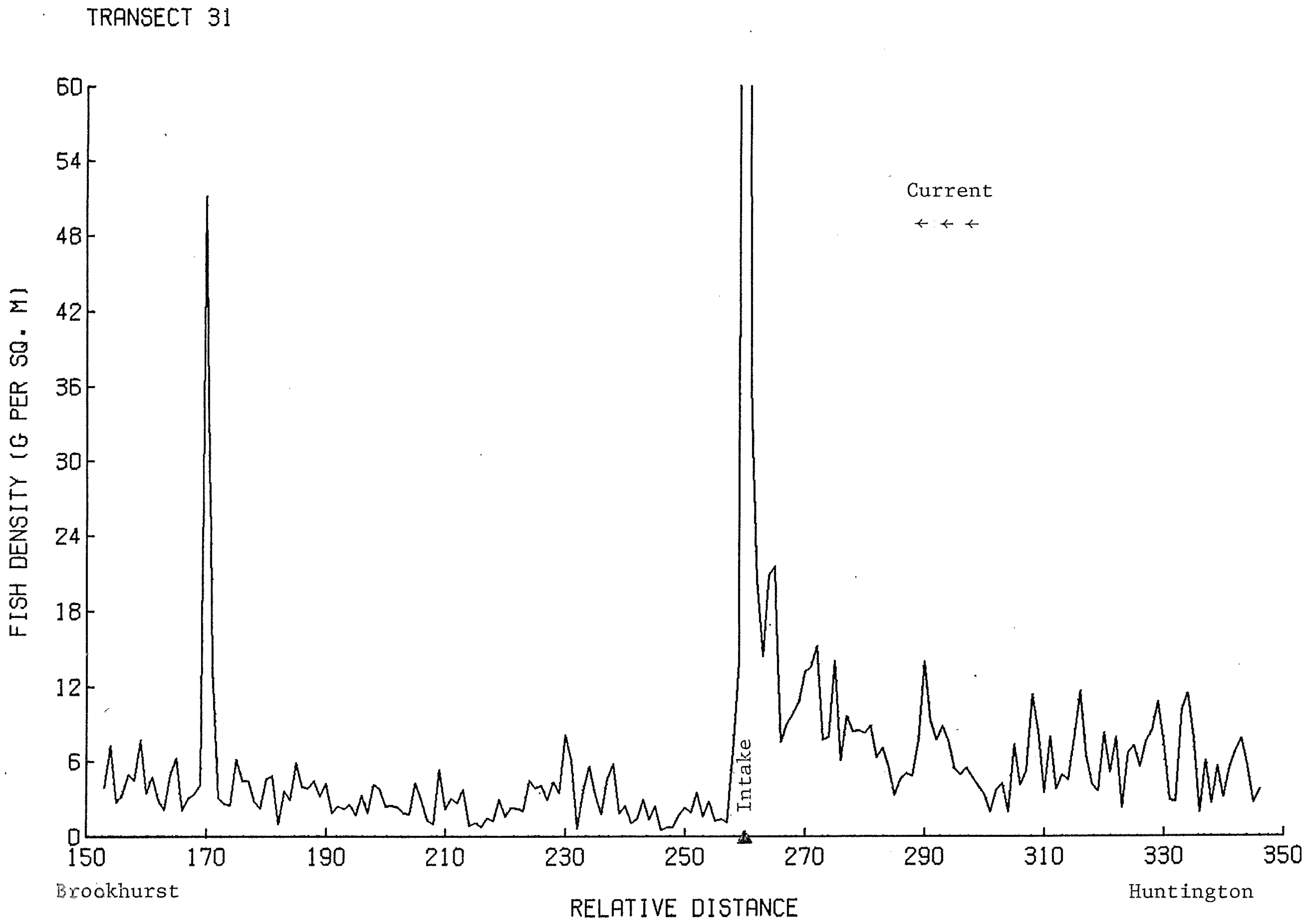


Fig. 14. Fish density versus relative distance (1 unit distance ∿ 20 m), within 1500 m upcoast and downcoast of intake at the Huntington Beach power plant, the night of June 25, 1979.

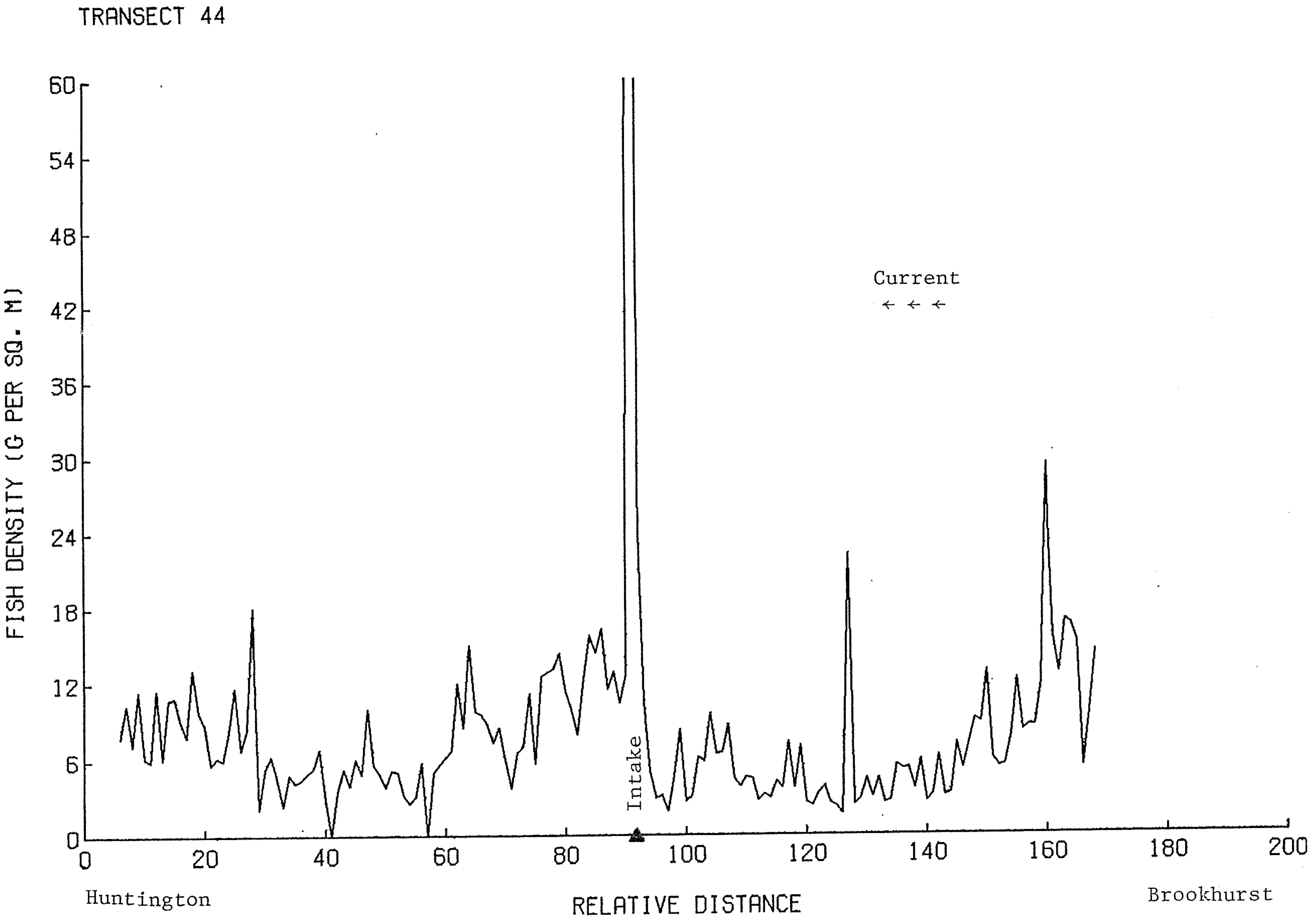


Fig. 15. Fish density versus relative distance (1 unit distance $\simeq$ 20 m), within 1500 m upcoast and downcoast of intake at the Huntington Beach power plant, the night of June 26, 1979.

3.6 Offshore Species Composition (P_i)

The lampara catch composition (P_i), a subsample of acoustically observed targets, was used to determine the species composition of the fishes within 300 m of the intake structure. The percentages of queenfish (P_1), white croaker (P_2), and northern anchovy (P_3) are presented by catch and night for the 3 days of lampara net fishing (Table 5). The catch per set of queenfish and white croaker followed the same trends, being highest during (19 and 50 kg/set, respectively) and lowest after the heat treatment (13 and 23 kg/set, respectively). The catch per set of northern anchovy displayed a decreasing trend (44 to 28 to 24 kg/set) during the 3 sample days.

3.7 Offshore Biomass by Species (B_i)

Hourly estimates of offshore biomass within 300 m of the intake structure were calculated for queenfish, white croaker, and northern anchovy from the products of B_T and P_i (Table 6). Because of difficulties with boat equipment P_i values were not obtained on June 24 and 28.

The estimates of hourly queenfish biomass were highest during and after the heat treatment (Mann Whitney U, $\alpha = 0.05$). The estimates of white croaker biomass were higher during the heat treatment (Mann Whitney U, $\alpha = 0.025$). The hourly biomass estimates of anchovy were not different between pre-, during, and post-heat treatment intervals. These results suggest that the heat treatment may have caused increased densities of queenfish and white croaker.

3.8 Entrapment to Biomass (E/B) Ratios

Hourly estimates of E/B were computed for queenfish, white croaker, northern anchovy, and all species combined (Table 7). The E/B ratios for queenfish were higher during and after the heat treatment (Mann Whitney U, $\alpha = 0.05$). The E/B ratios for white croaker were higher after the heat treatment (Mann Whitney U, $\alpha = 0.05$). The northern anchovy E/B values were larger during the heat treatment hours (Mann Whitney U, $\alpha = 0.05$). There were no trends in the E/B ratios for all species combined.

The interval with the highest E/B ratio was, for all three species, the last hour of the heat treatment on June 26. This peak in entrapment vulnerability was associated with the tunnel swapping procedure when reversing flow direction.

Table 5. Lampara catch per set (kg) and percent (P_i) for queenfish, white croaker, and northern anchovy offshore of the Huntington Beach Generating Station, June 25-27, 1979.

		Queenfish			White croaker			Northern anchovy		
Date	Set	kg	P_1	$\bar{P}_1$	kg	P_2	$\bar{P}_2$	kg	P_3	$\bar{P}_3$
6/25	1	9.46	9.3		50.88	50.1		34.33	33.8	
	2	10.48	11.6	13.38	43.62	48.2	40.88	29.46	32.5	38.98
	3	9.13	7.3	±8.14	50.16	39.9	±11.29	56.59	45.1	±6.75
	4	31.27	25.3		31.27	25.3		55.04	44.5	
6/26	5	13.36	15.2		48.79	55.7		22.32	25.5	
	6	16.89	13.8	17.10	56.56	46.1	47.45	30.74	25.1	25.98
	7	12.23	11.8	±7.14	53.66	51.7	±8.41	31.91	30.7	±3.40
	8	31.78	27.6		41.80	36.3		26.10	22.6	
6/27	9	21.52	26.7		35.42	43.9		14.59	18.1	
	10	11.77	15.4		46.71	60.9		8.38	10.9	
	11	8.27	17.7	20.76	14.54	31.1	31.92	12.29	26.3	35.58
	12	6.76	21.3	±4.40	0	0	±22.75	22.68	71.5	±25.16
	13	16.66	22.7		17.39	23.7		37.44	51.1	

Table 6. Offshore estimates of fish biomass by species (B_i) for queenfish (B_1), white croaker (B_2), and northern anchovy (B_3) in Kg at Huntington Beach, June 24-28, 1979.

Status	Date	Time	B_1	$\bar{B}_1$	B_2	$\bar{B}_2$	B_3	$\bar{B}_3$
Pre-Heat Treatment	6/25	2330	220	377	640	1090	638	1190
		0030	242		705		703	
		0130	388		1120		1120	
		0230	560		1630		1620	
		0330	459		1330		1330	
Heat Treatment	6/26	2330	611	523	1650	1410	913	781
		0030	500		1350		746	
		0130	739		1990		1110	
		0230	669		1800		1000	
		0330	399		1070		596	
Post-Heat Treatment	6/27	2330	500	568	876	995	733	822
		0030	348		610		511	
		0130	493		864		723	
		0230	794		1390		1160	
		0330	683		1190		1000	

Table 7. Hourly ratios of fish entrapment (kg/hr) to offshore fish biomass (kg), E_i/B_i, for queenfish (i = 1), white croaker (i = 2) and northern anchovy ((i = 3), and all species combined (i = T) at Huntington Beach Generating Station, June 24-28, 1979.

Status	Water Trans- parency (ft)	Date	Time	E_1/B_1	E_1/B_1	E_2/B_2	E_2/B_2	E_3/B_3	E_3/B_3	E_T/B_T	E_T/B_T
Pre-Heat Treat.	3-4	6/24	0030							0.0007	0.0066
			0130							0.0038	
			0230							0.0092	
			0330							0.0128	
Pre-Heat Treat.	7-8	6/25	2330	0.0096	0.0029	0.0001	0.0001	0.0002	0.0001	0.0022	0.0007
			0030	0.0024		0.0000*		0.0001		0.0004	
			0130	0.0009		0.0002		0.0001		0.0004	
			0230	0.0008		0.0000*		0.0001		0.0003	
			0330	0.0010		0.0002		0.0001		0.0004	
Pre-Heat Treat.	4-6	6/26	2330	0.0048	0.0294	0.0000*	0.0007	0.0011	0.0046	0.0014	0.0069
			0030	0.0035		0.0000		0.0021		0.0015	
			0130	0.0028		0.0000*		0.0015		0.0013	
			0230	0.0024		0.0002		0.0047		0.0028	
			0330	0.1334		0.0032		0.0138		0.0281	
Post-Heat Treat.	3-4	6/27	2330	0.0276	0.0107	0.0005	0.0005	0.0002	0.0002	0.0068	0.0036
			0030	0.0087		0.0006		0.0003		0.0036	
			0130	0.0062		0.0006		0.0003		0.0020	
			0230	0.0027		0.0093		0.0001		0.0026	
			0330	0.0082		0.0006		0.0002		0.0029	
Post-Heat Treat.	2-3	6/28	0130							0.0045	0.0056
			0230							0.0054	
			0330							0.0069	

4.0 DISCUSSION

The ability to calculate real time entrapment rates and offshore fish density synchronously has enabled us to evalute the effects of an intake on a fish assemblage in a manner not previously possible. This ability minimized the possibility that the results of our field evaluation of intake effects would be misinterpreted because of changes in either offshore density or physical parameters. The ability to measure offshore fish density synchronously with entrapment was made possible through the use of hydroacoustics.

The statistical technique for adjusting entrapment rates by offshore fish biomass has been simply to form the ratio of entrapment to density (E/B). This ratio is felt to represent the relative vulnerability of a fish assemblage to an intake. Therefore, by synchronously monitoring E and B through major changes in operational modes of an intake, we hope to describe major effects.

Vulnerability to entrapment (E/B) is negatively correlated with water tranparency (Thomas and Johnson, in press). The effect of water transparency on the entrapment vulnerability of queenfish and white croaker was demonstrated in the first study of this series (Johnson et al. 1979). This observation suggests that fish may avoid entrapment by visual means. This possibility is also supported by the fact that fish entrapment is greater at night (Thomas et al. 1979). Visual avoidance of fish to being captured is a well recognized problem of fisheries assessment. Ahlstrom (1954) described visual avoidance of sampling gear by larval fishes. Juvenile sockeye salmon have been demonstrated to avoid trawls at light intensities down to 10^{-6} lux (Robinson and Barraclough 1978). In view of the large effect of water transparency on entrapment, turbidity monitoring should be an important facet of entrapment and site selection studies.

Decreased water transparency appears to occur as a result of heat treatments. Therefore higher entrapment vulnerabilities during this interval would be expected.

These changes in water transparency counfounded the data available for the before, during, and after heat treatment E/B comparison procedures. Despite this, the ability to make several hourly observations within single night intervals provided a large enough sample size for some statistical inferences.

Queenfish, white croaker, and anchovy were all observed to have increased entrapment associated with the during and/or post-heat treatment interval. A major part of these increased vulnerabilities can be explained as the result of increased fish density in the vicinity of the intake and the operation of the intake system in reverse (without a velocity cap) during portions of the heat treatment. The density dependence of entrapment (Thomas and Johnson, in press) predicted the fish entrapment would increase as the fish density increased. The data suggest that higher fish densities maybe a result of heat treatments.

Higher entrapment vulnerability has been observed during no-velocity cap conditions (Thomas and Johnson, in press). The facts that the intake system was operated in reverse flow during the heat treatment and that the peak vulnerabilities were observed in the hours of the actual tunnel swapping support the concept that these events were causative factors.

In general the heat treatment is a short-term event and so appears its influence on fish entrapment. However, within this short interval large fish mortalities may result from tunnel swapping operations and/or the increased fish densities near the intake. Therefore the scheduling of heat treatment to intervals which minimize fish entrapment, periods of clear water and/or during daylight hours, should be evaluated for its potential as 316(b) demonstration for reducing fish entrapment.

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