ATTACHMENT 5

Southern California Edison Company, El Segundo Generating Station 316 (B) Demonstration. Technical Appendix: Impact Assessment Model/Bight-Wide Plankton Investigations. Prepared for California Regional Water Quality Control Board, Los Angeles Region. Dated September 20, 1982

SOUTHERN CALIFORNIA EDISON COMPANY
316(b) DEMONSTRATION

TECHNICAL APPENDIX

Impact Assessment Model
Bight-Wide Plankton Investigations

Prepared for

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

LOS ANGELES REGION
SAN DIEGO REGION
SANTA ANA REGION

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SOUTHERN CALIFORNIA EDISON COMPANY
Rosemead, California

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CHAPTER 1

INTRODUCTION

This demonstration of "best technology available for minimizing adverse environmental impact", in compliance with Section 316(b) of the Federal Water Pollution Control Act of 1972 (PL 92-500), evaluates the physical and biological effectiveness of cooling water intake systems at Southern California Edison Company (SCE) coastal power stations in minimizing impact on offshore fish populations. An Impact Assessment Model is utilized to compare cooling system intake fish losses (entrainment and impingement) to offshore larval and adult stocks. Results of numerous individual 316(b) study elements were integrated into the Technical Appendix to form the database used to develop the Impact Assessment Model. The results of the comparison are expressed as a probability of survival for each individual fish over a given life span. These results are developed for each intake in the SCE system and are presented in individual station-specific demonstrations.

This Technical Appendix was designed to document the approach and methodology discussed briefly in each station-specific demonstration, and to provide detailed documentation for model assumptions and methodology in a concise format for easy reference.

The Impact Assessment Model and a description of its incorporated database are presented in Chapter 2. The model approach and methodology is more fully developed than that presented in the station-specific reports. Extensive field stock estimates are developed for six major target species. The derivation of entrainment and impingement loss terms, and the rationale for estimates of offshore stock terms, are more completely defined. The use of the model in assessing the impact of the existing intake systems, and the incorporation of effectiveness factors associated with alternative technologies, are presented. Significant figures associated with population or impact estimates have not been standardized in order to allow comparisons of the relative behavior of variables within and between species.

The database of offshore ichthyoplankton stocks was developed during a one-year sampling program by the Los Angeles County Museum of Natural History. The methods and results of the study are presented in Chapter 3, and were incorporated into the Impact Assessment Model as the term defining abundance and distribution of offshore stocks for key target species.

CHAPTER 2

IMPACT ASSESSMENT MODEL

INTRODUCTION

The assessment of impact of individual generating stations on offshore fish populations is accomplished by a model which incorporates offshore population abundance and dynamics and the effect of station operation. The model utilizes input from a large number of sources, represented by numerous studies conducted by SCE and others over the last several years.

Input includes estimates of daily loss of fish larvae at generating station intakes (SCE 1982), impingement losses of adult fish at those intakes, and abundance of larval fishes in nearshore waters (Lavenberg and McGowen 1982, and Chapter 3 of this Appendix). Abundance of adult fishes in offshore waters was estimated from a number of sources, including Young (1963), DeMartini (1979), Thomas et al. (1980a,b), and Wingert (1981). Input for the factors influencing intake performance in impingement, entrainment, and exclusion studies came from Schlotterbeck et al. (1979), Thomas et al. (1980a,b), and LMS (1979, 1981, 1982).

Objectives

The objectives of this chapter are to: 1) summarize information on the abundance and distribution of several nearshore fish species subject to entrainment and impingement; 2) describe methodology used to determine estimates of entrainment and impingement losses at SCE coastal generating stations; 3) present a method for relating intake losses to source waterbody fish population estimates; and 4) evaluate intake losses at coastal generating stations. A method to determine effectiveness of alternative intake structures is also presented.

Organization of Data

Data from several physical, hydraulic, and biological studies at SCE coastal generating stations and source waters were utilized to develop the Impact Assessment Model. In addition, a rationale was developed to define the extent of the distributions of fish populations potentially affected by SCE station intake operations, and estimates were made of the volume of water encompassed by the nearshore zone that provides the source water for SCE cooling water intakes and habitat for the affected species.

Data from a number of sources, including some SCE studies, were utilized to estimate the size and age distributions of major fish species in the source water body. Extensive estimates were developed for six of fifteen target species. Methodology used in estimating entrainment and impingement losses at SCE stations is presented, and the resulting loss estimates are compared to field estimates via the Impact Assessment Model. The incremental effect of alternative intake technologies, and the resulting effects on the assessment of impact, is addressed.

Key Species

Target species were selected in consultation with three California Regional Water Quality Control Boards and the California Department of Fish and Game on the basis of potential effects on their abundance and distribution. Criteria established for selection of key species included: 1) importance in the trophic structure (either as planktivorous, piscivorous, or benthic feeders, and importance as a prey food source); 2) presence in the source water body with at least minimal abundance during most periods of the year to lend statistical integrity to analyses; 3) species subject to entrainment and impingement during most of their life history; 4) species which, if adversely impacted, may indicate general community effects; and 5) sport or commercial value. An evaluation of species was conducted (Wintersteen and Dorn 1979), and the final list included 15 species:

Northern anchovy	Engraulis mordax
Queenfish	Seriphus politus
White croaker	Genyonemus lineatus
White surfperch	Phanerodon furcatus
Shiner surfperch	Cymatogaster aggregata
Walleye surfperch	Hyperprosopon argenteum
Pacific butterfish	Peprilus simillimus
Kelp bass	Paralabrax clathratus
Barred sand bass	Paralabrax nebulifer
Sargo	Anisotremus davidsonii
Spotfin croaker	Roncador stearnsii
Bocaccio	Sebastes paucispinis
Black surfperch	Embiotoca jacksoni
Yellowfin croaker	Umbrina roncador
Black croaker	Cheilotrema saturnum

These species represent approximately 85% of SCE system impingement losses and 80% of entrainment losses (the latter excluding members of the families Gobiidae and Clinidae).

DISTRIBUTION OF MAJOR FISH SPECIES

Establishment of a source water body, or zone of influence, is essential to predict the potential effects of a cooling water intake system. The first step in the development of the Impact Assessment Model consisted of defining a continuous population of fish species based on the unique physical and biological characteristics of the Southern California Bight.

Homogeneity of the Nearshore Zone

The submarine topography of the Pacific Coast (Figure 2-1) is such that many nearshore fish species are constrained within a very long and narrow depth contour zone of the Southern California Bight (Figure 2-2). Winant (1980) reviewed the oceanographic features of this nearshore zone and determined that significant longshore currents in the range of 2 to 20 cm/sec occur in most seasons. This implies a potential longshore transport of approximately 5 km/day, which is about 1% of the linear length of the nearshore zone from Point Conception to the Mexican border. With the exception of the Palos Verdes peninsula, little coastal topography exists to significantly interrupt longshore mixing within the Bight. Because fish egg and larval stages inhabit the water column for 30 to 100 days, they are transported over potentially large distances during development. Studies of the water masses in the Bight indicate dynamic water motions, often on a large scale (Grove and Sonu 1981). Typical examples include: 1) upwelling off Point Conception; 2) eddy shedding off Palos Verdes; and 3) longshore water movements (Figure 2-3). Such large scale coastal oceanographic events imply major transport and mixing processes throughout the Bight nearshore zone.

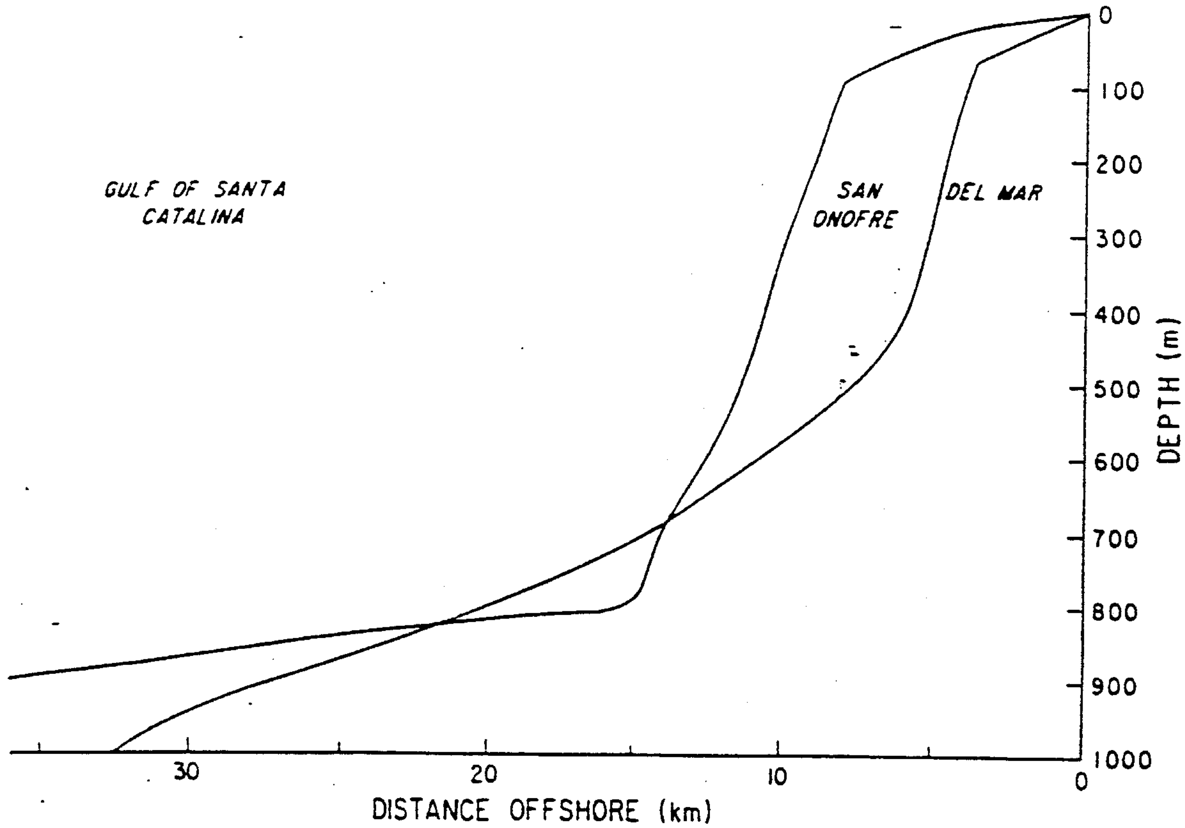

Figure 2-1. Bottom profile of the Gulf of Santa Catalina in a plane perpendicular to the shore off Del Mar and San Onofre (from Winant 1980).

Larval and Adult Fish Distribution

The coastline bordering the Southern California Bight has few large natural embayments or estuarine areas which serve as major nursery areas for larval fishes. Recent ichthyoplankton collections in some southern California embayments (IRC 1981, Stephens 1982, McGowen and Lavenberg, unpublished data) demonstrated no exceptional concentrations of any of the target species. Several studies do indicate, however, that species of surfperch, including shiner and white, migrate to shallow embayments for reproductive purposes (Odenweller 1975, Eckmayer 1979, Stephens 1982).

Data on adult fish movements within the Bight are generally lacking. Most tagged fish disappear too rapidly for adequate data return (Stephens, personal communication). Kelp bass are known to move tens of kilometers, with some individuals apparently moving from the Channel Islands to the coast (Young 1963). However, substantial differences have been reported in chlorinated hydrocarbon concentrations in white croaker populations associated with sewage outfalls from Palos Verdes and Dana Point, and there may be some "homing" tendency in surfperch (Ebling, personal communication). There is no evidence of morphological differentiation associated with geographical position within the Bight (Miller and Lea 1972). A recent study (Beckwitt 1981) on the genetics of queenfish, white croaker, kelp bass, and white surfperch also showed no differentiation related to geographical position. A similar lack of genetic structure in another comparatively large system (Lake Michigan) was reported for yellow perch (Leary and Brook 1982). If selection for these alleles is intense, migration would be required to maintain such homogeneity.

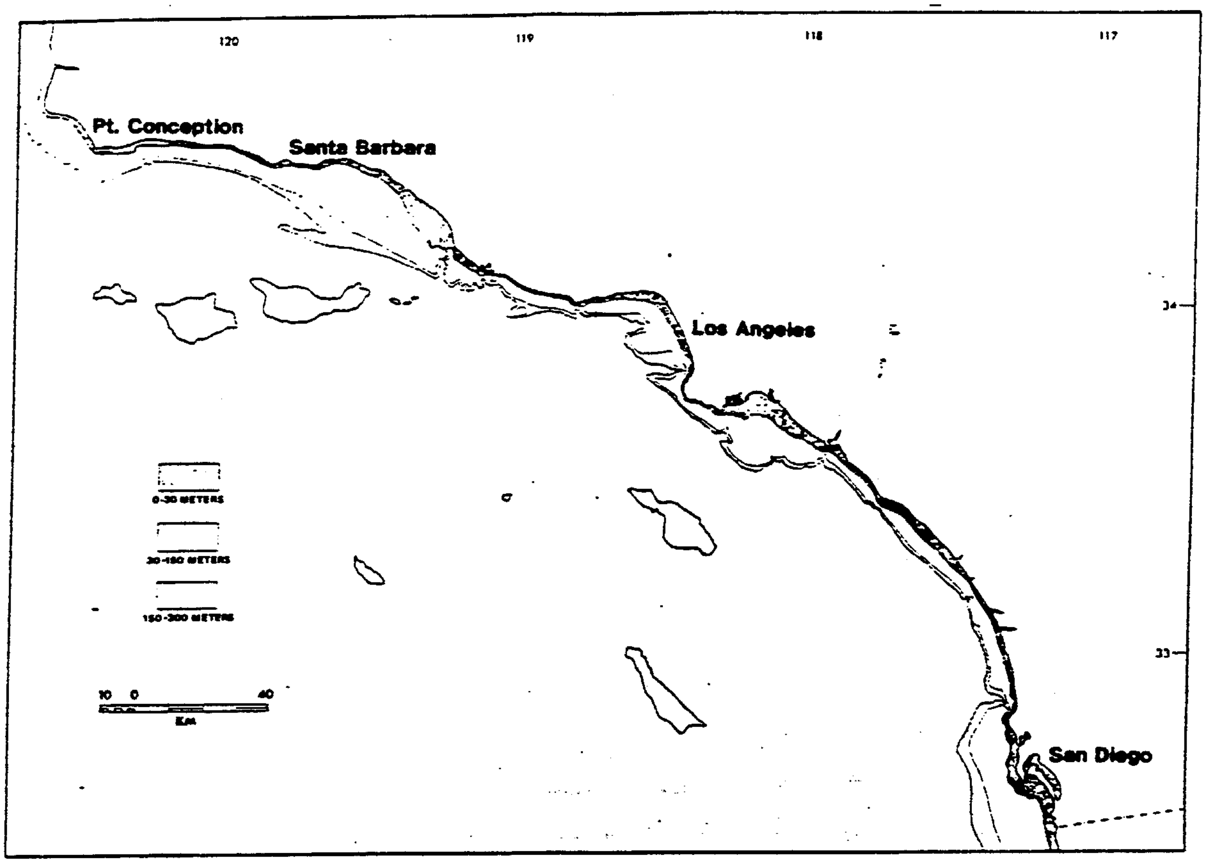

Figure 2-2. Nearshore depth contours along the coastline encompassed by the Southern California Bight.

North-south geographical trends for some tropical or temporal forms in the Bight have been established; however, the present species of concern are continuously distributed as larvae and adults throughout the Bight from Point Conception to the Mexican border (Horn 1974, Horn and Allen 1976, Word and Mearns 1978, Patton 1982, Lavenberg and McGowen 1982). Numerous studies indicate that abundance in any single locale may vary greatly over both the short and long term (years). A high proportion of this variation is due to water movement and/or transport. Stephens' (1982) seven-year study of larval and adult fish within King Harbor, adjacent to a cooling water intake, showed that adults and larvae follow diverse seasonal and annual trends in numbers. These trends are primarily influenced by coastal and local water temperature regimes. Fish abundance in King Harbor is, to a large extent, determined by movement of adults or transport of larvae. This conclusion is indicated by two lines of evidence: 1) rapid (time scale of hours to weeks) changes in density of fish in response to changes in sea temperature structure; and 2) the very local "standing stock" of adults and/or larvae of some cryptic species is exceeded by the annual entrainment or impingement losses of those species to the intake. Fish numbers have persisted over the period of the study, however, indicating a flux of fish through the area. Additional evidence that apparent "standing" stocks are actually "moving" stocks is demonstrated by rapid recruitment to new artificial reefs in areas remote from the "normal" habitat of reef species (Turner et al. 1969, Wilson et al. 1981).

Evidence indicates no outstanding localization of fish populations within the Bight. Populations of target species fishes are continuously distributed in alongshore direction throughout the Bight.

Figure 2.3 Enhanced infra-red TIROS-N satellite photograph of mass water body

Estimate of Affected Habitat Volume

The volume of water in the nearshore zone representing potential habitat for target species fish was determined (Chapter 3). This volume was used in conjunction with offshore density data to estimate nearshore populations. Habitat volume data were combined with that of Barnett (1980a) and a geometric model of the volume of the nearshore habitat to develop Bight-wide population estimates of ichthyoplankton for each species (Appendix 2-A). The model of habitat volume, as a function of depth, is summarized in Figure 2-4.

POPULATION ESTIMATE OF MAJOR FISH SPECIES

Population Database

With the exception of northern anchovy (Figure 2-5), which is oceanic (Huppert et al. 1980), the 316(b) target species are restricted to the extreme nearshore zone both as larvae and adults. Barnett et al. (1980a) developed on-offshore patterns of distribution for several nearshore larvae (Figure 2-6). All of the entrained nearshore species except northern anchovy were generally confined as larvae to within the 75 m depth contour. Barnett et al. (1980a) demonstrated that the older larvae of northern anchovy, queenfish and white

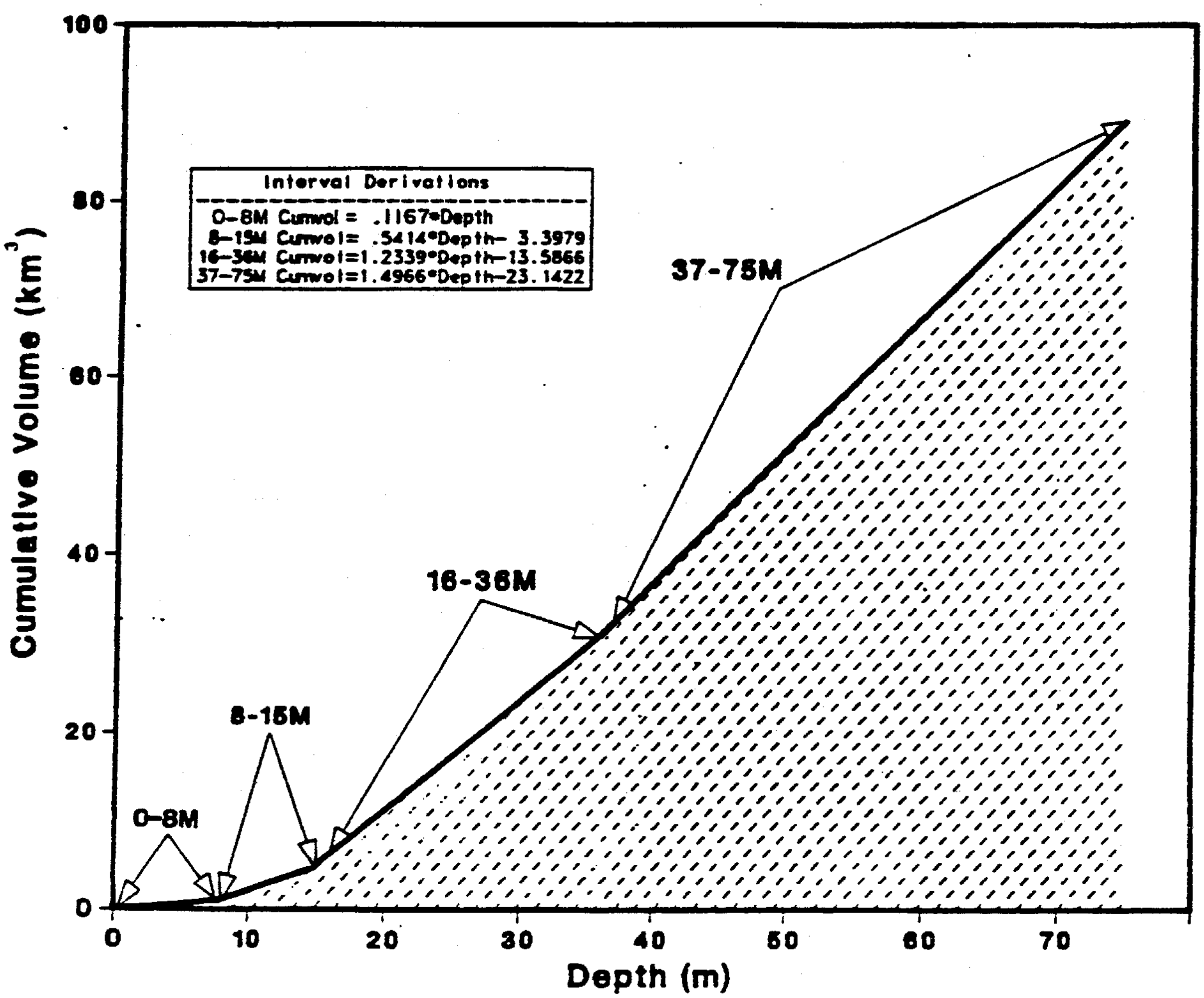

Figure 2-4. Volume of water encompassed by major depth contours in the 316(b) Bight-wide ichthyoplankton study.

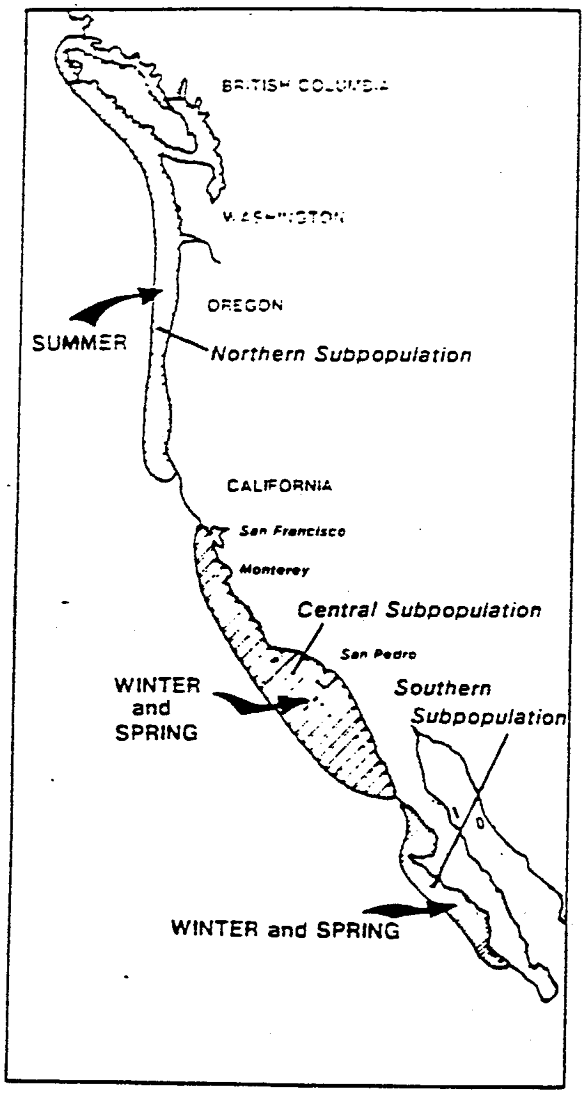

Figure 2-5. Regions of northern anchovy subpopulations (from Smith and Lasker 1978).

croaker were concentrated in the inner nearshore epibenthic zone (the bottom at <10 m depth). Early larvae of these species were produced in slightly deeper water (ca. 20 m) and, as they developed (20 to 80 days of age), moved to shallow epibenthic waters (ca. 10 m).

Except for northern anchovy, the adults of these species are also restricted to the same general nearshore zone. Analysis of the on-offshore distribution in several hundred nearshore trawl collections throughout the Southern California Bight between 1972 and 1980 (Wingert 1981) indicated these species were most frequently encountered in shallow water (<90 m depth, Table 2-1). The restriction of these species to the nearshore zone was also apparent by their relative paucity in sampling programs which emphasized collections beyond the 30 m depth zone (Mearns 1979).

Northern anchovy, queenfish, white croaker, kelp bass, and barred sand bass are dominant members of the nearshore ichthyoplankton of the Bight (Table 2-2). The plankton densities of these species were determined from monthly samples collected throughout the Southern California Bight during the 316(b) study year (August 1979 to July 1980) by the Bight-wide Ichthyoplankton Study (Lavenberg and McGowen 1982). These data are reported in detail by Lavenberg and McGowen (1982), and methodology is presented in Chapter 3. The sampled area is shown in Figure 2-7. Based on these data, the estimated average standing stock of ichthyoplankton by size class was determined and is summarized below and presented in Table 2-3.

Northern Anchovy

The number of adult northern anchovy was determined from the estimate of the number of eggs in the Bight habitat volume by extrapolation of general mortality rates to the adult stage (Smith, personal communication; Huppert et al. 1980; Hanan 1981). Details of the estimate are provided in Appendix 2-B. This population estimate is considerably less than that of the central subpopulation (Huppert et al. 1980), but for comparative purposes it scales northern anchovy to the habitat volume of the other nearshore species.

White Croaker and Queenfish

Estimates of population size for the croakers (white croaker and queenfish) were also made from ichthyoplankton data, but involved several steps which

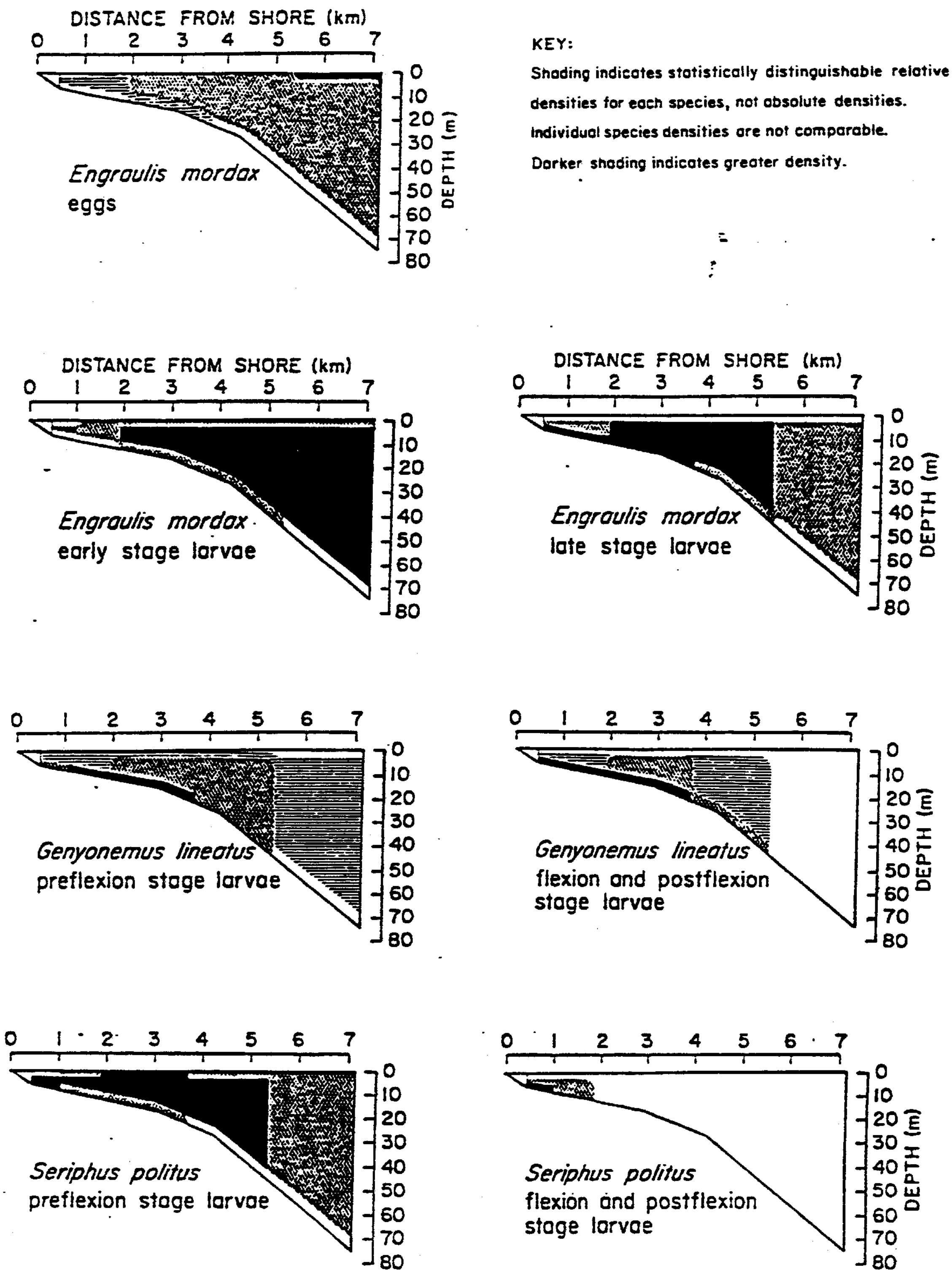

Figure 2-6. **On-offshore abundance and distribution patterns in three water column levels of some 316(b) target species larval fish (from Barnett et al. 1980a).**

Table 2-1. Depth distribution of adult nearshore fish summarized from Wingert (1981)*.

Depth (m)	white croaker	queenfish	northern anchovy	white surfperch	walleye surfperch	No. of Trawls
	Species					
5	121.5	16.8	25.9	2.0	14.2	31
14	98.6	6.6	15.7	1.0	10.4	73
23	24.8	12.2	5.4	0.2	2.8	55
32	7.9	0	0	0.2	0.2	12
41	3.4	0.03	7.8	0.03	5.3	27
50	4.9	0	0	0	2.6	14
69	2.3	0.03	0.1	0	0	68
90	1.6	0.02	0.03	0.01	0	158

* Data represent mean catch per unit effort (CPUE) of 438 trawls made in the nearshore between Ormond Beach and San Onofre in the period 1972 to 1980.

Table 2-2. Relative abundance of ichthyoplankton in the Southern California Bight (from Lavenberg and McGowen 1982).

Species	Rank	Percentage of Total
northern anchovy	1	46.2
white croaker	2	30.6
queenfish	3	5.1
cheekspot goby	4	2.7
California grunion	5	1.7
jacksmelt	6	1.6
Gobiidae Type C	7	1.6
Gobiidae Type D	8	1.3
blennies	9	1.2
California halibut	10	1.1
Gobiidae Type O/S	11	0.5
Pacific sardine	12	0.4
Atherinidae, unid.	13	0.4
basses	14	0.4
Clinidae Type A	15	0.4

are discussed in detail in Appendix 2-C. Since eggs of these species are not easily identified, the number of eggs produced per year was calculated from larval data using an egg-to-larval mortality rate developed by Barnett et al. (1980b). The number of females required to produce this quantity of eggs was calculated using fecundity information on queenfish (DeMartini and Fountain 1981) and white croaker (Love et al. 1982), and adult mortality rates estimated from Lampara net catch curves (Thomas et al. 1980a). The total number of adults was taken to be twice as great as the estimated number of females.

Kelp Bass

The number of adult kelp bass (a classification including both kelp and barred sand bass) was estimated from fishery catch data, as well as the natural and fishing mortality rates of 75 and 5% per annum, respectively, reported by Young (1963). The procedure for this calculation is presented in Appendix 2-D.

Surfperches

Surfperch are live bearing and therefore not members of the ichthyoplankton; thus, estimates based on plankton densities cannot be made. Estimates of fishing mortality were extracted from fishery sources and used to determine population estimates as described in Appendix 2-E.

Size-age Frequency Curve Development

A summary of adult population estimates is presented in Table 2-4. The procedures involved estimates of the total adult populations, which are comprised of various size (or age) classes. Because the impingement profile is estimated in 10 mm size classes, it is convenient to maintain similar size classes for the adult population. The abundance of an initial size class of the adult population was calculated, and abundances of successive size classes estimated. This procedure assumed that the age classes of adult populations are distributed as given by the estimated mortality rates. The assumption is a reasonable approximation, since the mortality rates were estimated from the age distribution of catch curves (See Appendix 2-F).

Both original impingement and field catch data were recorded as size frequency distributions. To effectively work with the population dynamics, size estimates were converted to age estimates (Appendix 2-G) and applied to size data presented in Tables 2-3 and 2-4.

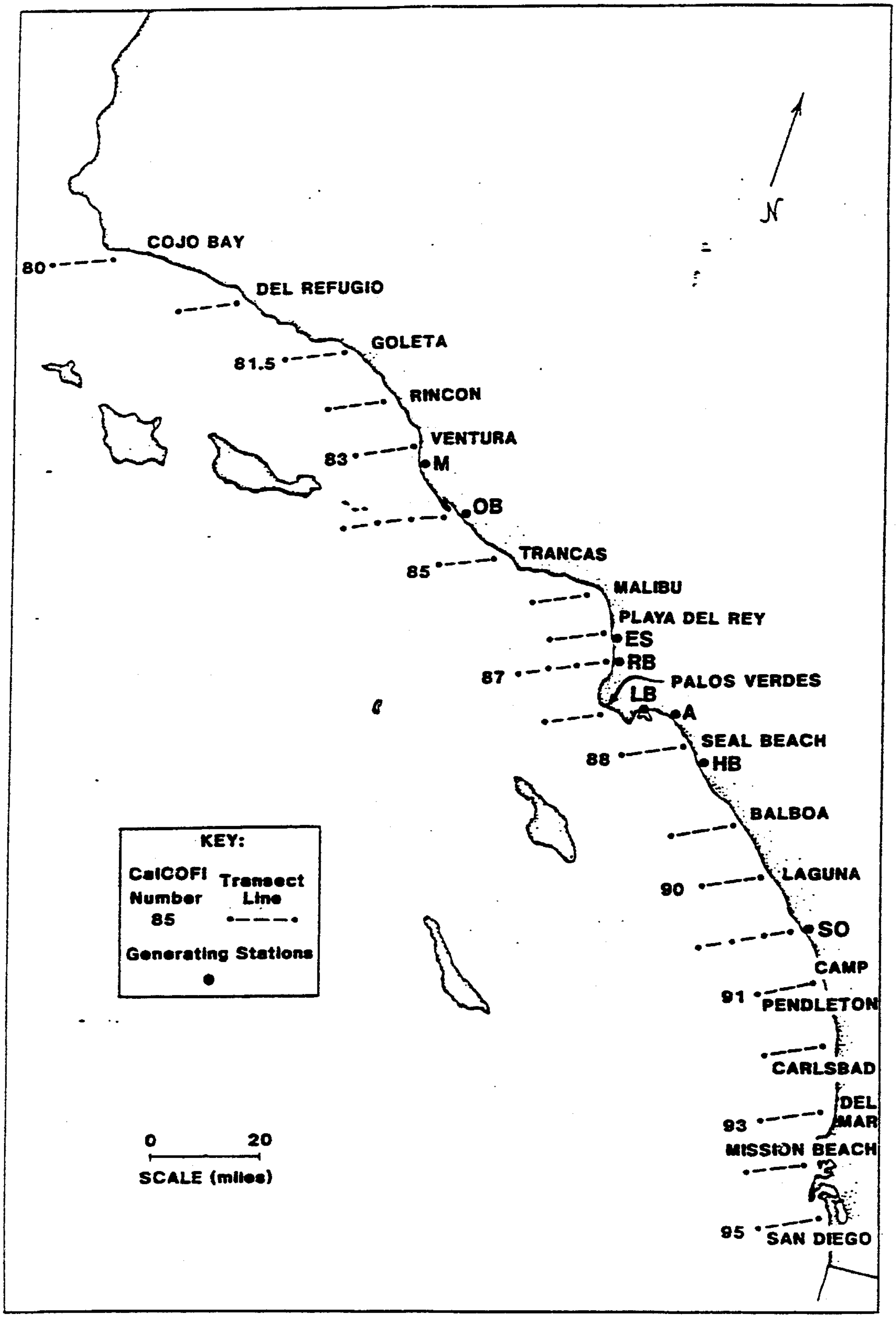

Figure 2-7. Sampling transects for the Bight-wide plankton study.

Table 2-3. Estimated average standing stocks of ichthyoplankton in the Southern California Bight to a depth of 75 m. See Appendix 2-B for details of calculations.

Size (mm)	northern anchovy	queenfish	white croaker	kelp bass
2- 3	$2.240x10^{10}$	$2.571x10^{9}$	$1.719x10^{10}$	$7.391x10^{8}$
3- 4	$3.620x10^{10}$	$8.570x10^{8}$	$9.227x10^{9}$	$4.628x10^{8}$
4- 5	$1.183x10^{10}$	$9.624x10^{8}$	$5.588x10^{9}$	$2.284x10^{8}$
5- 6	$1.189x10^{10}$	$6.653x10^{8}$	$3.581x10^{9}$	$4.031x10^{7}$
6- 7	$1.117x10^{10}$	$3.874x10^{8}$	$2.288x10^{9}$	$1.044x10^{7}$
7- 8	$8.681x10^{9}$	$4.612x10^{7}$	$3.916x10^{8}$	$1.413x10^{7}$
8- 9	$8.108x10^{9}$	$2.801x10^{7}$	$1.435x10^{9}$	$4.307x10^{6}$
9-10	$6.838x10^{9}$	$1.880x10^{7}$	$1.725x10^{9}$	$2.301x10^{6}$
10-11	$6.214x10^{9}$	$2.260x10^{7}$	$2.575x10^{9}$	$8.453x10^{6}$
11-12	$4.309x10^{9}$	$1.281x10^{7}$	$1.484x10^{9}$	$4.020x10^{6}$
12-13	$2.931x10^{9}$	$1.202x10^{7}$	$1.075x10^{9}$	$3.010x10^{6}$
13-14	$5.988x10^{9}$	$4.041x10^{6}$	$5.686x10^{8}$	$2.250x10^{6}$
14-15	$1.888x10^{9}$	$5.436x10^{6}$	$4.187x10^{8}$	
15-16	$1.729x10^{9}$	$4.918x10^{6}$	$2.443x10^{8}$	
16-17	$2.844x10^{9}$	$5.078x10^{6}$	$1.288x10^{8}$	
17-18	$9.187x10^{8}$	$5.948x10^{6}$	$1.614x10^{7}$	
18-19	$1.080x10^{9}$	$1.670x10^{7}$	$2.968x10^{7}$	
19-20	$2.035x10^{9}$	$1.357x10^{7}$	$8.748x10^{6}$	
20-21	$6.523x10^{8}$	$2.858x10^{6}$	$1.137x10^{7}$	
21-22	$4.070x10^{8}$	$5.117x10^{5}$	$1.400x10^{7}$	
22-23	$1.047x10^{9}$	$2.592x10^{6}$	$1.309x10^{7}$	
23-24	$2.155x10^{8}$	$1.030x10^{6}$	$1.309x10^{7}$	
24-25	$1.180x10^{8}$	$1.163x10^{6}$	$1.309x10^{7}$	
25-26	$1.993x10^{8}$	$1.163x10^{6}$	$1.218x10^{7}$	
26-27	$7.067x10^{7}$	$1.296x10^{6}$		
27-28	$1.491x10^{8}$	$1.296x10^{6}$		
28-29	$3.533x10^{7}$			
29-30	$2.403x10^{7}$			
30-31	$3.957x10^{7}$			
31-32	$1.908x10^{7}$			
32-33	$7.067x10^{6}$			
33-34	$2.120x10^{6}$			
34-35	$2.120x10^{6}$			
35-36	$2.827x10^{6}$			
36-37	$2.120x10^{6}$			
37-38	$7.067x10^{5}$			

A sampling gap frequently existed between the last larval and first adult data. This gap also occurred in the intake loss data. Fish of this age are sufficiently large to avoid plankton nets and too small to be effectively sampled by larger mesh techniques used for collecting adults. Further, fish of this age may concentrate in the epibenthos or other specialized habitats, and thus be unavailable to traditional water column sampling devices. These size classes are typically poorly sampled in fishery studies (Stephens, personal communication). Population (and loss) estimates for these size groups were developed by applying mortality rates developed for each species and interpolating between points of collection data, using the assumption that losses did exist in these categories but were not effectively sampled.

FISH LOSSES AT COASTAL POWER STATION INTAKES

The estimation of fish loss is associated with each specific station intake because it involves subsampling the entrainment and impingement loss rates and extrapolating to station operational levels. Details of sampling methods were reported by SCE (1982) and are discussed in the individual station-specific reports.

Table 2-4. Estimates of adult stocks in the Southern California Bight. Details of calculations are given in Appendices 2-C, 2-D, 2-E, and 2-F.

Size (mm)	northern anchovy	queenfish	white croaker	kelp bass	shiner surfperch	white surfperch
90-100	$3.263x10^{9}$	$5.168x10^{6}$	$3.161x10^{7}$	$2.023x10^{6}$	$2.754x10^{5}$	$4.902x10^{5}$
100-110	$2.179x10^{9}$	$5.523x10^{6}$	$3.168x10^{7}$	$1.967x10^{6}$	$5.689x10^{5}$	$7.992x10^{5}$
110-120	$1.353x10^{9}$	$5.562x10^{6}$	$3.077x10^{7}$	$1.905x10^{6}$	$2.648x10^{5}$	$7.167x10^{5}$
120-130	$7.571x10^{8}$	$5.270x10^{6}$	$2.899x10^{7}$	$1.838x10^{6}$	$1.719x10^{5}$	$7.317x10^{5}$
130-140	$3.603x10^{8}$	$4.688x10^{6}$	$2.652x10^{7}$	$1.767x10^{6}$		$7.209x10^{5}$
140-150	$1.287x10^{8}$	$3.904x10^{6}$	$2.358x10^{7}$	$1.694x10^{6}$		$6.854x10^{5}$
150-160		$3.034x10^{6}$	$2.039x10^{7}$	$1.619x10^{6}$		$6.287x10^{5}$
160-170		$2.191x10^{6}$	$1.714x10^{7}$	$1.544x10^{6}$		$5.560x10^{5}$
170-180		$1.464x10^{6}$	$1.402x10^{7}$	$1.469x10^{6}$		$4.738x10^{5}$
180-190		$9.021x10^{5}$		$1.395x10^{6}$		$3.887x10^{5}$
190-200				$1.321x10^{6}$		
200-210				$1.250x10^{6}$		
210-220				$1.180x10^{6}$		
220-230				$1.112x10^{6}$		
230-240				$1.047x10^{6}$		
240-250				$9.840x10^{5}$		
250-260				$9.235x10^{5}$		
260-270				$8.656x10^{5}$		
270-280				$8.102x10^{5}$		
280-290				$7.575x10^{5}$		
290-300				$7.074x10^{5}$		
300-310				$6.598x10^{5}$		
310-320				$6.148x10^{5}$		
320-330				$5.723x10^{5}$		
330-340				$5.321x10^{5}$		
340-350				$4.943x10^{5}$		

Entrainment

Entrainment samples were collected directly from the intake flow by a pump system at offshore velocity cap intakes (Figure 2-8). This procedure produced estimates of the density of ichthyoplankton in the cooling water flow. Twenty-four 100 m^3 samples were collected over a 24-hr period, and were combined into a daily average by weighting for the relative length of day and night periods. Monthly sampling at four SCE intakes over a 12-month period resulted in the collection of a total of 1,152 entrainment samples of 100 m^3 volume (Table 2-5).

Monthly estimates were combined into an annual average density by weighting for the intervals between sampling periods (SCE 1982). A monthly sequence of station sampling was maintained to minimize temporal bias, and stations were sampled as synoptically as possible, both in terms of proximity and in conjunction with offshore collections.

The estimation of individual station losses is discussed in detail in each station report. Entrainment at

Table 2-5. Relative abundance of fish entrained (SCE 1982) and impinged at SCE coastal power stations.

Percentage of Total Number of Individuals			
ENTRAINMENT		IMPINGEMENT	
*white croaker	33.17	*queenfish	54.43
*northern anchovy	26.86	*white croaker	8.98
*queenfish	7.12	*walleye surfperch	7.25
cheekspot goby	6.65	*northern anchovy	6.07
yolk sac larvae	3.76	*Pacific butterfish	5.11
reef finspot	3.66	*shiner surfperch	4.48
fragments	3.62	topsmelt	4.37
kelpfish	3.30	*white surfperch	3.82
blenny	2.79	jacksmelt	0.52
bay goby	1.60	blacksmith	0.50
blacksmith	1.50	California grunion	0.47
California halibut/ fantail sole	1.14	plainfin midshipman	0.45
		Tilapia sp.	0.34
California clingfish	0.91	*kelp bass	0.32
goby (Type D)	0.90	*black surfperch	0.23
goby (unid.)	0.51	deep body anchovy	0.20
clinid (unid.)	0.28	pileperch	0.14
Pacific sardine	0.27	staghorn sculpin	0.11
California corbina	0.26	kelp surfperch	0.11
diamond turbot	0.23	round stingray	0.10
goby (*Lythrypnus* sp.)	0.23	California halibut	0.09
jacksmelt	0.16	*barred sand bass	0.09
Cottidae (Type 7)	0.14	spiny dogfish	0.08
*spotfin croaker	0.13	sculpin	0.08
sanddab	0.13	California needlefish	0.08
hornyhead turbot	0.11	basketweave cusk-eel	0.07
blind goby	0.11	California corbina	0.07
giant kelpfish	0.08	bay ray	0.06
northern lampfish	0.07	*California electric ray	0.06
California lizardfish	0.06	speckled sanddab	0.06
longjaw mudsucker	0.04		

* 316(b) target species

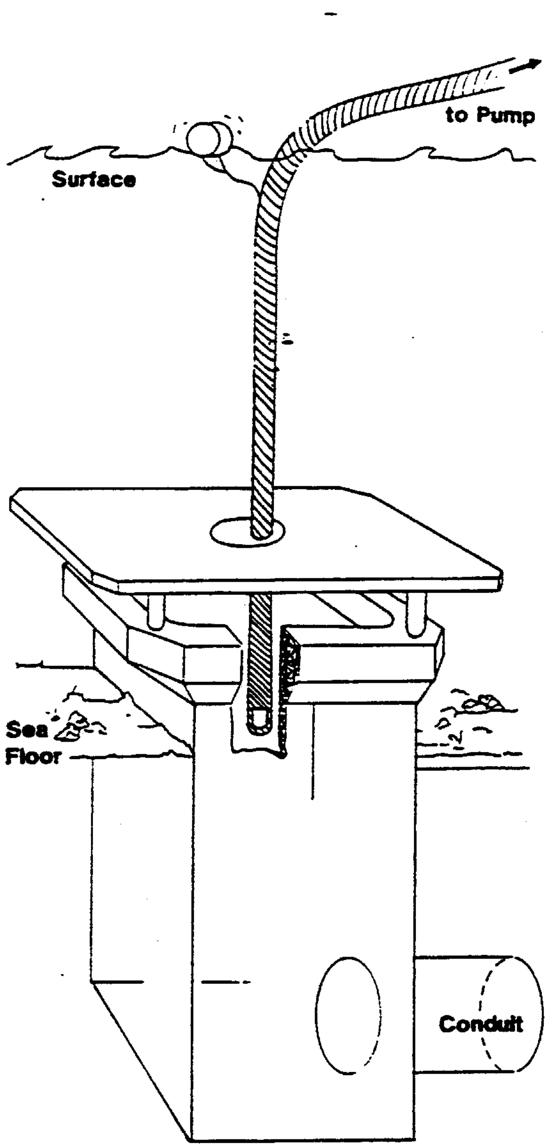

Figure 2-8. Standpipe and velocity cap configuration (from SCE 1982).

non-sampled stations was determined by application of a volume conversion factor (from sampled stations determined to be physically, hydraulically, and biologically similar; Schlotterbeck et al. 1979). Loss data were incorporated into a specialized statistic relating losses to offshore stocks as discussed below. Station losses were estimated based on actual, rather than rated, flow volumes. Estimated combined entrainment mortality by size class (as % survival compared to the absence of an intake) are given in Table 2-6.

Table 2-6. Combined intake losses for all SCE coastal power stations, expressed as % survival compared to survival in the absence of existing cooling water intakes. This is the R_c statistic detailed in Appendix 2-H.

Size Class (mm)	Kelp Bass	Northern Anchovy	Queenfish	Shiner Surfperch	White Croaker	White Surfperch
0- 5	99.964	99.955	99.459		99.070	
5- 10	99.713	99.957	98.442		99.728	
10- 15	99.950	99.787	98.747		99.353	
15- 20		99.545	99.380		99.904	
20- 25		99.712	99.[illegible]32		99.953	
25- 30		99.893			99.996	
30- 35		99.999				
*Mid Region	98.722	99.638	98.880		99.898	
35- 40				99.711		
40- 50				99.430		
50- 60				99.430		99.993
60- 70				99.430		99.986
70- 80				99.430		99.986
80- 90				99.430		99.986
90-100	100.000	99.999	99.436	97.794	99.975	99.950
100-110	99.999	99.999	99.301	96.701	99.977	99.924
110-120	99.999	99.999	98.958	96.817	99.971	99.894
120-130	99.999	99.998	98.974	98.920	99.960	99.834
130-140	99.998	99.998	98.786		99.965	99.811
140-150	99.998	99.999	98.617		99.971	99.717
150-160	99.998		98.146		99.970	99.294
160-170	99.997		97.963		99.961	98.902
170-180	99.995		97.924		99.958	98.556
180-190	99.992		97.767			98.260
190-200	99.989					
200-210	99.987					
210-220	99.985					
220-230	99.987					
230-240	99.990					
240-250	99.991					
250-260	99.995					
260-270	99.996					
270-280	99.997					
280-290	99.997					
290-300	99.998					
300-310	99.998					
310-320	99.998					
320-330	99.999					
330-340	99.998					
340-350	99.997					
350-360	99.994					

* Mid-region is the accumulated size classes between the last entrained size class and first impinged size class.

Impingement

Adult impingement in 10 mm size classes was measured at all stations (Table 2-5). Adult size was taken at 90 mm because the impingement catch curves for the croakers, surfperch, and northern anchovy generally decline after this size class (Herbinson, personal communication). Impingement studies do not adequately sample smaller fish because they pass through the mesh of the traveling screens and are more difficult to detect and remove from associated traveling screen debris. This sampling bias was demonstrated by comparison of size frequency distributions for small fish impinged on different size meshes of traveling screens (Thomas et al. 1980a). The estimation of the undersampled portion of the loss distribution (generally 30 to 90 mm) is discussed in the next section. Impingement samples were collected over 24-hr periods, approximately twice a week during the year, and during all heat treatments. Both of these data sets were combined to yield an average daily catch for the entire year. Although exact flow records are available for converting entrainment density into catch rates, a 365 day operational year was assumed for extrapolation of impingement losses. Even when a plant is off line, some flow is typically maintained, allowing fish to enter the screenwell; a full operational year was assumed to develop a conservatively high impingement estimate.

All impinged adult fish were removed from the screenwell, so the mortality rate was 100%. The entrainment mortality rate was also assumed to be 100%. However, the Marine Ichthyoplankton Entrainment Studies (SCE 1982) indicated that approximately one-third of the older larvae may successfully transit the cooling system. Therefore, results of site-specific analyses are considered conservative. Smaller larvae which do not transit the system are apparently removed by fouling organisms in the conduits (SCE 1982; Barnett, unpublished data). Estimated combined impingement losses are included in the impact statistic as shown in Table 2-6.

IMPACT OF INTAKE LOSSES ON FIELD POPULATIONS

The impact analysis approach utilized in the 316(b) study was developed by MacCall et al. (1982) for assessment of intake losses of southern California coastal fish species. Their procedure is similar to that developed independently by Chesson (1980) and utilized in assessing the impact of a coastal power station (MRC 1980). Primarily, the strength of a stock of fish under some regime of cropping pressure is calculated. The cropping regime includes loss of early life stages as well as older fish. The effect of these losses is accumulated and passed on to later stages. The analysis produces the probability of a fish surviving entrainment and impingement mortality through a specific age. Five years was chosen as a standard for the average life span of most nearshore species. For example, a value of 99% indicates that members of a given species have a 99% chance of not being entrained or impinged through five years of life. The number combines the effects of both entrainment and impingement and provides a measure of the intensity of power station cropping, and is calculated as

$$R_{c_i} = e^{-[\sum_{i=1}^{i=c} (L_i/N_i)(t_i)]}.$$

where

R_c = relative strength through the c^{th} stage; compared to an unaffected population (probability of survival)

L_i = daily losses of the i^{th} stage;

N_i = field population of the i^{th} stage;

t_i = duration of the i^{th} stage in days;

$$\text{age of the } c^{th} \text{ stage} = \sum_{i=1}^{i=c} t_i.$$

The derivation of this formula is presented in Appendix 2-H. The ratio L_i/N_i represents the per capita intake mortality rate per day for a given stage (i), and can be calculated from the size frequency distributions of loss and stock data. The multiplication of L_i/N_i by the estimated duration of the stage, t_i, gives a value which incorporates the duration of exposure to the loss rate. For those stages which are undersampled (i.e. about 20 to 90 mm), L_i/N_i terms were estimated on the assumption of an exponential decline between the last well-sampled small stage and the 90 mm stage (Appendix 2-H). The cumulative R_c value integrates both field and loss data over all life history stages. When the R_c value is multiplied by 100 it can be interpreted as the percentage survival of entrainment and impingement to five years. These values are useful as a measure of the level of impact and for comparisons between species. They were calculated for each species at each station (where sufficient data were available) and are presented and discussed in detail in the individual station reports. The expression, R_c, is also useful to demonstrate how a given intake control technology can change the level of impact.

EFFECT OF LOSS REDUCTIONS ON ASSESSMENT OF IMPACT

A given intake technology will modify the L_i/N_i-term. The coefficient for a specific technology, Q_i, can be introduced into the expression for R_c as a factor of L_i/N_i:

$$R_{cQ} = e^{-[\sum_{i=1}^{i=c} (Q_i)(L_i/N_i)(t_i)]}.$$

For example, a technology which decreases losses by 90% would have a Q_i of 0.1, because the intake mortality rate is decreased to 10% of its original value. The assignment of intake technology coefficients for alternative technologies is discussed in the review of intake technologies (LMS 1982). The value of Q_i for the existing intake technology is 1.0, resulting in no change for the L_i/N_i ratios.

SYSTEM IMPACT ASSESSMENT

The R_c concept is useful for investigating changes in impact levels and for comparisons of various alternative intake technologies in the individual station demonstrations. The significance of intake fish losses has been the subject of widespread investigation and debate over the past several years (Saila 1975, McFadden 1977, Van Winkle 1977, and Schubel and Marcy 1978). Most approaches lack sufficient empirical data regarding the response of fish populations to variations in population density, interaction with other species, and physical factors. There are a variety of compensatory mechanisms which allow fish populations to augment reproductive rates and offset increased mortality; however, actual mechanisms are rarely quantified, even for well-studied species.

Fish populations have been demonstrated to support high levels of continuous fishery pressure (Ricker 1954, Roedel 1975). High levels for a typical stock are 20 to 25% of the standing stock harvested per year, although higher rates can be sustained (McFadden 1977). These rates, combined with natural mortality, will maintain the majority of the population at an age within five years of the entry age into the fishery. A comparison of R_c values calculated on this basis for a typical fishery can be made with those detailed in the station reports. R_c values resulting from five years of 20% per annum fishing mortality would range from 1 to 21% when added to natural survival rates of 35% (e.g. northern anchovy) to 75% (e.g. kelp bass). Typical station R_c values are greater than 99%. A ten-fold increase in intake loss over this level would result in an R_c near 82%. Thus, intake losses are insignificant in comparison to potential fishery impacts.

CHAPTER 3

BIGHT-WIDE PLANKTON INVESTIGATIONS

INTRODUCTION

The Bight-wide plankton survey was established to provide a database for the abundance and distribution of eggs and larvae of fishes throughout the nearshore coastal zone of the Southern California Bight. The database allowed estimation of mortality rates and density of early life history stages of important fish species, which are used in assessing the significance of intake losses.

The Bight-wide plankton survey was initiated in August 1979. Sampling techniques were patterned after those used by the California Cooperative Oceanic Fisheries Investigations (CALCOFI) for analyses of ichthyoplankton in offshore waters (Kramer et al. 1972; Smith and Richardson 1977). This sampling strategy allowed compatibility and information exchange between the Bight-wide survey and those of the offshore CALCOFI surveys. The sampling strategies and laboratory procedures designed by the CALCOFI institutions have been refined and modified since their establishment in 1949, and were subsequently adopted by the United Nations Food and Agricultural Organization (FAO) as standard techniques for assessing zooplankton and ichthyoplankton.

STATION SELECTION

Originally, the nearshore transect lines were selected by extending the offshore deep water CALCOFI transect lines into the shallower coastal zone. The cardinal CALCOFI station lines are 120 miles apart and numbered from north to south (i.e. 60, 70, 80, etc.; Figure 3-1). Additional station lines are utilized as needed and can be as closely spaced as 12 miles apart (i.e. 60, 61, 62, etc.). Station lines less than 12 miles apart are expressed as a fraction (i.e. 60.1, 60.2, 60.3, etc.). In establishing the Bight-wide plankton survey, the CALCOFI grid was extended into the coastal zone along the shoreline of the continental margin at station lines 80, 81.5, 83, 85, 87, 88, 90, 91, 93 and 95 (Figure 3-2). The area extended from Point Conception in the north to San Diego and encompassed the entity known as the coastal zone of the Southern California Bight. Ten additional transects were selected on the basis of substratum-type and geographical distance between the original ten transects and, therefore, are not directly compatible with the CALCOFI scheme. For this reason they are indicated by letters rather than numbers (Figure 3-2).

Stations were established along each transect line at pre-chosen depths, and were numbered with respect to water depth (in meters). An example of this identification is 80-8. This station is on transect line 80 at the 8 m contour. The transect lines, as drawn in Figure 3-2, usually were not perpendicular to the shoreline because the contours do not necessarily parallel the coastline, and along some transects stations were moved laterally along contours to avoid dense stands of kelp.

Stations were established at the 8 and 22 m contour depths for most of the 20 transects in the Bight (Table 3-1). Based on data from Barnett et al. (1978), stations were selected at 8 and 22 m as representative and cost-effective for estimating nearshore ichthyoplankton populations. There were five deviations from this arrangement of stations. On two of the transects (PV and 90) it was impossible for the vessel to maneuver in shallow water and occupy the station

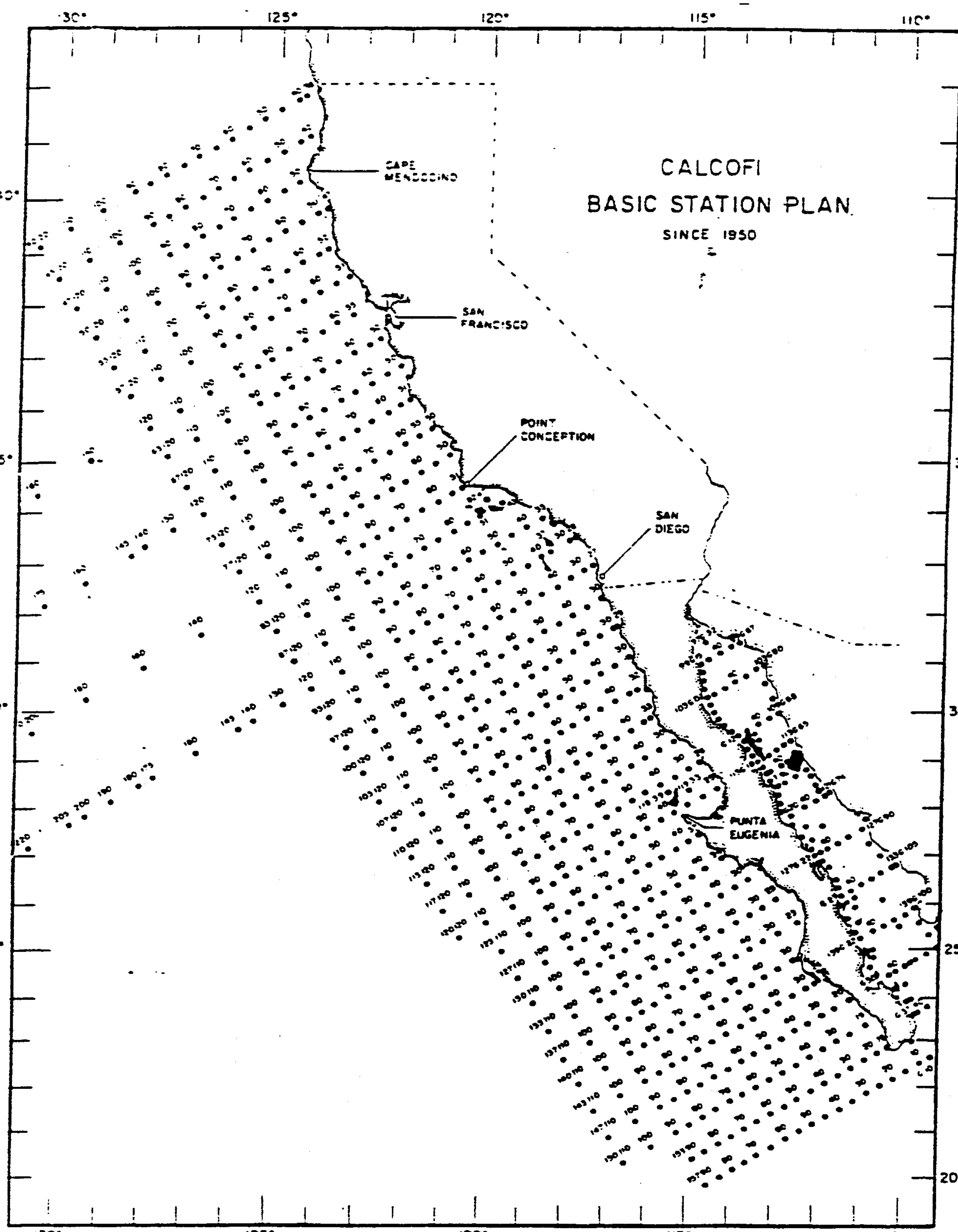

Figure 3-1. Basic CALCOFI station pattern.

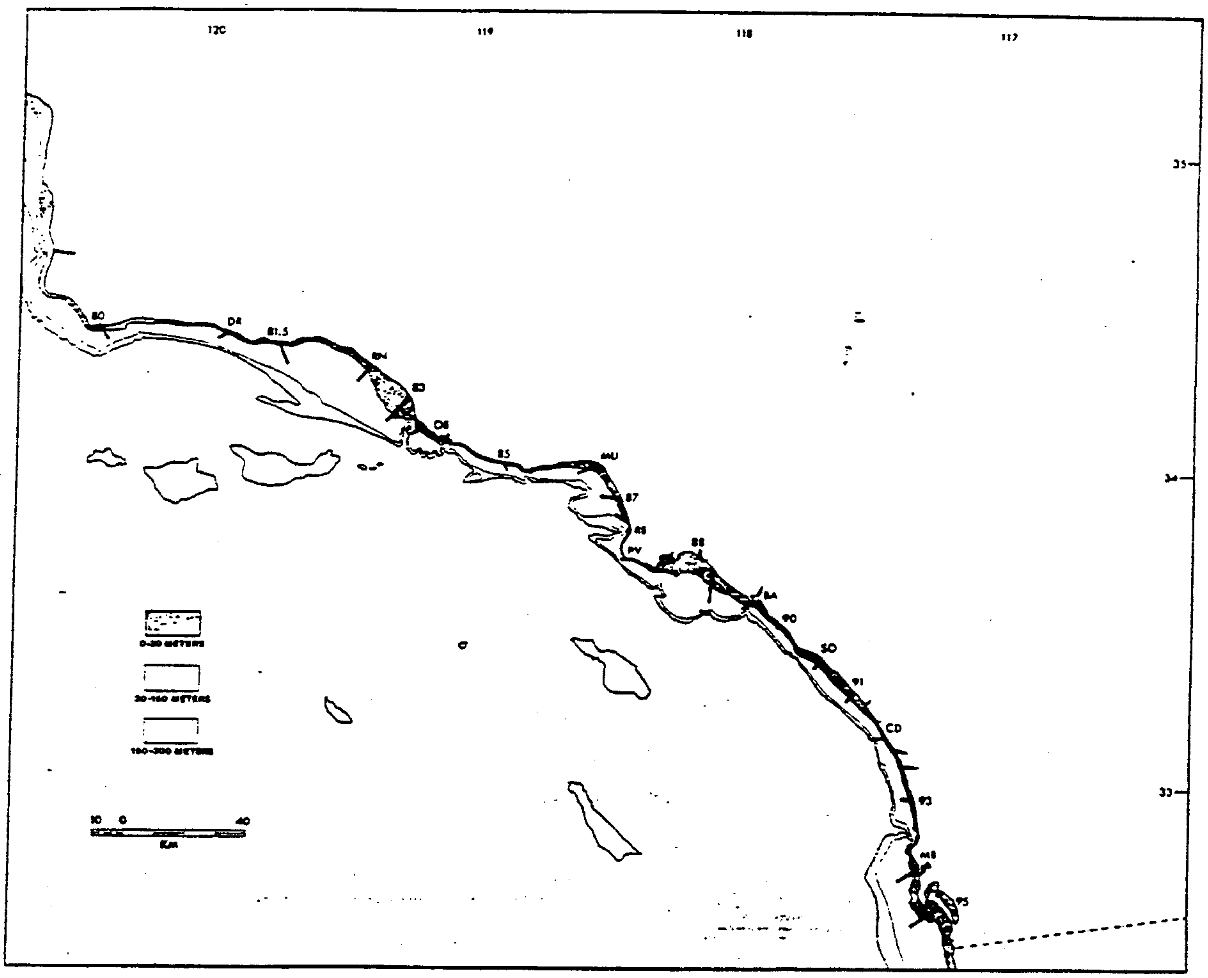

Figure 3-2. Bight-wide plankton program sampling stations.

at 8 m; consequently, stations at 15 m were substituted. At transects in the northern (OB), central (RB) and southern (SO) portions of the Bight, a four station strategy at 8, 15, 22, and 36 m depths was established. Four stations were occupied along these three transects to collect comprehensive sampling data in the immediate vicinity of three SCE generating stations.

METHODS AND MATERIALS

FIELD PROCEDURES

Ichthyoplankton Sample Collection

Plankton samples were collected with three different types of gear for specialized collections of different water column levels: Bongo net, Manta net and Auriga net (Figure 3-3). Plankton netting was constructed of 335 micron mesh Nitex, including the cod-ends. The 335 micron mesh was selected on the basis of retention of all eggs and larvae of fishes. Larger mesh sizes (i.e. 505 microns as used in the CALCOFI field program) allow the extrusion of smaller eggs and larvae (Lenarz 1972).

The Bongo net sampler (McGowan and Brown 1966) is a paired opening-closing net that was used to sample plankton populations throughout the water column.

Table 3-1. Station location data for the Bight-wide plankton program.

Transect	Station	North Latitude		West Longitude		Bottom Substratum	Kelp Present
80	8	34	26.7	120	28.6	sand/rock	Yes
80	22	34	26.5	120	26.3	sand/rock	Yes
DR	8	34	27.5	120	03.0	---	---
DR	22	34	27.3	120	04.4	---	---
81.5	8	34	24.7	119	47.6	sand/rock	Yes
81.5	22	34	23.9	119	46.4	sand/rock	Yes
RN	8	34	22.0	119	27.5	---	---
RN	22	34	21.3	119	28.7	---	---
83	8	34	15.6	119	16.6	sand	No
83	22	34	13.6	119	21.2	sand	No
08	8	34	07.5	119	10.4	---	---
08	15	34	07.0	119	11.0	---	---
08	22	34	06.6	119	11.7	---	---
08	36	34	06.0	119	12.8	---	---
85	8	34	03.2	118	58.2	sand/rock	Yes
85	22	34	02.5	118	58.0	sand	No
MU	8	34	02.2	118	36.1	---	---
MU	22	34	01.6	118	37.3	---	---
87	8	33	57.0	118	27.2	sand/rock	No
87	22	33	56.9	118	28.5	sand	No
RB	8	33	51.1	118	24.1	---	---
RB	15	33	51.0	118	24.5	---	---
RB	22	33	51.0	118	24.9	---	---
RB	36	33	51.9	118	26.2	---	---
PV	15	33	45.2	118	25.1	---	---
PV	22	33	45.0	118	25.2	---	---
88	8	33	42.4	118	04.4	sand	No
88	22	33	39.5	118	04.9	sand	No
BA	8	33	36.0	117	54.4	---	---
BA	22	33	35.6	117	54.8	---	---
90	15	33	30.4	117	45.4	sand/rock	No
90	22	33	30.4	117	45.5	sand	No
SO	8	33	21.8	117	34.0	---	---
SO	15	33	20.9	117	34.3	---	---
SO	22	33	20.4	117	34.6	---	---
SO	36	33	20.0	117	35.0	---	---
91	8	33	15.2	117	26.4	sand	No
91	22	33	14.2	117	27.5	sand	No
CD	8	33	07.5	117	20.2	---	---
CD	22	33	07.2	117	20.6	---	---
93	8	32	57.8	117	16.4	sand	No
93	22	32	57.5	117	17.1	sand	No
MB	8	32	46.7	117	15.5	---	---
MB	22	32	46.2	117	16.5	---	---
95	8	32	37.8	117	08.7	sand	No
95	22	32	36.9	117	11.2	sand	No

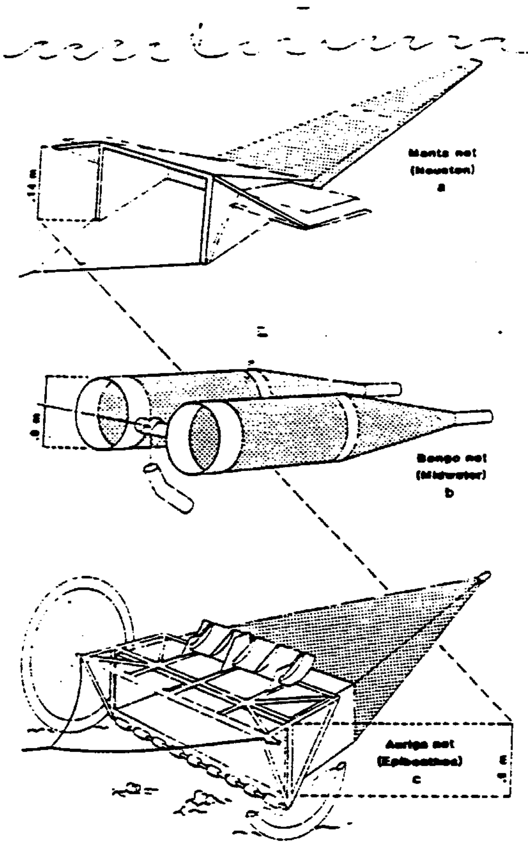

Figure 3-3. Sampling gear utilized for discrete depth collections.

The Bongo net, and other bridle-free nets, are superior to plankton nets preceeded by a bridle because the former reduce net avoidance by fish larvae (Vrooman 1972). Each side of the paired Bongo net was 70 cm in diameter. The nets consisted of a 1.5 m cylindrical section followed by a 1.5 m conical section that led to a cod-end container. Unlike the original design, the apparatus used in this study was equipped with wheels that allowed collections near the bottom with less likelihood of damage to the gear. The Bongo sampler was utilized for collections both obliquely throughout the water column and at disrete depths (including both a mid-depth tow approximately halfway between the surface and the bottom and an epibenthic tow when the Auriga net was not available).

The Manta sampler (Brown 1979) skims along the surface of the water and was used to sample neustonic populations. The net used on the Manta frame was identical to those used on the Bongo frame except that it was stretched around a rectangular opening (dimensions: 88 x 16 cm) instead of a circular opening.

The Auriga net was used to sample epibenthic populations. This sampler was equipped with wheels which enable it to roll along the bottom. The mouth of the Auriga net was 200 by 50 cm with its lower edge located 25 cm above the bottom. It fished an area 2 m wide by 0.5 m deep approximately 0.25 m above the substratum. The net was conical in shape and 6 m in length.

All of the zooplankton samplers were equipped with General Oceanic flowmeters installed in their mouth openings to provide data needed to estimate the volumes of water filtered per tow. Flowmeters were calibrated before and after each cruise by moving each a known distance through the water at a speed of about 1 m/sec. This provided an estimate of counts per meter traveled. These procedures were repeated several times for each flowmeter. From these trials a mean value of counts per meter traveled were obtained for each flowmeter, and was designated the calibration factor. The average of the calibration factors obtained prior to and subsequent to each cruise was used to compute the distance traveled by the net during the actual tow. By combining this estimate of distance towed with the surface area of the net opening, an estimate of volume of water filtered was calculated.

Oblique Water Column Collections

The primary plankton sampling technique utilized was to tow the Bongo net obliquely from just above the bottom to the surface. The objective of the oblique tow trajectory was to filter water through the net at a constant rate per unit depth from the bottom to the surface. Equivalent filtration per unit depth is a basic criterion to estimate ichthyoplankton abundances under defined units of sea surface area (Smith and Richardson 1977). The highly stratified nature of ichthyoplankton populations underscores the importance of the even passage of the net through the water column (Ahlstrom 1959, Barnett et al. 1978).

With the ship underway at approximately 0.95 m/sec (Table 3-2), the Bongo net sampler was lowered to the bottom with the canvas doors in place (Figure 3-4a). When the net was just above the bottom the doors were opened by a cable messenger (Figure 3-4b), and retrieval began at a constant rate of about 0.17 m/sec (Table 3-2). In conjunction with the ship's speed this resulted in a net speed of approximately 1.12 m/sec. Retrieval time varied with station depth (i.e. amount of cable paid out; Table 3-3) During the retrieval procedure, a wire angle of about 45 degrees was maintained. Ship speed was monitored by a General Oceanics flowmetering system equipped with continuous deck output. A Martek depth transducer was mounted directly on the Bongo net frame, and the depth of the net was monitored continuously on deck. A General Oceanics instrumented trawl sheave allowed continuous monitoring of the rate of retrieval, meters of cable out, and wire angle. A summarization of the actual volumes of water filtered is given in Table 3-4.

Table 3-2. Ship's speed data (m/sec) for each type of plankton sampling device used during the Bight-wide plankton program.

Tow Type	Cruise	Station	N	Mean	Standard Deviation.	Range
oblique Bongo	All	All	1097	0.95	0.03	0.7 - 1.1
Manta	All	All	144	1.07	0.06	0.9 - 1.3
mid-depth Bongo	All	All	144	1.06	0.06	0.9 - 1.3
benthic Bongo	15	All	7	1.01	0.04	0.95- 1.1
Auriga	All	All	133	1.07	0.05	0.9 - 1.1
Retrieval rate*	All	All	1061	10.07	0.46	8 -16

* The retrieval rates listed here are expressed in meters/minute and apply only to the oblique bongo tows.

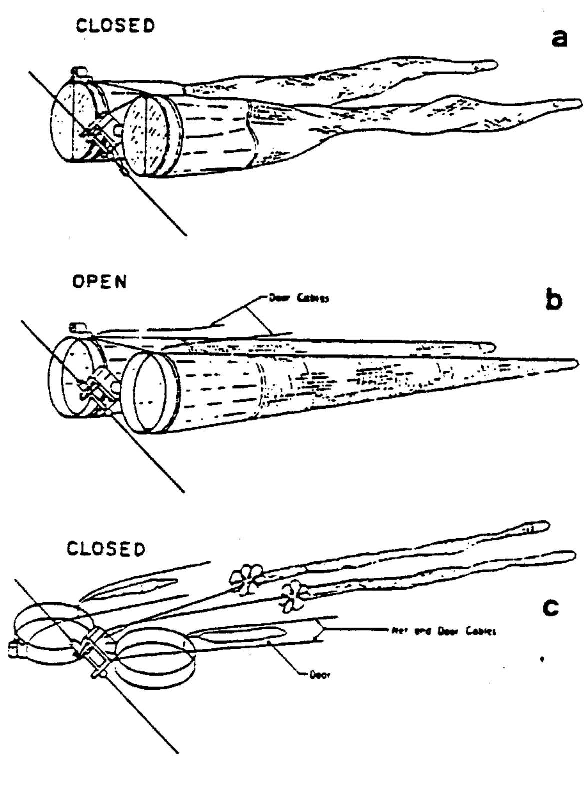

Figure 3-4. Bongo net deployment: a) prior to collections; b) open and sampling; and c) closed for retrieval.

Table 3-3. Length of fishing time (seconds) for each type of plankton sample collected during the Bight-wide plankton program.

Tow Type	Cruise	Station	N	Mean	Standard Deviation	Range
oblique Bongo	All	8	407	77.52	9.57	40 - 141
oblique Bongo	All	15	199	136.91	9.09	110 - 168.5
oblique Bongo	All	22	479	199.86	11.91	140 - 241
oblique Bongo	All	36	72	317.97	17.16	245.5 - 358.5
Manta	15-19	All	60	644.87	45.30	360 - 704
Manta	20-21*	All	16	481.13	1.13	479 - 483
Manta	21-26	All	67	542.41	4.14	538 - 569
mid-depth Bongo	15-18	All	48	182.58	5.14	176 - 202
mid-depth Bongo	19-26	All	96	144.90	3.77	138 - 156
benthic Bongo	15	All	8	188.38	15.13	178 - 222
Auriga	15-18	All	40	143.29	5.61	128 - 154
Auriga	19-26	All	96	73.26	9.83	60 - 101

* On Cruise 21 these include data for the San Onofre Transect (SO) only.

Discrete Depth Samples

The discrete depth samples were taken only along the three transects (SO, RB and OB) located near SCE generating stations to provide data on patterns of vertical distribution. Surface samples were collected with the Manta net, mid-water samples were taken using the paired Bongo nets, and epibenthic samples were collected using the Auriga net.

With the ship underway at approximately 1.1 m/sec (Table 3-2), the Manta net was deployed off a boom located on the port-midship of the vessel. This allowed the net to fish outside of the ship's wake as much as possible. The net was towed for 10 min and retrieved during a one-minute period for a total of approximately 11 min (Table 3-3). This strategy was used from August 1979 through December 1979. During the January 1980 cruise the towing time was reduced to eight minutes plus a one minute retrieval period for a total of about nine minutes (Table 3-3).

The mid-depth Bongo net tows also were made with the ship underway at a speed of approximately 1.1 m/sec (Table 3-2). The net was lowered with the canvas doors closed to depths of about 4, 8, 11 and 18 m at the 8, 15, 22 and 36 m stations, respectively. The doors were opened by messenger release and the net was fished for three minutes (Table 3-3). The nets were closed by a messenger and the sampler was retrieved. In December 1979 the fishing time was altered to two minutes and 20 seconds (Table 3-3). In August 1979, when the Bongo sampler was used to collect epibenthos, it was operated as a mid-depth tow, except that it was lowered to the bottom and rolled along with the lower edge of the mouth opening approximately 18 cm above the substratum.

Table 3-4. Volumes of water filtered (m3) for each type of plankton sample collected during the Bight-wide plankton program.

Tow Type	Stations	N	Mean	Standard Deviation	Range
oblique Bongo	8	216	135.4	20.8	45.6-272.8
oblique Bongo	15	60	241.1	20.4	206.2-286.3
oblique Bongo	22	240	354.9	35.3	242.2-496.7
oblique Bongo	36	36	550.6	52.2	427.1-647.3
Manta	8	36	116.0	18.6	82.4-157.6
Manta	15	36	117.2	16.1	89.9-148.8
Manta	22	36	113.2	18.6	72.0-152.4
Manta	36	36	115.7	18.2	87.4-159.8
mid-depth Bongo	8	36	133.9	24.2	105.0-192.0
mid-depth Bongo	15	36	125.5	20.3	96.0-176.1
mid-depth Bongo	22	36	126.3	21.7	94.2-180.3
mid-depth Bongo	36	36	123.6	24.3	81.5-190.7
benthic Bongo	8	2	204.6	31.9	182.0-227.1
benthic Bongo	15	2	185.3	35.7	160.1-210.6
benthic Bongo	22	2	178.2	40.3	149.7-206.7
benthic Bongo	36	2	202.2	24.1	185.1-219.3
Auriga	8	34	167.1	60.0	100.8-299.4
Auriga	15	34	181.3	58.5	108.5-345.3
Auriga	22	34	196.3	61.4	99.0-358.1
Auriga	36	34	214.4	74.3	87.2-352.0

The Auriga net was lowered to the bottom with the ship stopped. Although the net was open and capable of fishing, it was assumed that this procedure resulted in insignificant contamination from the water column as the net descended to the bottom. The ship was then placed in gear and brought up to a speed of approximately 1.1 m/sec (Table 3-2) as additional cable was payed out at a rate consistent with the forward movement of the ship. Thus, the net rested on the bottom without fishing. Once the desired amount of cable was payed out the net was fished for approximately two minutes and 18 seconds. However, in December 1979 the fishing time was reduced to approximately one minute (Table 3-3). At the completion of a tow a messenger was used to release the primary towing bridle and activate a secondary towing bridle that caused the entire frame to flip over and close the net. In this closed position the Auriga net would not fish, and thereafter was retrieved.

The discrete depth sampling strategies were designed to filter 100 m^3 per tow. However, the actual volumes filtered varied considerably (Table 3-4), particularly for the epibenthic tows.

Logistics permitting, all plankton samples were collected during hours of darkness to eliminate variances associated with day-night differences in net avoidance (Lenarz 1972, Murphy and Clutter 1972).

Environmental Data Collection

Selected environmental data were collected at each station. These included qualitative estimates of atmospheric and sea conditions as well as measurements of temperature, dissolved oxygen, salinity, and pH estimates obtained at the surface and from depths of approximately 2, 4, 6, 8, 10, 15, 18, 25, 30 and 36 m, depth permitting. Data were collected using a Martek Mk VI Water Quality Monitor. Chlorophyll *a* was determined by the *in vitro* (acetone extraction) fluorometric technique (Strickland and Parsons 1972) from triplicate water samples collected at the surface and at depths of approximately 2, 4, 6, 8, 10, 18, 30 and 36 m, depth permitting.

LABORATORY PROCEDURES

Plankton Volumes

Wet plankton volumes were determined following the method recommended by Smith and Richardson (1977), with the exception that the determinations were not necessarily made soon after bringing the samples ashore. In this study, the length of time between sample collection and volume determination varied from a few days to several months.

Sample Processing

Samples were generally split and some portion sorted. The procedures by which the samples were processed varied during the program. On the basis of the tandem design of the Bongo sampler the two collection sides were designated as port and starboard. Samples obtained from the port and starboard sides were combined in the field and fixed as a single sample prior to December 1979. Each of the two replicate oblique Bongo samples collected at every station during August and at most of the stations during September were sorted separately. About one-half of these (65 of 144) were sorted completely. Those remaining were split either once or twice on the basis of the volume of plankton using a Folsom splitter (McEwen et al. 1954). In all cases, at least 25% of any given sample was sorted. The data from the two replicates were then combined and analyzed as a single sample.

The oblique samples from part of Cruise 16 (September 1979) and all of Cruises 17 and 18 (October and November 1979 respectively) were split once. Half of each replicate was then archived without being sorted. Those plankton samples from the other half of each of the two replicates were mixed together to create a new hybrid sample, identified as an 03 sample. This hybrid sample was then split; half was archived and half processed. For almost all of these samples only 25% of the original Bongo samples collection was sorted and processed.

Between December 1979 and July 1980 zooplankton from the port and starboard nets from each tow were preserved separately. The sample collected by the port net of each tow during Cruise 19 (December 1979) was archived without sorting. Samples from the starboard nets from the two replicates collected at each station were combined and treated as a single sample (03). This hybrid sample was split using a Folsom splitter; half was archived in an unprocessed state, and the other half sorted. This resulted in 25% of the total original sample being processed. In rare circumstances when neither eggs nor larvae of fishes were observed in that portion of the sample selected for processing, additional 25% units of the sample were sorted until at least one egg and one larva were detected. In these cases (2 of 46) as much as 100% of the sample was sorted and processed.

The plankton samples collected from replicate tows and from each side of the Bongo sampler on Cruises 20 through 26 (January through July 1980 respectively) were never combined. Samples were selected for processing from either the port or starboard side of the net on a random basis. That half selected for processing was then split once with a Folsom splitter. One portion of the split (25% of the total sample) was then sorted. The remaining 75% was archived without sorting. Data from the two replicates were combined and treated as a single sample for analytical purposes (an 03 sample). As before, in the few cases (7 of 322) when either no fish eggs or larvae were observed in the 25% aliquot originally processed, additional portions up to 100 percent were sorted.

The discrete depth samples were treated more consistently than were the obliques. The neustonic and epibenthic samples were always split twice and 25% of the sample was sorted. In six of 144 Manta samples a second 25% was sorted because the first aliquot lacked either a fish egg or larva. Two of the 144 epibenthic samples required that a second 25% aliquot be sorted and in one case the entire sample was sorted due to an absence of either the eggs or larvae of fishes.

Samples from the port and starboard nets of the mid-depth Bongo samples collected prior to December 1979 were combined. This total sample was then split twice with a Folsom splitter and 25% was processed. Beginning in December 1979 samples from the port and starboard sides were preserved separately. One of these was selected at random and split once with a Folsom splitter. Of the two aliquots that resulted, one (25% of the total) was processed, whereas the other was archived. Absence of either fish eggs or larvae in the first aliquot that was processed dictated that an additional 25% aliquot be processed, which occurred in 6 of the 144 mid-depth zooplankton samples.

Once the splitting procedure was completed, the eggs and larvae of fishes were removed from that portion of the sample. The goal was to sort samples with at least a 90% sorting efficiency. Each sample was checked for this level of efficiency by having a second technician remove and sort 10% of the sample using a Hensen-Stemple pipette. If the number of either eggs or larvae exceeded 1% of the total count for eggs or larvae previously reported in the sample, suggesting that more than 10% of the individuals in the entire sample were missed, the sample was resorted completely. This sort-check procedure was repeated until the counts obtained through this process indicated that the sample was sorted at an efficiency of 90% or greater. Samples containing fewer than 100 eggs or individual fishes posed a problem because the finding of a single egg or larva constituted sort-check failure. The procedure was modified for this contingency. For those samples where the original sorting produced 33 or fewer eggs or larvae the sort-check failed if even one egg or larva was found. If the sample, after sorting, contained between 34 and 49 eggs or larvae the finding of one egg or larva in the ten percent sort check did not necessarily constitute failure. If one egg or larva was found then it was mandatory that an additional 20% of the aliquot be sorted. The sort-check could be passed only if no additional eggs or larvae were detected in the 20%; if any were observed the sort-check failed. For those samples where the original sorting produced 50 to 99 eggs or larvae the finding of a single egg or larva did not indicate failure; but, an additional 10% portion of the aliquot was sorted. If no egg or larva was detected in this second portion the sample was considered to have passed the required level of efficiency.

After a sample passed at the 90% sorting level it was archived and the eggs and larvae identified. Emphasis was directed towards the identification of larvae rather than eggs, and where possible, to the specific level. Although little emphasis was placed upon the identification of fish eggs, anchovy eggs (almost exclusively *Engraulis mordax*) were routinely identified and enumerated separately. No attempt was made to identify the other eggs collected during the survey.

Larval Measurements

Larvae of 11 taxa (Table 3-5) were selected to be measured. Individuals were measured to the nearest 0.5 mm using either an ocular micrometer or a millimeter rule taped to the stage of a dissecting microscope. When exceptionally large numbers of individuals of any of these taxa occurred, an aliquot generally consisting of 60 to 85 randomly selected individuals was taken, and only those specimens were measured.

Census Estimates

Data on plankton displacement volume, total eggs, total larvae and individual taxa from each sample were scaled to estimate numbers per thousand cubic meters and number under ten square meters of sea surface following the procedures outlined in Smith and Richardson (1977). These data were then utilized to estimate the numbers of individuals of the various taxa occurring within sections of the study area and ultimately the entire study area.

Table 3-5. 316(b) target species with free-swimming planktonic larval stages.

Species	Common Name
1. *Engraulis mordax*	northern anchovy
2. *Genyonemus lineatus*	white croaker
3. *Seriphus politus*	queenfish
4. *Cheilotrema saturnum*	black croaker
5. *Umbrina roncador*	yellowfin croaker
6. *Roncador stearnsii*	spotfin croaker
7. *Paralabrax clathratus*	kelp bass
8. *P. nebulifer*	barred sand bass
9. *Anisotremus davidsonii*	sargo
10. *Sebastes paucispinis*	bocaccio
11. *Peprilus simillimus*	Pacific butterfish

AREAL AND VOLUMETRIC ESTIMATES

Areal and volumetric estimates were derived for ocean water bordered by the Southern California Bight ichthyoplankton assessment transects. By knowing the total area and volume contained within these transects, the theoretical magnitude of ichthyoplankton populations in the Southern California Bight was calculated.

Coordinates of actual sampling stations taken from Lavenberg and McGowan (1982) were plotted on relatively small scale bathymetric charts. Transects were drawn through these stations to include

5 different depth station locations of 8, 15, 22, 36 and 75 m. The coordinates of all stations were recorded. Dividers were used to measure the closest distance from shore to each station in nautical miles as determined from the chart scales. The distance was then converted to kilometers (Table 3-1).

The navigation charts used for making the areal estimates (NOAA 18740 and 18720) had contours marked at 10 fm intervals. The distance measured along the 20 fm (36.6 m) contour was used to determine the longshore distance between transects, since it was approximately the middle of the depth zone being measured (0 to 75 m). Using this standard distance measurement for all depths was considered more accurate than straight line measurements at each depth, since it followed the actual contour of the bottom. This type of measurement was particularly important where the coastline was irregular.

Knowing the surface dimensions and sample depths, and assuming a constant slope on the sea bottom, a wedge-shaped prism model was developed to represent the areal and volumetric extents of neritic waters composing the Southern California Bight (Figure 3-5). The assumption that the sea bottom has a constant slope was somewhat unrealistic and introduced an element of error; however, a more precise estimate was not required given the variation of the ichthyoplankton data.

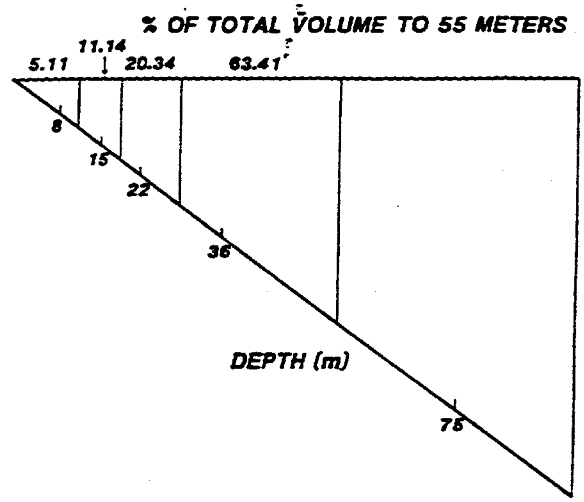

Figure 3-5. Prism model of % volume to a depth of 55 m in the Southern California Bight.

The following formulae were used to determine the area and volume of a "neritic prism" bounded by two transects:

Volume Calculations:

$$\text{Volume} = 1/8\ [A + \text{station (km)}]\ [D_1 + D_2]\ [H_1 + H_2]$$

where

A = first station depth in interval (e.g. "0" in the 0 to 8 m interval)

station (km) = second station depth in interval (e.g. "8" in the 0 to 8 m interval)

D_1 = length of coastline between transects (for 0 to 8 m station calculations)

= length of the 20 fathom contour between transects (for all other station calculations)

D_2 = length of the 20 fathom contour between transects for all station calculations

H_1 = transect distance between stations for the first transect

H_2 = transect distance between stations for the second transect

Area Calculations:

$$\text{Area}_{(8\text{ m station})} = 1/4\ [d_1 + d_2]\ [h_1 + h_2]$$

$$\text{Area}_{(15,\ 22,\ 36,\ \text{and}\ 75\ \text{m stations})} = 1/2\ d_1\ [h_1 + \bar{h}_2]$$

where

d_1, d_2, h_1 and h_2 definitions are the same as those for the volume calculations.

Using the above formulae, estimated surface areas and volumes of ocean water bordered by the various transects and depth stations were calculated. These data form the basis for calculations of total ichthyoplankton abundance along the southern California coast and are discussed below.

RESULTS

DESCRIPTION OF DATA SUMMARIES

The ichthyoplankton data were summarized into two data appendices incorporating the variables of larval stage, area (transect location), depth, sample type (oblique Bongo, Manta, Auriga, or midwater Bongo), and year class.

The first (Appendix 3-A) is an estimate of size class density for the Southern California Bight, weighted for volume at depth. The table shows estimated densities for both a combination of Manta, oblique Bongo, and Auriga at power plant transects, and oblique Bongo only at all transects.

Appendix 3-B gives an estimate of density of size classes, where length data for select species is summarized to show the number of individuals per 1000 m^3 falling into each 1 mm size class at each depth. The data are grouped by sample type and area.

METHODS USED TO DEVELOP DATA SUMMARIES

Appendix 3-A, the estimate of size class densities in numbers per 1000 m^3 for the Southern California Bight, provides densities using either combined sample types (Manta, oblique Bongo, and Auriga) or using oblique Bongo tows only. The table is a result of the following steps:

a. The raw data for each sample type was first scaled to reflect ichthyoplankton densities in numbers per 1000 m^3 in that portion of the water column sampled by each device.

b. Mean density through the water column was then determined by proportionally summing the densities according to the amount of the water column sampled by each method, then dividing by the total depth. The assumption was made that the Manta net samples the surface to a depth of 0.1 m; the Auriga net samples the bottom 0.5 m of the water column and the oblique Bongo net samples the intermediate depths, i.e., total depth in meters minus 0.6. The formula was then:

$$0.1d_m + (D - 0.6)d_o + 0.5d_a = \text{Mean density of ichthyoplankton in water column at depth "D"},$$

where d_m = density in Manta samples;
d_o = density in oblique Bongo samples;
d_a = density in Auriga samples;
D = depth in meters.

c. After density was determined for the water column at each depth increment, that density was multiplied by the estimated percentage of the

Southern California Bight volume occupied by water of that depth. Methods used in determining the areas and volume of depths from 0 to 8 m, 8 to 15 m, 15 to 22 m, etc., were discussed previously. Further calculations were made to determine Bight-wide volumes bracketing the sample mid-point depths of 8, 15, 22, 36, and 75 m, that is, changing the cut-off points to 11.5, 18.5, 29 and 55.5 m. This was accomplished by regression of the original data to determine volumes (and areas) included between points equidistance between two adjacent sample depths (Figure 3-5).

d. Using the volume weighting factors for each depth range, densities were determined independently for each 1 mm size class for each depth range. Density throughout the Bight was then calculated for each size class by summing densities from each depth range then dividing by 4, the number of depth ranges considered. The densities were calculated using all sample types (= combined) and using oblique Bongo data only. The size class densities were determined by developing a ratio betwen the density of measured larvae versus total larval density. The percent contribution of each 1 mm size class of the measured larvae was then multiplied by total larval density to extrapolate size class densities among all larvae collected.

Appendix 3-B presents size class distributions by depth for each species. Densities were weighted to reflect density per 1000 m^3 for each depth. The data was repeated for each sample type (Manta, Auriga, oblique and mid-depth Bongo) at power plant transects and again for oblique Bongo only at all transects (all samples). A size class is missing if no larvae occurred at any depth for that size class. Other size classes were adjusted to reflect total numbers of larvae sampled as explained for Appendix 3-A above.

APPENDIX 2-A

ESTIMATION OF BIGHT ICHTHYOPLANKTON STOCKS

The volume of water in the nearshore zone to a depth of 75 m between Cojo Bay and San Diego was determined by the method described in Chapter 3. This estimate of the nearshore Bight habitat volume was used to estimate ichthyoplankton populations from average annual density data from each depth strata.

The cumulative volume of the nearshore Bight as a function of depth is shown in Figure 2-4. Interpolated cumulative values in one meter depth increments are given in Table 2A-1.

Ichthyoplankton data were available from two major surveys: the Bight-wide survey (Lavenberg and McGowen 1982) which was part of the SCE 316(b) study plan, and the surveys in the San Onofre region conducted by Marine Ecological Consultants (MEC) for the Marine Review Committee, Inc. (Barnett et al. 1980a). Similar sampling methods were used for both surveys and taxonomic calibration was maintained by a series of periodic meetings directed by the Los Angeles County Museum of Natural History (McGowen, personal communication). The MEC study featured an extensive offshore transect. Samples were taken in the following depth zones: 6 to 9, 9 to 12, 12 to 22, 22 to 45, and 45 to 75 m. The Bight-wide study sampled at 8, 15, 22, and 36 m depths. Although the sampling periods did not coincide, comparisons of the on-offshore trends in both sets of data indicated general similarity. MEC data were accepted as generally representative of the on-offshore distribution of nearshore ichthyoplankton as reported by Barnett et al. (1980a). The size frequency distributions of the Bight-wide data for northern anchovy, white croaker, queenfish, and kelp and barred sand bass are presented in Figure 2A-1. Noteworthy features were older larvae in the 8 m zone, early larvae predominating at 22 m, and reduced concentrations of younger larvae at 36 m. This pattern corroborates the more detailed discussion of Barnett et al. (1980a).

Table 2A-1. Interpolated cumulative values for the nearshore Southern California Bight habitat volume to a depth of 75 m (see Chapter 2).

Depth (m)	Cumulative Volume (km^3)	Depth (m)	Cumulative Volume (km^3)	Depth (m)	Cumulative Volume (km^3)
8	0.9333	31	24.6643	54	57.6742
9	1.4747	32	25.8982	55	59.1708
10	2.0161	33	27.1321	56	60.6674
11	2.5575	34	28.3660	57	62.1640
12	3.0989	35	29.5999	58	63.6606
13	3.6403	36	30.8338	59	65.1572
14	4.1817	37	32.2320	60	66.6538
15	4.7231	38	33.7286	61	68.1504
16	6.1558	39	35.2252	62	69.6470
17	7.3897	40	36.7218	63	71.1436
18	8.6236	41	38.2184	64	72.6402
19	9.8575	42	39.7150	65	74.1368
20	11.0914	43	41.2116	66	75.6334
21	12.3253	44	42.7082	67	77.1300
22	13.5592	45	44.2048	68	78.6266
23	14.7931	46	45.7014	69	80.1232
24	16.0270	47	47.1980	70	81.6198
25	17.2609	48	48.6946	71	83.1164
26	18.4948	49	50.1912	72	84.6130
27	19.7287	50	51.6878	73	86.1096
28	20.9626	51	53.1844	74	87.6062
29	22.1965	52	54.6810	75	89.1028
30	23.4304	53	56.1776		

The ichthyoplankton standing stock estimates were developed by assuming the Bight-wide data were representative samples of the following depth strata: 0 to 12, 12 to 19, 19 to 29, and 29 to 56 m, at the mid-depth of which the samples were actually collected. These represent habitat volumes of 3.10, 6.76, 12.34, and 38.47 km^3, respectively. Size frequency distributions for the ichthyoplankton weighted by the proportion of segment volume to the total (0.0511, 0.1114, 0.2034, and 0.6341) are given in Table 2-3. These represent the average size frequency density distribution over the Bight-wide sampling volume (60.68 km^3). MEC data indicated that a fifth depth stratum

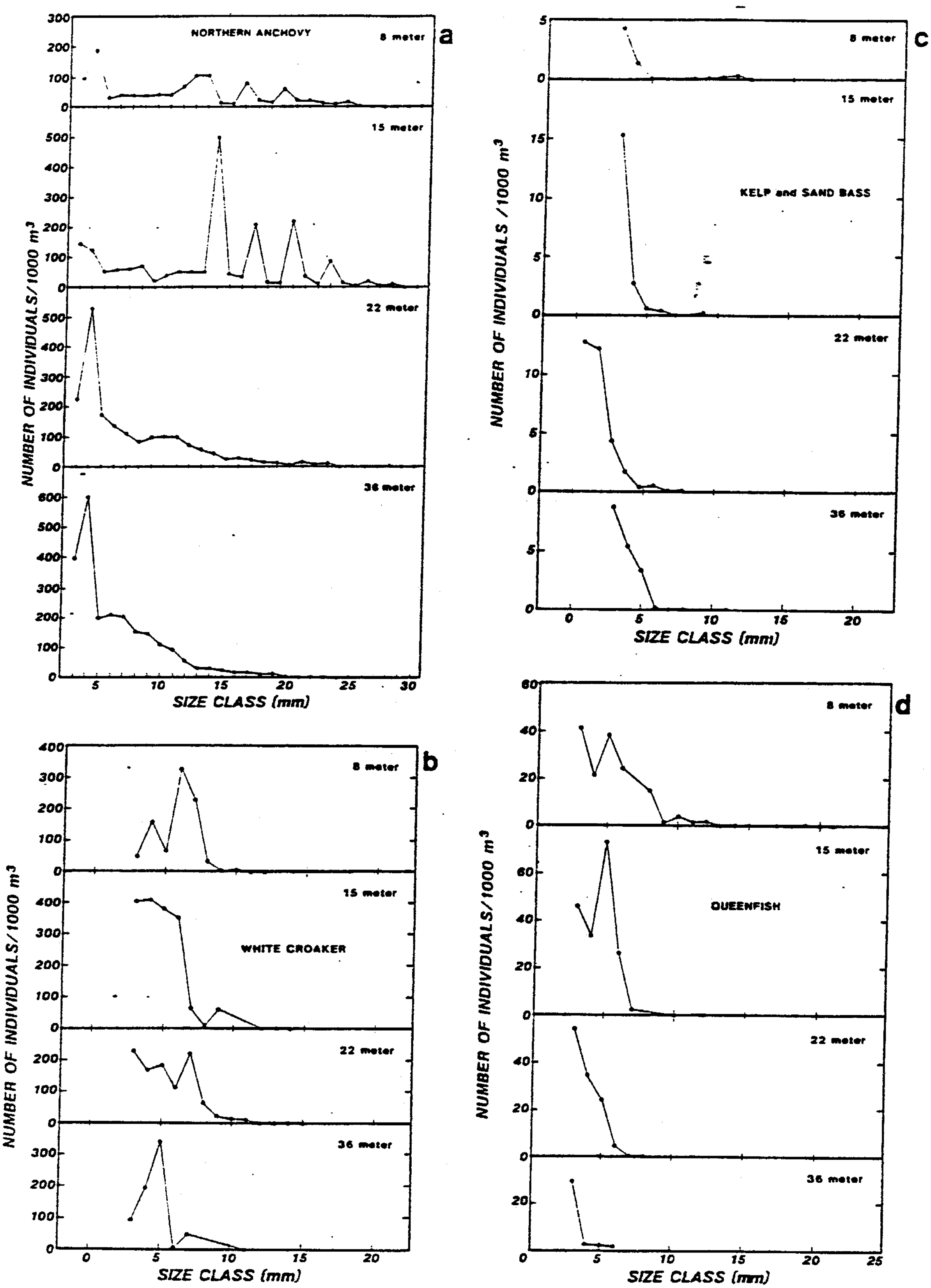

Figure 2A-1. Mean Bight-wide size frequency distributions of four 316(b) target species larvae: a) northern anchovy; b) white croaker; c) kelp and barred sand bass; and d) queenfish.

of 56 to 75 m should be included in population estimates. To determine the magnitude of the population in this zone, the Bight-wide (BT) estimates were adjusted by estimating the population in the habitat volumes to 56 m and 75 m with the following formula:

$$BT_{56} = (3.1\ BT_8 + 6.8\ BT_{15} + 12.3\ BT_{22} + 38.5\ BT_{36})\ (10^6);$$

$$BT_{75} = (BT_{56} + MEC_e/MEC_d)\ (BT_{36})\ (10^6),$$

where BT_8, BT_{15}, BT_{22}, BT_{36} = Bight-wide ichthyoplankton densities at 8, 15, 22, and 36 m depth (number/1000m^3), and

MEC_d, MEC_e = MEC ichthyoplankton densities for the last two depth MEC strata (22 to 45 and 45 to 75 m).

The ratio, MEC_e/MEC_d, is a good approximation because the last Bight-wide depth stratum and penultimate MEC strata practically coincide. Absolute MEC values were not used because MEC samples were not synoptic with the entrainment sampling as was the case for the Bight-wide data. Summary results of this comparison for total larvae is given in Table 2A-2. Although the additional volume in the 56 to 75 m depth stratum adds about 47% to the volume sampled by the Bight-wide study, typically it adds a smaller percentage of larvae, as densities declined with depth.

Table 2A-2. Summary ichthyoplankton density data used to estimate Bight-wide standing stocks. Densities in number per 1000 m3 averaged over the respective study periods.

	Bight-wide Sample Depths (m)*				MEC Sample Depths (m)**		
Species	8	15	22	36	22-45	45-75	Stock Ratio***
Northern anchovy	2150	2180	5239	5190	3050	1540	1.26
White croaker	877	1699	1036	684	1860	374	1.07
Queenfish	177	181	117	38	38	16	1.10
Kelp and sand bass	6	20	32	18	29	14	1.21

* Bight-wide August 1979-July 1980

** MEC January 1978-October 1979

*** Stock to 75 m (Bight-wide and MEC)/Stock to 56 m (Bight-wide only)

APPENDIX 2-B

POPULATION ESTIMATE FOR NORTHERN ANCHOVY

Northern anchovy is the only abundant member of the nearshore ichthyoplankton for which it is possible to easily identify the egg stage. The Bight-wide estimate for mean anchovy egg densities was as follows:

Depth (m)	Density Number/1000 m^3
08	2150
15	2180
22	5239
36	5190

Apparently, the most intensive spawning occurs in the deeper nearshore waters (beyond about 20 m). By the depth weighting technique described in Appendix 2-A, the standing stock of eggs to 75 m was estimated to be 3.6×10^{11}. Smith (personal communication) gives a general finite exponential mortality rate of 0.41 per day (= -0.5276) for the first eight days of northern anchovy life. Assuming the egg stage to endure for 2.5 days and that the standing stock of eggs is distributed by this exponential rate, it is possible to estimate the initial production of eggs by the formula:

$$N_o = \frac{(-Z)(N_{tot})}{[1-e^{(Z\ t)}]}$$

where N_o = the initial number of eggs;

Z = the exponential mortality rate (-0.5276);

N_{tot} = the total standing stock (3.6×10^{11});

t = the duration of the egg stage (2.5 days).

Substitution into this formula gives an estimate of $N_o = 2.6 \times 10^{11}$. Smith also provided mortality rates for several stages through 365 days, and estimates of adult mortalities are available from the literature (Hanan 1981, Huppert et al. 1980). From these the following mortality model can be constructed:

Age Interval (days)	Exponential Mortality Rate (per day)
0-8	-0.5276
8-20	-0.1278
20-50	-0.0387
50-150	-0.0151
150-365	-0.0041
365-1825	-0.0030

The formula:

$$N_t = N_0 e^{(Z_i t)}$$

where N_t = number at day t;
N_0 = initial number;
Z_i = exponential mortality rate,

can be applied successively starting with N_0 = the initial production of eggs, to calculate age class abundances at latter ages. The number of 331 day northern anchovy = 2.4×10^7, and 365 day northern anchovy = 2.1×10^7. The 331 day northern anchovy are equivalent to 90 mm size fish (see Appendix 2-G). The formula:

$$N_{tot} = \frac{-N_t [1-e^{(Z T)}]}{Z}$$

where N_{tot} = total number in an age interval;
N_t = number at beginning of age interval;
T = duration of age interval;
Z = mortality rate,

can be used to calculate the number of fish in an age interval. By applying the above two formulae in succession, it is possible to generate the abundances of successive age classes. This was accomplished for age classes determined by 10 mm size class steps starting at 90 mm (see Appendix 2-G). In producing the northern anchovy population values in Table 2-4, the slightly higher mortality rate for adults (0.0030) was applied to all stages. This results in slightly lower population estimates and is therefore a conservative choice.

An estimate of the egg to early larval mortality rate was developed from the Bight-wide data using the abundance of the egg standing stock as 3.6×10^{11} and that of the second class (to 3 mm) as 6.46×10^{10}. Assuming the mid-age of the egg class is 1.25 days and that of the second class is 4.47 days, a mortality rate was estimated as

$$Z = \frac{\ln (6.46 \times 10^{10}) - \ln (3.6 \times 10^{11})}{(4.47-1.25)} = -0.5335,$$

which is similar to the value of Smith (personal communication).

APPENDIX 2-C

ESTIMATES OF ADULT QUEENFISH AND WHITE CROAKER FIELD POPULATIONS

Adult field populations were estimated by determining the number of eggs from the larval field data and estimating the number of females required to produce the eggs. From the number of females, the total population of adults was estimated by assuming a 1:1 sex ratio.

Estimation of the Number of Eggs

Eggs of these species cannot be easily identified; therefore, the number of early larvae was used to estimate the number of eggs. The number of early larvae was estimated by applying the formula for the initial abundance of an age class given in Appendix 2-B,

$$N_0 = \frac{-N_t Z}{[1-e^{(Z\ T)}]}$$

where N_t = total abundance in class;
Z = mortality rate;
T = duration of a class.

The abundance of larvae through 5 mm in size was used. Larvae this small are not seriously undersampled due to net avoidance. The nominal first size of this class is taken as 2 mm. The abundance of these early larvae is:

	Queenfish	White Croaker
Estimated Stock to 5 mm	4.49×10^9	4.29×10^{10}

The slope of the age frequency distribution for queenfish in this class is -0.25, which is in general agreement with that expected for queenfish in the same class (Barnett et al. 1980a). The mortality rate for white croaker was set at -0.10, which is the value given for that species by Barnett et al. (1980b). This value is conservatively low in that a higher rate leads to a larger population estimate. The size-age relations (see Appendix 2-G) provide an age range of 7 to 19 days for queenfish and 14 to 29 for white croaker. This initial age for white croaker appears rather high because this size class should contain the recently hatched larvae of about 5 days age (Lavenberg, personal communication). Accordingly, it was set at 7 days in parallel with queenfish. Inserting these values into the formula gives an estimate of the stock of day-7 larvae:

	Queenfish	White Croaker
Estimated Stock of day-7 larvae	1.19×10^9	4.85×10^9

An extrapolation from the initial early day class to the number of eggs is estimated with an egg to early larvae mortality rate. An estimate of -0.5276 for egg to early northern anchovy was presented in Appendix 2-B. The rate represents about a 40-fold decline in 7 days. Barnett et al. (1980b) estimated the mortality rate of queenfish as a function of age. Their estimate depended upon a net estimate of ichthyoplankton and a net (Lampara seine) estimate of adult queenfish density. The capture efficiency of the Lampara net was estimated using tagged queenfish. However, given the sensitivity of queenfish to handling (Stephens, personal communication), marked queenfish were probably easier to catch than wild queenfish. Thus, the number of eggs which were estimated from the number of adult females was probably underestimated. This results in estimating a lower than actual mortality rate for egg to early larvae. For instance, the decline in queenfish to age 7 days is only about 11 fold. However, because it is conservative to assume a lower rate, the early survivorship developed for queenfish was used to project egg abundances from early larvae for both these species.

An estimate for average daily egg production can be obtained by multiplication of the 7-day larval class abundance by 11. If this value is multiplied by 365 an estimate of the annual egg production for these two croakers may be obtained. These values are:

	Queenfish	White Croaker
Estimated Annual Egg Production	4.68×10^{12}	1.91×10^{13}

The value for queenfish can be compared to an estimate for egg production of 1 km of shoreline by Barnett et al. (1980b). The value for the Bight is 193 times larger indicating the value used in the model (4.68×10^{12}) is conservatively low, since there are about 440 km of coast in the nearshore Bight, as defined in this study. These eggs are produced by the standing stock of female fish over the course of a year. This stock can be estimated given adult fecundity and survivorship data.

Recent studies on queenfish (DeMartini and Fountain 1981) and white croaker (Love et al. 1982) produced detailed quantitative descriptions of the fecundity of these species in the Southern California Bight. These studies provide data for the relation of batch fecundity to size and the proportion of batch spawning females during the year as a function of size. The pertinent data from these studies are summarized in Table 2C-1. Also required to calculate the number of females which produce the estimated production of eggs is the mortality rate of adults. Lampara samples of white croaker and queenfish size frequency distribution were made at several locations throughout the Bight during the Fish Encounter Studies (Thomas et al. 1980b). Their data are summarized in Table 2C-2. From these data, adult mortality rates can be estimated as the regression of ln(abundance) against age, as was accomplished above for larval mortality rates.

The resulting estimates of the (per day) mortality rates are summarized below:

white croaker: -0.00115;
queenfish: -0.0019.

These compare to previous values for queenfish of -0.0020 (DeMartini 1979) and -0.0017 for white croaker (Phillips et al. 1972).

The total egg production estimates, the fecundity data, and the adult mortality data can be analyzed to produce an adult population estimate as follows:

$$TE = \sum_{x=1}^{n} NF_x \; FE_x$$

Table 2C-1. Spawning frequency and batch fecundity relationships for female queenfish and white croaker.

Size (mm)	Average number of spawns per year*	
	Queenfish	White Croaker
<105	0.25	2.44
110	9.35	10.63
115	14.76	11.55
120	17.96	13.30
125	22.63	14.18
130	23.68	17.28
>135	24.68	18.73

*Size/Batch Fecundity Relation

Queenfish

$$E(x) = 10^{[3.3809 + (0.4343) \ln (x) - 3.1455]}$$

White Croaker

$$E(x) = e^{(4.048 [\log(x/10)] - 2.683)}$$

where

$E(x)$ = number of eggs per batch
x = standard length in mm.

(from DeMartini et al. 1982, Love et al. 1982, and Love, personal communication).

Table 2C-2. Age-frequency distributions for white croaker and queenfish. Aggregated Lampara seines from the nearshore Bight offshore Ormond Beach, Huntington Beach, El Segundo, and San Onofre (from Thomas et al. 1980b).

White Croaker		Queenfish	
Age class (days)	Abundance	Age class (days)	Abundance
509- 579	1066	221- 261	1689
579- 653	1333	261- 306	1272
653- 732	971	306- 357	784
732- 815	887	357- 413	543
815- 903	856	413- 475	475
903- 995	816	475- 543	485
995-1092	978	543- 617	530
1092-1194	616	617- 699	527
1194-1301	622	699- 787	389
1301-1412	599	787- 883	329
1412-1529	532	883- 987	335
1529-1650	556	987-1099	271
1650-1776	534	1099-1220	194
1776-1908	491	1220-1349	207
1908-2045	323	1349-1488	139
2045-2186	310	1488-1637	110
2186-2333	187	1637-1795	73
2333-2486	121	1795-1964	61
2486-2644	650	1964-2143	29
2644-2807	490	2143-2334	30
2807-2975	410	2334-2536	26
2975-3149	130	2536-2750	13
3149-3329	400	2750-2976	9
3329-3514	200	2976-3215	14
		3215-3467	1
		3467-3732	1

where TE = total eggs;
NF_x = number of females of size class x;
FE_x = total fecundity at size x.

Total fecundity is the product of batch fecundity and the average number of spawning individuals at size x. All the values of NF_x can be derived from the initial value, NF_1, which is the 90 mm class, by the relations

$$NF'_x = NF_1 \, e^{(Z\ T)}, \quad \text{(initial number)}$$

and

$$NF_x = -NF'_x \frac{[1-e^{(Z\ t)}]}{Z} \quad \text{(total number in the size class interval)}$$

where NF'_x = initial day class of the size class x;
T = duration of size class x;
t = duration from NF_1 to NF_x.

The value of NF'_1, the abundance of females at the onset of fertility, can be determined since it is the only unknown quantity (Table 2C-3).

From these population estimates, the number of fish at size 90 mm (day 265 for white croaker and day 185 for queenfish) can be calculated using the formula for initial numbers as 3.05×10^5 and 7.35×10^4, respectively. These are the values used as input into the calculations for R_c values (Appendix 2-H).

Table 2C-3. Total adult queenfish and white croaker stocks in the Southern California Bight determined from fecundity data (from Demartini and Fountain 1981 and Love et al. 1982).

Average age of Females (days)	Batch Fecundity	Total Fecundity	Age Class Fecundity	Cumulative Fecundity
		Queenfish		
202	3185	796	1.01×10^{9}	1.01×10^{9}
240	3805	951	1.27×10^{9}	2.28×10^{9}
283	4504	1126	1.55×10^{9}	3.84×10^{9}
331	5290	1322	1.86×10^{9}	5.70×10^{9}
384	6168	57677	8.12×10^{10}	8.69×10^{10}
443	7144	105453	1.47×10^{11}	2.34×10^{11}
508	8224	147708	2.00×10^{11}	4.33×10^{11}
580	9414	213043	2.75×10^{11}	7.09×10^{11}
658	10720	253860	3.09×10^{11}	1.01×10^{12}
742	12149	298877	3.37×10^{11}	1.35×10^{12}
835	13707	337209	3.46×10^{11}	1.70×10^{12}
935	15401	378878	3.48×10^{11}	2.05×10^{12}
1043	17237	424049	3.43×10^{11}	2.39×10^{12}
1159	19223	472885	3.30×10^{11}	2.72×10^{12}
1284	21364	525555	3.10×10^{11}	3.03×10^{12}
1418	23667	582227	2.86×10^{11}	3.32×10^{12}
1562	26141	643071	2.57×10^{11}	3.57×10^{12}
1715	28791	708262	2.26×10^{11}	3.80×10^{12}
1879	31624	777973	1.94×10^{11}	3.99×10^{12}
2053	34649	852382	1.62×10^{11}	4.16×10^{12}
2238	37872	931667	1.32×10^{11}	4.29×10^{12}
2435	41301	1.02×10^{6}	1.06×10^{11}	4.39×10^{12}
2643	44942	1.11×10^{6}	8.20×10^{10}	4.48×10^{12}
2863	48804	1.20×10^{6}	6.20×10^{10}	4.54×10^{12}
3095	52894	1.30×10^{6}	4.56×10^{10}	4.58×10^{12}
3340	57220	1.41×10^{6}	3.27×10^{10}	4.62×10^{12}
3599	61788	1.52×10^{6}	2.28×10^{10}	4.64×10^{12}
3871	66608	1.64×10^{6}	1.54×10^{10}	4.65×10^{12}
4157	71687	1.76×10^{6}	1.01×10^{10}	4.66×10^{12}
4458	77033	1.90×10^{6}	6.47×10^{9}	4.67×10^{12}
4773	82653	2.03×10^{6}	4.00×10^{9}	4.67×10^{12}
5103	88556	2.18×10^{6}	2.40×10^{9}	4.68×10^{12}
5449	94750	2.33×10^{6}	1.40×10^{9}	4.68×10^{12}
5811	101243	2.49×10^{6}	7.86×10^{8}	4.68×10^{12}
6189	108043	2.66×10^{6}	4.28×10^{8}	4.68×10^{12}
6584	115159	2.83×10^{6}	2.25×10^{8}	4.68×10^{12}
6997	122598	3.02×10^{6}	1.15×10^{8}	4.68×10^{12}
		White Croaker		
292	273	667	5.35×10^{9}	5.35×10^{9}
348	373	911	7.38×10^{9}	1.27×10^{10}
408	501	1224	9.94×10^{9}	2.27×10^{10}
473	665	1623	1.31×10^{10}	3.58×10^{10}
543	870	9251	7.35×10^{10}	1.09×10^{11}
617	1125	13000	1.01×10^{11}	2.10×10^{11}
695	1440	19155	1.44×10^{11}	3.55×10^{11}
778	1824	25875	1.88×10^{11}	5.42×10^{11}
867	2291	39592	2.74×10^{11}	8.16×10^{11}
960	2852	53431	3.50×10^{11}	1.17×10^{12}
1057	3524	68511	4.23×10^{11}	1.59×10^{12}
1160	4322	84026	4.84×10^{11}	2.07×10^{12}
1269	5265	102357	5.46×10^{11}	2.62×10^{12}
1382	6373	123897	6.08×10^{11}	3.23×10^{12}
1501	7668	149080	6.67×10^{11}	3.89×10^{12}
1625	9175	178381	7.23×10^{11}	4.62×10^{12}
1754	10921	212320	7.73×10^{11}	5.39×10^{12}
1889	12935	251463	8.17×10^{11}	6.21×10^{12}
2029	15248	296430	8.53×10^{11}	7.06×10^{12}
2175	17895	347889	8.80×10^{11}	7.94×10^{12}
2327	20914	406568	8.97×10^{11}	8.84×10^{12}
2484	24344	473252	9.04×10^{11}	9.74×10^{12}
2648	28229	548788	9.00×10^{11}	1.06×10^{13}
2817	32617	634089	8.87×10^{11}	1.15×10^{13}
2992	37558	730138	8.64×10^{11}	1.24×10^{13}
3173	43106	837986	8.33×10^{11}	1.32×10^{13}
3360	49319	958761	7.94×10^{11}	1.40×10^{13}
3553	56258	1.09×10^{6}	7.49×10^{11}	1.48×10^{13}
3753	63991	1.24×10^{6}	6.99×10^{11}	1.55×10^{13}
3958	72588	1.41×10^{6}	6.45×10^{11}	1.61×10^{13}
4170	82124	1.60×10^{6}	5.89×10^{11}	1.67×10^{13}
4388	92680	1.80×10^{6}	5.33×10^{11}	1.72×10^{13}
4613	104340	2.03×10^{6}	4.77×10^{11}	1.77×10^{13}
4844	117194	2.28×10^{6}	4.22×10^{11}	1.81×10^{13}
5082	131338	2.55×10^{6}	3.70×10^{11}	1.85×10^{13}
5326	146874	2.86×10^{6}	3.21×10^{11}	1.88×10^{13}
5577	163908	3.19×10^{6}	2.76×10^{11}	1.91×10^{13}

Queenfish: Estimate of total population Age 185 days to 6787 days = 3.87×10^{7} individuals

Input Parameters:
- Daily Mortality Rate = -0.0019
- Total Eggs = 4.68×10^{12}
- Start Size = 90 mm
- End Size = 270 mm

White croaker: Estimate of total population Age 265 days to 5451 days = 2.65×10^{8} individuals

Input Parameters:
- Daily Mortality Rate = -0.00115
- Total Eggs = 1.91×10^{13}
- Start Size = 90 mm
- End Size = 270 mm

APPENDIX 2-D

ESTIMATES OF ADULT POPULATIONS OF KELP BASS AND BARRED SAND BASS

Young (1963) summarized kelp bass fishery and biological information, which included some tagging data, an estimate of mortality rate in an unexploited population at 25% per annum, and a size-age relation. He implied that the sport fishery may increase natural mortality 5% per annum. Review of the sport fish data indicated that the party boat catch is about 500,000 fish per year; half of these may come from the Channel Islands. Pinkas et al. (1968) indicated that about half of the total sport catch is counted in the party catch, so 500,000 fish per year is an order of magnitude estimate of annual kelp bass catch. Using this value and assuming that the fishery adds a 5% per annum mortality to a natural mortality of 25%, it is possible to estimate the fishery stock which is assumed to be comprised of fish between 5 and 10 years of age and to have a stable age distribution. The technique is to solve for the number of age 5-year fish entering the fishery given that fishing mortality is a fixed proportion of overall mortality. The abundance of all age classes in the fishery is related to the abundance of the entry class (age 5-year) by

$$N_{(T+5)} = N_5 \, e^{(m+f)\,T}$$

where m = natural mortality;
f = fishing mortality;
T = years from entry age class (e.g. 0, 1, 2, 3, 4, 5).

The number of fish which die while in the fishery is

$$D = N_5 - N_{10}$$

The proportion of D which is lost to the fishery is f/f+m. Therefore, the catch, C, can be expressed as

$$C = \frac{f}{f+m}\,(N_5 - N_{10})$$

N_{10} can be replaced by $N_5 \, e^{(f+m)5}$,

so $$C = \frac{f}{f+m}\,[N_5 - N_5 \, e^{5(f+m)}],$$

or $$C = \frac{f}{f+m}\,N_5\,[1 - e^{5(f+m)}].$$

Given that $C = 500{,}000$;
$f+m = \ln(0.70) = -0.3567$;
$m = \ln(0.75) = -0.2877$;
$f = -0.069$,

N_5 can be calculated from

$$500{,}000 = \frac{-0.09}{-0.3567}\,N_5\,[1-e^{(-1.7835)}],$$

$$N_5 = 3.107 \times 10^6.$$

Using this number and the formulae given in Appendix 2-C, the following population parameters can be calculated:

Total stock between age class 5 and 10 = 7.69×10^6;
Abundance of day class 1825 = 10,121;
Abundance of day class 491 (size 90 mm) = 28,962.

The last value is used to initialize the adult age class estimates in calculating R_c values (Appendix 2-H).

APPENDIX 2-E

ESTIMATE OF SURFPERCH POPULATIONS

Abundances of adult white and shiner surfperch were estimated in a manner analogous to that developed in Appendix 2-D for kelp bass.

COMMERCIAL CATCH

Catch statistics for perch species are sparse and often vague. All perch and perch-like species (halfmoon, opaleye, sargo, etc.) are lumped into a single "perch" category for commercial catch records. To relate commercial fishery losses to white surfperch, reference will be made to observations by Frances Clark (Bureau of Commercial Fisheries 1937) that "somewhat more than half the landings consist of Pacific white perch". Clark noted that most of the southern California perch is caught incidentally in lampara nets used by bait fishermen.

The mean annual southern California perch catch from 1973 through 1976 was 59,588 lbs. Assuming 50% of this to be white surfperch results in an annual white surfperch catch of 29,794 lbs. The number/weight ratio of fish impinged at coastal power plants was used to convert weight data to number of individuals (Herbinson, personal communication). Average weight of white surfperch over the two-year period from August 1978 through September 1980 was 0.147 pounds. Assuming these surfperch to enter the fishery at age class 3-year and the fishery to exist over the four succeeding age classes, and that the fishing mortality is less than for kelp bass (2% for white surfperch), estimates of white surfperch abundance can be made given estimates of mortality rates. Mortality for white surfperch is assumed the same as for white croaker. Using these figures, the estimated number of white surfperch caught per year is 202,267.

Shiner surfperch are taken primarily by pier and jetty fishermen with very few fish being taken from boats (Pinkas et al. 1968). This is consistent with the habitat preference of this species for shallow back-bay waters (Odenweller 1975). Because this type of habitat is rather restricted in southern California and adjacent to fishing access, it seems reasonable to assume conservatively that fishing pressure may be higher (Stephens, personal communication). The fishing mortality was assumed to add 2.5% to natural mortality. A total mortality rate was estimated from the aggregate impingement catch curve to be 42% per annum, which is very close to the rate for queenfish. The annual catch is estimated by Pinkas et al. (1968) at 133,000 in 1963. This figure has been used as typical.

Summary values utilized in the model were:

white surfperch:	Catch	= 200,000
	Total Mortality	= 34%/year (Z = -0.42)
	Natural Mortality	= 32%/year (m = -0.39)
	Fishing Mortality	= 2%/year (f = -0.03)
	Age of Entry in Fishery	= 3 year class
	Duration of Fishery	= 4
shiner surfperch:	Catch	= 133,000
	Total Mortality	= 42%/year (Z = -0.55)
	Natural Mortality	= 39.5%/year (m = -0.54)
	Fishing Mortality	= 2.5%/year (f = -0.01)
	Age of Entry in Fishery	= 2 year class
	Duration of Fishery	= 4

Applying the formula developed in Appendix 2-D

N_3 white surfperch = 3.4×10^6 $N_{(day\ 353)} = 10624$

N_2 shiner surfperch = 1.94×10^6 $N_{(day\ 757)} = 6902$

The given mortality model applies to fish of about ≥90 mm in size. The corresponding ages are 353 days for white surfperch and 757 days for shiner surfperch.

IMPINGEMENT LOSSES

Average annual impingement of white and shiner surfperch is 86,258 and 98,231, respectively (Herbinson, personal communication). Since these species are live bearers of well-developed young, larval entrainment is not a factor. To assess losses to the developing young, the impingement loss during periods of gravidity (Lane and Hill 1975; Herbinson, personal communication) was multiplied by the percent mature fish during that period and percent female during the same period. Percent mature was based on estimated length at maturity of 100 mm for white surfperch and 80 mm for shiner surfperch. Percent female was based on sexual composition of impinged fish (Herbinson, personal communication). These data are presented in Table 2E-1. By multiplying the number of mature females by the number of embryos carried (6 to 16, Lane and Hill 1975), an estimate of the number of embryos lost with gravid females is obtained.

Table 2E-1. Estimated number of mature female surfperch impinged per year at all SCE generating stations combined.

Month	% Mature*	% Female	% Mature females	Estimated monthly Impingement	Est. number of mature females impinged/month
			White Surfperch		
1	75.24	53.89	40.55	4,463	1,810**
2	73.58	61.33	45.13	15,730	7,099**
3	80.99	62.08	50.28	12,527	6,299**
4	84.94	73.60	62.52	3,331	2,083**
5	40.74	79.07	32.21	2,841	915
6	40.93	73.03	29.89	18,521	5,536
7	54.08	77.57	41.95	10,005	4,197
8	43.57	81.41	35.47	4,542	1,611
9	40.75	73.18	29.82	2,020	602
10	70.90	60.12	42.63	3,170	1,351
11	47.96	54.29	26.04	4,733	1,232
12	75.29	57.47	43.27	4,375	1,893
Total				50,207	17,291 (34.4%)
			Shiner Surfperch		
1	39.92	68.99	27.54	4,851	1,336
2	59.69	67.72	40.42	3,254	1,315
3	71.80	76.82	55.16	8,115	4,476**
4	96.67	84.82	82.00	2,277	1,867**
5	94.79	74.97	71.06	10,264	7,294**
6	80.03	80.32	64.28	10,675	6,862**
7	81.95	73.83	60.50	9,586	5,800
8	36.15	58.68	21.21	11,568	2,454
9	13.87	65.85	9.13	9,983	911
10	11.39	66.99	7.63	8,189	625
11	8.05	59.77	4.81	18,344	882
12	18.78	62.50	11.74	1,125	132
Total				98,231	20,499 (20.9%)

* Based on estimated length at maturity of 80 mm.

** Gravid period

The number of mature females impinged per year was multiplied by the fecundity (10.5 embryos/female) of the perch (Stephens, personal communication). These values were assumed to represent the 'virtual' catch of the first size class of perch (very young perch are too small, e.g. <90 mm, to be adequately sampled in the screenwells). An exponential rate of decline was estimated between the first class and the 90 to 100 mm size class. This rate was assumed to apply in the field. The calculation of mortality rate was

20,499 gravid females x 10.5 embryos/female = 214,420
number at size 90 to 100 mm = 16,180

$$\text{rate} = \frac{\ln (16180) - \ln (214420)}{409} = -0.0063$$

This compares to an adult mortality rate of -0.0015 estimated from the impingement catch curve.

APPENDIX 2-F

ADULT SIZE CLASS DETERMINATIONS

As outlined in Appendices 2-B through 2-E, several techniques were applied to estimate total adult populations (Table 2-4). The adult population is defined operationally as those individuals greater than 90 mm in length. The initial age in the population for a species is given by the size-age relation value for 90 mm (see Appendix 2-G). The distribution of the population into size class abundances was calculated using the following formulas:

1) initial number (N_i) in a population

$$N_i = \frac{-N_p\ Z}{[1-e^{(Z\ T)}]}$$

where N_p = total population;
Z = mortality rate;
T = duration in a stage (e.g. 90 to 100 mm),

calculates the initial number at the beginning of the interval. The estimated number of queenfish (Appendix 2-C) between 90 mm and 270 mm is

$N_p = 3.87 \times 10^7$;
T = 6787 (age 270 mm) - 185 (age 90 mm) = 6602 days;
$Z = -.0019$,

thus, $N_i = 7.35 \times 10^4$, is the population of day class 185.

2) The number of any subsequent class (N_t)

$$N_t = N_i\ e^{(Z\ T)}$$

where N_i = initial number (eg. as calculated above);
T = age difference between T and I;
Z = mortality rate,

e.g. $N_i = 7.35 \times 10^4$;
T = 262 (age 100 mm) - 185 (age 90 mm) = 77 days;
$Z = -\ .0019$,

thus $N_t = 6.35 \times 10^4$.

3) The number (N_s) within any size class

$$N_s = -N_t\ [1-e^{(Z\ T)}]/Z$$

where N_t = initial number in class (from application of 1 and 2 above);

T = age duration of class;
Z = mortality rate;

e.g. $N_t = 6.35 \times 10^4$ (from example for 2 above);
T = 357 (age 110 mm) - 261 (age 100 mm) = 96 days;
Z = -.0019,

thus, $N_s = 5.57 \times 10^6$.

By applying these relations, the size class abundances shown in the individual station reports and Table 2-4 were generated.

APPENDIX 2-G

SIZE-AGE RELATIONSHIPS

The basic field data on fish is in the form of length-frequency distributions. These data must be converted to age data to determine the duration of exposure to loss, which is required by the loss model. The various sources of information and the expressions used to convert size to age are discussed below.

NORTHERN ANCHOVY

The most recent and comprehensive study of growth in early life stages of northern anchovy is that of Methot (1981). Methot (personal communication) provided the following size-age relation for larval anchovy:

given L_o = 4.2 mm;
L_{oo} = 27.0 mm;
and $\alpha = 0.04031 + (0.0001192)$ (month),

then $\ln (L) = L (L_{oo}) + \ln (L_o/L_{oo})\, e^{(-\alpha t)}$

where month = 1 for January, 2 for February ...;
t = age in days post yolk absorption;
L = length in mm.

This relation can be solved for age (in days after yolk absorption) as a function of length. Results are given in Table 2G-1. There is relatively little variation within a size class over the year. It was considered appropriate to average over the year and fit a single expression relating size to age.

The least squares fit resulting is:

$$y = e^{(1.5206 \ln(x) - 0.6827)}$$

where x = size in mm;
y = age post yolk sac absorption.

A reasonable age for post-yolk sac larvae is between 3 and 4 days (O'Connell and Raymond 1970). Thus, if a value of 3.5 is added to the expression given above, an absolute age is estimated. The projected age at 5 mm is 9.34 days. Age data for larvae less than 5 mm was obtained by a linear approximation to values generated from an expression given by Hunter (1976). Values are provided in Table 2G-2. These data were used to fit a linear relation (Figure 2G-1). The intercept was adjusted slightly so that the age at 5 mm was the same as that derived above (9.34 days). This relation is

$$y = 2.8513\, x - 3.5670.$$

Table 2G-1. Age of larval anchovy as a function of month of the year (after Methot 1981).

Size (mm)	Age (days) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5	5	5	5	5	5	5	5	5	5	5	5	5
6	8	8	8	8	8	8	8	8	8	8	8	8
7	10	10	10	10	10	10	10	10	10	10	10	10
8	13	13	13	13	13	13	13	13	13	13	13	13
9	16	15	15	16	16	16	16	16	16	15	15	16
10	18	18	18	18	18	18	18	18	18	18	18	18
11	21	20	20	20	20	20	20	20	20	20	20	20
12	23	23	23	23	23	23	23	23	23	23	22	22
13	26	26	25	25	25	25	25	25	25	25	25	25
14	28	28	28	28	28	28	28	28	28	28	28	27
15	31	31	31	31	31	31	31	30	30	30	30	30
16	34	34	34	34	34	33	33	33	33	33	33	33
17	37	37	37	37	37	36	36	36	36	36	36	36
18	40	40	40	40	40	40	40	39	39	39	39	39
19	44	44	43	43	43	43	43	43	43	43	43	42
20	48	47	47	47	47	47	47	47	47	46	46	46
21	52	52	52	52	51	51	51	51	51	51	51	50
22	57	57	57	57	56	56	56	56	56	56	55	55

For larval sizes 22 to 30 mm, the age difference between the 22 and 21 mm class (3.8 days) was used (Methot, personal communication). The expression for this size segment is:

$$y = 3.7947\ x - 24.4192.$$

Table 2G-2. Early size-age relationships in anchovy larvae.

Size (mm)	Age* (days)	Age** (days)
3.118	4.500	4.594
3.463	5.500	5.484
3.829	6.500	6.429
4.216	7.500	7.428
4.624	8.500	8.481
5.051	9.500	9.585

* from Hunter (1976)
** linear fit to 1; $y = 2.5813x - 3.4543$
x = size in mm

WHITE CROAKER

Size age data on 266 male and 368 female white croaker collected in southern California waters was available Love et al. (1982). There was a slight difference in growth between males and females, with females tending to obtain a larger size at older ages. The fitted curves are shown in Figure 2G-2.

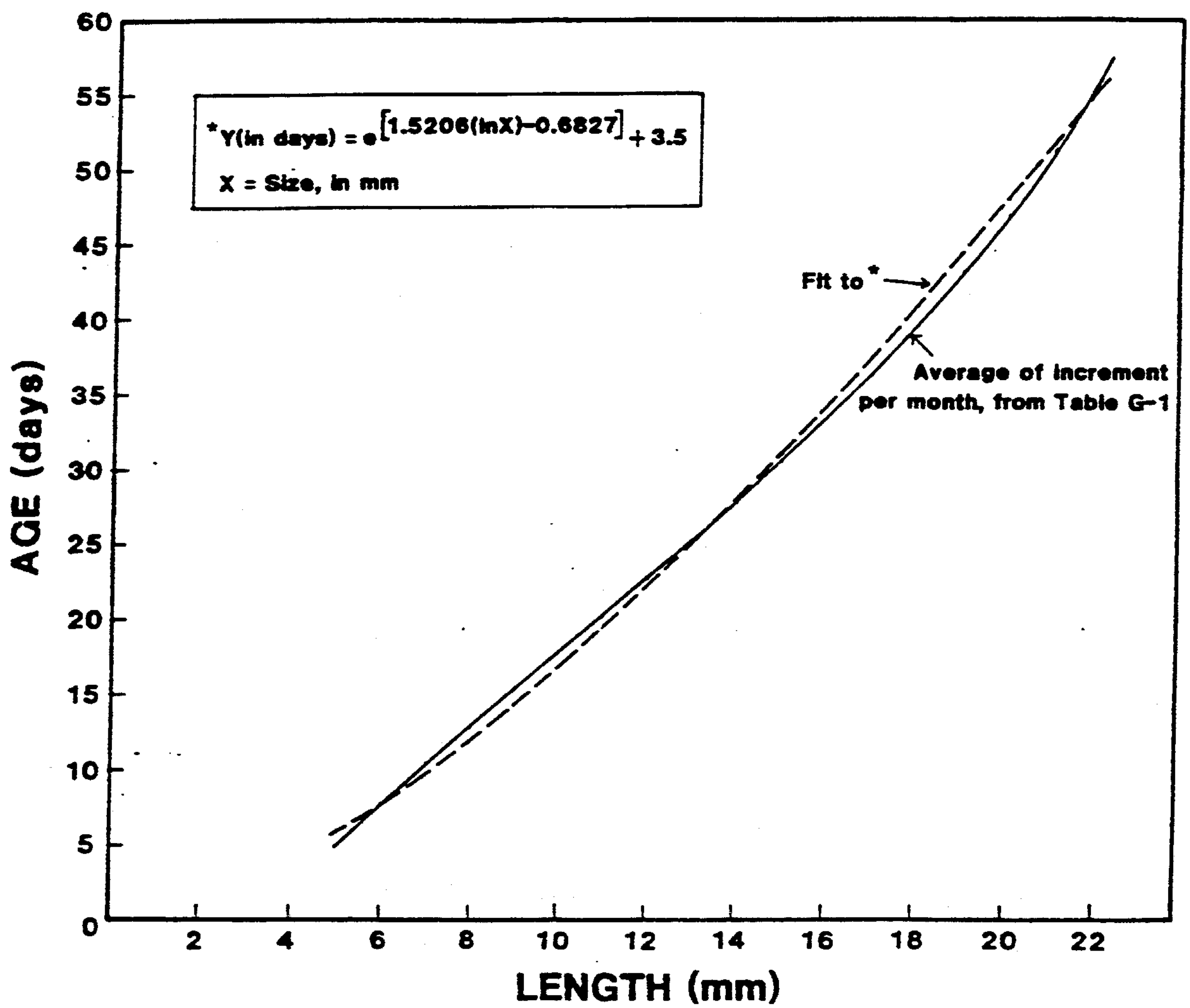

Figure 2G-1. Size-age relationship in larval anchovy.

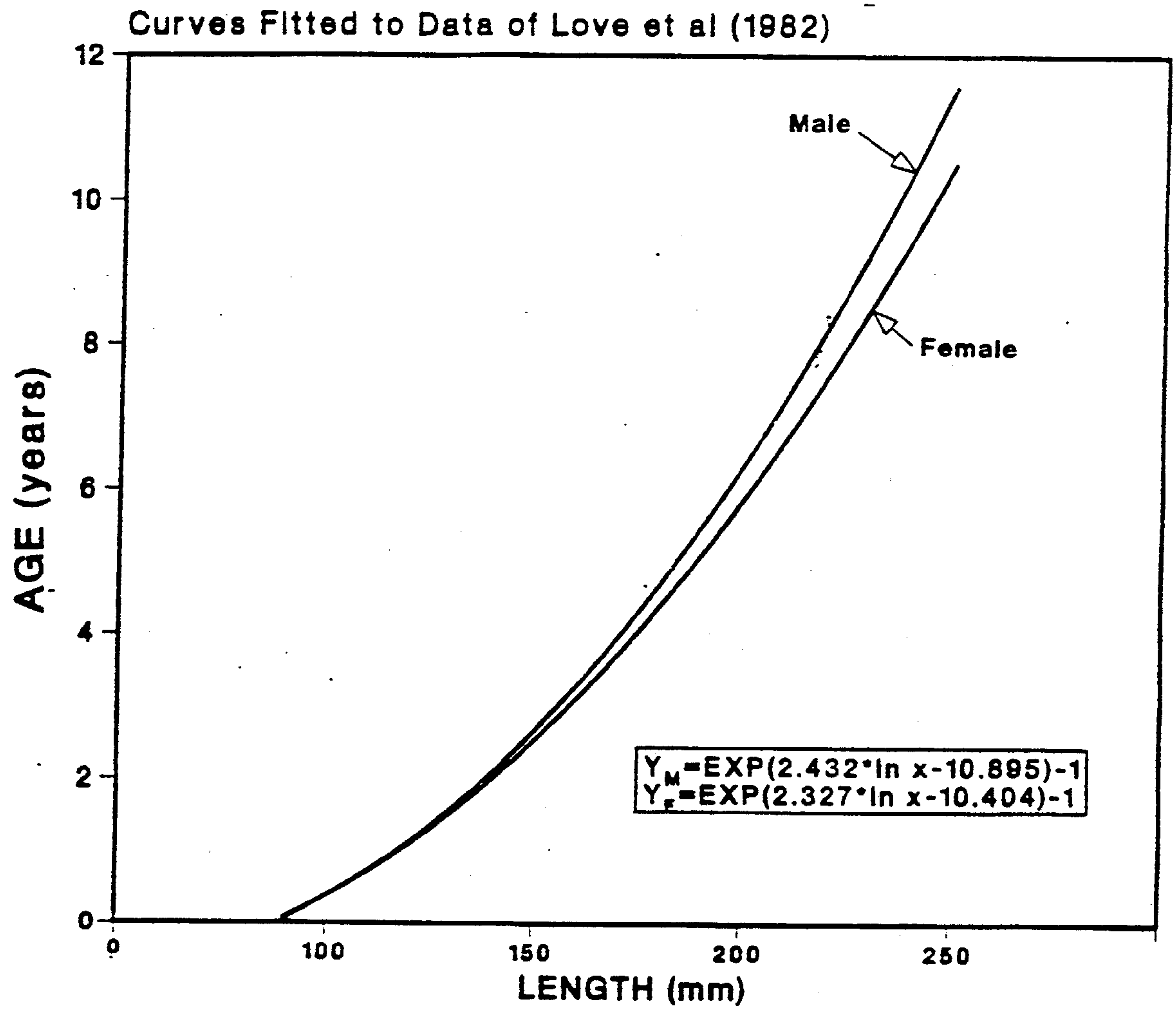

Figure 2G-2. Size-age relationship in adult white croaker.

Original data was in year class (0, 1, 2, etc.). To convert the expression to days, the age at size 90 mm was set at 270 days (Love, personal communication). The expressions for males and females were also averaged so that the size age relation for adult white croaker is

$$y = 365\ \frac{e^{(2.327\ \ln(x)-10.404)} + e^{(2.432\ \ln(x)-10.895)} - 2}{2} + 270$$

where y = age in days
x = size (SL) in mm.

For larval croaker the relation of Watson (1978), derived from otolith studies, was used. The relation is:

$$y = 4.96\ x + 3.81$$

where y = age in days;
x = size (SL) in mm.

QUEENFISH

DeMartini (1979) developed a von Bertalanffy growth equation based on adult queenfish otolith data. The relation was

$$L_t = e^{235\ [1-e^{-0.21295(t+2.033)}]}$$

where L_t = length (SL mm);
t = age in years.

A difficulty with this expression is that it underestimates age at small size (e.g. 90 mm). To 'straighten out' the relation a hundred points between 0.6 and 6.6 years were calculated and fit to a least squares model

$$y = 365\ e^{[3.278\ \ln(x)\ -\ 15.441]}$$

where y = age in days;
x = size (SL) in mm.

The relation between this model and the von Bertalanffy relation is given in Table 2G-3. The close fit at large sizes is apparent as is the more realistic fit at the smallest size. (DeMartini's [1979] data indicated an age of about one year for a fish of about 100 mm.)

A size-age relation for larval queenfish based on otolith analysis was developed by Watson (1978).

$$y = 3.90\ x\ -0.86$$

where y = age in days;
x = size (SL) in mm.

The size range of analyzed larvae was between 3 and 11 mm. It was extrapolated to larger larvae (>20 mm) as the best available information.

KELP BASS

Young (1963) provided tabular data on the size age relation in kelp bass. A part of his data was used to estimate an expression for this relation. His data was in total length. Since fish impingement data is measured in standard length (SL), the data of Young were converted to SL by multiplication by 0.89 (Herbinson, personal communication). These data are presented in Table 2G-4. The expression derived from these data to estimate age is

$$y = e^{(1.295\ \ln(x)\ +\ 0.3692)}$$

where y = age in days;
x = size (SL) in mm.

The age-size relation used for larval white croaker was applied to kelp bass.

Table 2G-3. Size-age relationship for adult queenfish.

Size (mm)	Age (days) v.B.*	Age (days) ln ln**
90	85	183
100	208	258
110	340	353
120	483	470
130	638	611
140	810	779
150	1001	976
160	1216	1206
170	1461	1472
180	1747	1775
190	2091	2119

* von Bertalanffy (DeMartini 1979)
** ln/ln plot (see text)

Table 2G-4. Size-age relationship for adult kelp bass (after Young 1963).

TL* (mm)	SL** (mm)	Age*** (Days)
105	93	547
180	159	913
215	190	1277
255	226	1643
305	270	2008
325	280	2372

TL=total length SL=standard length
* size class midpoint in Young (1963, Table 24)
** Conversion to SL = (0.89)TL
*** Age from Young (1968, Table 24) interpreted as mid-year in days, e.g. Age 1 = 365 + 365/2

WHITE SURFPERCH

Eckmayer (1979) published size-age data on white surfperch. His data is consistent with unpublished data of Stephens (personal communication). The data of Eckmayer is summarized and the fit to this data is shown in Table 2G-5. Age at 90 mm is projected to be 215 days. Size at birth for white surfperch is about 55 mm (Stephens, personal communication). Assuming an age of 1 day at birth, a linear extrapolation was made between these points to estimate age for size classes less than 90 mm. These size age relations are

<90 mm $y = 6.12\,x - 335.6;$

>90 mm $y = e^{(2.928 \ln(x) - 7.806)}.$

SHINER SURFPERCH

Stephens (personal communication) provided data on size-at-age for shiner surfperch. A least squares fit of the natural log-transformed size and age data was made. The back-calculated values of the resulting function are given with the original data in Table 2G-6. To estimate durations for size classes <90 mm a linear fit between 90 mm (757 days) and 35 mm (1 day) was made.

Table 2G-5. Size-age relationship in adult white surfperch.

Size (mm)	Age Days*	Age Days**
1.053×10^2	3.650×10^2	3.409×10^2
1.405×10^2	7.300×10^2	7.933×10^2
1.613×10^2	1.095×10^3	1.189×10^3
1.738×10^2	1.460×10^3	1.479×10^3
1.848×10^2	1.825×10^3	1.770×10^3
1.934×10^2	2.190×10^3	2.022×10^3

* Average of male + female length at end of year class (Eckmayer 1971, Table 4).
** $y = e^{(2.928 \ln(x) - 7.806)}$
y = age in days
x = size in mm

Table 2G-6. Size-age relationship for shiner surfperch.

Size (mm)	Age Days*	Age Days**
8.000×10^1	5.470×10^2	5.462×10^2
9.600×10^1	9.130×10^2	9.055×10^2
1.100×10^2	1.278×10^3	1.321×10^3
1.180×10^2	1.642×10^3	1.605×10^3

* Stephens, personal communiciation
** $y = e^{(2.773 \ln(x) - 5.8478)}$
x = size in mm

These relations are

$$<90 \text{ mm}: y = 13.7455x-480$$

$$>90 \text{ mm}: y = e^{(2.773 \ln(x) -5.8478)}$$

where y = age in days
x = SL size in mm.

Data published by Odenweller (1975) is in general agreement with the data of Stephens. A relation published by Eckmeyer (1979) contains a typographic error, and so a comparison cannot be made.

APPENDIX 2-H

RELATIVE COHORT REDUCTION

A summary of the derivation of R_c given by MacCall et al. (1982) is presented below.

From an initial production of eggs, P, the abundance of a cohort N'_c at some reference age is given by:

(1) $$N'_c = P\, e^{\left(-\sum_{i=1}^{T} Z_i\, t_i\right)}$$

where
- T = number of stages;
- t_i = the length of time in age interval i;
- N'_c = the abundance at some reference age = $\sum_{i=1}^{T} t_i$;
- P = the initial production of newly spawned eggs;
- Z_i = the instantaneous rate of mortality from all sources <u>except</u> intake loss.

This relation (1) can be modified to express the abundance of a cohort at the reference age when intake losses due to entrainment and impingement are operative in the system. The expression then becomes:

(2) $$N_c = P\, e^{\left[-\sum_{i=1}^{T} (E_i + Z_i)\, t_i\right]}$$

where E_i = the instantaneous per capita rate of intake loss. Since entrainment refers to loss of early life stages and impingement to latter stages and E_i is indexed to age, both categories of loss are brought into the same analytical focus in this expression.

The abundance of a cohort which sustains intake losses can be compared to an unimpacted cohort by the expression

$$R_c = \frac{N_c}{N'_c}$$

where N'_c is as defined in (1) and N_c is as defined in (2). R_c will be called the relative abundance. Now

(3) $$R_c = \frac{N_c}{N'_c} = e^{\left(-\sum_{i=1}^{T} E_i\, t_i\right)}$$

since the common term $Z_i\ T_i$ is removed from the ratio.

The relative abundance, R_c, is the parameter of interest for the 316(b) analysis. To estimate it, a value for E_i, the instantaneous per capita loss rate, must be estimated. When the loss of fish to intake mortality is small relative to the abundance in the source water then losses can be expressed as

(4) $$L_i = E_i \; N_i$$

where L_i = intake losses;
F_i = abundance in the source water. This expression is easily solved for E_i as

(5) $$E_i = \frac{L_i}{N_i} .$$

This expression, the ratio of the intake losses to the abundance in the source water, is the rate at which fish of a given age interval (stage) are lost to intake mortality.

The expression for E_i can be substituted in expression (3):

(6) $$R_c = e^{-[\sum_{i=1}^{T} (L_i/N_i) \; t_i]}$$

This substitution shows that R_c can be evaluated by estimating values for L_i and N_i.

Reference to the indidivual station reports provides the complete input data developed to calculate R_c for a given case. A particular problem in developing this input data was that there is apparent undersampling in the size range 10 to 90 mm, depending upon the species in question. In addition, eggs can only be identified for northern anchovy. Since the R_c calculations require only the ratio of L_i/N_i and not the absolute values of L_i or N_i, it is possible to estimate values for the ratio in the poorly sampled size stages, even though neither L_i or N_i is known. Egg L_i/F_i terms were estimated as equal to the L_i/N_i value of the first size class (up to 3 mm). This is reasonable since both eggs and early larvae are probably well mixed in the mid-water column from which intake water is withdrawn and the age separation is only a few days.

The difference between the last entrainable larvae and the first impingeable adult fish is, however, quite large. In general, the larvae are apparently more susceptible to loss relative to their densities than adults. That is, there tend to be order-of-magnitude differences between larval L_i/N_i and adults L_i/N_i ratios, which most likely reflect a much reduced susceptibility of adults to intake cropping. Therefore, to estimate L_i/N_i values an exponential decline in L_i/N_i was assumed. After flexion (about 10 mm), fish rapidly become more adult-like, and the ratio should be weighted toward an adult-like value. A rate of decline was estimated from the expression

$$B = \frac{\ln \frac{L_2}{N_2} - \ln \frac{L_1}{N_1}}{\text{age (2)} - \text{age (1)}}$$

where 1 = value of L_i/N_i for the last well-sampled larval class;
2 = value of L_i/N_i for 90 mm adult class.

L_i/N_i was then assumed to decline to L_2/N_2 at the exponential rate B.

For kelp/sand bass there is a further biological question in that larvae greater than about 10 mm were not sampled by either the Bight-wide or the Entrainment Sampling Project (SCE 1982). Several investigators (Stephens, DeMartini, personal communication) believe that larvae of these important species may recruit to specialized habitats. The implication is that there may be virtually no entrainment of larvae between about 10 and 50 mm. For sizes between 30 and 90 mm (Table 2-6) are most likely a considerable (e.g. about 75%) over-estimate. The conservative value was used in the analysis for consistency in method.

APPENDIX 2-I

FISHERY LOSS MODEL AND DOCUMENTATION OF VARIABLES

The Fishery Loss Model utilized to develop R_C values for impact assessment at SCE generating stations (SCEFLM) is presented below.

```
999        UPDATED 8-10-82
1000 INPUT"DO YOU WISH TO RESET THE AUTO-RUN CAPABILITIES (Y/N)";Y$ : IF Y$="Y" THEN 1010 ELSE 1040
1010 OPEN"R",1,"SPERUN.TXT",8 : FIELD 1,8 AS T$ : LSET T$=MKD$(2) : PUT 1,1 : CLOSE
1020 OPEN"R",1,"LFTSUM.TXT",8 : FIELD 1,8 AS T$ : LSET T$=MKD$(0) : FOR I=1 TO 287 : PUT 1,I : NEXT : CLOSE
1030 OPEN"R",1,"SOLFTSUM.TXT",8 : FOR I=1 TO 287 : PUT 1,I : NEXT : CLOSE
1040 CLEAR : ON ERROR GOTO 4730
1050 '
1060 '        initialize constants from keyboard input
1070 '
1080 HOME : PRINT "              SCE Station Specific Fish Loss Model" : PRINT : PRINT
1090 DPY=365 :  K1$="##.###^^^^" : K2$="###.####" : K3$="###" : K4$="####.###" : STP=1
1100 PRINT : PRINT
1110 '
1120 '       input the station number
1130 '
1140 OPEN"R",1,"SPERUN.TXT",8 : FIELD 1,8 AS T$
1150 GET 1 : ROWS=CVD(T$) : IF ROWS=394 THEN CLOSE : CHAIN "SUMMPRT.BAS",1000,ALL,DELETE 1000-4750
1160 GET 1,ROWS : IFIL$=MID$(T$,1,INSTR(T$," ")-1)+"9.MAT" : GET 1 : EFIL$=MID$(T$,1,INSTR(T$," ")-1)+"9.MAT"
1170 GET 1 : STNO=CVD(T$) : GET 1 : SPNO=CVD(T$) : CLOSE
1180 PRINT "EFIL$...";EFIL$,"IFIL$...";IFIL$,"STNO =";STNO,"SPNO =";SPNO,"ROWS =";ROWS
1190 IF SPNO=1 AND STNO=6 THEN SKP=1 : GOTO 3310
1195 IF SPNO=7 AND STNO=1 THEN SKP=1 : GOTO 3310
1200 IF STNO<4 OR STNO=7 OR STNO=8 THEN IF SPNO=1 THEN SKP=1 : GOTO 3310
1210 DIM STA$(15),FLD(7),ZRATE(7),SPE$(7),Q22(7),FFIL$(7),E22FIL$(7),T(5),STFAC(15),SSP(15),WSP(15),FRFAC(15)
1220 FOR I=1 TO 15 : READ STA$(I),FRFAC(I),SSP(I),WSP(I),STFAC(I) : NEXT
1230 FOR I=1 TO 7 : READ SPE$(I),FLD(I),ZRATE(I),Q22(I),FFIL$(I),E22FIL$(I) : NEXT I
1240 FLD=FLD(SPNO): ZRATE=ZRATE(SPNO): Q22=Q22(SPNO): SPE$=SPE$(SPNO): STA$=STA$(STNO): FFIL$=FFIL$(SPNO): SSP=SSP(STNO)
1250 STFAC=STFAC(STNO) : FRFAC=FRFAC(STNO)
1260 WSP=WSP(STNO) : E22FIL$=E22FIL$(SPNO) : ERASE FLD,ZRATE,Q22,SPE$,STA$,FFIL$,E22FIL$,STFAC,SSP,WSP,FRFAC
1270 '
1280 '            set up the correct larval and adult age algorithms
1290 '
1300 ON SPNO GOTO 1420,1360,1320,1310,1400,1340,1380
1310 DEF FNE1(X)=3.9*X-.86 : DEF FNET(X)=3.9*X-.86 : DEF FNIT(X)=365*EXP(3.278*LOG(X)-15.441): GOTO 1560        'queenfish
1320 DEF FNE1(X)=2.5813*X-3.567 : DEF FNET(X)=EXP(1.5206*LOG(X)-.6827)+3.5 : DEF FNE2(X)=3.7947*X-24.4192
1330 DEF FNIT(X)=365*(-1.71-LOG(1-X/165.52)/.3) : GOTO 1560                                                      'anchovy
1340 DEF FNE1(X)=4.96*X+3.81 : DEF FNET(X)=4.96*X+3.81
1350 DEF FNIT(X)=246+365*(EXP(2.327*LOG(X)-10.404)+EXP(2.432*LOG(X)-10.895)-2)/2 : GOTO 1560                      'white croaker
1360 DEF FNE1(X)=5.999*X-5.729 : DEF FNET(X)=1.699*X+19.576
1370 DEF FNIT(X)=EXP(1.295*LOG(X)+.3692):GOTO 1560                                                               'kelp bass
1380 DEF FNET(X)=6.12*X-335.6 : DEF FNIT(X)=EXP(2.928*LOG(X)-7.806): BEGLEN=54                                   'white surf perch
1390 PFAC=WSP : BEGPOP=8.97 : GOTO 1430
1400 DEF FNET(X)=13.7455*X-480 : DEF FNIT(X)=EXP(2.773*LOG(X)-5.8478): BEGLEN=35                                 'shiner surf perch
1410 PFAC=SSP : BEGPOP=104.7 : GOTO 1430
1420 DEF FNE1(X)=5.999*X-5.729 : DEF FNET(X)=1.699*X+19.576 : DEF FNIT(X)=EXP(1.295*LOG(X)+.3692) : GOTO 1560  'cal. halibut
1430 '
1440 '         read in perch data and fill in loss counts
1450 '
1460 OPEN"R",1,"B:"+IFIL$,8 : FIELD 1,8 AS T$
1470 GET 1 : COLS=CVD(T$) : GET 1 : ROWS=CVD(T$) : DIM A(ROWS+7,3),AD(40,3) : INCR=10 : AGE=0 : FLG=1
1475 IF ROWS = 0 THEN CLOSE : GOTO 4745
1480 FOR I=10*INT(BEGLEN/10) TO 80 STEP 10
1490   ACNT=ACNT+1
1500   A(ACNT,1)=I+1 : IF I=10*INT(BEGLEN/10) THEN A(ACNT,1)=BEGLEN+1 : DAGE=0 : ELSE DAGE=FNET(A(ACNT,1)-1)
1510   A(ACNT,2)=I+10 : A(ACNT,3)=-PFAC*BEGPOP*EXP(-.0063*AGE)*(1-EXP(-.0063*(FNET(I+10)-DAGE)))/(-.0063)
1520   AGE=FNET(I+10)
1530 NEXT I : ACNT=ACNT+1
1540 FOR J=1 TO 3 : FOR I=ACNT TO ACNT+ROWS-1 : GET 1  : A(I,J)=CVD(T$) : NEXT I,J : CLOSE : A(1,1)=A(1,1)-1
1550 ROWS=ROWS+ACNT-1 : GOTO 1630
1560 '
1570 '          get entrainment data
1580 '
1585 IF EFIL$="HYEK89.MAT" THEN DIM ENT(10,11) : ECNT = 1 : GOTO 1890
1590 OPEN"R",1,"B:"+EFIL$,8 : FIELD 1,8 AS T$ : INCR=1
1600 GET 1:COLS=CVD(T$):GET 1:ROWS=CVD(T$): ADCNT=0: IF ROWS=0 THEN CLOSE : GOTO 4745
1610 DIM A(ROWS,COLS),AD(40,COLS)
1620 FOR J=1 TO COLS : FOR I=1 TO ROWS : GET 1 : A(I,J)=CVD(T$) : NEXT I,J : CLOSE : A(1,1)=A(1,1)-FLG
1630 '
1640 '       correct the entrainment losses if the data from a different station is being used
1650 '
1660 IF FLG=0 OR STNO>12 THEN FOR I=1 TO ROWS : A(I,3)=A(I,3)*STFAC : NEXT I
1670 '
1680 '        fill in missing data with mean of boundary values
1690 '
1700 FOR I=2 TO ROWS
1710   A(I,1)=A(I,1)-FLG
1720   IF A(I,1) > A(I-1,2) THEN ADD=(A(I,1)-A(I-1,2))/INCR : GOSUB 4220
1730 NEXT
1740 IF FLG=1 THEN 1930
1750 '
1760 '      combine missing value estimates w/ existing data into one array changing to loss/day, and adding egg loss & field terms
1770 '
1780 DIM ENT(ROWS+ADCNT+1,11) : ACNT=1 : CNT=0
1790 FOR I=1 TO ROWS+ADCNT+1
1800   IF I>1 THEN 1820 ELSE ENT(I,3)=A(ACNT,3)/DPY : ENT(I,1)=0 : ENT(I,2)=2 : CHK=A(ACNT,2)
1810      I=I+1 : ENT(I,1)=ENT(I-1,2) : ENT(I,2)=A(ACNT,2) : ENT(I,3)=ENT(I-1,3) : ENT(I-1,0)=1 : ACNT=2 : GOTO 1840
1820   IF CHK=A(ACNT,1) THEN ENT(I,3)=A(ACNT,3)/DPY: ENT(I,1)=A(ACNT,1): ENT(I,2)=A(ACNT,2): CHK=A(ACNT,2): ACNT=ACNT+1: GOTO 1840
1830   IF CHK=AD(CNT+1,1) THEN CNT=CNT+1: ENT(I,3)=AD(CNT,3)/DPY: ENT(I,1)=AD(CNT,1): ENT(I,2)=AD(CNT,2): ENT(I,0)=1: CHK=AD(CNT,2)
```

```
1840 NEXT I : ECNT=ROWS+ADCNT-1
1850 IF ENT(ECNT,2)<6 THEN ENDAGE=FNE1(ENT(ECNT,2)) ELSE ENDAGE=FNET(ENT(ECNT,2))
1860 IF SPNO=3 AND ENT(ECNT,2)>21 THEN ENDAGE=FNE2(ENT(ECNT,2))
1870 IF SPNO=3 THEN AGE30=FNE2(30) ELSE AGE30=FNET(30)
1880 ERASE A,AD
1890 '
1900 '        get impingement data and interpolate missing data points using the same routines as for entrainment (FLG now = 1)
1910 '
1920 OPEN"R",1,"B:"+IFIL$,8 : FIELD 1,8 AS T$ : FLG=1 : INCR=10 : ADCNT=0 : GOTO 1600
1930 DIM IPG(ROWS+ADCNT,11) : ACNT=1 : CNT=0
1940 '
1950 '        for impingement, combine interpolated values with real values into one array, changing to less/day
1960 '
1970 FOR I=1 TO ROWS+ADCNT
1980   IF I=1 THEN IPG(I,3)=A(ACNT,3)/DPY : IPG(I,1)=A(ACNT,1) : IPG(I,2)=A(ACNT,2) : CHK=A(ACNT,2) : ACNT=2 : GOTO 2010
1990   IF CHK=A(ACNT,1) THEN IPG(I,3)=A(ACNT,3)/DPY: IPG(I,1)=A(ACNT,1): IPG(I,2)=A(ACNT,2): CHK=A(ACNT,2): ACNT=ACNT+1: GOTO 2010
2000   IF CHK=AD(CNT+1,1) THEN CNT=CNT+1: IPG(I,3)=AD(CNT,3)/DPY: IPG(I,1)=AD(CNT,1): IPG(I,2)=AD(CNT,2): IPG(I,0)=1: CHK=AD(CNT,2)
2010 NEXT I : ICNT=ROWS+ADCNT : ADCNT=1 : ACNT=1
2020 '
2030 '        cut off non-perch fish lengths of <90 mm
2040 '
2050 IF SPNO=5 OR SPNO=7 THEN 2840
2060 IF A(ACNT,1)<90 THEN ACNT=ACNT+1 : GOTO 2060 : ELSE ACNT=ACNT-1
2070 IF AD(ADCNT,1)<90 AND AD(ADCNT,1)>0 THEN ADCNT=ADCNT+1 : GOTO 2070 : ELSE ADCNT=ADCNT-1
2080 ICNT=ICNT-ADCNT-ACNT : IF ADCNT+ACNT=0 THEN GOTO 2120
2090 ISUM=0 : FOR I=1 TO ICNT
2100   IPG(I,3)=IPG(I+ADCNT+ACNT,3): IPG(I,1)=IPG(I+ADCNT+ACNT,1): IPG(I,2)=IPG(I+ADCNT+ACNT,2): IPG(I,0)=IPG(I+ADCNT+ACNT,0)
2110 NEXT I
2120 ERASE A,AD
2130 '
2140 '        get entrainment sized field estimate data
2150 '
2160 OPEN"R",1,"A:"+FFIL$,8  : GET 1 : GET 1 : FLG=3 : ACNT=1
2170 FOR I=ENT(ACNT,1)+FLG TO ENT(ACNT,2)
2180   GET 1 : T=T+CVD(T$)
2190 NEXT I : FLG=1 : ENT(ACNT,4)=T : T=0
2200 IF ACNT=ECNT THEN CLOSE ELSE ACNT=ACNT+1 : GOTO 2170
2210 ENT(1,4)=ENT(2,4)
2220 '
2230 '        calculate L/F, delta T, (L/F)*T, and 100*exp(-(L/F)*T) for the entrainment data
2240 '
2245 IF EFIL$="HYEKB9.MAT" THEN ENT(ECNT,5)=1E-12 : GOTO 2350
2250 ELFSUM=0 : FOR I=1 TO ECNT : ENT(I,5)=ENT(I,3)/ENT(I,4) : IF ENT(I,1)=0 THEN AGE1=0 ELSE AGE1=FNET(ENT(I,1))
2260 IF ENT(I,1)>0 AND ENT(I,1)<6 THEN AGE1=FNE1(ENT(I,1))
2270 IF SPNO=3 AND ENT(I,1)>21 THEN AGE1=FNE2(ENT(I,1))
2280 IF ENT(I,2)<6 THEN AGE2=FNE1(ENT(I,2)) ELSE AGE2=FNET(ENT(I,2))
2290 IF SPNO=3 AND ENT(I,2)>22 THEN AGE2=FNE2(ENT(I,2))
2300   ENT(I,6)=AGE2-AGE1 : ENT(I,7)=ENT(I,5)*ENT(I,6) : ENT(I,8)=100*EXP(-ENT(I,7))
2310   ENT(I,9)=ENT(I-1,9)+ENT(I,7) : ENT(I,10)=100*EXP(-ENT(I,9))
2320   ENT(I,11)=ENT(I,4)*(100/ENT(I,10)-1)
2330   IF ENT(I,1)<10 THEN ELFSUM=ELFSUM+ENT(I,7)
2340 NEXT I
2350 '
2360 '        determine F, L/F, T, (L/F)*T, AND 100*e^(-(L/F)*T) values for impingement data
2370 '
2380 AGE=0 : IPG(1,4)=-FLD*EXP(ZRATE*AGE)*(1-EXP(ZRATE*(FNIT(IPG(1,2))-FNIT(IPG(1,1)))))/ZRATE
2390 IPG(1,5)=IPG(1,3)/IPG(1,4) : IF IPG(1,5)=0 THEN IPG(1,5)=1E-23 : IPG(1,0)=1
2400 LFMID=-ENT(ECNT,5)*(1-EXP(LOG(IPG(1,5)/ENT(ECNT,5))))/(LOG(IPG(1,5)/ENT(ECNT,5)))
2410 IPG(0,9)=ENT(ECNT,9)+LFMID*(FNIT(90)-ENDAGE)
2420 ISUM=0 : FLG=0 : FLDSUM=0 : AETOT=0 : ILFSUM=0 : AGE=0 : FOR I=1 TO ICNT
2430   IF FLG=1 THEN 2580
2440   IF SPNO<>2 AND FNIT(IPG(I,2))>1825 THEN FLG=1 : ICNT=I
2450   IPG(I,6)=FNIT(IPG(I,2))-FNIT(IPG(I,1))
2460   IPG(I,4)=-FLD*EXP(ZRATE*AGE)*(1-EXP(ZRATE*IPG(I,6)))/ZRATE
2470   IPG(I,5)=IPG(I,3)/IPG(I,4)
2480   IPG(I,7)=IPG(I,5)*IPG(I,6)
2490   IPG(I,8)=100*EXP(-IPG(I,7))
2500   IPG(I,9)=IPG(I-1,9)+IPG(I,7)
2510   IPG(I,10)=100*EXP(-IPG(I,9))
2520   IPG(I,11)=IPG(I,4)*(100/IPG(I,10)-1)
2530   ILFSUM=ILFSUM+IPG(I,7)
2540   AGE=FNIT(IPG(I,2))-FNIT(90)
2550   AETOT=AETOT+IPG(I,11)
2560   FLDSUM=FLDSUM+IPG(I,4)
2570   ISUM=ISUM+IPG(I,3)
2580 NEXT I
2590 '
2600 '        extend entrainment data out to 10 mm if required
2610 '
2615 IF EFIL$="HYEKB9.MAT" THEN ELFSUM=0 : E2SUM=0 : AGE1=FNIT(90) : GOTO 2790
2620 IF ENT(ECNT,2) >= 10 THEN 2670
2630   ELFSUM=ELFSUM+(FNET(10)-ENDAGE)*LFMID
2640 '
2650 '        calculate (L/F)*T for the E2 group
2660 '
2670 MARK30=ECNT : IF ENT(ECNT,2) >= 30 THEN DAGE=0 ELSE GOTO 2690
2680 IF ENT(MARK30,1)>=30 THEN MARK30=MARK30-1 : GOTO 2680
2690   MARK10=ECNT
2700   IF ENT(MARK10,1) >=10 THEN MARK10=MARK10-1 : GOTO 2700
2710   IF MARK10=ECNT THEN DAGE=AGE30-FNET(10) : GOTO 2740
2720 IF MARK30=ECNT THEN DAGE=AGE30-ENDAGE
2730      FOR I=MARK10+1 TO MARK30 : E2SUM=E2SUM+ENT(I,7) : NEXT I
2740  E2SUM=E2SUM+DAGE*LFMID : AGE1=AGE30
2750 '
2760 '        calculate the I1 TERM
2770 '
2780 IF MARK30<ECNT THEN FOR J=I TO ECNT : I1SUM=I1SUM+ENT(J,7) : NEXT J : AGE1=ENDAGE
2790 I1SUM=I1SUM+(FNIT(90)-AGE1)*LFMID
2800 '
2810 '        put the term values into the T vector
2820 '
2830 T(1)=ELFSUM : T(2)=E2SUM : T(3)=I1SUM : T(4)=ILFSUM :  : T(5)=T(1)+T(2)+T(3)+T(4) : GOTO 3080
2840 '
2850 '        determine F, L/F, T, T*(L/F), and 100*e^(-T*L/F) for the perches
2860 '
2870 FLG=0 : FLDSUM=0 : ISUM=0 : AETOT=0 : ILFSUM=0 : AGE=0 : FOR I=1 TO ICNT
2880   IF FLG=1 THEN 3060
2890   IF FNIT(IPG(I,2))>1825 THEN ICNT=I : FLG=1
2900   IF IPG(I,1)<105 THEN A1#=FNET(IPG(I,1)) ELSE A1#=FNIT(IPG(I,1))
2910   IF IPG(I,2)<105 THEN A2#=FNET(IPG(I,2)) ELSE A2#=FNIT(IPG(I,2))
2920   IPG(I,6)=A2#-A1#
```

```
2930   IF IPG(I.1)<90 THEN Z=-.0063 : IPG(I.0)=1 : ELSE Z=ZRATE
2940   IPG(I.4)=-FLD*EXP(Z*AGE)*(1-EXP(Z*IPG(I.6)))/Z
2950   IPG(I.5)=IPG(I.3)/IPG(I.4)
2960   IPG(I.7)=IPG(I.5)*IPG(I.6)
2970   IPG(I.8)=100*EXP(-IPG(I.7))
2980   IPG(I.9)=IPG(I-1.9)+IPG(I.7)
2990   IPG(I.10)=100*EXP(-IPG(I.9))
3000   IPG(I.11)=IPG(I.4)*(100/IPG(I.10)-1)
3010   IF IPG(I.1)<90 THEN I1SUM=I1SUM+IPG(I.7) ELSE I2SUM=I2SUM+IPG(I.7) : ISUM=ISUM+IPG(I.3)
3020   IF IPG(I.2)<105 THEN AGE=FNET(IPG(I.2)) ELSE AGE=FNIT(IPG(I.2))
3030   IF IPG(I.1)>=90 THEN AETOT=AETOT-IPG(I.11)
3040   FLDSUM=FLDSUM+IPG(I.4)
3050   IF J=SPNO*17+1 THEN LPRINT"FISH LARGER THAN 250mm ENCOUNTERED!!!":STOP
3060 NEXT I
3070 T(1)=0 : T(2)=0 : T(3)=I1SUM : T(4)=I2SUM : T(5)=T(3)+T(4)
3080 '
3090 '         write the E1.E2.I1.I2 terms into the summary matrix file
3100 '
3110 IF STNO>14 THEN 3320
3120 OPEN"R".1."SCESUMM.TXT".8 : FOR I=1 TO 4 : LSET T$=MKD$(T(I)) : PUT 1.((I-1)*98+(SPNO-1)*14+STNO) : NEXT I : CLOSE
3130 IF STNO<13 THEN OPEN"R".1."LFTSUM.TXT".8 ELSE OPEN"R".1."SOLFTSUM.TXT".8
3140 FIELD 1.8 AS T$ : J=0 : DIM SUM(41)
3150 FOR I=1 TO ECNT
3160   IF ENT(I.1)>=J AND ENT(I.1)<J+5 THEN SUM(J/5+1)=SUM(J/5+1)+ENT(I.7) : GOTO 3180
3170   J=J+5 : IF J<35 THEN 3160 ELSE PRINT"ERROR --- TOO MANY ENTRAINMENT SIZE CLASSES" : STOP
3180 NEXT I
3190 SUM(8)=SUM(8)+LFMID*(FNIT(90)-ENDAGE) : J=35 : STP=5
3200 FOR I=1 TO ICNT
3210    IF IPG(I.1)>=J AND IPG(I.1)<J+STP THEN SUM(INT(J/10)+6)=SUM(INT(J/10)+6)+IPG(I.7) : NF=0 : GOTO 3230
3220   NF=1
3230   J=J+STP : IF STP=5 THEN STP=10
3240   IF J=360 AND I<ICNT THEN PRINT"ERROR --- TOO MANY IMPINGEMENT SIZE CLASSES" : STOP
3250   IF NF=1 THEN 3210 ELSE 3260
3260 NEXT I
3270 J=(SPNO-1)*41
3280 FOR I=1 TO 41
3290   GET 1.I+J : T=CVD(T$)+SUM(I) : LSET T$=MKD$(T) : PUT 1.I+J
3300 NEXT I : CLOSE
3310 OPEN"R".1."SPERUN.TXT".8 :FIELD 1.8 AS T$ :GET 1.1 :ROWS=CVD(T$)+4 :LSET T$=MKD$(ROWS) :PUT 1.1 :CLOSE :PRINT"ROWS =":ROWS
3320 IF SKP=1 THEN 1040
3330 '
3340 '           read in the intake technology matrix
3350 '
3360 DIM ITECH$(11).ITECH(2.11.4).EFCY(11).COST(11)
3370 FOR I=1 TO 10:READ ITECH$(I):FOR J=1 TO 4:READ ITECH(1.I.J) : IF I=4 AND J<4 THEN ITECH(1.4.J)=FRFAC
3380 ITECH(2.I.J)=ITECH(1.I.J)*T(J) : EFCY(I)=EFCY(I)+ITECH(2.I.J) : NEXT J
3390    READ COST(I) : EFCY(I)=100*EXP(-EFCY(I)) : NEXT I
3400 IF STNO>3 THEN 3420 ELSE COST(4)=1.9 : COST(6)=3.3 : COST(7)=2.5 : COST(8)=2! : ITECH$(3)="NONE"
3410   ITECH$(5)="NONE" : ITECH$(9)="NONE" : ITECH$(10)="NONE" : ITECH$(1)="NONE" : ITECH$(2)="EXISTING CANAL"
3420 IF STNO=3 THEN COST(4)=1.1 : COST(6)=3.3 : COST(7)=2.5 : COST(8)=1!
3430 IF STNO=5 OR STNO=6 OR STNO=9 OR STNO=11 THEN COST(6)=7.8 : COST(7)=9.6 : COST(8)=2.4
3440 IF STNO<>7 THEN 3460 ELSE COST(4)=.8 : COST(6)=3.3 : COST(7)=4.1 : COST(8)=1.8 : ITECH$(3)="NONE"
3450   ITECH$(4)="NONE":ITECH$(5)="NONE":ITECH$(9)="NONE":ITECH$(10)="NONE":ITECH$(1)="NONE":ITECH$(2)="EXISTING EMBAYMENT"
3460 IF STNO<>8 THEN 3480 ELSE COST(4)=.8 : COST(6)=3.3 : COST(7)=4.1 : COST(8)=1! : ITECH$(3)="NONE"
3470   ITECH$(5)="NONE" : ITECH$(9)="NONE" : ITECH$(10)="NONE" : ITECH$(1)="NONE" : ITECH$(2)="EXISTING CANAL"
3480 FOR I=1 TO 9 : MARK=I
3490   FOR J=I+1 TO 10
3500     IF COST(MARK)>COST(J) THEN MARK=J
3510   NEXT J
3520   SWAP COST(I).COST(MARK) : SWAP ITECH$(I).ITECH$(MARK) : SWAP EFCY(I).EFCY(MARK)
3530 NEXT I
3540 '
3550 '           read in the 22m entrainment conversion factors
3560 '
3570 IF SPNO=5 OR SPNO=7 THEN 3670
3580 OPEN"R".1."A:"+E22FIL$.8 : GET 1 : GET 1 : E22CNT=CVD(T$)
3590 IF E22CNT=0 THEN INPUT"FILE NAME ERROR -- REINPUT THE (22/8) m CONVERSION FILE NAME":E22FIL$ : GOTO 3580
3600 FLG=0 : FOR I=1 TO E22CNT : GET 1 : IF I>ECNT THEN 3630 ELSE IF ENT(I.2)>10 THEN 3620
3610   E122=E122+ENT(I.7)*CVD(T$) : GOTO 3630
3620   E222=E222+CVD(T$)*ENT(I.7)
3630 NEXT I : CLOSE
3640 I122=(FNIT(90)-AGE30)*LFMID*Q22
3650 FOR I=1 TO ICNT : I222=I222+IPG(I.7)*Q22 : NEXT I
3660 EFCY(9)=100*EXP(-(I122+I222+E122+E222)) : GOTO 3740
3670 '
3680 '      calculate the 22m technology for the perches
3690 '
3700 FOR I=1 TO ICNT
3710   IF IPG(I.1)<90 THEN I122=I122+IPG(I.7)*Q22 ELSE I222=I222+IPG(I.7)*Q22
3720 NEXT I
3730 EFCY(9)=100*EXP(-(I122+I222))
3740 '
3750 '          print routine
3760 '
3770 LPRINT TAB(30):SPE$:"    AT    ":STA$
3780 LPRINT : LPRINT "SIZE CLASS":TAB(16):"DAILY":TAB(28):"FIELD":TAB(65):"CUMULATIVE"
3790 LPRINT "    (mm)":TAB(16):"LOSS":TAB(27):"ESTIMATE":TAB(40):"DAYS/CLASS":TAB(55):"Rc":TAB(68):"Rc"
3800 LPRINT STRING$(75."=")
3810 LPRINT"ENTRAINMENT"
3820 IF SPNO=5 OR SPNO=7 THEN LPRINT STRING$(75."-") : LPRINT : GOTO 3940
3830 FOR I=1 TO ECNT : IF I=1 THEN LPRINT "    EGGS":TAB(18):"*":TAB(31):"*": : GOTO 3870
3840   LPRINT USING K3$:ENT(I.1): : LPRINT " - ": : LPRINT USING K3$:ENT(I.2):
3850   LPRINT TAB(13): : LPRINT USING K1$:ENT(I.3): : IF ENT(I.0)=1 THEN LPRINT"*":
3860   LPRINT TAB(26): : LPRINT USING K1$:ENT(I.4):
3870   LPRINT TAB(39): : LPRINT USING K1$:ENT(I.6): : LPRINT TAB(52): : LPRINT USING K2$:ENT(I.8):
3880   LPRINT TAB(65): : LPRINT USING K2$:ENT(I.10)
3890 NEXT I
3900 LPRINT STRING$(75."-")
3910 LPRINT USING K3$:ENT(ECNT.2): : LPRINT" - ": : LPRINT USING K3$:IPG(1.1):
3920 LPRINT TAB(18):"*":TAB(31):"*"::LPRINT TAB(39)::LPRINT USING K1$:FNIT(90)-ENDAGE:
3930 LPRINT TAB(52): : LPRINT USING K2$:100*EXP(-LFMID*(FNIT(90)-ENDAGE))::LPRINT TAB(65)::LPRINT USING K2$:100*EXP(-IPG(0.9))
3940 LPRINT"IMPINGEMENT"
3950 FOR I=1 TO ICNT : LPRINT USING K3$:IPG(I.1): : LPRINT " - ": : LPRINT USING K3$:IPG(I.2):
3960   LPRINT TAB(13): : LPRINT USING K1$:IPG(I.3): : IF IPG(I.0)=1 THEN LPRINT"*":
3970   LPRINT TAB(26): : LPRINT USING K1$:IPG(I.4): : LPRINT TAB(39): : LPRINT USING K1$:IPG(I.6):
3980   LPRINT TAB(52): : LPRINT USING K2$:IPG(I.8): : LPRINT TAB(65): : LPRINT USING K2$:IPG(I.10)
3990 NEXT I : LPRINT STRING$(75."=")
4000 LPRINT"* denotes interpolated data values"
4010 LPRINT"E denotes scientific notation. e.g. : 1E06 = 1x10^6"
4020 LPRINT : LPRINT : LPRINT TAB(23):"% CONTRIBUTION" : LPRINT "CLASS":TAB(16):"Rc":TAB(23):"TO TOTAL LOSS"
4030 LPRINT STRING$(36."=")
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4040 LPRINT"EGGS - 10mm":TAB(13): : LPRINT USING K2$:100*EXP(-T(1)): : LPRINT TAB(26): : LPRINT USING K2$:100*T(1)/T(5)
4050 LPRINT"10mm - 30mm":TAB(13): : LPRINT USING K2$:100*EXP(-T(2)): : LPRINT TAB(26): : LPRINT USING K2$:100*T(2)/T(5)
4060 LPRINT "30mm - 90mm":TAB(13): : LPRINT USING K2$:100*EXP(-T(3)): : LPRINT TAB(26): : LPRINT USING K2$:100*T(3)/T(5)
4070 LPRINT "90mm +":TAB(13): : LPRINT USING K2$:100*EXP(-T(4)): : LPRINT TAB(26): : LPRINT USING K2$:100*T(4)/T(5)
4080 LPRINT : LPRINT " TOTAL":TAB(13): : LPRINT USING K2$:100*EXP(-T(5))
4090 LPRINT STRING$(36,"=")
4100 LPRINT : LPRINT TAB(52):"COST" : LPRINT"INTAKE TECHNOLOGY":TAB(26):"Rc":TAB(36):"CHANGE IN Rc":TAB(51):"(x10^6)"
4110 LPRINT STRING$(59,"=")
4120 TOF=27-ICNT-ECNT : IF TOF<0 THEN TOF=TOF+66
4130 FOR I=1 TO 10 : IF ITECH$(I)="NONE" THEN TOF=TOF+1 : GOTO 4160
4140   LPRINT ITECH$(I):TAB(23): : LPRINT USING K2$:EFCY(I): : LPRINT TAB(36): : LPRINT USING K2$:EFCY(I)-EFCY(2):
4150   LPRINT TAB(49): : LPRINT USING "$$##.###":COST(I)
4160 NEXT I : LPRINT STRING$(59,"=")
4170 FOR I=1 TO TOF : LPRINT : NEXT
4180 GOTO 1040
4190 '
4200 '          subroutine to fill in missing data
4210 '
4220 JCNT=-INCR :FOR J=ADCNT TO ADCNT+ADD
4230   JCNT=JCNT+INCR : IF JCNT=0 THEN 4270
4240   AD(J,1)=A(I-1,2)+JCNT-INCR
4250   AD(J,2)=AD(J,1)+INCR
4260   AD(J,3)=(A(I,3)+A(I-1,3))/2
4270 NEXT J : ADCNT=ADCNT+ADD : RETURN
4280 '
4290 '      station name     flo rdcn   ssp imp      wsp imp       intake factor ( for entrainment data from other station source )
4300 '         (STA$)        (FRFAC)    (SSP)        (WSP)             (STFAC)
4310 DATA  ALAMITOS 1&2.       .875,    .0039,       .0013,            .2600  :' from haynes near field data
4320 DATA  ALAMITOS 3&4.       .875,    .0135,       .0026,            .5016  :' from haynes near field data
4330 DATA  ALAMITOS 5&6.       .875,    .0507,       .0138,            .7938  :' from haynes near field data
4340 DATA  EL SEGUNDO 1&2.     .875,    .0089,       .0472,            .3125  :' from ormond beach data
4350 DATA  EL SEGUNDO 3&4.     .875,    .0554,       .0511,            .5603  :' from ormond beach data
4360 DATA  HUNTINGTON BEACH.   .875,    .0700,       .3003,            1.000  :' separate file containing (SD)*1.088 + OD*.6811)/2
4370 DATA  LONG BEACH.          1.0,    .0021,       .0003,            .1889  :' from haynes near field data
4380 DATA  MANDALAY.           .875,    .4549,       .0438,            .3286  :' from haynes near field data
4390 DATA  ORMOND BEACH.       .875,    .1408,       .4206,            1.000  :' actual ormond beach data
4400 DATA  REDONDO BEACH 1-6..94375.    .0959,       .0230,            2.220  :' from redondo beach 5&6 data
4410 DATA  REDONDO BEACH 7&8. .875,     .0684,       .0127,            1.000  :' actual redondo beach 7&8 data
4420 DATA  SAN ONOFRE 1.        1.0,    .0356,       .0833,            1.000  :' actual san onofre 1 data
4430 DATA  SAN ONOFRE 2.        1.0,    .0356,       .0833,           2.7995  :' from san onofre 1 data
4440 DATA  SAN ONOFRE 3.        1.0,    .0356,       .0833,           2.7995  :' from san onofre 1 data
4450 DATA  TYPICAL STA.         1.0,    .1132,       .1132,            1.000  ;' from a variety of sources...
4460 '
4470 '                                                   22m intk      field
4480 '       species              pop @ 90 mm     zrate      factor      est. file  22/8 m ratio
4490 '       (SPE$)                 (FLD)        (ZRATE)     (Q22)        (FFIL$)    (E22FIL$)
4500 DATA CALIFORNIA HALIBUT.        39943. -7.8817E-4.         0.      CHBT.VEC.   CH22R.VEC
4510 DATA KELP BASS.                 28989. -7.8817E-4.         1.      KBBT.VEC.   KB22R.VEC
4520 DATA NORTHERN ANCHOVY.         2.42E7.        -3E-3.     .2085.    NABT.VEC.   NA22R.VEC
4530 DATA QUEENFISH.                7.35E4.       -.0019.     .7262.    QFBT.VEC.   QF22R.VEC
4540 DATA SHINER SURF PERCH.          6902.       -.0015.     .1972.    ??BT.VEC.   SS22R.VEC
4550 DATA WHITE CROAKER.          3.0548E5.      -.00115.     .2041.    WCBT.VEC.   WC22R.VEC
4560 DATA WHITE SURF PERCH.          10624.      -.00115.     .1000.    ??BT.VEC.   WS22R.VEC
4570 '
4580 '  intake technlgy           E1           E2          I1          I2       cost x 10^6
4590 '      (ITECH$)            (ITECH)      (ITECH)     (ITECH)     (ITECH)    (COST)
4600 DATA W/O VEL CAP.             1.           1.          1.         10.          0
4610 DATA EXISTING VEL CAP.        1.           1.          1.          1.         .5
4620 DATA MODIFIED VEL CAP.        1.           1.          1.         .9.          1
4630 DATA FLOW REDUCTION.          1.           1.          1.          1.        1.5
4640 DATA OFFSHORE CAISSON.        1.          .5.         .5.        .25.       11.1
4650 DATA ANGLED SCREENS.          1.          .5.        .25.         .1.       30.8
4660 DATA LOUVERS.                 1.           1.         .5.         .1.       30.8
4670 DATA MODIFIED VTS.            1.          .5.         .5.         .5.       30.8
4680 DATA 22m INTAKE.              1.           1.          1.          1.       73.5
4690 DATA POROUS DYKE.             1.          .5.        .25.         .1.       97.7
4700 '
4710 '          error trapping routines
4720 '
4730 IF ERR=68 THEN 4745 ELSE PRINT" ERROR #":ERR:" HAS OCCURRED IN LINE #":ERL
4740 BEEP 5.5 :  FOR Q=1 TO 100 : NEXT Q : GOTO 4740
4745 PRINT : PRINT : PRINT : PRINT : PRINT "<< PUT IN NEW DISK AND PRESS RETURN >>"
4750 FOR I=1 TO 100 : BEEP 1.5 : IF INKEY$=" " THEN 1040 ELSE NEXT : GOTO 4750
```

DOCUMENTATION

Character String Variables

STA$	Station Name
SPE$	Species Name
FFIL$	Field Estimate of entrainment sized fish data file name
E22FIL$	8m to 22m intake conversion factors for entrainment sized fish file name
EFIL$	Data set name of entrainment sized fish
IFIL$	Data set name of impingement sized fish
K1$, K2$, K3$, K4$	Lineprinted number output formats

Character String Arrays

ITECH$	Alternative intake technology names

Single Precision Matrices

ENT Entrainment sized data matrix with rows denoting fish size classes and columns as described

Column	Description
1	Starting fish length for size class
2	Ending fish length for size class
3	Number of fish in size class entrained (loss)
4	Field estimate of this size class of fish (field)
5	Loss/Field ratio for size class
6	Amount of time (in days) in which fish are in size class (ΔT)
7	(Loss/Field) ΔT
8	$100\ e^{(-(L/F)\ \Delta T)}$
9	Cumulative $(L/F)\Delta T$
10	Cumulative $100\ e^{(-(L/F)\Delta T)}$

IPG Impingement sized data matrix with rows denoting fish size classes and columns as described above

A A work array which holds actual input data from EFIL$ and IFIL$

AD A work array which holds data interpolated between the values in array A. They will be incorporated into ENT and IPG

ITECH A 3-dimensional matrix which holds the flow reduction factor by station and size group (E1, E2, I1, I2) and the product of flow reduction X size group R_c

Single Dimensioned Arrays

T R_c values for size groups E1, E2, I1, I2, and total (summed from ENT and IPG)

SUM Array which holds $(L/F)\Delta T$ values by size class for writing into a standardized-increment size class data file

EFCY Total R_c value calculated for each intake technology

COST Estimated cost in $$ for each intake technology alternative

Single Precision Variables

DPY Days per year (365)

ROWS Number of rows in a data file. Equal to the number of size classes of actual input data

COLS Number of columns in a data set (always 3). Column 1 = beginning size class length in mm; Column 2 = ending size class length in mm; Column 3 = number of fish within this size class

STNO The station number

SPNO The species number

SKP	The skip flag which when on (SKP=1) does not write data to the summary files
FLD	Species specific field population estimate of 90 mm day class fish
ZRATE	Species specific Z-rate for this species
QZZ	The species specific (22 m/8 m) intake relocation conversion factor
STFAC	The flow volumne correction factor for using entrainment data from other stations
SSP	Shiner surfperch impingement susceptability factor
WSP	White surfperch impingement susceptability factor
FRFAC	Station specific maximum possible flow reduction factor
BEGPOP	Field estimate of 1 day old surfperch
BEGLEN	Surf perch length at birth
PFAC	Surf perch impingement susceptability factor (SSP or WSP)
INCR	Millimeter increment between successive size classes
AGE	Cumulative age of size classes
FLG	Flag which when on denotes impingement size classes are being worked with and when off denotes that entrainment size classes are being worked with
DAGE	Difference in days between successive size classes
ACNT	Number of input actual data values in ENT and IPG or, for perches, the number of extrapolated BEGLEN to 90 mm fish
ECNT	Number of entrainment (E1, E2) size classes in ENT (number of rows in ENT)
ICNT	Number of impingement (I2) size classes in IPG (number of rows in IPG)
ADCNT	Number of size classes being interpolated into ENT or IPG
CNT	Count value used for combining arrays A and AD into ENT or IPG
CHK	A variable used to search for equivalent values for the interpolation process
ENDAGE	Age of last size class in ENT
AGE30	Age at 30 mm
ELFSUM	$(L/F)\Delta T$ sum for E1 size group
AGE1	Beginning size class age in days
AGE2	Ending size class age in days

LFMID	(L/F)ΔT for region between last size class in ENT and first size class in IPG
ISUM	Cumulative sum of loss estimate
FLDSUM	Cumulative sum of field estimate
ILFSUM	Impingement (I2) sized cumulative (L/F)ΔT
E2SUM	Sum of E2 sized (L/F)ΔT size group
MARK30	The marker for ENT which separates <30 mm and >30 m size classes
MARK10	The marker for ENT which separates <10 mm and >10 mm size classes
I1SUM	Sum of I1 sized (L/F)ΔT size group
Z	Z rate for surfperch juvenile fish
STP	Incrementing step for indexing of arrays
E22CNT	Number of 22 m/8 m conversion factors in E22FIL$
E122	22 m E1 (L/F)ΔT term
E222	22 m E2 (L/F)ΔT term
I122	22 m I1 (L/F)ΔT term
I222	22 m I2 (L/F)ΔT term
TOF	Number of lines needed to be line printed to reach the top of the page

Appendix 3-A. Estimate of target species size-frequency (number/1000 m3) for the Southern California Bight using volume-at-depth weighting.

SIZE CLASS	COMBINED: MANTA, OBLIQUE BONGO, AURIGA	OBLIQUE: ALL SAMPLES

COMMON NAME=NORTHERN ANCHOVY SPECIES=ENGRAULIS MORDAX

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	344.79	326.10
3.00- 3.99MM	494.08	524.54
4.00- 4.99MM	166.80	171.46
5.00- 5.99MM	163.19	173.10
6.00- 6.99MM	161.33	163.01
7.00- 7.99MM	122.66	126.09
8.00- 8.99MM	128.06	118.30
9.00- 9.99MM	97.76	98.66
10.00-10.99MM	87.65	88.70
11.00-11.99MM	57.26	60.44
12.00-12.99MM	31.49	40.23
13.00-13.99MM	95.26	75.86
14.00-14.99MM	24.06	26.41
15.00-15.99MM	17.97	23.58
16.00-16.99MM	42.65	36.53
17.00-17.99MM	12.62	12.76
18.00-18.99MM	13.90	14.97
19.00-19.99MM	34.32	24.55
20.00-20.99MM	6.36	8.16
21.00-21.99MM	4.54	5.44
22.00-22.99MM	17.71	13.02
23.00-23.99MM	3.57	2.66
24.00-24.99MM	3.13	1.53
25.00-25.99MM	3.76	2.39
26.00-26.99MM	1.41	0.86
27.00-27.99MM	1.63	1.84
28.00-28.99MM	0.99	0.46
29.00-29.99MM	0.75	0.31
30.00-30.99MM	0.67	0.51
31.00-31.99MM	0.46	0.25
32.00-32.99MM	0.36	0.10
33.00-33.99MM	0.13	0.02
34.00-34.99MM	0.32	0.03
35.00-35.99MM	0.32	0.04
36.00-36.99MM	0.18	0.03
37.00-37.99MM	0.00	0.01
SPECIES	2142.15	2142.96

Appendix . . (Cont.)

SIZE CLASS	COMBINED: MANTA, OBLIQUE BONGO, AURIGA	OBLIQUE: ALL SAMPLES

COMMON NAME=WHITE CROAKER SPECIES=GENYONEMUS LINEATUS

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	123.903	144.386
3.00- 3.99MM	209.193	209.826
4.00- 4.99MM	432.478	300.756
5.00- 5.99MM	103.993	73.065
6.00- 6.99MM	71.232	90.767
7.00- 7.99MM	3.808	14.891
8.00- 8.99MM	11.196	10.752
9.00- 9.99MM	1.441	3.793
10.00-10.99MM	0.239	2.719
11.00-11.99MM	0.946	0.611
12.00-12.99MM	0.504	0.628
13.00-13.99MM	0.471	0.655
14.00-14.99MM	0.074	0.010
15.00-15.99MM	0.178	0.000
16.00-16.99MM	0.084	0.000
17.00-17.99MM	0.062	0.000
18.00-18.99MM	0.070	0.000
19.00-19.99MM	0.085	0.000
20.00-20.99MM	0.079	0.000
22.00-22.99MM	0.017	0.000
SPECIES	965.061	852.860

COMMON NAME=QUEENFISH SPECIES=SERIPHUS POLITUS

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	37.80	36.30
3.00- 3.99MM	11.77	12.52
4.00- 4.99MM	12.74	14.92
5.00- 5.99MM	9.15	5.76
6.00- 6.99MM	5.22	1.68
7.00- 7.99MM	0.62	0.70
8.00- 8.99MM	0.38	0.08
9.00- 9.99MM	0.25	0.17
10.00-10.99MM	0.30	0.08
11.00-11.99MM	0.17	0.10
12.00-12.99MM	0.16	0.00
13.00-13.99MM	0.05	0.00
14.00-14.99MM	0.07	0.00
15.00-15.99MM	0.07	0.00
16.00-16.99MM	0.07	0.00
17.00-17.99MM	0.08	0.00
18.00-18.99MM	0.22	0.02
19.00-19.99MM	0.13	0.03
20.00-20.99MM	0.04	0.00
21.00-21.99MM	0.01	0.00
22.00-22.99MM	0.03	0.00
23.00-23.99MM	0.01	0.00
26.00-26.99MM	0.02	0.00
27.00-27.99MM	0.02	0.00
SPECIES	79.44	72.40

Appendix 3-A. (Cont.).

SIZE CLASS	COMBINED: MANTA, OBLIQUE BONGO, AURIGA	OBLIQUE: ALL SAMPLES

COMMON NAME=PACIFIC BUTTERFISH   SPECIES=PEPRILUS SIMILLIMUS

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	6.406	7.9239
3.00- 3.99MM	6.431	6.8100
SPECIES	12.837	14.7339

COMMON NAME=SEA BASSES   SPECIES=PARALABRAX

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	9.5718	9.8935
3.00- 3.99MM	5.2882	6.2585
4.00- 4.99MM	3.0704	3.1618
5.00- 5.99MM	0.8098	0.5205
6.00- 6.99MM	0.1738	0.1350
7.00- 7.99MM	0.1327	0.1899
8.00- 8.99MM	0.0652	0.0503
9.00- 9.99MM	0.0192	0.0286
10.00-10.99MM	0.1060	0.1200
11.00-11.99MM	0.0034	0.0006
SPECIES	19.2405	20.3588

COMMON NAME=SARGO   SPECIES=ANISOTREMUS DAVIDSONII

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	0.0893	0.1984
3.00- 3.99MM	0.2275	0.3974
4.00- 4.99MM	0.0000	0.0770
5.00- 5.99MM	0.0089	0.0307
6.00- 6.99MM	0.0000	0.0073
7.00- 7.99MM	0.0000	0.0084
8.00- 8.99MM	0.0000	0.0073
10.00-10.99MM	0.0265	0.0048
SPECIES	0.3522	0.7313

COMMON NAME=SPOTFIN CROAKER   SPECIES=RONCADOR STEARNSII

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	0	0.0102
4.00- 4.99MM	0	0.0076
SPECIES	0	0.0178

COMMON NAME=BLACK CROAKER   SPECIES=CHEILOTREMA SATURNUM

CLASS	COMBINED	OBLIQUE
0.00- 2.99MM	0.1072	0.2186
3.00- 3.99MM	0.0000	0.0779
4.00- 4.99MM	0.0000	0.0163
SPECIES	0.1072	0.3128

Appendix 3-B. Estimate of target species size-frequency (number/1000 m3) for the Southern California Bight at four depth intervals.

SAMPLE TYPE: OBLIQUE, ALL SAMPLES	ESTIMATED DENSITY OF SIZE CLASS (NUMBERS/1000 M3)
SIZE CLASS	DEPTH IN METERS

COMMON NAME=NORTHERN ANCHOVY SPECIES=ENGRAULIS MORDAX

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	96.02	143.59	223.83	395.19
3.00- 3.99MM	190.28	122.22	531.00	600.72
4.00- 4.99MM	30.00	51.81	171.83	197.33
5.00- 5.99MM	40.34	58.21	134.72	208.55
6.00- 6.99MM	38.36	59.01	109.90	200.51
7.00- 7.99MM	38.63	70.01	82.72	151.78
8.00- 8.99MM	41.63	19.97	97.87	142.69
9.00- 9.99MM	39.33	39.06	99.32	110.70
10.00-10.99MM	63.13	52.55	93.79	92.26
11.00-11.99MM	106.73	51.89	73.17	54.96
12.00-12.99MM	105.07	50.43	57.80	29.55
13.00-13.99MM	16.37	497.80	45.78	30.18
14.00-14.99MM	12.51	43.64	26.80	24.87
15.00-15.99MM	80.00	33.96	30.16	16.51
16.00-16.99MM	23.40	208.49	24.68	17.04
17.00-17.99MM	15.58	17.54	16.32	10.93
18.00-18.99MM	61.10	13.64	13.71	12.38
19.00-19.99MM	27.02	218.82	7.54	2.37
20.00-20.99MM	25.12	34.23	19.01	0.41
21.00-21.99MM	16.31	10.48	9.66	2.84
22.00-22.99MM	11.30	87.47	13.21	2.84
23.00-23.99MM	18.63	14.20	2.02	0.16
24.00-24.99MM	5.10	4.25	3.40	0.39
25.00-25.99MM	2.52	20.14	2.18	0.00
26.00-26.99MM	0.90	5.80	1.49	0.00
27.00-27.99MM	2.12	10.32	4.20	0.00
28.00-28.99MM	0.71	0.02	2.27	0.00
29.00-29.99MM	2.18	0.23	0.99	0.00
30.00-30.99MM	0.57	0.00	2.60	0.00
31.00-31.99MM	0.02	0.31	0.36	0.09
32.00-32.99MM	0.00	0.00	0.52	0.00
33.00-33.99MM	0.00	0.21	0.02	0.00
34.00-34.99MM	0.00	0.00	0.17	0.00
35.00-35.99MM	0.00	0.00	0.19	0.00
36.00-36.99MM	0.00	0.00	0.17	0.00
37.00-37.99MM	0.01	0.00	0.04	0.00
SPECIES	1116.81	1940.34	1908.99	2305.23

Appendix 3-B. (Cont.).

SAMPLE TYPE: OBLIQUE, ALL SAMPLES	ESTIMATED DENSITY OF SIZE CLASS (NUMBERS/1000 M3)
SIZE CLASS	DEPTH IN METERS

COMMON NAME=WHITE CROAKER SPECIES=GENYONEMUS LINEATUS

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	46.525	405.14	227.60	92.005
3.00- 3.99MM	153.839	410.59	167.61	197.323
4.00- 4.99MM	65.035	381.79	182.80	333.311
5.00- 5.99MM	326.738	353.52	110.31	6.964
6.00- 6.99MM	223.004	66.54	218.67	49.293
7.00- 7.99MM	35.521	10.26	65.77	0.000
8.00- 8.99MM	6.024	63.47	24.49	0.000
9.00- 9.99MM	7.760	0.00	18.36	0.000
10.00-10.99MM	0.307	0.00	13.88	0.157
11.00-11.99MM	0.842	3.96	1.10	0.000
12.00-12.99MM	0.000	2.46	2.13	0.000
13.00-13.99MM	1.184	0.75	2.84	0.000
14.00-14.99MM	0.000	0.00	0.05	0.000
17.00-17.99MM	0.039	0.00	0.00	0.000
SPECIES	876.835	1698.77	1035.61	684.058

COMMON NAME=QUEENFISH SPECIES=SERIPHUS POLITUS

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	41.09	46.07	53.77	29.78
3.00- 3.99MM	21.40	33.51	34.30	2.99
4.00- 4.99MM	33.59	72.85	23.81	2.88
5.00- 5.99MM	24.23	25.93	4.18	2.17
6.00- 6.99MM	26.60	2.60	0.44	0.22
7.00- 7.99MM	15.03	0.00	0.09	0.00
8.00- 8.99MM	1.72	0.00	0.00	0.00
9.00- 9.99MM	3.75	0.02	0.00	0.00
10.00-10.99MM	1.79	0.00	0.00	0.00
11.00-11.99MM	1.79	0.21	0.00	0.00
12.00-12.99MM	0.09	0.00	0.00	0.00
13.00-13.99MM	0.02	0.00	0.00	0.00
16.00-16.99MM	0.02	0.00	0.00	0.00
17.00-17.99MM	0.06	0.00	0.00	0.00
18.00-18.99MM	0.48	0.00	0.00	0.00
19.00-19.99MM	0.76	0.00	0.00	0.00
20.00-20.99MM	0.02	0.00	0.00	0.00
SPECIES	177.44	181.19	116.59	38.04

Appendix 3-B. (Cont.)

SAMPLE TYPE: OBLIQUE, ALL SAMPLES	ESTIMATED DENSITY OF SIZE CLASS (NUMBERS/1000 M3)
SIZE CLASS	DEPTH IN METERS

COMMON NAME=PACIFIC BUTTERFISH SPECIES=PEPRILUS SIMILLIMUS

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	2.6263	14.4338	18.1208	4.5538
3.00- 3.99MM	0.0000	0.0000	2.1960	9.4893
SPECIES	2.6263	14.4338	20.3169	14.0431

COMMON NAME=SEA BASSES SPECIES=PARALABRAX

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	4.29469	15.3169	12.7498	8.7323
3.00- 3.99MM	1.31610	2.8109	12.1754	5.4237
4.00- 4.99MM	0.03938	0.6854	4.3146	3.3936
5.00- 5.99MM	0.00000	0.4986	1.7154	0.2269
6.00- 6.99MM	0.00000	0.1347	0.4302	0.0622
7.00- 7.99MM	0.06077	0.0000	0.4576	0.1420
8.00- 8.99MM	0.07347	0.3539	0.0702	0.0000
9.00- 9.99MM	0.15938	0.0000	0.1133	0.0000
10.00-10.99MM	0.26815	0.0090	0.0000	0.1598
11.00-11.99MM	0.01320	0.0000	0.0000	0.0000
SPECIES	6.22594	19.8105	32.0570	18.1406

COMMON NAME=SARGO SPECIES=ANISOTREMUS DAVIDSONII

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	0.82165	0.15812	0.57034	0.05847
3.00- 3.99MM	0.14105	0.07906	0.99530	0.29233
4.00- 4.99MM	0.00000	0.00000	0.41037	0.00000
5.00- 5.99MM	0.03505	0.00000	0.15518	0.00000
6.00- 6.99MM	0.00000	0.07906	0.00000	0.00000
7.00- 7.99MM	0.18487	0.00000	0.00000	0.00000
8.00- 8.99MM	0.00000	0.07906	0.00000	0.00000
10.00-10.99MM	0.10458	0.00000	0.00000	0.00000
SPECIES	1.28720	0.39530	2.13219	0.35080

COMMON NAME=SPOTFIN CROAKER SPECIES=RONCADOR STEARNSII

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	0.0000	0	0.0545	0
4.00- 4.99MM	0.1668	0	0.0000	0
SPECIES	0.1668	0	0.0545	0

COMMON NAME=BLACK CROAKER SPECIES=CHEILOTREMA SATURNUM

CLASS	_08_	_15_	_22_	_36_
0.00- 2.99MM	1.12500	0.90825	0.44333	0
3.00- 3.99MM	0.44415	0.55205	0.03404	0
4.00- 4.99MM	0.21855	0.00000	0.03404	0
SPECIES	1.78770	1.46030	0.51141	0

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