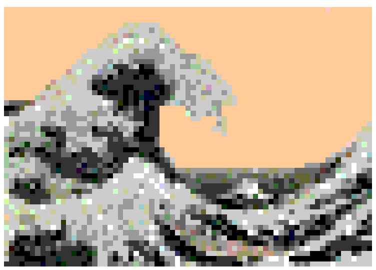
Entrainment and Impingement Studies:
What you need to know about fishes and their life histories



Gregor M. Cailliet
Professor, MLML
Consultant, RWQCB and CEC

For the

SWRCB Training Session: Regulation and Impact Assessment of Once-Through Cooling Systems of California Coastal Power Plants

August 2006

BASIC OBJECTIVES

Understanding fish life histories to help evaluate their population and community ecology

and

Evaluating both natural and anthropogenic influences on fishes and their habitats & ecosystems.

OUTLINE OF TALK

What are Fishes?

- **Common Characteristics**
- **Evolution, Taxonomy & Diversity of Fishes**
  - **Jawless Fishes (Agnatha)**
  - **Cartilaginous Fishes (Chondrichthyes: Sharks, Rays, Chimaeras)**
  - **Bony Fishes (Osteichthyes)**

Life Histories of Fishes Relevant to Impact Assessment

- **Reproduction (various modes, those producing eggs & larvae)**
- **Development of Fishes (eggs to larvae to juveniles to adults…)**
- **Growth and Age Composition**

Recruitment (dispersal, immigration, emigration, mortality, etc.)

Habitats used by different life stages of fishes with different life styles.

Fish Assemblages by Habitats (Chapters from Allen et al. 2006)

Introduction to Ichthyoplankton (Chapter 11: Moser and Watson))

- **Egg & Larval Development**
- **CalCOFI Program**
- **Larval Fish Morphotypes & Pigment Groups**
- **Summary of Larval Assemblages**

Temporal Variation in Ichthyoplankton

- ***Decadal***
  - **El Nino and La Nina Cycles**
  - **Oceanic Regimes (Pacific Decadal Oscillation)**
    - **Sardine and Anchovy Example**
- ***Seasonal***
  - **Variation in Spawning Seasons…**

Declining Fish Stocks (& Causes)

- **Rockfishes (genus *Sebastes* spp.)**
- **Importance of Recruitment and Oceanic Regimes**
- **CalCOFI Data Series (Moser et al. 2000, CalCOFI Reports)**

What is impingement and entrainment?

Basic Methods of Estimation

(John Steinbeck will describe in detail)

Fecundity Hindcast (FH)

Adult Equivalent Loss (AEL)

Proportional Mortality (PM)

California Power Plant Ichthyoplankton Entrainment Studies

"Target" Species" (Steinbeck et al. 2006 CEC)

Larval Fish Entrainment Example Results

Seasonal & spatial variation, time & sizes at risk, etc.)

Example: Diablo Canyon Power Plant (Blackeye Goby)

Research on Ecological Effects of Once-Through Cooling

Mitigation (Pete Raimondi will describe)

Effect on Adult Fish Populations (Ditto)

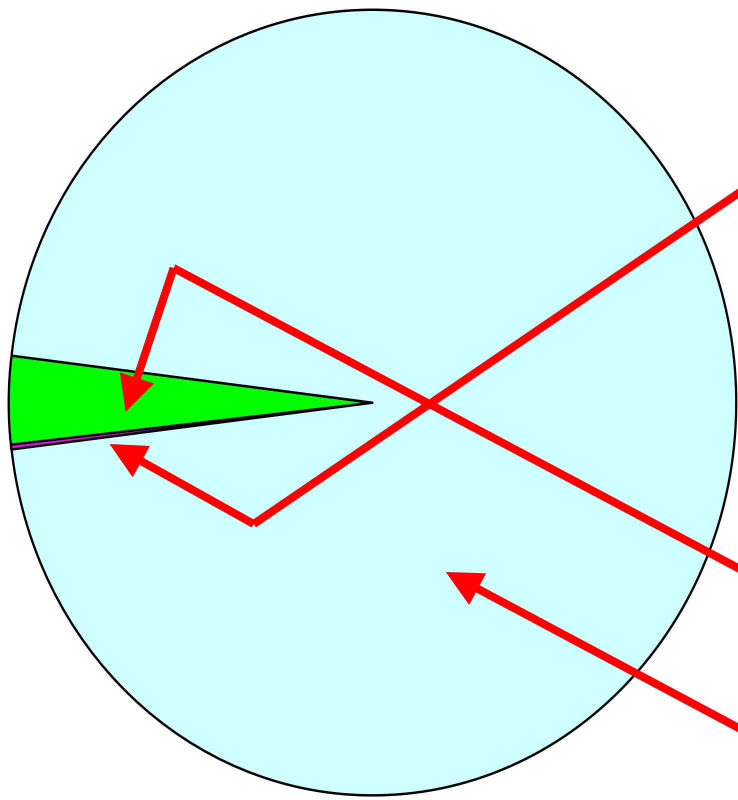
How to monitor habitat restoration mitigation

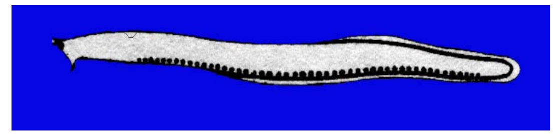
Summary

What are Fishes?

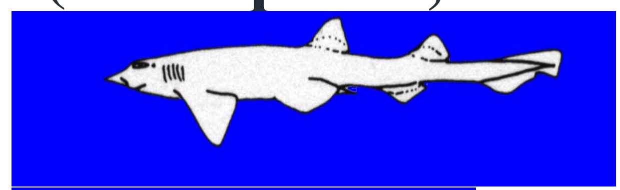
(cold-blooded vertebrates with jaws, backbones, median and paired fins, scales, lateral lines, etc.)

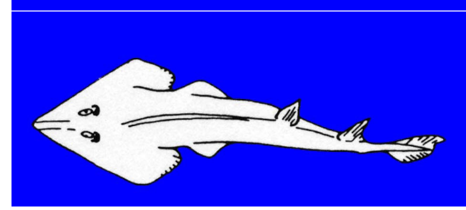
General Types of Fishes





Jawless Fishes
(85 + Species, > 1%)

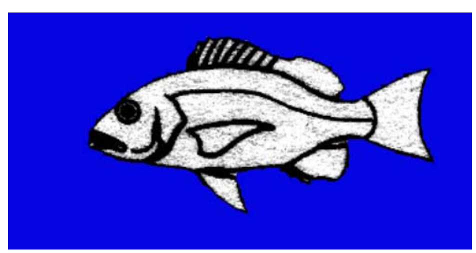




Cartilaginous Fishes
(1,000 + species, 3.5%)

Bony Fishes
(23,000 + species, 95%)

(Total Number of Species ~ 25,000+)

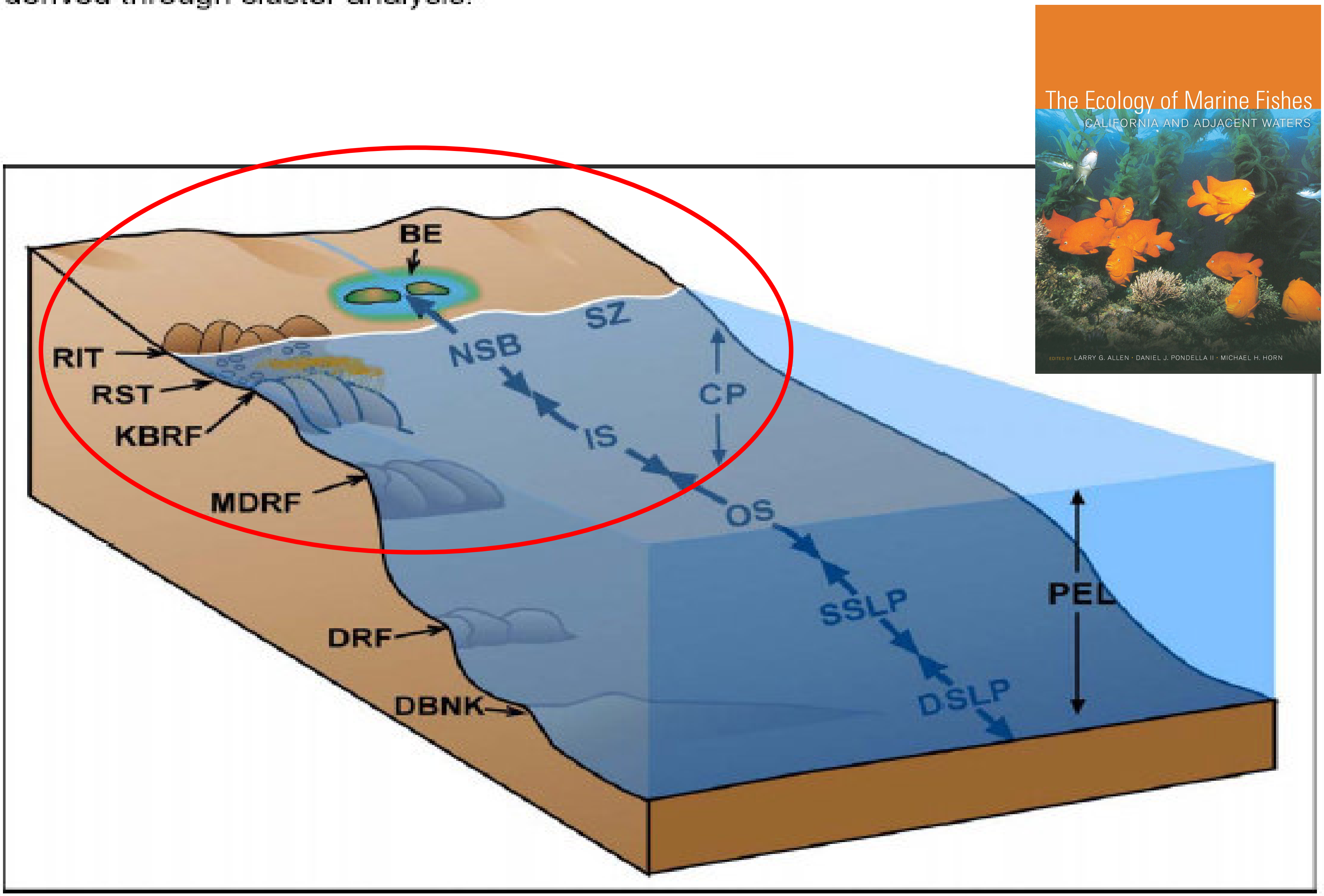


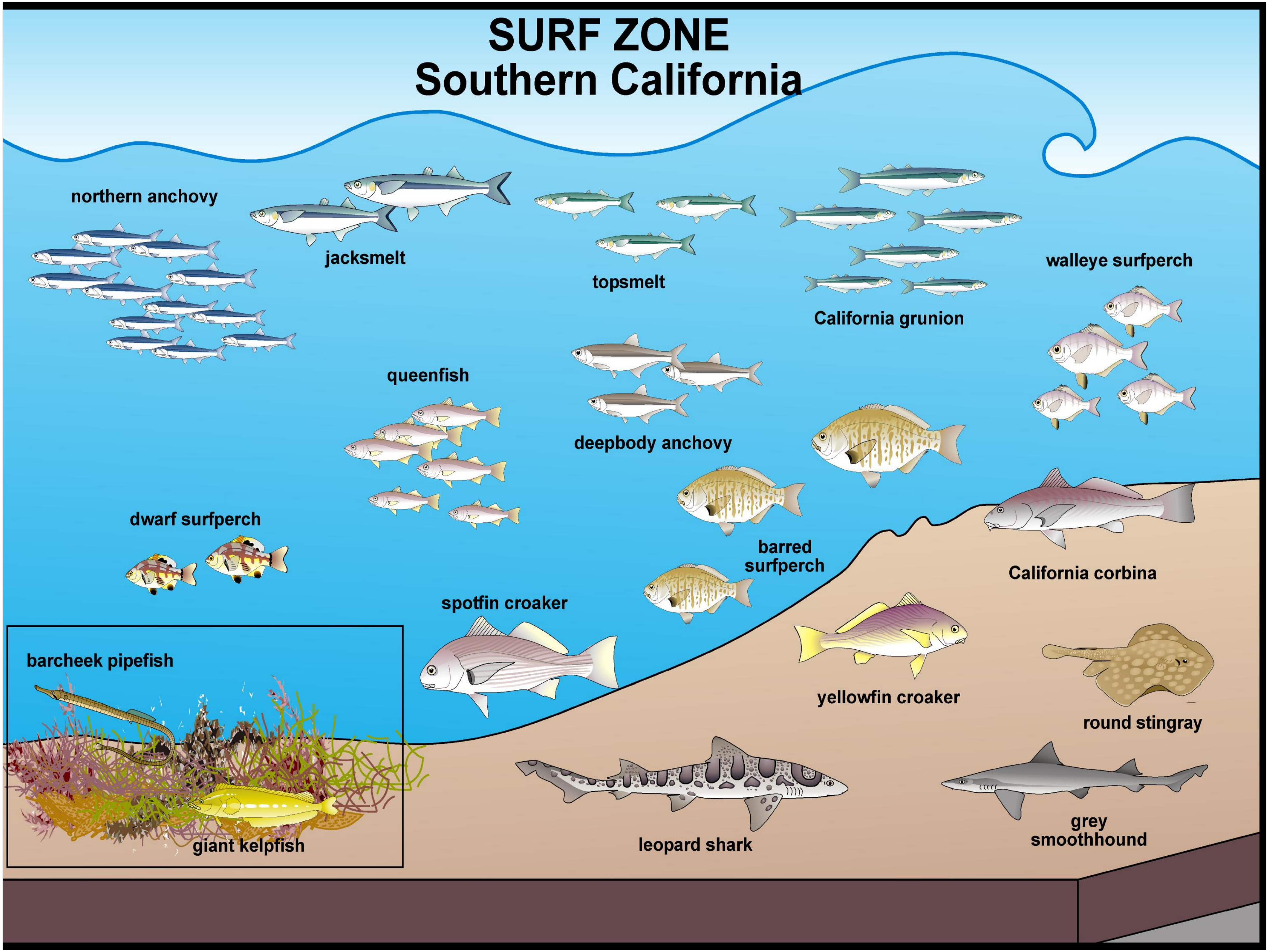

Life History Characteristics of Fishes

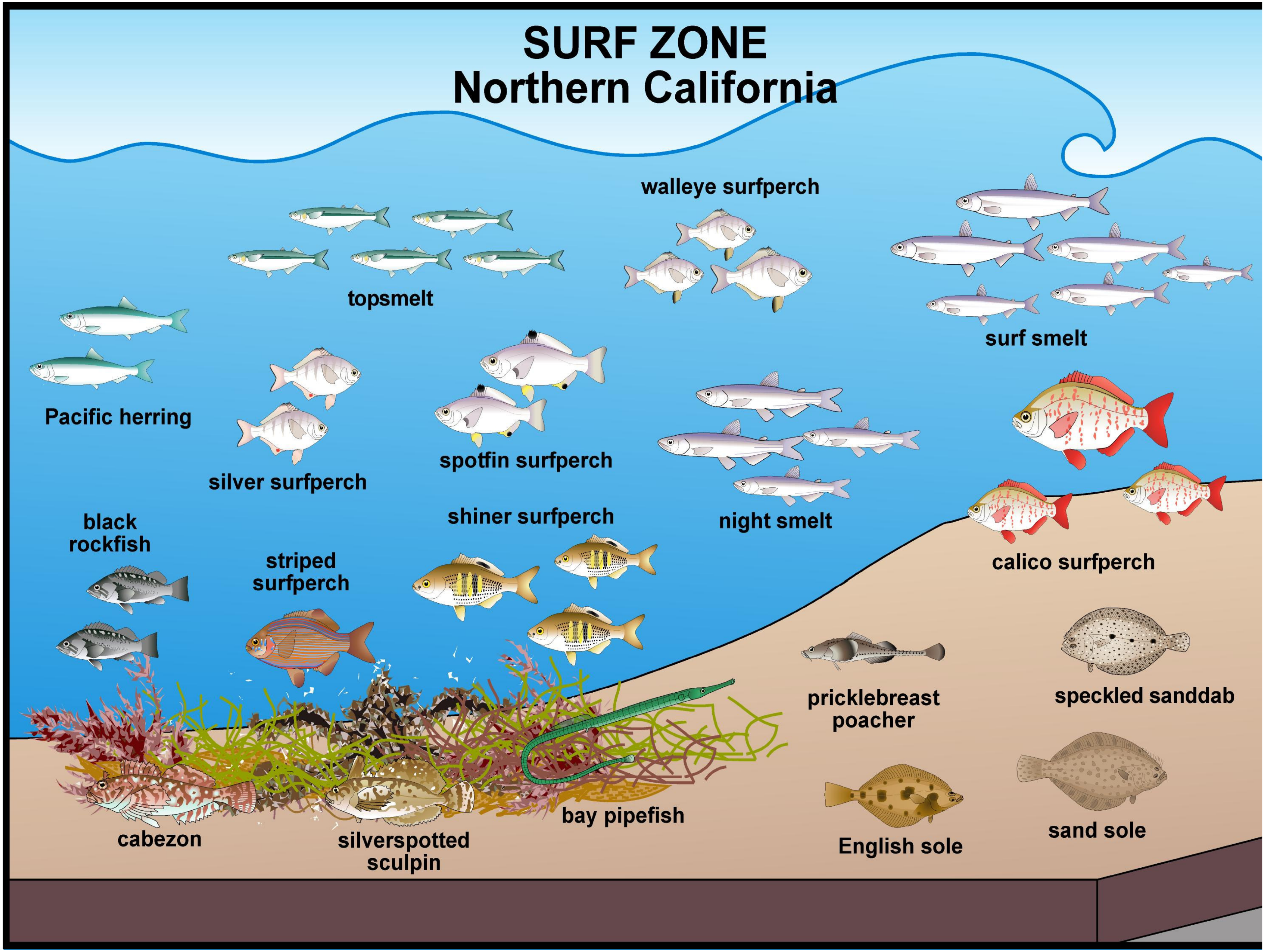
Habitats of Fishes in California (Allen et al. *2006*)

31

Figure 3. Diagrammatic representation of the relative positioning of the major habitats derived through cluster analysis.

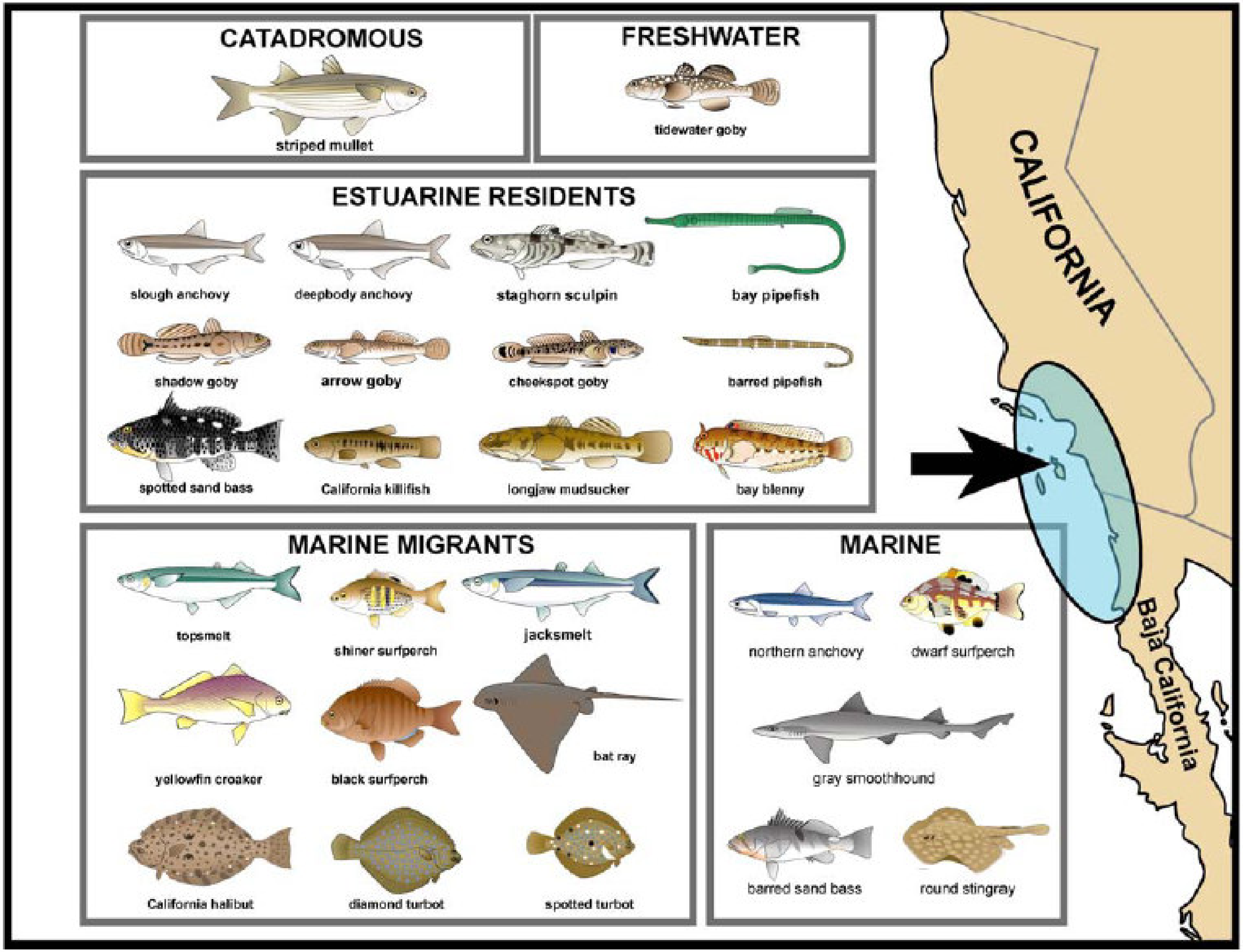



SURF ZONE
Southern California
northern anchovy
jacksmelt
topsmelt
California grunion
walleye surfperch
queenfish
deepbody anchovy
dwarf surfperch
barred surfperch
California corbina
spotfin croaker
yellowfin croaker
round stingray
barcheek pipefish
giant kelpfish
leopard shark
grey smoothhound

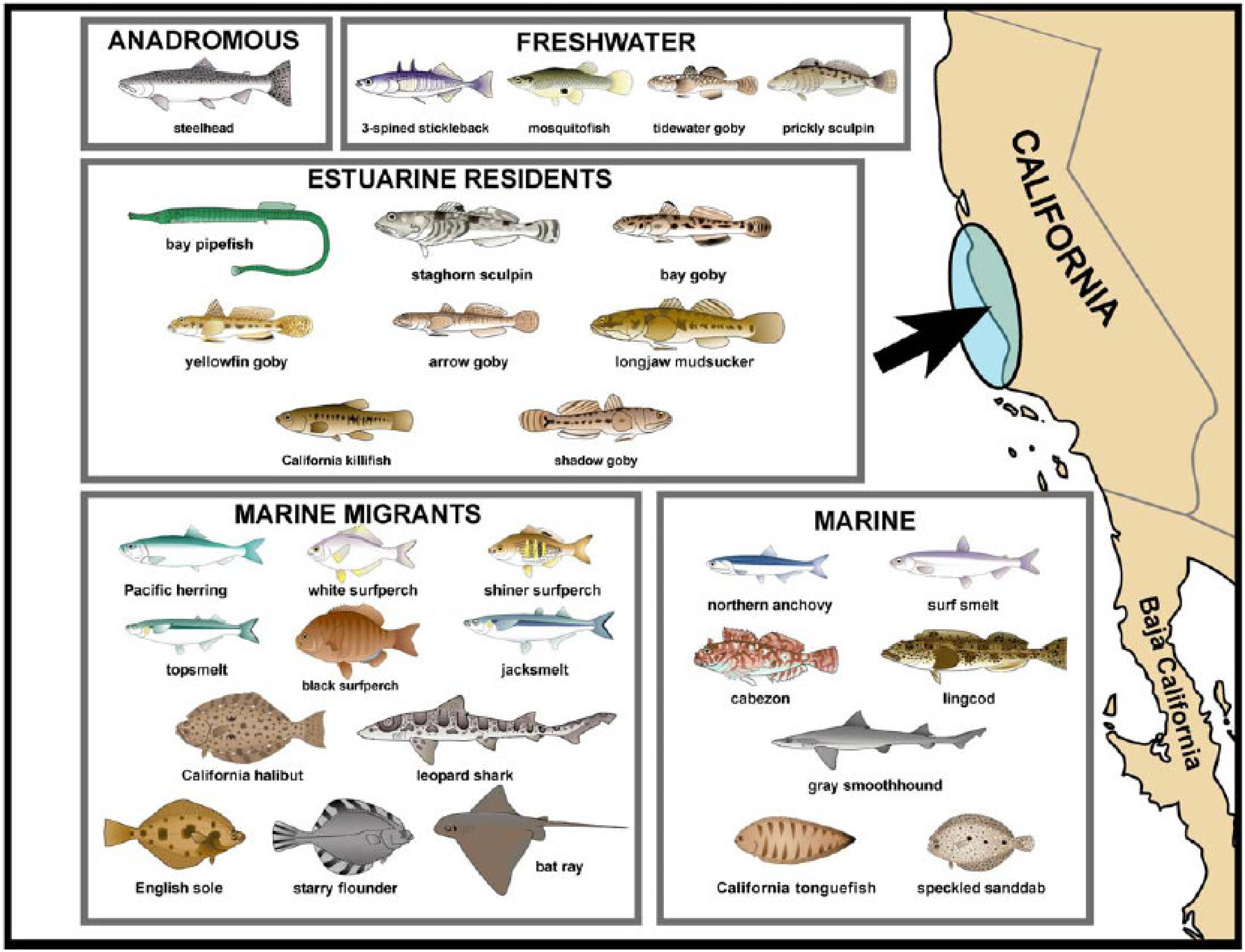


SURF ZONE
Northern California
walleye surfperch
topsmelt
surf smelt
Pacific herring
silver surfperch
spotfin surfperch
night smelt
black rockfish
shiner surfperch
striped surfperch
calico surfperch
pricklebreast poacher
speckled sanddab
bay pipefish
cabezon
silverspotted sculpin
English sole
sand sole

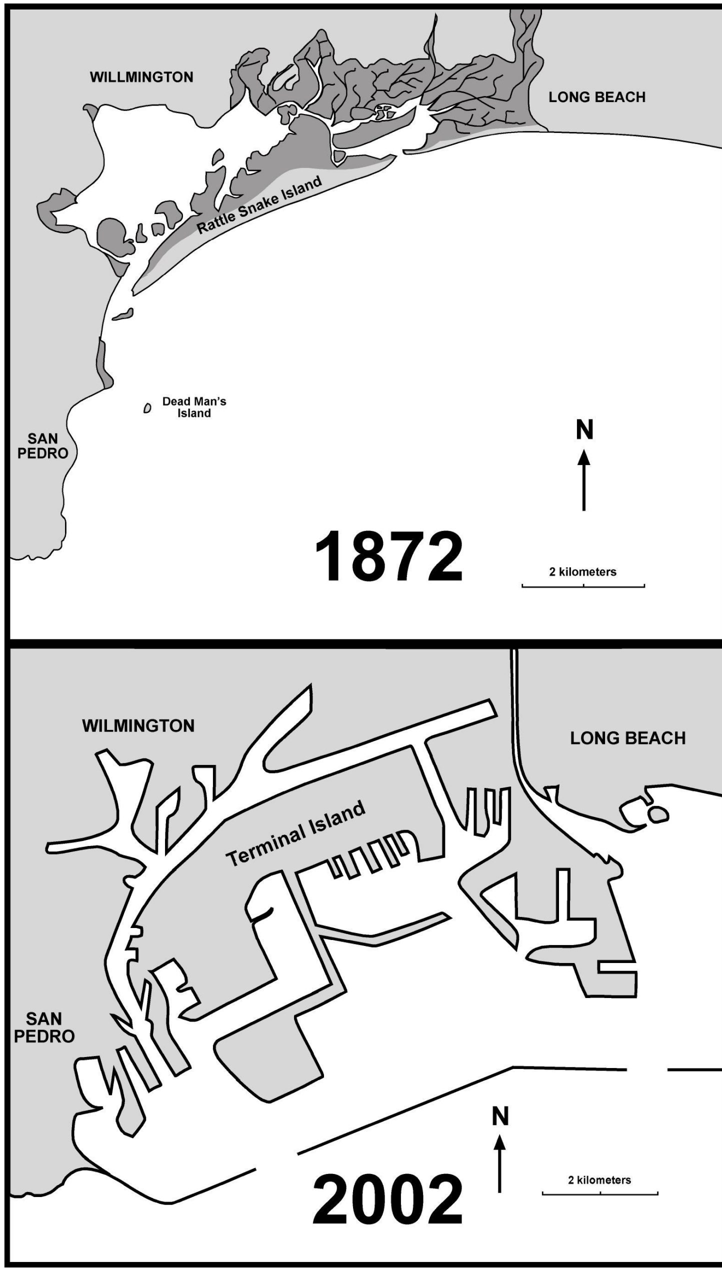
SOUTHERN CALIFORNIA BAYS AND ESTUARIES

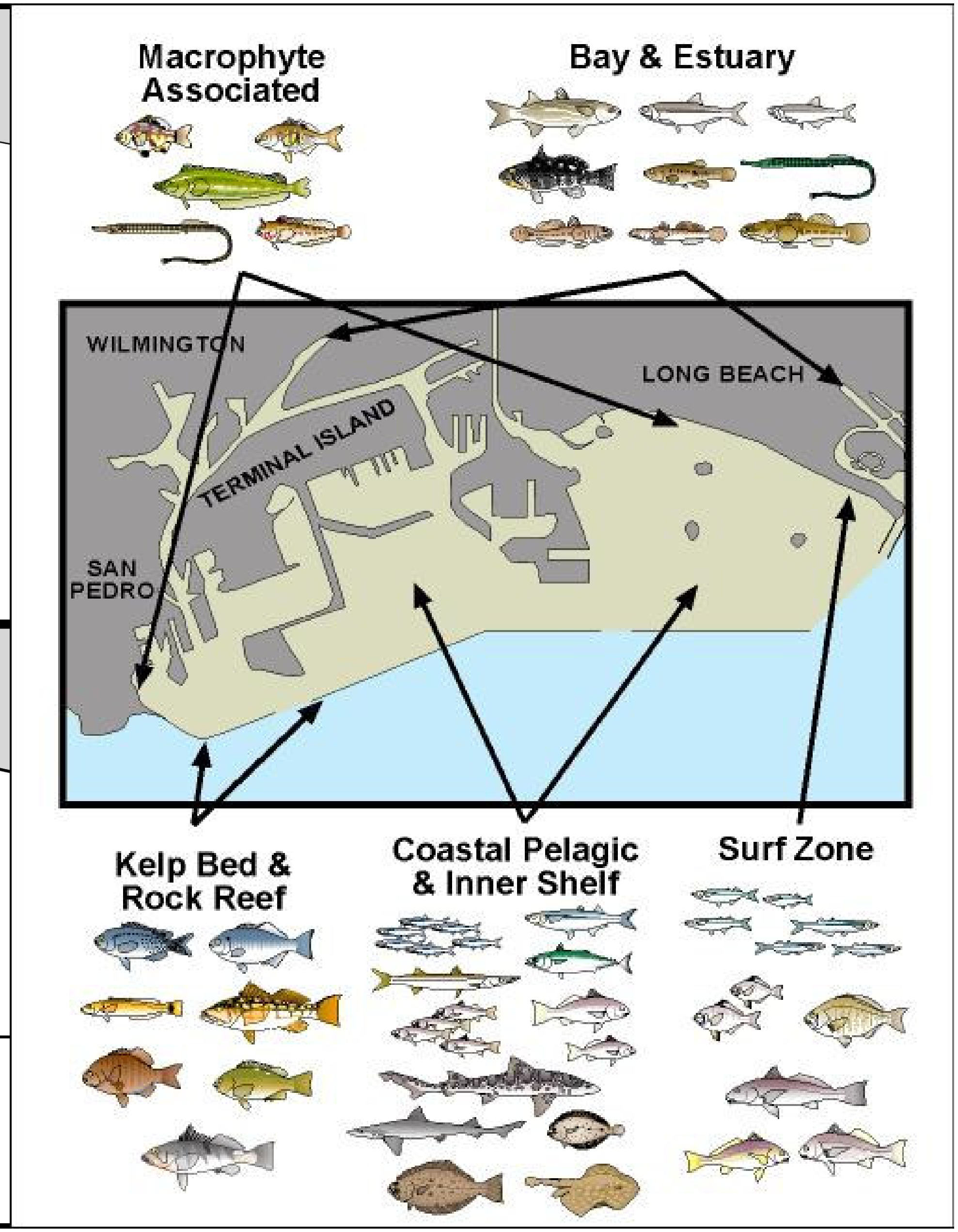


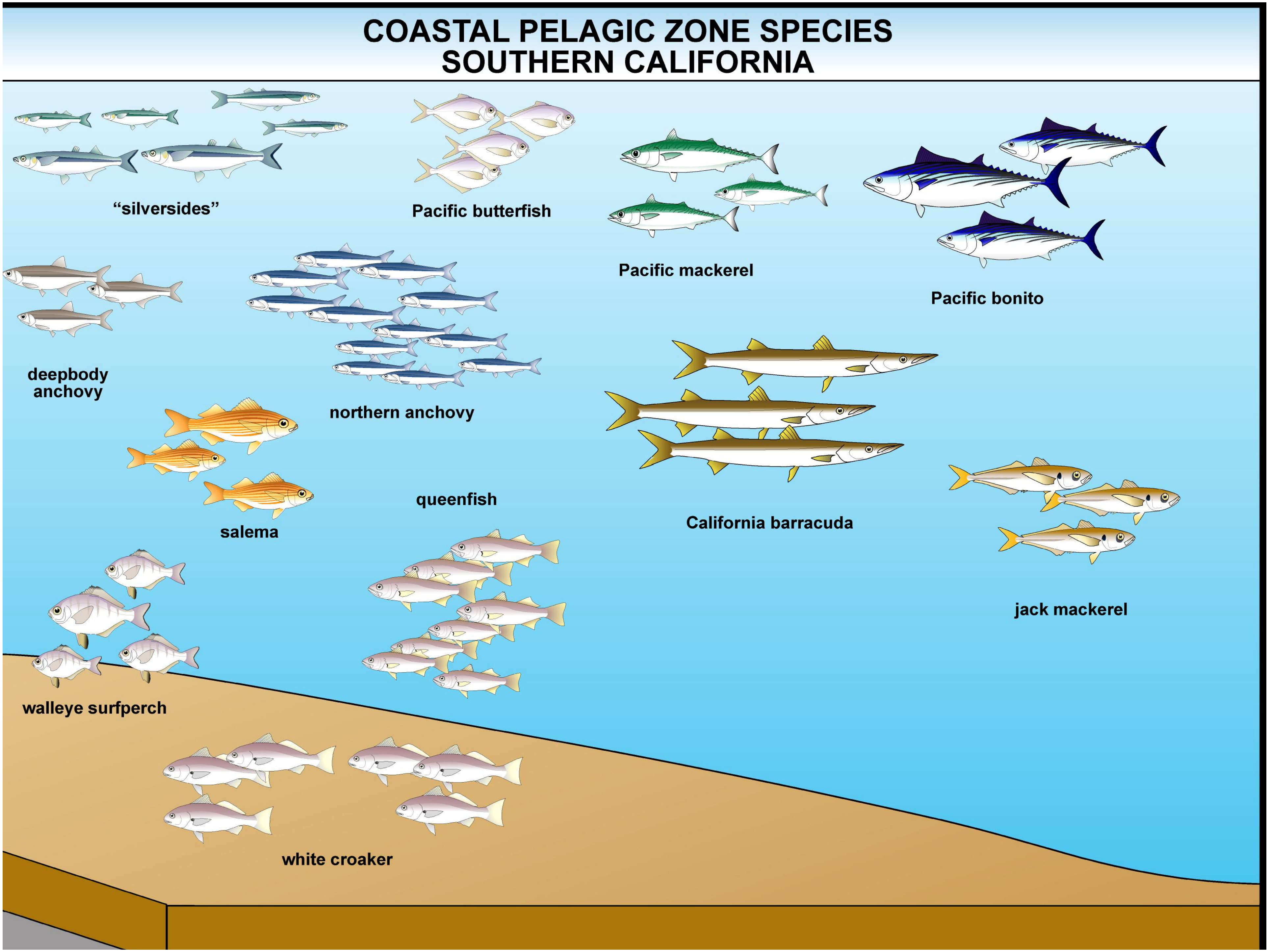
CENTRAL CALIFORNIA BAYS AND ESTUARIES



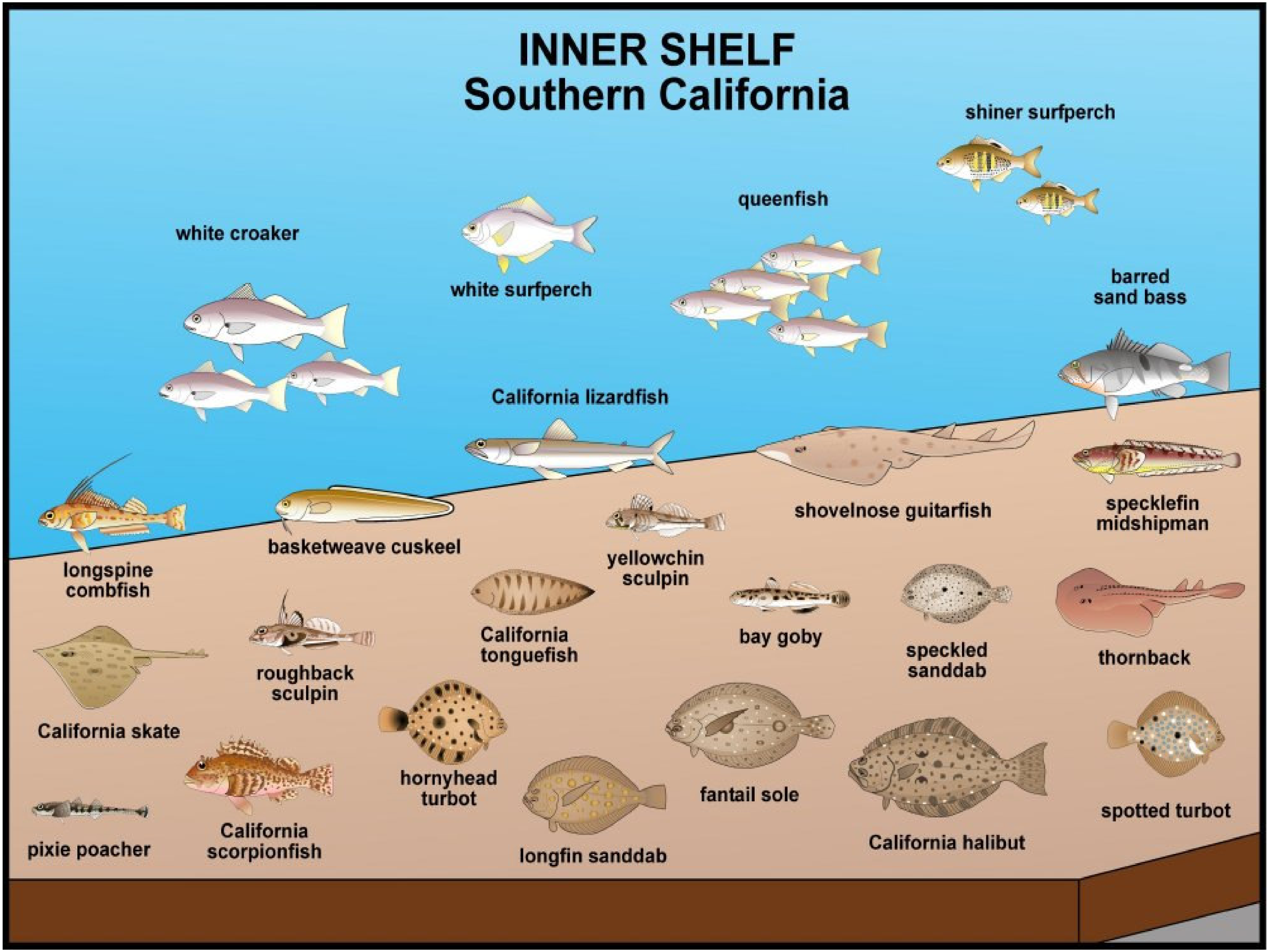
Harbors (like LA) can have several different habitats and fishes inhabit them.





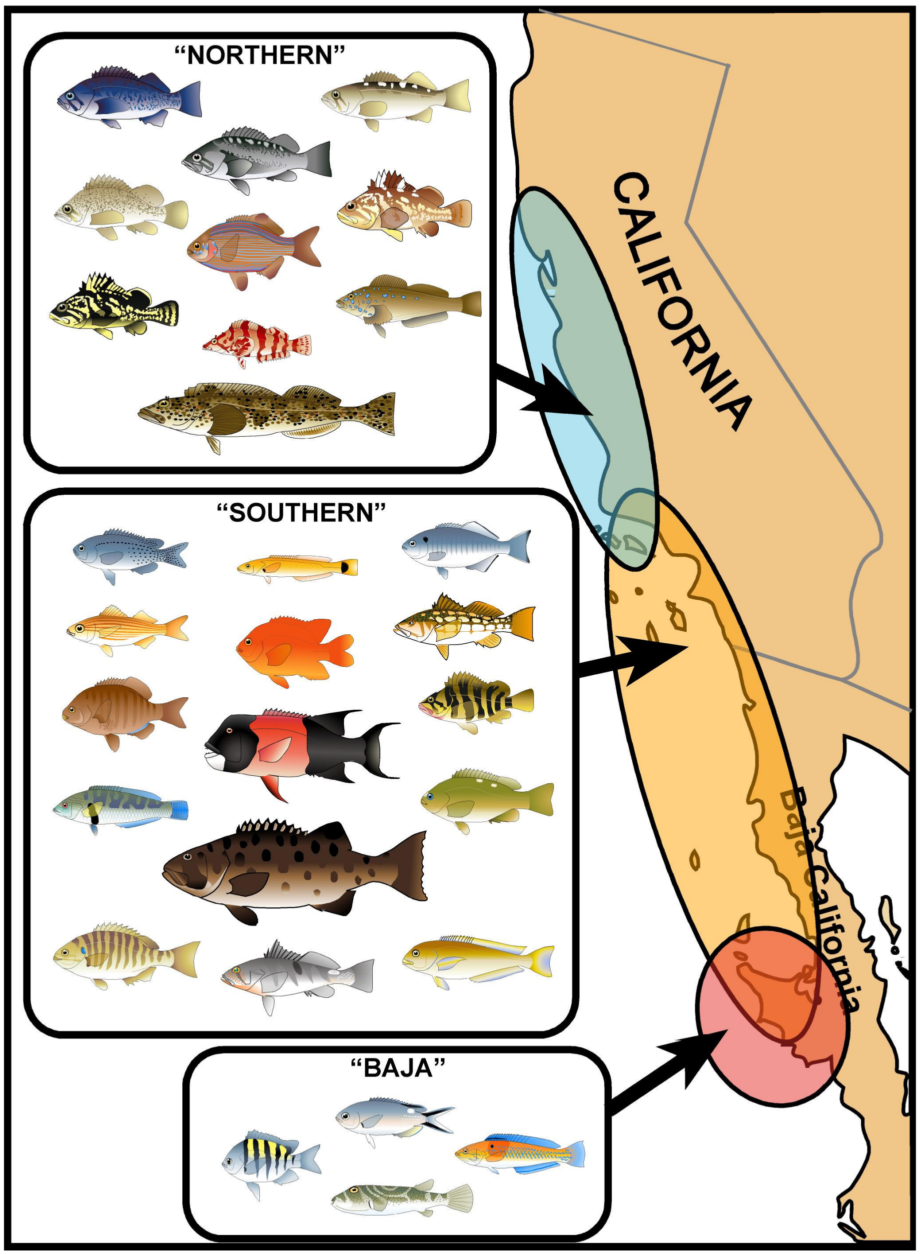


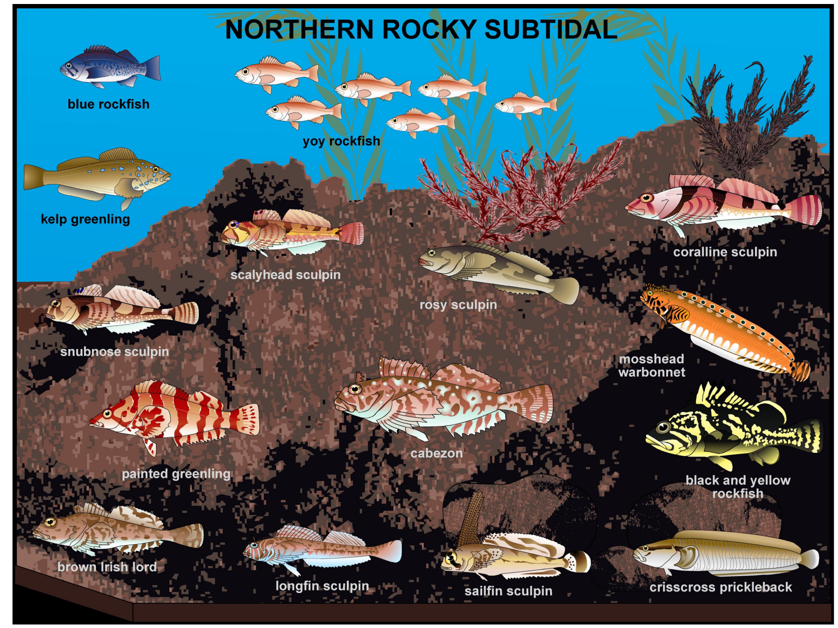
COASTAL PELAGIC ZONE SPECIES
SOUTHERN CALIFORNIA
"silversides"
Pacific butterfish
Pacific mackerel
Pacific bonito
deepbody anchovy
northern anchovy
salema
queenfish
California barracuda
jack mackerel
walleye surfperch
white croaker

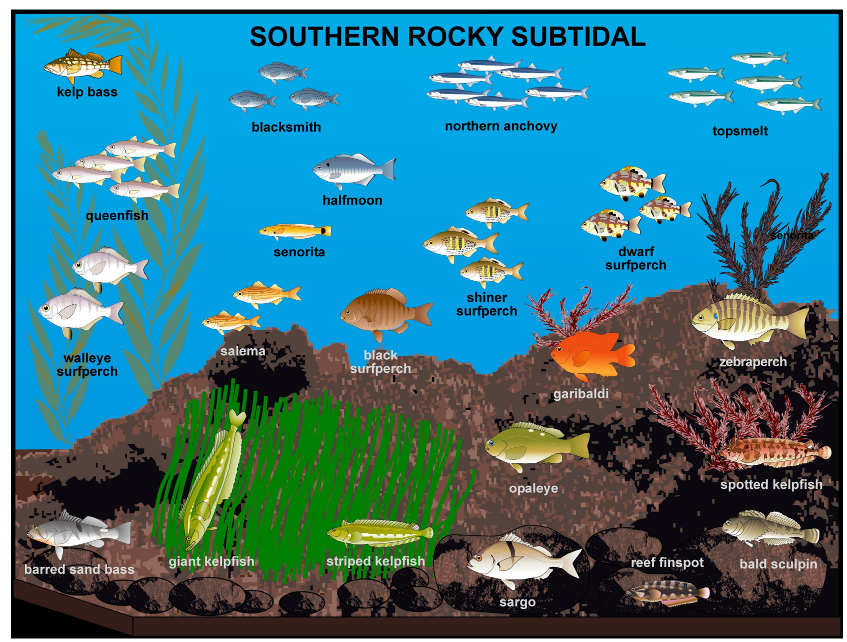


INNER SHELF
Southern California
shiner surfperch
queenfish
white croaker
white surfperch
barred sand bass
California lizardfish
shovelnose guitarfish
specklefin midshipman
longspine combfish
basketweave cuskeel
yellowchin sculpin
California tonguefish
bay goby
speckled sanddab
thornback
roughback sculpin
California skate
hornyhead turbot
fantail sole
California halibut
spotted turbot
pixie poacher
California scorpionfish
longfin sanddab

COMMON SPECIES
CALIFORNIA KELP BED / ROCKY REEF





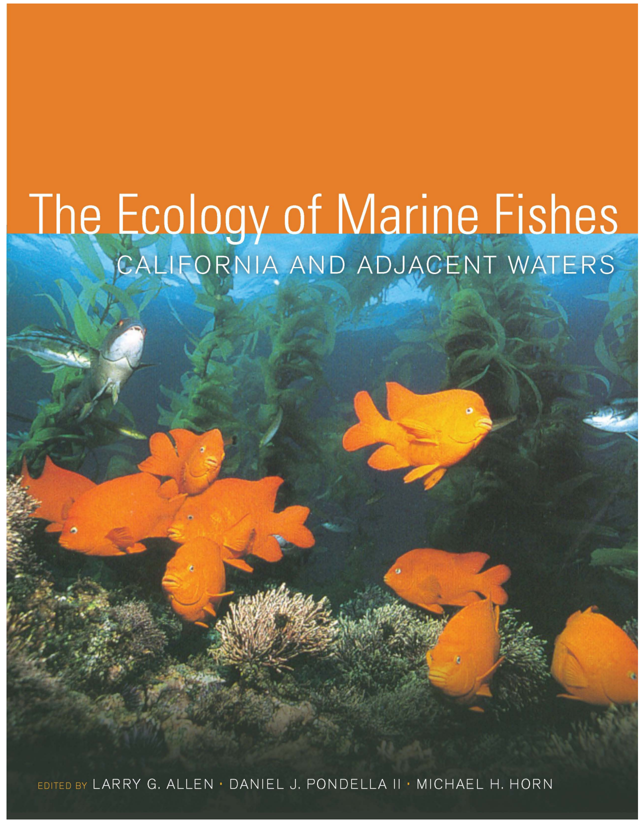


Different life stages of fishes with different life styles often occupy different habitats.

Eggs, Larvae, YOY, Juveniles, Sub adults, Adults

***ESSENTIAL FISH HABITAT* (EFH)**

It is the juveniles and adult fishes that can get IMPINGED by power plants and other industries that use once-through cooling systems. But, usually this is not of major significance…



CHAPTER 11

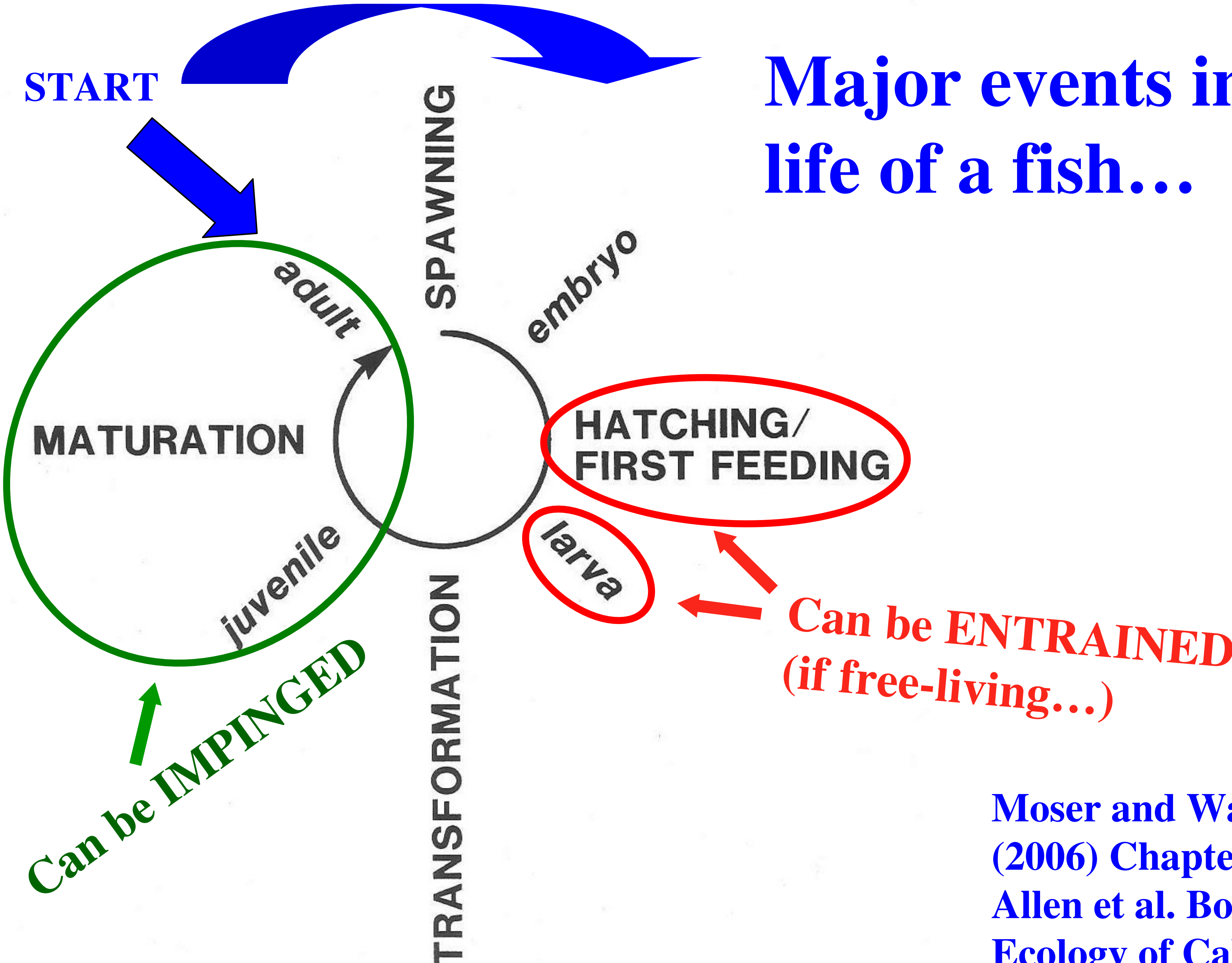
Ichthyoplankton

H. G. MOSER AND W. WATSON

It is the fish eggs and larvae of fishes that are subject to ENTRAINMENT by these facilities…

p. 269-319. In: The Ecology of Marine Fishes: California and Adjacent Waters. 2006.
L.G. Allen, D.J. Pondella, and M. H. Horn (eds.). University of California Press, Berkeley, 670 pp.

Major events in the life of a fish…



Moser and Watson (2006) Chapter 11 *In*: Allen et al. Book on Ecology of California Marine Fishes

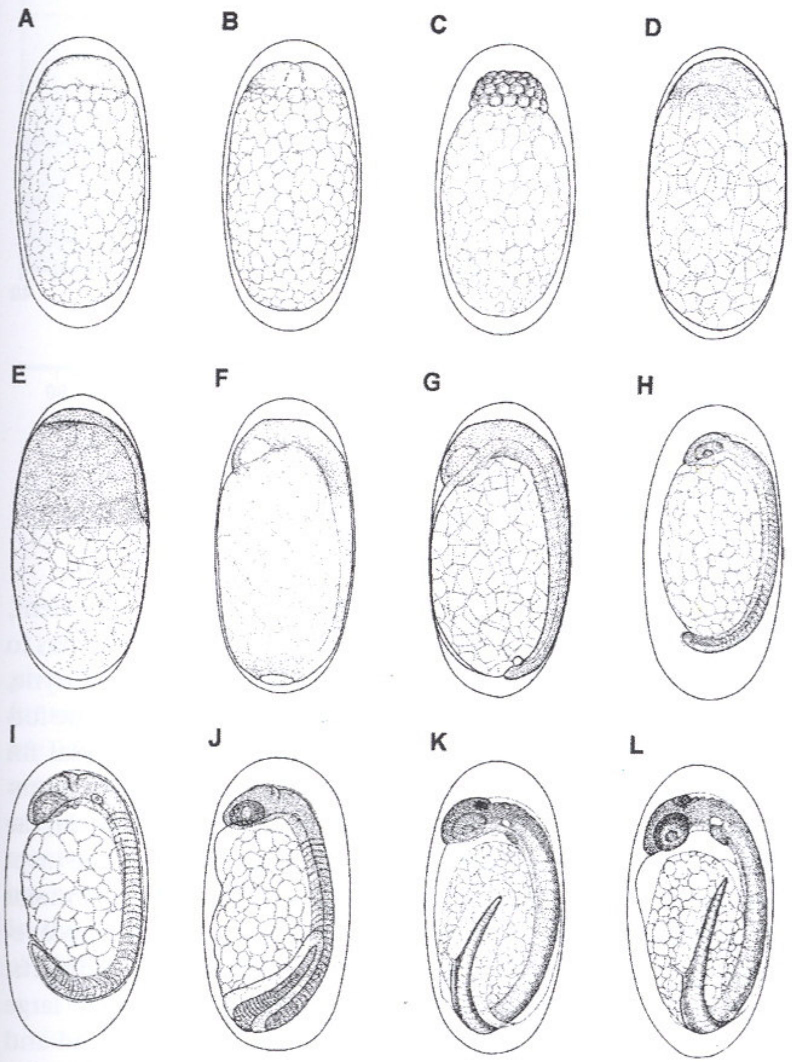


FIGURE 11-3 Developmental stages of northern anchovy (*Engraulis mordax*) eggs (modified from Moser and Ahlstrom, 1985). A: Stage I; B: early Stage II; C: Stage II; D: Stage III; E: Stage IV; F: Stage V; G: Stage VI; H: Stage VII; I: Stage VIII; J: Stage IX; K: Stage X; L: Stage XI. A–D are "early stage"; E–F are "middle stage"; G–L are "late stage."

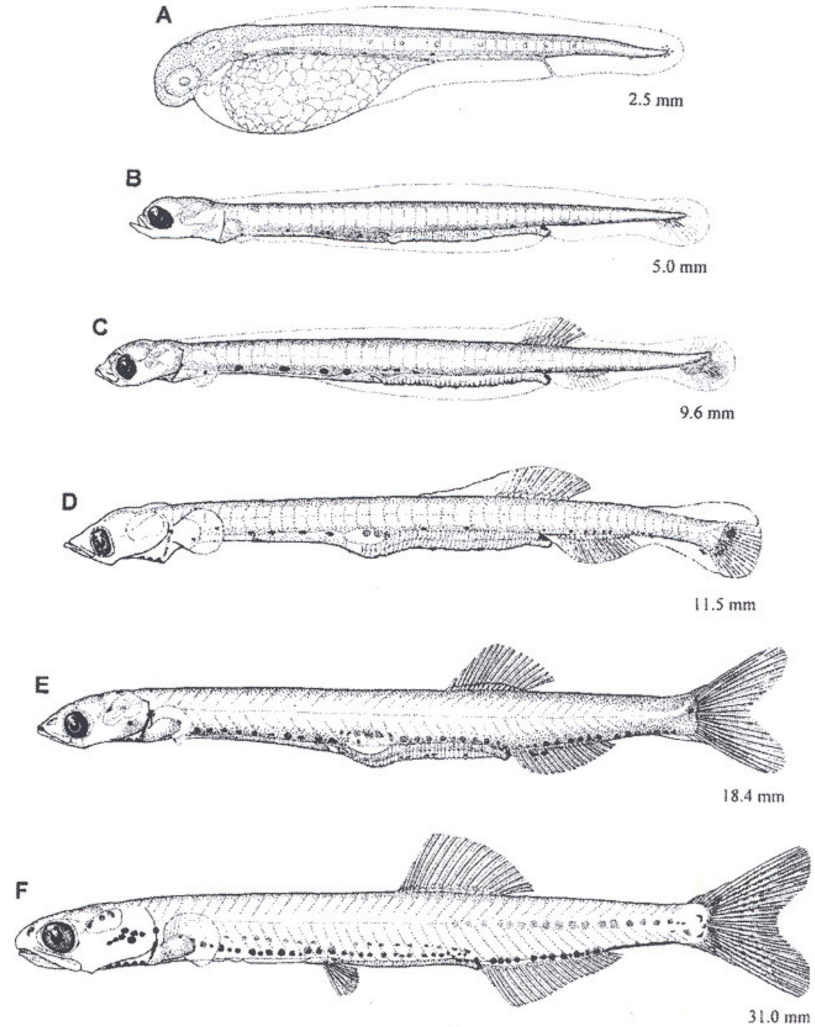
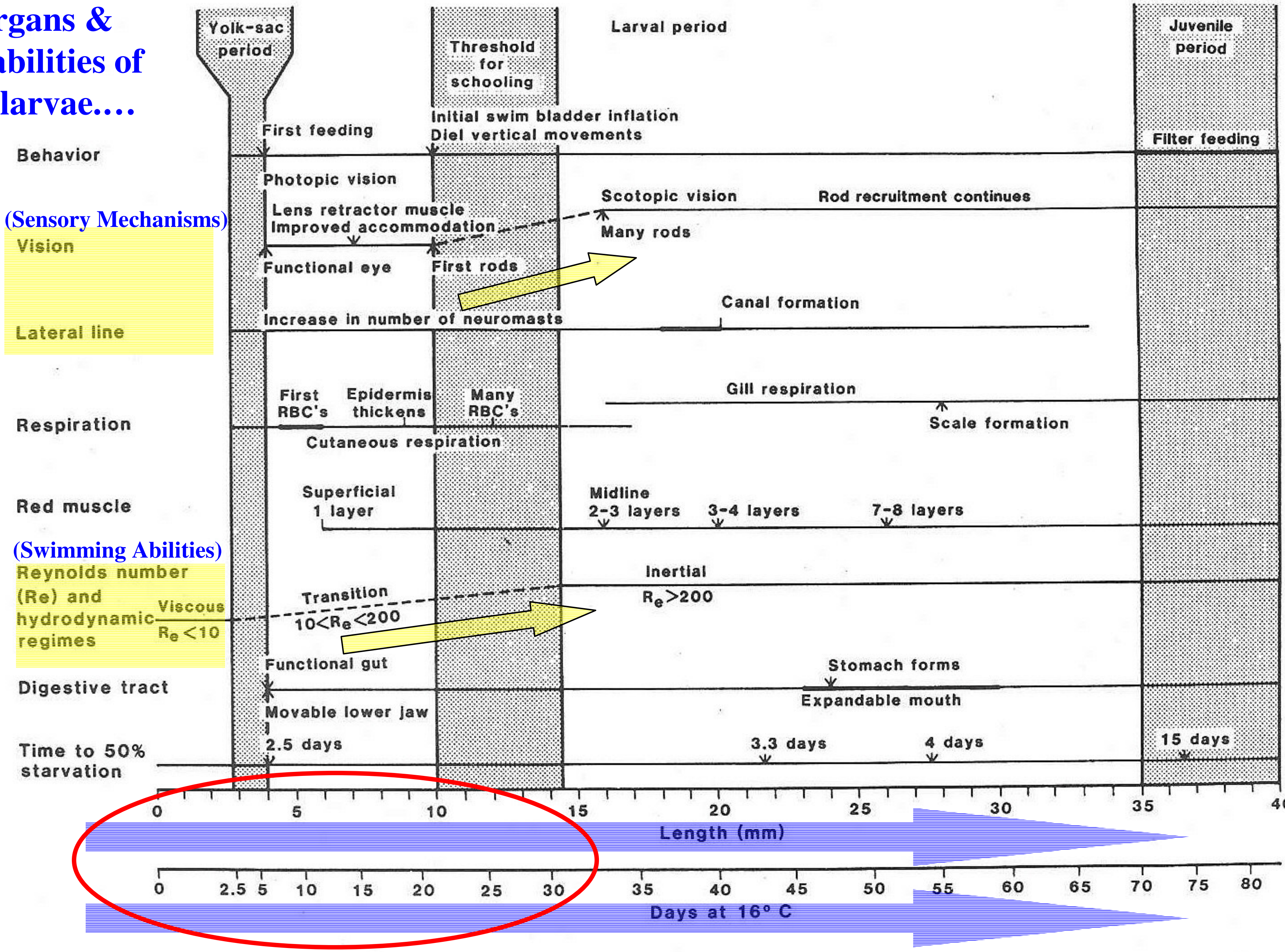


FIGURE 11-4 Developmental stages of northern anchovy (*Engraulis mordax*) larvae. A: yolk-sac stage, 2.5 mm; B: preflexion stage, 5.0 mm; C: early flexion stage, 9.6 mm; D: late flexion stage, 11.5 mm; E: postflexion stage, 18.4 mm; F: transformation stage, 31.0 mm. Illustrations from Kramer and Ahlstrom (1968).

Moser and Watson (2006) Chapter 11 *In*: Allen et al. Book on Ecology of California Marine Fishes

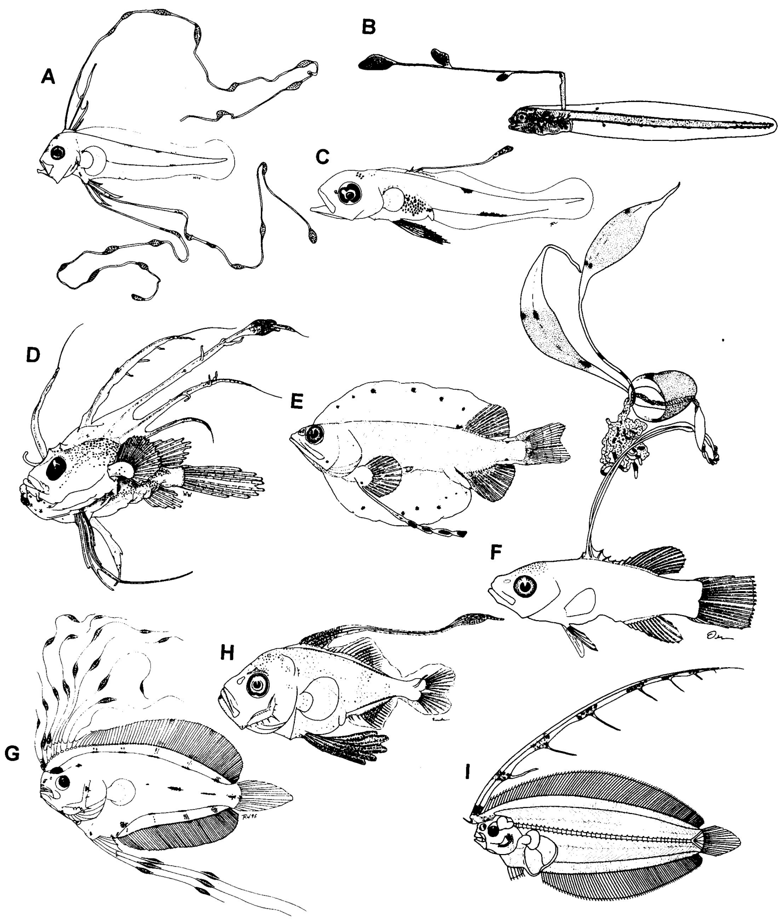
Development of organs & capabilities of fish larvae….

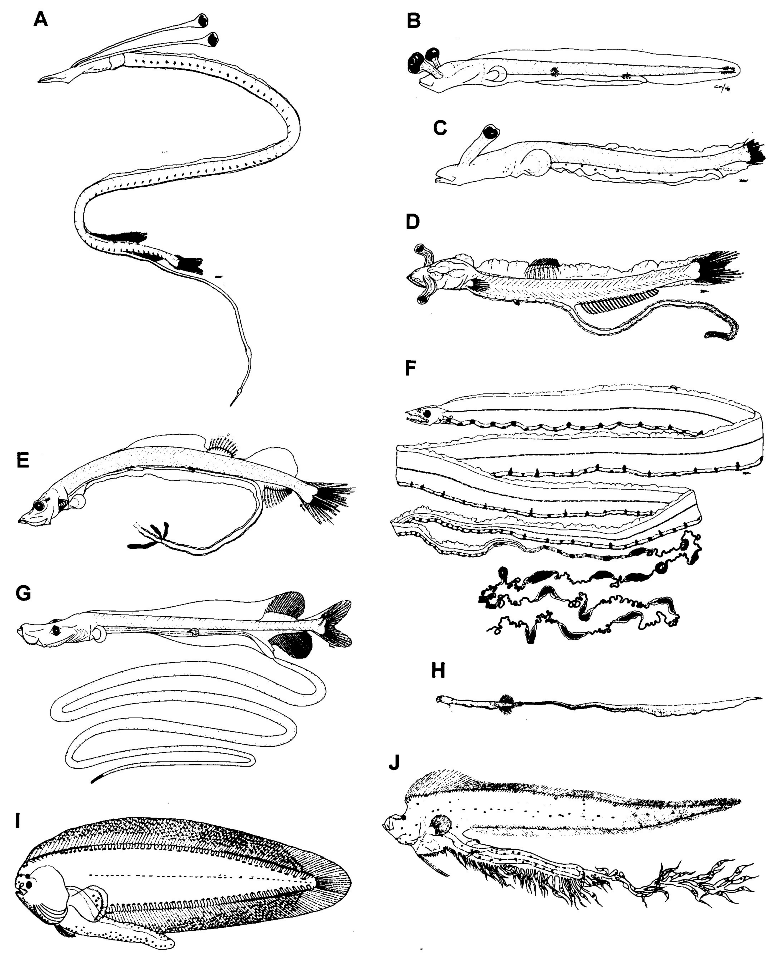


Moser and Watson (2006) Chapter 11 *In*: Allen et al. Book on Ecology of California Marine Fishes

LARVAE (ESPECIALLY ROCKFISHES) ARE REALLY DIFFICULT TO IDENTIFY… SOME MORPHOTYPES…

Fish larvae with elongate, ornamented spinous, or segmented fin-rays…such as some lanternfishes and flatfishes.





Fish larvae with elongate soft tissue structures…includes deep-sea eels, dragonfishes, smelts, and lanternfishes, plus flatfishes, etc.

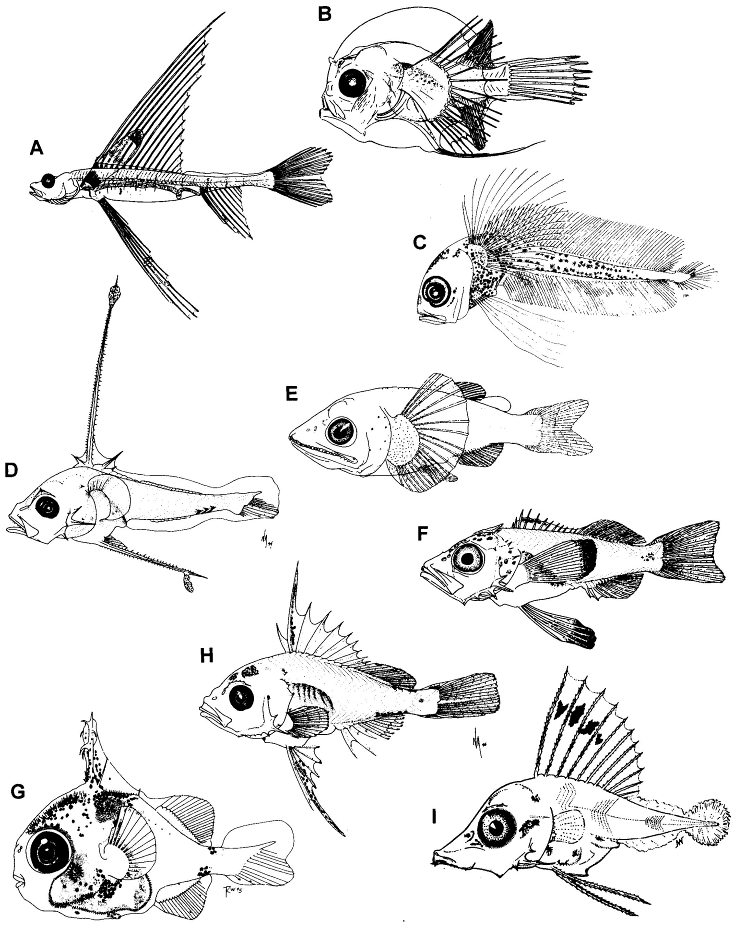
CHAPTER 11

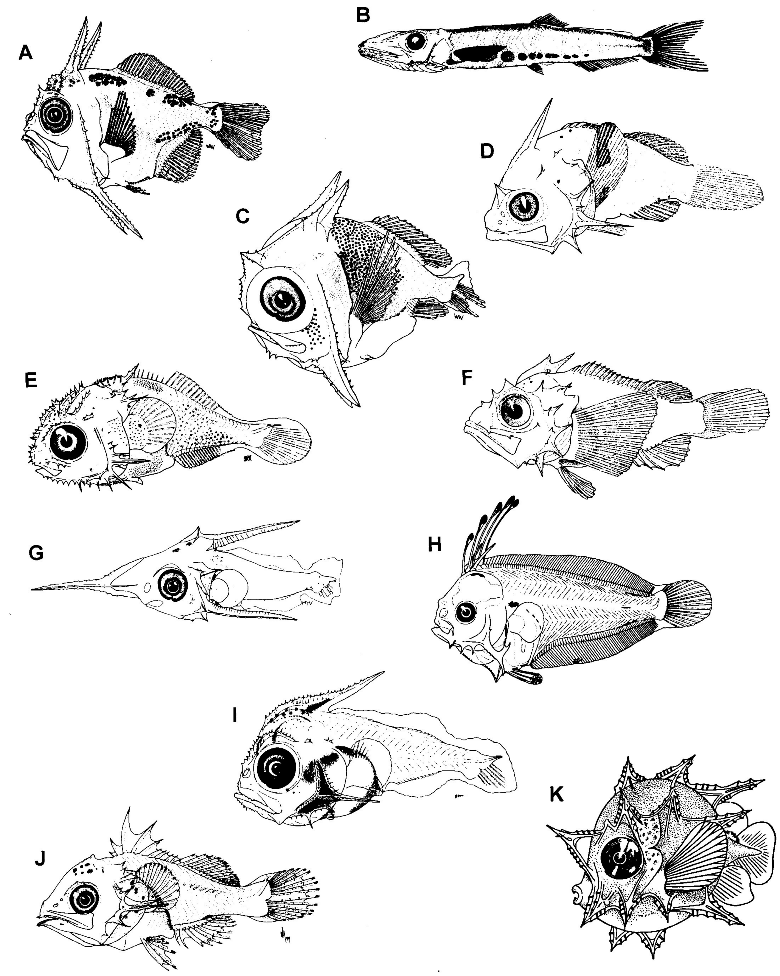
Ichthyoplankton

H.G. MOSER AND W. WATSON

Morphotypes, continued….

Fish larvae with enlarged or elaborate fins… includes many deep-sea fishes, plus rockfishes (family Scorpaenidae, genus *Sebastes*), etc.





Fish larvae with enlarged spines on head and/or pectoral girdle… includes some rockfishes (family Scorpaenidae, genus *Sebastes*), and flatfishes, etc..

CHAPTER 11

Ichthyoplankton

H.G. MOSER AND W. WATSON

But, first you have to sample these fish larvae….

- It requires a vessel
- And a winch and a-frame
- And one or more plankton nets
- And lots of time to cover all months and depths that are of interest relative to the intake of the CWIS…
- And jars in which to store the preserved samples..

$$$$$$

Then, you have to sort through all the zooplankton, pulling out the fish larvae….

- This requires lots of people
- And a lot of time
- And expertise at identifying the larvae
- And lots more time to count and measure the larvae
- And, then there is the data analysis…

$$$$$$$$$

You get lists of all taxa collected and these larvae can be placed into recurrent groups….

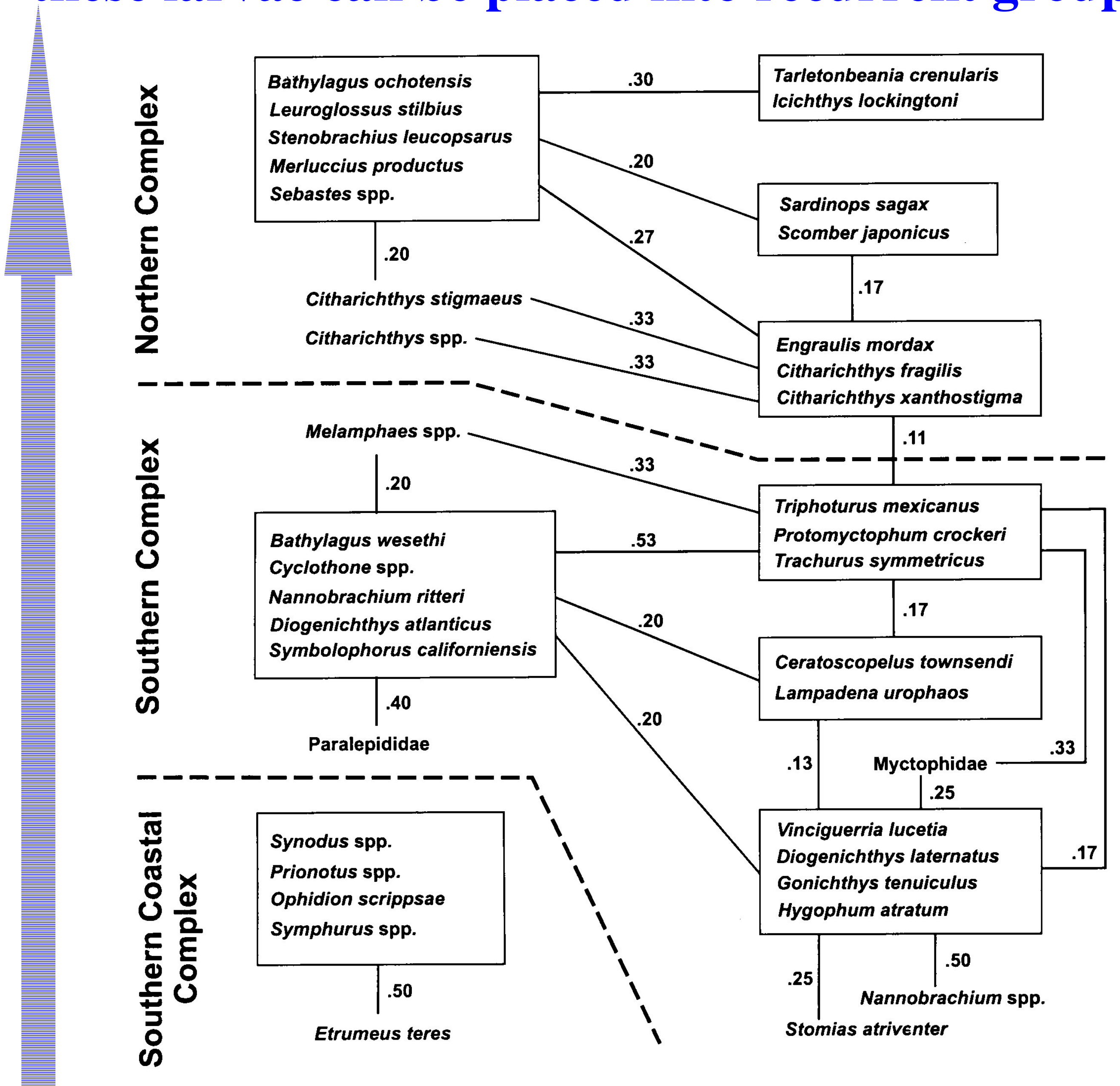


FIGURE 11-7 Recurrent groups and their associates in the CalCOFI survey area, 1954–1960. A line between two groups indicates that there are intergroup pairs with significant affinity indexes (≥ 0.3). The number associated with each line is the fraction of significant affinity pairs divided by the number of possible pairs. Northern, Southern, and Southern Coastal Complexes are separated by dashed lines (modified from Moser et al., 1987).

CHAPTER 11

Ichthyoplankton

H.G. MOSER AND W. WATSON

For example, here are five recurrent groups of fish larvae from CalCOFI coastal samples, southern California Continental Bight, 1954-1960. Virtually, all of these are commonly entrained, especially the **Gobies.**

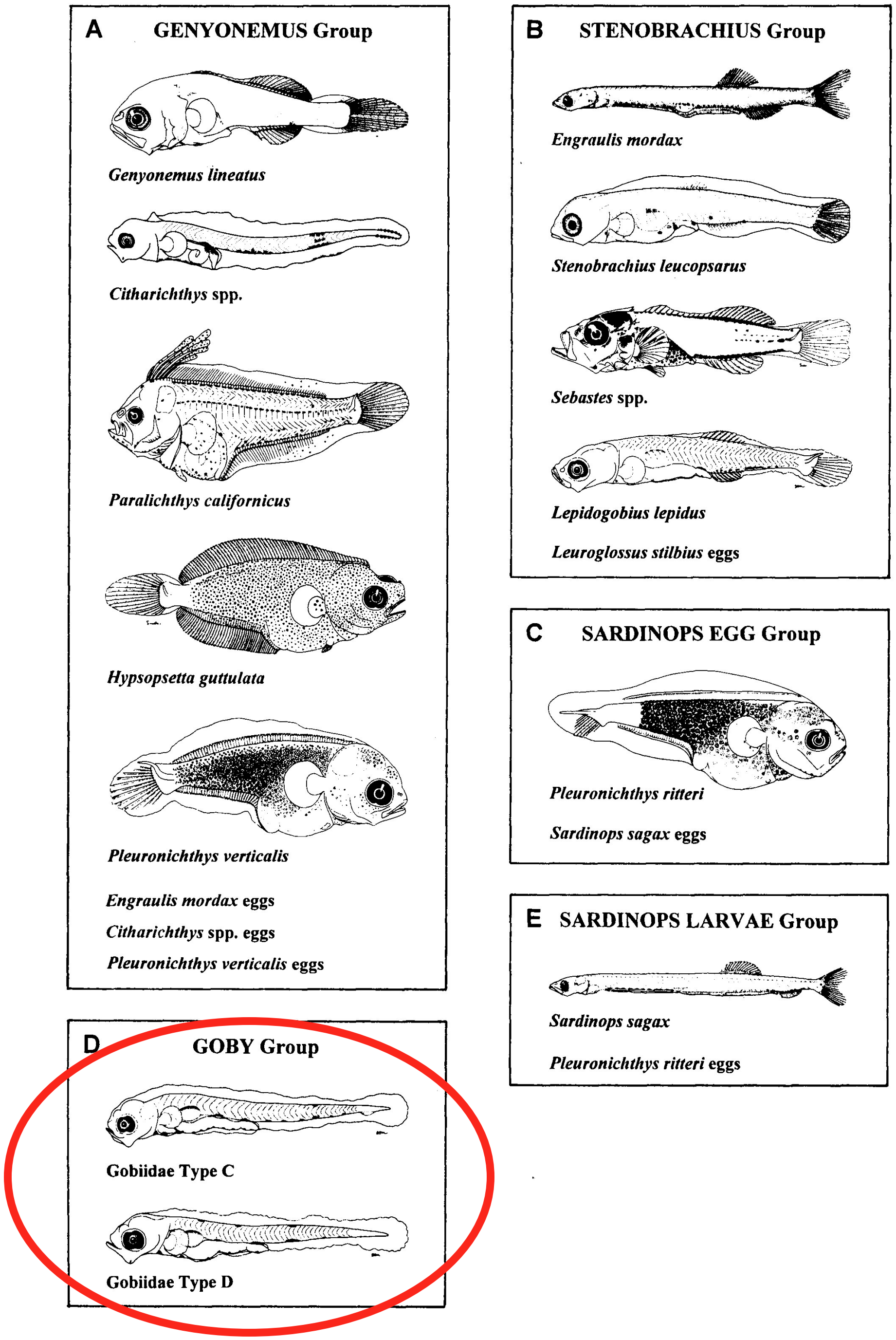


FIGURE 11-24 Members of the Genyonemus (A), Stenobrachius (B), Sardinops Egg (C), Goby (D), and Sardinops larvae (E) coastal ichthyoplankton assemblages of the Southern California Bight (McGowen, 1993). All illustrations are from publications by personnel at SWFSC and are reproduced from Moser (1996), where original attributions can be obtained.

CHAPTER 11

Ichthyoplankton

H. G. MOSER AND W. WATSON

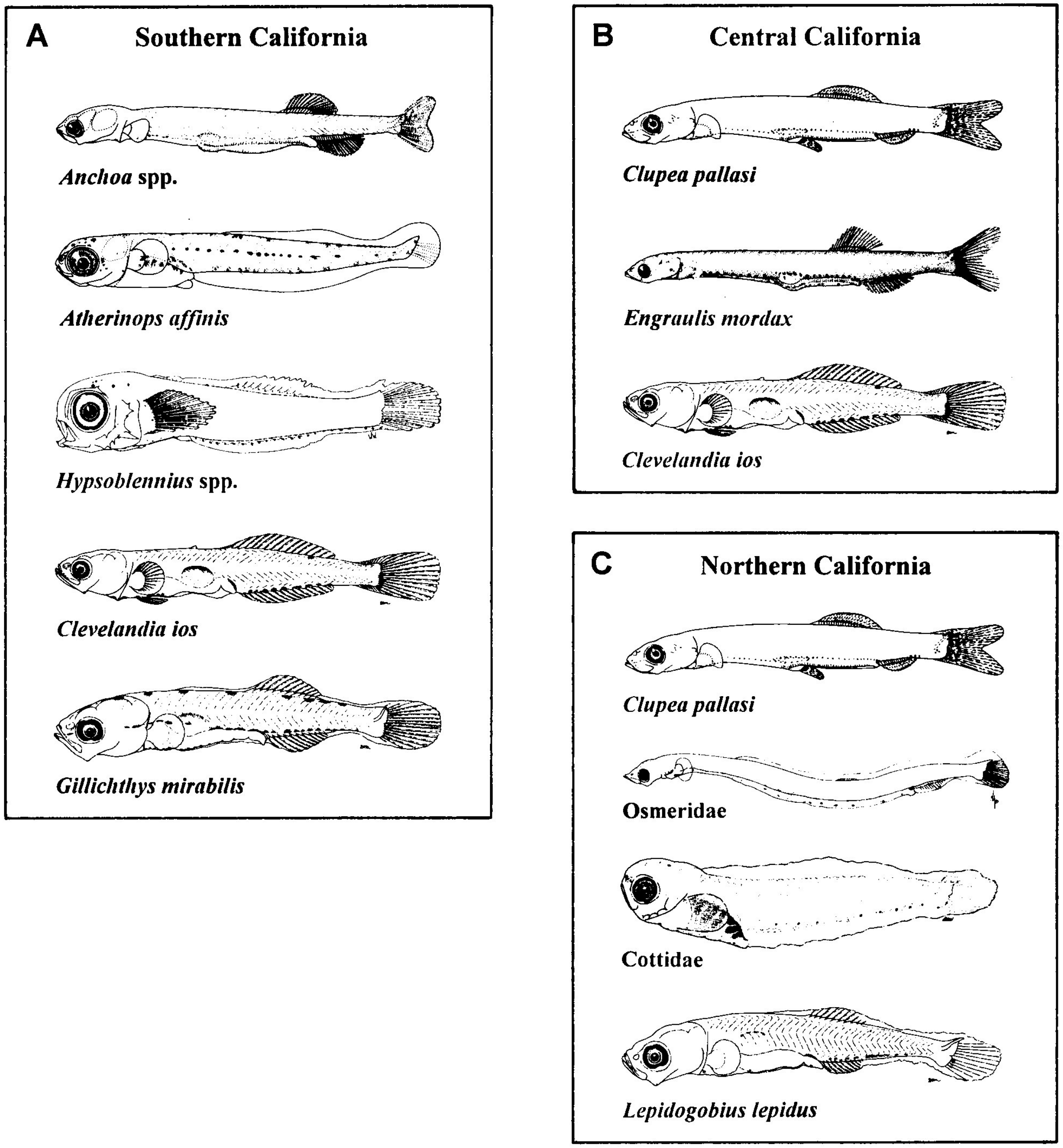


FIGURE 11-32 Characteristic taxa of bay and estuarine larval fish assemblages of (A) southern California, (B) central California, and (C) northern California. Most illustrations are from publications by personnel at SWFSC and are reproduced from Moser (1996), where original attributions can be obtained; *Anchoa* spp. from Caddell (1988), *Atherinops affinis* and *Clupea pallasi* from Matarese et al. (1989), and Cottidae from Richardson and Washington (1980).

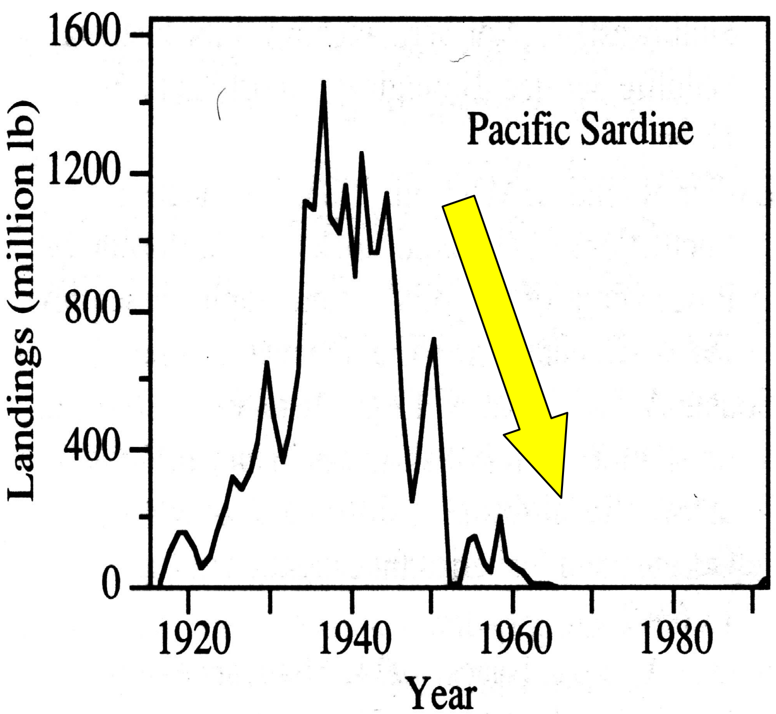
In many coastal power plants, these bay and estuarine larval fish groups are commonly entrained.

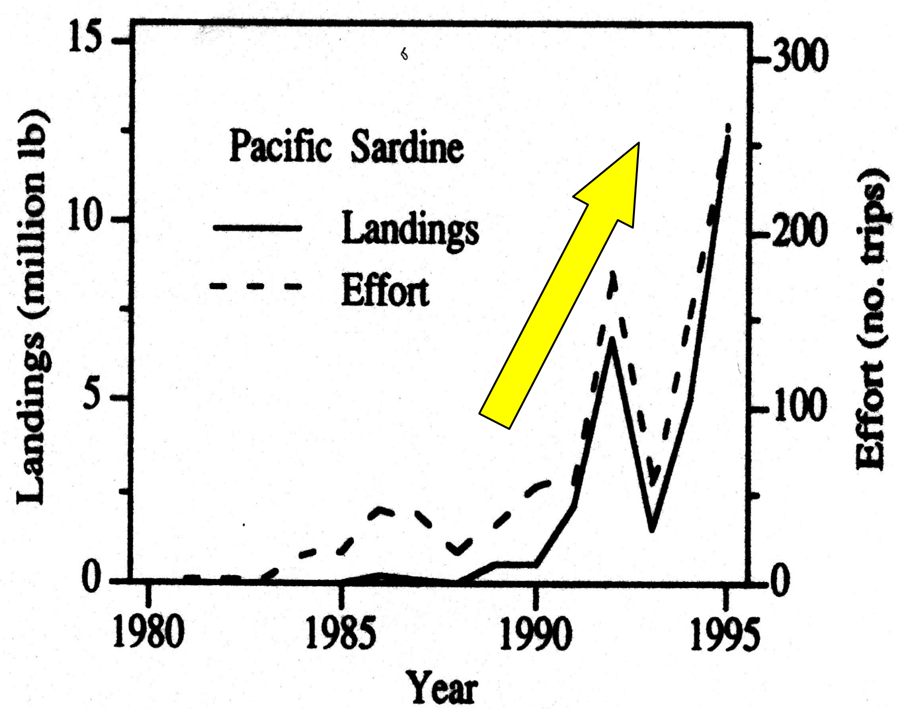
CHAPTER 11

Ichthyoplankton

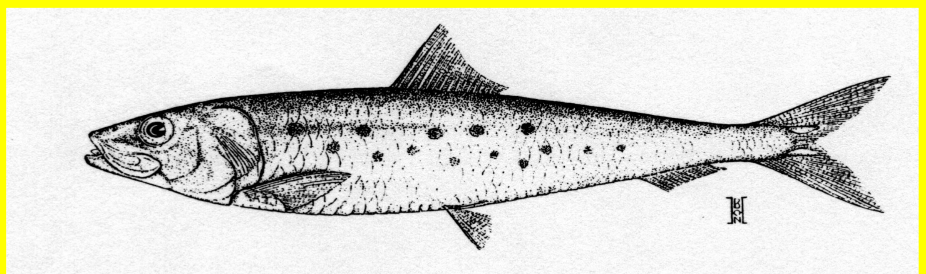
H. G. MOSER AND W. WATSON

Many coastal fish species in California have suffered population (and fishery) declines…For example, the Pacific Sardine in California (1916-1995)





Sardinops sagax



Starr *et al.* 1998

The question is are these changes natural or anthropogenic?

REVIEW

CLIMATE

From Anchovies to Sardines and Back: Multidecadal Change in the Pacific Ocean

Francisco P. Chavez,[1*] John Ryan,[1] Salvador E. Lluch-Cota,[2] Miguel Ñiquen C.[3]

In the Pacific Ocean, air and ocean temperatures, atmospheric carbon dioxide, landings of anchovies and sardines, and the productivity of coastal and open ocean ecosystems have varied over periods of about 50 years. In the mid-1970s, the Pacific changed from a cool "anchovy regime" to a warm "sardine regime." A shift back to an anchovy regime occurred in the middle to late 1990s. These large-scale, naturally occurring variations must be taken into account when considering human-induced climate change and the management of ocean living resources.

andings of sardines show synchronous variations off Japan, California, Peru, and

Climate Indices and Regime Shifts

dance data (*19*) and anchovy and sardine landings off Peru (Fig. 1G). The seabird record, compiled from guano harvest and direct bird counts, extends back to the early 1900s. The seabirds are represented primarily by a single species, the cormorant (*Phalacrocorax bougainvillii*), which feeds almost exclusively on anchoveta (the anchovy, *Engraulis ringens*). The ecosystem index suggests a regime shift in the mid-1990s (Fig. 1F); the sardine catch decreased from 4 million metric tons in the late 1980s to 40,000

www.sciencemag.org SCIENCE VOL 299 10 JANUARY 2003

(Chavez et al., 2003)

There have been decadal cycles caused by climate and oceanographic features…as well as fisheries. And, over 2,000+ years…

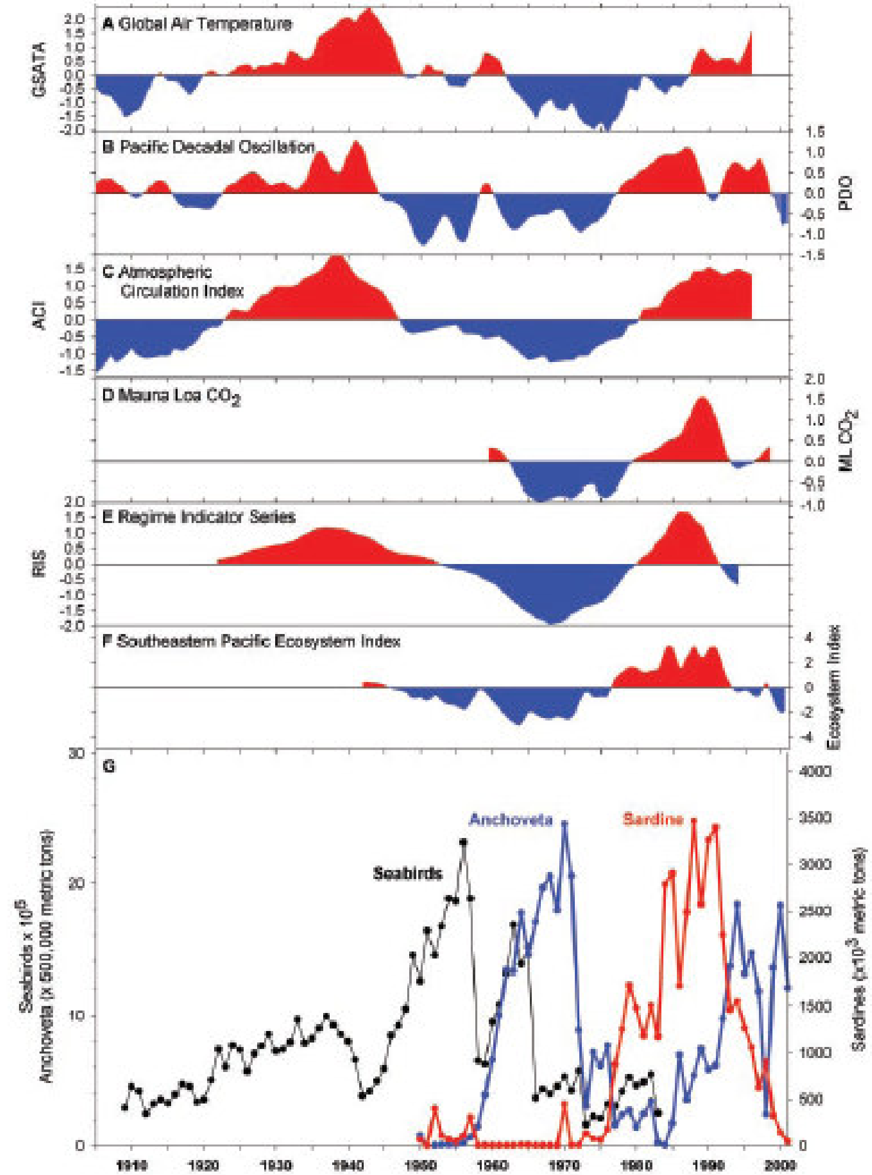
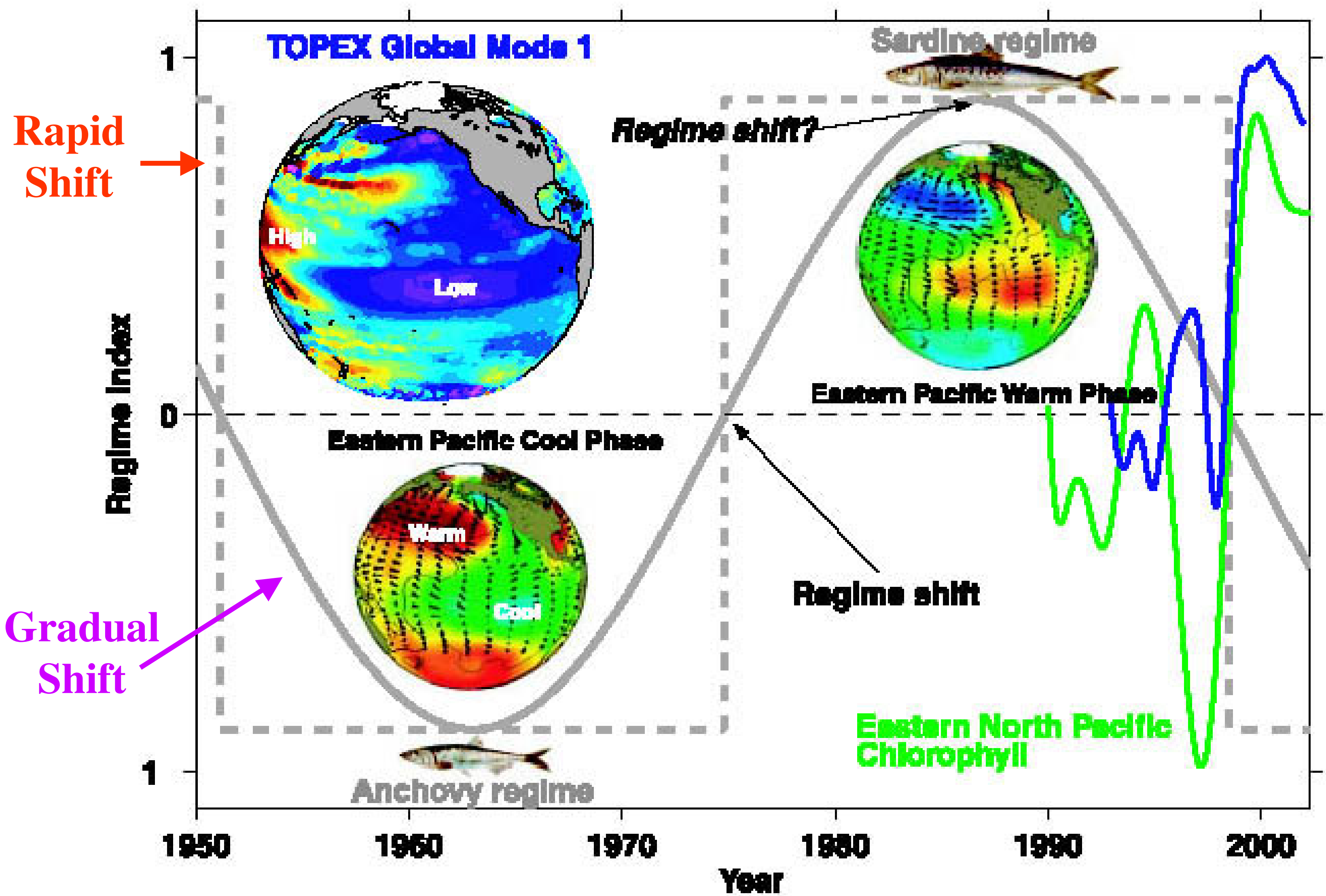


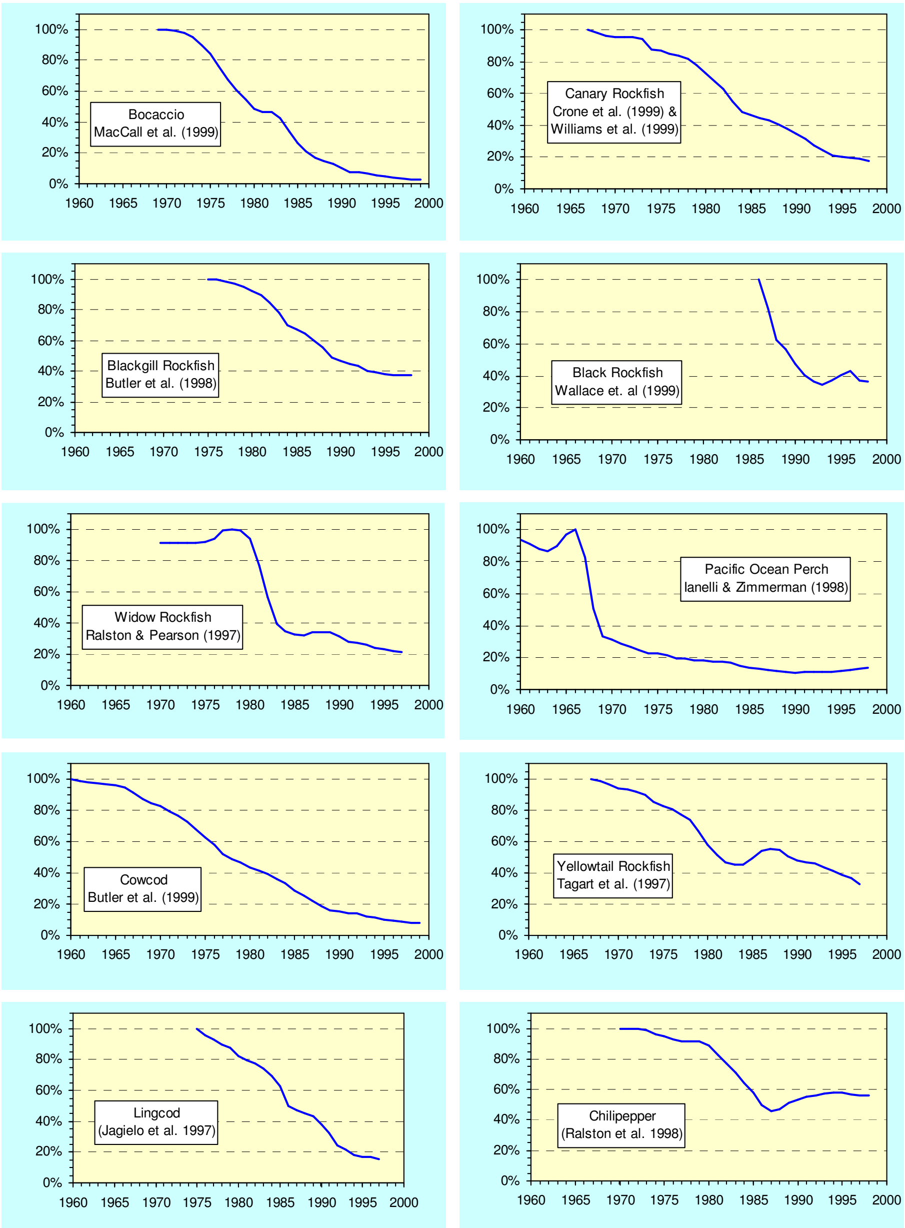
Fig. 1. Anomalies of (A) global air temperature, with the long-term increase removed (*8*); (B) the Pacific decadal oscillation (PDO) index (°C), derived from principal component analysis of North Pacific SST (*10*); (C) the atmospheric circulation index (ACI), which describes the relative dominance of zonal or meridional atmospheric transport in the Atlantic-Eurasian region (*9*); (D) atmospheric CO_2 measured at Mauna Loa (parts per million) with the long-term anthropogenic increase removed (*7*); (E) the regime indicator series (RIS) that integrates global sardine and anchovy fluctuations (*5*); and (F) a southeastern tropical Pacific ecosystem index based (*19*) on (G) seabird abundance and anchoveta and sardine landings from Peru. All series have been smoothed with a 3-year running mean.

Hypothetical Regime Oscillation Index



(Chavez et al., 2003)

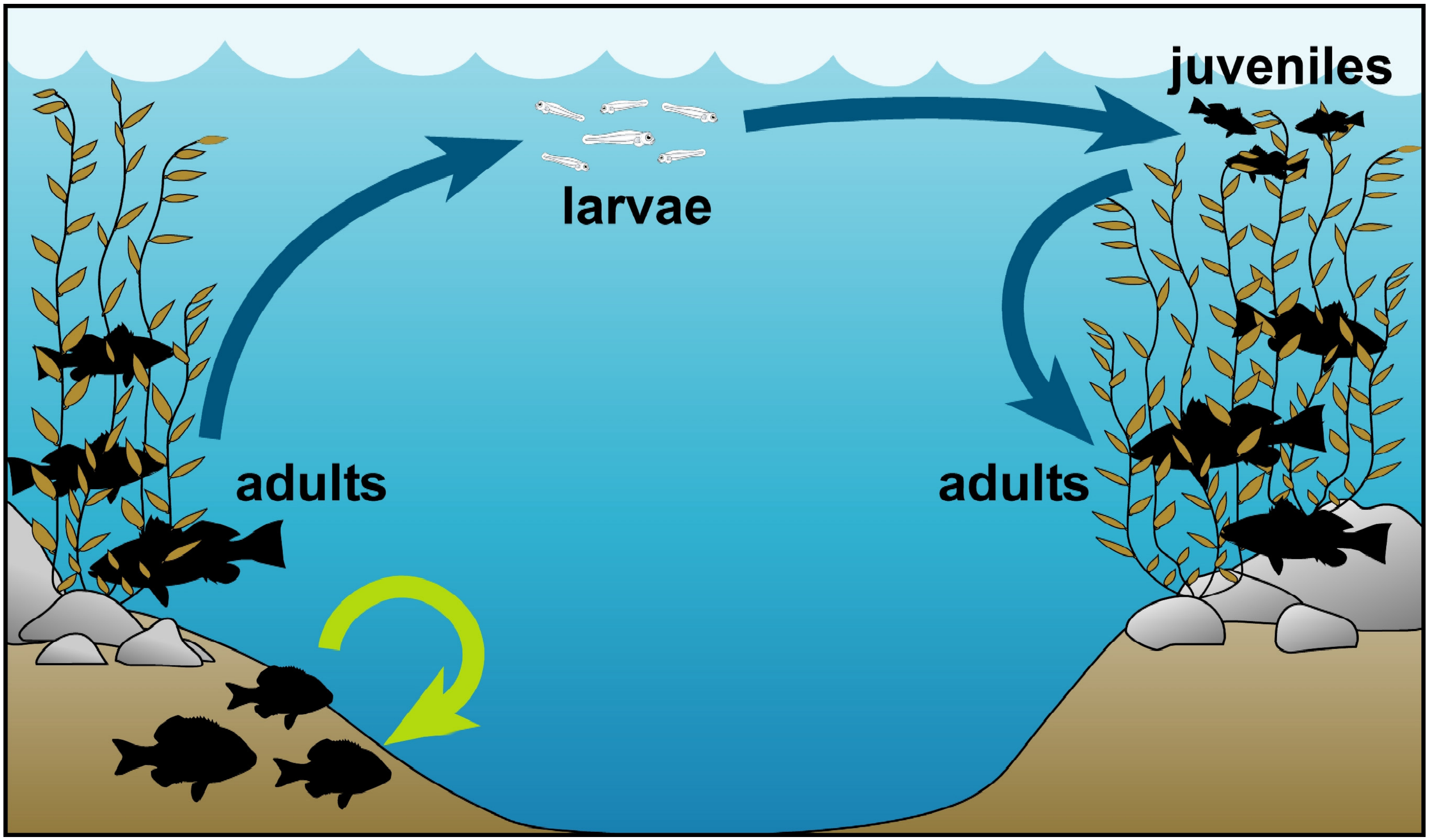
Declining rockfish stocks have also led to concern about their sustainability to harvest rate



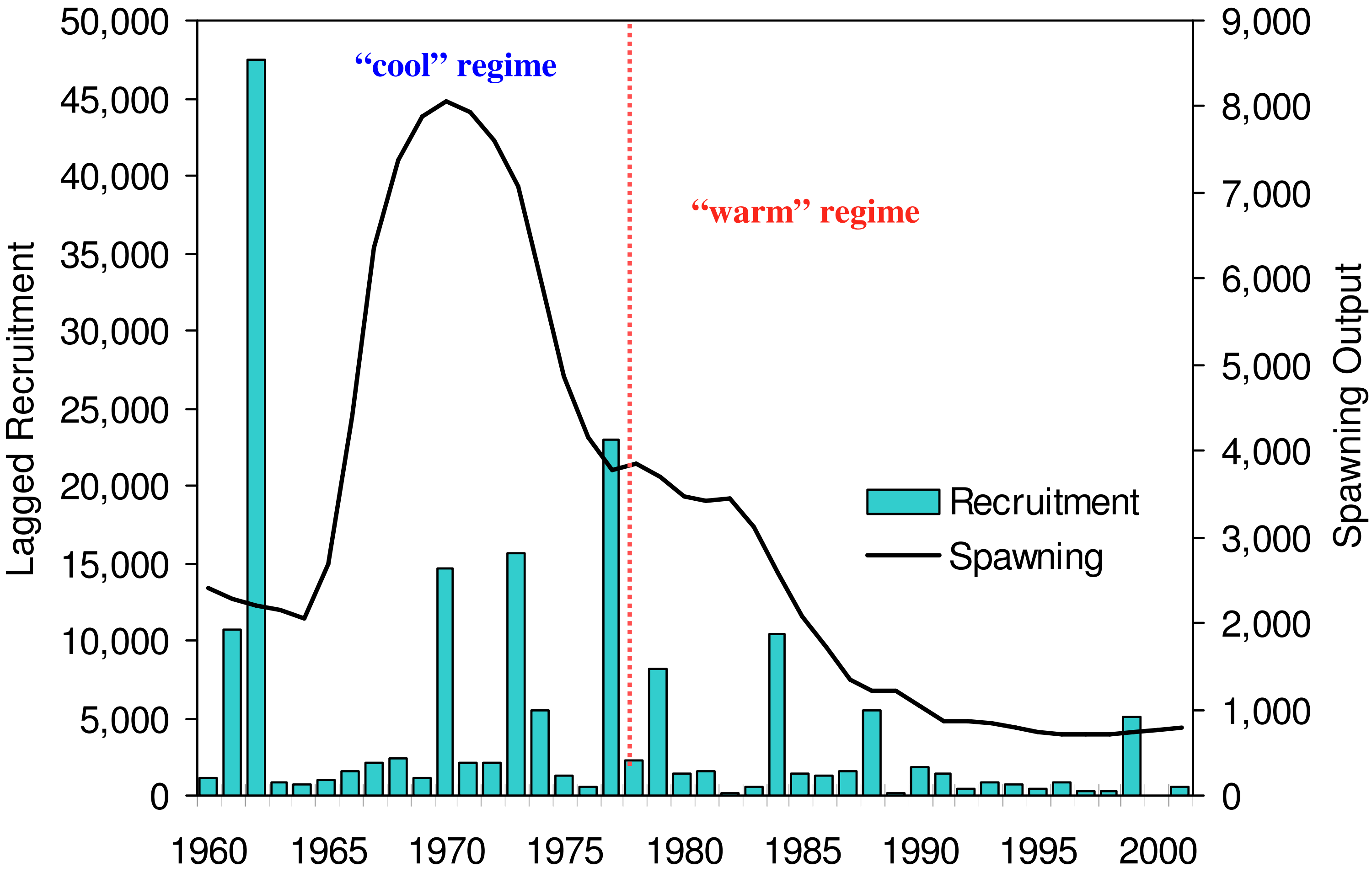
From: Ralston. S. 1998. The status of federally managed rockfish on the U. S. west coast, pp. 6-16. In: M. Yoklavich (ed.), Marine Harvest Refugia for West Coast Rockfish.

Recruitment

(Carr and Syms 2006, Chapter 15 in Allen et al. 2006)



For *Sebastes*, recruitment variability largely determines stock productivity



Taken from: MacCall, A. D. 2003. Bocaccio Rebuilding Analysis for 2003 (Draft 2, May 2003). Pacific Fishery Management Council, Portland, Oregon, 14 p.

Decadal effects on rockfish spawning (density of larvae)

ABUNDANCE AND DISTRIBUTION OF ROCKFISH (*SEBASTES*) LARVAE IN THE SOUTHERN CALIFORNIA BIGHT IN RELATION TO ENVIRONMENTAL CONDITIONS AND FISHERY EXPLOITATION

H. GEOFFREY MOSER, RICHARD L. CHARTER, WILLIAM WATSON, DAVID A. AMBROSE,
JOHN L. BUTLER, SHARON R. CHARTER, AND ELAINE M. SANDKNOP
Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
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La Jolla, California 92038-0271
gmoser@ucsd.edu

MOSER ET AL.: ABUNDANCE AND DISTRIBUTION OF ROCKFISH LARVAE
CalCOFI Rep., Vol. 41, 2000

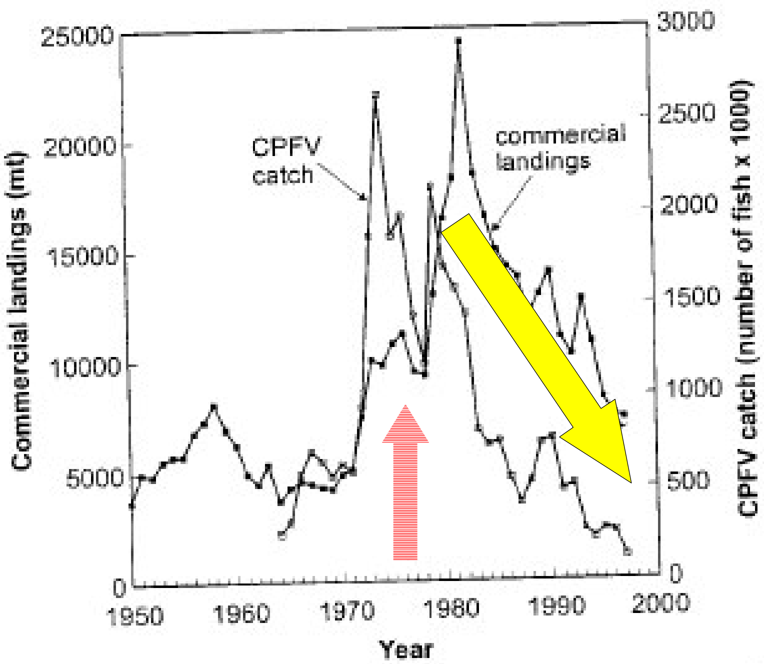


Figure 1. Total California rockfish landings by the commercial fleet in California and total commercial passenger fishing vessel (CPFV) catch for southern California. Data for commercial landings are from Thomas Barnes, California Department of Fish and Game (pers. comm.); data for CPFV catch are from California Department of Fish and Game CPFV logbooks (see Hill and Barnes 1998). CPFV catch is approximately one-half of the total recreational catch.

MOSER ET AL.: ABUNDANCE AND DISTRIBUTION OF ROCKFISH LARVAE
CalCOFI Rep., Vol. 41, 2000

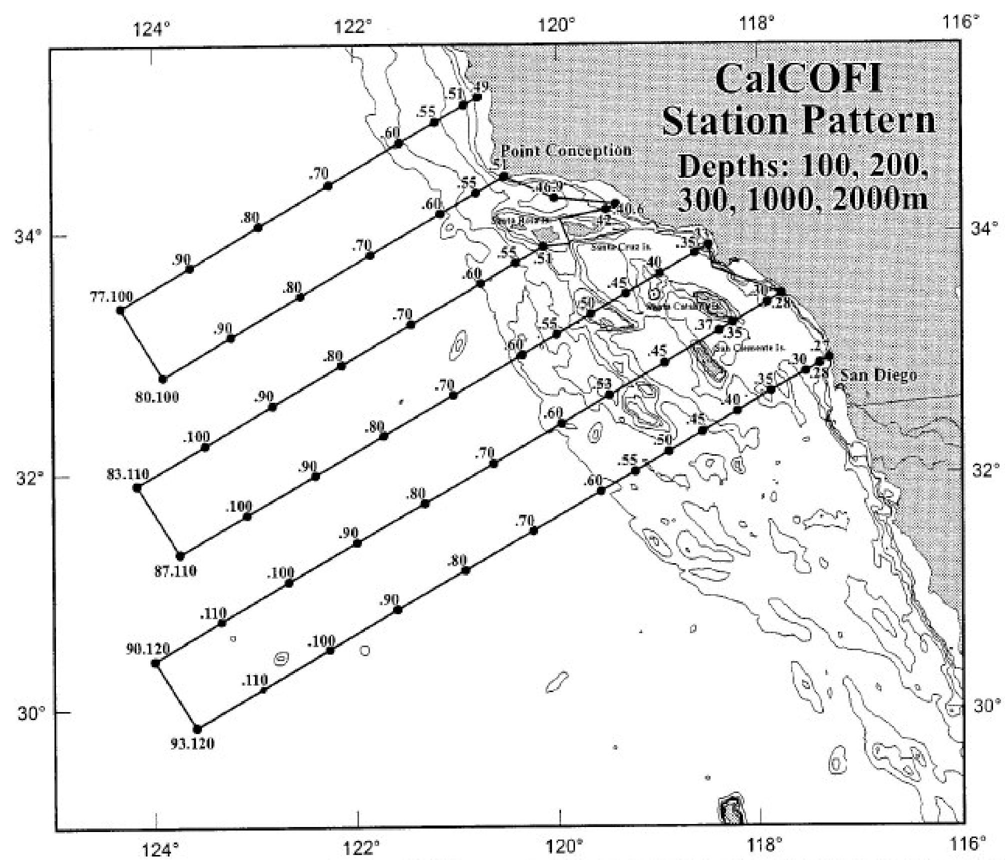


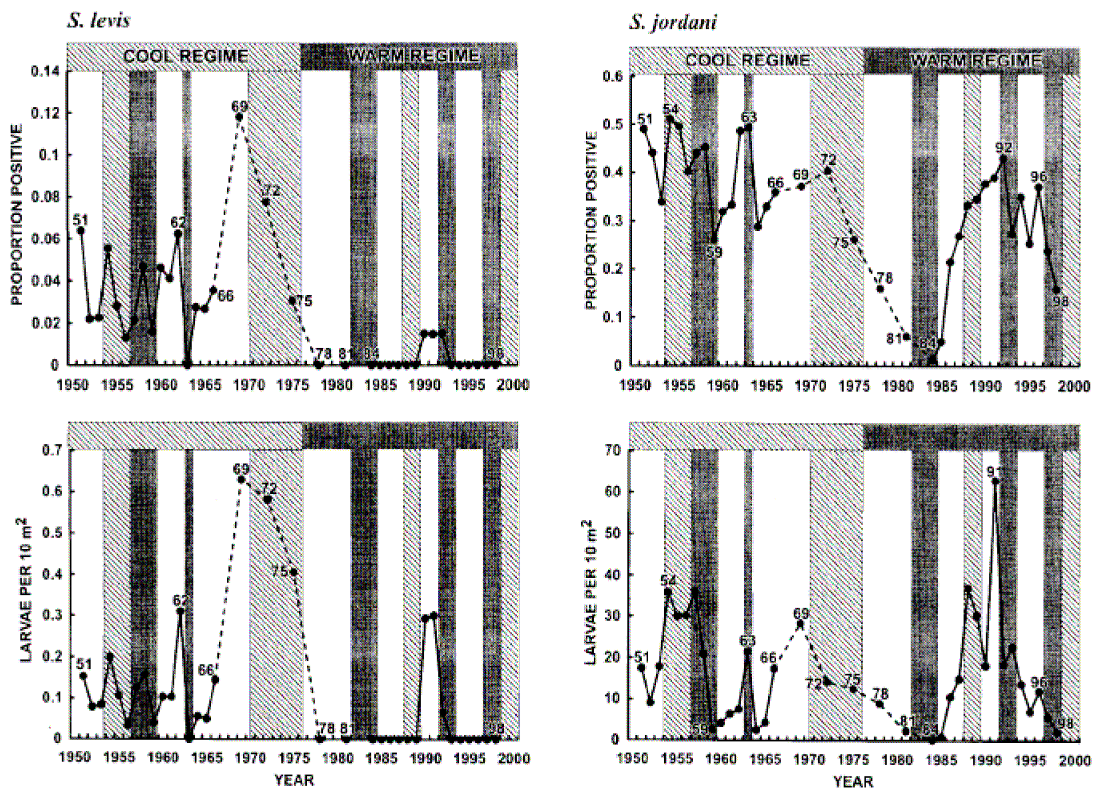
Figure 2. Station pattern for CalCOFI survey cruises from 1985 to the present, and bathymetry of the survey region. Isobaths are 100, 200, 500, 1000, and 2000 m.

Decadal effects on rockfish spawning (density of larvae)

TABLE 1

Average Occurrence (Proportion of Positive Tows) and Abundance (Larvae per 10 m²) for Larvae of Six *Sebastes* Taxa during Cool (1951–76) and Warm (1977–98) Regimes in the Southern California Bight Region

Taxon	Proportion of positive tows: Cool regime	Proportion of positive tows: Warm regime	Proportion of positive tows: Percentage change	Average larvae per 10 m²: Cool regime	Average larvae per 10 m²: Warm regime	Average larvae per 10 m²: Percentage change
Sebastes spp.	0.56	0.43	−23.2	27.65	30.79	+11.4
S. paucispinis	0.31	0.12	−61.3	4.69	2.24	−52.2
S. levis	0.04	0.002	−95.0	0.18	0.03	−83.3
S. jordani	0.39	0.22	−43.6	17.41	13.77	−20.9
S. aurora	0.09	0.03	−66.7	0.50	0.36	−28.0
S. diploproa	0.14	0.05	−64.3	0.99	0.55	−44.4



Effect of El Nino and La Nina on Rockfish Recruitment (Carr and Syms 2006, Chapter 15 in Allen et al. 2006)

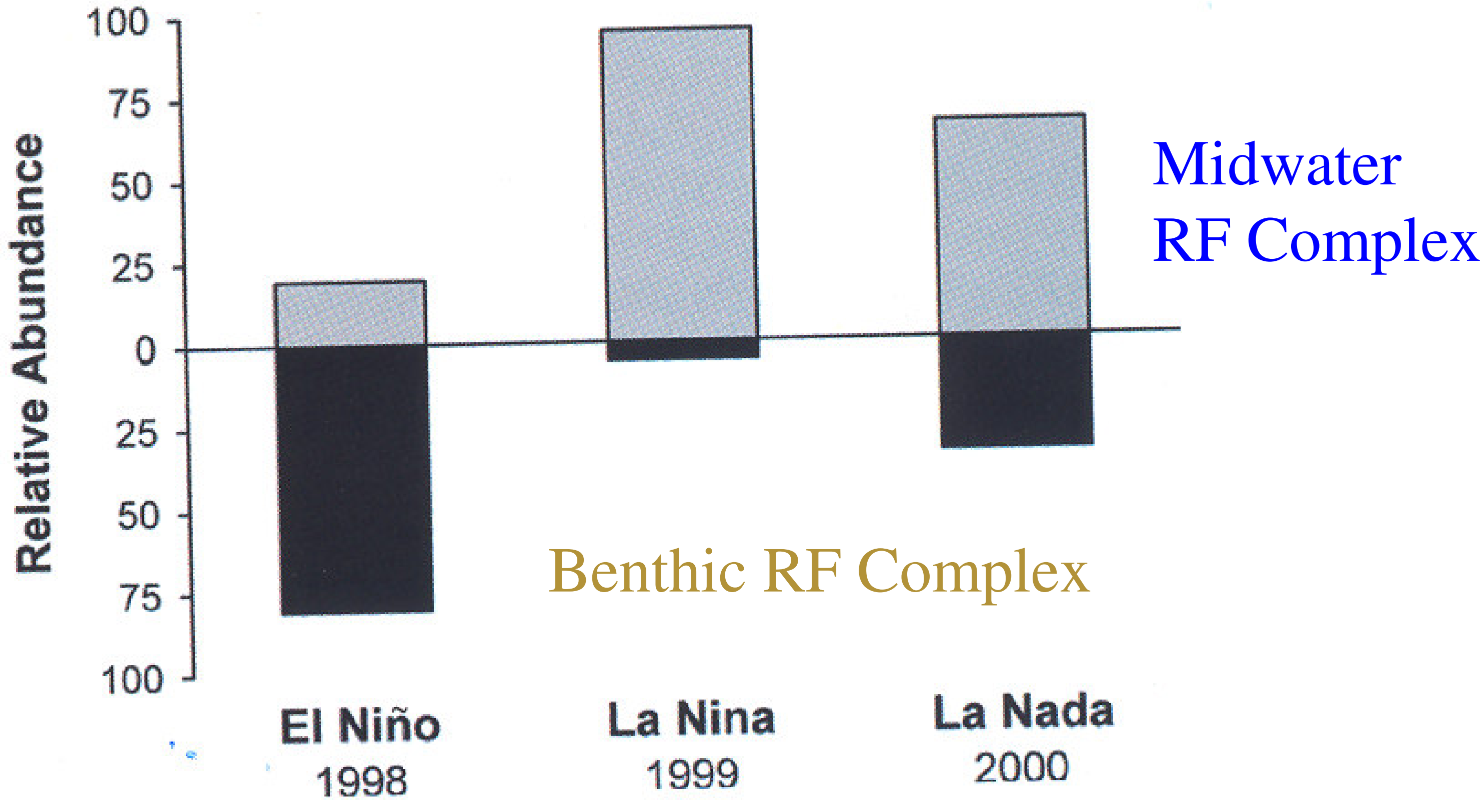


FIGURE 15-5 Relative abundance of midwater complex rockfish recruits (light gray bars above the line) relative to benthic complex rockfish recruits (black bars below line). El Niño conditions favor recruitment of the benthic complex, whereas La Nina favors recruitment of the midwater complex. During normal years, abundances are more equitable.

Seasonal Effects on Larval Fish Recruitment…

Fish Reproduce at different time of the years.

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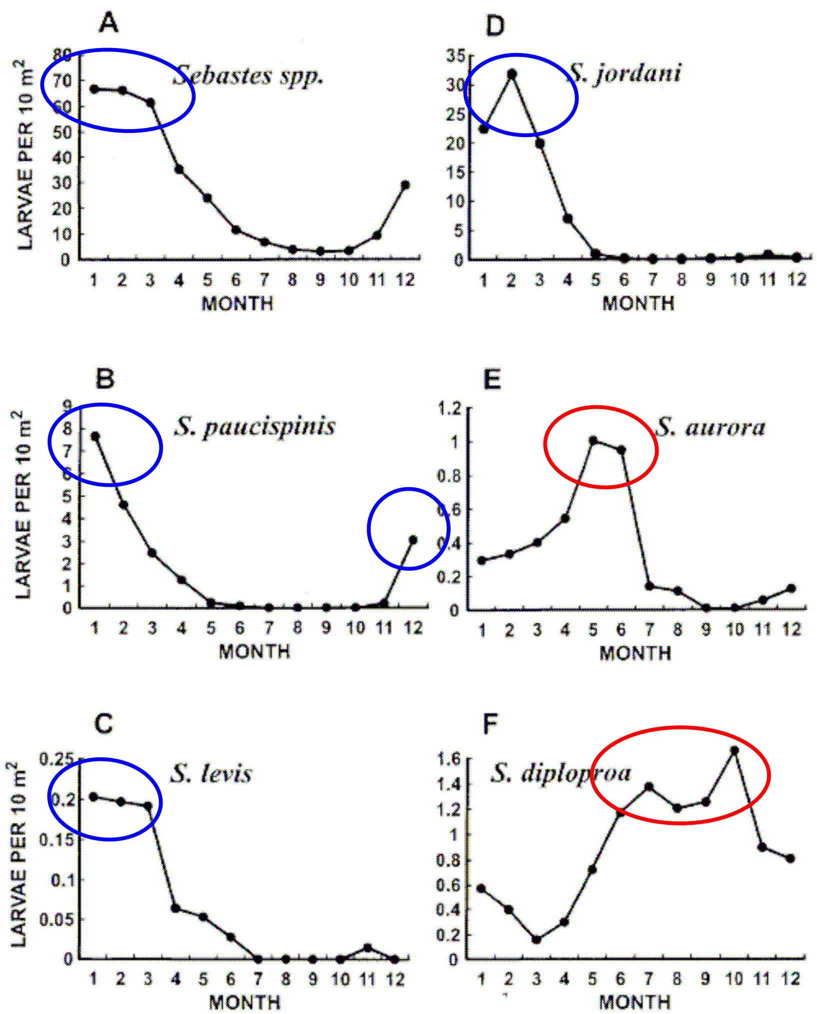
Winter Spawners



Summer Spawners

Figure 5. Seasonal abundance (average number per 10 m^2) of larvae of six *Sebastes* taxa from the CalCOFI time series. *A, Sebastes* spp., unidentified rockfish larvae; *B, S. paucispinis*, bocaccio; *C, S. levis*, cowcod; *D, S. jordani*, shortbelly rockfish; *E, S. aurora*, aurora rockfish; *F, S. diploproa*, splitnose rockfish.

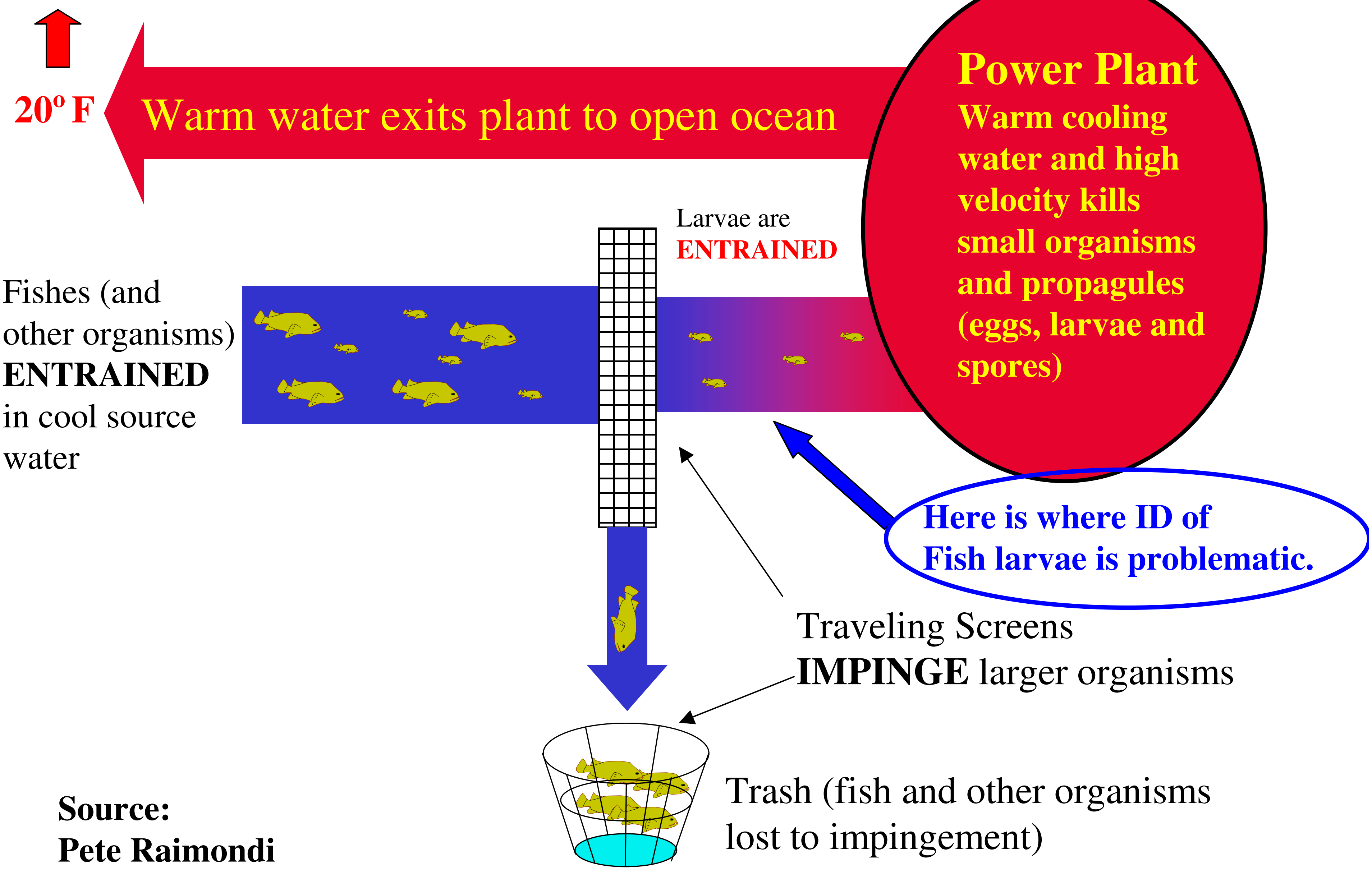
And, what <u>is</u>

IMPINGEMENT

and

ENTRAINMENT?

Thermal Effects, Impingement and Entrainment



Source:
Pete Raimondi

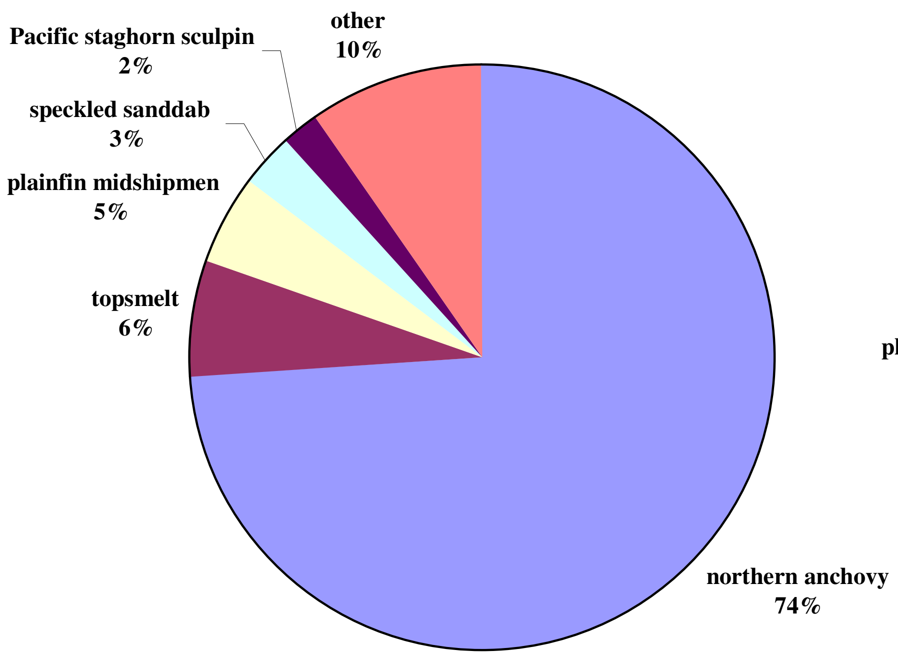
Entrainment and Impingement Losses

Estimation of Impingement

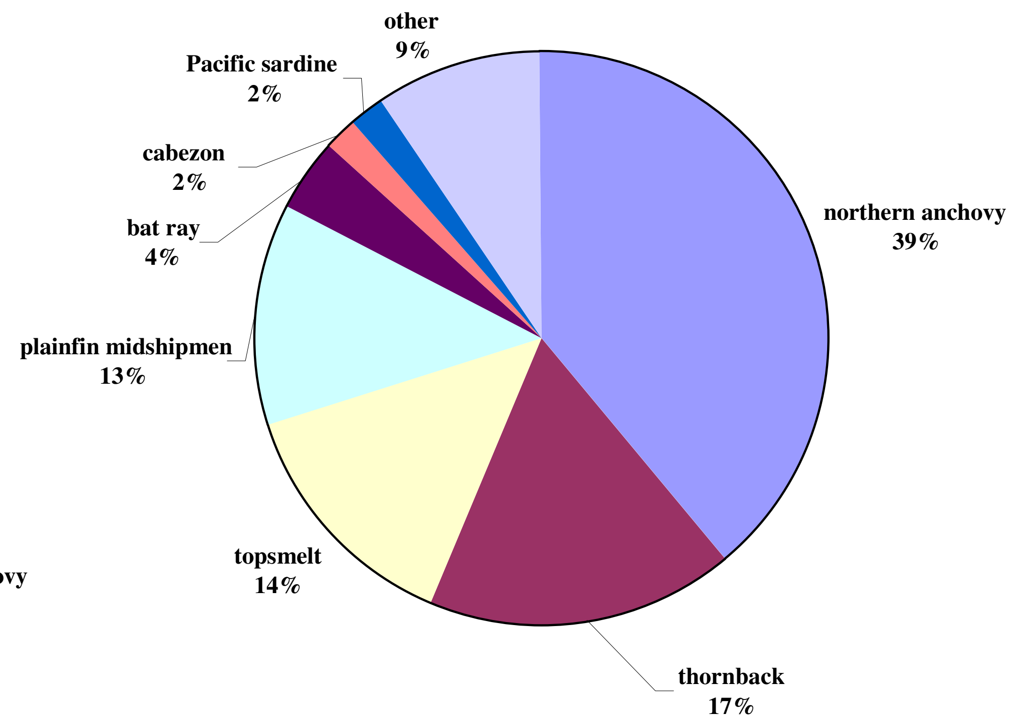
Estimation of Entrainment

Estimation of Ecological Effects due to Entrainment and Impingement

Results of Impingement Study (9/99 – 9/00)
Morro Bay Power Plant
Fish



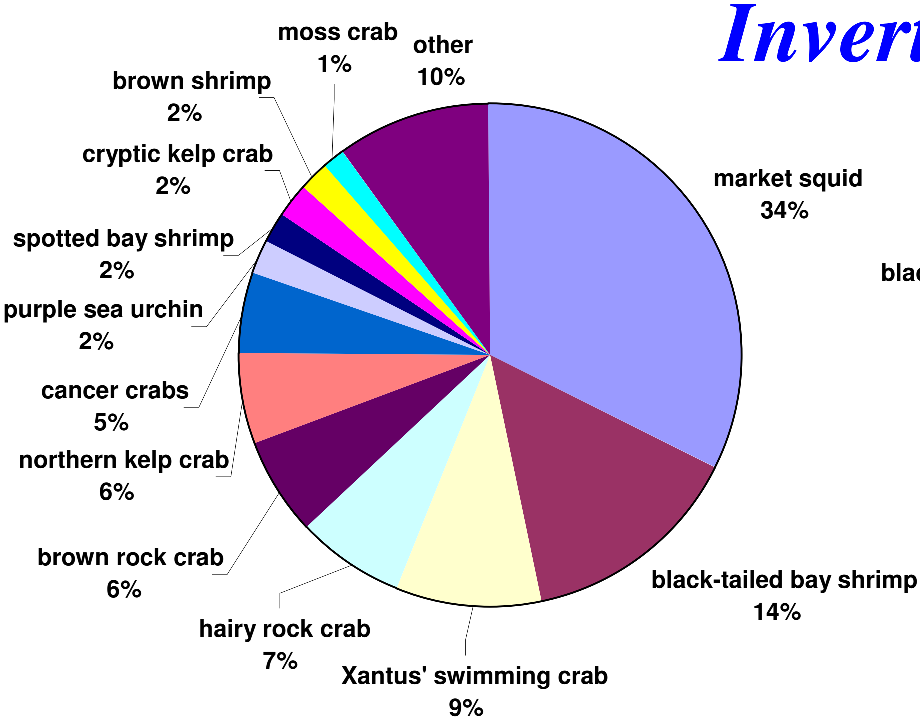
Abundance

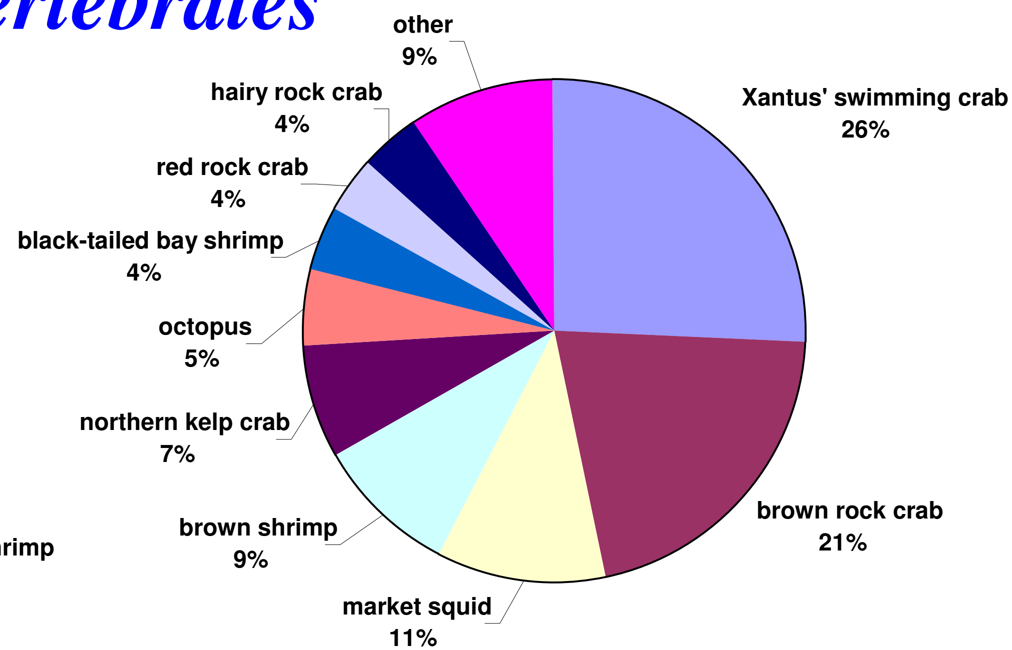


Biomass

78,000 individuals, 2,800 lbs per year

Results of Impingement Study (9/99 – 9/00)
Morro Bay Power Plant
Invertebrates





Abundance **Biomass**

55,000 individuals, 849 lbs per year

RESEARCH NEEDED TO BETTER UNDERSTAND THE ECOLOGICAL EFFECTS OF ONCE-THROUGH COOLING SYSTEMS

Impingement

1. Investigate **adult fish behavior** relative to intakes as the results would improve intake design and impact prediction (e.g., effects of turbulence, structure, velocity)
2. **Engineering structures** to prevent fishes and other organisms from getting close to the intake screens.

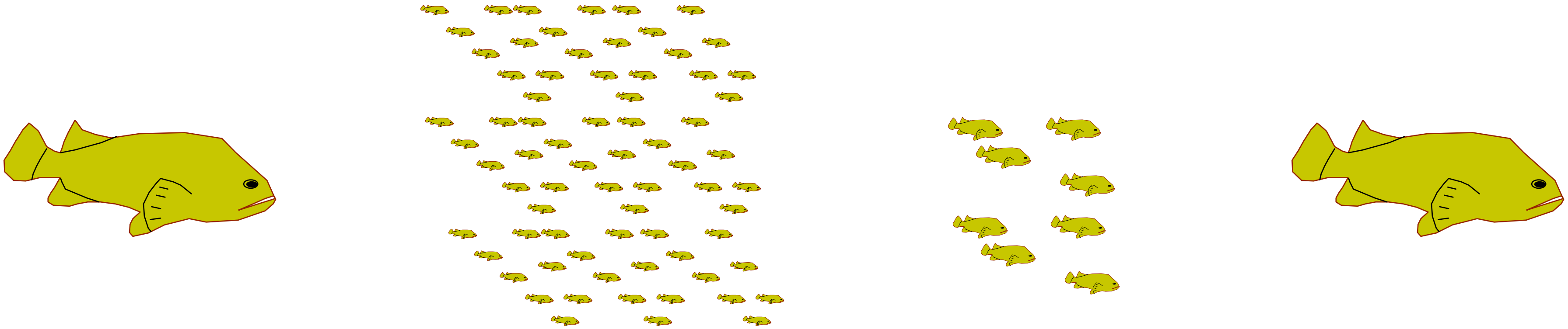
Entrainment and Impingement Losses

Estimation of Impingement

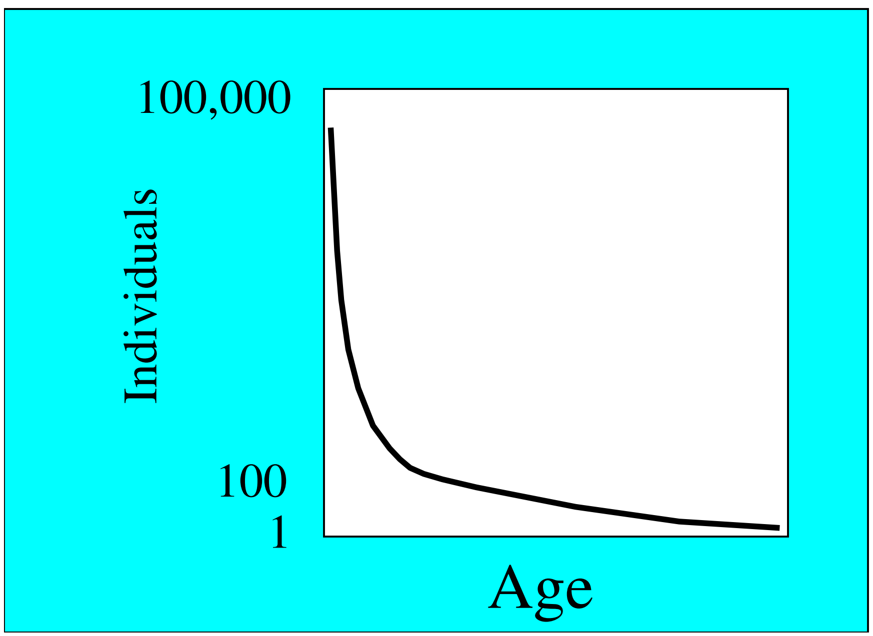
Estimation of Entrainment

Estimation of Ecological Effects due to Entrainment and Impingement

Typical reproduction and survivorship for larval producing organisms



1 female → 100,000 larvae → 100 juveniles → 2 adults



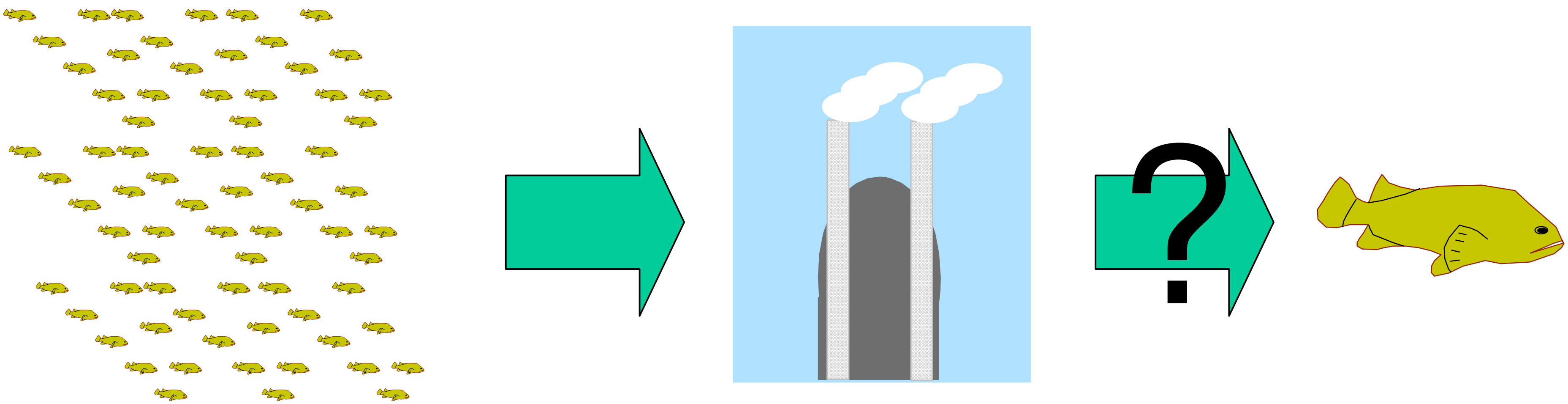
99.9%

98%

Mortality Rate

Source:
Pete Raimondi

Importance of larval losses due to entrainment



Larvae

Loss of ????
Adult fish

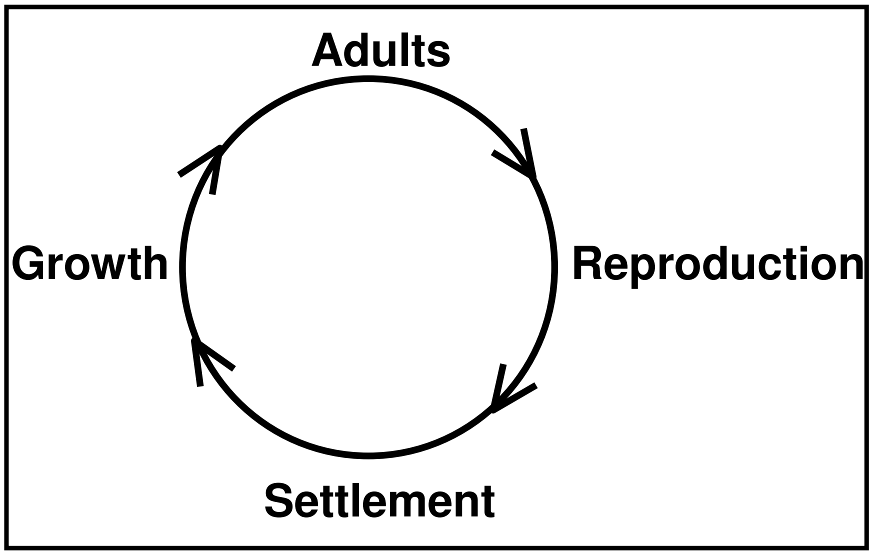
Question: How to estimate losses to adult populations?

Source:Pete Raimondi

Need to know which species are likely to be susceptible to larval entrainment:

NO

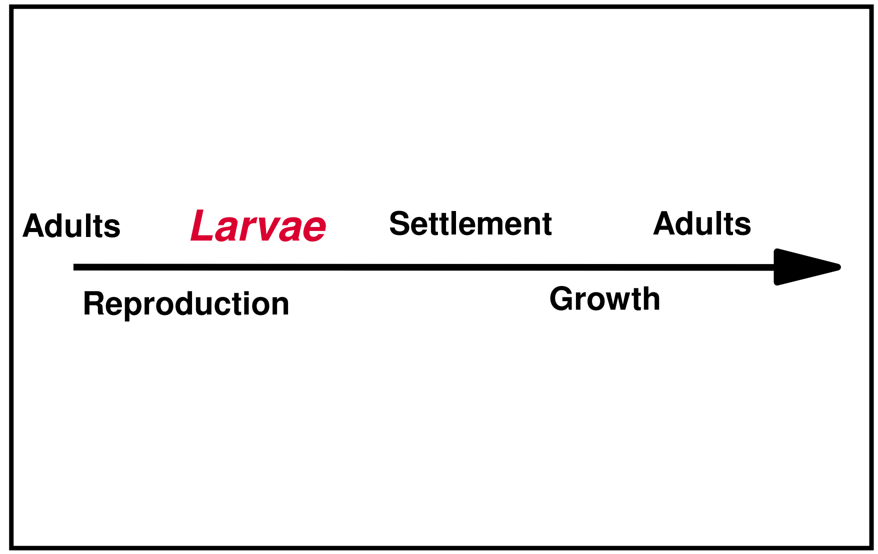
Closed System (no larval phase: live bearers…)



Surf Perches
Sharks
Rays

YES

Open System (have a larval phase)



Gobies
Blennies
Sculpins
Herring
Clams
Crabs

Source: Pete Raimondi

Need determine period when larvae are at risk

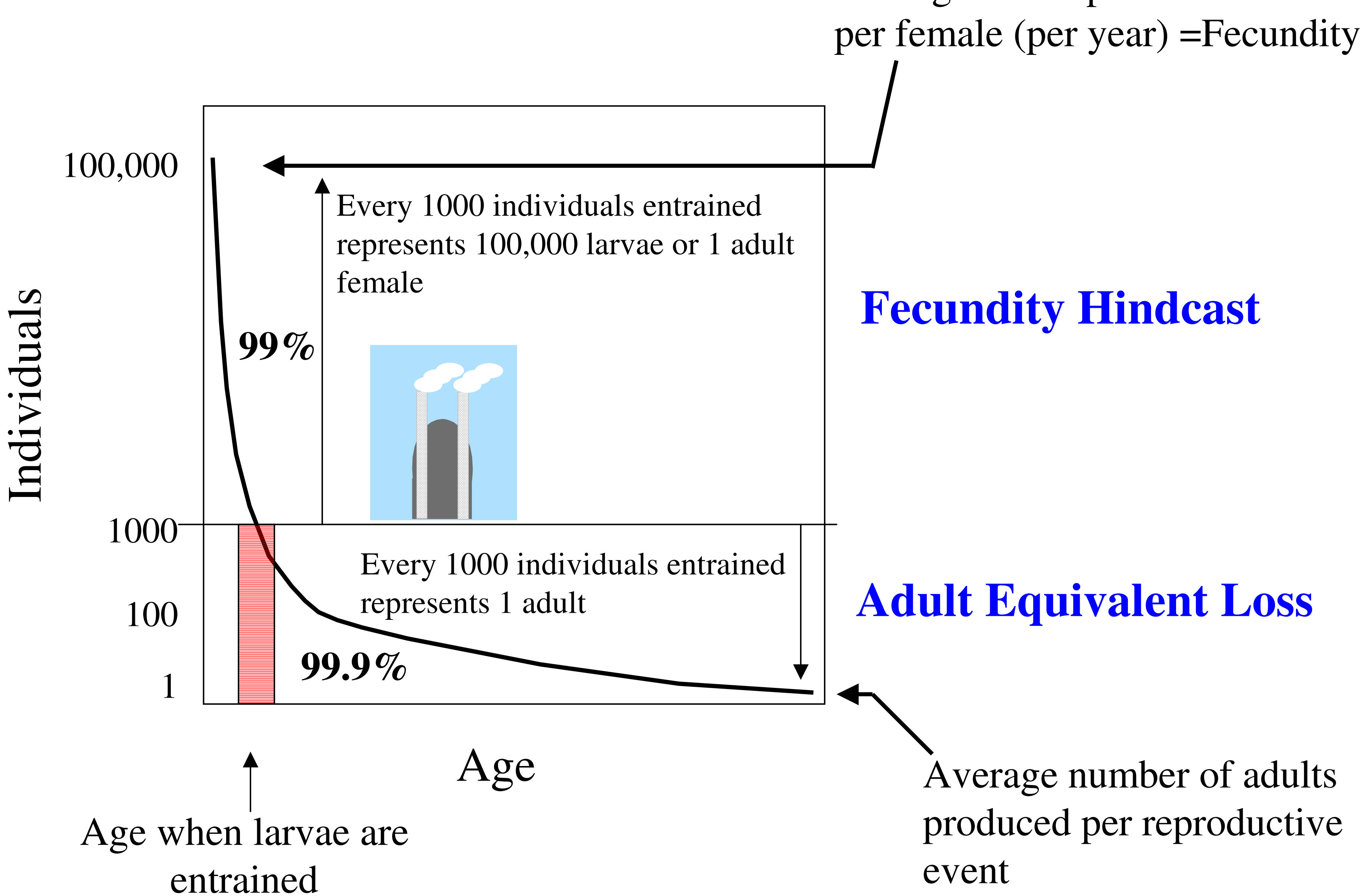
(Remember the size/age at which they can swim and sense predation – or power plants…)

d = days at risk (determined from entrainment samples)

Example	Larval Period	Days at Risk	
		Mean	Max
Unidentified Goby	90-120 days??	4.2 days	20.7 days
Shadow Goby	Up to 60 days	2.1 days	5.1 days
Combtooth Blenny	90 days	4.0 days	8.1 days
Staghorn Sculpin	56 days	15.5 days	25 days
Jacksmelt	Unknown	9.7 days	24.8 days

Source:Pete Raimondi

Estimation of Adult Losses



Source:Pete Raimondi

Example: Diablo Canyon Nuclear (Nucular?) Power Plant

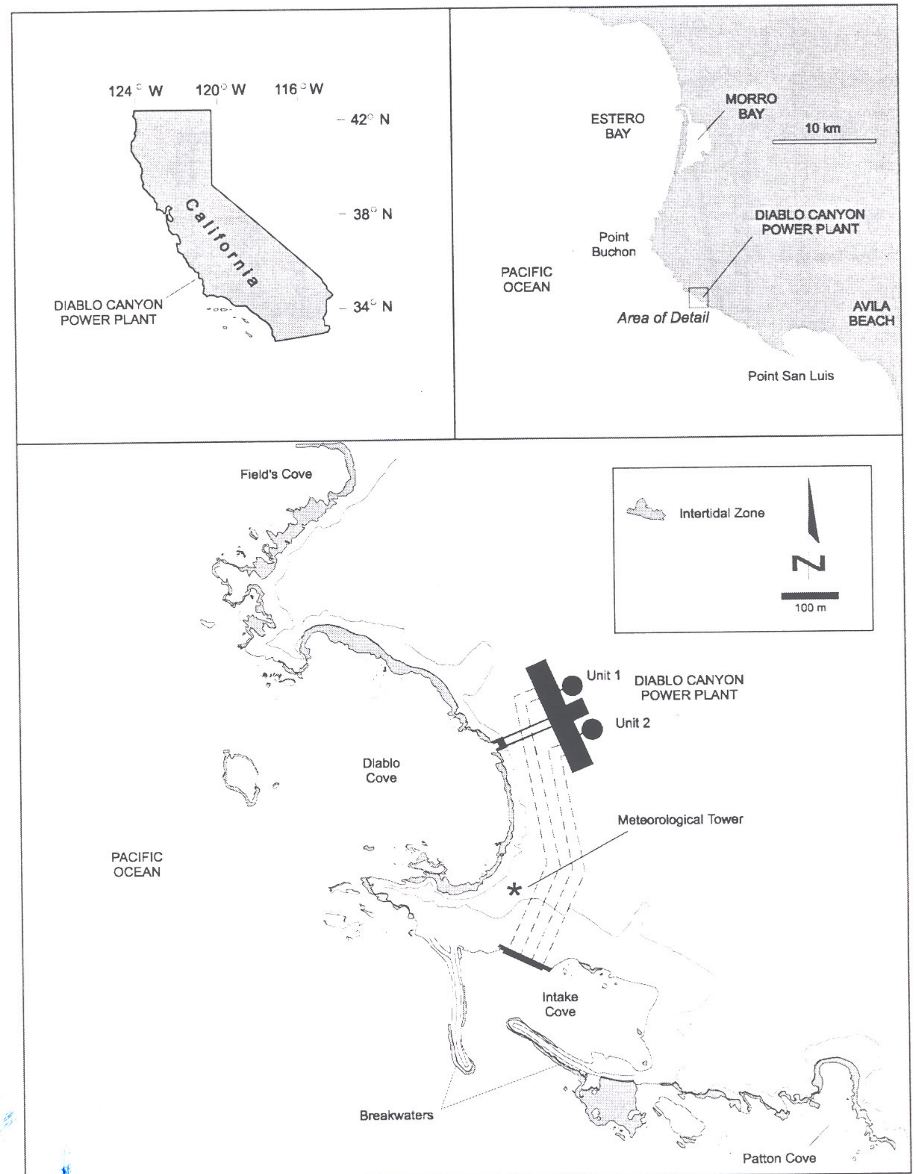


Figure 3-1. Location of Diablo Canyon Power Plant.

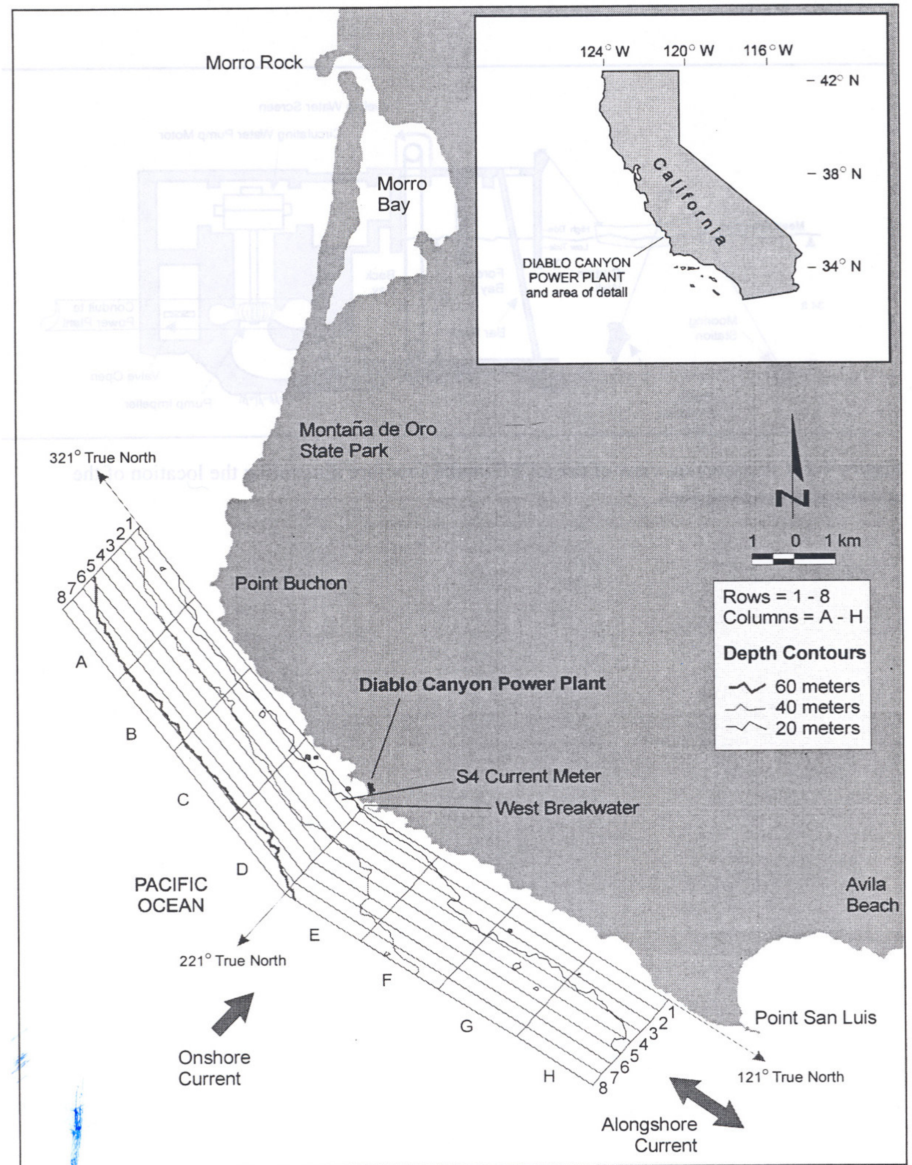


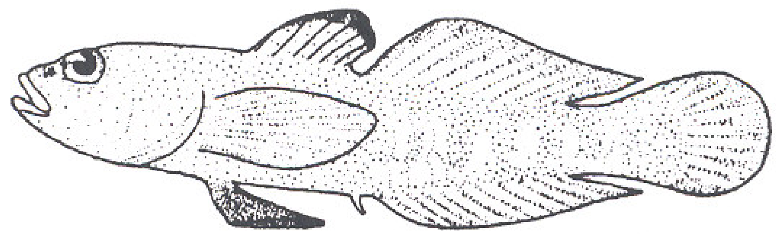
Figure 4-3. DCPP 316(b) study grid and depth contours.

H	G	F	E	D	C	B	A
8	8	8	8	8	8	8	8
7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6
5	5	5	5	5	5	5	5
4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1

DCPP Intake Cove

Does this look like the CalCOFI grid?

5.2.10 *Assessment of Blackeye Goby* (*Coryphopterus nicholsi*)



Coryphopterus nicholsi (Bean 1882); blackeye goby; length to 15 cm; northern British Columbia to south of Punta Rompiente, central Baja California; intertidal to 106 m; pale tan with some brown or greenish speckling; small blue dot below eye (Miller and Lea 1972; Eschmeyer et al. 1983).

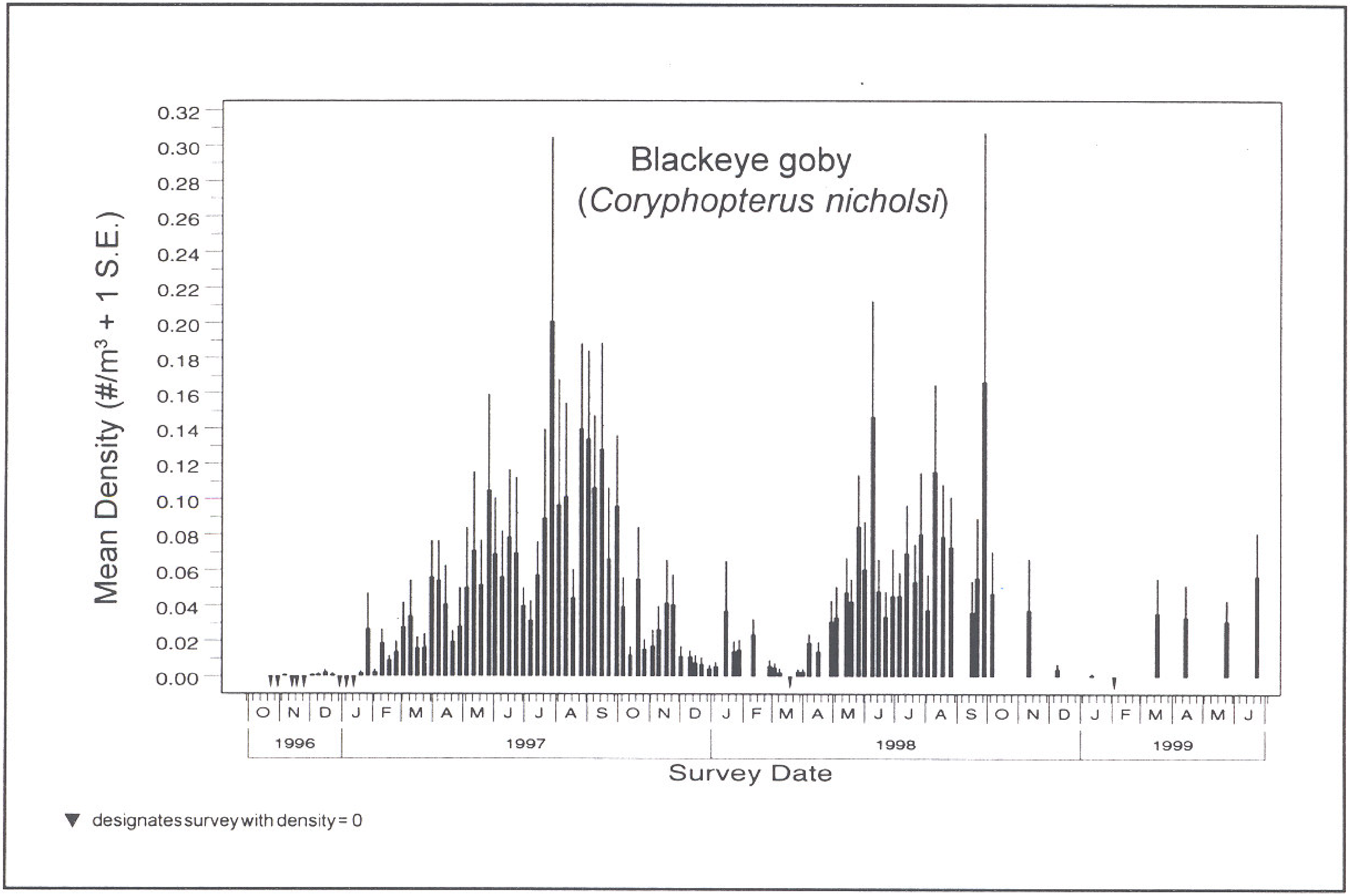


Figure 5.2.10-1. Weekly mean larval density (#/m^3 + 1 S.E.) at the DCPP intake.

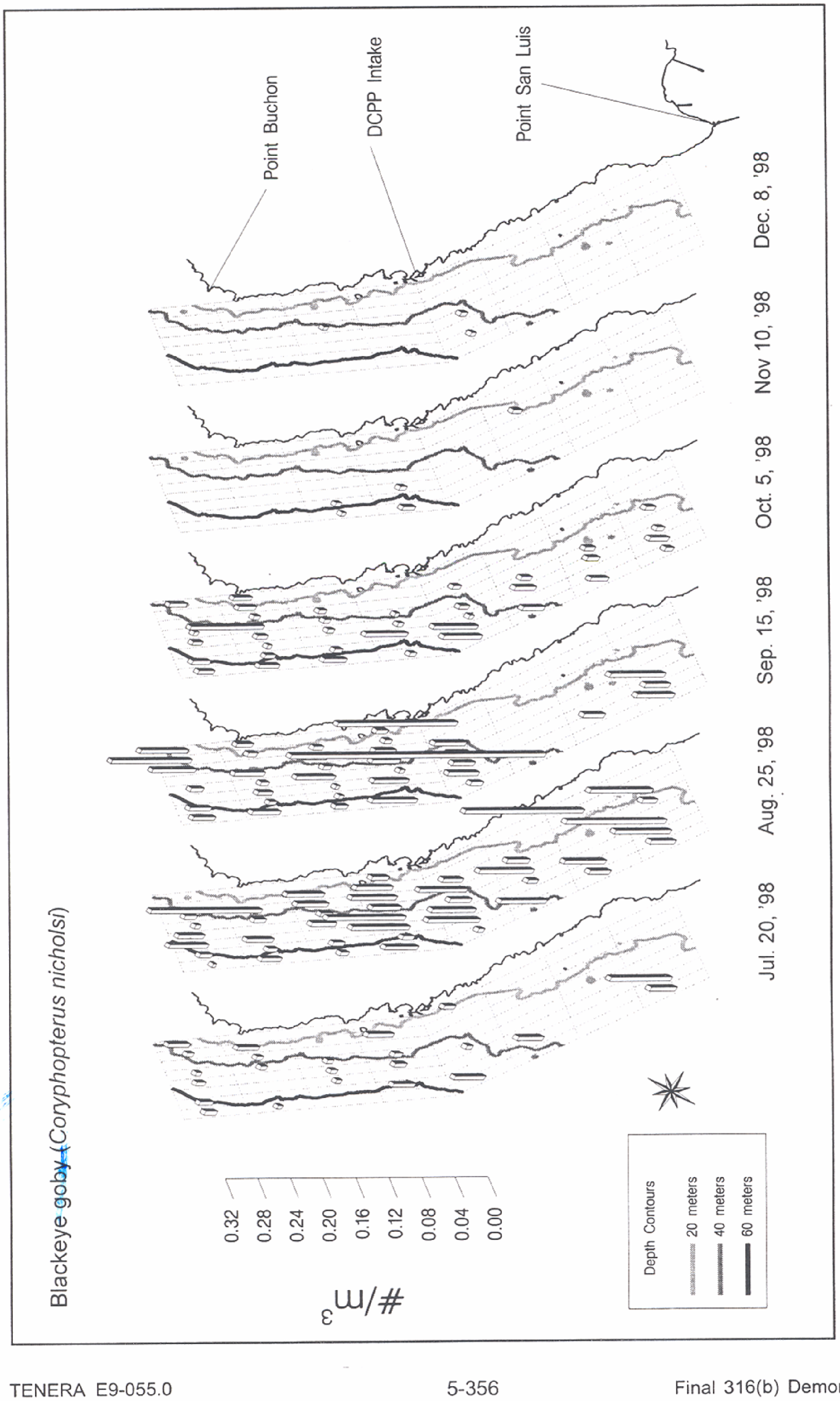


Figure 5.2.10-2c (continued). Mean larval density (#/m^3) collected in the DCPP study grid cells and at the entrainment sampling location.

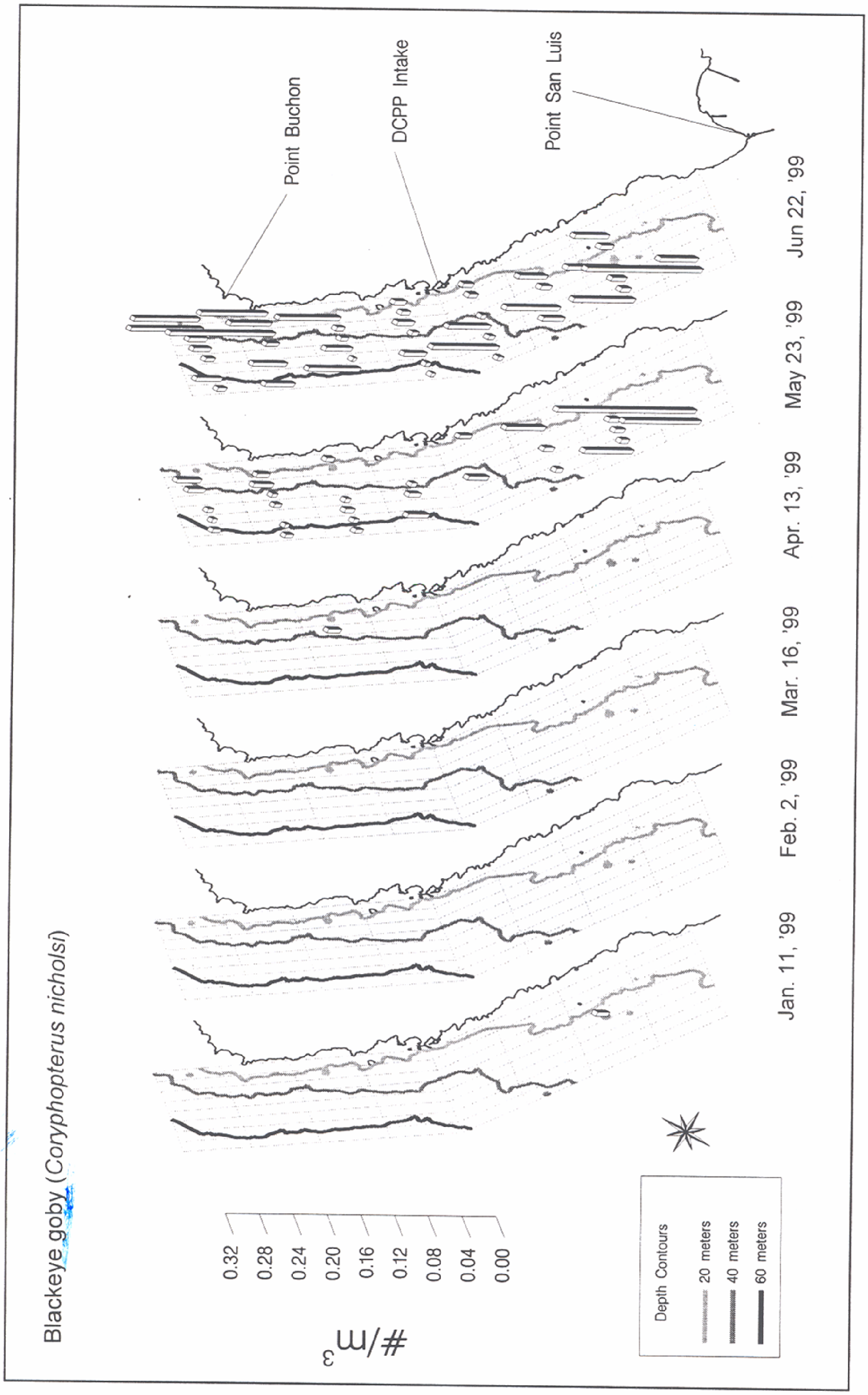


Figure 5.2.10-2d (continued). Mean larval density (#/m^3) collected in the DCPP study grid cells and at the entrainment sampling location.

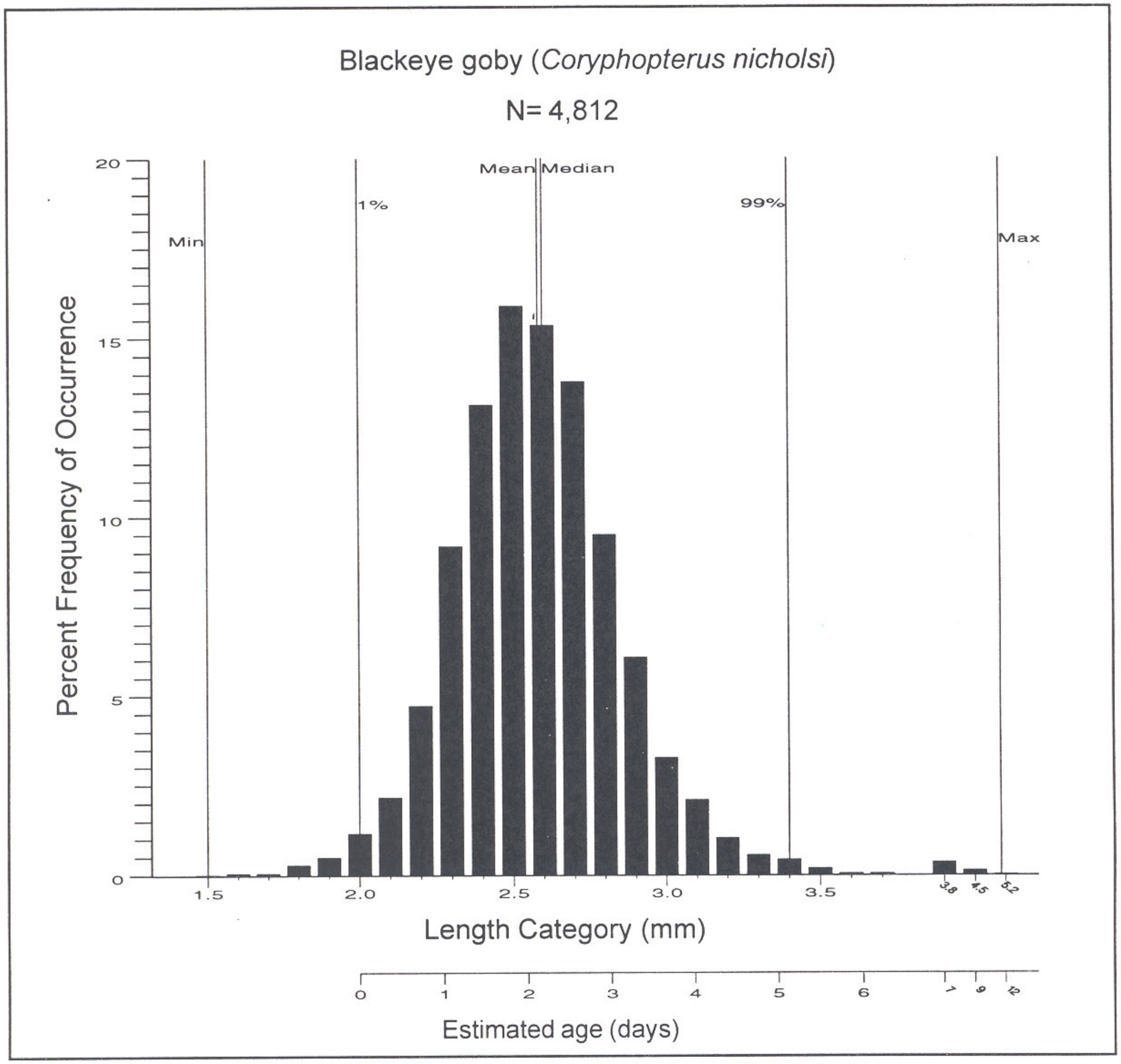


Figure 5.2.10-3. Length frequency of all measured larval fish collected in the entrainment samples. Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

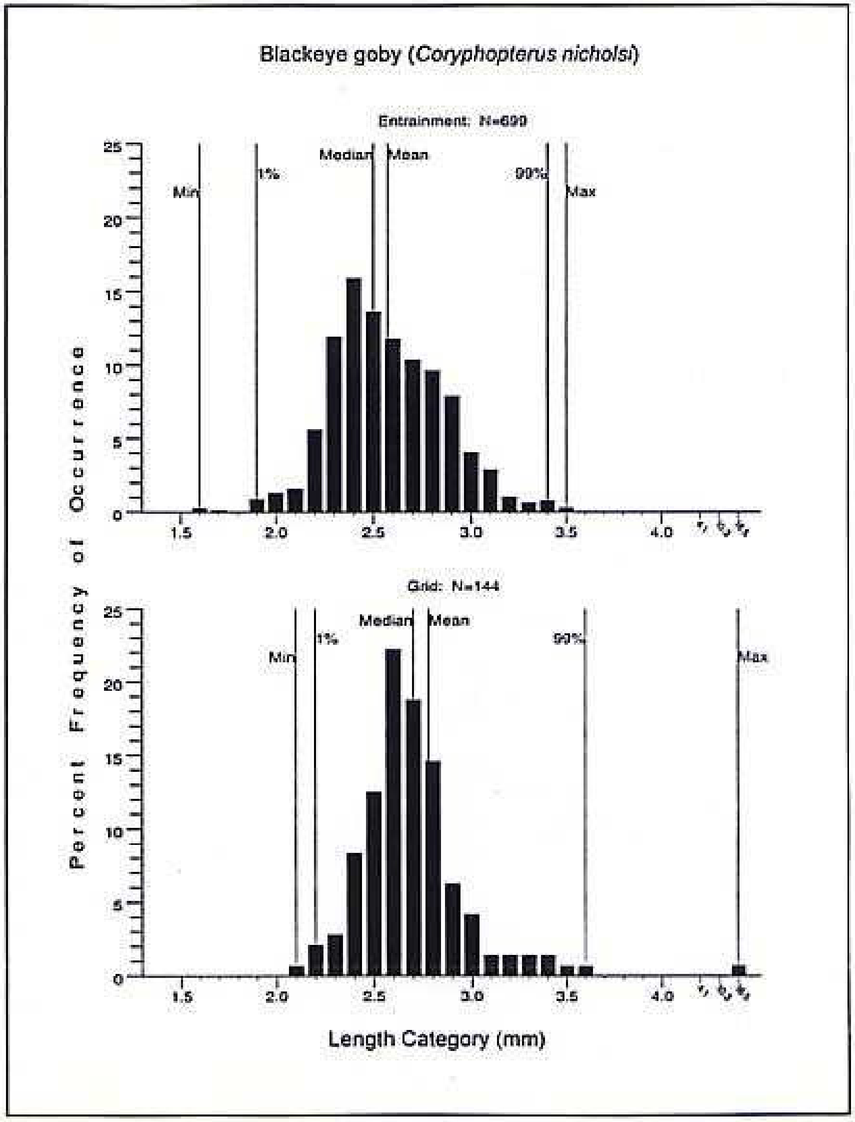


Figure 5.2.10-4. Length frequency of measured fish from entrainment surveys that paired with grid surveys (both years combined). Minimum, median, mean, maximum, and central 98% of the larval lengths are noted. X-axis scale is not continuous at larger lengths.

RESEARCH NEEDED TO BETTER UNDERSTAND THE ECOLOGICAL EFFECTS OF ONCE-THROUGH COOLING SYSTEMS

***Entrainment* (* = priorities)**

1. Identify **species** that would best serve as **indicators of impact** on all species entrained (to improve Habitat Production Foregone/mitigation analyses).

*2. Determine **life history parameters** to accurately estimate impacts on populations of indicator species (e.g., fecundity, size-specific survival, egg and larval durations).

*3. Develop **entrainment sampling methods** needed to accurately determine impacts on indicator species.

*4. Identify **species with 'special status'** likely to be entrained, and do 2. & 3. for them (e.g., threatened, endangered).

5. Investigate **larval fish behavior** relative to intakes as the results would improve intake design and impact prediction.

6. Refine nearshore oceanographic and **larval dispersal models** to **improve estimations of source waters**.

Entrainment and Impingement Losses

Estimation of Impingement

Estimation of Entrainment

Estimation of Ecological Effects due to Entrainment and Impingement

(How it relates to mitigation & monitoring)

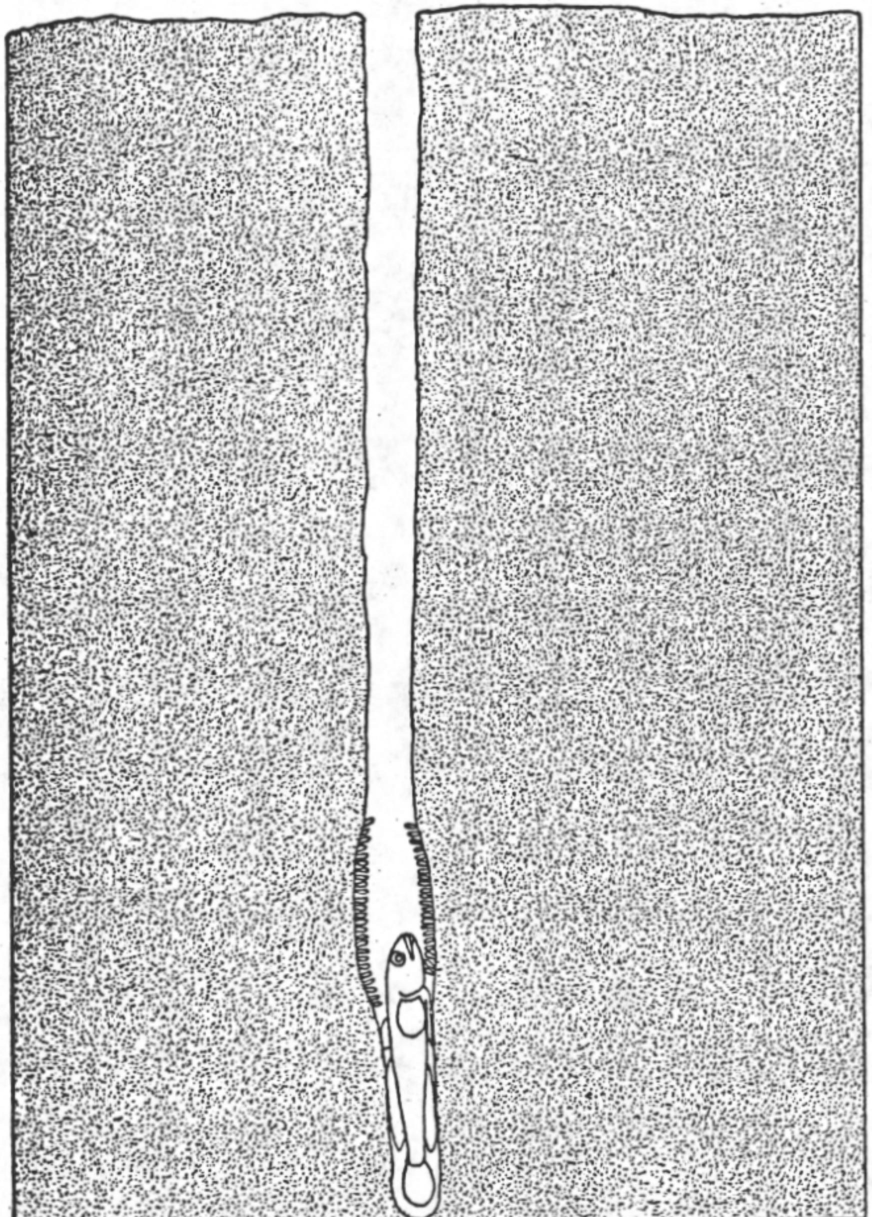
What do we need to know about adults?

Something about their densities and habitats to assess where larvae are coming from

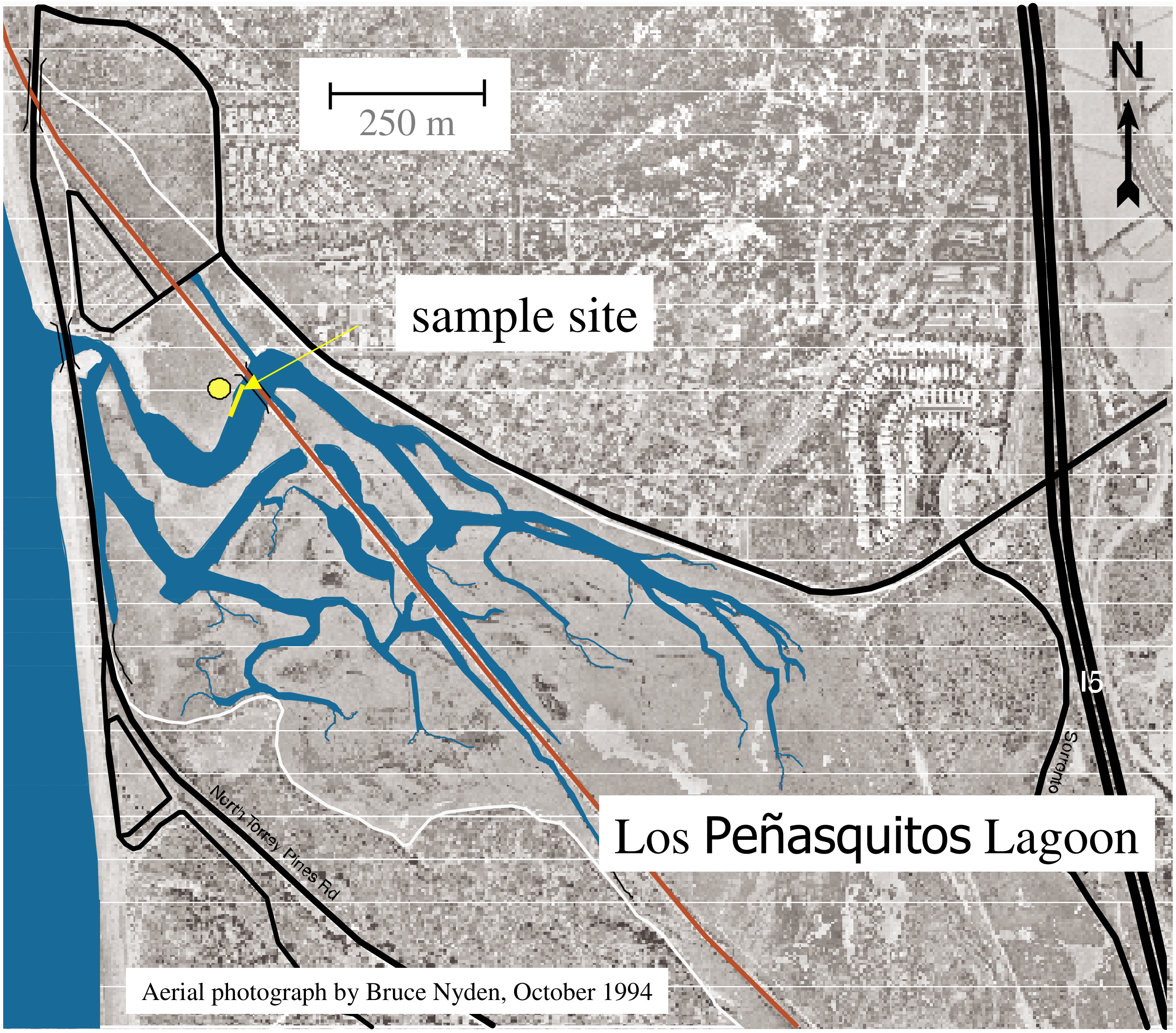
(e.g. Monitor mudflat and tidal creek fishes like blennies or gobies in estuaries)

Recent results from three estuaries in southern California provide examples of how different tidal habitats are sampled. Here are some techniques for estimating goby densities at different tidal heights.

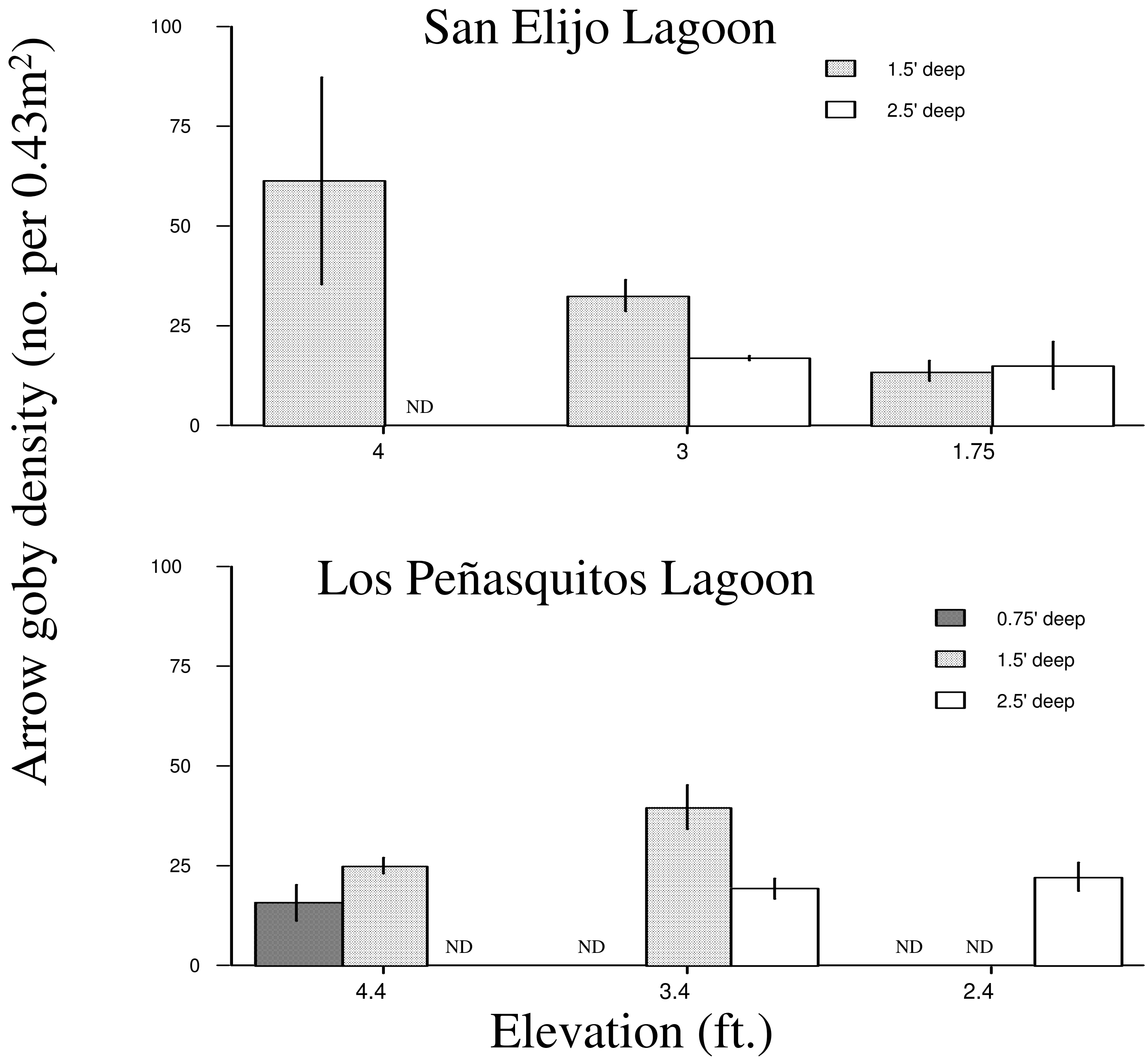
(Personal communication from Drs. Steve Schroeter, Mark Page, and Dan Reed, UCSB)



The goby *Ilypnus* burrows.
Brothers (1975)


250 m
N
sample site
I5
Sorrento
North Torrey Pines Rd
Los Peñasquitos Lagoon
Aerial photograph by Bruce Nyden, October 1994

Sample site at San Elijo lagoon


Arrow goby density (no. per 0.43m2)
San Elijo Lagoon
1.5' deep
2.5' deep
100
75
50
25
0
ND
4
3
1.75
Los Peñasquitos Lagoon
0.75' deep
1.5' deep
2.5' deep
100
75
50
25
0
ND
ND
ND
ND
4.4
3.4
2.4
Elevation (ft.)

Summary

Scientists need to know the life history of fishes to evaluate their impingement and entrainment.

These need to be size-, stage-, and/or age-specific life history traits.

Habitat utilization patterns of fish life stages need to be better understood.

Dispersal processes relative to ocean currents, are essential to determine the larval source water body to evaluate power plant entrainment mortality more accurately.

Impingement and entrainment models need to be agreed upon and used widely.

Results need to be translated into mitigation policies that have a close nexus to the impact on fish populations, if possible.