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A FIELD EVALUATION OF THE EFFECT OF NIGHTTIME FLOW REDUCTION ON ENTRAPMENT OF FISH

by

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TECHNICAL REPORT
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1.0 INTRODUCTION

The following paper reports on the first of a series of tasks proposed by the hydroacoustics group, University of Washington, and the Fish Encounter Studies (FES), Occidental College. A combined inplant impingement, hydroacoustic, and net sampling survey was conducted between June 2 and 10, 1979, at the Huntington Beach Generating Station (HBGS).

The specific objectives of the June 2 to 10 survey were to measure offshore fish density and inplant entrapment simultaneously. The results were employed to test the hypothesis that fish entrapment at night during full flow and half flow are the same. Hypothesis testing in this interim report is on only this main effect. Underlying assumptions will be addressed in greater detail in the December 1979 final report.

1.1 Background Information

Weight (1958) and Johnson et al. (1976) reported entrapment rates varied with flow, which is proportional to the number of circulator pumps in operation. Schuler and Larson (1975) demonstrated that fish entrapment in model intake structures was directly related to intake entrance velocity. These observations suggest that one method of reducing total entrapment may be to reduce flow during off-peak production hours. Such operational procedures are being considered as regulatory requirements for utilities elsewhere (Milburn and Ginsburg 1977).

The off-peak production hours which are of greatest interest are between midnight and sunrise. Thomas et al. (1979) demonstrated that the midwater fish densities and fish entrapment rates were highest during this interval. In view of these facts we feel that potentially the reduction of entrapment by turning off circulating water pumps (i.e., reducing flow) during the nighttime off-peak hours may be a valuable contribution to the best technology available (BTA) demonstration plan as well as remove unnecessary mortality of the nearshore fish populations.

2.0 METHODS

In order that fish response to plant operations may be described, the survey procedures were designed to minimize the natural variability due to fish behavior patterns in the study area. The survey design, theory, and details are presented in Thomas et al. (1979).

Briefly, the midwater fish density (D_M) was measured with hydroacoustics, the relative abundance of a species i (P_i) was measured by subsampling the acoustic targets with a lampara seine, and the relative density of fish in the surface and bottom strata which are not measured via hydroacoutics (D_{S+B}) was measured with vertical gillnets. The equation for calculating the abundance of a species (D_i) was

$$D_i = P_i \, D_T$$

where $D_T = D_{S+B} + D_M$, the total fish density.

The offshore fish density by species was determined in this manner at approximately hourly intervals between 2330 and 0430 each survey day. Simultaneously, the inplant entrapment of each species was determined by monitoring impingement hourly after chlorine/mini-heat treatments (Thomas et al. 1979) of the screenwells. The results of the inplant and offshore surveys were then combined to yield a ratio of entrapment over fish density which was then examined for response to changes in flow.

Fish entrapment and offshore abundance were monitored for 4 consecutive days. Flow was reduced from full to half during the midnight to dawn interval of alternate sampling days.

All fish density estimates and subsequent derivations used in this report are relative only to this survey and are not comparable to other surveys. In the final factors such as the acoustic system gain and selectivity and efficiency characteristics of the nets will be standardized in order to make possible between-survey comparisons of fish density and vulnerability to entrapment.

3.0 RESULTS

3.1 Physical Conditions

Water temperature, transparency, 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 ranging from 2 to 3 ft from June 1 to June 6 (Fig. 1) was measured in the screenwell during daylight hours with a Secchi disk. On June 6 water transparency increased to 6 to 8 ft. This change in water transparency was accompanied by an increase in the ambient intake water temperature (Fig. 1).

Wind speeds during the interval June 1 to June 10 ranged up to 7 mph. Peak wind speeds were generally observed late each afternoon (Fig. 2). Wind speeds of zero to 4 mph were observed during the midnight to dawn sampling intervals.

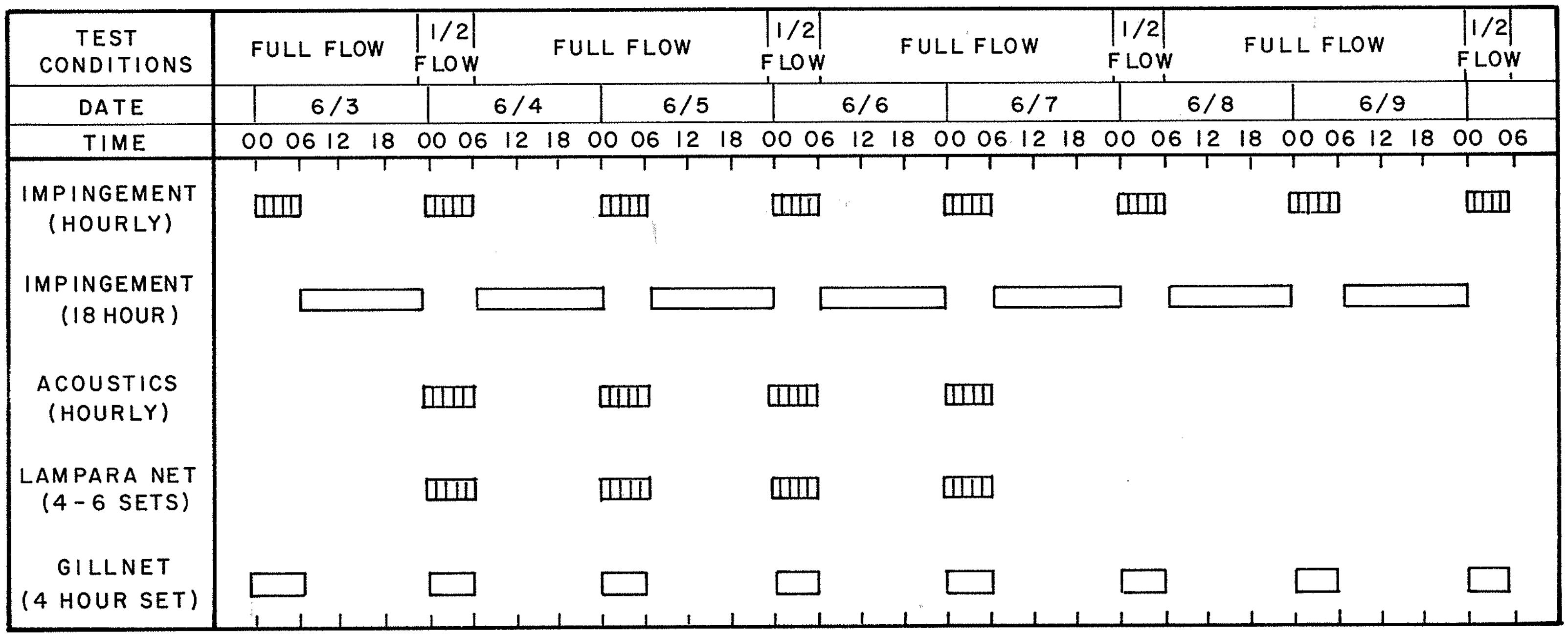

Fig. 1. Impingement, hydroacoustic, lampara net, and gillnet survey schedule during a field evaluation of the effect of nighttime flow reduction on entrapment of fish at the Huntington Beach Generating Station.

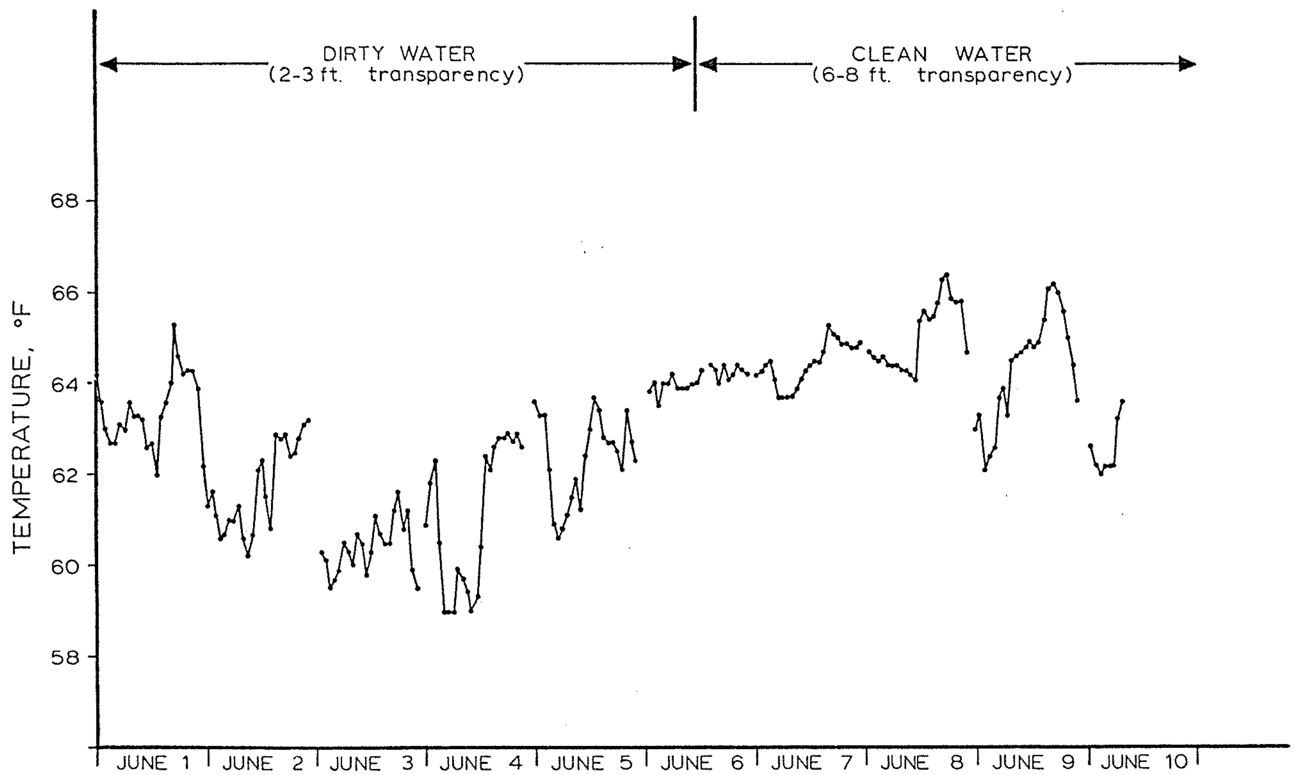

Fig. 2. Intake water temperature (F°) and transparency (ft) at Huntington Beach Generating Station, June 1-10, 1979.

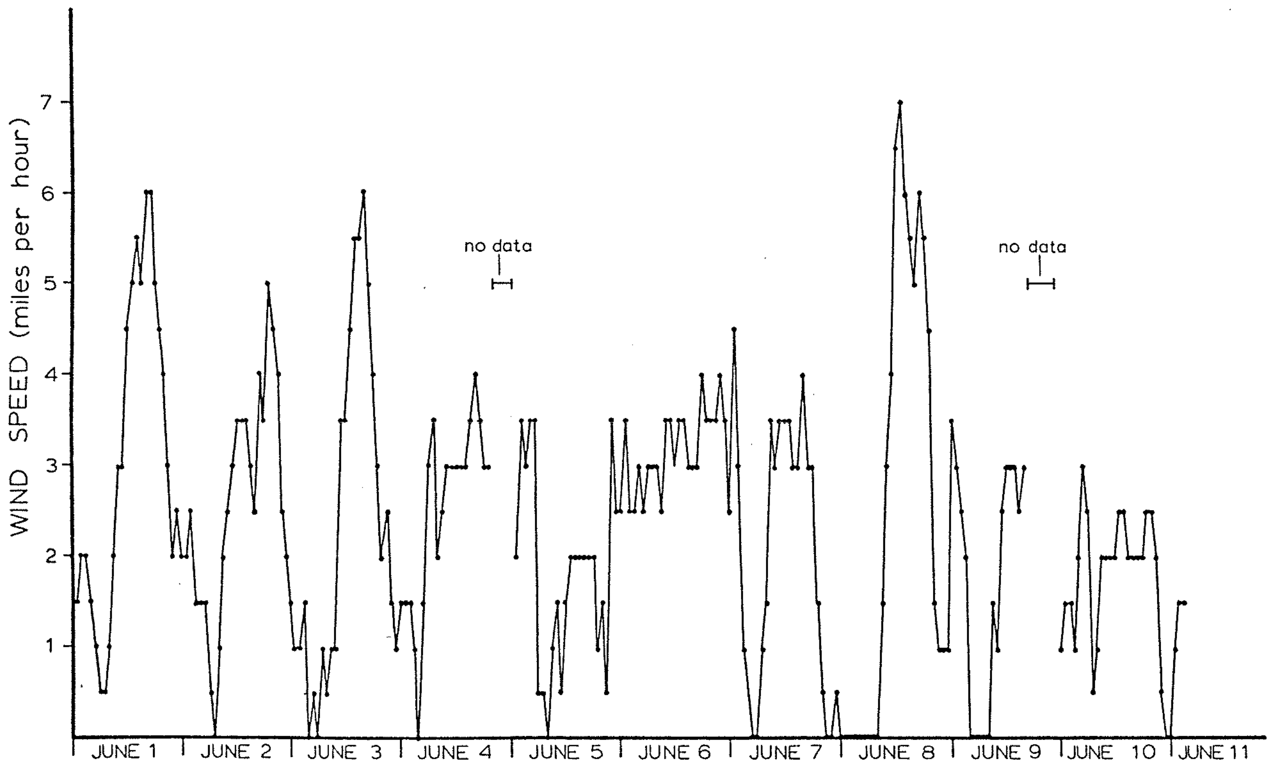

Fig. 3. Wind speed (mph) at Huntington Beach Generating Station, June 1-10, 1979.

3.2 Indicator Species (i)

The species compositions of fishes entrapped inplant and captured in the field were examined to determine relative density. Fishes that composed significant percentages of the inplant and field catches (i.e., the indicator species) were selected for use in the following data analyses. These fishes were queenfish (*Seriphus politus*), northern anchovy (*Engraulis mordax*), and white croaker (*Genyonemus lineatus*) (Table 1).

3.3 Sampling Selectivity

The length frequency distributions of the queenfish, white croaker, and northern anchovy captured in the lampara seine, gillnets, and plant screenwell were compared to determine if the different survey methods were monitoring the same component of each fish population.

Queenfish

All three survey methods appeared to be monitoring the same range in lengths of queenfish (Fig. 4). Figure 3 also demonstrates the low selectivity of the gillnets for queenfish less than 110 mm standard length (S.L.) relative to the impingement and lampara samples.

These results suggest P_1 (where P represents lampara catch and i = 1 = queenfish) to be an unbiased estimate of the offshore populations of queenfish relative to entrapment. However, the lower relative selectivity of the gillnet for small queenfish suggests that D_{S+B} (vertical gillnet catch) should be examined and possibly adjusted for sampling bias.

White Croaker

The inplant and lampara methods appeared to be monitoring the same length range of white croaker (Fig. 5). However, the gillnets failed to retain individuals below 100 mm S.L. (Fig. 5). Figure 4 also suggests differential selectivity between the impingement and lampara sample for fish shorter than 100 mm S.L.

The absolute density estimates indicate that the density of white croaker and northern anchovy increased after the first survey day. The majority of fluctuation in fish density between hours was attributed to the movement of fish aggregations (especially northern anchovy) into and out of the study area.

These results suggest that P_2 (where i = 2 = white croaker) should be examined and possible adjusted for sampling bias and that D_{S+} does not represent white croaker less than 100 mm S.L.

Table 1. The species composition of fishes caught in-plant and offshore of the Huntington Beach Generating Station, June 2-10, 1979. (Ranked by biomass impinged)

Scientific name	Common name	Impingement % biomass	Impingement % number	Lampara catch % biomass	Lampara catch % number
Seriphus politus	queenfish	52.43	29.00	5.24	1.25
Engraulis mordax	northern anchovy	13.07	42.63	71.72	91.64
Genyonemus lineatus	white croaker	9.21	7.48	12.69	2.47
Phanerodon furcatus	white surfperch	8.86	10.49	*	**
Hyperprosopon argenteum	walleye surfperch	2.42	6.77	*	**
Embiotoca jacksoni	black surfperch	2.20	0.63	*	**
Porichthys notatus	plainfin midshipman	1.43	0.47	*	**
Peprilus simillimus	Pacific butterfish	1.32	0.23	*	**
Cymatogaster aggregata	shiner surfperch	1.07	1.33	*	**
Urolophus halleri	round stingray	0.99	0.05	*	**
Anisotremus davidsonii	sargo	0.08	0.03	--	--
Paralichthys californicus	California halibut	0.07	0.05	*	**
Paralabrax clathratus	kelp bass	0.06	0.08	--	--
Rhacochilus toxotes	pile surfperch	0.06	0.04	--	--
Scorpaena guttata	sculpin	0.06	0.07	*	**
Paralabrax nebulifer	barred sand bass	0.04	0.04	--	--
Damalichthys vacca	pile surfperch	0.04	0.03	--	--
Cheilotrema saturnum	black croaker	0.04	0.05	--	--
Otophidum scrippsi	basketweave cusk-eel	0.03	0.12	*	**
Mustelus californicus	gray smoothhound	0.03	0.01	--	--
Cynoscion nobilis	white seabass	0.02	0.01	--	--
Paralabrax maculatofasciatus	spotted sand bass	0.02	0.02	*	**
Synodus lucioceps	California lizardfish	0.02	0.02	*	**
Sebastes rastrelliger	grass rockfish	0.01	0.02	--	--
Menticirrhus undulatus	California corbina	0.01	0.02	*	**
Porichthys myriaster	specklefin midshipman	0.01	0.01	--	--
Girella nigricans	opaleye	0.01	0.01	--	--
Sebastes auriculatus	brown rockfish	0.01	0.02	--	--
Platyrhinoides triseriata	thornback	0.01	0.01	*	**
Atherinops affinis	topsmelt	0.01	0.01	--	--
Leptocottus armatus	staghorn sculpin	0.01	0.05	--	--
Pleuronichthys verticalis	horneyhead turbot	--	0.05	*	**
Scomber japonicus	Pacific mackerel	--	0.01	*	**
Parophrys vetulus	English sole	--	0.01	--	--
Pleuronichthys coenosus	C.O. turbot	--	0.01	*	**
Amphisticus argenteus	barred surfperch	--	0.01	--	--
Sebastes paucispinis	bocaccio	--	0.03	--	--
Hypsoblennius jenkinsi	mussel blenny	--	0.01	--	--
Symphurus atricauda	California tonguefish	--	0.01	--	--
Oxyjulis californica	señorita	--	0.01	--	--
Chromis punctipinnis	blacksmith	--	0.01	--	--
Unidentified Fish		--	0.01	--	--
Sygnathus sp.	pipefish	--	0.02	*	**
Hypsoblennius sp.	blenny	--	0.02	--	--
Unidentified juvenile flatfish		--	0.02	--	--
Torpedo californica (not weighed)	Pacific eel ray	--	0.01	--	--
Myliobatis californica	bay ray	--	--	*	**
Anchoa compressa	deepbody anchoa	--	--	*	**
Citharichthys stigmaeus	speckled sanddab	--	--	*	**
Sphyraena argentea	California barracuda	--	--	*	**
TOTAL CATCH		497.45Kg	17,333	3,118.33Kg	377,772

*Miscellaneous species represented 10.35% of the lampara catch biomass.

**Miscellaneous species represented 3.64% of the lampara catch numbers.

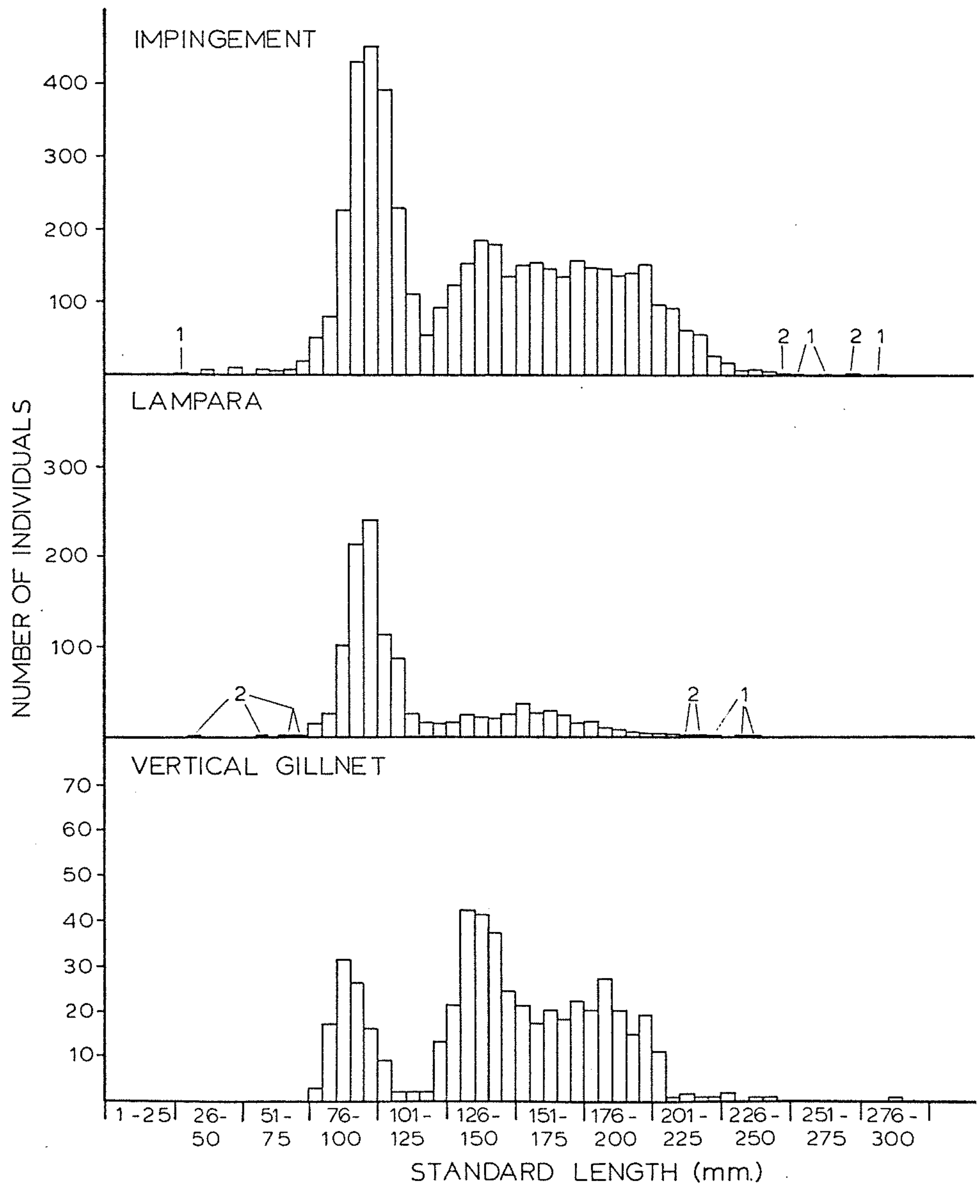

Fig. 4. The length-frequency distribution of queenfish caught inplant and offshore of the Huntington Beach Generating Station, June 2-10, 1979.

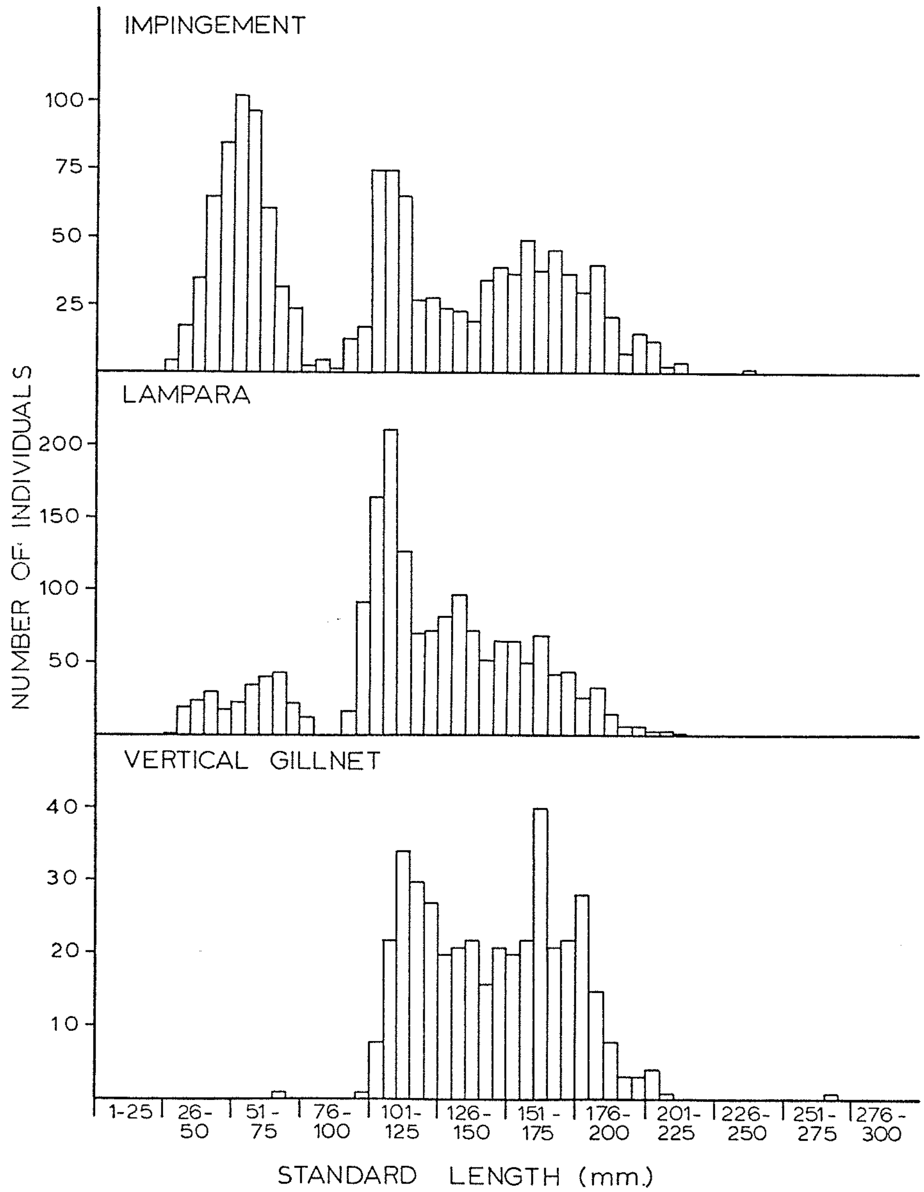

Fig. 5. The length-frequency distribution of white croaker caught inplant and offshore of the Huntington Beach Generating Station, June 2-10, 1979.

Northern Anchovy

The inplant and lampara methods appeared to be monitoring similar length ranges of northern anchovy (Fig. 6). The gillnet catches did not retain anchovy less than 100 mm S.L.

These results suggest that P_3 (where i = 3 = northern anchovy) to be an unbiased estimation of the offshore population relative to entrapment. However, the absence of anchovy less than 100 mm S.L. in the gillnet catch means D_{S+B} does not represent that proportion of the northern anchovy population.

It is important to note that smaller sizes of these species (larvae) are entrained through the plant cooling system and that this study is addressing only those fish populations in which the individuals are large enough to be retained on the screenwell's traveling screen system (i.e., entrapment, not entrainment).

3.4 Fish Entrapment (E)

Hourly entrapment rates (E) for queenfish, white croaker, and northern anchovy are presented in Tables 2a, 2b, and 2c, respectively. In general, the rate of entrapment decreased during the study period. The most noticeable decline occurred between the survey nights of June 6 and 7 when there was a noticeable change in the water transparency. Because the water transparency increase was associated with decreasing entrapment rates, the appropriate comparison of full and half flow regimes was to pair survey night operations with similar transparency values: 6/3, 6/4; 6/5, 6/6; 6/7, 6/8; 6/9, 6/10 (i.e., full flow, half flow, etc.). This pairing of the data resulted in minimal overlap between the mean daily entrapment rates at half flow and full flow for all three species (Fig. 7). The magnitude of the mean daily fish entrapment suggested that reduction to half flow reduced the fish lost by 3- to 4-fold for queenfish, greater than 4-fold for white croaker, and 3- to 10-fold for northern anchovy, assuming that the density of fish was stable throughout the survey period. If in fact the fish density was stable, the data suggest the effect of water transparency to be much larger than flow effect in reducing the fish entrapment (by 14- to 24-fold for queenfish, greater than 25-fold for white croaker, and 5- to 100-fold for northern anchovy).

3.5 Offshore Fish Density (D_M D_T)

The density of fish (g/m^2 surface) in midwater within 300 m of the intake structure was determined with hydroacoustic techniques during the nighttime hours, June 4 to June 7 (Table 3). The hydroacoustic measurement represents only those fish from approximately 1 to 3 m from the surface to 1 m above the bottom (D_M). The nearsurface strata which were not sampled with acoustics varied depending on surface conditions.

Table 2a. Hourly impingement rates (E_1) observed for Seriphus politus during nighttime intervals at the Huntington Beach Generating Station, June 3-10, 1979.

Time	6/3 Full Flow		6/5 Full Flow		6/7 Full Flow		6/9 Full Flow	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
2330-0030			109	8.11	10	.81	8	.354
0030-0130	161	9.86	98	5.80	7	.21	7	.39
0130-0230	334	17.16	126	7.65	4	.15	8	.29
0230-0330	335	15.0	230	15.83	3	.05	1	.021
0330-0430	275	11.03	234	13.26	5	.22	2	.23
0430-0530	240	8.75	233	11.00	14	.31	4	.30
$\bar{x}$	269	12.36	171.7	10.28	7.17	.29	5.0	.264
S.D.	72.7	3.57	67.1	3.79	4.17	.27	3.1	.131

Time	6/4 Half Flow		6/6 Half Flow		6/8 Half Flow		6/10 Half Flow	
	No.	Kg	No	Kg	No.	Kg	No.	Kg
2330-0030								
0030-0130	72	3.51	36	2.45				
0130-0230	40	1.26	6	.19	3	.23	1	.15
0230-0030	25	1.30	1	.35	1	.2	0	0
0330-0430	45	2.36	8	.57	0	0	0	0
0430-0530	83	2.14	3	.17	1	.04	1	.072
$\bar{x}$	53.0	2.11	10.8	.75	1.25	.12	.50	.06
S.D.	23.86	.92	14.34	.97	1.26	.11	.58	.07

Table 2b. Hourly impingement rates (E_2) observed for Genyonemus during nighttime intervals at the Huntington Beach Generating Station, June 3-10, 1979.

	6/3		6/5		6/7		6/9	
	Full Flow		Full Flow		Full Flow		Full Flow	
Time	No.	Kg	No.	Kg	No.	Kg	No.	Kg
2330-0030			62	.33	0	0	.33	.0106
0030-0130	38	2.25	55	.24	2	.05	.33	.0106
0130-0230	34	5.59	26	.54	0	0	.33	.0106
0230-0330	36	3.78	50	1.53	2	.07	0	0
0330-0430	57	3.37	87	4.98	5	.01	0	0
0430-0530	79	4.25	192	5.76	0	0	0	0
$\bar{x}$	48.80	3.85	78.67	2.23	1.5	.02	.165	.005
S.D.	19.23	1.22	58.9	2.49	1.97	.03	.181	.006

	6/4		6/6		6/8		6/10	
	Half Flow		Half Flow		Half Flow		Half Flow	
Time	No.	Kg	No.	Kg	No.	Kg.	No.	Kg
2330-0030								
0030-0130	18	.52	8	.07				
0130-0230	8	.14	5	.06	0	0	0	0
0230-0330	5	.07	1	.01	0	0	0	0
0330-0430	7	.06	1	.05	0	0	0	0
0430-0530	21	.47	2	.02	0	0	0	0
$\bar{x}$	11.8	.25	3.4	.04	0	0	0	0
S.D.	7.19	.22	3.05	.03	0	0	0	0

Table 2c. Hourly impingement rates (E_3) observed for <u>Engraulis</u> during nighttime intervals at the Huntington Beach Generating Station, June 3-10, 1979.

Time	6/3 Full Flow No.	6/3 Full Flow Kg	6/5 Full Flow No.	6/5 Full Flow Kg	6/7 Full Flow No.	6/7 Full Flow Kg	6/9 Full Flow No.	6/9 Full Flow Kg
2330-0030			446	4.73	27	.2	147	1.36
0030-0130	18	.1	283	2.82	50	.47	91	.90
0130-0230	39	.43	191	1.95	23	.2	65	.6
0230-0330	107	1.15	278	2.23	22	.25	2	.002
0330-0430	128	1.53	263	2.27	10	.15	18	.14
0430-0530	239	2.55	306	2.45	5	.17	9	.11
$\bar{x}$	106.2	1.15	294.5	2.74	22.83	.24	55.33	.519
S.D.	87.2	.97	83.9	1.02	15.74	.12	56.83	.536

Time	6/4 Half Flow No.	6/4 Half Flow Kg	6/6 Half Flow No.	6/6 Half Flow Kg	6/8 Half Flow No.	6/8 Half Flow Kg	6/10 Half Flow No.	6/10 Half Flow Kg
2330-0030								
0030-0130	51	.54	54	.48	1	.06	1	.005
0130-0230	70	.50	23	.19	0	0	1	.007
0230-0330	13	.12	14	.07	0	0	1	.011
0330-0430	6	.05	29	1.3	0	0	0	0
0430-0530	13	.11	19	.06	0	0	0	0
$\bar{x}$	30.6	.26	27.8	.42	.20	.012	.60	.0046
S.D.	28.25	.24	15.64	.52	.45	.03	.55	.0047

Table 3. Midwater density of fish, D_M (grams/m^2 surface), total offshore fish density, D_T, at Huntington Beach, June 4-6,1979.

Date	Time	D_M	D_T
6/4	2330	0.198	0.430
6/4	0030	0.487	1.057
6/4	0130	0.321	0.697
6/4	0230	0.238	0.516
6/4	0330	0.286	0.621
6/4	2330	0.769	1.669
6/5	0030	0.803	1.743
6/5	0130	0.379	0.822
6/5	0230	0.455	0.987
6/5	0330	0.534	1.159
6/5	2330	0.983	2.133
6/6	0030	0.510	1.107
6/6	0130	0.570	1.237
6/6	0230	0.912	1.979
6/6	0330	0.730	1.584
6/6	0430	0.953	2.068
6/6	2330	0.524	1.137
6/7	0030	1.725	3.743
6/7	0130	1.770	3.841
6/7	0230	1.525	3.309
6/7	0330	0.569	1.235

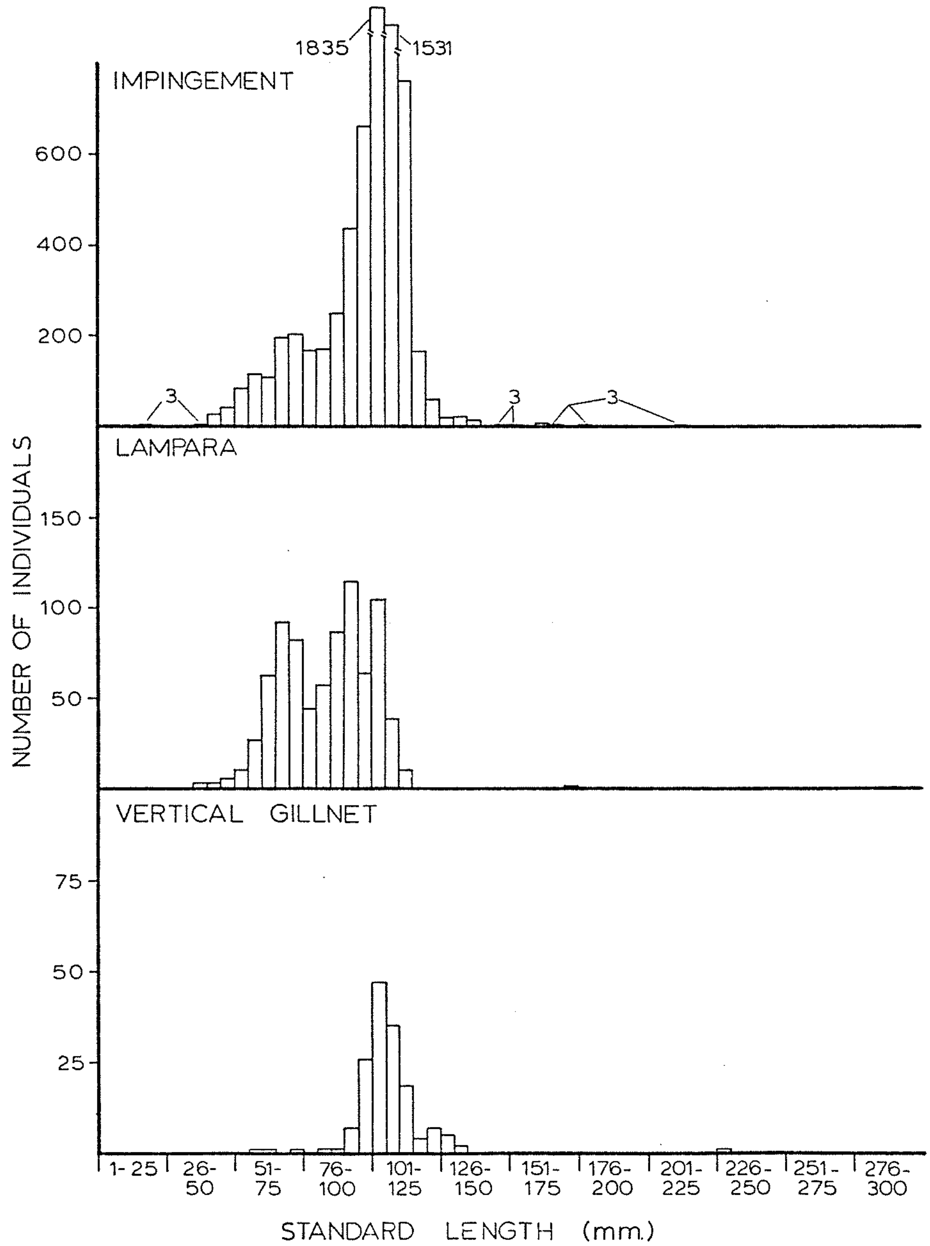

Fig. 6. The length-frequency of northern anchovy caught inplant and offshore of the Huntington Beach Generating Station, June 2-10, 1979.

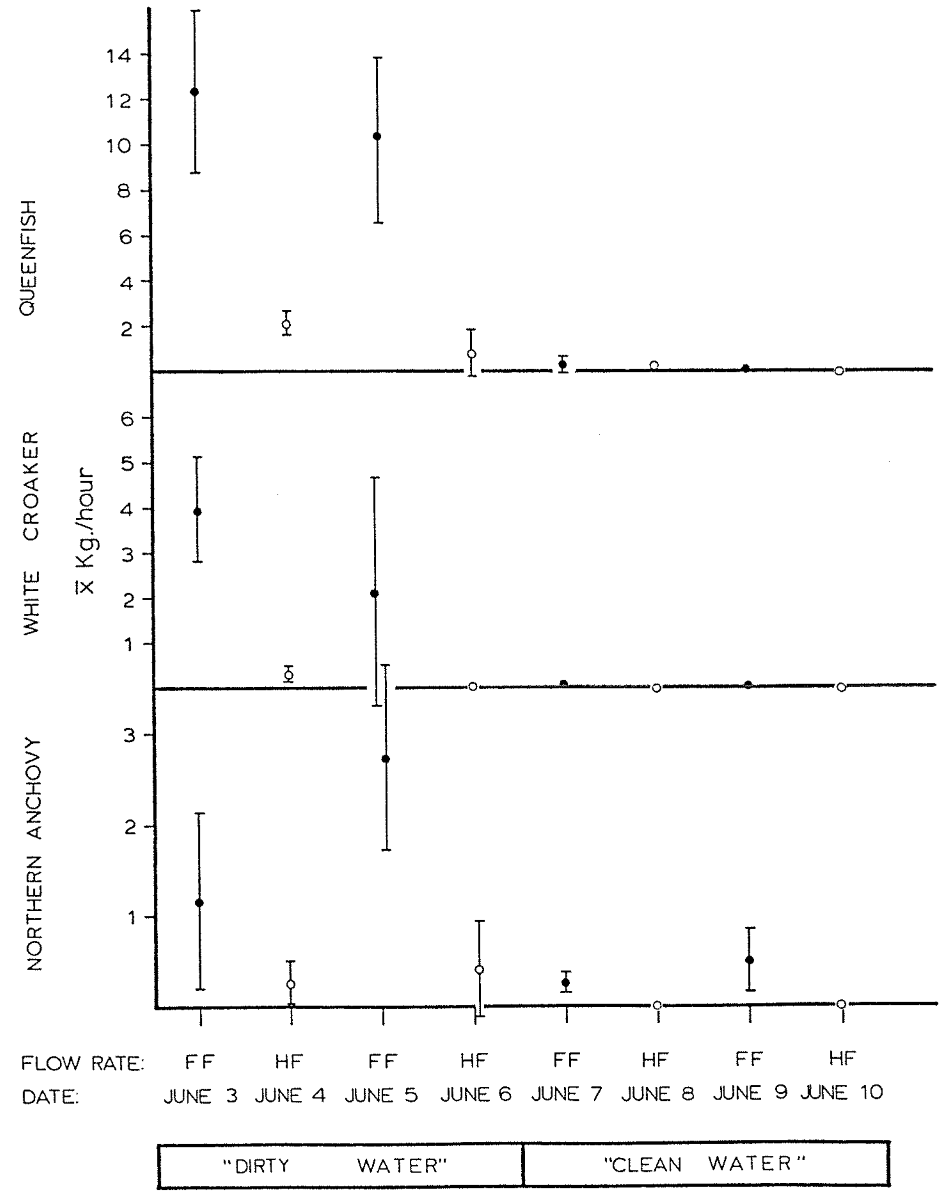

Fig. 7. Mean hourly entrapment rates of queenfish, white croaker and northern anchovy during full flow (solid circles) and half flow (open circles) nighttime intervals at the Huntington Beach Generating Station, June 3-10, 1979.

The near-bottom strata which were not sampled with acoustics were constant and were determined by beam pattern characteristics and by the bottom tracking buffer used during integration of acoustic tapes.

The relative magnitude of fish in the surface and the bottom strata of the water column which were not sampled acoustically was determined from vertical gillnet catches. The vertical distribution (percent weight by depth) is presented in Table 4. The vertical gill-net catches in the first three surface depth increments and the bottom depth increment of the water column were used to estimate the percent of fish by weight in the water column unaccounted for by acoustics ($P_{S+B} = 0.54$). The adjustment of midwater fish density (D_M) to total fish density (D_T) was made by computing the following proportion:

$$D_{S+B} = \frac{P_{S+B}\ D_M}{P_{S+B}\ -1} = \frac{0.54\ D_M}{0.54-1} = 1.17\ D_M,$$

therefore,

$$D_T = 1.17\ D_M + D_M = 2.17\ D_M$$

The total fish density by hour for each survey day is presented in Table 3.

The mean fish density increased from 0.31 to 1.22 g/m^2 surface between June 4 and 7. The hourly estimates were lower ($\alpha = 0.05$) on the first day of the survey than on subsequent survey days. These results suggested that decreasing entrapment rates during the survey were the result of operational and environmental processes and not associated with decrease in fish abundance.

3.6 Species Composition (P_i)

The lampara catch composition, a subsample of the acoustically observed targets was used to determine the species composition of the fish densities within 300 m of the intake structure (Table 5). The northern anchovy, white croaker, and queenfish dominated the lampara catches during the survey. Silversides (Atherinidae) were abundant only during the first day of the survey interval. There was an increase in the catch per set (c/f) of northern anchovy after the first survey day. White croaker and queenfish c/f remained relatively uniform throughout the survey (Table 6).

The c/f of the lampara set alone is not indicative of the fish density measured acoustically between days because it represents a subsample of the largest fish concentrations present during each particular day. Therefore correlations between lampara and acoustic data are restricted to a set-by-set comparison to be presented in the final report. Correlation of $r_s = +0.78$ (n = 24) between lampara c/f and acoustically integrated fish density were observed in previous studies (Thomas 1979).

Table 4. Vertical distribution (% weight by depth) of fishes caught in vertical gillnets June 2-10, 1979. Each depth increment equals 8.3% of the total water column.

Average Depth (m)	Depth Increment	All species combined
0 m (surface)	1	15.03 kg
	2	20.64
	3	12.93
	4	7.55
	5	7.16
	6	5.18
	7	3.91
	8	3.56
	9	5.53
	10	7.61
	11	5.50
9.45 m (bottom)	12	5.41
	Total catch	121.87 kg

Table 5. Mean lampara catch per day (P_i) in percent for three dominant species: queenfish, white croaker, and northern anchovy.

Date	Number of sets	Queenfish P_1 $\overline{X}$	Queenfish P_1 s.d.	White Croaker P_2 $\overline{X}$	White Croaker P_2 s.d.	Northern Anchovy P_3 $\overline{X}$	Northern Anchovy P_3 s.d.
6/4	4	12.75	6.41	17.98	6.09	37.33	11.41
6/5	4	7.33	5.97	17.33	15.87	66.50	26.03
6/6	4	6.03	1.32	15.20	6.35	71.25	9.99
6/7	4	4.90	3.36	18.95	10.25	70.50	13.33

Table 6. Lampara catch per set in kilograms and percent (L) for three dominant species: queenfish, white croaker, and northern anchovy.

Date	Set	Queenfish kg	Queenfish %	White Croaker kg	White Croaker %	Northern Anchovy kg	Northern Anchovy %
6/4	1	3.16	18.5	3.16	18.5	26.44	37.2
6/4	2	4.76	3.6	13.44	10.3	57.71	44.1
6/4	3	8.01	15.0	9.59	17.9	24.96	46.7
6/4	4	6.03	13.9	12.45	25.2	10.48	21.3
6/5	5	19.4	3.3	21.8	3.7	501.61	85.8
6/5	6	9.17	5.1	45.11	25.0	109.57	60.8
6/5	7	9.31	4.7	9.11	4.6	174.53	87.4
6/5	8	14.13	16.2	31.56	36.0	28.01	32.0
6/6	9	24.48	6.5	28.22	7.5	310.35	82.6
6/6	10	15.80	7.1	27.76	12.5	166.99	75.0
6/6	11	5.93	4.1	29.18	20.0	99.54	68.3
6/6	12	8.76	6.4	28.67	20.8	81.42	59.1
6/7	13	18.60	7.5	44.89	20.2	158.51	64.3
6/7	14	5.18	1.8	23.22	8.1	250.89	87.6
6/7	15	7.24	8.1	34.77	15.1	169.29	73.5
6/7	16	2.52	2.2	39.77	32.4	66.02	56.6

3.7 Offshore Density by Species (D_i)

Hourly estimates of offshore density within 300 m of the intake structure were calculated for queenfish, white croaker, and northern anchovy from the products of D_T and P_i (Table 7). The hourly density of queenfish did not change between survey days (α = 0.05). The hourly estimates of density for white croaker and northern anchovy were different between the first survey day, June 6, and the remainder of the survey days (α = 0.05). The absolute density estimates indicate that the density of white croaker and northern anchovy increased after the first survey day. The majority of fluctuation in fish density between hours was attributed to the movement of fish aggregations (especially northern anchovy) into and out of the study area.

3.8 Fish Loss with Reduced Flow

Hourly ratio estimates of entrapment to density (E/D) were computed for queenfish, white croaker, and northern anchovy (Table 8). As previously discussed, the 4 survey days were divided into 2 pairs: one day at half flow (6/4) and 1 day at full flow (6/5) during turbid water conditions and the same operational schedule repeated on 6/6 and 6/7 during clear water conditions. The exact time of the change in water transparency was not recorded; however, the first hourly measurement (0030) on 6/6 was suspected to be made during this transition period. Assuming that greater transparency and/or associated factor directly affected entrapment, the vulnerability of each important species to entrapment (E/D) was different between the low and high water clarity periods (α = 0.01). In fact, the E/D ratios for queenfish, white croaker, and northern anchovy were too low to test for operational differences of reduced flow under clear water conditions during June 6 and 7, 1979.

The operational effects of reduced flow during the intervals of turbid water (6/4 and 6/5) indicated substantial reduction of fish entrapment at half flow. There was no overlap in the E/D ratios of queenfish and nothern anchovy at high and low flow in turbid water. Despite overlap in the E/D ratios of white croaker, the average E/D at high flow was much larger than low flow; however, a larger sample size is needed for statistical verification of this difference.

The relative magnitude of the E/D ratios suggests that the relative order of vulnerability to entrapment is queenfish, white croaker, and then northern anchovy.

4.0 DISCUSSION

The ability to calulate real time impingement rates and offshore fish density synchronously has enabled us to evaluate 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

Table 7. Offshore estimates of fish density by species (D_i) for queenfish (D_1), white croaker (D_2), and northern anchovy (D_3) g x 10^2/surface m^2 at Huntington Beach, June 4-7,1979.

Date	Time	D_1	D_2	D_3
6/4	0030	13.48	19.00	39.46
6/4	0130	8.89	12.53	26.02
6/4	0230	6.58	9.28	19.26
6/4	0330	7.92	11.17	23.18
6/4	2330	12.23	28.92	110.99
6/5	0030	12.78	30.21	115.91
6/5	0130	6.03	14.25	54.66
6/5	0230	7.23	17.10	65.64
6/5	0330	8.50	20.03	77.07
6/6	0030	6.70	16.83	78.87
6/6	0130	7.48	18.80	88.14
6/6	0230	11.97	30.08	141.00
6/6	0330	9.58	24.08	112.86
6/6	0430	12.51	31.43	147.35
6/6	2330	5.57	21.55	80.16
6/7	0030	18.34	70.93	263.88
6/7	0130	18.82	72.79	270.79
6/7	0230	16.21	62.71	233.28
6/7	0330	6.05	23.40	87.07

Table 8. Hourly ratios of fish entrapment (kg/hr) to offshore fish density (g x 10^2/surface m^2), E_i/D_i, for queenfish (i=1), white croaker (i=2), and northern anchovy (i=3) at Huntington Beach, June 4-7,1979.

Date	Time	Number of pumps	Water transparency	E_1/D_1	E_2/D_2	E_3/D_3
6/4	0030	4	D	0.26	0.18	.01
6/4	0130	4	D	0.14	0.10	.02
6/4	0230	4	D	0.20	0.14	.01
6/4	0330	4	D	0.30	0.21	*
6/4	2330	8	D	0.66	0.28	.04
6/5	0030	8	D	0.45	0.19	.02
6/5	0130	8	D	1.27	0.54	.04
6/5	0230	8	D	2.19	0.93	.03
6/5	0330	8	D	1.56	0.66	.03
6/6	0030	4	**	0.37	0.15	.01
6/6	0130	4	C	0.03	0.01	*
6/6	0230	4	C	0.03	0.01	*
6/6	0330	4	C	0.06	0.02	.01
6/6	0430	4	C	0.01	0.01	*
6/6	2330	8	C	0.15	0.04	*
6/7	0030	8	C	0.01	*	*
6/7	0130	8	C	0.01	*	*
6/7	0230	8	C	*	*	*
6/7	0330	8	C	0.04	.01	*

*Trace.

**Estimated time of water transparency change suspected to have been low transparency.

C = high
D = low

evaluation of intake effects would be misinterpreted because of changes in either offshore density or physical parameters. The ability to meausre offshore fish density synchronously with entrapment was made possible through the use of hydroacoustics.

The statistical technique for adjusting entrapment rates by offshore fish density has been simply to form the ratio of entrapment to density (E/D). This ratio is felt to represent the relative vulnerability of a fish assemblage to an intake. Therefore by monitoring E and D through major changes in operational modes of an intake we hope to describe the "main" effects. Refinement of the statistics used and assessment of the variability inherent in the technique will be addressed in the 1979 and 1980 annual reports. For example, the low selectivity of vertical gillnets for small fishes suggest that D_{S+B} should be examined and possibly adjusted for sampling bias. We believe that this bias has a relatively small effect because biomass estimation is influenced only slightly by smaller fishes.

The gillnet catches indicated that over 50% of this biomass was in the top and bottom 3 m. This suggests that the greater sampling effort of acoustics is not very effective in monitoring the shallow water nearshore fish densities. However, we believe at this time the vertical distribution of biomass (from the gillnets) to be biased high in the surface 2 m because of the high relative efficiency of the gillnets for atherinids. The vertical distribution of biomass minus atherinids indicates only 23% of the fish biomass to be missed by acoustics. Since the atherinids are not important to present entrapment studies and the vertical distribution correction factor exerts a uniform positive bias on density, we feel the trends observed in this data analysis are representative of the important fishes; queenfish, northern anchovy, and white croaker. Of these three species only the white croaker appears to have a non-uniform distribution by depth (bottom preference) and therefore may be influenced the most by the bias resulting from variable gillnet efficiency. The determination of selectivity and efficiency patterns of the gillnet will allow for the evaluation of and possibly the adjustment for these biases. These analyses are scheduled for the final report.

The evidence which is building suggests that some abundant and commercially important species (i.e., northern anchovy) are not as vulnerable to entrapment as some commercially non-important species. For instance, in this study the relative order of vulnerability to entrapment (E/D) was queenfish, white croaker, and <u>then</u> northern anchovy. In preliminary studies associated with this research there was some evidence that mackerels, bonita, and Pacific butterfish also had relatively low vulnerabilities to entrapment. This type of evidence will be closely examined in our upcoming studies as it may be a favorable point in the future evaluation of the effectiveness of Southern California Edison's intake design in minimizing entrapment.

The E/D ratio appeared to be robust enough to determine some differences in the fish assemblage's vulnerability to entrapment under differing conditions of flow and water transparency. The fact that entrapment vulnerability changed with water clarity suggests that fish may avoid entrapment by visual means. This possibility is supported by the fact that fish entrapment is higher at night (Thomas et al. 1979). In view of the large effect of water transparency, turbidity monitoring should be an important facet of entrapment and site selection studies.

Despite the fact that the water transparency changed in the middle of this study and reduced the amount of data for the full and half flow comparison procedures, the ability to make several hourly observations within single night intervals provided us with a large enough sample size for some statistical inferences. The significant differences between full flow and half flow E/D (6/4 and 6/5) suggested that minimizing fish entrapment by reducing flow during off-peak demand intervals (late night) is very promising and deserves future field investigations.

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