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College of Fisheries
University of Washington
Seattle, Washington 98195

with

Moore Laboratory of Zoology
Occidental College
Los Angeles, California 90041

A COMPARISON OF FISH ENTRAPMENT AT FOUR SOUTHERN CALIFORNIA EDISON COMPANY COOLING WATER INTAKE SYSTEMS

by

Gary L. Thomas[1], Llew Johnson[2],
R. E. Thorne[1], and W. C. Acker[3]

TECHNICAL REPORT

to

Southern California Edison Company

[1] Fisheries Research Institute, University of Washington.
[2] Fish Encounter Studies, Occidental College.
[3] Applied Physics Laboratory, University of Washington.

Approved

Submitted: December 23, 1980

Robert L Burgner
Robert L. Burgner, Director
Fisheries Research Institute

J. S. Stephens, Jr., Director
Moore Laboratory of Zoology

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1.0 INTRODUCTION

The following paper reports on one of a series of tasks accomplished by the hydroacoustic group, University of Washington, and the Fish Encounter Studies Group, Occidental College, at the request of the Southern California Edison Company (SCE). A combined in-plant impingement, offshore hydroacoustic, and net sampling survey was conducted at four of SCE's coastal generating stations between August 6 and September 7, 1979. This study was designed to compare the nighttime vulnerability of fish to entrapment (E/B) among the four stations (where E represents fish entrapment [kg] and B represents the biomass [kg] of fish near an intake during the same time interval). The comparison was made in order to estimate between-station variability in intake performance. Through better understanding of the between-intake variability in fish entrapment, SCE may avoid having to conduct redundant studies at different sites. In addition, the stations with greatest fish loss relative to fish density become candidates for more detailed studies.

The four generating stations selected for study were as follows: Ormond Beach Generating Station (OBGS); El Segundo Generating Station Units 3 & 4 (ESGS); Huntington Beach Generating Station (HBGS); and San Onofre Nuclear Generating Station Unit One (SONGS). These stations were chosen because: 1) they are believed to have been responsible for the majority of fish loss within the SCE system; 2) they are representative of different types of intake structures; and 3) they span the full range of SCE's service territory.

A brief description of the cooling water intake systems and surrounding marine environments is presented in Appendix 1 and summarized in Table 1 for each station. More complete descriptions of the intake systems and surrounding environments are given in McGroddy et al. (1979), Benson (1972), Lockheed Aircraft Service Co. (1976), Marine Biological Consultants, Inc. (1975), and Environmental Quality Analysts, Inc. (1973).

Table 1. Characteristics of four Southern California Edison Coastal Generating Stations (abstracted from McGroddy et al. 1979).

	OBGS	ESGS (3 and 4)	HBGS	SONGS
Station Electrical Output (MW)	1510	650	941	430
Flow Rate (gpm)	476,000	276,800	356,600	350,620
Entrance Velocity (fps)	2.7	2.4	2.0	2.2
Opening Height (ft)	4.0	3.3	5.0	4.0
Screen Mesh Size (in)	5/8	5/8	3/8	5/8

2.0 METHODS

The primary objectives of the field survey were to simultaneously measure offshore fish density and in-plant 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 all fish within the cooling water intake system so that they became impinged and removed by traveling screens. These techniques were originally developed in 1978 at Huntington Beach (Thomas et al. 1979). An updated description of the methods is presented in Appendix 2.

2.1 Sampling Schedule

The typical daily sampling schedule included 6 consecutive hours of offshore acoustic and in-plant entrapment measurement between 2330 and 0530 each survey night (Fig. 1). In addition, 18-hr measurements of entrapment were made after the hourly sampling periods. Lampara seining was conducted in conjunction with acoustic measurements.

Synchronous fish entrapment and offshore density measurements were accomplished on August 6, 7, and 8 at OBGS; August 13, 14, and 15 at ESGS; August 20, 27, and 28 at HBGS; and September 6 and 7 at SONGS. A total of 14 lampara sets were made at OBGS, 10 at ESGS, 7 at HBGS and 9 at SONGS during the acoustic sampling intervals.

2.2 Data Analysis

Two problems were addressed in this survey. The first was to determine the feasibility of comparing the entrapment vulnerability of fishes between stations. The second was to determine if the vulnerability to entrapment was different between stations.

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 rejection region for all testing procedures was determined using $\alpha = 0.05$.

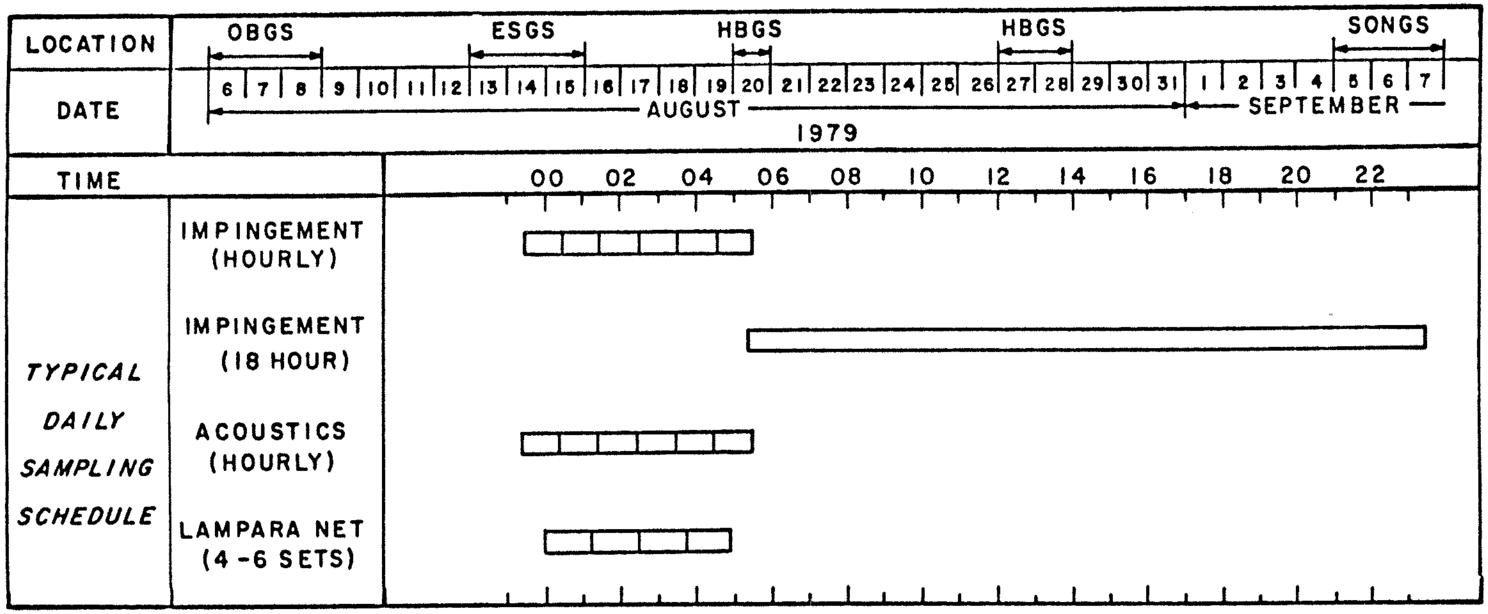

Fig. 1. Dates sampled, sampling station, and typical daily sampling schedule for a comparison of fish entrapment rates of four SCE cooling water intake systems.

3.0 RESULTS AND DISCUSSION

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 rates or offshore abundance.

Water transparency varied between stations and survey days (Table 2). The water transparency during the survey days ranged from 6.0 m to 6.5 m at OBGS, 3.3 m to 7.0 m at ESGS, and 4.0 m to 4.8 m at HBGS, respectively. Transparency readings were not made at SONGS because of the design of the screenwells.

Water temperature varied between stations and survey days. Temperatures at the OBGS were lower than temperatures at the other stations surveyed. The water temperature ranged from 56°F to 68°F at OBGS, 62°F to 73°F at ESGS and SONGS, and from 59°F to 73°F at HBGS.

Wind speeds ranged from 0 to 15 mph at all stations. In general, the highest wind speeds (10 to 15 mph) were observed in the afternoon of the survey days. Wind speeds during the midnight to dawn sampling intervals were generally less than 8 mph.

3.2 Indicator Species (i)

The species composition of fishes entrapped and captured in the field (Tables 3a, b, c, d) were examined to determine their relative importance in the fish assemblage. Fishes that comprised significant percentages of the in-plant and field catches at all four of the stations surveyed were selected for use in data analysis.

Five species and two families of fishes were found to dominate the offshore lampara catch (Table 4). The ranked abundance of these fishes indicated that for all stations combined, white croaker were the most frequently caught fish, followed in order by queenfish, butterfish, the silverside family, northern anchovy, the mackerels, and bat ray. Of these fishes, only the white croaker and queenfish were entrapped in number at all four stations (Table 5). Thus, species-specific comparisons of entrapment to density (E/B) among stations were confined to these two fishes.

3.3 Length-frequency

The length-frequency histograms for queenfish and white croaker captured by lampara seine and entrapped in-plant are presented by station in Figs. 2a-d. In-plant versus offshore comparisons of these

Table 2. Transparency measurements during the 1979 multi-station survey.

Station	Date	Secchi disc reading (m)
OBGS	8/6	--
	8/7	6.5
	8/8	6.0
ESGS	8/13	7.0
	8/14	3.5
	8/15	3.3
HBGS	8/20	4.3
	8/27	4.0
	8/28	4.8

Table 3a. The species composition of fishes caught in-plant and offshore of the Ormond Beach Generating Station, August 9, 1979 (ranked by biomass impinged).

		Impingement		Lampara catch	
Scientific name	Common name	% biomass	% number	% biomass	% number
Torpedo californica	Pacific electric ray	31.4	0.5	0	0
Porichthys notatus	plainfin midshipman	14.3	10.6	0	0
Seriphus politus	queenfish	12.1	55.1	2.0	4.1
Rhacochilus vacca	pile surfperch	9.4	2.4	0	0
Paralabrax clathratus	kelp bass	8.3	1.9	0	0
Phanerodon furcatus	white surfperch	5.9	9.7	*	*
Rhacochilus toxotes	rubberlip surfperch	5.7	1.2	*	*
Embiotoca jacksoni	black surfperch	3.4	1.9	0	0
Paralabrax nebulifer	barred sand bass	2.5	0.5	0	0
Hyperprosopon argenteum	walleye surfperch	1.6	9.9	*	*
Scorpaenichthys marmoratus	cabezon	1.5	0.2	0	0
Genyonemus lineatus	white croaker	0.8	0.5	3.1	2.5
Myliobatis californica	bat ray	0.7	0.2	1.6	0.2
Sebastes rastrelliger	grass rockfish	0.5	0.2	0	0
Sebastes mystinus	blue rockfish	0.5	0.2	0	0
Engraulis mordax	northern anchovy	0.4	2.8	1.8	7.0
Medialuna californiensis	halfmoon	0.3	0.2	0	0
Otophidium scrippsae	basketweave cusk-eel	0.3	0.2	*	*
Atherinopsis californiensis	jacksmelt	0.2	0.2	53.1	30.8
Sebastes paucispinis	bocaccio	0.1	0.5	0	0
Unidentified biomass		0.1	0.2	*	*
Sebastes dalli	calico rockfish	*	0.2	0	0
Cymatogaster aggregata	shiner surfperch	*	0.7	*	*
Atherinops affinis	topsmelt	0	0	9.0	6.3
Peprilus simillimus	Pacific butterfish	0	0	24.3	43.9
Scomber japonicus	Pacific mackerel	0	0	1.9	0.5
Synodus lucioceps	California lizardfish	0	0	*	*
Citharichthys sordidus	Pacific sanddab	0	0	*	*
Citharichthys stigmaeus	spotted sanddab	0	0	*	*
Trachurus symmetricus	jack mackerel	0	0	*	*
Paralabrax maculatofasciatus	spotted sand bass	0	0	*	*
Platyrhinoidis triseriata	thornback ray	0	0	*	*
Mustelus californicus	gray smoothhound	0	0	*	*
Leuresthes tenuis	California grunion	0	0	*	*
Parophrys vetulus	English sole	0	0	*	*
	%	100	100	96.8**	95.3***
TOTAL CATCH	kg	42.11		1,778.79	
	#'s		425		30,759

*Trace.
**Miscellaneous species represented 3.2% of the lampara catch biomass.
***Miscellaneous species represented 4.7% of the lampara catch numbers.

Table 3b. The species of fishes caught in-plant and offshore of the El Segundo Generating Station, August 13 to August 15, 1979 (ranked by biomass impinged).

		Impingement		Lampara catch	
Scientific name	Common name	% biomass	% number	% biomass	% number
Paralabrax clathratus	kelp bass	44.9	9.2	0	0
Anisotremus davidsonii	sargo	24.6	2.1	0	0
Hyperprosopon argenteum	walleye surfperch	8.0	4.6	*	*
Seriphus politus	queenfish	5.7	67.7	4.6	5.4
Atherinopsis californiensis	jacksmelt	5.7	1.4	0.1	*
Genyonemus lineatus	white croaker	4.7	1.8	25.9	3.5
Paralabrax nebulifer	barred sand bass	2.4	0.4	0	0
Scorpaena guttata	sculpin	1.4	0.4	0	0
Cheilotrema saturnum	black croaker	1.0	0.4	0	0
Engraulis mordax	northern anchovy	0.5	12.0	12.9	88.1
Scomber japonicus	Pacific mackerel	0	0	32.6	1.6
Synodus lucioceps	California lizardfish	0	0	*	*
Cymatogaster aggregata	shiner surfperch	0	0	*	*
Pleuronichthys verticalis	hornyhead turbot	0	0	*	*
Myliobatis californica	bat ray	0	0	1.8	*
Chromis punctipinnis	blacksmith	0	0	*	*
Peprilus simillimus	Pacific butterfish	0	0	0.3	0.1
Leuresthes tenuis	California grunion	0	0	*	*
Phanerodon furcatus	white surfperch	0	0	*	*
Sarda chiliensis	Pacific bonito	0	0	20.1	0.2
Sardinops sagax caeruleus	Pacific sardine	0	0	*	*
Citharichthys sp.	sanddab	0	0	*	*
Trachurus symmetricus	jack mackerel	0	0	*	*
Citharichthys sordidus	Pacific sanddab	0	0	*	*
Paralichthys californicus	California halibut	0	0	*	*
Sphyraena argentea	California barracuda	0	0	*	*
TOTAL CATCH	%	100	100	99.96**	98.9***
	kg	15.224		549.97	
	#'s		282	45,858	

*Trace.

**Miscellaneous species represented 1.66% of the lampara catch biomass.

***Miscellaneous species represented 1.1% of the lampara catch numbers.

Table 3c. The species composition of fishes caught in-plant and offshore of the Huntington Beach Generating Station, August 20, 27, and 28, 1979 (ranked by biomass impinged).

		Impingement		Lampara catch	
Scientific name	Common name	% biomass	% number	% biomass	% number
Seriphus politus	queenfish	56.5	44.8	25.6	10.3
Engraulis mordax	northern anchovy	8.8	39.1	18.7	73.5
Unidentified biomass		6.7	0	0	0
Paralabrax clathratus	kelp bass	3.6	0.3	0	0
Hyperprosopon argenteum	walleye surfperch	3.6	3.0	*	*
Genyonemus lineatus	white croaker	2.6	4.2	28.6	8.0
Cymatogaster aggregata	shiner surfperch	2.5	3.2	*	*
Phanerodon furcatus	white surfperch	2.0	3.4	*	*
Scorpaena guttata	sculpin	1.8	0.2	0	0
Atherinopsis californiensis	jacksmelt	1.7	0.1	0.4	*
Chromis punctipinnis	blacksmith	1.3	0.1	0	0
Menticirrhus undulatus	California corbina	1.1	0	0	0
Paralabrax nebulifer	barred sand bass	0.9	0.1	0	0
Otophidium scrippsi	basketweave cusk-eel	0.8	0.1	*	*
Embiotoca jacksoni	black surfperch	0.8	0.1	0	0
Damalichthys vacca	pile surfperch	0.6	0	0	0
Pleuronichthys verticalis	hornyhead turbot	0.6	0	*	*
Atherinops affinis	topsmelt	0.6	0.2	0.1	*
Peprilis simillimus	Pacific butterfish	0.4	0.2	8.2	2.8
Symphurus atricauda	California tonguefish	0.3	0.1	*	*
Paralichthys californicus	California halibut	0.3	0	*	*
Porichthys myriaster	specklefin midshipman	0.3	0	*	*
Heterostichus rostratus	giant kelpfish	0.1	0.3	0	0
Citharichthys xanthostigma	longfin sanddab	0.1	0	0	0
Hypsoblennius sp.	blenny	0	0.1	0	0
Rhacochilus toxotes	rubberlip surfperch	0	0	0	0
Syngnathus californiensis	kelp pipefish	0	0	0	0
Anisotremus davidsonii	sargo	0	0	0	0
Leuresthes tenuis	California grunion	0	0	2.2	3.7
Myliobatis californica	bat ray	0	0	1.3	*
Synodus lucioceps	California lizardfish	0	0	*	*
Porichthys notalus	plainfin midshipman	0	0	*	*
Pleuronichthys ritteri	spotted turbot	0	0	*	*
Hypsopsetta guttulata	diamond turbot	0	0	*	*
Parophrys vetulus	English sole	0	0	*	*
Trachurus symmetricus	jack mackerel	0	0	*	*
Leptocottus armatus	staghorn sculpin	0	0	*	*
Alopias vulpinus	common thresher shark	0	0	*	*
Paralabrax maculatofasciatus	spotted sand bass	0	0	*	*
TOTAL CATCH	%	100	100	85.1**	98.3***
	kg	43.86		233.64	
	#'s		2,888		19,516

*Trace.

**Miscellaneous species represented 14.9% of the lampara catch biomass.

***Miscellaneous species represented 1.7% of the lampara catch numbers.

Table 3d. The species composition of fishes caught in-plant and offshore of the San Onofre Nuclear Generating Station, September 5 to September 7, 1979 (ranked by biomass impinged.

		Impingement		Lampara catch	
Scientific name	Common name	% biomass	% number	% biomass	% number
Seriphus politus	queenfish	45.9	74.2	30.6	35.2
Anisotremus davidsonii	sargo	15.4	2.3	0	0
Genyonemus lineatus	white croaker	10.8	12.4	10.2	10.2
Mustelus californicus	gray smoothhound	3.9	0.3	0	0
Porichthys myriaster	specklefin midshipman	3.4	0.3	0	0
Atherinops affinis	topsmelt	2.3	2.0	8.3	5.5
Cheilotrema saturnum	black croaker	2.3	0.4	0	0
Urolophus halleri	round stingray	1.7	0.1	0	0
Medialuna californiensis	halfmoon	1.6	0.4	0	0
Hyperprosopon argenteum	walleye surfperch	1.6	3.3	*	*
Embiotoca jacksoni	black surfperch	1.6	0.2	0	0
Menticirrhus undulatus	California corbina	1.4	0.1	*	*
Damalichthys vacca	pile surfperch	1.2	0.1	0	0
Atherinopsis californiensis	jacksmelt	1.1	0.1	3.6	1.2
Paralabrax clathratus	kelp bass	0.8	0.2	0	0
Cymatogaster aggregata	shiner surfperch	0.8	2.2	*	*
Cynoscion nobilis	white sea bass	0.6	0.1	*	*
Unidentified Teleost					
Xenistius californiensis	salema	0.5	0.2	*	*
Platyrhinoidis triseriata	thornback ray	0.5	0.1	0	0
Sebastes rastrelliger	grass rockfish	0.4	0.1	0	0
Umbrina roncador	yellowfin croaker	0.4	0.1	0	0
Unidentified Atherinidae	smelt	0.4	0.3	0	0
Petrilus simillimus	Pacific butterfish	0.3	0.3	16.9	12.9
Heterostichus rostratus	giant kelpfish	0.3	0.1	0	0
Phanderodon furcatus	white surfperch	0.1	0.3	*	*
Scorpaena guttata	sculpin	0.1	0.1	*	*
Engraulis mordax	northern anchovy	0.1	0.2	2.1	20.8
Hypsoblennius sp.	blenny	0	0.1	0	0
Myliobatis californica	bat ray	0	0	9.8	*
Rhinobatos productus	shovelnosed guitarfish	0	0	*	*
Otophidium scrippsi	basketweave cusk-eel	0	0	*	*
Paralichthys californicus	California halibut	0	0	*	*
Anchoa compressa	deepbody anchovy	0	0	*	*
Leuresthes tenuis	California grunion	0	0	*	*
Trachurus symmetricus	jack mackerel	0	0	*	*
Rhacochilus toxotes	rubberlip surfperch	0	0	*	*
Scomber japonicus	Pacific mackerel	0	0	4.6	0.7
Sarda chiliensis	Pacific bonito	0	0	0.5	*
Citharichthys sordidus	Pacific sanddab	0	0	*	*
Sphyraena argentea	California barracuda	0	0	*	*
Paralabrax nebulifer	barred sand bass	0	0	*	*
Porichthys notatus	plainfin midshipman	0	0	*	*
Amphisticus argenteus	barred surfperch	0	0	*	*
	%	100	100	86.6**	86.5***
TOTAL CATCH	kg	53.98		215.13	
	#'s		1,512		8,422

*Trace.

**Miscellaneous species represented 13.4% of the lampara catch biomass.

***Miscellaneous species represented 13.5% of the lampara catch numbers.

Table 4. The percentage (%) and ranked order of abundance (rΣr) for the five species and two families of fishes which dominated the lampara catches at the four SCE power generating stations (OBGS, ESGS, HBGS, and SONGS), August-September 1979.

	OBGS		ESGS		HBGS		SONGS			
Species	%	r	%	r	%	r	%	r	Σr	rΣr
White croaker	3.1	3	25.9	2	28.6	1	10.2	4	10	1
Queenfish	2.0	4	4.6	4	25.6	2	30.6	1	11	2
Northern anchovy	1.8	6	12.9	3	18.7	3	2.1	7	19	5.5
Silversides*	62.1	1	0.1	7	2.7	5	11.9	3	16	4
Butterfish	24.3	2	0.3	6	8.2	4	16.9	2	14	3
Mackerels**	1.9	5	52.7	1	0	7	5.1	6	19	5.5
Bat ray	1.6	7	1.8	5	1.3	6	9.8	5	23	7
Total Percentage	96.8		98.3		85.1		86.6			

* jacksmelt, topsmelt, grunion
** Pacific mackerel, Pacific bonito

Table 5. The percentage (% biomass) and rank order abundance (rΣr) entrapped of fishes that dominated the lampara catches at four SCE power generating stations (OBGS, ESGS, HBGS, and SONGS), August-September 1979.

	OBGS		ESGS		HBGS		SONGS			
Species	%	r	%	r	%	r	%	r	Σr	rΣr
White croaker	0.8	13	4.7	6	2.6	5	10.8	3	27	2
Queenfish	12.1	3	5.7	4	56.5	1	45.9	1	9	1
Northern anchovy	*	16	*	10	8.8	2	*	28	56	4
Silversides	*	18	5.7	5	2.3	6	8.7	5	34	3
Mackerels	0	--	0	--	0	--	0	--	--	-
Butterfish	0	--	0	--	*	17	*	22	--	-
Bat ray	*	13	0	--	0	--	0	--	--	-

* Trace

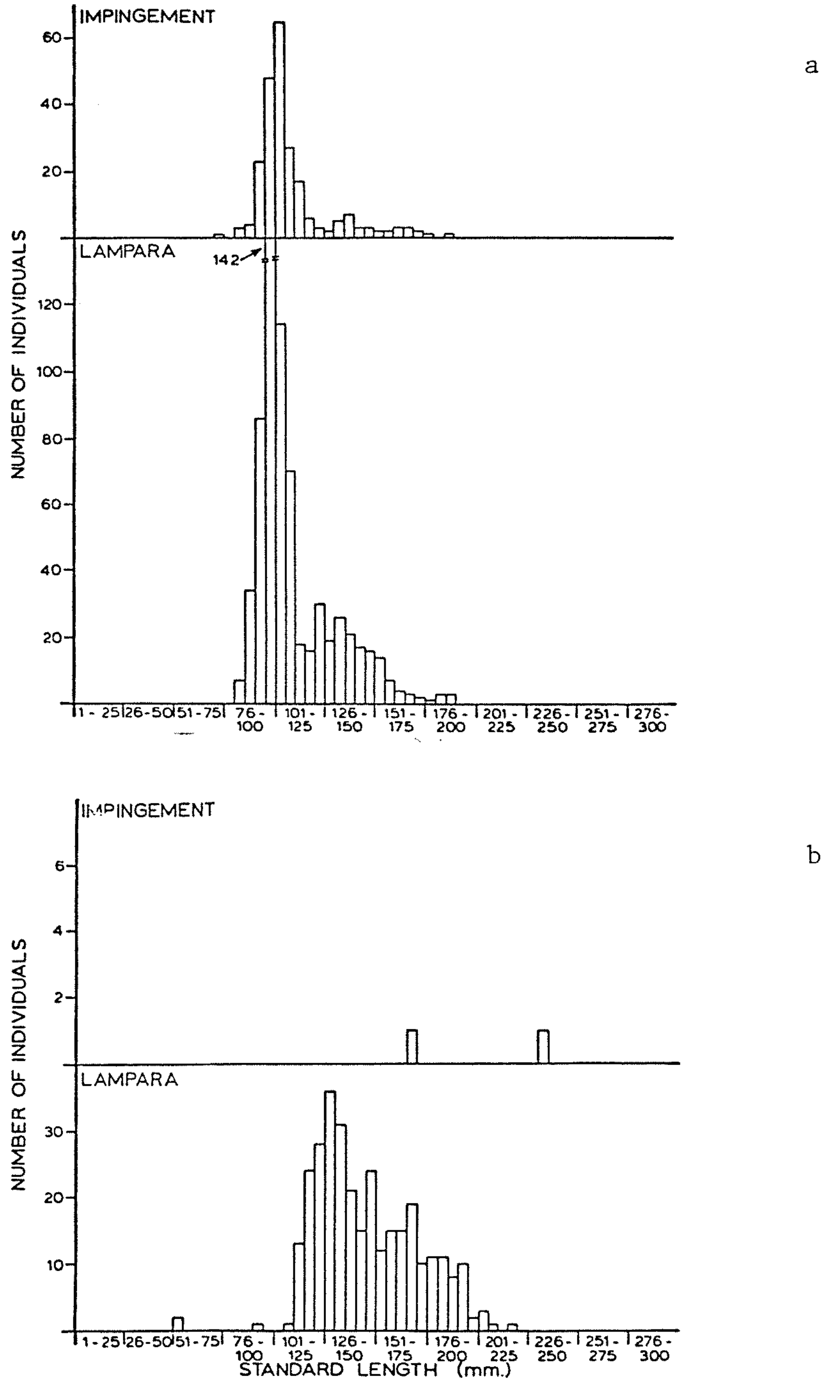

Fig. 2a. The length-frequency distribution of queenfish (a) and white croaker (b) caught in-plant and offshore of Ormond Beach Generating Station, August 5 to September 9, 1979.

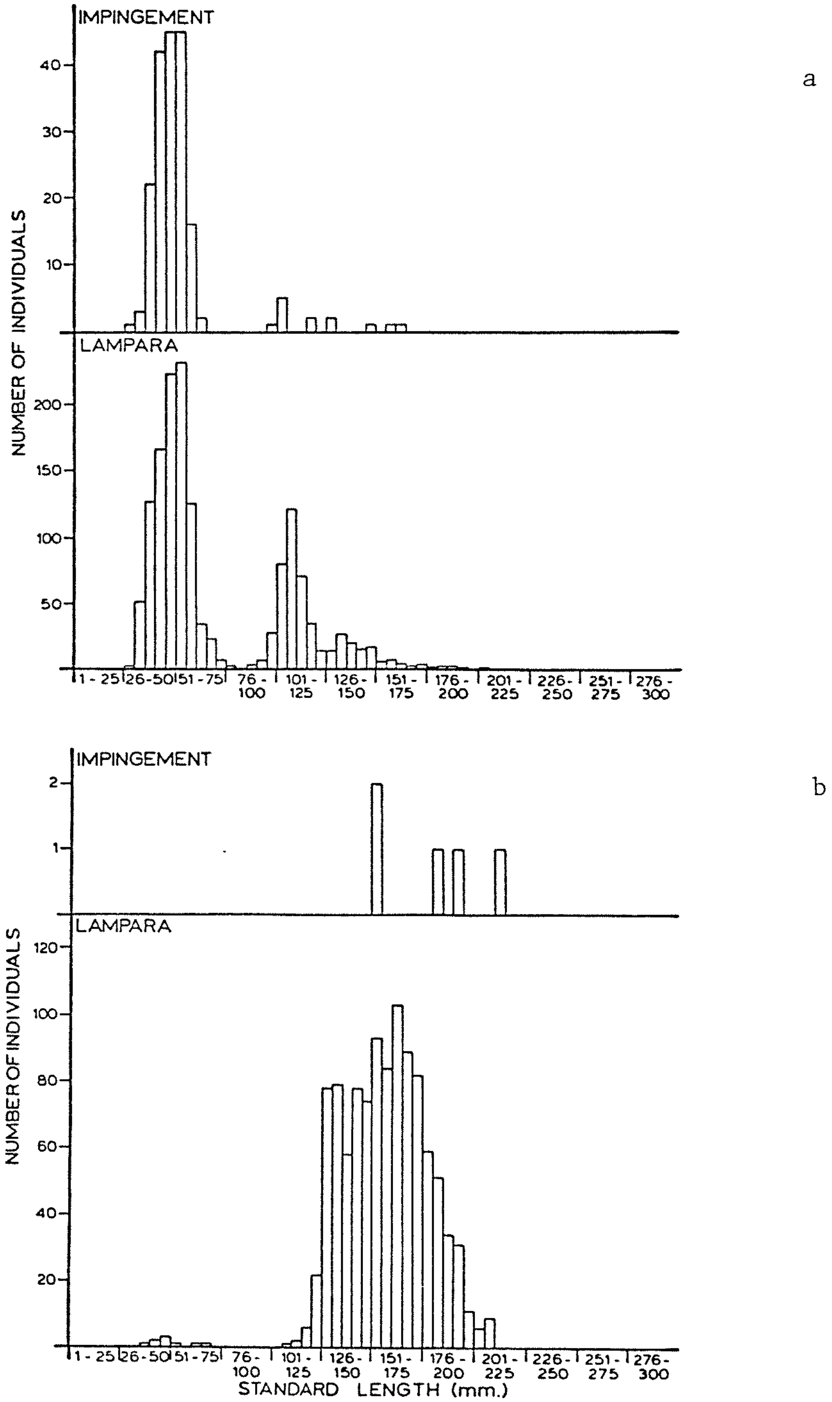

Fig. 2b. The length-frequency distribution of queenfish (a) and white croaker (b) caught in-plant and offshore of El Segundo Generating Station, August 10 to August 16, 1979.

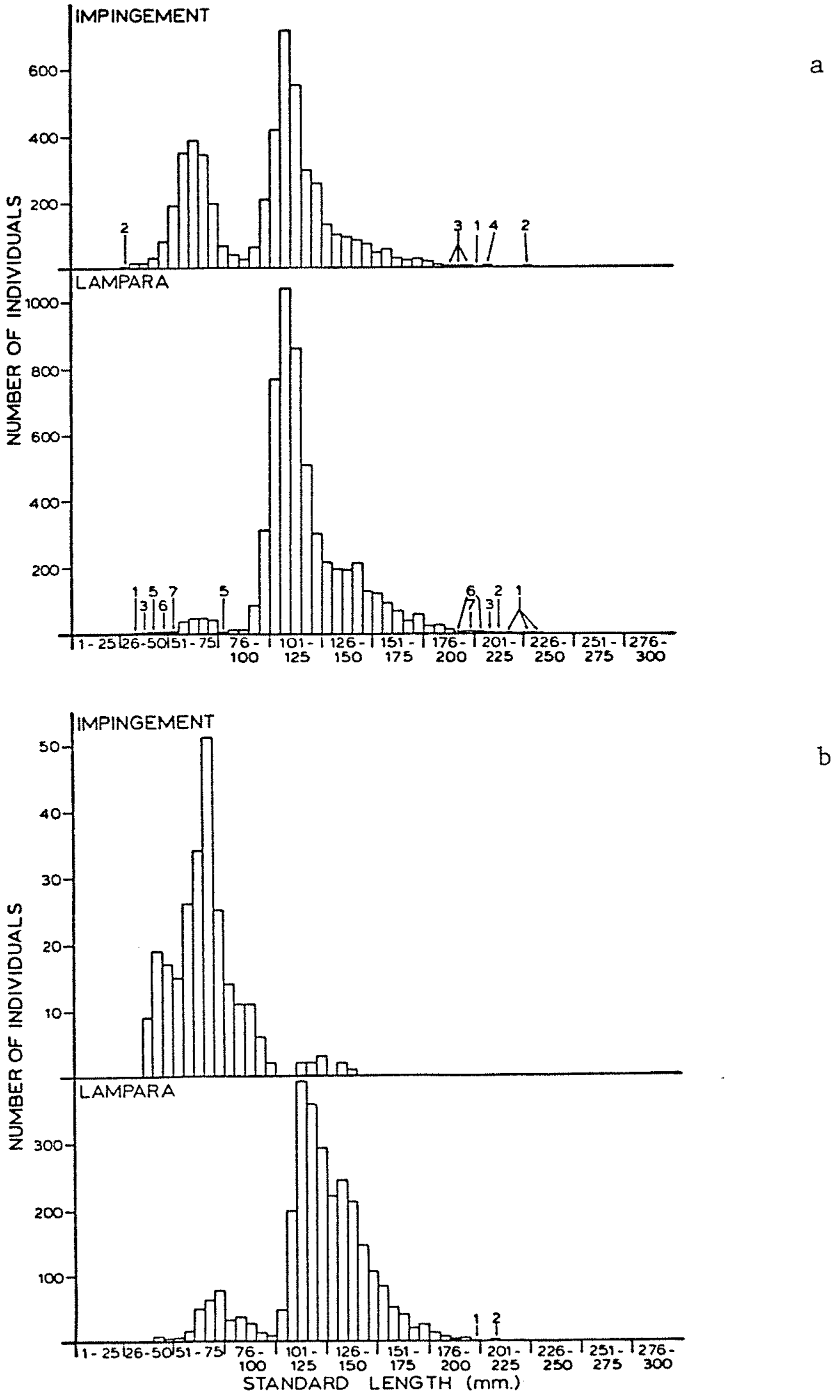

Fig. 2c. The length-frequency distribution of queenfish (a) and white croaker (b) caught in-plant and offshore of Huntington Beach Generating Station, August 19 to August 28, 1979.

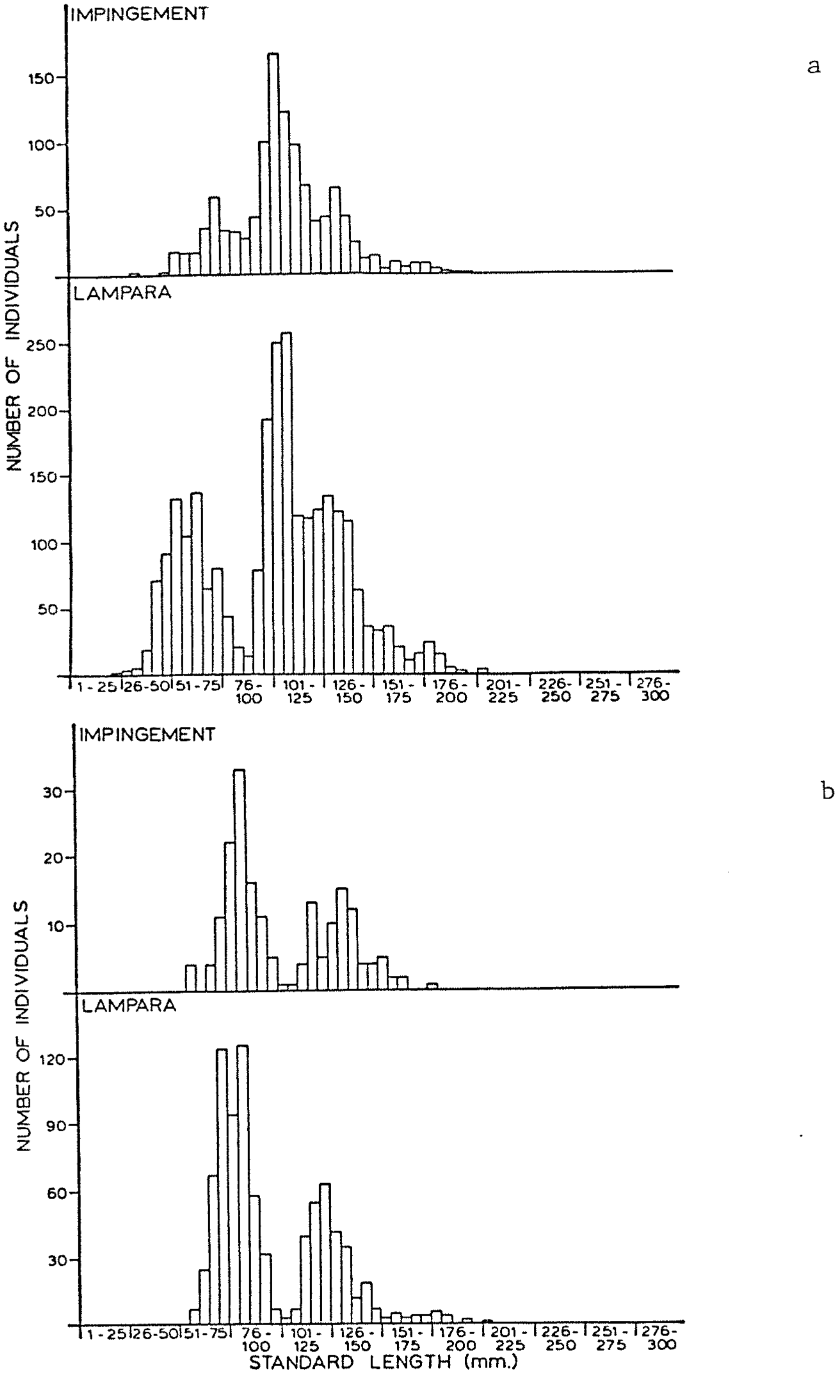

Fig. 2d. The length-frequency distribution of queenfish (a) and white croaker (b) caught in-plant and offshore of San Onofre Generating Station, September 4 to September 9, 1979.

results may be confounded by variations in the population structures because the lampara net sampled at discrete points in time, whereas the entrapment sample represented the entire nightly survey period.

The lampara queenfish histograms displayed: at OBGS, strong bimodality, at 100 and 125-135 mm (standard length), and suggested the possibility of a third mode at 180 mm; at ESGS, trimodality, at 55, 110 and 135 mm, and a long tail to include fish greater than 200 mm; at HBGS, trimodality, at 65, 110, 145, and suggested the possibility of a fourth mode at 170 mm within a long tail extending beyond 225 mm; and at SONGS, four modes at 50-65, 110, 130, and 180 mm. The modes at 50-65 mm, 100-110 mm, 130-145 mm, 170-180 mm correspond to sizes expected for age 0, 1, 2, and 3 queenfish and were assumed to be cohorts, respectively. The most conspicuous observations were the absence of age 0 queenfish at the northern most station, OBGS, and the low proportion of age 0 fish (relative to older fish) at HBGS and SONGS.

Assuming that the lampara catches were the best estimates of relative cohort strengths in the offshore fish population and that smaller queenfish were more vulnerable to entrapment than larger queenfish, it was expected that the proportion of smaller fish in the entrapment catch would be higher than that in the offshore lampara sample. This was true for OBGS, ESGS, and HBGS, but not for SONGS. In addition, at SONGS the mode of age 0 queenfish entrapped was larger than that caught by lampara (75 mm versus 60 mm). At the other stations the age 0 modes were the same in-plant and offshore. This suggested that the small individuals of the age 0 queenfish may not be retained in the SONGS screen systems and/or that they were not entrapped by the intake.

The lampara histograms for white croaker displayed: at OBGS, two modes at 120 and 170 and suggested possible modes at 150 and 185 mm; at ESGS, two modes at 130 and 160 mm; at HBGS, modes at 75 and 115 mm and suggested other modes after 135 mm; and at SONGS, modes at 70-80 and 125, with possible other modes subsequent to 145 mm. The modes at 70-80 and 115-125 correspond to ages 0 and 1 white croaker and were assumed to be cohorts. Larger fish represented ages 2 and older fish.

The most conspicuous observations in the white croaker histograms were the low proportion of age 0 fish at the two northern most stations, OBGS and ESGS, and the high proportion of age 2+ fish at ESGS.

The histograms of entrapped white croaker displayed: at HBGS, one mode at 70 mm and suggested two more at 45 and 125 mm; at SONGS, modes at 85, 120, and 135 mm. The sample sizes of entrapped fish at OBGS and ESGS were too small for length-frequency analyses. The most conspicuous observation in the length-frequency of white croaker entrapped was the higher proportion of age 0 fish relative to older fish at HBGS. This finding was analogous to the results of the queenfish comparisons.

The length-frequency analyses of queenfish and white croaker indicate that these two sciaenids may have range restrictions within SCE power plant locations; that is, both species were found in reduced numbers, and age 0 fish were absent at the northern most station, OBGS. The absence of young of the year fish could be expected because of OBGS′ northerly latitude. Northerly range restrictions of age 0 fish have been observed for other species of the southern California Bight. However, a temporal offset in seasonality could also explain this observation. If the species assemblage at the stations undergo offset periodic cycles, then field sampling should consider this factor in future multiple station comparisons.

3.4 Fish Entrapment (E_i)

A large amount of variation was observed in the hourly entrapment (E) for queenfish and white croaker (Table 6). In general the queenfish entrapment was lowest at OBGS and ESGS, intermediate at SONGS, and highest at HBGS. The white croaker entrapment was also lowest at OBGS and ESGS, but were intermediate at HBGS, and highest at SONGS. There was little within station variation in entrapment with the exception of HBGS where the entrapment was much higher on August 27 than on either August 20 or August 28.

3.5 Offshore Fish Biomass (B_T)

The biomass of fish (kg) within 300 m of the intake structure was determined with hydroacoustic techniques at OBGS, ESGS, HBGS, and SONGS (Table 7).

The average fish biomass values were largest at ESGS, intermediate at OBGS, and lowest at HBGS and OBGS.

The lampara catch compositions (P_i) were used to determine the species composition of acoustic targets observed within 300 m of the intake structures. The daily lampara catches of queenfish (P_1), and white croaker (P_2) are presented in Table 8.

Hourly estimates of offshore biomass within 300 m of the intake structures at OBGS, ESGS, HBGS, and SONGS were calculated for queenfish and white croaker respectively (Table 9). The measurements of P_1 and P_2 on August 13 and August 15 were averaged to estimate P_1 and P_2 for August 14 because lampara data were not available on August 14. The estimates of P_1 and P_2 from August 27 were used for August 28 calculations for the same reason.

The largest source of variability in queenfish biomass was attributed to differences among stations. Queenfish biomass decreased with increasing latitude, i.e., the highest biomass was observed at the San

Table 6. Hourly entrapment rates observed for queenfish and white croaker during the 1979 multiple-station survey.

			Queenfish		White croaker	
Station	Date	Time	No.	Kg	No.	Kg
OBGS	8/5	2330	--	--	--	--
	8/6	0030	--	--	--	--
	8/6	0130	4	0.06	0	0
	8/6	0230	2	0.03	0	0
	8/6	0330	3	0.04	0	0
	8/6	0430	14	0.30	0	0
	8/6	2330	0	0	1	0.24
	8/7	0030	0	0	0	0
	8/7	0130	0	0	0	0
	8/7	0230	0	0	0	0
	8/7	0330	1	0.02	0	0
	8/7	0430	5	0.10	0	0
	8/7	2330	4	0.23	0	0
	8/8	0030	0	0	0	0
	8/8	0130	0	0	0	0
	8/8	0230	0	0	0	0
	8/8	0330	2	0.08	0	0
	8/8	0430	2	0.11	0	0
ESGS	8/13	2330	5	0.02	1	0.15
		0030	0	0	1	0.13
		0130	0	0	0	0
		0230	1	0.01	0	0
		0330	1	0.01	0	0
		0430	0	0	0	0
	8/14	2330	25	0.10	0	0
		0030	0	0	0	0
		0130	1	0.04	0	0
		0230	1	0.01	0	0
		0330	2	0.04	0	0
		0430	0	0	1	0.07
	8/15	2330	9	0.08	0	0
		0030	13	0.04	0	0
		0130	7	0.02	0	0
		0230	15	0.03	0	0
		0330	3	0.01	0	0
		0430	14	0.05	0	0

Table 6. Hourly entrapment rates observed for queenfish and white croaker during the 1979 multiple-station survey - continued.

			Queenfish		White croaker	
Station	Date	Time	No.	Kg	No.	Kg
HBGS		2330	41	0.60	0	0
		0030	39	0.79	1	0.01
		0130	40	0.77	0	0
	8/20	0230	72	1.35	1	0.01
		0330	75	1.39	0	0
		0430	19	0.56	0	0
		2330	171	1.77	28	0.20
		0030	57	0.66	8	0.05
		0130	47	0.79	8	0.09
	8/27	0230	73	1.33	17	0.16
		0330	92	2.19	28	0.27
		0430	51	1.85	10	0.17
		2330	17	0.48	2	0.01
		0030	10	0.31	0	0
		0130	13	0.24	1	0.01
	8/28	0230	13	0.20	0	0
		0330	5	0.10	0	0
		0430	9	0.28	0	0
SONGS		2330	25	0.84	19	1.02
		0030	7	0.21	6	0.19
		0130	7	0.20	6	0.26
	9/6	0230	20	0.80	7	0.14
		0330	29	1.13	10	0.23
		0430	9	0.44	1	0.07
		2330	18	0.46	17	0.76
		0030	5	0.14	2	0.10
		0130	9	0.31	0	0
	9/7	0230	5	0.14	1	0.03
		0330	2	0.04	0	0
		0430	6	0.11	0	0

Table 7. Total offshore fish biomass, B_T (kg), by hour during the multi-station study in 1979.

Station	Date	Time	B_T	$\bar{B}_T$
OBGS	8/5	2330	463.792	
	8/6	0030	408.040	
	8/6	0130	343.198	573.316
	8/6	0230	795.476	
	8/6	0330	856.076	
	8/6	2330	201.758	
	8/7	0030	-0-	
	8/7	0130	305.262	307.131
	8/7	0230	353.177	
	8/7	0330	368.327	
	8/7	2330	519.948	
	8/8	0030	595.092	
	8/8	0130	1,147.360	843.229
	8/8	0230	1,185.740	
	8/8	0330	768.004	
ESGS	8/11	2330	435.108	
	8/12	0030	521.564	
	8/12	0130	879.912	737.219
	8/12	0230	976.872	
	8/12	0330	872.640	
	8/12	2330	755.076	
	8/13	0030	978.996	
	8/13	0130	1,207.556	1,084.174
	8/13	0230	1,114.636	
	8/13	0330	1,414.808	
	8/13	2330	1,696.800	
	8/14	0030	1,105.344	
	8/14	0130	1,053.632	1,220.322
	8/14	0230	1,016.060	
	8/14	0330	1,229.776	

Table 7. Total offshore fish biomass, B_T (kg), by hour during the multi-station study in 1979 - continued.

Station	Day	Time	B_T	$\bar{B}_T$
HBGS	8/19	2330	540.956	
	8/20	0030	393.657	
	8/20	0130	261.186	388.470
	8/20	0230	324.371	
	8/20	0330	422.180	
	8/26	2330	250.076	
	8/27	0030	144.713	
	8/27	0130	239.289	233.948
	8/27	0230	219.493	
	8/27	0330	316.170	
	8/27	2330	193.152	180.608
	8/28	0030	168.064	
SONGS	9/5	2330	410.464	
	9/6	0030	418.948	
	9/6	0130	308.454	388.478
	9/6	0230	427.836	
	9/6	0330	376.690	
	9/6	2330	485.204	
	9/7	0030	424.604	
	9/7	0130	335.642	368.642
	9/7	0230	253.752	
	9/7	0330	334.006	

Table 8. The daily catch of queenfish (P_1) and white croaker (P_2), and all species (kg and %) in the lampara seine, August-September 1979.

Date	Location	No. of sets	Total catch kg	Queenfish kg	Queenfish P_1	White croaker kg	White croaker P_2
8/6	OBGS	6	224.5	12.9	5.75	20.1	8.95
8/7	OBGS	4	107.3	5.7	5.31	8.4	7.83
8/8	OBGS	4	1,192.9	12.1	1.01	10.0	0.84
8/13	ESGS	5	345.1	11.9	3.45	82.1	23.79
8/15	ESGS	5	205.1	13.2	6.44	60.2	29.35
8/20	HBGS	3	141.4	45.7	32.32	25.5	18.03
8/27	HBGS	4	82.3	11.4	13.85	38.5	46.78
9/6	SONGS	5	116.0	34.6	29.83	9.5	8.19
9/7	SONGS	4	75.2	24.7	32.85	4.9	6.52

Table 9. Offshore estimates of queenfish (B_1) and white croaker (B_2) biomass (kg), by hour during the multiple-station study in 1979.

Station	Date	Time	B_1	B_2
OBGS	8/5	2330	26.65	41.52
	8/6	0030	23.45	36.53
	8/6	0130	19.72	30.73
	8/6	0230	45.71	71.22
	8/6	0330	49.19	76.65
	8/6	2330	10.72	15.79
	8/7	0030	-	-
	8/7	0130	16.22	23.90
	8/7	0230	18.76	27.65
	8/7	0330	19.57	28.83
	8/7	2330	5.27	4.36
	8/8	0030	6.04	4.99
	8/8	0130	11.64	9.62
	8/8	0230	12.03	9.94
	8/8	0330	7.79	6.44
	All days			
ESGS	8/12	2330	15.00	103.51
	8/13	0030	17.98	124.08
	8/13	0130	30.34	209.33
	8/13	0230	33.68	232.40
	8/13	0330	30.09	207.60
	8/13	2330	37.19	200.16
	8/14	0030	45.69	245.97
	8/14	0130	59.42	319.84
	8/14	0230	54.89	295.46
	8/14	0330	69.72	375.24
	8/14	2330	109.20	498.04
	8/15	0030	71.14	285.09
	8/15	0130	67.81	271.75
	8/15	0230	65.39	262.06
	8/15	0330	79.15	317.19
	All days			

Table 9. Offshore estimates of queenfish (B_1) and white croaker (B_2) biomass (kg), by hour during the multiple-station study in 1979 - continued.

Station	Date	Time	B_1	B_2
HBGS	8/19	2330	174.83	97.55
	8/20	0030	127.23	70.99
	8/20	0130	84.41	47.10
	8/20	0230	104.83	58.50
	8/20	0330	136.45	76.13
	8/26	2330	34.64	116.98
	8/27	0030	20.04	67.70
	8/27	0130	33.14	111.94
	8/27	0230	30.40	102.68
	8/27	0330	43.79	147.90
	8/27	2330	27.03	85.78
	8/28	0030	23.74	75.32
	All days			
SONGS	9/4	2330	122.43	33.61
	9/5	0030	124.96	34.31
	9/5	0130	92.00	25.26
	9/5	0230	127.61	35.04
	9/5	0330	112.36	30.85
	9/5	2330	159.37	31.61
	9/6	0030	139.46	27.67
	9/6	0130	110.24	21.87
	9/6	0230	83.35	16.53
	9/6	0330	112.99	22.41
	All days			

Onofre station and the lowest biomass was observed at Ormond Beach ($\alpha = 0.05$). Within-station variability was also observed, particularly at the Huntington Beach location where a five-fold decrease in queenfish biomass was observed between August 20 and 28. The large variability in offshore queenfish biomass at HBGS was attributed to the length of time required to collect 3 days normal flow data at this station. The 10-day span during the HBGS survey was due to a condenser tube leak that forced shutdown of several circulating pumps midway through the survey. As a result the queenfish biomass present at this and maybe at other stations is apparently subject to large weekly fluctuations.

White croaker biomass was the lowest at OBGS and highest at ESGS ($\alpha = 0.05$). Within-station variability was generally limited to less than two-fold fluctuation.

3.6 Vulnerability to Entrapment (E/B)

Hourly estimates of the vulnerability to entrapment (E/B) were computed for queenfish and white croaker (Table 10). The largest source of variability in queenfish and white croaker vulnerabilities was attributed to differences among stations. The highest E/B values were observed at HBGS ($\alpha = 0.05$). The E/B ratios were similar at OBGS, ESGS, and SONGS. One suspected mechanism for this observed difference among stations was the smaller mesh size of the HBGS traveling screens, 3/8 inch versus 5/8 inch at OBGS, ESGS, and SONGS. The smaller mesh at HBGS was expected to retain a larger proportion of the smaller fish than the traveling screens at OBGS, ESGS, and SONGS. This explanation was also supported by the previously discussed length-frequency data. Therefore, prior to making between station comparisons, vulnerability data require standardization for differences in screenwell retention. The difference in the retention of fish by the 3/8-inch and 5/8-inch mesh of the traveling screens is unknown. Another method to standardize comparisons is to separate entrapment and offshore density data into individual size classes, thereby allowing comparisons of cohorts equally retained by 3/8- and 5/8-inch meshes.

3.7 Entrapment Vulnerability by Cohort

The entrapment (E) of a species (i) by cohort (j) was analyzed for queenfish. Insufficient cohort data were available for the analysis of white croaker. Cohort strengths were determined from modes within the length-frequency distributions. The estimates of E_{1j}/B_{1j} (where j = 0, 1, and 2+) are presented in Table 11.

Queenfish entrapment vulnerability varied between stations and between cohorts. Age class 0 queenfish displayed a higher vulnerability to entrapment at the HBGS than at either ESGS or SONGS ($\alpha = 0.05$). An

Table 10. Hourly ratios of fish entrapment (kg/hr) to offshore fish biomass (kg) for queenfish (E_1/B_1) and white croaker (E_2/B_2) at OBGS, ESGS, HBGS, and SONGS 1, August-September 1979.

Station	Date	Time	E_1/B_1	E_2/B_2
OBGS	8/6	0130	.0030	0
	8/6	0230	.0007	0
	8/6	0330	.0008	0
	8/6	2330	0	.0152
	8/7	0130	0	0
	8/7	0230	0	0
	8/7	0330	.0010	0
	8/7	2330	.0436	0
	8/8	0030	0	0
	8/8	0130	0	0
	8/8	0230	0	0
	8/8	0330	.0103	0
ESGS	8/12	2330	.0013	.0014
	8/13	0030	0	.0010
	8/13	0130	0	0
	8/13	0230	.0003	0
	8/13	0330	.0003	0
	8/13	2330	0	0
	8/14	0030	0	0
	8/14	0130	0	0
	8/14	0230	0	0
	8/14	0330	0	0
	8/14	2330	.0007	0
	8/15	0030	.0006	0
	8/15	0130	.0003	0
	8/15	0230	.0005	0
	8/15	0330	.0001	0
HBGS	8/19	2330	.0034	0
	8/20	0030	.0063	.0001
	8/20	0130	.0091	0
	8/20	0230	.0129	.0002
	8/20	0330	.0102	0
	8/26	2330	.0511	.0017
	8/27	0030	.0329	.0007
	8/27	0130	.0238	.0008
	8/27	0230	.0437	.0016
	8/27	0330	.0500	.0018
	8/27	2330	0	0
	8/28	0030	0	0

Table 10. Hourly ratios of fish entrapment (kg/hr) to offshore fish biomass (kg) for queenfish (E_1/B_1) and white croaker (E_2/B_2) at OBGS, ESGS, HBGS, and SONGS 1, August-September 1979-continued.

Station	Date	Time	E_1/B_1	E_2/B_2
SONGS	9/5	2330	.0069	.0303
	9/6	0030	.0017	.0055
	9/6	0130	.0022	.0103
	9/6	0230	.0063	.0040
	9/6	0330	.0101	.0075
	9/6	2330	.0029	.0240
	9/7	0030	.0010	.0036
	9/7	0130	.0028	0
	9/7	0230	.0017	.0018
	9/7	0330	.0004	0

Table 11. The offshore biomass (kg), entrapment (kg), and E/B values for cohorts 0, 1 and 2+ queenfish (i=1) at OBGS, ESGS, HBGS, and SONGS in August-September 1979.

Station	Date	Time	E_{10}	B_{10}	E_{10}/B_{10}	E_{11}	B_{11}	E_{11}/B_{11}	E_{12+}	B_{12+}	E_{12+}/B_{12+}
OBGS	8/6	0130	0.00	0.000	-	0.06	9.454	0.006	000	10.266	0.00
OBGS	8/6	0230	0.00	0.000	-	0.03	21.948	0.001	0.00	23.762	0.00
OBGS	8/6	0330	0.00	0.000	-	0.04	26.732	0.001	0.00	22.458	0.00
OBGS	8/6	2330	0.00	0.000	-	0.00	5.670	0.00	0.00	5.050	0.00
OBGS	8/7	0030	0.00	0.000	-	0.00	-	-	0.00	-	-
OBGS	8/7	0130	0.00	0.000	-	0.00	8.583	0.00	0.00	7.637	0.00
OBGS	8/7	0230	0.00	0.000	-	0.00	9.936	0.00	0.00	8.824	0.00
OBGS	8/7	0330	0.00	0.000	-	0.02	10.362	0.002	0.00	9.208	0.00
OBGS	8/7	2330	0.00	0.000	-	0.04	2.012	0.020	0.19	3.258	0.06
OBGS	8/8	0030	0.00	0.000	-	0.00	2.286	0.00	0.00	3.754	0.00
OBGS	8/8	0130	0.00	0.000	-	0.00	4.416	0.00	0.00	7.224	0.00
OBGS	8/8	0230	0.00	0.000	-	0.00	4.586	0.00	0.00	7.444	0.00
OBGS	8/8	0330	0.00	0.000	-	0.00	2.957	0.00	0.08	4.833	.017
ESGS	8/12	2330	*	1.942	*	*	6.152	*	0.00	6.906	0.00
ESGS	8/13	0.030	0.00	2.328	0.000	0.00	7.366	0.00	0.00	8.286	0.00
ESGS	8/13	0130	0.00	3.937	0.000	0.00	12.433	0.00	0.00	13.970	0.00
ESGS	8/13	0230	*	4.379	*	0.00	13.813	0.00	0.00	15.488	0.00
ESGS	8/13	0330	*	3.888	*	0.00	12.340	0.00	0.00	13.852	0.00
ESGS	8/13	2330	0.06	4.821	0.012	0.00	17.119	0.00	0.04	15.250	0.003
ESGS	8/14	0030	0.00	5.934	0.00	0.00	21.038	0.00	0.00	18.718	0.00
ESGS	8/14	0130	0.00	7.732	0.00	0.00	27.331	0.00	0.04	24.357	0.002
ESGS	8/14	0230	*	7.138	*	0.00	25.228	0.00	0.00	22.524	0.00
ESGS	8/14	0330	*	9.056	*	0.04	32.089	0.001	0.00	28.575	0.00
ESGS	8/14	2330	*	15.270	*	0.01	54.614	0.001	0.03	39.316	0.001
ESGS	8/15	0030	0.02	9.960	0.002	0.02	35.570	0.001	0.00	25.610	0.00
ESGS	8/15	0130	0.02	9.493	0.002	0.00	33.905	0.00	0.00	24.412	0.00
ESGS	8/15	0230	0.03	9.155	0.003	0.00	32.695	0.00	0.00	23.540	0.00
ESGS	8/15	0330	0.01	11.081	0.001	0.00	39.575	0.00	0.00	28.494	0.00
HBGS	8/19	2330	0.11	1.748	0.063	0.28	110.143	0.003	0.21	62.939	0.003
HBGS	8/20	0030	0.05	1.272	0.039	0.38	80.155	0.005	0.37	45.803	0.008
HBGS	8/20	0130	0.05	.844	0.059	0.43	53.178	.008	0.29	30.388	0.010
HBGS	8/20	0230	0.07	1.048	0.067	1.05	66.043	0.016	0.23	37.739	0.006

Table 11. The offshore biomass (kg), entrapment (kg), and E/B values for cohorts 0, 1 and 2+ queenfish (i=1) at OBGS, ESGS, HBGS, and SONGS in August-September 1979 - continued.

Station	Date	Time	E_{10}	B_{10}	E_{10}/B_{10}	E_{11}	B_{11}	E_{11}/B_{11}	E_{12+}	B_{12+}	E_{12}/B_{12+}
HBGS	8/20	0330	0.10	1.365	0.073	1.17	85.964	0.014	0.12	49.121	0.002
HBGS	8/26	2330	0.60	0.693	0.866	0.59	9.699	0.061	0.58	24.248	0.024
HBGS	8/27	0030	0.22	.401	0.541	0.24	5.611	0.043	0.20	14.028	
HBGS	8/27	0130	0.17	.663	0.256	0.24	9.279	0.026	0.38	23.198	0.016
HBGS	8/27	0230	0.15	.608	0.247	0.84	8.482	0.099	0.34	21.310	0.016
HBGS	8/27	0330	0.14	.920	0.152	1.00	12.612	0.079	1.05	30.258	0.035
HBGS	8/27	2330	*	.541	*	0.25	7.406	0.034	0.23	19.083	0.012
HBGS	8/28	0030	*	.475	*	0.16	6.481	0.025	0.15	16.784	0.009
SONGS	9/5	2330	0.00	3.673	0.00	0.24	45.299	0.005	0.60	73.458	0.008
SONGS	9/6	0080	0.02	3.749	0.005	0.06	46.235	0.001	0.13	74.976	0.002
SONGS	9/6	0130	0.02	2.760	0.007	0.04	34.040	0.001	0.14	55.200	0.003
SONGS	9/6	0230	0.00	3.829	0.00	0.13	47.216	0.003	0.67	76.566	0.009
SONGS	9/6	0330	0.02	3.371	0.006	0.20	41.573	0.005	0.92	67.416	0.014
SONGS	9/6	2330	0.03	7.969	0.004	0.24	84.466	0.003	0.19	66.935	0.003
SONGS	9/7	0030	0.01	6.973	0.001	0.02	73.914	0.001	0.11	58.573	0.002
SONGS	9/7	0130	0.00	5.512	0.00	0.16	58.427	0.003	0.15	46.301	0.003
SONGS	9/7	0230	0.00	4.168	0.00	0.09	44.175	0.002	0.05	35.007	0.001
SONGS	9/7	0330	0.00	5.649	0.00	0.04	59.885	0.001	0.00	47.456	0.00

evaluation of the vulnerability of this youngest age class of queenfish was not possible at the OBGS as the age class was not observed offshore at the station. The vulnerability of age class 1 was also greater at the HBGS than at other stations ($\alpha = 0.05$). However, the vulnerability of age class 2+ queenfish was similar between HBGS and SONGS. The much lower abundance of older queenfish at the OBGS and ESGS precluded making comparisons of the vulnerability of large fish at these stations. In any case, the data available support the conclusion that queenfish vulnerability to entrapment varied among stations by cohort.

4.0 SUMMARY AND CONCLUSIONS

The proportion of the fish assemblage entrapped by an intake was computed from real-time offshore biomass (B) and in-plant entrapment (E) measurements. The ratio statistic (E/B) was used to represent the relative vulnerability of the fish assemblage to an intake. In this study the vulnerability of queenfish and white croaker was compared between four intakes in order to provide a better understanding of fish entrapment throughout the range of SCE intake designs and locations. Southern California Edison may be able to utilize this information to avoid having to conduct redundant research at each station.

The offshore and entrapment species lists were similar at each station. However, the relative abundance of species and/or cohorts was quite different between stations. In addition, the relative abundance of species and/or cohorts was different between the offshore assemblage and the fishes entrapped in the plant. This suggested that species-specific and size-specific differences in entrapment vulnerability existed and that comparisons between stations would have to be confined to those two species common to all the stations. Therefore, all comparisons in this paper were made on queenfish and white croaker.

Generally, queenfish and white croaker vulnerability to entrapment was greater at the HBGS than at the other three stations. Specifically, for queenfish, the increased vulnerability at the HBGS was largely associated with smaller size cohorts (age classes 0 and 1). Several differences in the design of the HBGS intake and screenwell may have accounted for the higher vulnerability of small queenfish.

The design of the HBGS intake and screenwell differed from the other three stations. These differences included: 1) greatest height of the entrance to the velocity cap (5 ft vs. 4 ft or less); 2) lowest entrance velocity (2.0 ft vs. 2.2 ft/sec or more); 3) the smallest distance between the intake and discharge (less than 100 m); 4) smallest traveling screen mesh size (3/8 inch vs. 5/8 inch); and 5) low velocity across the face of the traveling screens. The first three differences in design may have contributed to the increased vulnerability of queenfish and white croaker to the HBGS intake. The last two differences may have increased E/B values at the HBGS simply by impinging a larger proportion of the entrapped age 0 fishes. Older fishes are probably equally retained by the 3/8- and 5/8-inch mesh.

The observations that queenfish and white croaker vulnerabilities were greatest at HBGS suggest that this station is an appropriate site for evaluations of intake design and operational characters influencing entrapment. This is particularly true from the point of view that the HBGS' smaller traveling screen mesh size reduces the selectivity associated with the entrapment monitoring technique (i.e., it's a better sampler because it lets fewer small fish pass through the screens). All indications are that entrapment of small fish is underestimated at most stations with respect to HBGS because the smaller size groups observed are not fully recruited to the screens of OBGS, ESGS, SONGS, etc. However, it would be premature to make judgments about differences in intake designs based on just the information gathered in this study. An overall evaluation of intake differences should depend on collection of data at each station during intervals when fish assemblages offshore of each station are more similar. However, because it is unlikely that species assemblages will ever be the same between stations during surveys, comparisons should be restricted to representative species and size classes.

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APPENDIX I

STUDY AREA DESCRIPTION

Ormond Beach Generating Station (OBGS)

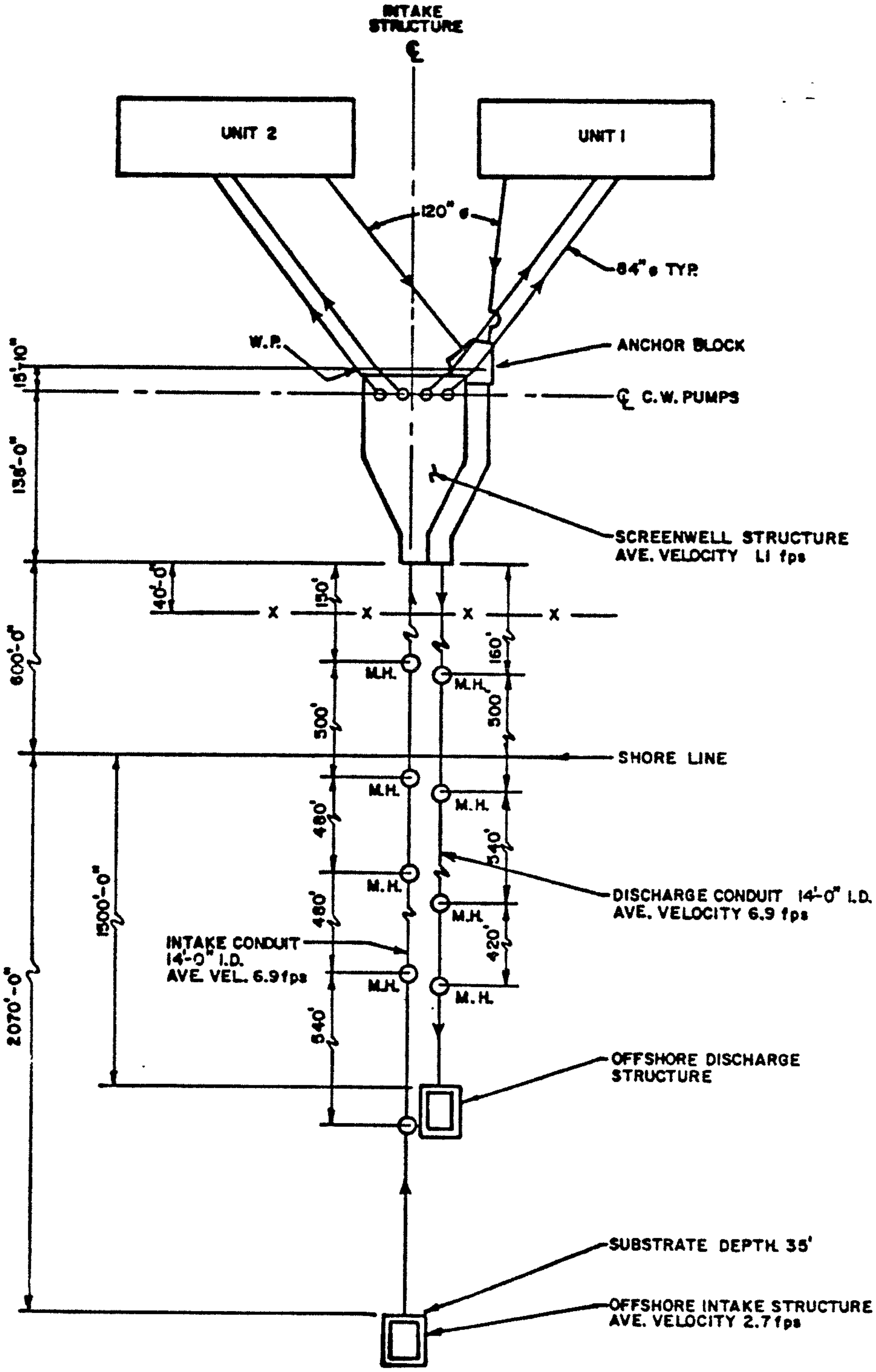
Ormond Beach Generating Station consists of two steam electric generating base load units, each rated at 755 MW. Cooling water is supplied to the station from the ocean through a vertical intake structure located 630.9 m (2,070 ft) offshore in 10.7 m (35 ft) of water (Fig. 1). A cap held by columns 1.2 m (4 ft) above the offshore intake imparts a horizontal current of 0.8 m/sec (2.7 fps) to the water at the point of withdrawal (Fig. 2). The circulating water flow of 30 m^3/sec (476,000 gpm) is conveyed to the onshore screen structure through a single 4.3 m (14 ft) inside diameter concrete conduit at a velocity of 2.1 m/sec (6.9 fps). Water enters the screen structure, passes through trash bars which remove heavy debris, and then through four traveling screens with 1.59 cm (5/8 inch) mesh screens which remove fine debris and fish.

Ormond Beach Generating Station is located in the City of Oxnard in Ventura County. The city of Oxnard is located on a coastal flood plain. The coastline adjacent to the generating station consists of sand dunes and gently sloping beaches. The nearshore ocean bottom is characterized by a wide, gentle slope, bordered by two submarine canyons. The slope extends approximately 7.24 km (4-1/2 mi) from the shoreline and depth increases at a rate of 8 m/1,000 m.

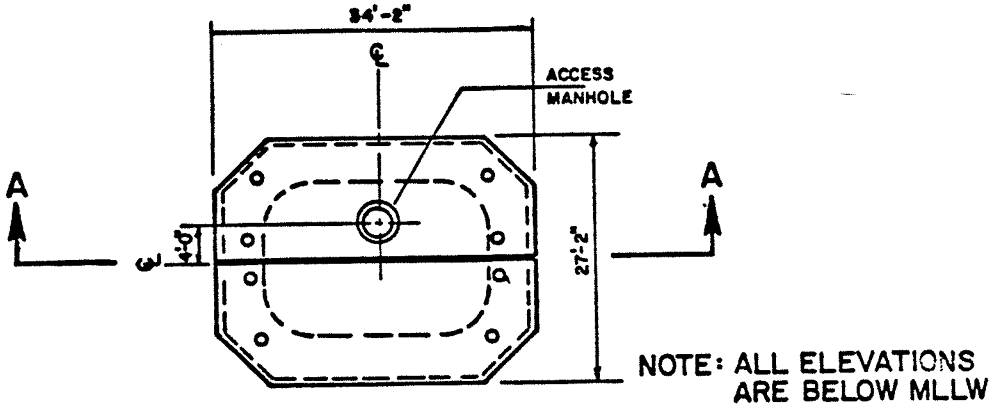
El Segundo Generating Station (ESGS)

The El Segundo Generating Station consists of four steam electric base load units. Units 1 and 2 are each rated at 125 MW. Units 3 and 4 are each rated at 325 MW. Cooling water is supplied from the ocean to the station through two separate offshore intakes and circulating water systems, one for Units 1 and 2 and one for Units 3 and 4. The cooling water intake system for Units 3 and 4 was the subject of this study and is described below.

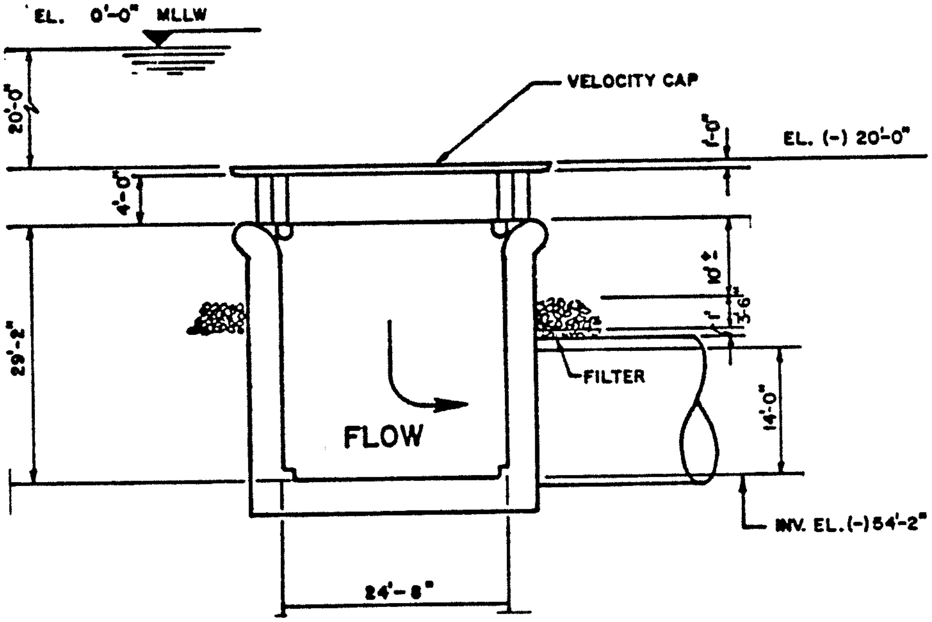
The layout of the Units 3 and 4 circulating water system is shown in Fig. 3. The water for Units 3 and 4 enters a vertical intake structure located 707.0 m (2,300 ft) offshore at a depth of 9.8 m (32 ft). A cap held by columns 1.0 m (3.3 ft) above the offshore intake imparts a horizontal current of 0.73 m/sec (2.4 fps) to the water at the point of withdrawal (Fig. 4). The circulating water flow of 17.5 m^3/sec (276,800 gpm) is conveyed to the Units 3 and 4 onshore screen structure through a single 3.7 m (12 ft) inside diameter concrete conduit at a



Appendix Fig. 1. Ormond Beach Generating Station circulating water system (SCE Ref. Dwg. 75471).

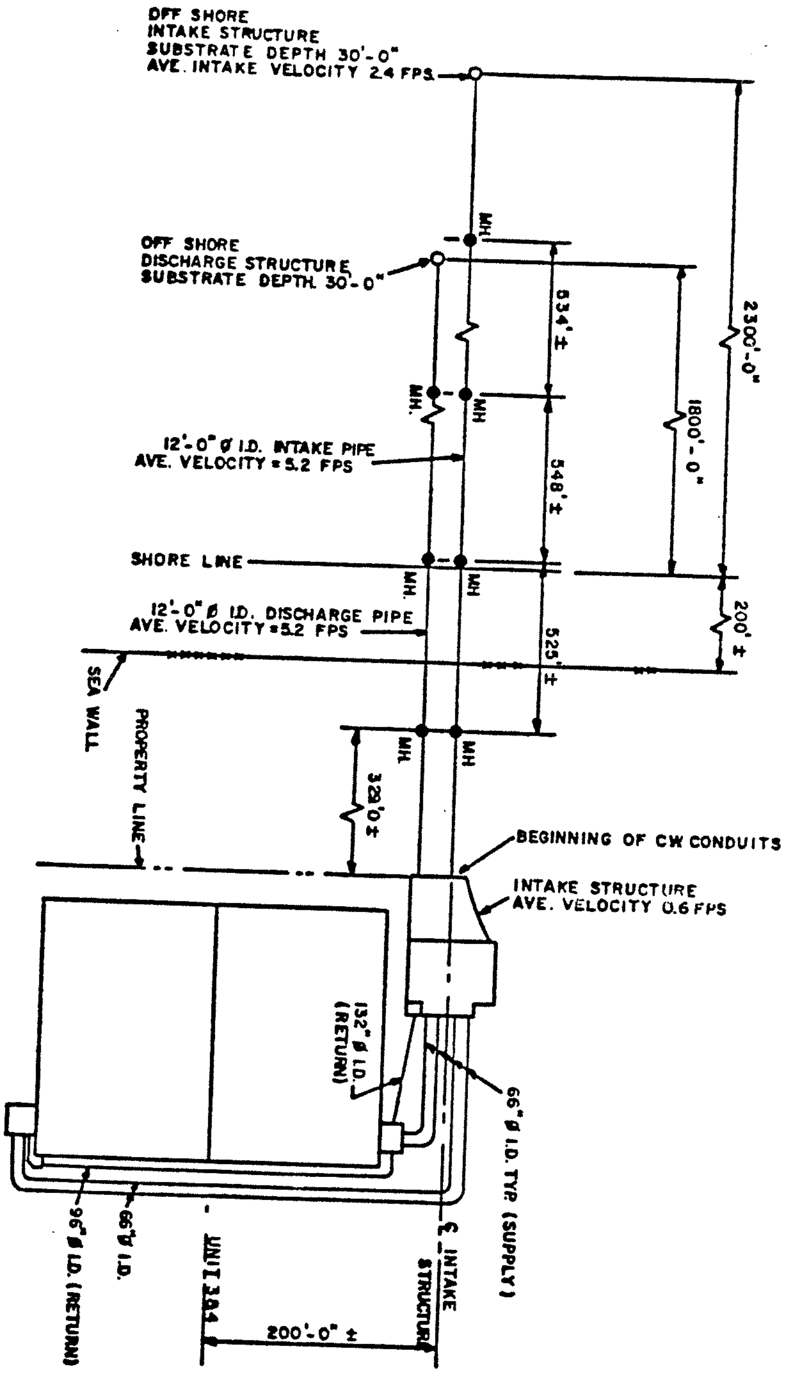


PLAN

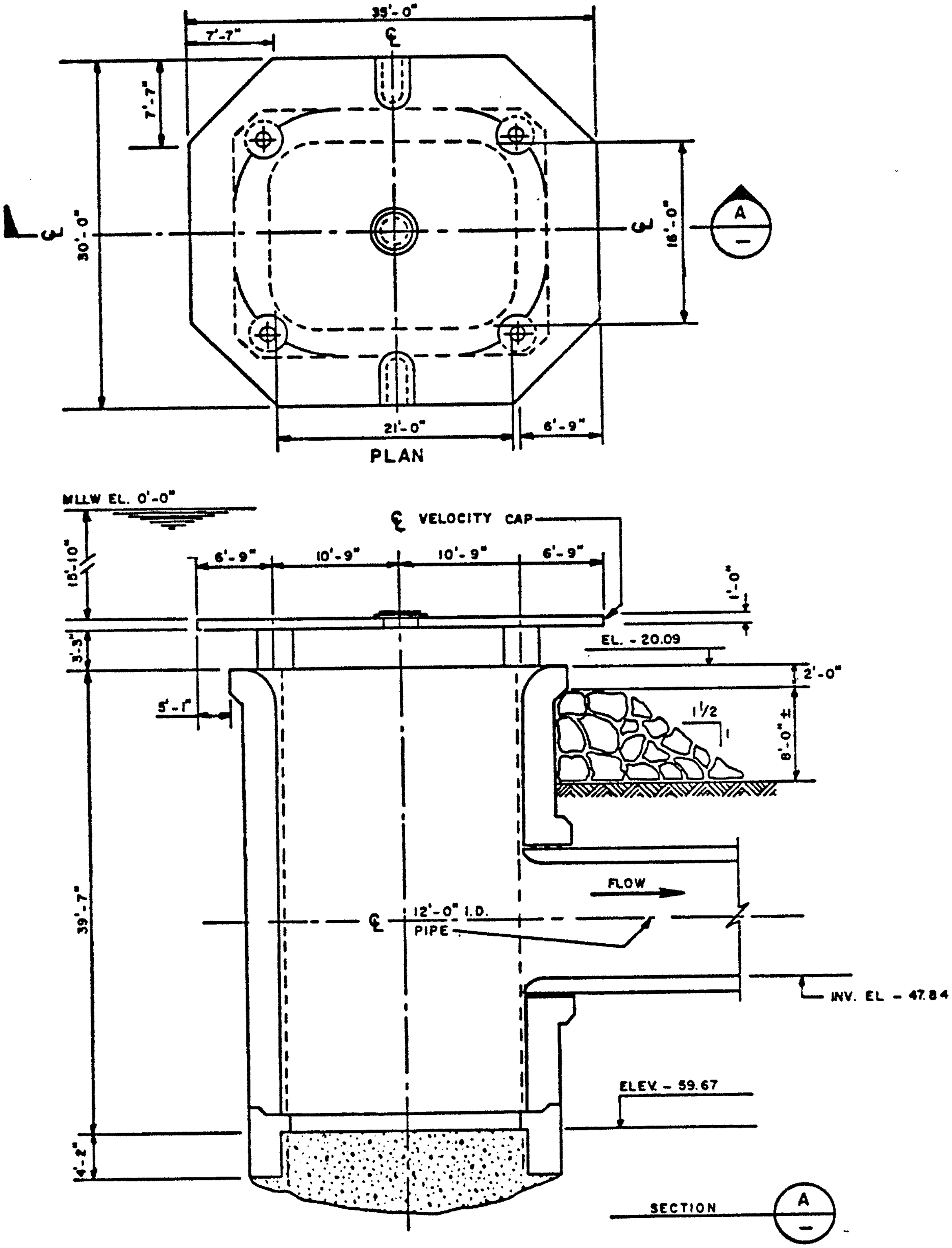


SECTION A-A

Appendix Fig. 2. Ormond Beach Generating Station offshore intake structure (SCE Ref. Dwgs. 598852, 598853).



Appendix Fig. 3. El Segundo Generating Station Units 3 and 4 circulating water system (SCE Ref. Dwgs. 585135, 565156).



Appendix Fig. 4. El Segundo Generating Station Units 3 and 4 offshore intake structure (SCE Ref. Dwgs. 565159, 565161).

velocity of 1.7 m/sec (5.5 fps). Water enters the screen structure, passes through trash bars, and then through 1.59 cm (5/8 inch) mesh screens.

The ESGS is located in the city of El Segundo, Los Angeles County. The topography offshore is generally smooth, and nearshore the substrate is generally medium-grained sand. There is little nearshore deposition of silt and clay. Isobaths parallel the shoreline and nearshore slope is approximately 13 m/1,000 m.

Huntington Beach Generating Station (HBGS)

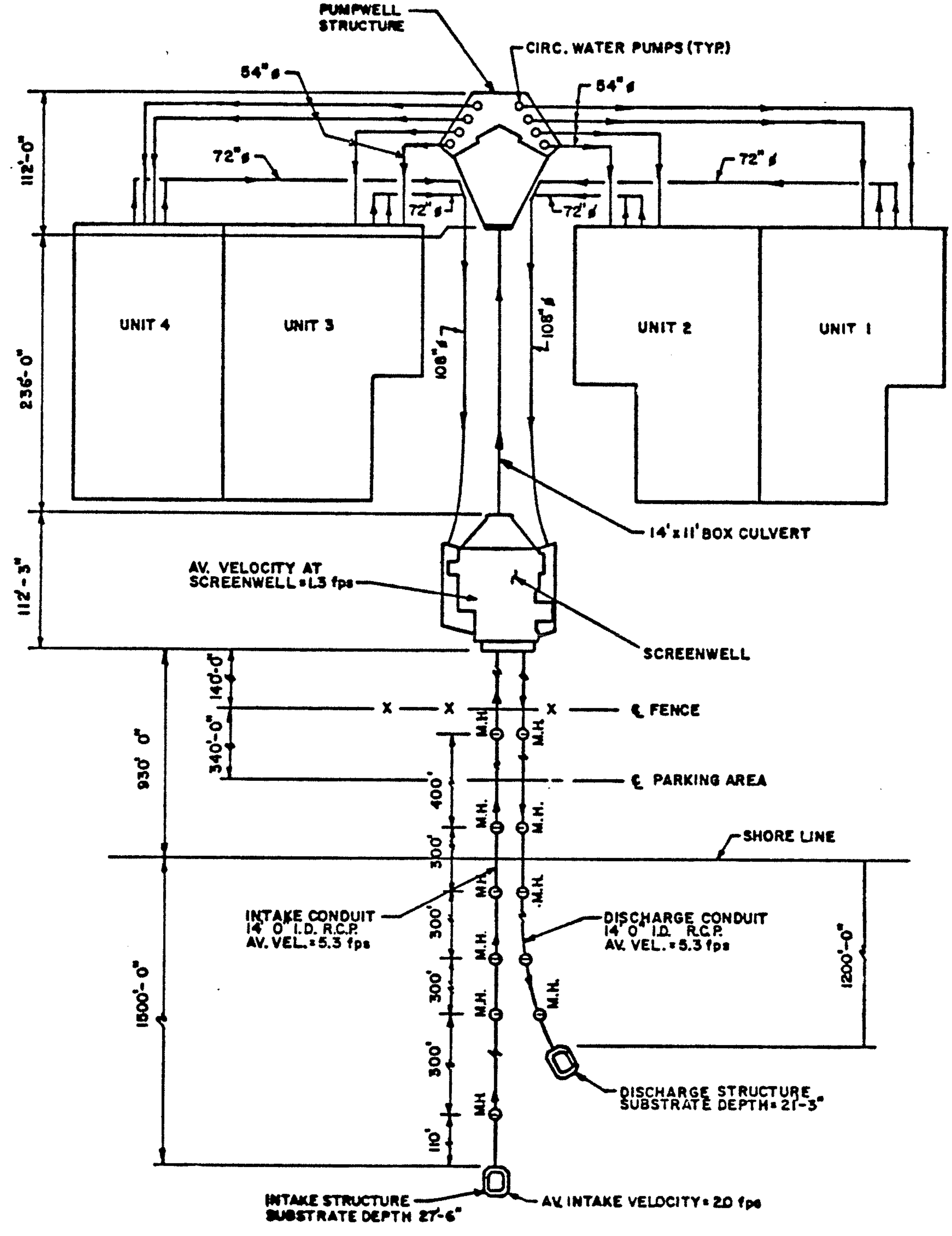
Huntington Beach Generating Station consists of four steam electric base load generating units and a gas turbine peaker. Units 1 and 2 are each rated at 200 MW and Units 3 and 4 are each rated at 210 MW. The gas turbine is rated at 121 MW.

Cooling water is supplied to the station through a vertical intake structure located 457.2 m (1,500 ft) offshore at a depth of 8.4 m (27.5 ft) (Fig. 5). A cap supported by columns 1.5 m (5 ft) above the intake imparts a horizontal current of 0.6 m/sec (2.0 fps) to the water at the point of withdrawal (Fig. 6). The circulating water flow of 22.5 m^3/sec (356,600 gpm) is conveyed to the onshore screen structure through a single 4.3 m (14 ft) inside diameter concrete pipe at a velocity of 1.6 m/sec (5.2 fps). Water enters the screen structure, passes through trash bars, and then through 0.95 cm (3/8 inch) mesh screens.

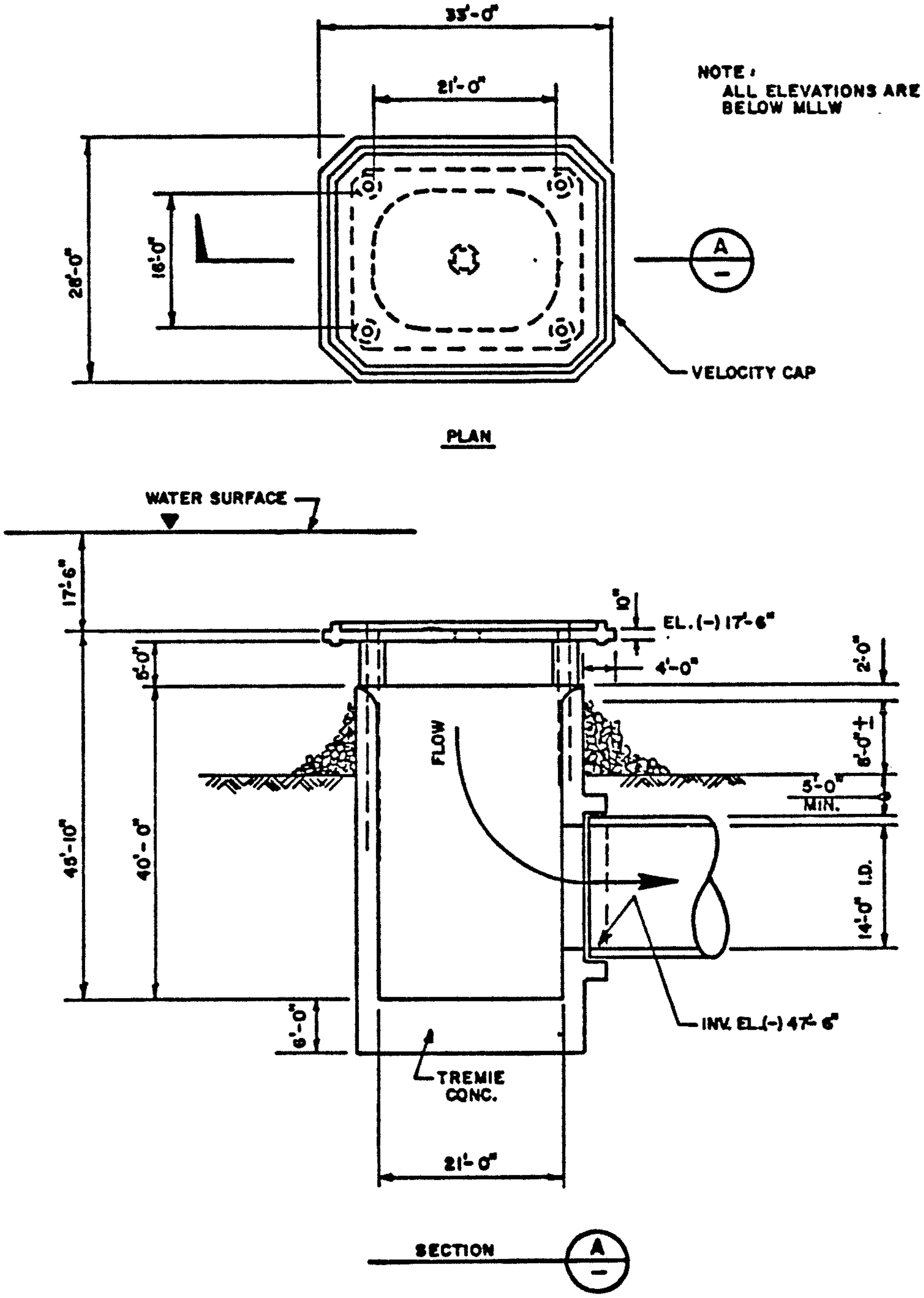
The Huntington Beach Generating Station is located in Orange County in the city of Huntington Beach. This city is located on the flood plain created by the Santa Ana River, which presently empties into the ocean approximately one and one-half miles downcoast of the station. The coastline is depositional and is fronted by a broad sandy beach and backed by lowland areas. The topography of the seafloor directly off Huntington Beach is generally smooth with isobaths parallel to the coastline; the average seaward slope of the bottom is approximately 8 m/1,000 m. Aproximately 5.5 km (3.5 mi) southeast of the HBGS is the Newport Submarine Canyon. The sediments of the nearshore area grade from fine-to-medium sand nearshore to sandy silt at a distance of 1.61 km (1 mi) from shore.

San Onofre Nuclear Generating Station (SONGS)

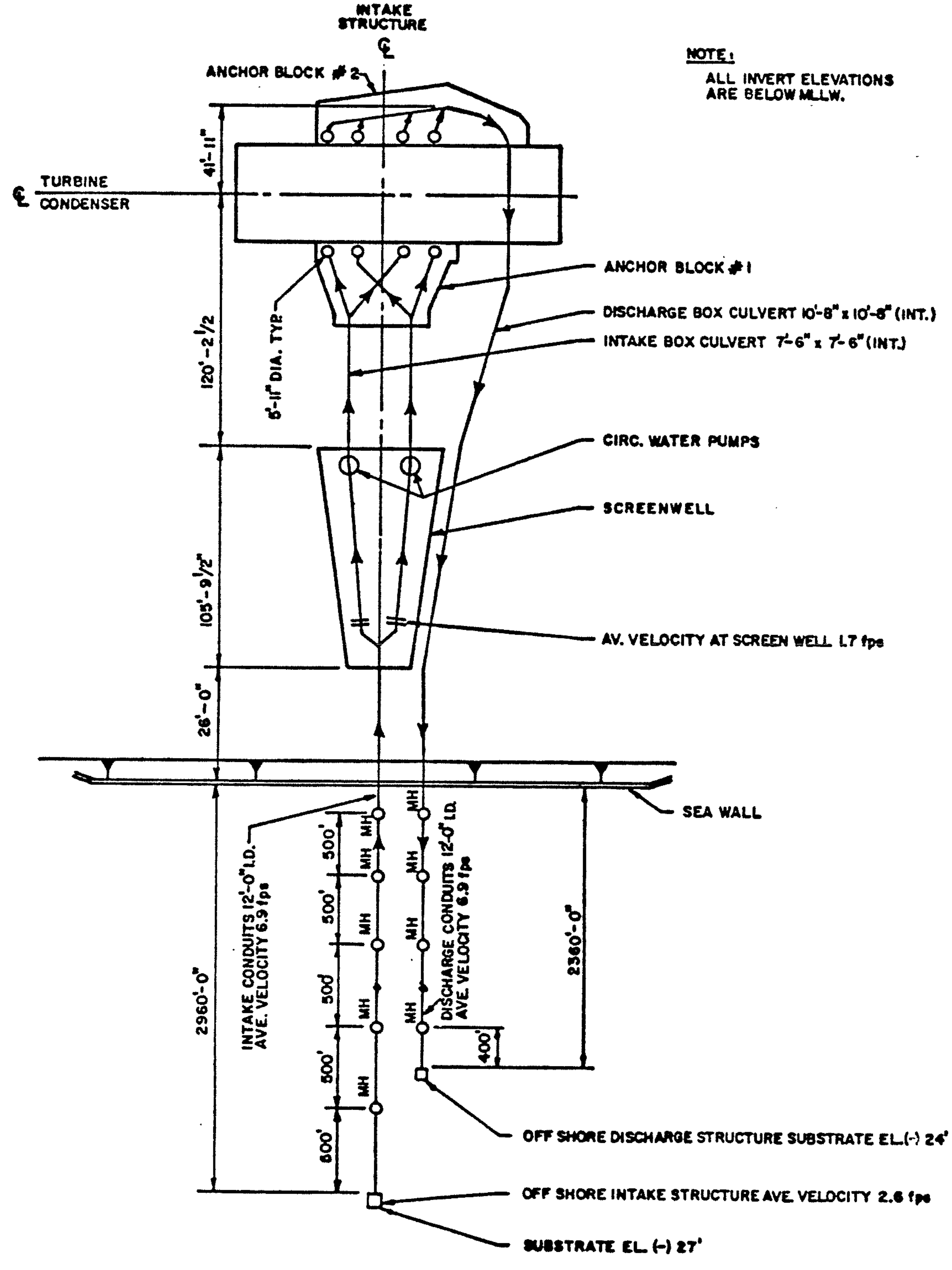
San Onofre Nuclear Generating Station Unit 1 is a nuclear powered base-load electric generating station with a rated capacity of 430 MW. Cooling water is supplied to the station through a vertical intake structure located 902.2 m (2,960 ft) from shore at a bottom depth of 8.2 m (27 ft) (Fig. 7). A cap supported by columns 1.2 m (4 ft) above



Appendix Fig. 5. Huntington Beach Generating Station circulating water system (SCE Ref. Dwg. 559464).



Appendix Fig. 6. Huntington Beach Generating Station offshore intake structure (SCE Ref. Dwgs. 545486, 546937).

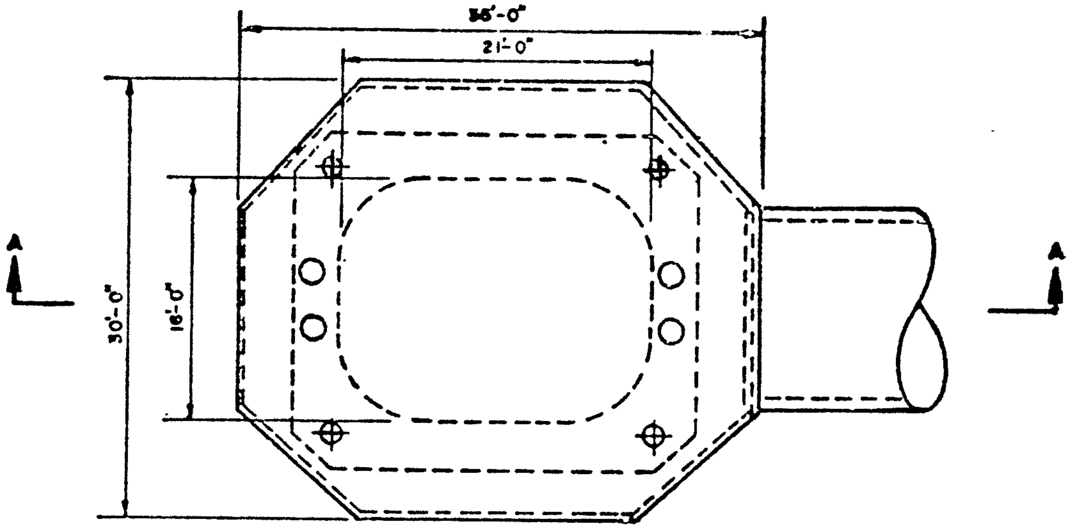


Appendix Fig. 7. San Onofre Nuclear Generating Station Unit 1 circulating water system (SCE Ref. Dwg. 579338).

the intake imparts a horizontal current of 0.7 m/sec (2.2 fps) to the water at the point of withdrawal (Fig. 8). The circulating water flow of 22.1 m^3/sec (350,620 gpm) is conveyed to the onshore screen structure through a single 3.7 m (12 ft) inside diameter concrete pipe at a velocity of 2.1 m/sec (6.9 fps). Water enters the screen structure, passes through trash bars and then through 1.59 cm (5/8 inch) mesh screens.

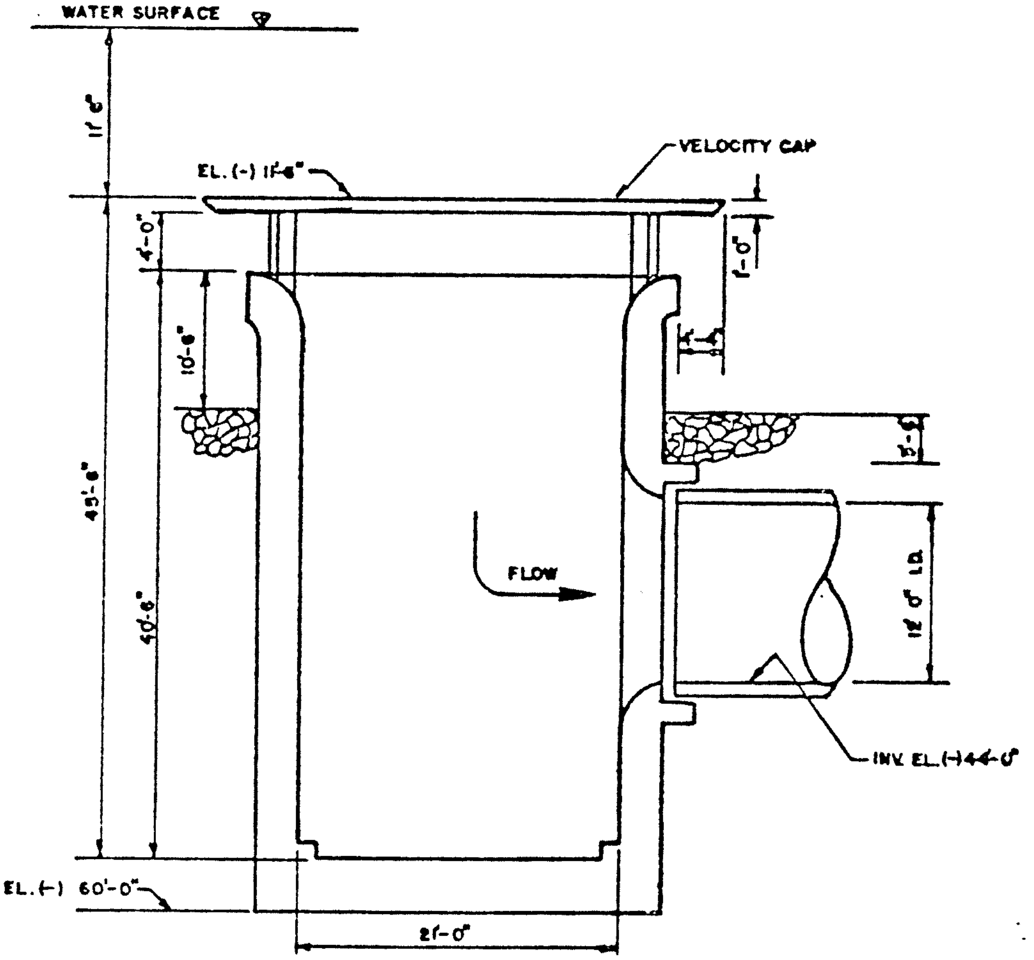
San Onofre Nuclear Generating Station I is located about 4.83 km (3 mi) south of the city of San Clemente in San Diego County. The station is located on a narrow coastal plain which extends approximately 3 km from the beach to coastal foothills. That portion of the benthic environment nearest the generating station is dominated by mixed sand/cobble/boulder substrate. The slope of the area offshore of the station is approximately 4.6 m/1,000 m.

Immediately adjacent to SONGS I, two new units are being built (SONGS II and III). The intake and discharge conduits for these stations were under construction at the time of this study.



PLAN

NOTE:
ALL ELEVATIONS ARE BELOW MLLW.



SECTION A-A

Appendix Fig. 8. San Onofre Unit 1 offshore intake structure (SCE Ref. Dwgs. 579340, 579344).

APPENDIX 2

FIELD SURVEY METHODS

Sampling Gear

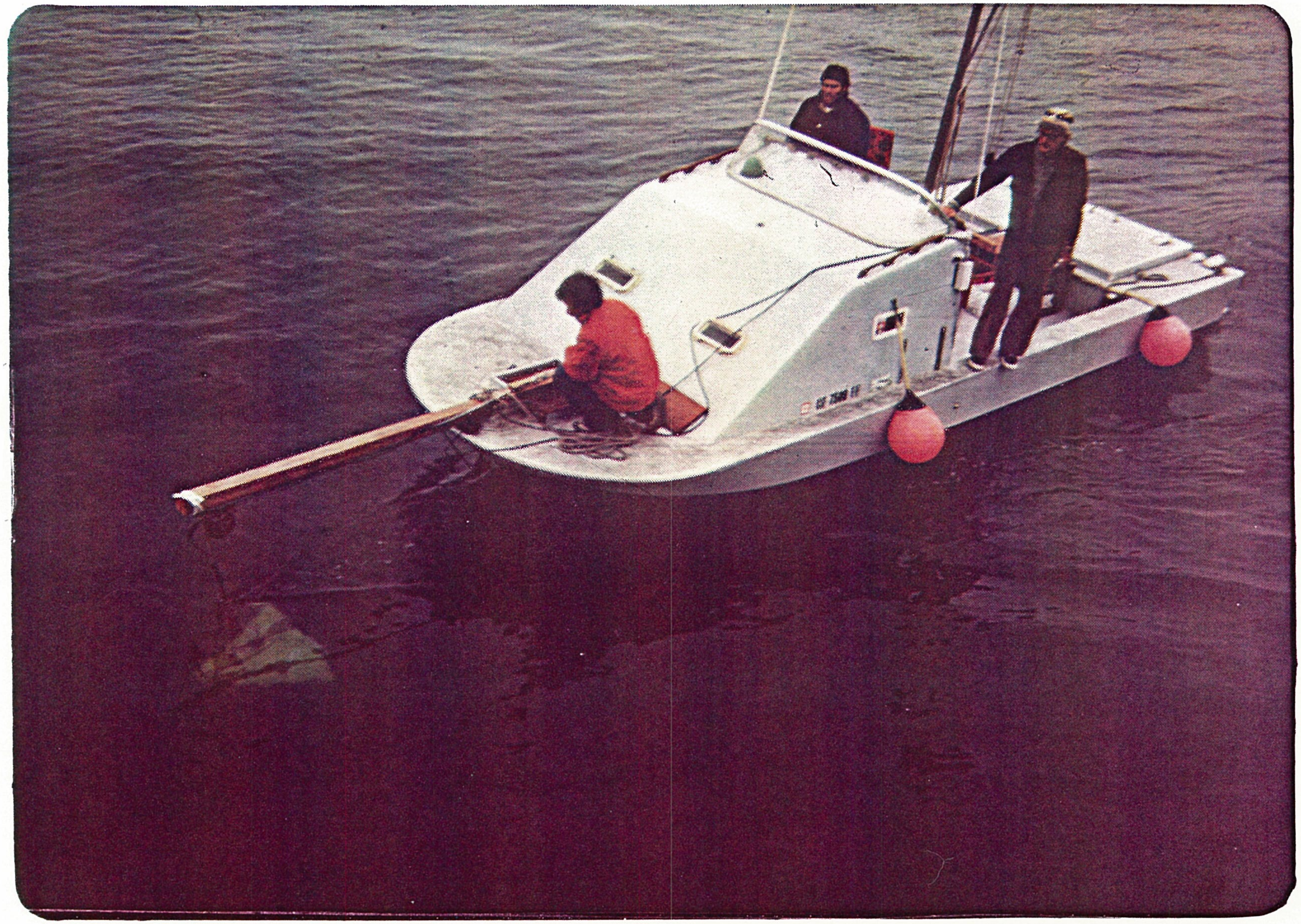
The acoustic measurement of fish density was made from the 24 ft charter boat Stingray (Fig. 1). An EK 120 Simrad Scientific Sounder was used in conjunction with a 120 kHz transducer with a beam angle of 9^{o} between +6 and -3dB points. The sounder was triggered with an APL modified Ross 500 SL chart 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 minimize 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 estimations. 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 1.6 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 bunt 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.

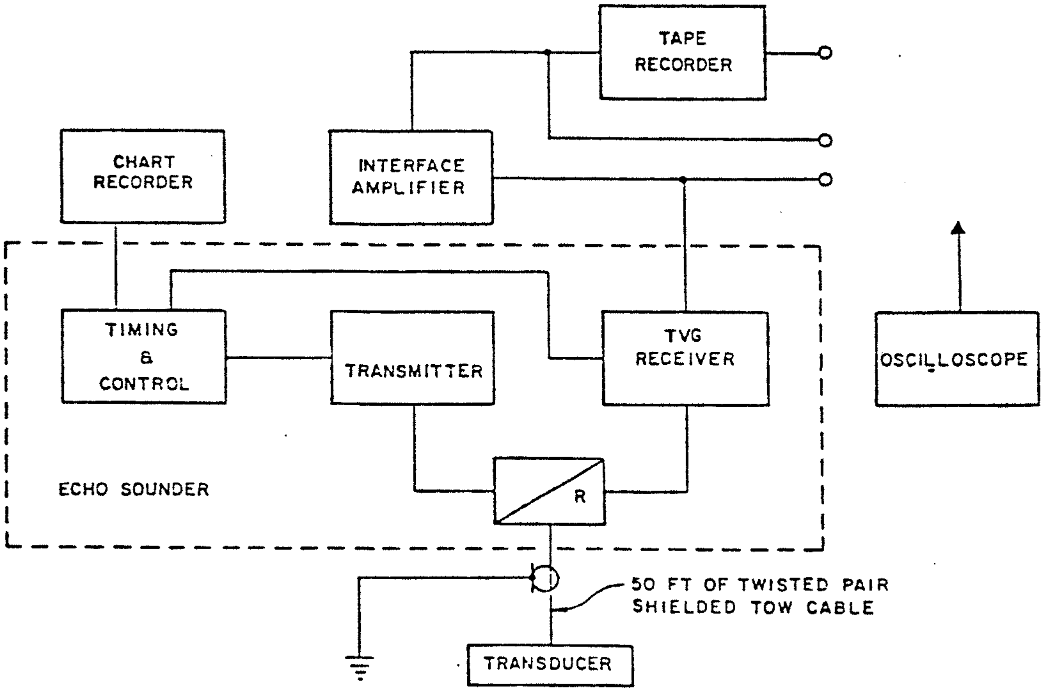
Sampling Procedures

Acoustic data were collected on a 600-m crossing transect survey grid and a 3000-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 located within the inshore strata of the survey area. The 600-m crossing transect grid was run 2 times per hr, starting at 2330, 0030, 0130, 0230, and 0330, for each survey night. The 3000-m transect was run whenever there was sufficient time between the hourly grid transects. The boat speed was approximately 4 knots.

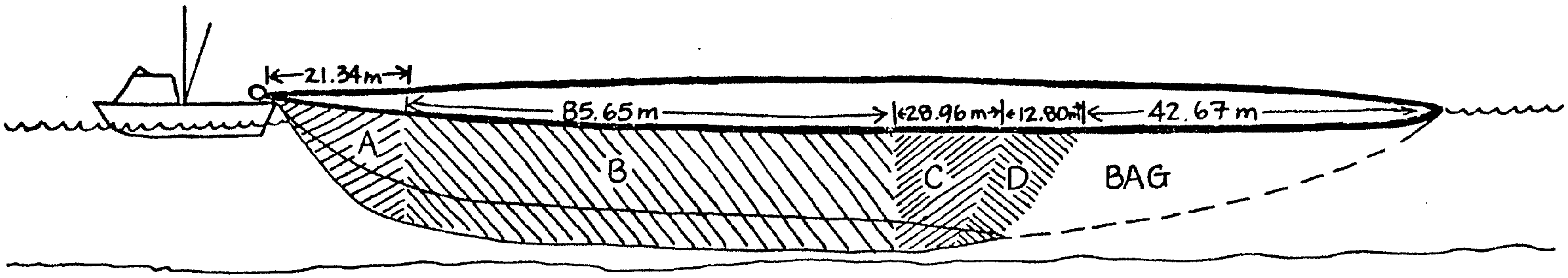
Lampara seine hauls were attempted after the hourly acoustic transecting. An attempt was made to sample all sides of the intake each survey night; however, weather, current, and bottom obstructions often disallowed this kind of effort. A small lighted surface buoy deployed



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



Appendix Fig. 2. Block diagram of data acquisition system.



LEGEND

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

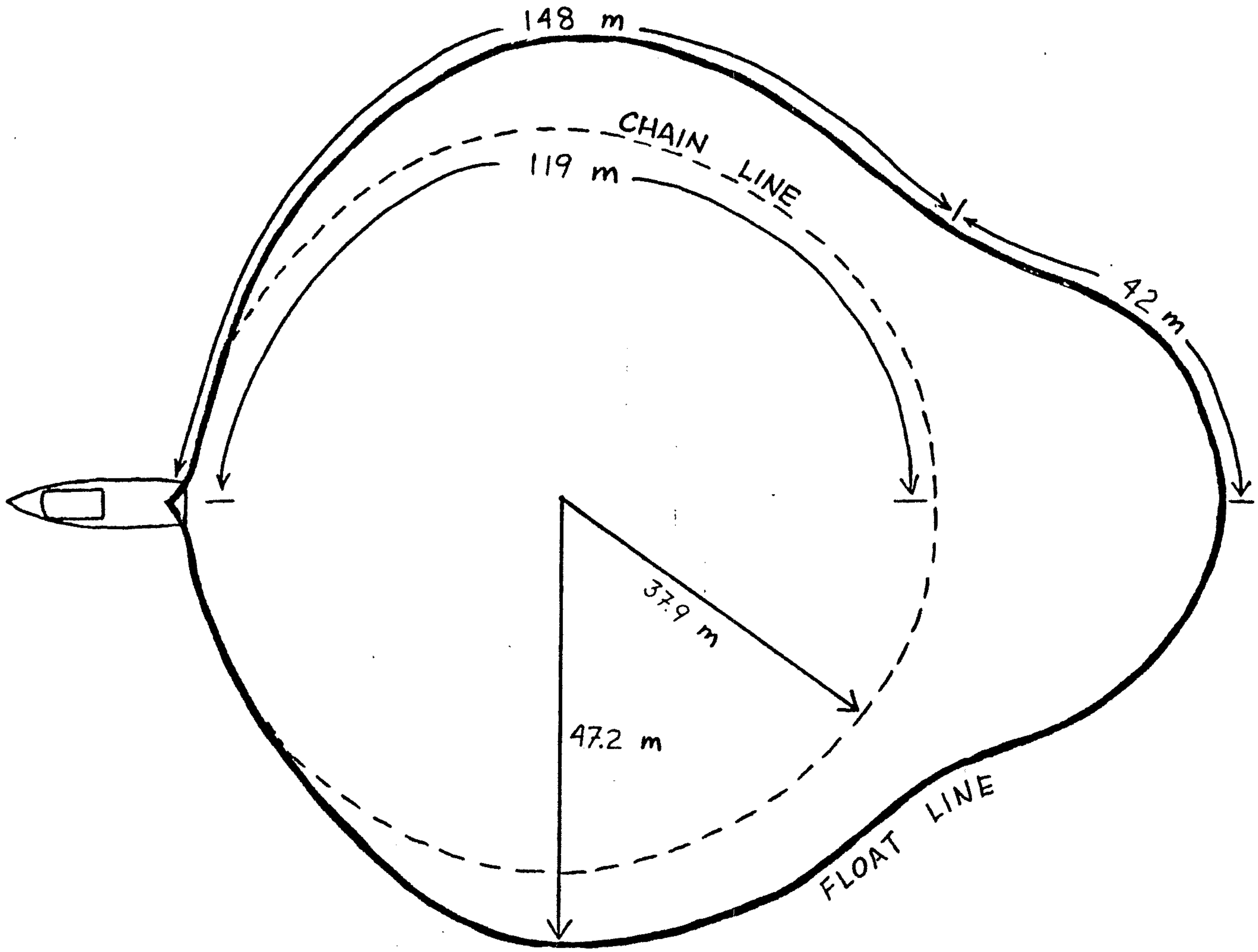
B - 17.78 cm stretch mesh, floats 40.64 cm on center, 30 fathoms vertically.

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

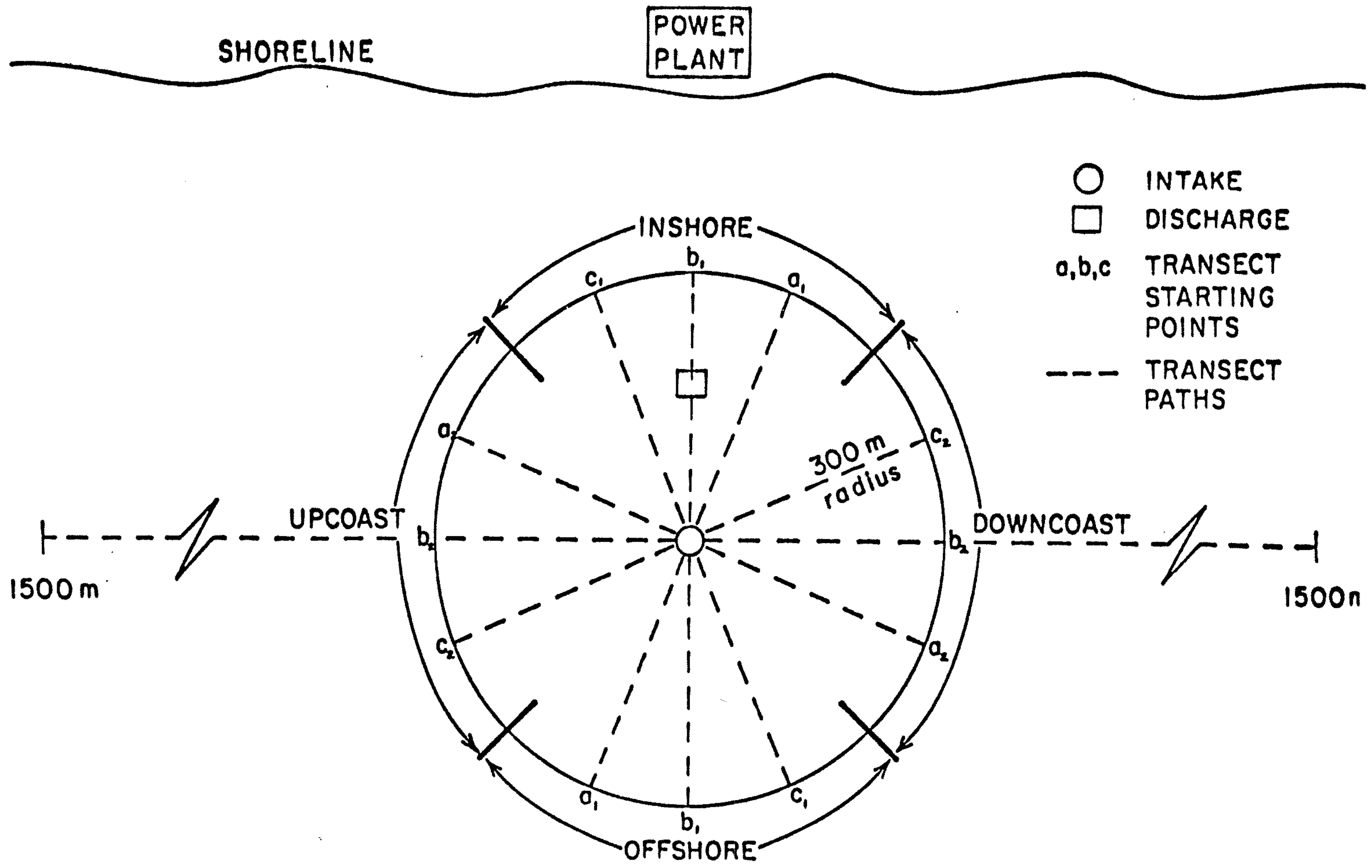
D - 3.81 cm stretch mesh, floats 35.56 cm on center.

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

Appendix Fig. 3. Horizontal view of lampara net.



Appendix Fig. 4. Top view of lampara net.



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

from the acoustic boat was used to mark the location for a lampara net to serve as a mark around which to set the net. Time required 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 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 and weighed by species as suggested by Paloheimo and Dickie (1963). A random selection of 100 individuals of each species was measured (standard length). However, queenfish and white croaker in the aliquot were stratified into three size groups prior to measuring. 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. A random selection of 100 individuals within each size group was measured (standard length).

The method used to measure entrapment was based on the assumption that all fish in the screenwell will eventually be entrapped, thereby making the rate of impingement equivalent to that of entrapment. Complete removal of fish from the screenwells was necessary in order to compare offshore fish density measurements to entrapment on an hourly basis. This was accomplished by sodium hypochlorite injections.

Chlorine was injected into the upstream end of a screenwell 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. Low flow areas in the screenwells were supplemented with surface injections of chlorine.

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. Injections of approximately 30 gal over a 5-min interval effectively cleared the species of concern from the screenwells. These injections resulted in Total Free Chlorine readings of less than the allowed maximum of 0.5 mg/liter at the offshore discharge bubble.

The amount of chlorine needed per injection to clear fish from the 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 made using a Secchi disk and/or a grid suspended in the screenwell. Intake water temperature (^{o}F) measurements were obtained from the plant operations. Wind speed (mph) measurements were obtained from the generating station operations.

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. The scattering properties are expressed in terms of fish weight since it has been shown experimentally that the mean scattering cross-section of an individual fish is a relatively constant proportion of its weight.

Therefore, in order to obtain a biomass estimate from a school of fish, it was necessary to determine the total intensity of the acoustic signal reflected from all the fish. This was done with a procedure called echo integration (Ehrenberg 1973). The scattering properties of fish vary from species to species and with size. However, all fishes with swimbladders appear to have similar mean back-scattering strengths as a function of size (Anonymous 1978). Acoustic target strength (TS) and scattering cross-section ($\frac{\sigma}{4\pi}$) are related by

$$TS = 10 \log_{10} \left(\frac{\sigma}{4\pi}\right), \qquad (1)$$

A target strength of -33 dB/kg was used to convert acoustic data to biomass estimates. Based on the literature this value appears reasonable for swimbladder fishes if the mean length of the fish population is between 10 and 30 cm.

The acoustic data were processed with a digital echo integration system shown in Fig. 6, steps 1 to 5. At "Echo Integration" (step 5) the data were integrated by meter of water column and the relative fish biomass was calculated from the input calibration information. At this step, the minimum horizontal and vertical dimensions of the acoustic sample were determined for the biomass output, the time varied gain (TVG) was corrected to obtain a perfect TVG (electronic TVGs are seldom perfect) with reference to particular depth; and system gain, beam pattern, target strength, etc., were used to standardize the biomass data. Density values were computed at 20-sec intervals along each transect (approximately 50 m).

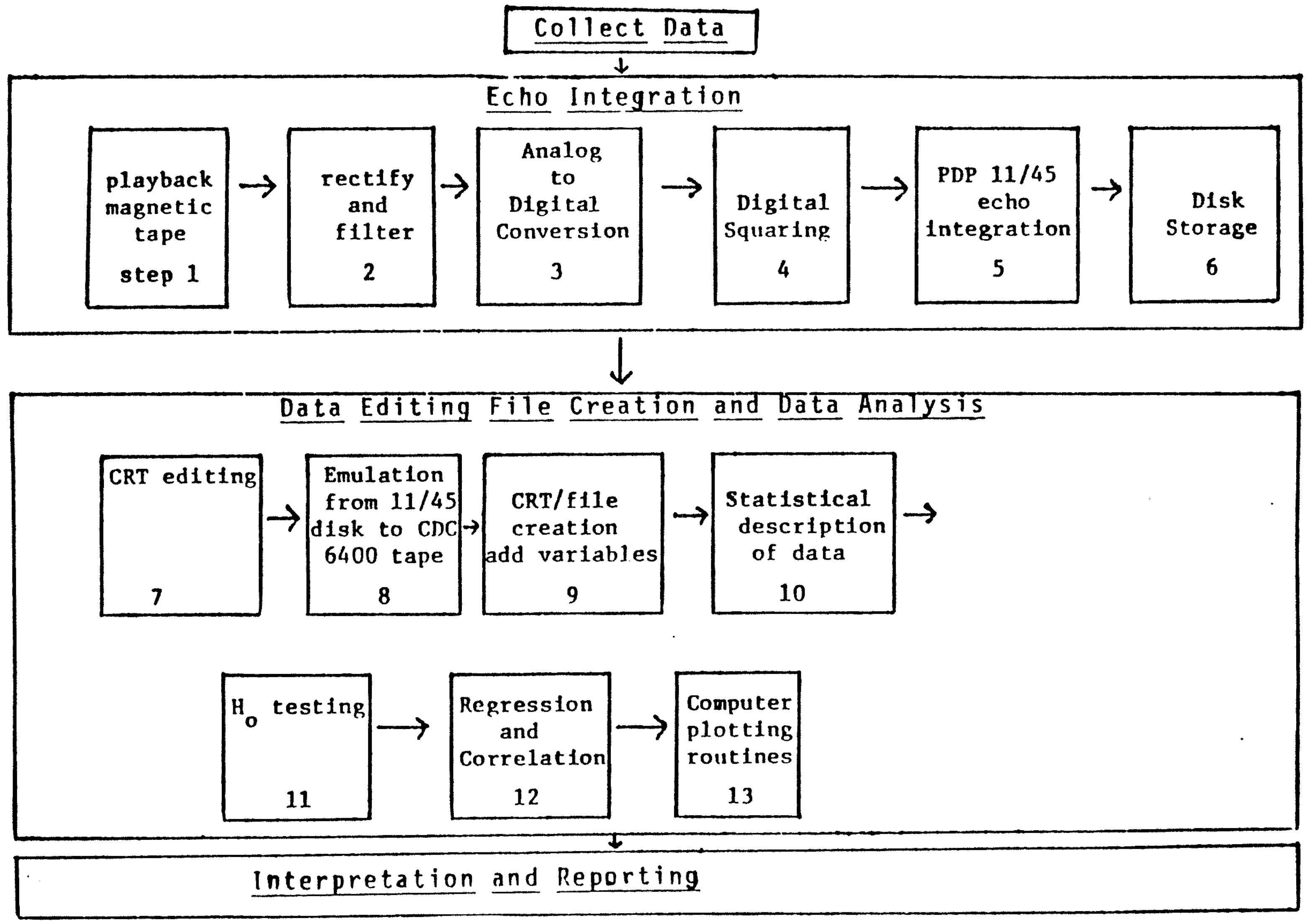
The water column was shallow enough to transmit at a rapid pulse rate (8 pings/sec) so that an almost continuous volume of water under the transducer was insonified. For purposes of illustration, the sample volume could be considered to be a cone of full angle width about the acoustic axis. In reality, 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 prevailing 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. 6, steps 6-11) illustrates what occurred 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 provided estimates of fish density (D_h, g/m^2 surface) for each transect. The estimates from two transects run within a one hour period were used to compute the mean fish density within each stratum ($\bar{D}_h$) (inshore, offshore, upcoast, downcoast - Fig. 5).

The following equation (Cochran 1977) was used to estimate the midwater fish density (D_m) of the entire survey area:

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



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

These estimates of midwater fish density represented the proportion of the water column approximately 2 m below the surface to 1 m above the bottom (Thomas et al. 1979).

$\bar{D}_h$ = mean fish density of stratum h computed from two transect estimates.

h = strata (in-, offshore, up-, downcoast)

If in every stratum the sample estimate $\bar{D}_h$ is unbiased, then $\bar{D}_h$ is an unbiased estimate of the population mean, D_m (mid-water fish density). Also if the samples are drawn independently in the strata:

$$\text{Var}(D_m) = \frac{1}{4} \sum_{h=1}^{4} \text{Var}\,(\bar{D}_h) \tag{3}$$

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

The mean species compositions (P_i's) were computed as the total weight of that species over the weight of the entire catch from the lampara sets made within one night. 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, 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.

$$\text{Therefore, } D_T = 1.43\ D_m \tag{4}$$

$$\text{with Var}\ (D_T) = (1.43)^2\ \text{Var}\ (D_m) \tag{5}$$

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

$$D_i = P_i\ D_T \tag{6}$$

The variance formula is:

$$\text{Var}\ D_i = P_i^2\ \text{Var}\ D_T, \tag{7}$$

Since P_i is treated as a constant within one night.

Homogeneous vertical distribution is a major assumption of this technique. The vertical gillnet data are providing information on the bias introduced by this assumption.

A limiting factor in this technique is that it requires all the lampara sets of one night to yield one estimate 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 area) and its species components D_i were expanded to biomass (B_T and B_i's in kg) by the following equation:

$$B_T = [2.826 \times 10^5 \,(m)^2) \times 10^{-3}\,(kg/g)] \quad D_T \; g/m^2 = 2.826 \times 10^2 \; D_T \qquad (9)$$

where 2.826×10^5 m^2 is the approximate surface area of the study site,

and 10^{-3}kg/g converts grams to kilograms.

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.

The formulae for Var B_T, B_i and Var B_i were:

$$\text{Var } B_T = (2.826 \times 10^2)^2 \; (\text{Var } D_T) \qquad (10)$$

$$B_i = 2.826 \times 10^2 \; (D_i) \qquad (11)$$

$$\text{Var } B_i = (2.826 \times 10)^2 (\text{Var } D_i)^2 \qquad (12)$$

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