

FISHERIES RESEARCH INSTITUTE
College of Fisheries
University of Washington
Seattle, Washington 98195

A FIELD EXAMINATION OF THE EFFECTIVENESS OF
A VELOCITY CAP IN MINIMIZING ENTRAPMENT

by

Llew Johnson¹, G. L. Thomas^{2,3}
R. E. Thorne² and E. C. Acker³

TECHNICAL REPORT

to Southern California Edison Company

with

Moore Laboratory of Zoology
Occidental College
Los Angeles, California

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Approved

Submitted February 22, 1980

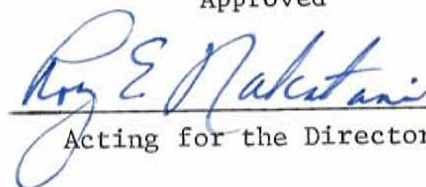

Acting for the Director

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1.0 INTRODUCTION

This paper reports on the third of a series of tasks proposed by the hydroacoustic group, University of Washington, and the Fish Encounter Studies (FES), Occidental College for Southern California Edison Company. A combined inplant impingement, hydroacoustic, and net sampling survey was conducted between July 15 and 22, 1979, at the Huntington Beach Generating Station (HBGS).

The specific objectives of the July 15 to 22 survey were to simultaneously measure offshore fish density and inplant entrapment. The results were employed to test the hypothesis that fish entrapment with and without a velocity cap 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

The only supporting document SCE has to defend a position that its existing velocity caps are environmentally acceptable and represent the "Best Intake Technology Available" for minimizing fish entrapment is a paper written by Weight (1958). This paper concludes that the installation of a velocity cap onto the El Segundo Generating Station's intake tower resulted in a 95% reduction in annual entrapment between 1956 and 1957. However, recent information indicating that entrapment rate is density-dependent, makes Weight's conclusion suspect, since he did not consider information on offshore fish density in reaching his conclusion. In a recent study of entrapment at the Redondo Beach Generating Station, variation in yearly entrapment rate of nearly the magnitude that Weight reported has been observed to occur independent of changes in the intake system (Johnson and Yuge, in preparation).

The velocity cap is not accepted on an industry-wide basis as the "Best Technology Available." Stupka and Sharma (1977) suggest that the velocity cap at the San Onofre Nuclear Generating Station "may actually serve to enhance the entrainment of fish." This statement was made in spite of Schuler's and Larson's study (1975) showing that in the laboratory a velocity cap can reduce entrapment of anchovy by "85 to 90%."

In light of the above, a field evaluation consisting of inplant monitoring of entrapment and offshore measurements of density was conducted in order to assess the effectiveness of a velocity cap in reducing fish entrapment.

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).

The sampling schedule for this survey is presented in Fig. 1. Fish entrapment (numbers and weight, kg) was measured at hourly intervals from 2330 to 0530 and once from 0531 to 2329; from 2330 July 14 to 0530 July 21, 1979. Acoustic measurements of fish density (g/m^2 surface) were made simultaneously with the hourly entrapment measurements between 2330 July 15 and 0530 July 21. Lampara netting was conducted between 0000 and 0530 on July 17, 18, and 19. The percent of each species in the lampara catch was computed for each survey day. Gillnetting was conducted between 2330 and 0430 from July 14 and 21. The percent of fish in the water volume not sampled acoustically was computed from the total gillnet catch by depth.

The acoustic, lampara, and gillnet data were used to compute the offshore fish density.

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 hydroacoustics (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 total hourly entrapment (kg/hr) and offshore fish density (g/m^2 surface) were used to compute (E/D). The hourly estimate of E/D were then used as an index of a species entrapment vulnerability.

In this survey hourly E/D for a 3-day period without a velocity cap were compared to a 3-day period with a velocity cap.

During the first 3 days the cooling water intake system was operated in reverse, drawing water into the system through an opening without a velocity cap. During the second 3 days, the cooling water intake system was operated in its normal mode, drawing water through an intake structure with a velocity cap.

Length frequency data were gathered from the fishes entrapped inplant and caught offshore by lampara and gillnet during the 2330-0530 sampling periods. Comparisons of the length frequency distributions were made in order to determine if the offshore samples were represen-

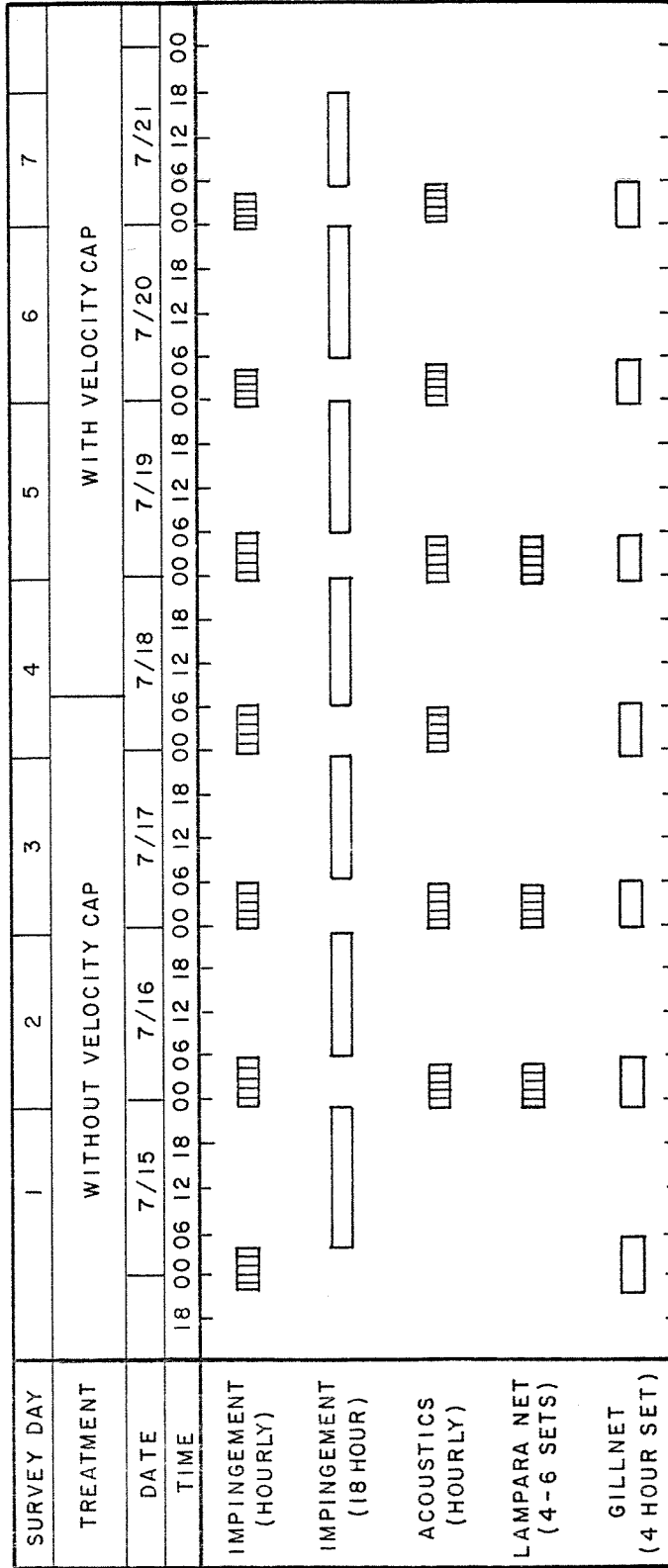


Fig. 1. Impingement, hydroacoustic, lampara net, and gillnet survey schedule during a field evaluation of the effectiveness of a velocity cap in reducing entrapment at the Huntington Beach Generating Stations.

tative of the fishes entrapped. Daily variability was not examined on a routine basis because it often required the entire survey period to collect sufficient numbers of fishes via lampara and gillnet methods.

Length frequency distributions were compared visually because this was deemed an adequate enough technique to show if sufficient numbers of similar length groups to that which were entrapped were also represented in the offshore measurements. Therefore, tedious statistical testing procedures were avoided.

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

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 ($^{\circ}\text{F}$) measurements were obtained from the HBGS plant operations. Wind speed (mph) measurements were obtained from the Newport Beach Harbor master's operations.

Non parametric 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 $\alpha = 0.05$.

2.1 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 rates or offshore abundance.

Water transparency, as measured in the screenwell during daylight hours, ranged from 1 to 5 ft July 15 to 21, 1979 (Fig. 1). During the without-velocity-cap sampling interval (July 16-18) water transparency ranged from 1 to 3 ft. During the with-velocity-cap period, the water was clearer with transparency values ranging from 3 to 5 ft. The change in water transparency was paralleled by a change in water temperature. During the interval of reduced water clarity, water temperature in the screenwell ranged from 55 to 60 $^{\circ}\text{F}$. During the interval of increased water transparency, the water temperature was higher, ranging from 60 to 68 $^{\circ}\text{F}$ (Fig. 2).

Table 1. Water transparency (m) at the Huntington Beach Generating Station screenwell, July 15-21, 1979.

Survey Day	Treatment	Date	Water transparency (m)
1	w/o cap	7/15	1.22
2	w/o cap	7/16	0.76
3	w/o cap	7/17	0.30
4	w/o cap	7/18	0.30
5	with cap	7/19	0.91
6	with cap	7/20	1.52
7	with cap	7/21	1.07

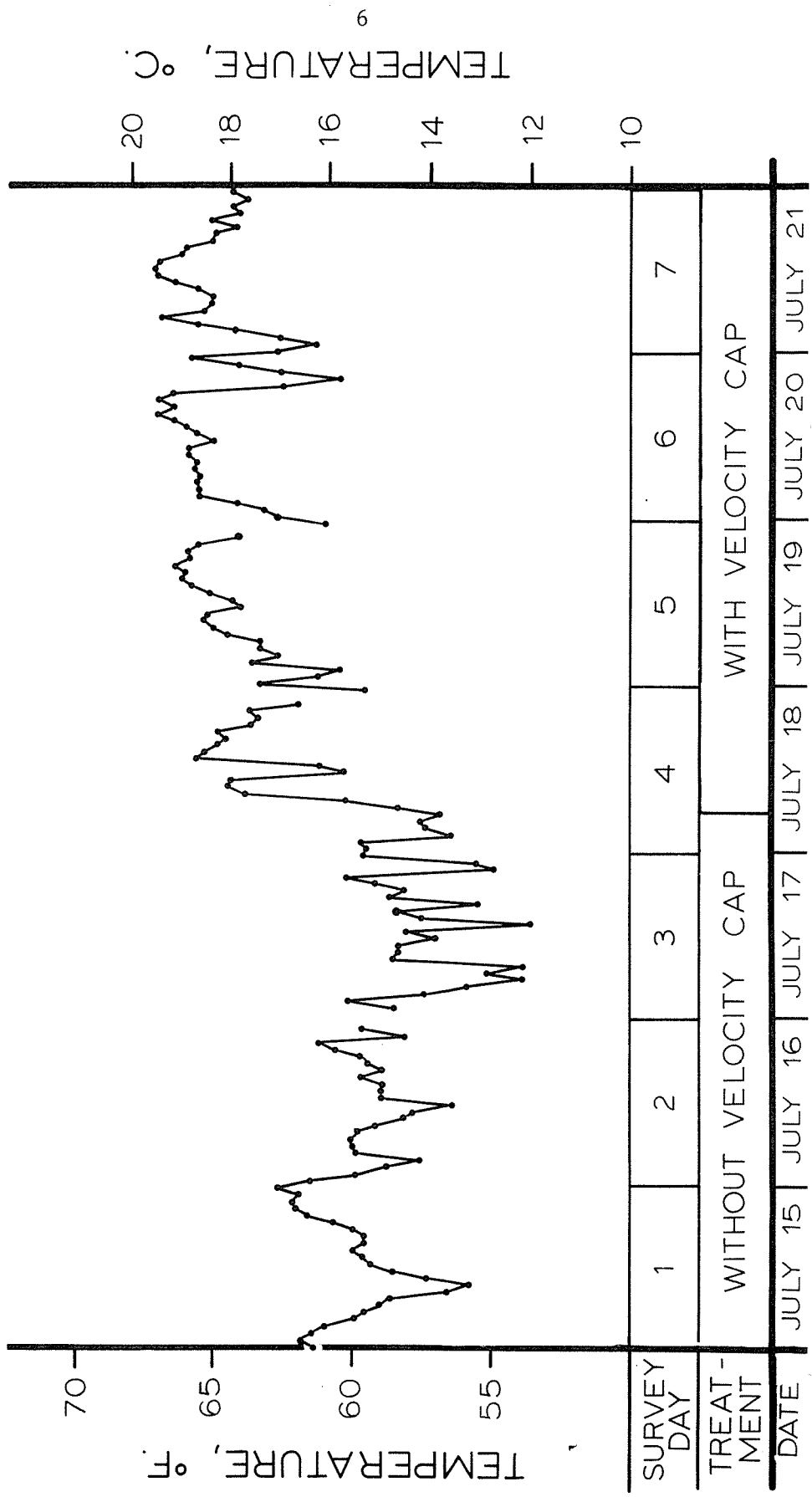


Figure 2. Intake water temperature (F°) at Huntington Beach Generating Station, July 14-21, 1979.

Wind speeds during the interval July 14 to 21 ranged up to 14 miles per hour. Wind speeds peaked each afternoon (Fig. 3). During the midnight to dawn sampling interval, wind speeds generally ranged up to 6 miles per hour.

2.2 Indicator Species (i)

The species composition (% biomass) of fishes entrapped inplant and captured in the field were examined to determine relative density. Species comprising significant percentages of the inplant and/or offshore catches (i.e., the indicator species) were selected for use in the following data analyses. These fish were queenfish (Seriphus politus), northern anchovy (Engraulis mordax), white croaker (Genyonemus lineatus), and jacksmelt (Atherinopsis californiensis) (Table 2).

2.3 Sampling Selectivity

The length frequency distributions of the queenfish, white croaker, northern anchovy, and jacksmelt 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.

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

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 5 also suggests differential selectivity between the impingement and lampara sample for fish shorter than 100 mm S.L.

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 90 mm S.L.

Figure 7 shows that the length, range, and size class distribution captured for Atherinops inplant and offshore with vertical gillnets were similar. Thus, the vertical distribution data observed offshore represents the portion of the silversides population that was entrapped. The length frequency histogram indicated the lampara net sampled size classes of silversides offshore which were not impinged, probably because the fish under 100 mm S.L. were too small to be retained on the 5/8 inch mesh traveling screens. Thus, our information

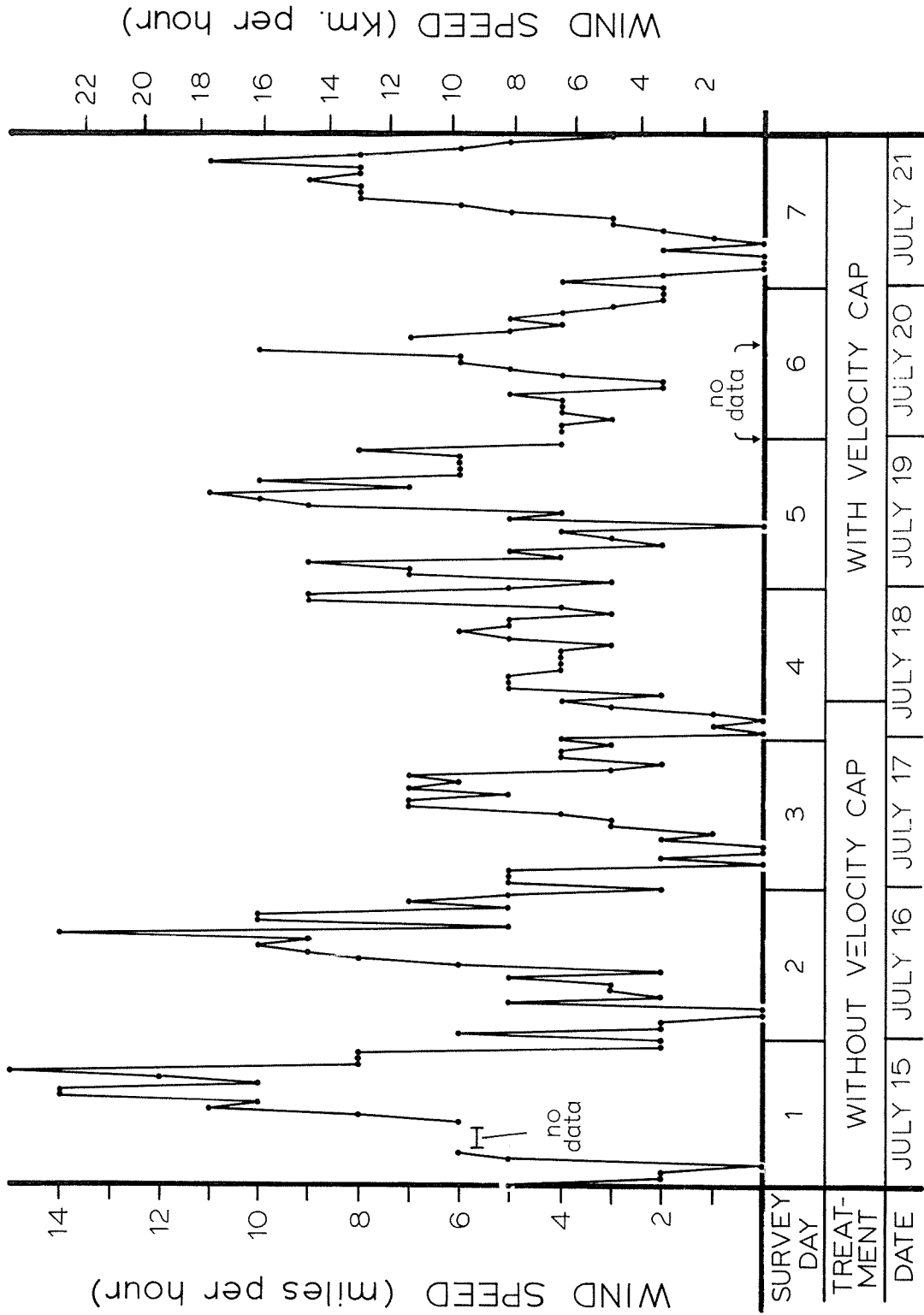


Figure 3. Wind speed (mph) at the Huntington Beach Generating Station, July 14-21, 1979.

Table 2. The species composition of fishes caught in-plant and offshore of the Huntington Beach Generating Station, July 15-21, 1979 (ranked by biomass impinged).

Scientific name	Common name	Impingement		Lampara catch	
		% biomass	% number	% biomass	% number
<i>Seriphus politus</i>	queenfish	41.45	22.97	19.46	5.55
<i>Genyonemus lineatus</i>	white croaker	25.27	18.91	43.09	11.70
<i>Atherinopsis californiensis</i>	jacksmelt	9.01	1.39	*	*
<i>Engraulis mordax</i>	northern anchovy	6.28	35.90	16.71	79.00
<i>Hyperprosopon argenteum</i>	walleyed surfperch	4.38	10.03	*	*
<i>Atherinops affinis</i>	topsmelt	2.18	1.42	*	*
<i>Peprilus simillimus</i>	Pacific butterfish	2.01	1.38	*	*
<i>Phanerodon furcatus</i>	white surfperch	1.74	5.33	*	*
<i>Menticirrhus undulatus</i>	California corbina	1.38	0.10	*	*
<i>Paralichthys californicus</i>	California halibut	1.02	0.10	*	*
<i>Myliobatis californica</i>	bat ray	0.77	0.04	*	*
<i>Cymatogaster aggregata</i>	shiner surfperch	0.47	1.49	*	*
<i>Squalus acanthias</i>	spiny dogfish	0.46	0.01	*	*
<i>Rhinobatos productus</i>	shovelnose guitarfish	0.39	*	*	*
<i>Paralabrax clathratus</i>	kelp bass	0.26	0.03	0	0
<i>Amphistichus argenteus</i>	barred surfperch	0.24	0.07	0	0
<i>Forichthys notatus</i>	plainfish midshipman	0.17	.04	*	*
<i>Embiotoca jacksoni</i>	black surfperch	0.16	0.04	0	0
<i>Leuresthes tenuis</i>	California grunion	0.16	0.29	*	*
<i>Paralabrax nebulifer</i>	barred sand bass	0.16	0.01	*	*
<i>Otophidium scrippsi</i>	basketweave cusk-eel	0.15	0.07	*	*
<i>Forichthys myriaster</i>	specklefin midshipman	0.14	0.01	0	0
<i>Cynoscion nobilis</i>	white seabass	0.14	0.01	0	0
<i>Sphyracna argentea</i>	California barracuda	0.13	0.01	0	0
<i>Leoptocottus armatus</i>	staghorn sculpin	0.12	0.10	*	*
<i>Damalichthys vacca</i>	pile surfperch	0.11	0.01	0	0
<i>Torpedo californica</i>	Pacific electric ray	0.11	*	*	*
<i>Pleuronichthys verticalis</i>	hornyhead turbot	0.11	0.02	*	*
<i>Cheilotrema saturnum</i>	black croaker	0.10	0.01	*	*
<i>Platyrrhinoidis triseriata</i>	thornback ray	0.08	0.01	0	0
<i>Synodus lucioceps</i>	lizard fish	0.08	0.01	*	*
<i>Chromis punctipinnis</i>	blacksmith	0.08	0.02	*	*
<i>Scorpaena guttata</i>	sculpin	0.07	0.01	0	0
<i>Girella nigricans</i>	opaleye	0.07	*	0	0
<i>Sebastes rastrelliger</i>	grass rockfish	0.07	0.01	0	0
<i>Pimelometopon pulchrum</i>	sheepshead	0.05	*	0	0
<i>Mustelus californicus</i>	gray smoothhound	0.04	*	*	*
<i>Xenistius californiensis</i>	salema	0.04	*	0	0
<i>Triakis semifasciata</i>	leopard shark	0.04	*	0	0
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	0.04	*	0	0
<i>Rhacochilus tomotes</i>	rubberlip surfperch	0.04	0.01	0	0
<i>Hypsopsetta guttulata</i>	diamond turbot	0.03	*	0	0
<i>Sebastes auriculatus</i>	brown rockfish	0.03	*	0	0
<i>Mustelus henlei</i>	brown smoothhound	0.03	*	0	0
<i>Xystreumys liolepis</i>	fantail sole	0.02	*	*	*
<i>Symphurus atricauda</i>	California tonguefish	0.02	0.01	*	*
<i>Urolophus halleri</i>	round stingray	0.02	*	0	0
<i>Anisotremus davidsonii</i>	sargo	0.02	*	0	0
<i>Oxyjulis californica</i>	senorita	0.02	*	0	0
<i>Scomber japonicus</i>	Pacific mackerel	0.02	*	*	*
<i>Heterostichus rostratus</i>	giant kelpfish	0.01	0.03	0	0
juv. flatfish (unidentified)		0.01	0.04	0	0
<i>Anchoa compressa</i>	deepbody anchovy	*	*	0	0
<i>Citharichthys stigmatæus</i>	speckled sanddab	*	0.03	0	0
<i>Sebastes dallii</i>	calico rockfish	*	*	0	0
goby (unidentified)		*	*	0	0
<i>Syngnathus</i>	pipefish	*	0.01	0	0
<i>Embiotoca lateralis</i>	striped surfperch	*	*	0	0
<i>Sebastes serranoides</i>	olive rockfish	*	*	0	0
Atherinidae (unidentified)		*	*	5.04	1.29
<i>Hypsurus caryi</i>	rainbow surfperch	*	*	0	0
<i>Chilura taylora</i>	spotted cusk-eel	*	*	0	0
blenny (unidentified)		*	*	0	0
<i>Sarda chiliensis</i>	bonito	0	0	*	*
<i>Trachurus symmetricus</i>	jack mackerel	0	0	*	*
	%	100	100	84.30**	97.54*
Total catch	kg	2189.43		1228.18	
	#'s		80,834		94,222

* Trace

** Trace species represented 15.70% of the lampara catch biomass.

*** Trace species represented 2.46% of the lampara catch numbers.

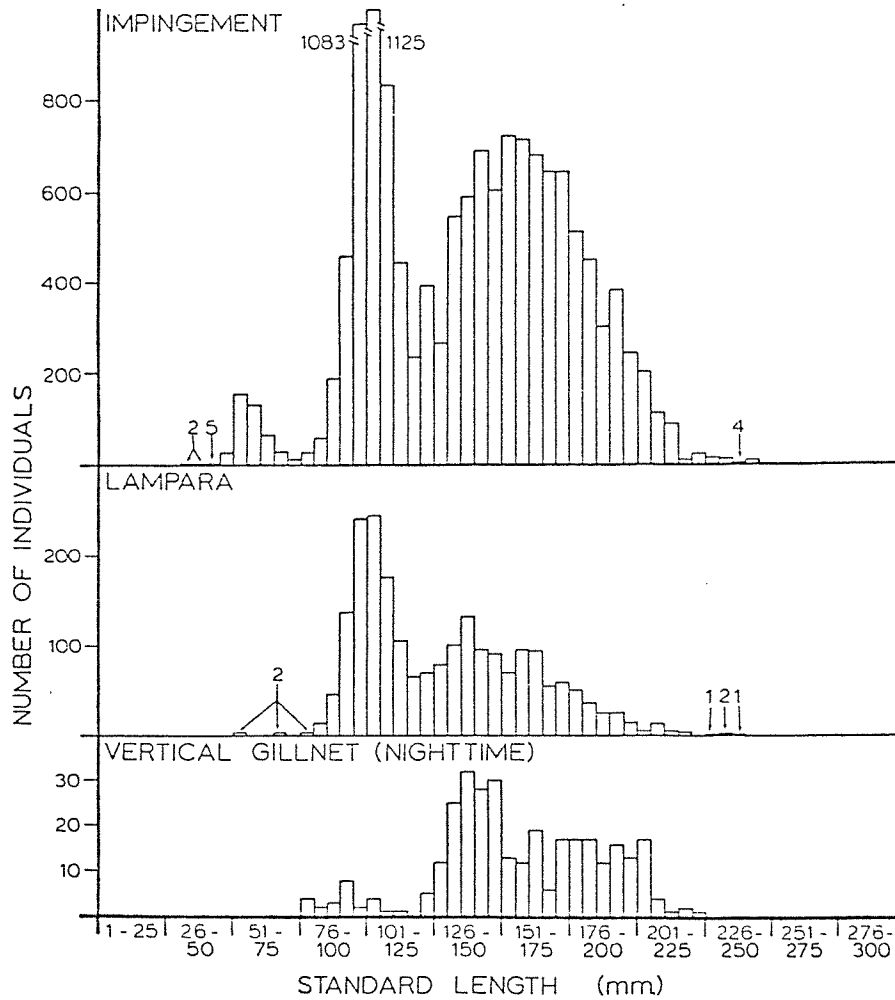


Figure 4. The length-frequency distribution of queenfish caught in-plant and offshore of the Huntington Beach Generating Station, July 15-21, 1979.

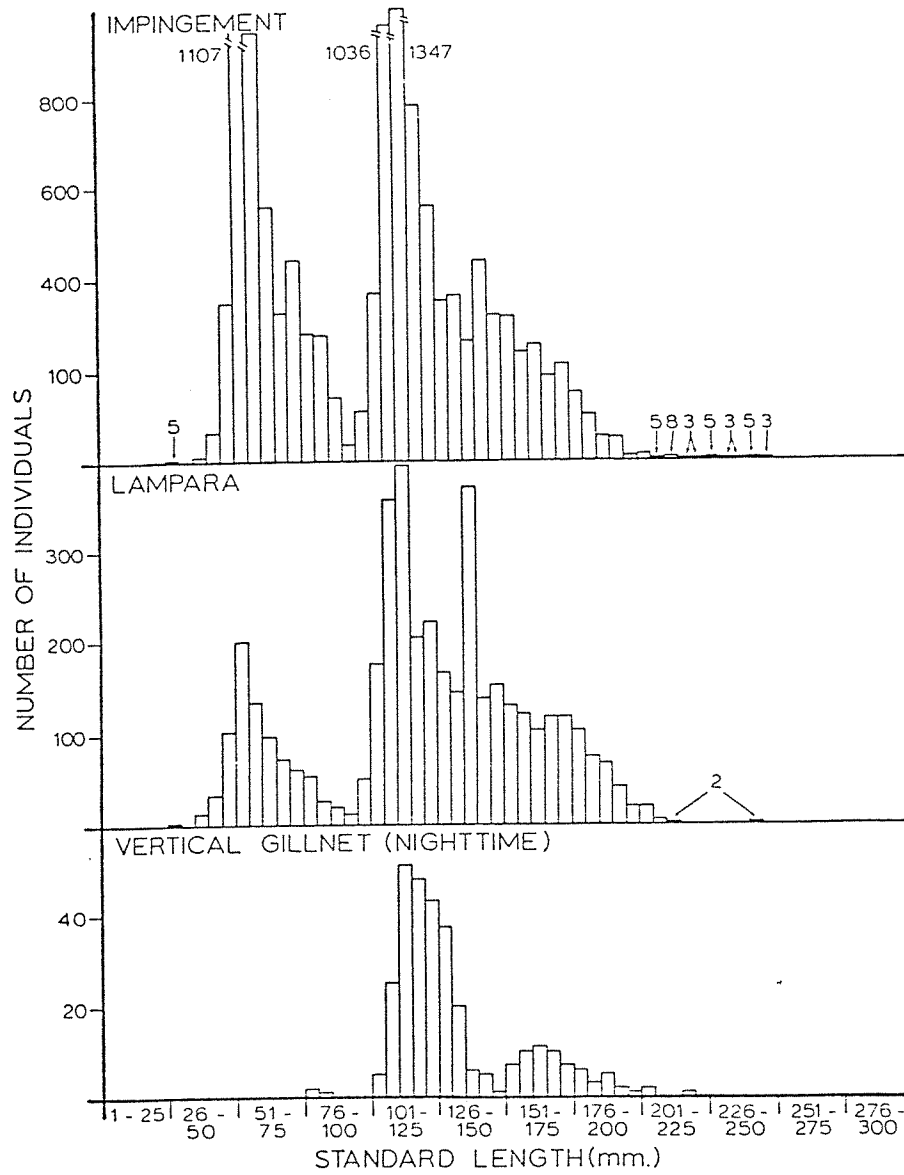


Figure 5. The length-frequency distribution of white croaker caught in-plant and offshore of the Huntington Beach Generating Station, July 15-21, 1979.

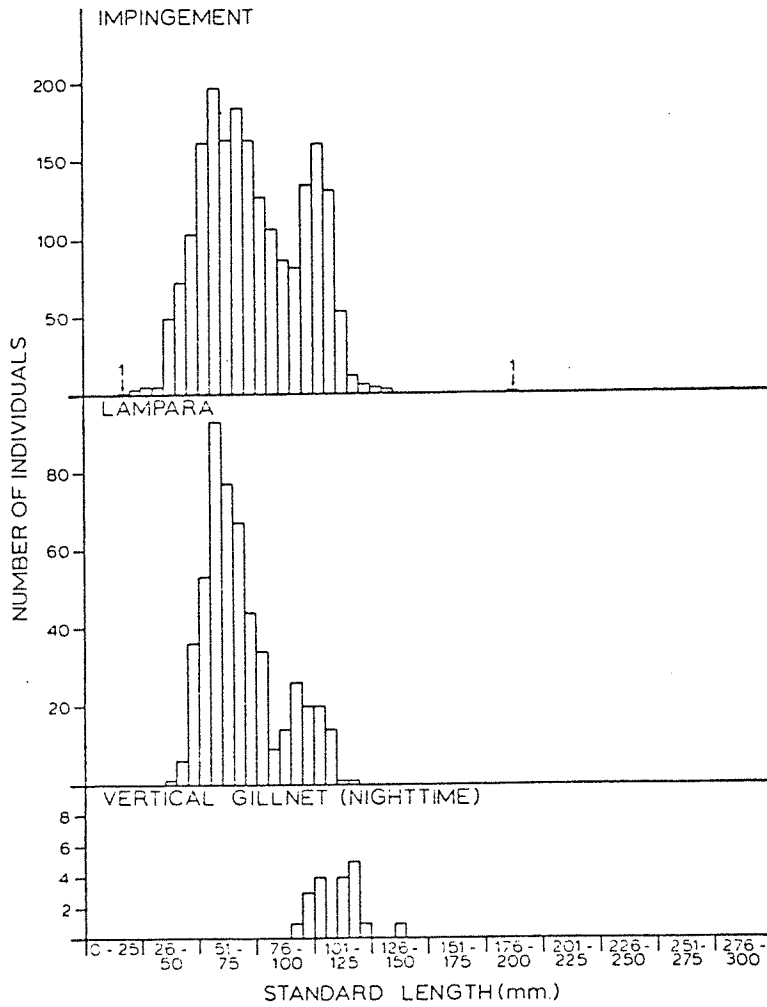


Figure 6. The length-frequency distribution of northern anchovy caught in-plant and offshore of the Huntington Beach Generating Station, July 15-21, 1979.

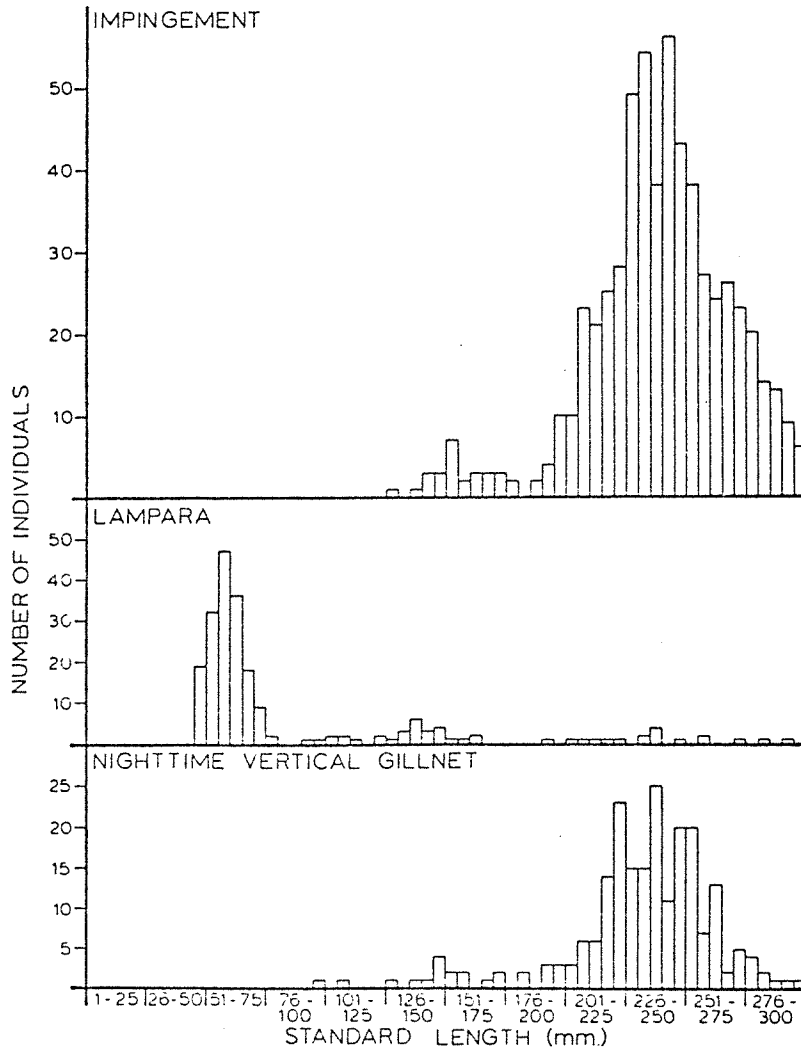


Figure 7. The length-frequency distribution of silversides caught in-plant and offshore of the Huntington Beach Generating Station, July 15-21, 1979.

on entrapment of silversides refers only to those fishes over 100 mm S.L.

It is important to note that smaller sizes of all these species (larvae) may be 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).

2.4 Fish Entrapment (Ei)

The species composition of all fishes impinged during 72-hr periods with and without a velocity cap (July 19, 20, 21, and July 16, 17, 18, respectively) are presented in Table 3. Five times as many fish were entrapped during the without-velocity-cap interval (67,153 weighing 1801.68 kg) than during the with-velocity-cap interval (13,671 weighing 389.25 kg). Increased total entrapment during the without-cap period was particularly apparent for queenfish, white croaker, jack-smelt anchovy, walleyed surfperch, topsmelt, Pacific butterfish, corbina, bat rays, shiner surfperch, kelp bass, grunion, white sea bass, and California halibut. One species, white surfperch, was entrapped in equally large numbers with and without the velocity cap. A total of 58 species was entrapped during the without-cap interval. Only 44 species were entrapped during the with-cap period. Several commercially important species, such as white sea bass, California barracuda, Pacific mackerel, and sargo, were caught only during without-cap operations.

Hourly nighttime entrapment rates (E) for queenfish, white croaker, northern anchovy, and silversides are presented in Table 4. For silversides a noticeable drop in the nightly entrapment rates occurred when the switch was made from without-cap to with-cap operations between July 18 and 19 (Fig. 8). For white croaker and queenfish there was too much variability in nightly entrapment rates to support any trends with statistical inference (Fig. 9). For northern anchovy, entrapment values were low, but tended to indicate reduced entrapment during the with-cap period (Fig. 9).

During normal operations (with-velocity-cap) entrapment is generally higher from midnight to dawn than during any other interval of the day (Thomas et al. 1979). This survey was conducted during the midnight to dawn hours primarily for this reason. Entrapment data collected during the with-velocity-cap portion of this survey support this decision (Table 5). However, entrapment information from the without-velocity-cap interval of this survey indicated that high rates of entrapment can also occur during other than the prescribed midnight to dawn sampling period (Table 5).

The fact that total entrapment rates for queenfish and white croaker were higher under without-cap conditions whereas nighttime

Table 3. The species composition of fishes impinged in-plant with and without a velocity cap at the Huntington Beach Generating Station, July 15-21, 1979.

Scientific Name	Common Name	* 72 hour total with cap		** 72 hour total w/o cap	
		Biomass (kg)	Number	Biomass (kg)	Number
<i>Seriplus politus</i>	queenfish	206.08	3,813	661.13	13,887
<i>Genyonemus lineatus</i>	white croaker	80.47	3,622	252.08	6,487
<i>Atherinopsis californiensis</i>	jacksmelt	3.13	16	165.47	820
<i>Engraulis mordax</i>	northern anchovy	8.97	2,438	123.94	25,407
<i>Hyperprosopon argenteum</i>	walleyed surfperch	7.91	827	76.50	6,303
<i>Atherinops affinis</i>	topsmelt	0.12	2	44.67	1,076
<i>Peprilus simillimus</i>	Pacific butterfish	4.08	127	38.78	956
<i>Phanerodon furcatus</i>	white surfperch	19.41	1,919	16.56	2,038
<i>Menticirrhus undulatus</i>	California corbina	3.11	8	16.73	38
<i>Paralichthys californicus</i>	California halibut	7.96	29	11.95	44
<i>Myliobatis californica</i>	bat ray	0.39	1	15.90	30
<i>Cymatogaster aggregata</i>	shiner surfperch	2.89	384	6.48	745
<i>Squalus acanthias</i>	spiny dogfish	10.14	8	-	-
<i>Rhinobatos productus</i>	shovelnose guitarfish	-	-	8.54	4
<i>Paralabrax clathratus</i>	kelp bass	1.45	5	3.89	14
<i>Amphistichus argenteus</i>	barred surfperch	5.15	53	-	-
<i>Porichthys notatus</i>	plainfin midshipman	2.54	25	0.89	5
<i>Embiotoca jacksoni</i>	black surfperch	1.38	18	2.19	13
<i>Leuresthes tenuis</i>	California grunion	-	-	3.50	237
<i>Paralabrax nebulifer</i>	barred sand bass	2.02	4	0.75	2
<i>Otophidium scrippsi</i>	basketweave cusk-eel	2.47	29	0.14	1
<i>Porichthys myriaster</i>	specklefin midshipman	2.66	10	0.40	1
<i>Cynoscion nobilis</i>	white seabass	-	-	2.76	4
<i>Sphyrna argentea</i>	California barracuda	-	-	2.77	6
<i>Leptocottus armatus</i>	staghorn sculpin	0.33	39	0.40	14
<i>Damalichthys vacca</i>	pile surfperch	0.91	3	1.24	4
<i>Torpedo californica</i>	Pacific electric ray	2.25	1	0.20	1
<i>Pleuronichthys verticalis</i>	hornyhead turbot	2.04	11	-	-
<i>Cheilotrema saturnum</i>	black croaker	0.63	3	1.59	5
<i>Platyrhinoidis triseriata</i>	thornback ray	-	-	0.83	3
<i>Synodus lucioceps</i>	lizard fish	1.03	3	0.40	1
<i>Chromis punctipinnis</i>	blacksmith	0.38	3	1.32	11
<i>Scorpaena guttata</i>	sculpin	0.77	4	0.81	4
<i>Girella nigricans</i>	opaleye	1.52	3	-	-
<i>Sebastes rastrelliger</i>	grass rockfish	1.46	5	-	-
<i>Pimelometopon pulchrum</i>	sheepshead	0.45	1	0.64	1
<i>Mustelus californicus</i>	gray smoothhound	0.14	1	-	-
<i>Xenistius californiensis</i>	salema	-	-	0.83	4
<i>Triakis semifasciata</i>	leopard shark	0.82	1	-	-
<i>Paralabrax maculatofasciatus</i>	spotted sand bass	0.31	1	0.48	2
<i>Rhacochilus toxotes</i>	rubberlip surfperch	0.01	1	0.75	4
<i>Hypsopsetta guttulata</i>	diamond turbot	0.53	2	-	-
<i>Sebastes auriculatus</i>	brown rockfish	-	-	-	-
<i>Mustelus henlei</i>	brown smoothhound	-	-	0.21	1
<i>Xystreurus liolepis</i>	fantail sole	0.04	2	0.48	1
<i>Symphurus atricauda</i>	California tonguefish	0.47	5	-	-
<i>Urolophus halleri</i>	round stingray	-	-	0.50	1
<i>Anisotremus davidsonii</i>	sargo	-	-	0.50	1
<i>Oxyjulis californica</i>	senorita	-	-	0.47	2
<i>Scomber japonicus</i>	Pacific mackerel	-	-	0.84	2
<i>Heterostichus rostratus</i>	giant kelpfish	0.09	13	0.08	4
juv. flatfish (unidentified)		0.01	1	0.15	31
<i>Anchoa compressa</i>	deepbody anchovy	-	-	0.022	1
<i>Citharichthys stigmaeus</i>	speckled sand dab	0.02	5	-	-
<i>Sebastes dallii</i>	calico rockfish	-	-	-	-
goby (unidentified)		-	-	-	-
<i>Syngnathus</i>	pipefish	0.01	4	0.01	3
<i>Embiotoca lateralis</i>	striped surfperch	-	-	0.02	1
<i>Sebastes serranoides</i>	olive rockfish	0.01	1	-	-
Atherinidae (unidentified)		-	-	0.01	1
<i>Hypsurus caryi</i>	rainbow surfperch	-	-	0.01	1
<i>Chilara taylori</i>	spotted cusk-eel	-	-	-	-
blenny (unidentified)		0.01	1	-	-
TOTAL CATCH		386.57	13,452 44 species	1,468.31	58,222.0 55 species

* with cap - 72 hr period was from 0530 7/18 to 0530 7/21

** without cap - 72 hr period was from 2330 7/15 to 2330 7/17

Table 4. Hourly entrapment (E_i) during nighttime at the Huntington Beach Generating Stations, July 15-21, 1979, for queenfish ($i = 1$), white croaker ($i = 2$), northern anchovy ($i = 3$), silversides ($i = 4$), and all species combined ($i = T$).

Survey				Hourly Entrapment (kg)									
Day	Treatment	Date	Time	E_1	\bar{E}_1	E_2	\bar{E}_2	E_3	\bar{E}_3	E_4	\bar{E}_4	E_T	\bar{E}_T
1	without velocity	7/14-15	2330-0030	-	-	-	-	-	-	-	-	-	-
		7/15	0030-0130	8.37		0.24		0.22		15.44		25.74	
	cap	7/15	0130-0230	1.96		0.32		0.22		3.56		6.90	
		7/15	0230-0330	2.79		0.01		0.28		5.91		5.83	
		7/15	0330-0430	3.32		0.08		1.53		6.37		13.16	
		7/15	0430-0530	3.66		0.24		9.80		5.89		23.71	
				4.02		0.18		2.41		7.43		15.07	
2	without velocity	7/15-16	2330-0030	6.81		0.67		1.34		16.96		34.77	
		7/16	0030-0130	4.19		0.27		0.09		6.07		13.35	
	cap	7/16	0130-0230	1.56		0.11		0.22		0.70		6.00	
		7/16	0230-0330	2.20		0.12		0.31		1.31		6.57	
		7/16	0330-0430	1.49		0.15		0.75		2.73		7.41	
		7/16	0430-0530	8.68		0.61		2.27		4.92		18.65	
				4.16		0.32		0.81		5.45		14.46	
3	without velocity	7/16-17	2330-0030	-	-	-	-	-	-	-	-	-	-
		7/17	0030-0130	9.41		6.96		0.24		3.60		24.50	
	cap	7/17	0130-0230	8.40		7.36		0.28		7.26		25.97	
		7/17	0230-0330	12.55		13.66		0.31		3.54		34.50	
		7/17	0330-0430	23.34		26.54		0.09		1.14		55.90	
		7/17	0430-0530	22.26		28.26		0.47		1.69		59.18	
				15.19		16.56		0.28		3.45		40.01	
4	without velocity	7/17-18	2330-0030	8.34		20.95		1.14		14.30		50.94	
		7/18	0030-0130	3.07		40.49		0.57		4.67		55.31	
	cap	7/18	0130-0230	3.02		48.94		0.38		1.22		58.33	
		7/18	0230-0330	4.75		42.12		0.58		6.84		57.99	
		7/18	0330-0430	3.48		32.51		0.42		2.31		42.06	
		7/18	0430-0530	-		-		-		-		-	
				4.53		-		0.62		5.87		52.93	
5	with cap	7/18-19	2330-0030	16.40		7.47		0.36		0.21		28.64	
		7/19	0030-0130	12.87		8.88		0.15		0.35		24.61	
	with cap	7/19	0130-0230	17.96		12.35		0.18		0.41		35.55	
		7/19	0230-0330	13.62		3.23		0.44		0.06		20.53	
		7/19	0330-0430	9.87		1.82		0.41		0		16.49	
		7/19	0430-0530	3.28		2.07		0.26		0		9.12	
				12.33		5.97		0.30		0.17		22.49	
6	with cap	7/19-20	2330-0030	6.33		0.95		0.31		0.20		11.31	
		7/20	0030-0130	6.19		1.84		0.15		0		12.07	
	with cap	7/20	0130-0230	6.17		0.62		0.10		0		7.87	
		7/20	0230-0330	2.41		0.27		0.14		0		3.65	
		7/20	0330-0430	4.05		0.67		0.23		0		5.75	
		7/20	0430-0530	2.14		0.44		0.27		0		3.88	
				4.55		0.88		0.20		0.20		7.42	
7	with cap	7/20-21	2330-0030	6.38		1.50		0.20		0		10.94	
		7/21	0030-0130	12.86		10.19		0.12		0.26		27.10	
	with cap	7/21	0130-0230	17.90		9.28		0.17		0.06		32.26	
		7/21	0230-0330	6.28		1.78		0.67		0		12.03	
		7/21	0330-0430	4.59		0.88		1.00		0		7.69	
		7/21	0430-0530	7.42		0.42		0.48		0.30		10.02	
				9.24		3.32		0.44		0.10		16.67	

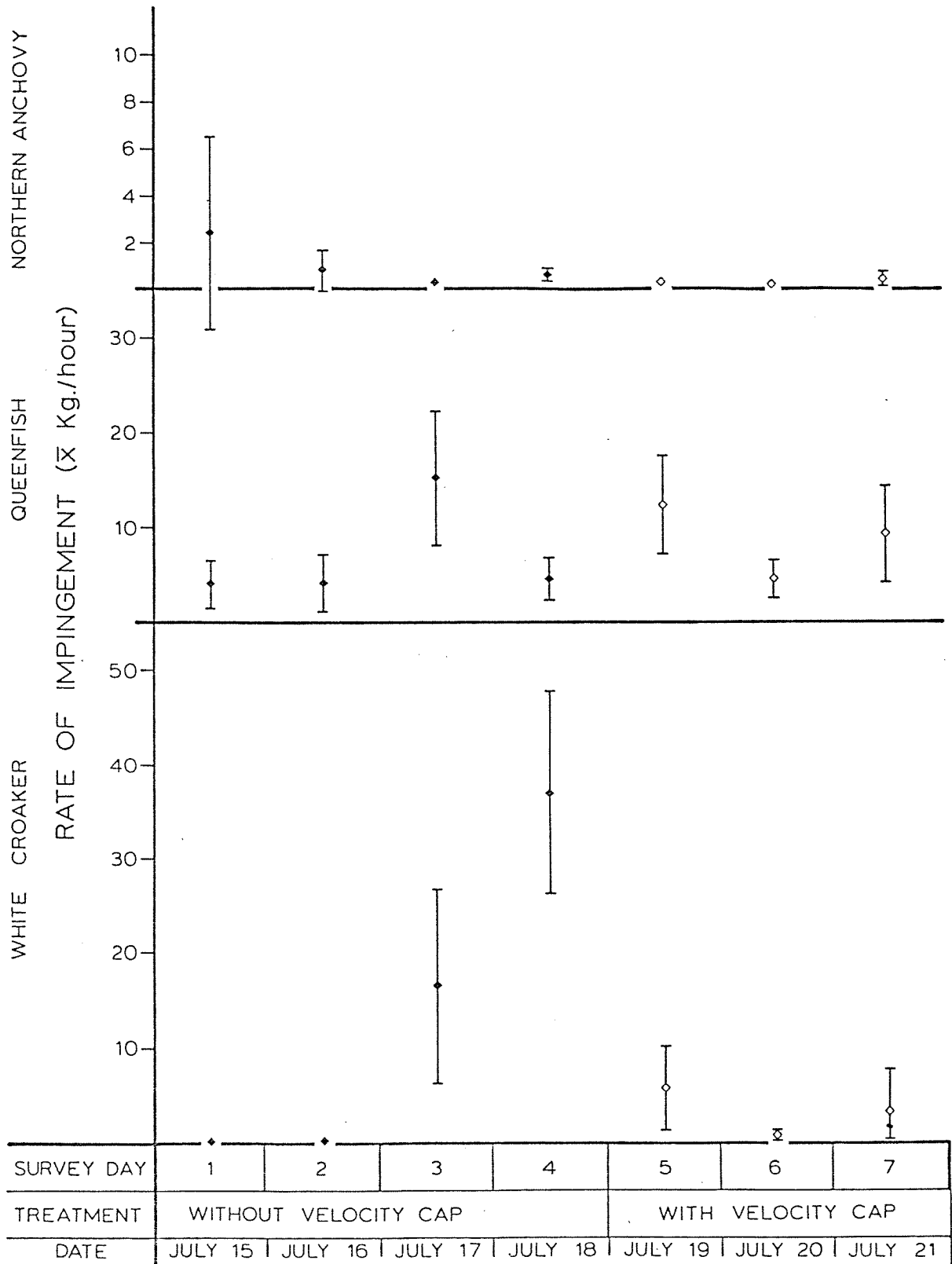


Figure 8. Mean nighttime entrapment rates of queenfish, white croaker, and northern anchovy (kg/hr) during without-cap and with-cap treatment intervals at the Huntington Beach Generating Stations, July 15-21, 1979.

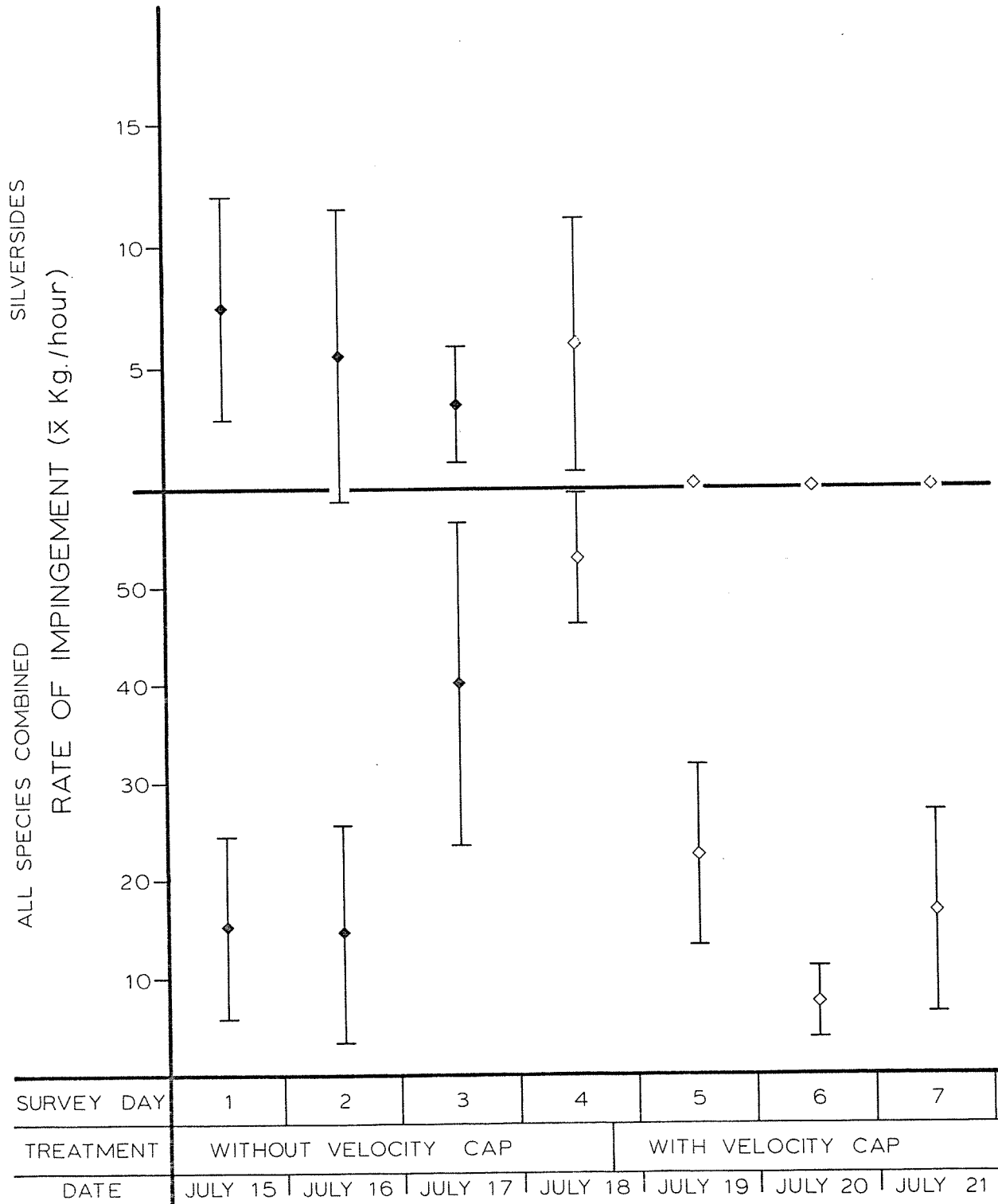


Figure 9. Mean nighttime entrapment rates of silversides, and all species combined (kg/hr) during without-cap and with-cap treatment intervals at the Huntington Beach Generating Stations, July 15-21, 1979.

Table 5. Comparison of hourly entrapment averages (kg/hour) during the 6-hour midnight to dawn sampling period and the remaining 18-hour portion of the day, July 15-21, 1979, Huntington Beach Generating Station.

Survey Day	Treatment	Date	Survey interval	E1 Queenfish	E2 White croaker	E3 Northern anchovy	E4 Silversides	E _T All species combined
1		7/14-15	6*	4.02	0.18	2.41	7.43	15.07
1	Without velocity cap	7/15-16	18	2.02	0.08	0.57	2.80	6.44
2		7/15-16	6	4.16	0.32	0.81	5.45	14.46
2	cap	7/16	18	18.10	1.75	0.41	1.92	23.88
3		7/16-17	6*	15.19	16.56	0.28	3.45	40.01
3		7/17	18	9.90	7.42	4.89	2.31	31.02
4		7/18	6*	4.53	37.00	0.62	5.87	52.93
<hr/>								
Average Hourly Ratio	(6-hour:18-hour)			0.7:1	4.4:1	0.5:1	2.4:1	1.6:1
<hr/>								
4		7/18	18	1.01	0.51	0.07	0.05	2.64
5		7/18-19	6	12.33	5.97	0.30	0.20	22.49
5	With velocity cap	7/19	18	1.01	0.24	0.08	0.03	2.03
6		7/19-20	6	4.55	0.88	0.20	0.03	7.42
6	cap	7/20	18	0.73	0.14	0.04	0	1.24
7		7/20-21	6	9.24	3.32	0.44	0.10	16.67
<hr/>								
Average Hourly Ratio	(6-hour: 18 hour)			9.5:1	11.4:1	4.9:1	3.5:1	7.9:1

* 5 hours

hourly rates were not, suggested that a major effect of the velocity cap may be the reduction of daytime entrapment.

2.5 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, July 15 to 21 (Table 6). 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 near-surface strata which were not sampled with acoustics varied depending on surface conditions. The near-bottom strata which were not sampled with acoustics were constant and were determined by the pulse-length beam pattern characteristics, and 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 7. The vertical gillnet 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:

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

$$\text{therefore, } D_T = 1.17 D_M + D_M = 2.17 D_M .$$

The density correction factor of 2.17 is subject to bias because of the selectivity and efficiency of the gillnets. Observations indicate atherinids are relatively more susceptible to capture by gillnets than the other fishes in the area. Therefore, the density correction factor is biased by the vertical distribution of atherinids. Since the atherinids display a strong surface orientation the density correction factor is believed to be biased high. The determination of selectivity and efficiency characteristics of the gillnets as well as the computation of variance estimates of the vertical gillnet catches should provide insight to the accuracy of this density correction factor and will be addressed in the final report.

In lieu of the fact that this correction factor is a constant, the following analysis of entrapment vulnerability was considered as valid for this survey period. The total fish density by hour for each survey day is presented in Table 6.

Table 6. Midwater density of fish, D_M (grams/m² surface), and total offshore fish density (D_T), at Huntington Beach, July 15-21, 1979.

Survey					
Day	Treatment	Date	Time	D_M	D_T
2	Without velocity cap	7/15-16	2330-0030	1.5531	3.53
		7/16	0030-0130	1.6946	3.85
		7/16	0130-0230	1.8759	4.26
		7/16	0230-0330	2.1132	4.80
		7/16	0330-0430	3.8841	8.83
		7/16	0930-0530	-	-
3	Without velocity cap	7/16-17	2330-0030	-	-
		7/17	0030-0130	0.8485	1.93
		7/17	0130-0230	1.3381	3.04
		7/17	0230-0330	7.4712	16.98
		7/17	0330-0430	2.3014	5.23
		7/17	0430-0530	-	-
4	Without velocity cap	7/17-18	2330-0030	8.8185	20.04
		7/18	0030-0130	13.5986	30.91
		7/18	0130-0230	5.0748	11.53
		7/18	0230-0330	3.0115	6.84
		7/18	0330-0430	3.8096	8.66
		7/18	0430-0530	-	-
5	with cap	7/18-19	2330-0030	3.9910	9.07
		7/19	0030-0130	4.3706	9.93
		7/19	0130-0230	6.6906	15.21
		7/19	0230-0330	24.4079	55.47
		7/19	0330-0430	18.6707	42.43
		7/19	0430-0530	-	-
6	with cap	7/19-20	2330-0030	2.4011	5.46
		7/20	0030-0130	2.8941	6.56
		7/20	0130-0230	-	-
		7/20	0230-0330	-	-
		7/20	0330-0430	8.7678	19.93
		7/20	0430-0530	-	-
7	with cap	7/20-21	2330-0030	5.1962	11.81
		7/21	0030-0130	3.6444	8.28
		7/21	0130-0230	5.5097	12.52
		7/21	0230-0330	8.6640	19.69
		7/21	0330-0430	13.6095	30.93
		7/21	0430-0530	-	-

Table 7. Vertical distribution (% weight by depth) of fishes caught in vertical gillnets on nights of hydroacoustic surveys. Each depth increment equals 8.3% of the total water column.

Average Depth (m)	Depth Increment	All species combined
0 m (surface)	1	18.81%
	2	17.69
	3	15.10
	4	6.59
	5	5.59
	6	6.63
	7	4.47
	8	4.21
	9	5.01
	10	6.77
	11	5.20
9.45 m (bottom)	12	3.93
		100.00%
Total catch		75.02 kg

The mean fish density ranged from 0.19 to 0.98 g/m² surface during the interval July 15 to 21. The hourly estimates of D_T were lower ($\alpha = 0.05$) on the first 2 survey days than on subsequent days. These results suggested that analysis of differences in entrapment rates must consider changes in fish density that occurred.

2.6 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 acoustic targets observed within 300 m of the intake structure. White croaker, queenfish, and anchovy dominated (90%) of the lampara catch during the 3 days of fishing (Table 8). Large numbers of individuals of the silverside family (Atherinidae) were occasionally present in net catches (between 1 and 5% of the biomass). The anchovy catch was initially low (1.69%), then increased severalfold (29.33%) on July 19. White croaker and queenfish catches were relatively uniform throughout the 3 days of lampara fishing.

2.7 Offshore Density by Species (D_i)

Hourly estimates of offshore density within 300 m of the intake structure were calculated for queenfish, white croaker, northern anchovy, and jacksmelt from the products of D_T and P_i (Table 9). Because the lampara vessel did not fish every survey night, P_i values from July 17 and 19 were averaged in order to estimate P_i values for July 18. The P_i values for July 19 were utilized in calculations of D_i values July 19 to 21.

Density values for the four species examined increased from their lowest magnitudes on July 16 to their highest on July 19. After July 19 the magnitude of the density values decreased.

2.8 Entrapment to Density (E/D)

Hourly estimates of E/D were computed for queenfish, white croaker, northern anchovy, and jacksmelt (Table 10). These E/D values were examined for differences between with- and without-velocity-cap periods. For queenfish and white croaker, there were no apparent differences between the with-cap and without-cap E/D ratios. The analysis, however, may have been confounded by the fact that water transparency values varied among survey days. Of some significance, though, are the observations of E/D from 2 survey days with similar water clarity. On both July 16 and 19 water transparency was about 3 ft. For both queenfish and white croaker mean E/D values were lower on the 16th (without-velocity-cap) than on the 19th (with-cap). In contrast to these observations were the E/D ratios for northern anchovy

Table 8. Lampara catch per set in kilograms and percent (P_i) for queenfish, white croaker, northern anchovy, and silversides offshore of the Huntington Beach Generating Station, July 16, 17, and 19, 1979.

Survey Day	Treatment	Date	Set	Queenfish			White croaker			Northern Anchovy			Silversides		
				kg	P ₁	P ₂	kg	P ₂	P ₂	kg	P ₃	P ₃	kg	P ₄	P ₄
2	without	7/16	1	15.08	10.02	26.60	38.10	25.31	44.51	0.35	0.23	1.69	0.02	0.02	0.78
	velocity	7/16	2	14.54	16.24		67.91	75.83		0.62	0.69		0.06	0.06	
	cap			25.70	53.53	±23.53	15.56	32.40	±27.35	1.99	4.14	±2.14	1.08	2.25	±1.28
3	without	7/17	4	10.08	11.64		63.21	73.00		0.76	0.87		4.79	5.54	
	velocity	7/17	5	9.22	15.75		40.56	69.27		0.68	1.16		0.10	0.17	
	cap	7/17	6	10.34	23.29	22.78	31.55	71.04	60.82	0.28	0.63	2.18	1.08	2.44	2.87
		7/17	7	37.66	31.15	± 9.09	63.42	52.46	±15.00	0.46	0.38	±3.19	2.00	1.65	±2.17
		7/17	8	14.06	32.09		16.80	38.34		3.45	7.87		1.99	4.55	
5	without	7/19	9	21.70	23.98		15.09	16.68		20.05	22.15		8.86	9.79	
	velocity	7/19	10	23.52	25.80	19.45	40.90	44.87	30.96	7.92	8.68	29.33	2.50	2.74	5.04
	cap	7/19	11	20.77	13.46	±6.34	31.57	20.45	±14.45	76.66	49.67	±17.78	9.05	5.86	±3.61
		7/19	12	36.39	14.67		104.50	41.83		92.01	36.83		4.44	1.78	

Table 9. Offshore estimates of fish density by species (D_i) for queenfish (D_1), white croaker (D_2), northern anchovy (D_3) and jacksmelet (D_4) in grams $\times 10^2$ /surface m^2 at Huntington Beach, July 15-20, 1979.

Survey day	Status	Date	Time	D_1	D_2	D_3	D_4
2		7/15-16	2330	0.94	1.57	0.06	0.03
		7/16	0030	1.02	1.71	0.06	0.03
		7/16	0130	1.13	1.90	0.07	0.03
		7/16	0230	1.28	2.14	0.08	0.04
		7/16	0330	2.35	3.93	0.15	0.07
3	Without velocity cap	7/16-17	2330	-	-	-	0.04
		7/17	0030	0.44	1.17	0.04	0.06
		7/17	0130	0.69	1.85	0.07	0.09
		7/17	0230	3.87	10.33	0.37	0.49
		7/17	0330	1.19	3.18	0.11	0.15
4		7/17-18	2330	4.23	9.20	3.16	0.79
		7/18	0030	6.53	14.18	4.87	1.22
		7/18	0130	2.43	5.29	1.82	0.46
		7/18	0230	1.44	3.14	1.08	0.27
		7/18	0330	1.83	3.97	1.37	0.34
5		7/18-19	2330	1.76	2.81	2.66	0.46
		7/19	0030	1.93	3.17	2.91	0.50
		7/19	0130	2.96	4.70	4.46	0.77
		7/19	0230	10.78	17.16	12.26	2.79
		7/19	0330	8.25	13.13	12.44	2.14
6	With velocity cap	7/19-20	2330	1.06	1.69	1.60	0.28
		7/20	0030	1.28	2.04	1.93	0.33
		7/20	0130	-	-	-	-
		7/20	0230	-	-	-	-
		7/20	0330	3.87	6.16	5.84	1.00
7		7/20-21	2330	2.29	3.65	3.46	0.59
		7/21	0030	1.61	2.56	2.43	0.42
		7/21	0130	2.43	3.87	3.67	0.63
		7/21	0230	3.83	6.09	5.77	0.99
		7/21	0330	6.01	9.57	9.07	1.56

Table 10. Hourly ratio of fish entrapment, E_i/D_i , (kg/hour) to offshore density ($g \times 10^2/\text{surface } m^2$) for queenfish ($i = 1$), white croaker ($i = 2$), northern anchovy ($i = 3$), and jacksmelt ($i = 4$), at Huntington Beach, July 16-21, 1979.

Survey day	Status	Date	Time	E_1/D_1	E_2/D_2	E_3/D_3	E_4/D_4	
2	Without velocity cap	7/15-16	2330	0.91	0.05	2.79	74.94	
			0030	0.51	0.02	0.18	26.82	
			0130	0.17	0.01	0.39	2.75	
			0230	0.22	0.01	0.48	4.21	
3	Without velocity cap	7/16	0330	0.08	0.01	0.63	5.08	
			7/16-17	2330	0.38	0.02	0.89	22.76
				0030	-	-	-	-
				0130	2.68	0.74	0.71	7.95
0230	1.52	0.50		0.52	10.27			
4	Without velocity cap	7/17	0330	2.46	1.04	0.11	0.91	
			7/17-18	0330	1.77	1.04	0.11	0.96
				2330	0.25	0.29	0.05	2.26
				0030	0.06	0.36	0.01	0.48
0130	0.16	1.16		0.02	0.34			
5	With velocity cap	7/18	0230	0.24	1.68	0.07	3.14	
			0330	0.24	1.02	0.04	0.85	
			7/18-19	2330	0.19	0.90	0.04	1.41
				0030	1.16	0.33	0.02	0.06
0130	0.83	0.35		0.01	0.09			
0230	0.76	0.33		0.01	0.07			
6	With velocity cap	7/19	0330	0.15	0.02	0.01	0.01	
			7/19-20	0330	0.61	0.02	0.01	0
				2330	0.75	0.07	0.02	0.10
				0030	0.60	0.11	0.01	0.13
0130	-	-		-	-			
7	With velocity cap	7/20	0230	-	-	-	-	
			0330	0.13	0.01	0.01	0	
			7/20-21	2330	0.49	0.07	0.01	0.08
				0030	0.35	0.05	0.01	0
0130	1.00	0.50		0.01	0.08			
0230	0.92	0.30		0.01	0.01			
7	With velocity cap	7/21	0330	0.21	0.04	0.02	0	
			0330	0.10	0.02	0.02	0	
				0.51	0.02	0.18	0.02	

and jacksmelt. For both of these latter fishes E/D ratios during with-velocity-cap operations were different than those observed without-cap ($\alpha's = 0.001$). The magnitude of E/D values for these two surface-oriented species suggested their entrapment vulnerabilities were higher in the absence of the velocity cap.

If in fact the entrapment of queenfish and white croaker is higher during the daytime under without-cap conditions as the data suggest, then it is logical to assume that this is the result of increased vulnerability and/or density of these fishes in the intake area. Additional diel data must be collected in order to determine if the vulnerability to entrapment of these two scienids is reduced by the velocity cap presence.

3.0 DISCUSSION

The ability to calculate 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 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 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 synchronously 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.

The data collected during this study indicated that entrapment rates are lower with than without a velocity cap for a number of commercial and/or sportfishing valuable species. These species included northern anchovy, white croaker, walleye surfperch, Pacific butterfish, California corbina, halibut, barracuda, kelp bass, white sea bass, and Pacific mackerel. That the velocity cap reduces the entrapment of the above valuable species is an important demonstration of the effectiveness of a velocity cap in reducing fish entrapment.

The E/D ratios were used to detect differences between with- and without-velocity-cap vulnerabilities to entrapment. Analyses of nighttime E/D ratios demonstrated that northern anchovy and jacksmelt vulnerabilities to entrapment were lower with the velocity cap. Thus, the vulnerability data corresponded with the 72-hr entrapment data for these two species. The 72-hr entrapment data suggested that anchovy entrapment may be reduced about 90%. This value is similar to Schuler's and Larson's (1975) laboratory estimate of the effectiveness of a velocity cap in reducing anchovy entrapment. For surface-oriented species such as topsmelt and jacksmelt the velocity cap reduced 72-hr impingement rates over 95%.

In contrast to the above observations on surface-oriented fishes, the nighttime E/D ratios between with- and without-cap periods were not different for queenfish or white croaker. That differences were not observed was surprising, particularly so because 72-hr entrapment rates with-velocity-cap were dramatically lower than 72-hr entrapment rates without-cap for both these species. This suggests that the effectiveness of a velocity cap in reducing entrapment may have a diel component of variability for some species. That is, the velocity cap reduces the vulnerability to entrapment for white croaker and queenfish during day-

light hours (or some other portion of the 18-hr periods not monitored intensively) but not at night during the designated survey interval. This may explain the reduced ability of the velocity cap to prevent nighttime entrapment of these two species.

The observation that for queenfish and white croaker the velocity cap's ability to reduce entrapment may have a diel component of variability suggests that vision may play an important role in the entrapment of these two species. This suggestion is supported by observations of increased entrapment of these fish during periods of reduced water clarity. The diel component of variability in a velocity cap's effectiveness needs verification. We suggest that synchronous measurements of entrapment and density be made during daylight and night hours, with- and without-velocity-cap.

The suggestion that there is species specific variability in velocity cap effectiveness implies that an accurate update of Weight's 1958 evaluation of velocity caps must consider site-specific and seasonal variations in offshore species composition. This suggestion also has important implications for site selection studies. Such studies should consider the abundances of those species most vulnerable to entrapment. It would be valuable for both site selection studies and studies of velocity cap effectiveness if laboratory data on the vulnerability to entrapment for fishes other than anchovy were available.

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