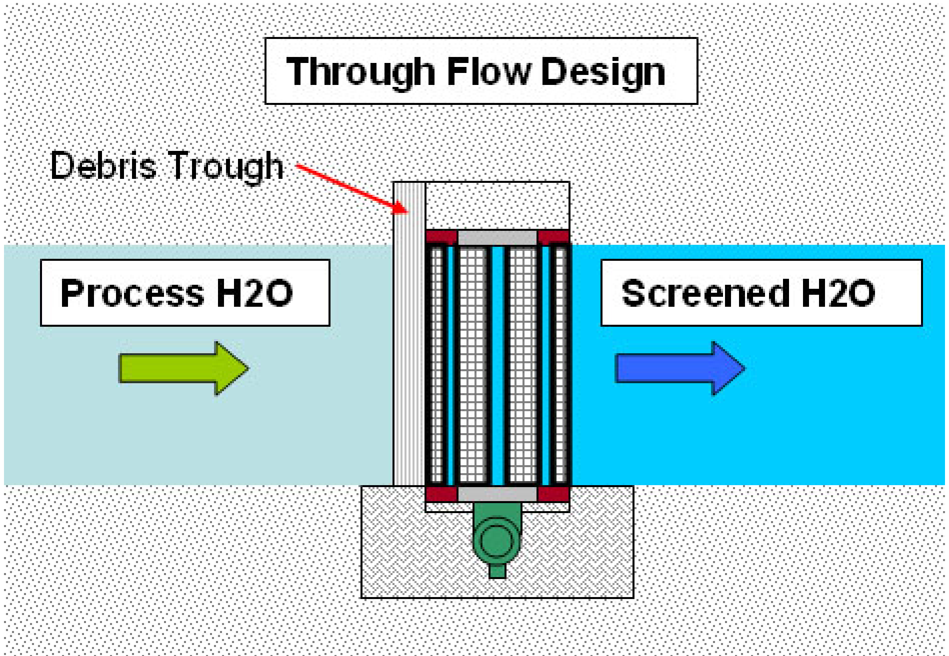
Entrainment and Impingement Losses

- **Definitions**
- Estimation of Impingement
- Estimation of Entrainment
- Estimation of Ecological Effects due to Entrainment and Impingement



General schematics for intake and discharge structures

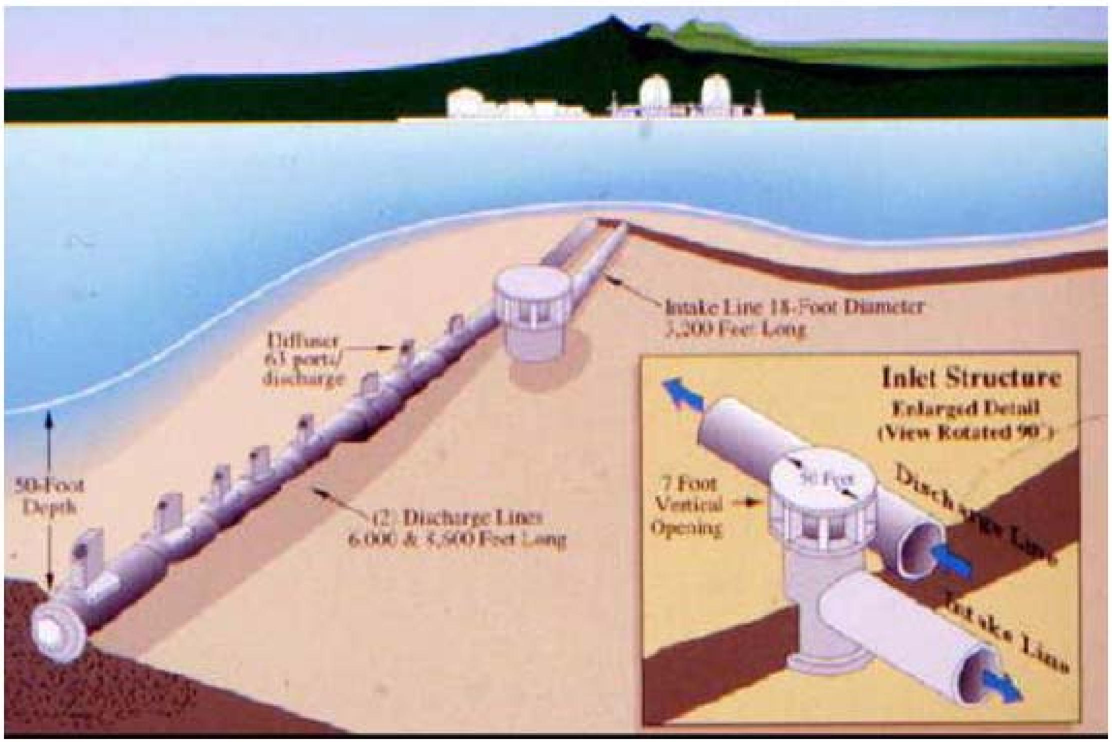
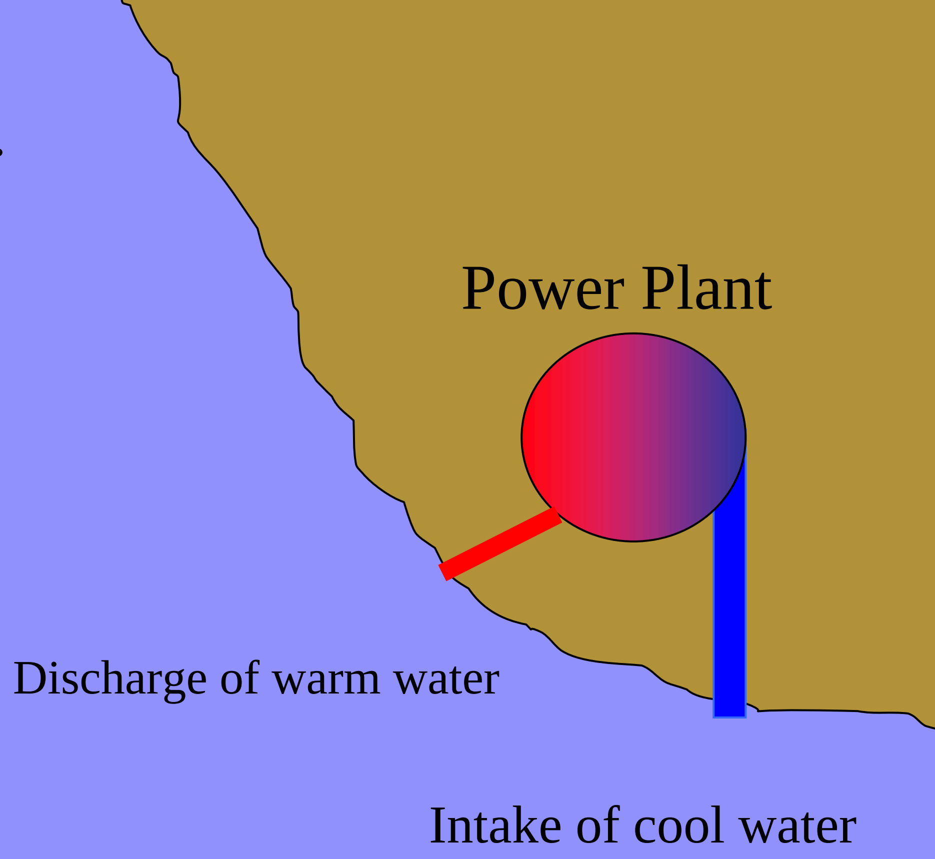


Figure 1 - Schematic of SONGS submerged offshore intake and velocity cap

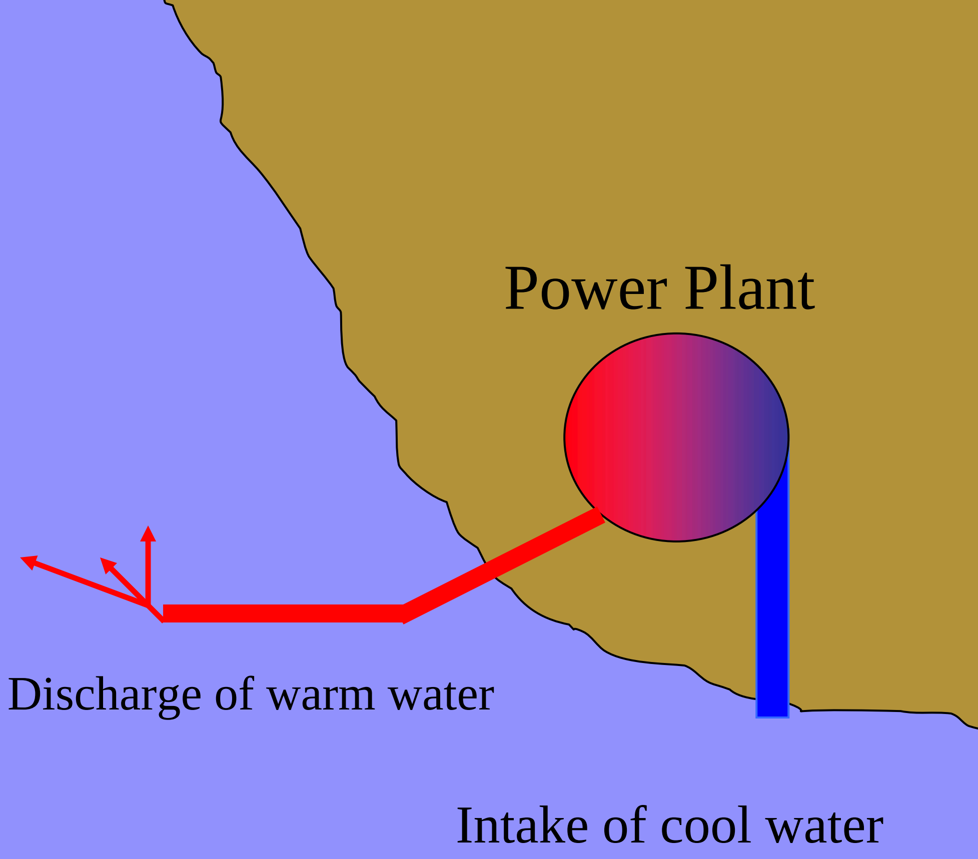
General schematic for intake and discharge of cooling water (e.g. Diablo, Potrero)

1. Onshore intake and outfall
   - Minimizes construction and maintenance costs
   - Minimizes impingement
   - Entrainment of nearshore species
   - Entrainment of drifting organisms that “pile up” on shore



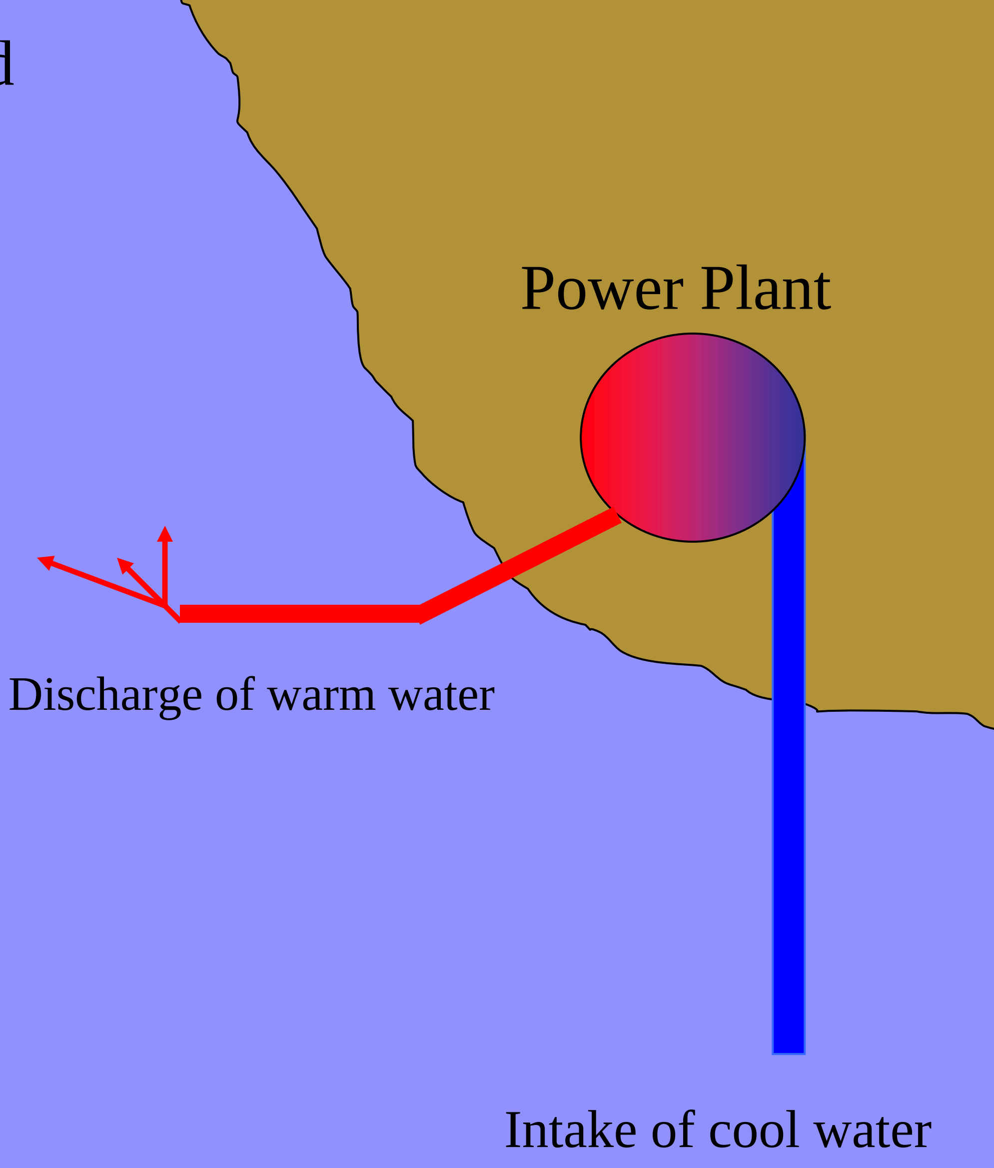
General schematic for intake and discharge of cooling water (e.g. Moss Landing)

2. Onshore intake and offshore outfall
   - Minimizes impingement
   - Allows for diffusion of warm water (makes it easier to meet NPDES conditions)
   - Entrainment of nearshore species

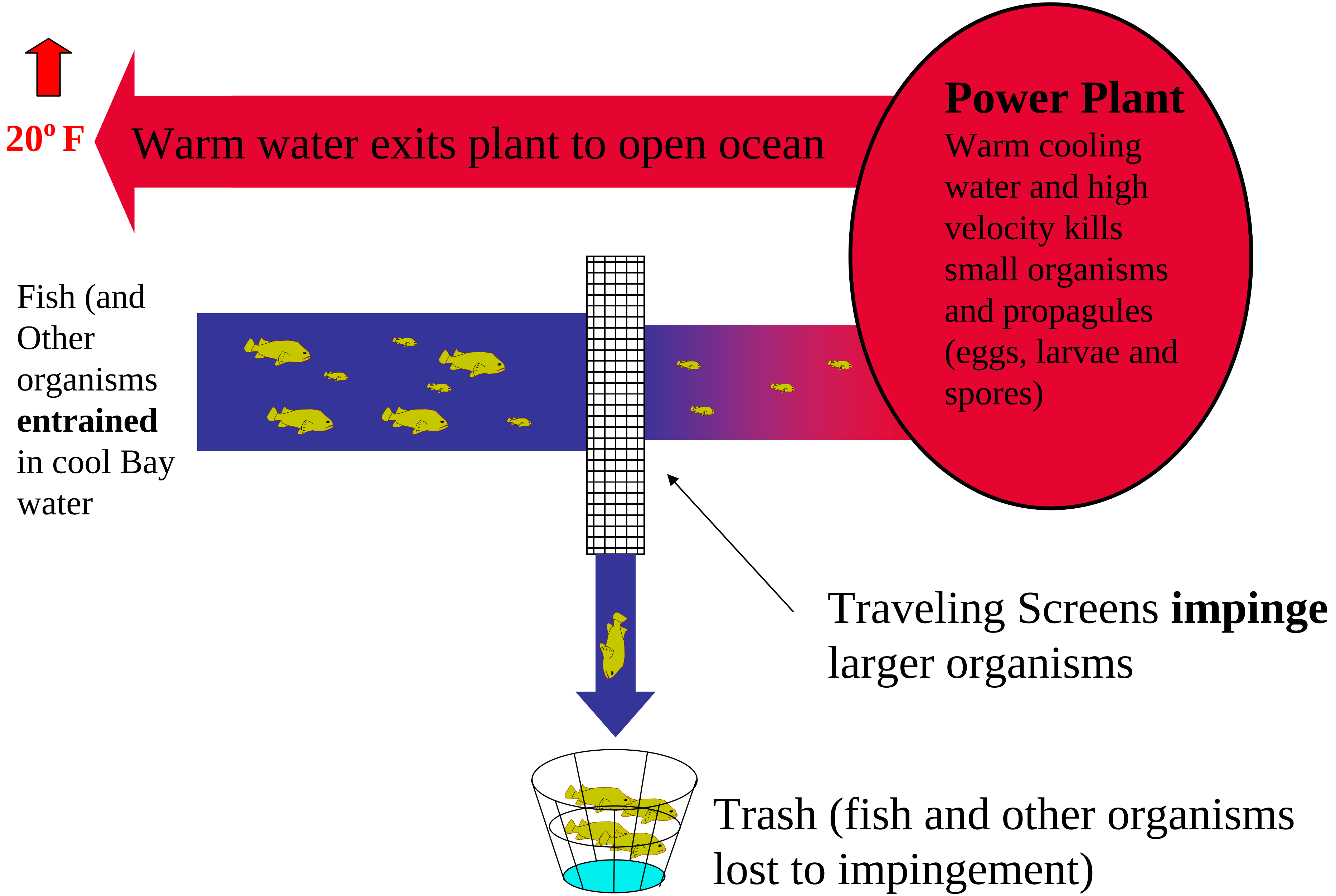


General schematic for intake and discharge of cooling water (e.g. San Onofre)

3. Offshore intake and outfall
   - Increases impingement
   - Allows for diffusion of warm water (makes it easier to meet NPDES conditions)
   - Entrainment of more offshore species



Thermal Effects, Impingement and Entrainment



Example Case: Estimation of impacts due to use of cooling water at Huntington Beach Generating Station (HBGS)

- Impingement
- Entrainment

Huntington Beach Generating Station

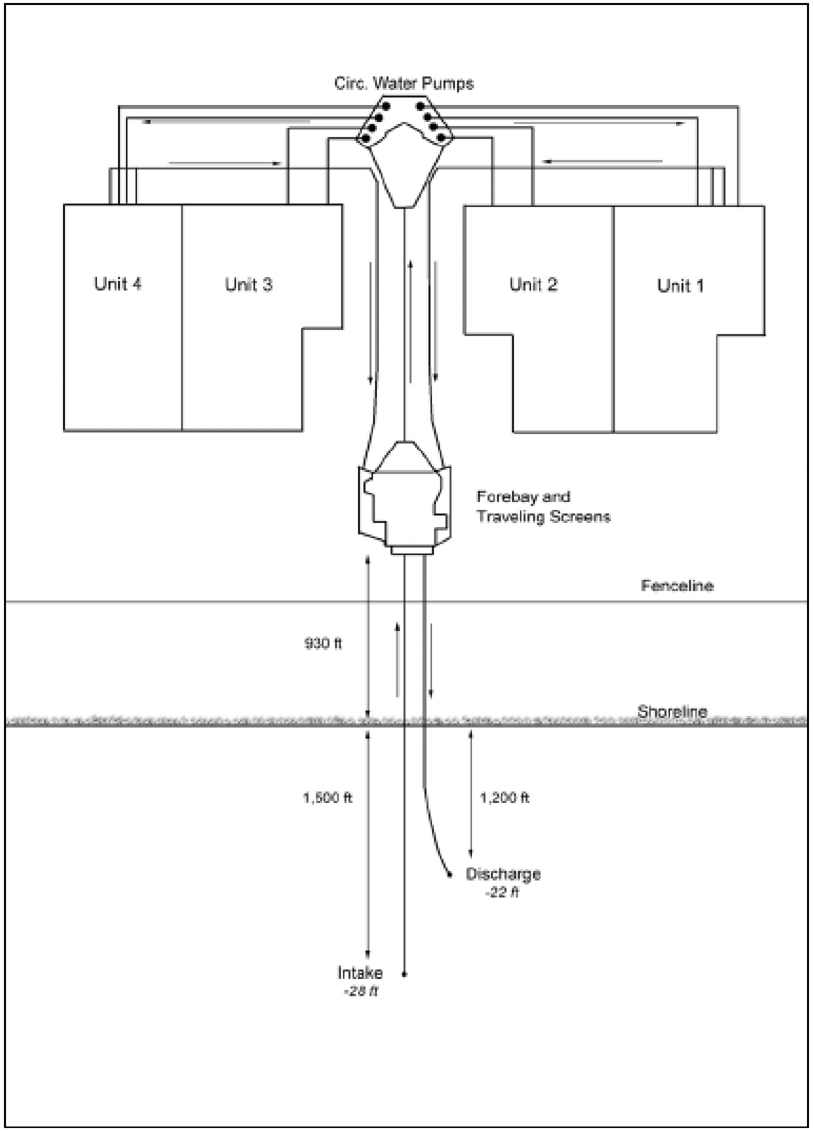


Figure 2-2. Schematic of the AES HBGS cooling water intake system.

Relevant comparisons

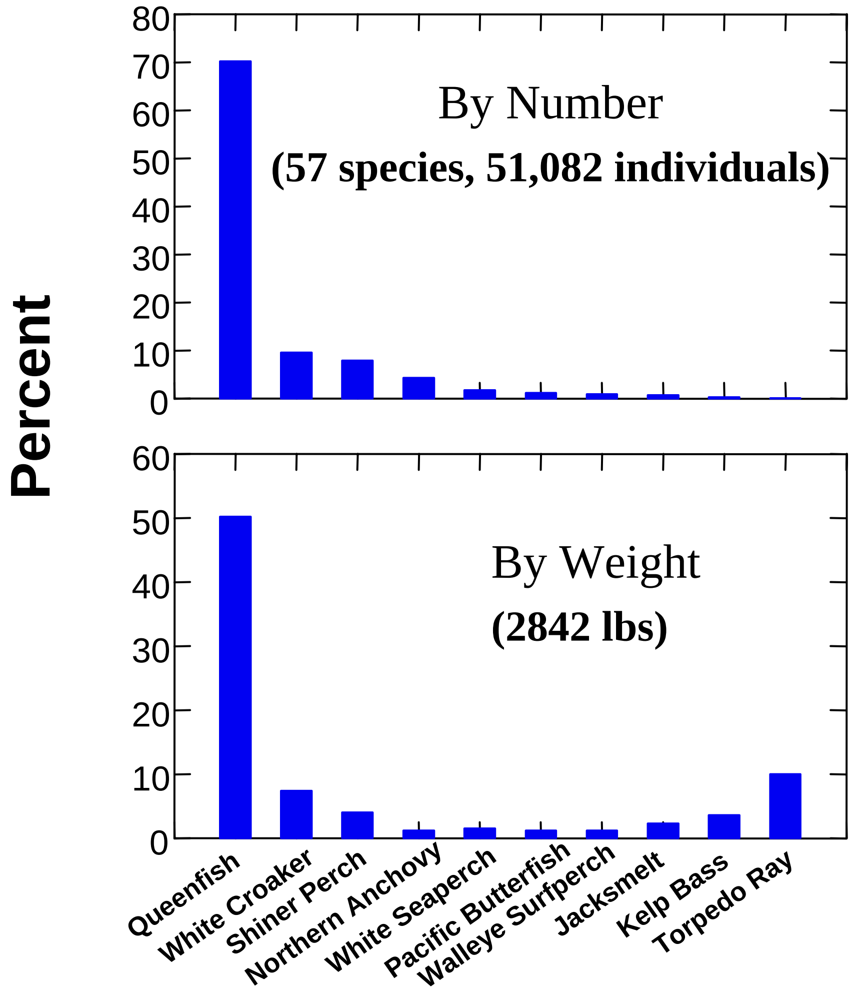
Characteristic	**Huntington Beach (Units 3,4)**	**Diablo Canyon**	**New Moss Landing (Units 1 & 2)**
Water Withdrawal	176,000 gallons per minute	~1,750,000 gallons per minute	250,000 gallons per minute
Intake Velocity	1.9-3.7 feet per second	0.5 feet per second	0.5 feet per second
Screen opening diameter	3/8th inch	3/8th inch	5/16th inch
Power capacity	225 MW per unit	2200 MW (plant)	530 MW per unit

Entrainment and Impingement Losses

- Definitions
- Estimation of Impingement
- Estimation of Entrainment
- Estimation of Ecological Effects due to Entrainment and Impingement

Huntington Beach

Impingement (2003-2004)



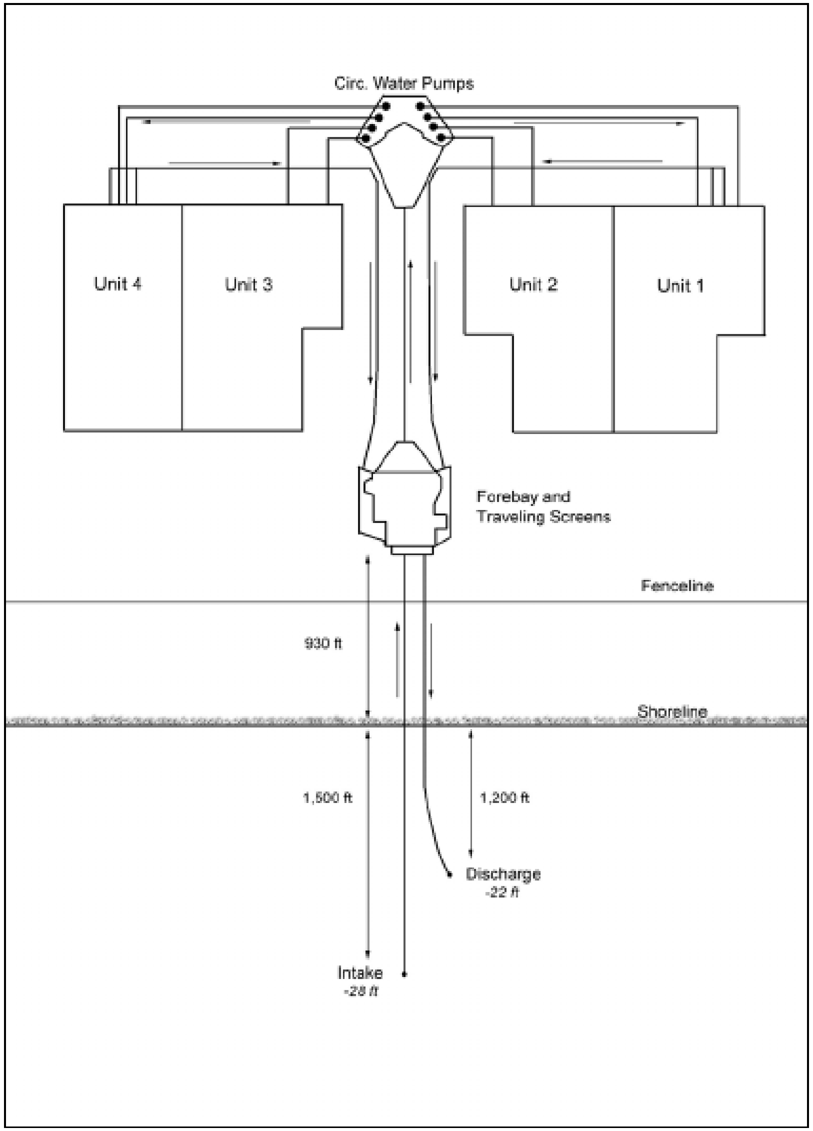


Figure 2-2. Schematic of the AES HBGS cooling water intake system.

Impingement at SONGS

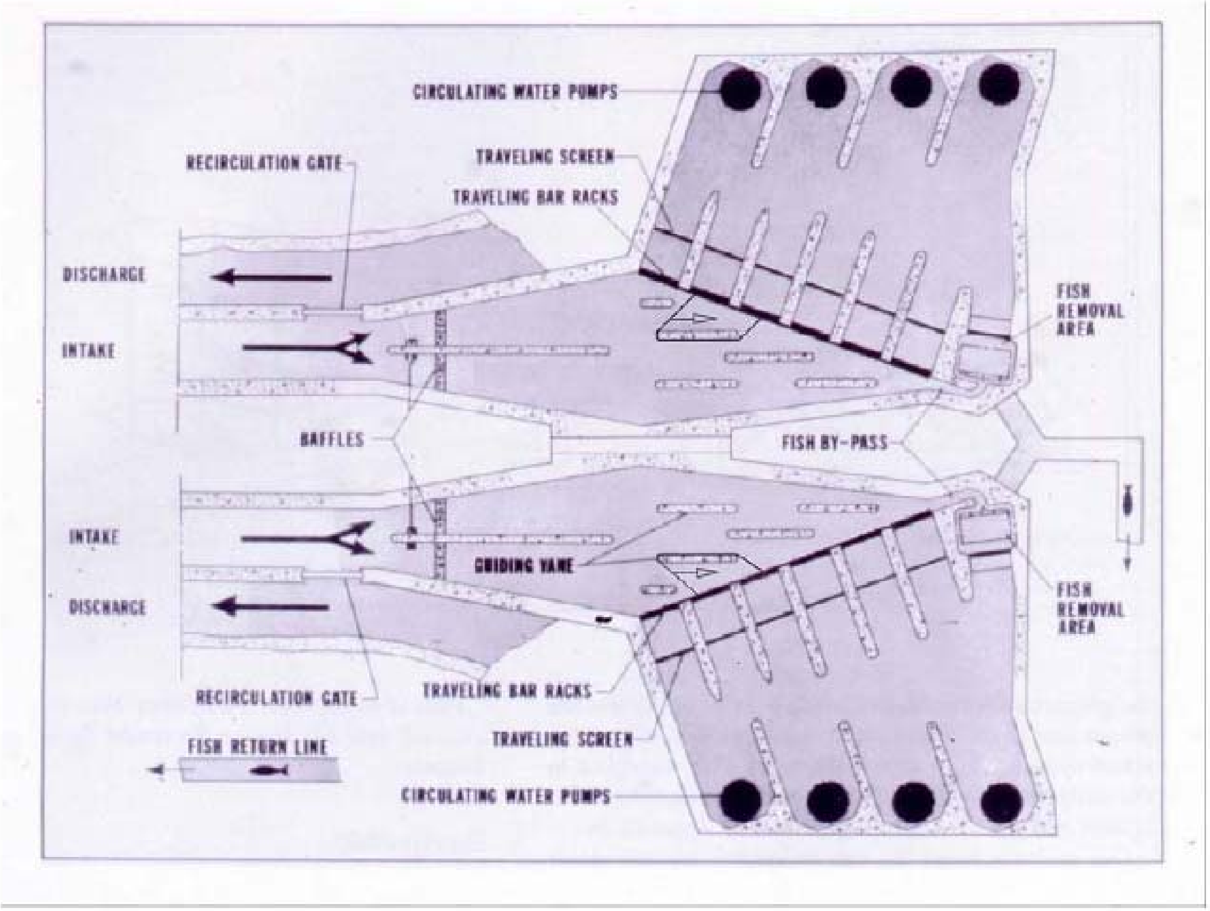
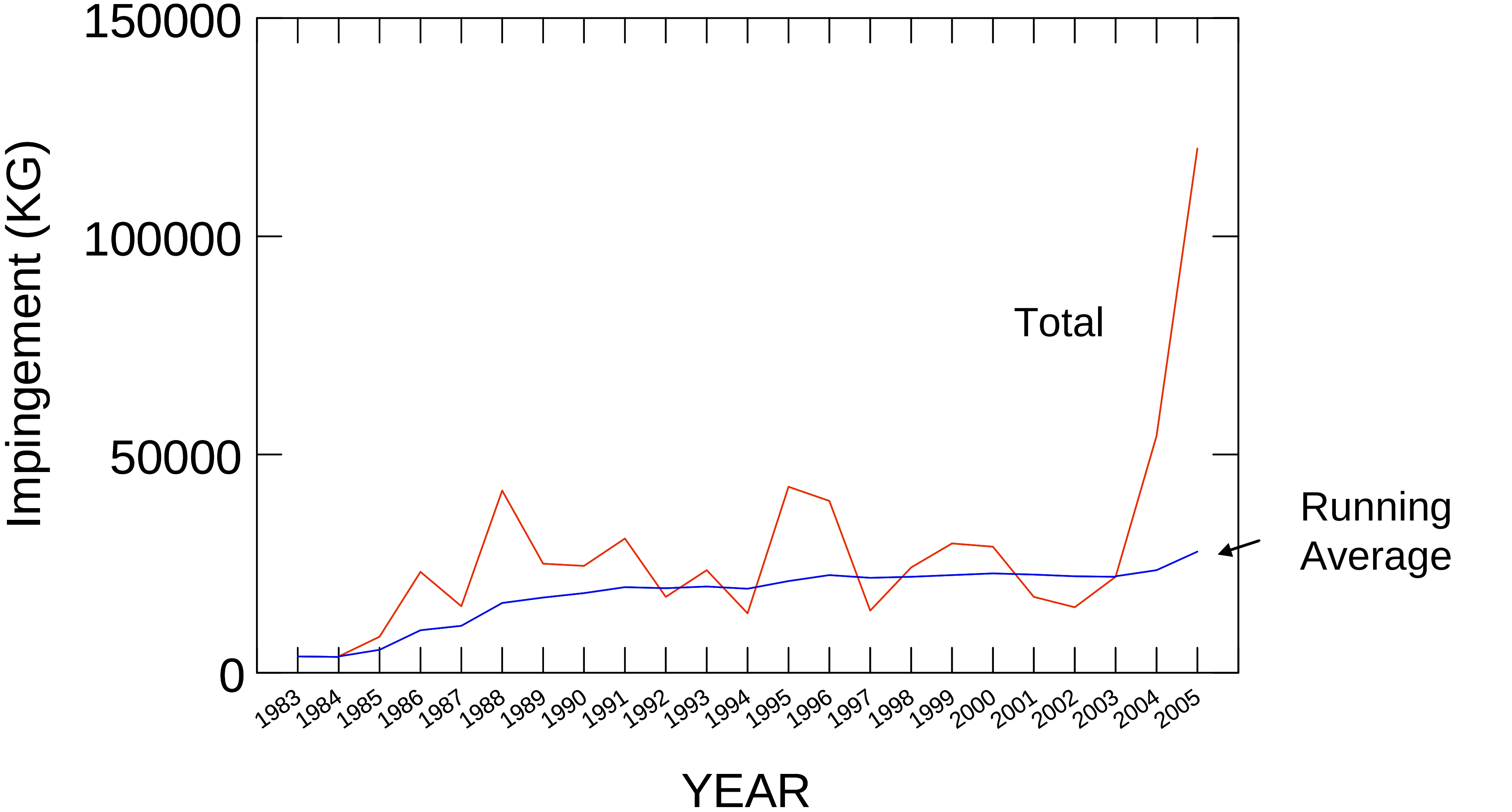


Figure 2 - Top view of SONGS on shore cooling water intake structure and fish return system

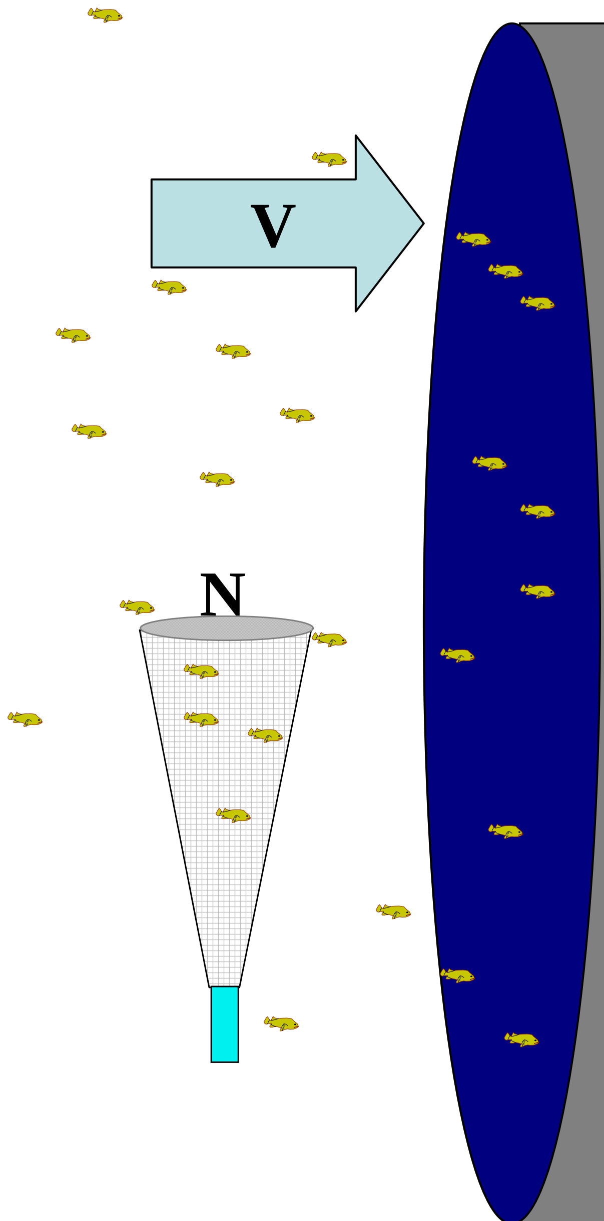
Total and average Impingement at SONGS



Entrainment and Impingement Losses

- Definitions
- Estimation of Impingement
- Estimation of Entrainment
- Estimation of Ecological Effects due to Entrainment and Impingement

Estimation of larval losses due to entrainment



1. Calculate volume of cooling water entering the plant per year (V)
2. Measure concentration of larvae (number per volume) that are entrained (N)
3. ***Assume no survival of larvae through the plant*** – then
4. NV = the annual loss of larvae due to entrainment

Huntington Beach: Percentage of Fish Taxa accounting for more than 1 percent of individuals entrained

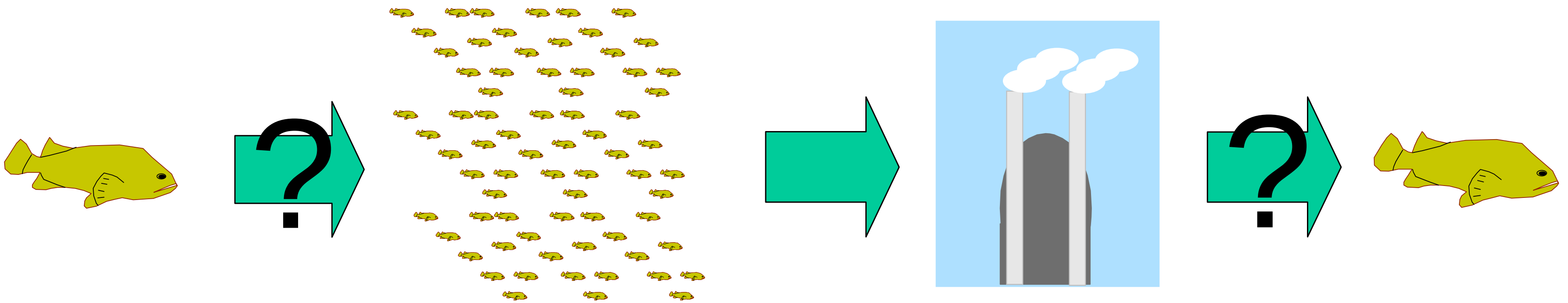
Fish Taxon	Common Name	Percent of Individuals in Entrainment Samples
Gobiidae (CIQ Complex)	gobies	36.95
Engraulidae	anchovies	17.98
Roncador stearnsi	spotfin croaker	13.57
Genyonemus lineatus	white croaker	6.53
Seriphus politus	queenfish	4.55
Sciaenidae	unidentified croakers	3.63
Hysoblennius spp.	blennies	2.47
Xenistius californiensis	salema	2.28
Paralichthys californicus	California halibut	1.46
Atherinopsidae	silversides	1.44
Cheilotrema saturnum	black croaker	1.43
Hypsopsetta guttulata	diamond turbot	1.29
Paralabrax spp.	kelp/sand bass	0.71
Chromis punctipinnis	blacksmith	0
Sardinops sagax	Pacific sardine	0.06
Sphyraena argentea	California barracuda	0.21

Estimation of Ecological Effects due to Entrainment

- Methods of Estimation
  - Fecundity Hindcast (FH)
  - Adult Equivalent Loss (AEL)
  - Proportional Mortality (PM)

Importance of larval losses due to entrainment

Fecundity Hindcast (FH) Adult Equivalent Loss (AEL)



Adult Stock (Females)

Larvae

Loss of Adult fish

Question: How to estimate losses to adult populations?

Table 5-1. Summary of entrainment modeling estimates on target taxa based on the three modeling techniques (*FH, AEL,* and *ETM* [P_M]). The *FH* model estimates an equivalent number of breeding adult females, therefore this estimate is multiplied by two for comparison with the AEL model that estimates an equivalent numbers of adults irrespective of sex. The comparison assumes a 50:50 ratio of males:females in the population. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the estimate.

Taxon	Estimated Annual Entrainment	2·*FH*	*AEL*
CIQ goby complex	113,166,834	202,538	147,493
northern anchovy	54,349,017	53,490	304,125
spotfin croaker	69,701,589	NA	NA
queenfish	17,809,864	NA	NA
white croaker	17,625,263	NA	NA
black croaker	7,128,127	NA	NA
salema	11,696,960	NA	NA
blennies	7,165,513	6,466	NA
diamond turbot	5,443,118	NA	NA
California halibut	5,021,168	NA	NA
sand crab megalops	69,793	NA	NA
California spiny lobster	0	NA	NA
ridgeback rock shrimp	0	NA	NA
market squid	0	NA	NA
rock crab megalops	6,411,171	NA	NA

NA – Estimate not available due to either insufficient life history information or low abundance in entrainment samples.

Huntington Beach

Estimation of Ecological Effects due to Entrainment

Methods of Estimation

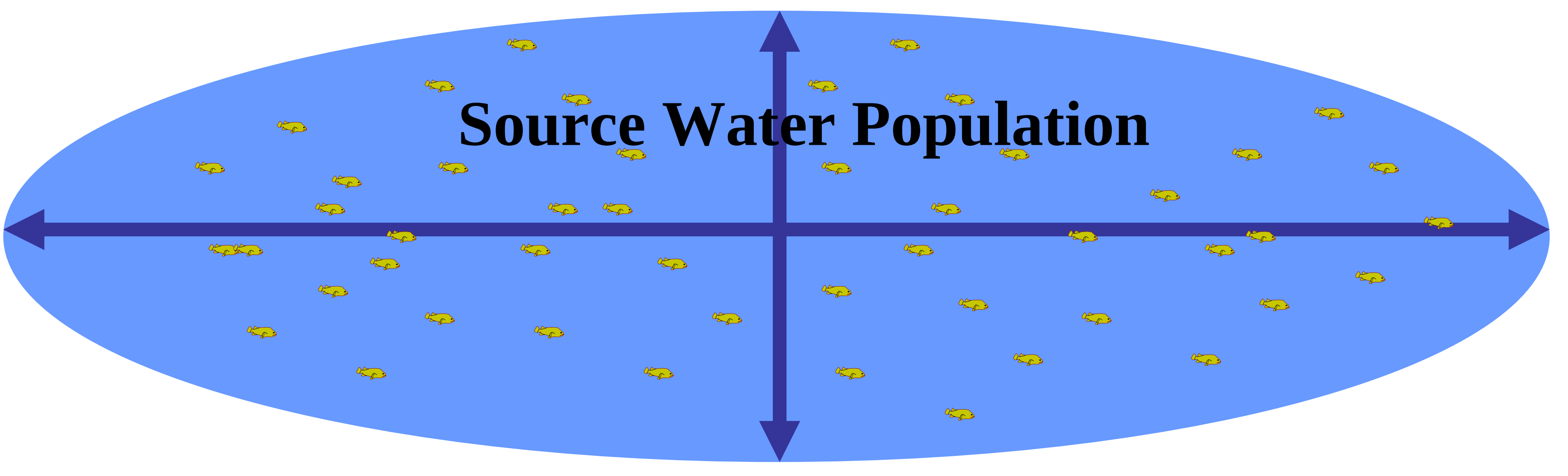
- **Fecundity Hindcast (FH)**
  - **Need estimate of average fecundity per female**
    - **Sometimes extremely variable estimates**
  - **Need estimate of mortality between reproduction and entrainment – unknown for most species**
- **Adult Equivalent Loss (AEL)**
  - **Need estimate of mortality between entrainment and maturity for most species – unknown for most species**
- **Proportional Mortality (PM) based on ETM**

How to interpret P_m (proportional mortality)

- What counts as significant?
  - Are low P_m values indicative of insignificant mortality rates?
  - To understand this idea – use an example

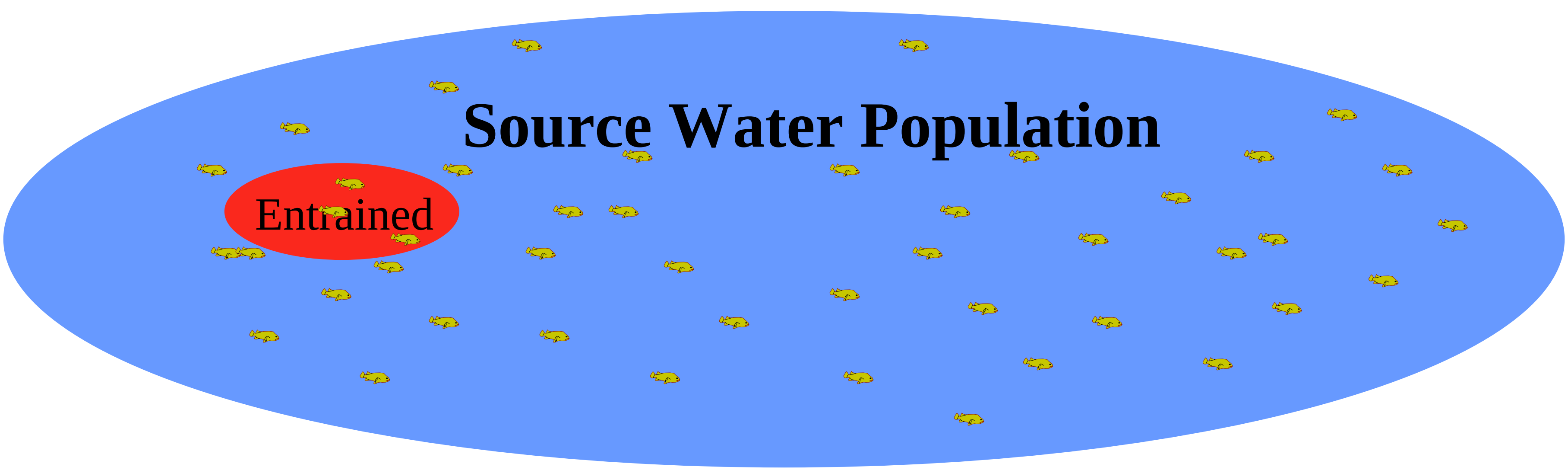
Understanding "Source Water Population" (SWP) and "Proportional Mortality" (P_m)

The SWP is that spatial area that contains the larvae at risk of entrainment.

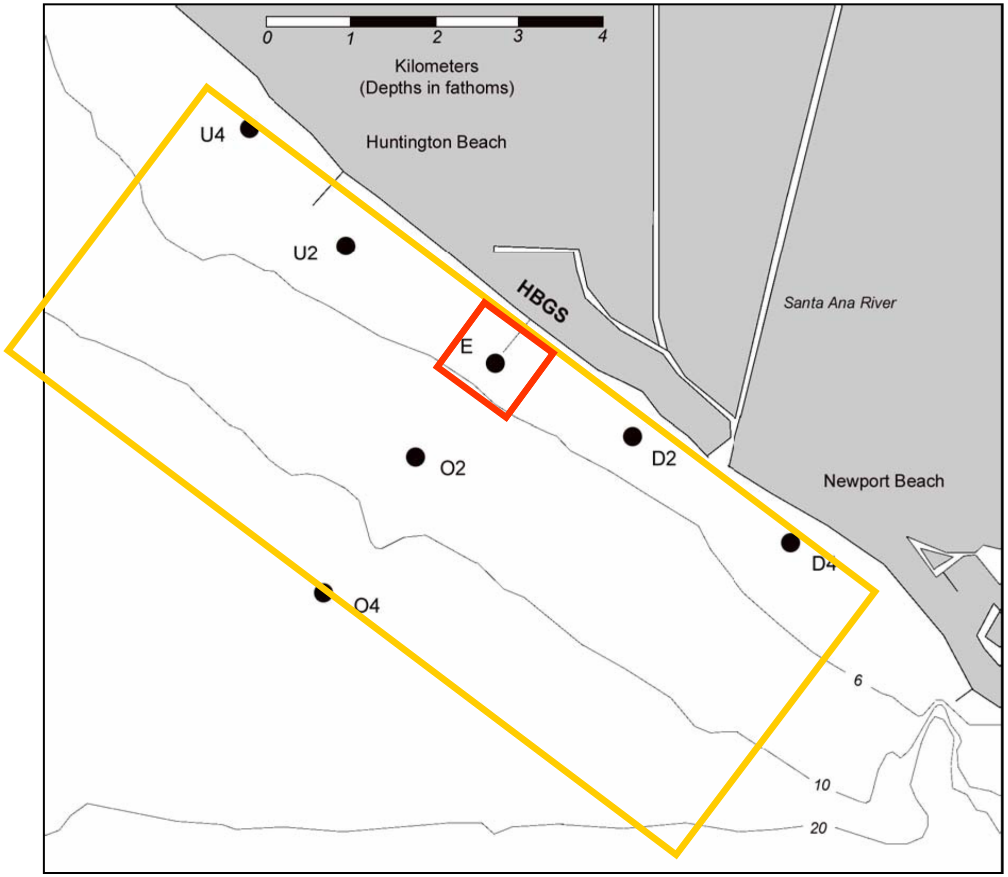


Understanding "Source Water Population" (SWP) and "Proportional Mortality" (P_m)

P_m is the percentage of the larvae at risk that are entrained and killed (e.g. 2%).



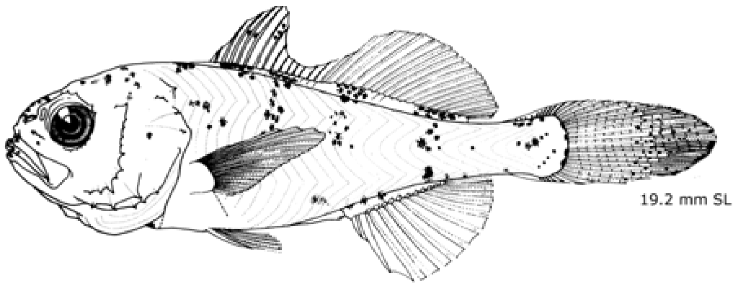
Source Water Sampling at Huntington Beach



Each species will have a different Source Water Population
Example: Queenfish (50.9 miles along coast)

Based on:

- Period of vulnerability to entrainment
- Distance larvae could have come from during the period of vulnerability



Entrainment Study – ETM Model results

Taxon	Estimated Annual Entrainment	Length of Source Water Population (Miles)
spotfin croaker	69,701,589	**10.1**
Queenfish	17,809,864	**50.9**
white croaker	17,625,263	**28.7**
black croaker	7,128,127	**11.6**
Salema	11,696,960	
Blennies	7,165,513	**7.7**
diamond turbot	5,443,118	**10.1**
California halibut	5,021,168	**18.5**
rock crab	6,411,171	**15.9**
AVERAGE		
AVERAGE (acres)		

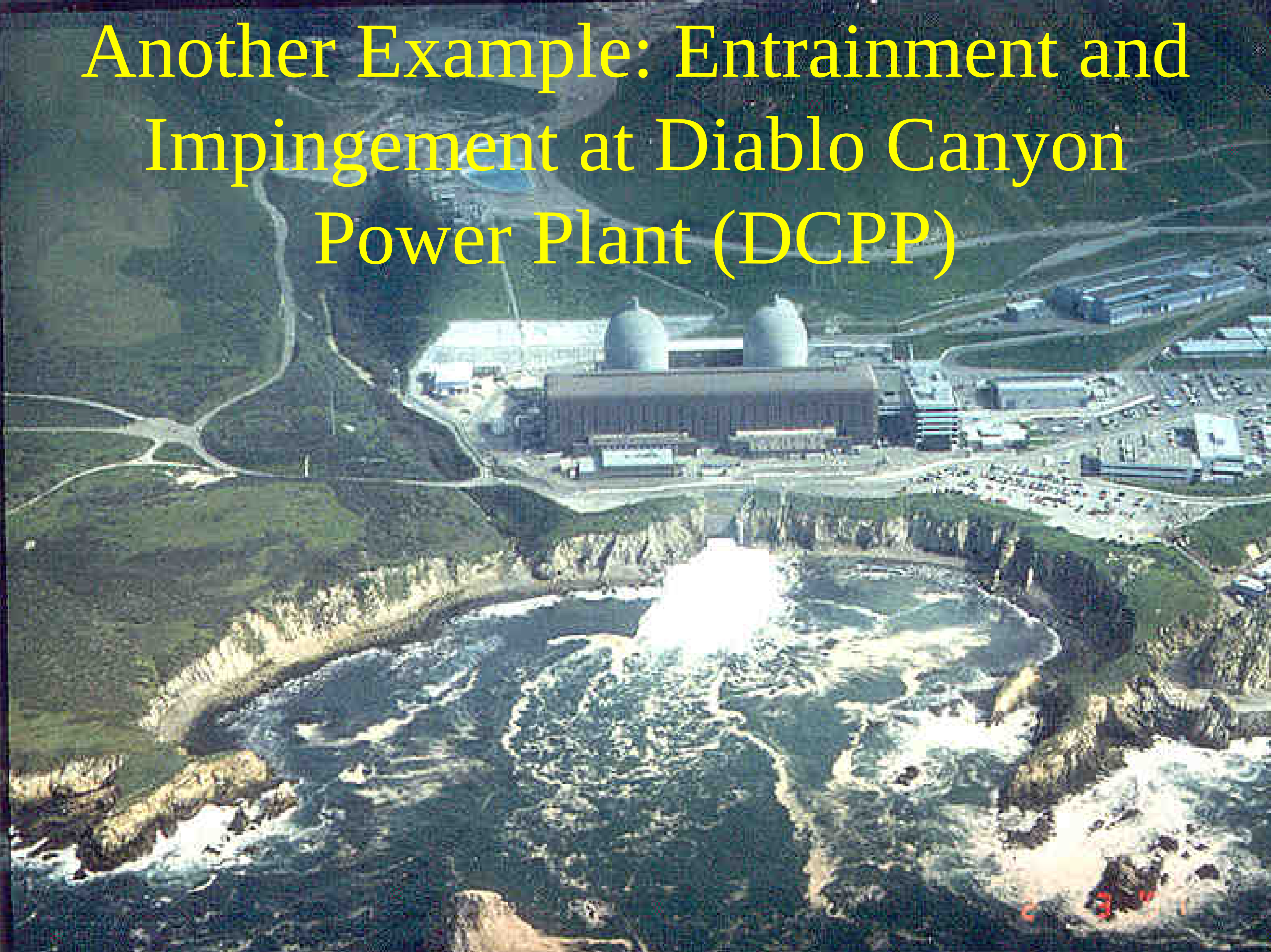
The ETM Model: Calculation Of Average Mortality due to entrainment

1. Determine target species
2. Determine period when larvae are at risk
3. Calculate rates of mortality (P_m) for target species
4. Assume that target species represent other species that were not targets
5. These values represents the estimated rate of mortality for all species having a larval phase whose PM's were not directly determined

Huntington Beach Entrainment Study – ETM Model results based on: (1) "best estimate" and estimate including uncertainty.

Taxon	Estimated Annual Entrainment	P_m Alongshore Extrapolation (Mean)	P_m Alongshore Extrapolation (+ 1 SE)
spotfin croaker	69,701,589	0.30%	37%
Queenfish	17,809,864	0.60%	29%
white croaker	17,625,263	0.70%	24%
black croaker	7,128,127	0.10%	38%
Salema	11,696,960	NA**	
Blennies	7,165,513	0.80%	28%
diamond turbot	5,443,118	0.60%	28%
California halibut	5,021,168	0.30%	21%
rock crab	6,411,171	1.10%	35%
AVERAGE		**0.56%**	**30.0%**
AVERAGE (acres)			

Another Example: Entrainment and Impingement at Diablo Canyon Power Plant (DCPP)



Diablo Canyon

Table 2: Estimates of duration at risk, mortality rate and source water body for target species.

Taxa	Adult Habitat	Sample Period	Duration at Risk (Days)	Mortality rate (Pm)	Source water body, alongshore distance over which Pm can be calculated (km)
smoothhead sculpin	Rocky	97-98	34.94	10.83%	124.10
		98-99	34.94	14.90%	139.40
monkeyface prickleback	Rocky	97-98	25.40	12.58%	117.30
		98-99	25.40	9.24%	136.00
Clinid kelpfishes	Rocky	97-98	31.60	15.72%	124.10
		98-99	31.60	18.97%	105.40
blackeye goby	Rocky	97-98	5.19	8.52%	40.80
		98-99	5.19	4.90%	30.60
cabezon	Rocky	97-98	8.00	0.76%	59.50
		98-99	8.00	1.16%	42.50
snubnose sculpin	Rocky	97-98	13.98	7.50%	73.10
		98-99	13.98	15.72%	71.40
painted greenling	Rocky	97-98	24.10	5.18%	105.40
		98-99	24.10	3.45%	124.10
KGB rockfishes	Rocky	97-98	16.43	3.05%	86.70
		98-99	16.43	3.25%	113.90
blue rockfish	Rocky	97-98	12.86	0.27%	69.70
		98-99	12.86	1.68%	85.00
white croaker	Sandy	97-98	22.00	0.57%	93.50
		98-99	22.00	3.47%	66.30
sanddabs	Sandy	97-98	11.00	0.77%	54.40
		98-99	11.00	0.63%	59.50
California halibut	Sandy	97-98	22.14	0.31%	103.70
		98-99	22.14	4.60%	91.80
	Averages for Rocky reef species			**7.65%**	**92**

Interpretation of estimate of LOSS (FH, AEL and PM)

- With FH and AEL we can estimate adult loss
- With PM we can estimate proportional larval loss
  - **Question: what level of loss is environmentally important?**
    - **What counts as important?**
      - **Local**
      - **Regional**
      - **National**

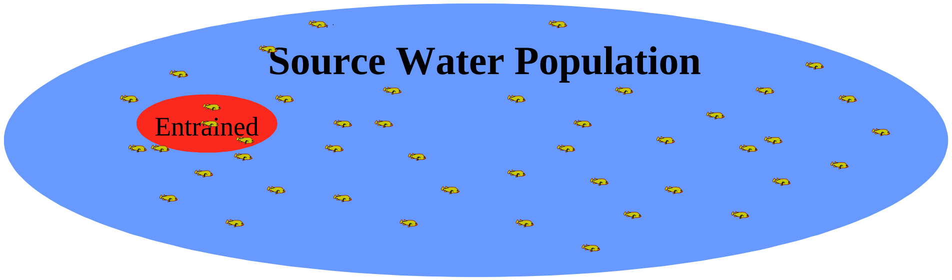
Area of Production Foregone – a way to interpret loss

- Method allows for conversion of organismal loss to habitat
- Can work for any source of loss
  - Impingement or entrainment

Understanding “Source Water Population” (SWP) and “Proportional Mortality” (P_m)

You cannot interpret P_m without knowing the size of the SWP

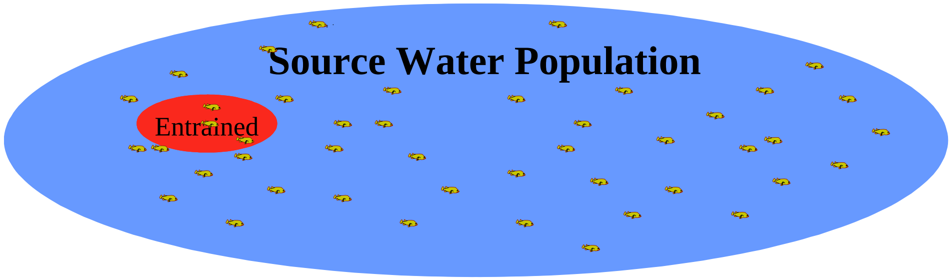
	Scenario 1	Scenario 2
P_m	10%	1%
SWP		



Understanding "Source Water Population" (SWP) and "Proportional Mortality" (P_m)

You cannot interpret P_m without knowing the size of the SWP

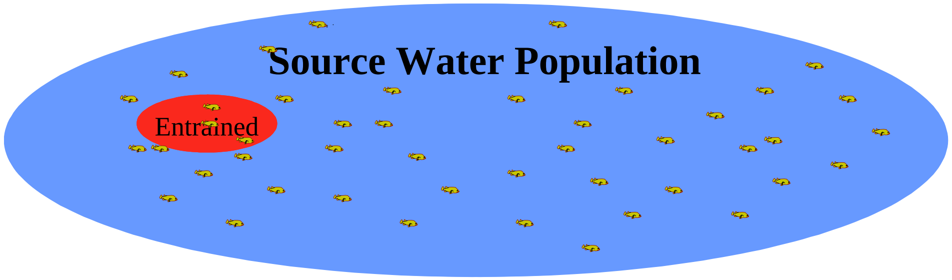
	Scenario 1	Scenario 2
P_m	10%	1%
SWP	1 acre	640 acres



Understanding "Source Water Population" (SWP) and "Proportional Mortality" (P_m)

You cannot interpret P_m without knowing the size of the SWP. The product of P_m and SWP is the Area of Production forgone (APF), which is the best way to understand the impact

	Scenario 1	Scenario 2
P_m	10%	1%
SWP	1 acre	640 acres
APF	**0.1 acre**	**6.4 acres**



Example: Proportional mortality for Queenfish (average) = 0.60%

1. Calculate area of Source water Population (SWP)
2. Then the habitat required to compensate for larval losses =

SWP x 0.006

SWP = 89,920 acres (140.5 sq. miles)

89,920 x 0.006 = 539 **acres** (0.84 sq. miles) of new bay habitat would be needed to produce larvae equivalent to losses

Example: Proportional mortality for Queenfish (+1 SE) = 29%

1. Calculate area of Source water Population (SWP)
2. Then the habitat required to compensate for larval losses =

SWP x 0.29

SWB = 89,920 acres (140.5 sq. miles)

89,920 x 0.29 = 26,077 **acres** (40.74 sq. miles) of new bay habitat would be needed to produce larvae equivalent to losses

Entrainment Study – ETM Model results

Taxon	Estimated Annual Entrainment	P_m Alongshore Extrapolation (Mean)	Pm Alongshore Extrapolation (+ 1 SE)	Length of Source Water Population (Miles)	Area (mi^2) of Production Foregone (Mean)	Area (mi^2) of Production Foregone (+1 SE)
spotfin croaker	69,701,589	0.30%	37%	10.1	0.085	10.3141
Queenfish	17,809,864	0.60%	29%	50.9	0.911	40.7404
white croaker	17,625,263	0.70%	24%	28.7	0.583	19.0109
black croaker	7,128,127	0.10%	38%	11.6	0.039	12.1661
Salema	11,696,960	NA**				
Blennies	7,165,513	0.80%	28%	7.7	0.170	5.9506
diamond turbot	5,443,118	0.60%	28%	10.1	0.170	7.8053
California halibut	5,021,168	0.30%	21%	18.5	0.131	10.7226
rock crab	6,411,171	1.10%	35%	15.9	0.486	15.3594
AVERAGE (sq. miles)					0.325	15.26
AVERAGE (acres)					**208**	**9765**
Based on units 3-4 (acres)					**104**	**4882.5**

Huntington Beach: What does this mean

- If 104 (4882.5) acres of new bay habitat were added to the system (in general area of source water body) then (for Units 3 &4):
  - Direct impacts to sampled fish and invertebrates would be mitigated for
  - Direct impact to other entrained species would probably be mitigated for (assuming the Pm values were proxies for all species)
  - Indirect impacts would also probably be mitigated for

Assuming that new bay habitat was a comparable mixture of habitats to that in source water body

Diablo Canyon Power Plant

Best Estimate of Larval Loss Resulting from Entrainment

7.65% of larvae associated with Rocky Reef Organisms over a 92 km stretch of coast

Equal to

300 – 1000 acres of rocky reef