The Why, When and How of Assessing Impingement and Mainly Entrainment Impacts

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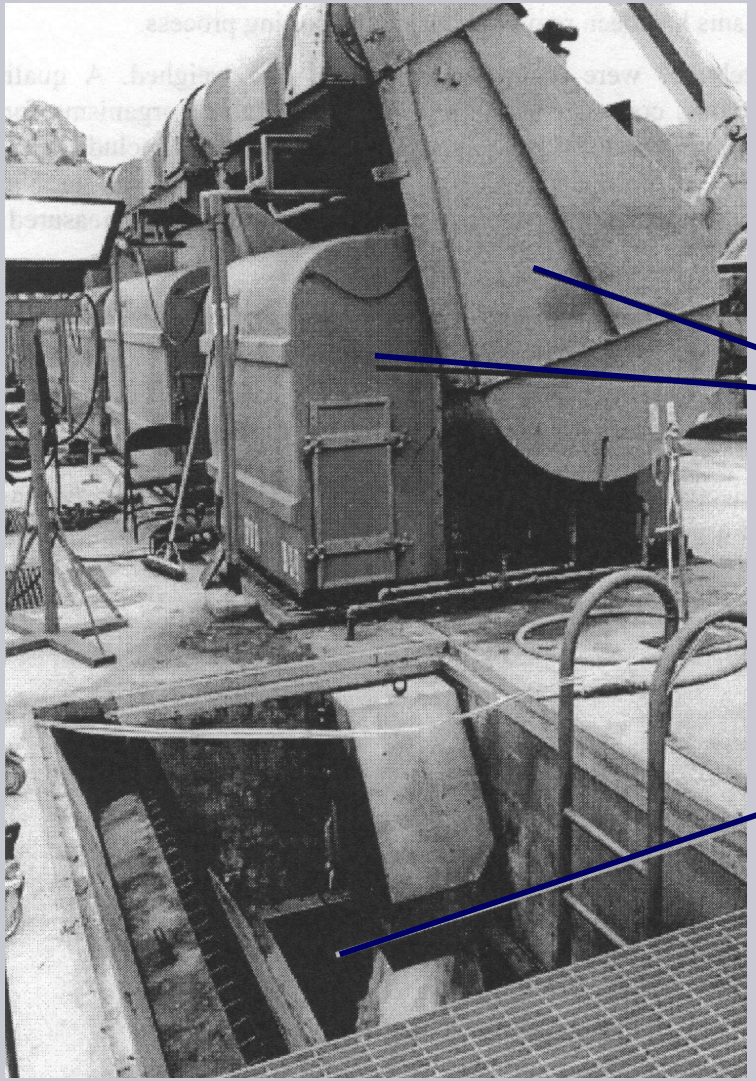
Assessing Impingement and Entrainment (I&E) Impacts

- **Introduction**
  - Goal of I&E studies
  - Impingement studies
- **Entrainment Studies**
  - Study design
  - Assessment approaches
  - Data requirements
  - Examples
- **Conclusions**

Goals of I&E Studies

- Basic goal of these studies is estimation – not hypothesis testing
- Use estimates to model effects on populations (demographic or conditional mortality) necessary for providing context for effects and assessing impacts.
- Contrast with more rigorous approaches for impact analysis, ex. BACI, requiring long-term sampling in source water with reference stations, etc.

Impingement Studies



Impingement Studies

- Impingement affected by flow but, more importantly, intake location, intake design
  - Open ocean location, ex. Diablo Canyon, low impingement likely due to low intake velocities and strong swimming ability of the fishes out on the open exposed coast
  - Impingement at plants in more protected harbors and bays generally higher
  - Offshore intakes fitted with velocity caps effective at reducing impingement
- Generally not considered a large problem at California plants, with the exception of San Onofre

Impingement Assessment

- Assessment straightforward since adult organisms (after adjusting for age differences) can be compared to fishery data or fishery-independent population estimates
- One possible reason for historical focus on fishery species in I&E studies is lack of fishery-independent data

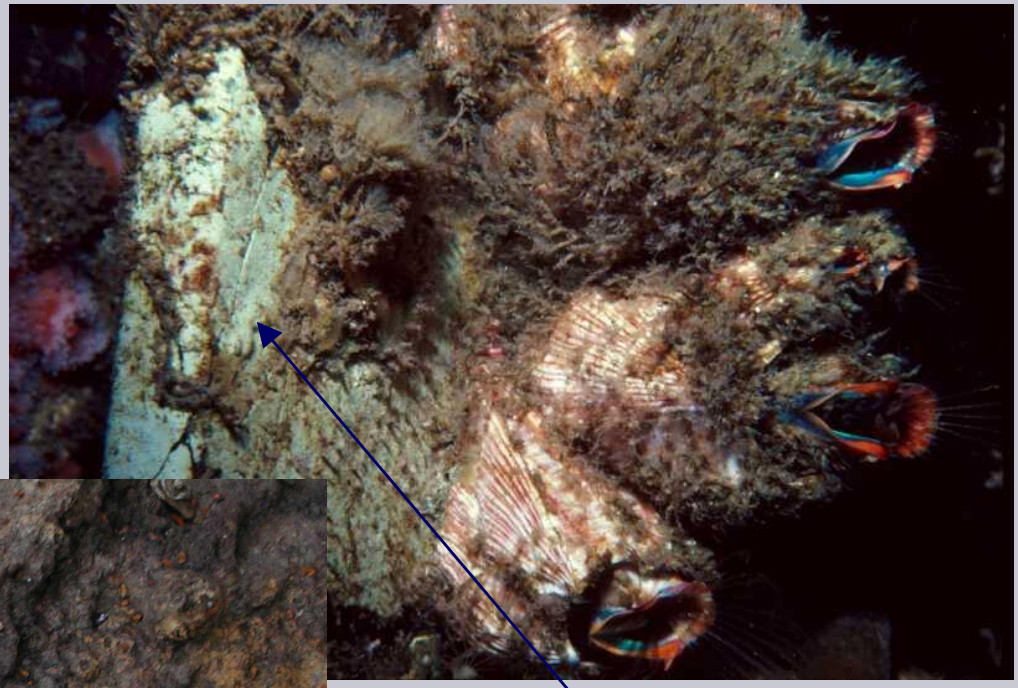
Entrainment Studies

- Much more difficult and costly to collect data, and process samples
- Possibly greater potential for impacts due to large CWIS volumes at some facilities
- Site-specific factors (plant and source water) affect study design
- Site-specific factors also affect ability to interpret results

Entrainment Studies
Design Considerations

- Where to get a representative sample?
- What to sample?
- Sample processing – resources, taxonomy
- How to assess results?

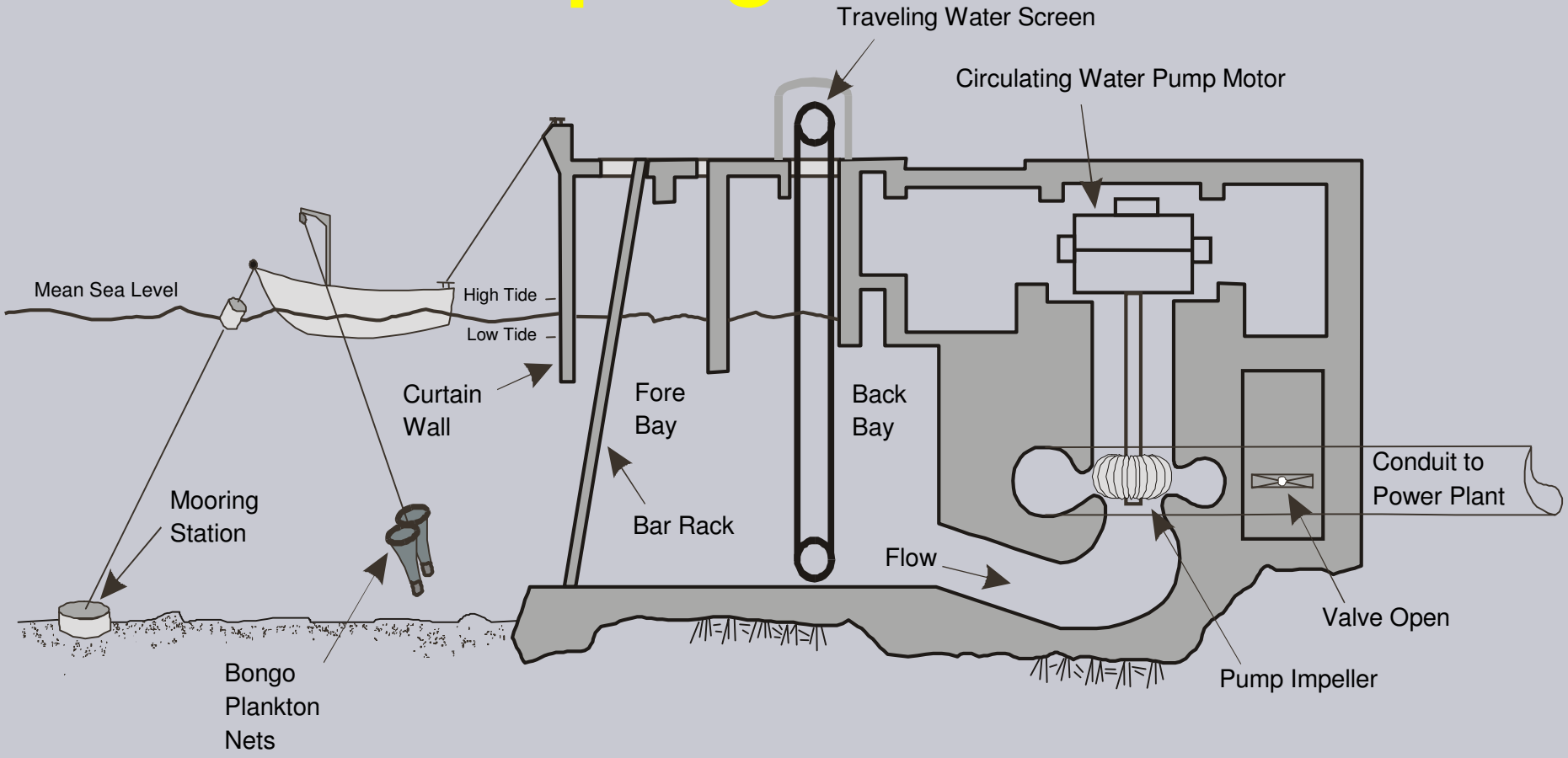
Entrainment Studies
Sampling Location



bar racks

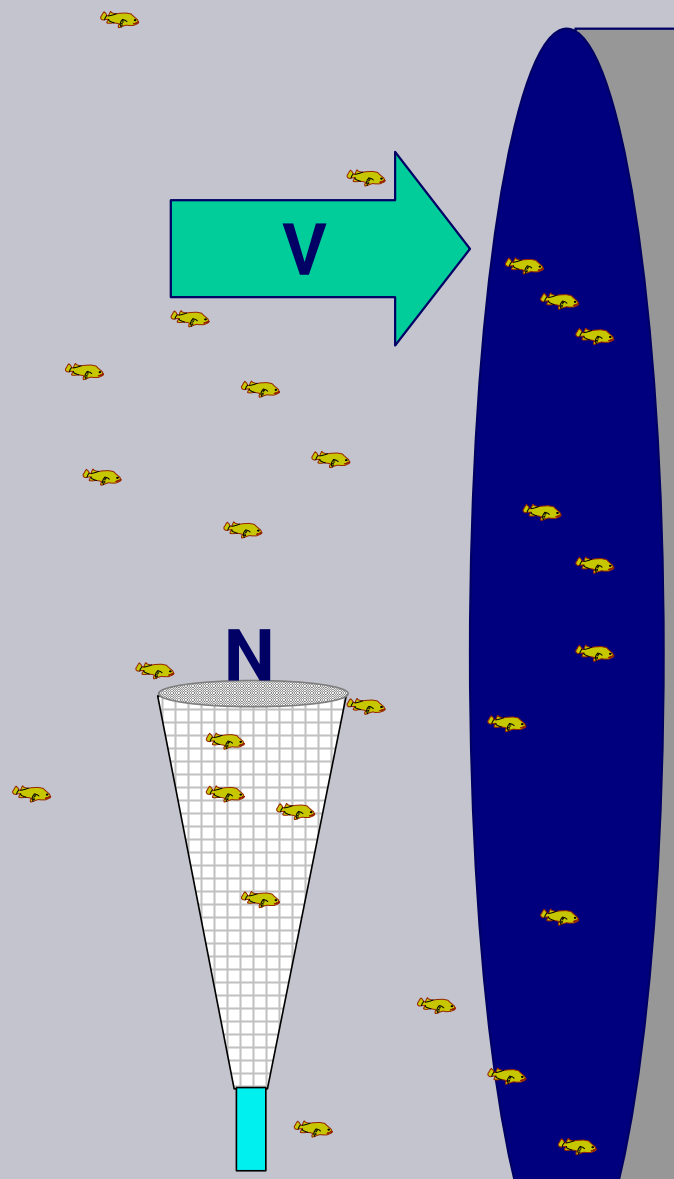
conduit walls

Entrainment Studies
Sampling Location



Due to biofouling and other issues samples collected with plankton nets in front of, or in vicinity of intakes

Entrainment



1. Measure concentration of larvae (number per volume) that are entrained (N)
2. Calculate volume of cooling water entering the plant (V)
3. **Assume** no survival for **fish larvae** through the plant – <u>do not know</u> so assume 100%, never meant to apply to all organisms
4. Entrainment = N x V

Entrainment Studies
What to Sample?

- Focus on fish larvae and some invertebrates (shellfish) – original 1977 EPA guidance
  - Many planktonic forms (e.g. diatoms) distributed over large areas of ocean, have short generation times (days), and may be capable of reproducing as long as environmental conditions are favorable. Also may be better able to survive entrainment due to hard shell or exoskeleton.
  - Larvae of fish and invertebrates have limited distributions as adults along narrow coastal shelf, and may have limited spawning periods. Less likely to survive entrainment – soft bodied.

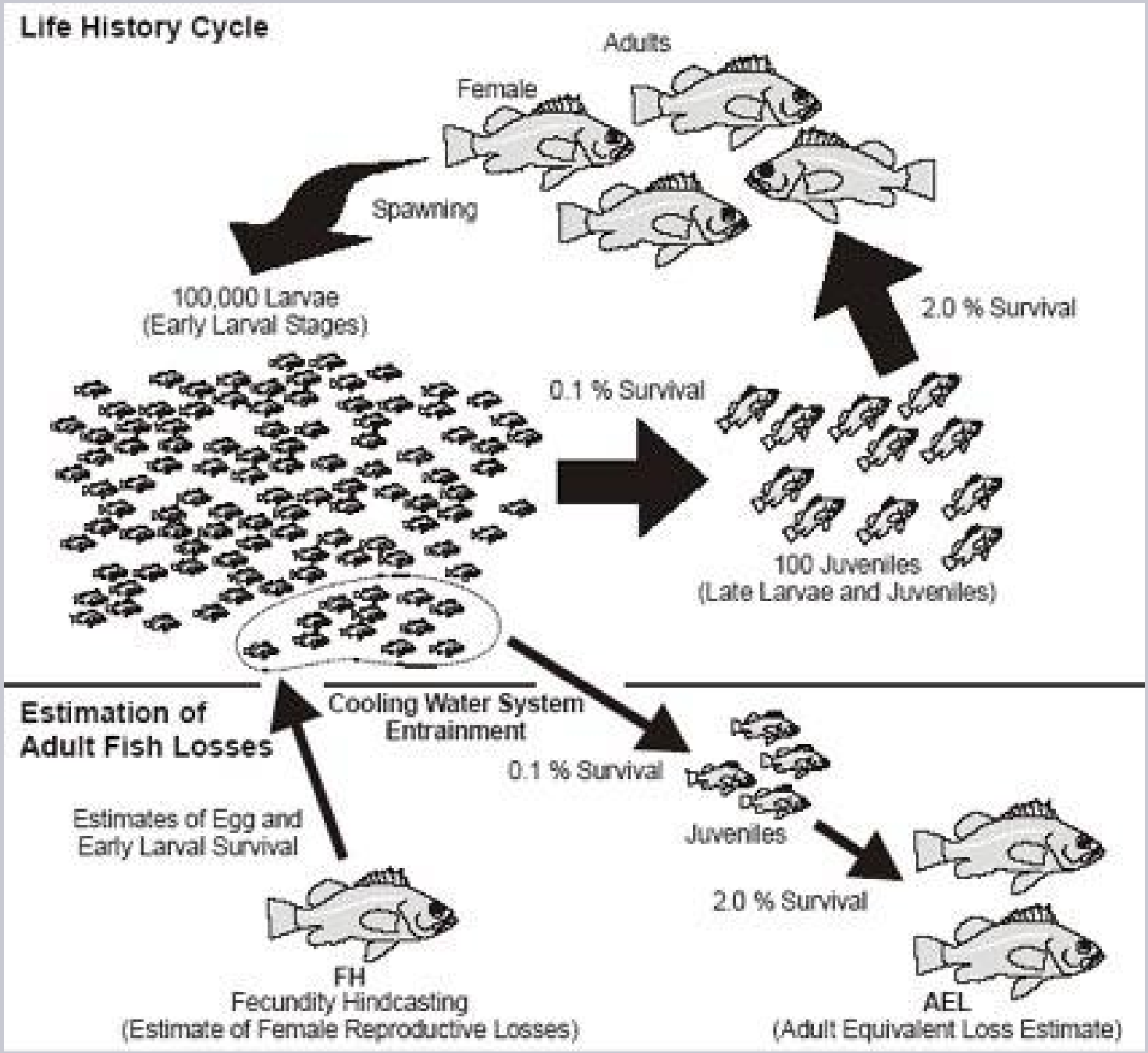
Entrainment Studies
Assessment Models

- **Demographic Models** – useful in cost benefit analyses
  - Adult Equivalent Loss (AEL)
  - Fecundity Hindcasting (FH)
  - Production Foregone
- **Conditional Mortality Models** – useful in scaling restoration
  - Empirical Transport Model (ETM)

Entrainment Studies

Demographic Models

- fecundity
- age at maturity
- longevity
- survival data – eggs, larvae, other stages



Entrainment Studies
Demographic Model Data

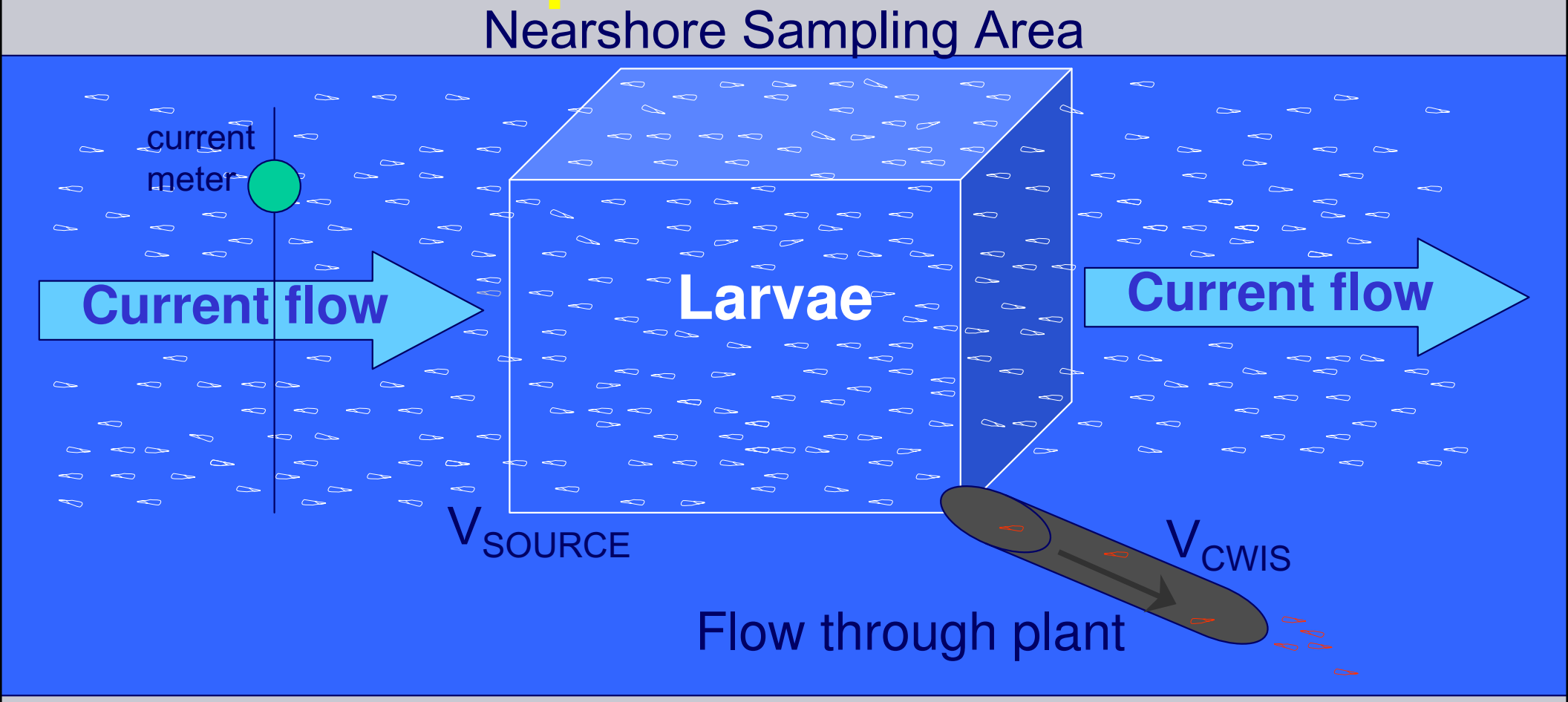
Demographic Models

- AEL – larval, juvenile, adult survival
- FH – fecundity, age at maturity, egg and larval survival

All of these values usually drawn from literature – not site-specific, unknown what environmental, compensatory, depensatory, or other factors operating on populations that will affect accuracy of estimates

Not available for most CA fishes

Entrainment Studies
Conceptualization of *ETM*



Conditional mortality due to entrainment (*PE*) = $$\frac{\rho_{Entrainment} \bullet V_{CWIS}}{\rho_{SourceWater} \bullet V_{SOURCE}}$$

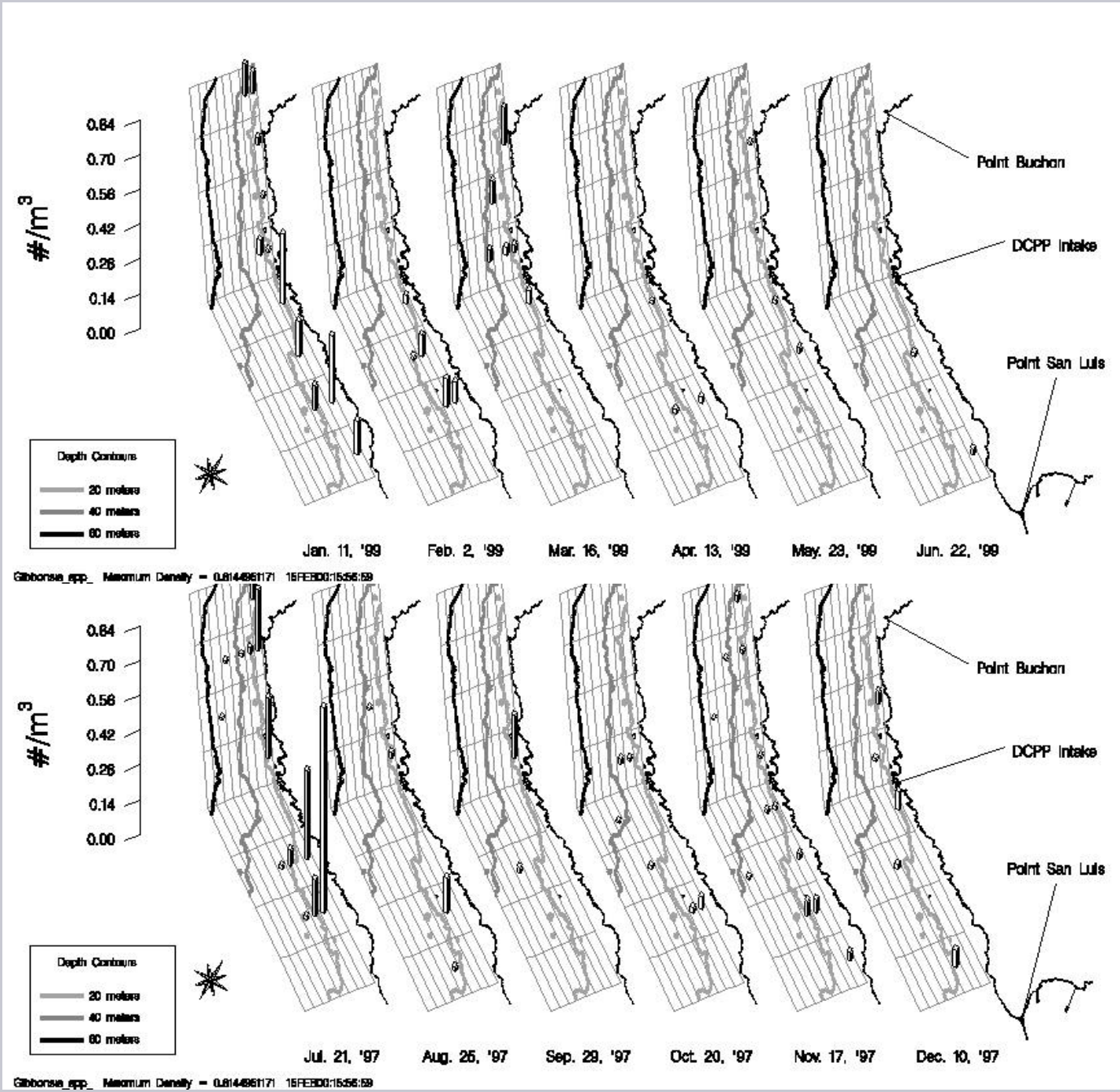
Entrainment Studies
Source Water Sampling

- Required for ETM unless assuming volumetric model
- Representative of range of habitats and species potentially affected by entrainment – listed spp., unique habitats
- For ETM, estimating daily proportional entrainment (PE) – area potentially subject to entrainment due to current or tidal flow
  - In open coast can be estimated using current data
  - In tidal estuary may encompass entire area

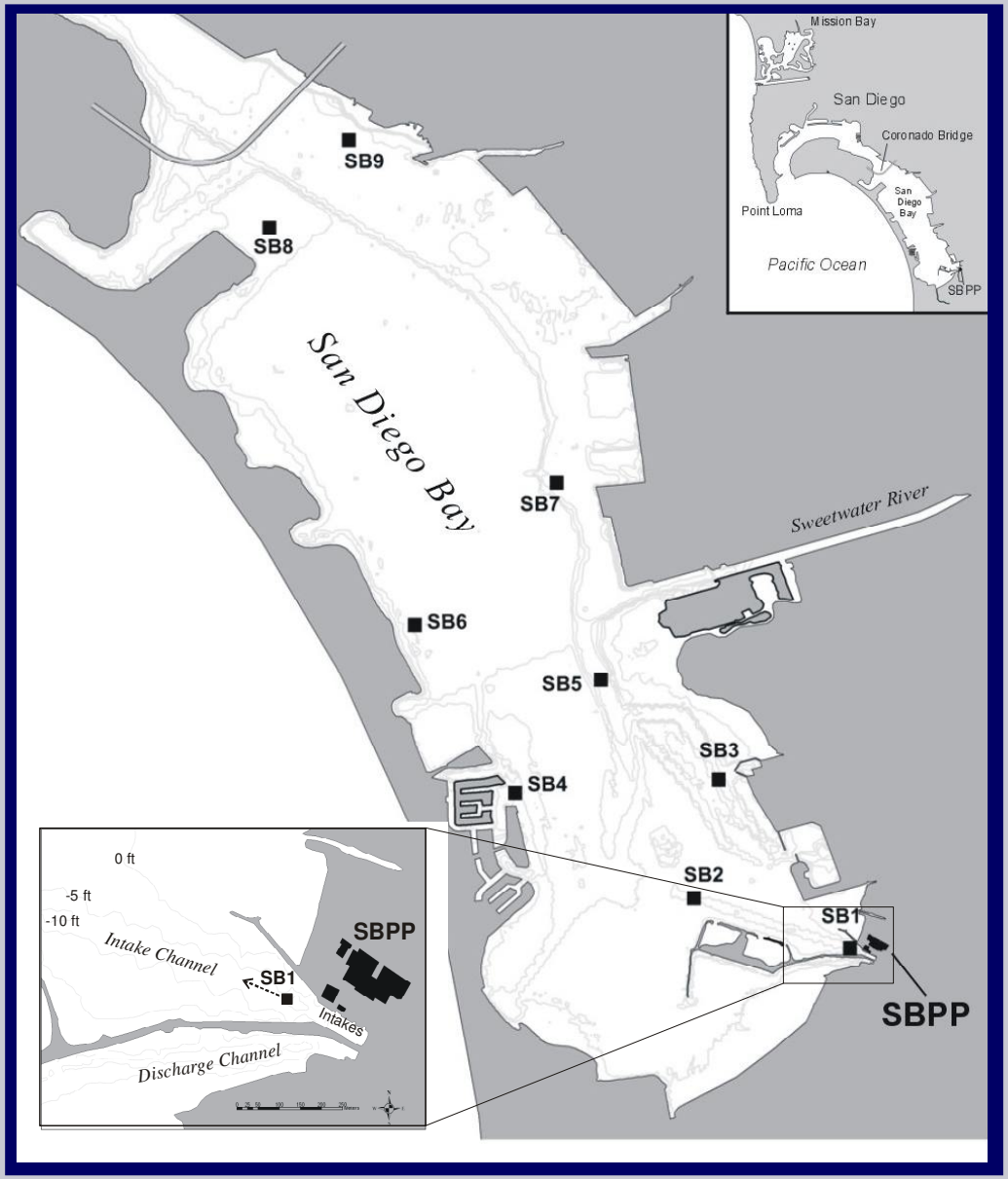
Larval kelpfish – Diablo Canyon Source Water

Source Water Sampling

Distribution of fish larvae may be closely associated with adult habitats

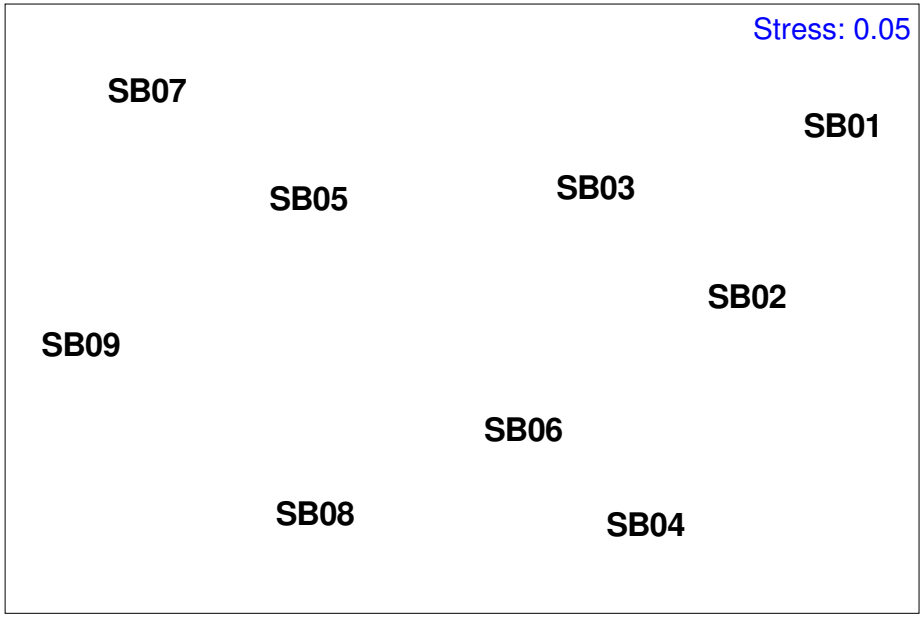


Entrainment Studies
Source Water Sampling



- Differences in composition of fish larvae closely related to spatial differences among stations

MDS of larval fish composition



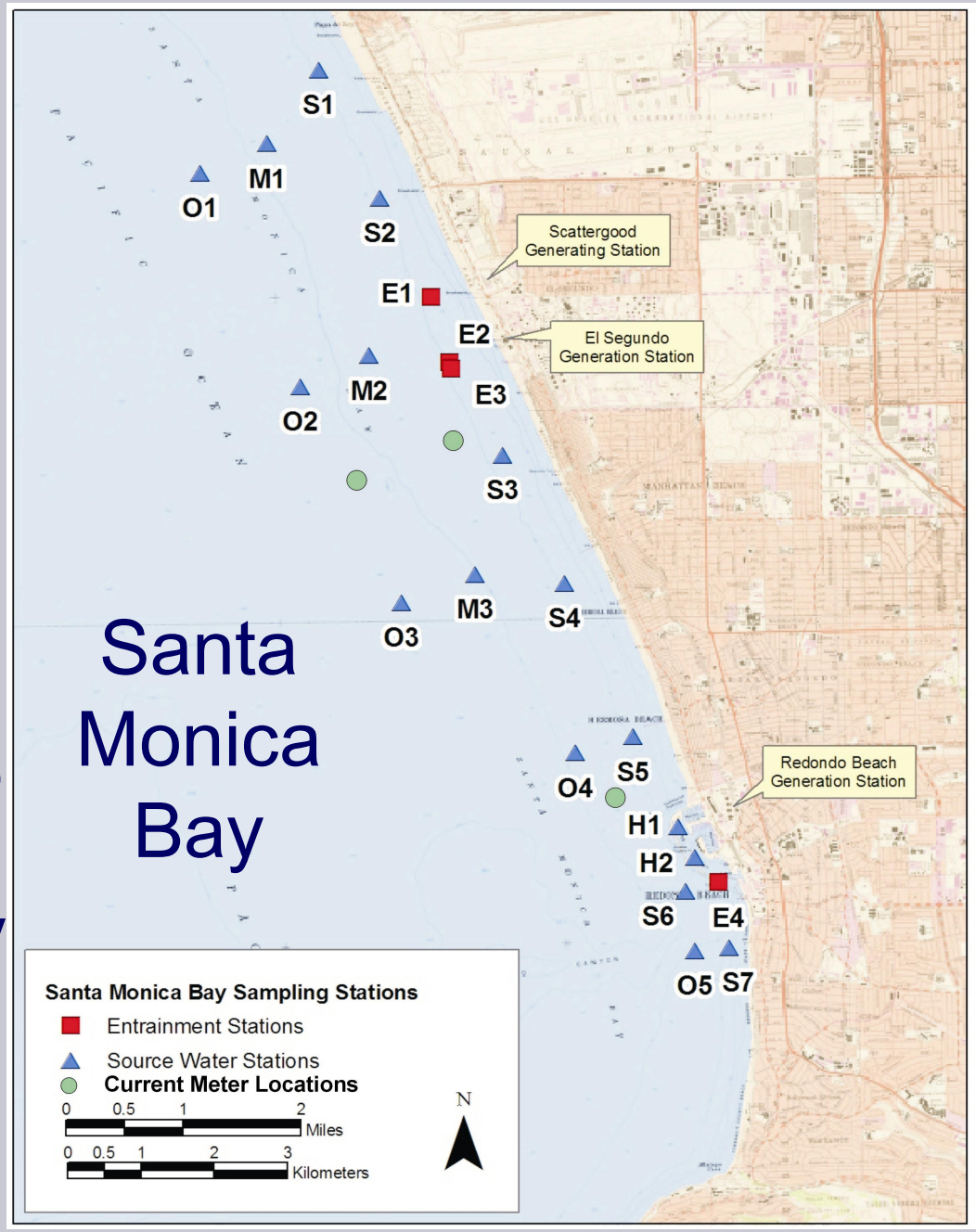
Source Water Sampling Example

– Cooperation among AES, NRG, and LADWP resulted in comprehensive design - 21 stations and 3 current meters

– No strong habitat differences – sampling grid

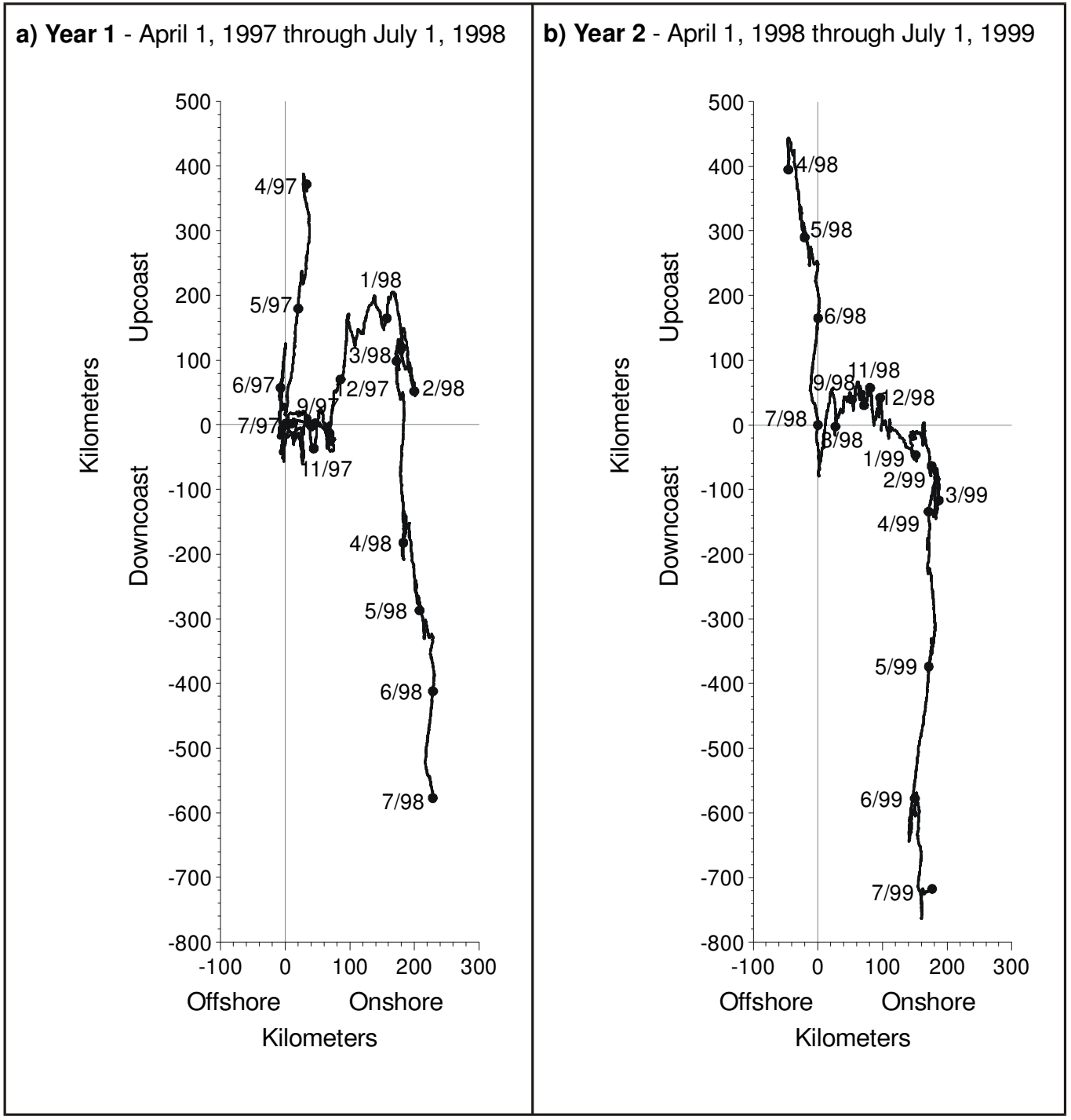
– Data from Hickey (1992 and 1993) used to estimate alongshore current speed to place stations N and S of intake to correspond to daily estimate of *PE*

– Current meter data used to estimate SW populations

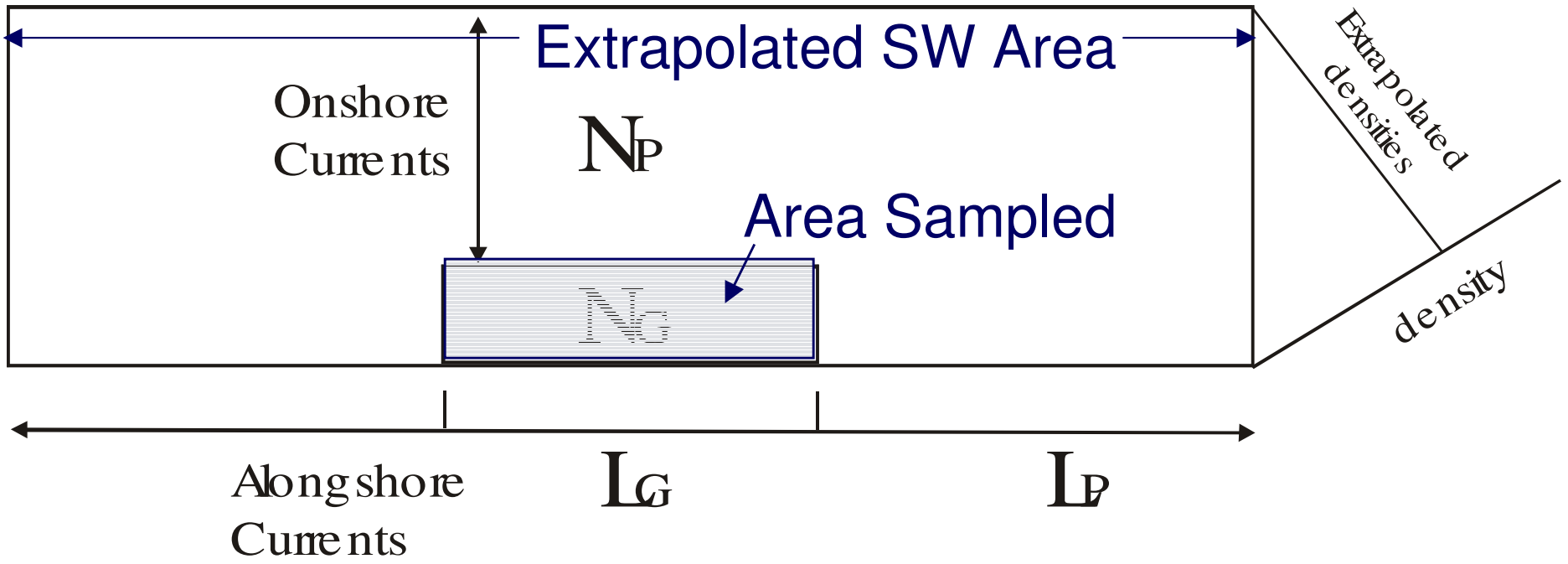


ETM Assessment

- Cumulative current displacement used to estimate total area for source water population estimates
- Displacement over days larvae potentially exposed to entrainment



Entrainment Studies
ETM Assessments
Source Water Extrapolations



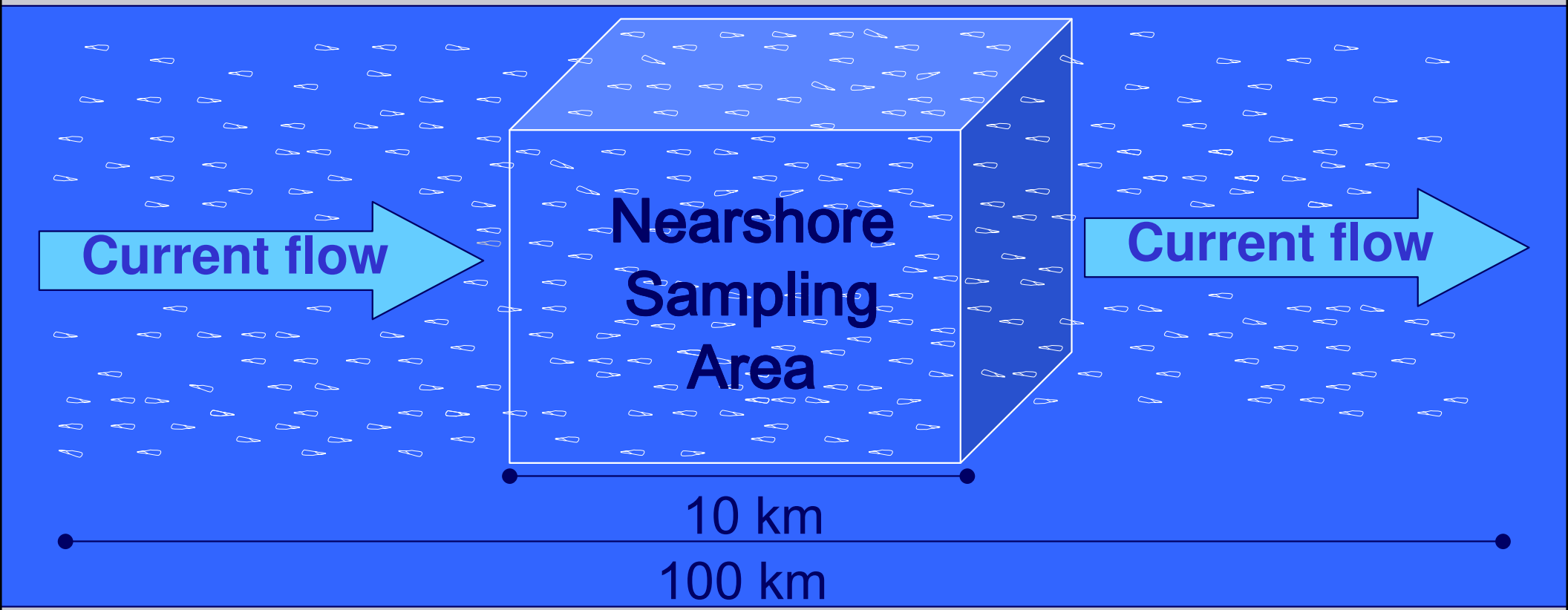
Nearshore $P_S = \frac{L_G}{L_P}$

Offshore $P_S = \frac{N_G}{N_P}$

Entrainment Studies
ETM Assessments
Other Potential Data Requirements

- Power plant cooling water flow (actual, design, or planned) for entrainment estimates
- Bathymetry for source water volume estimates
- Hydrodynamic data for determining source water in estuarine systems

Conceptualization of *ETM* and *APF*



P_S = 10 km/100 km or 0.10

If P_M = 5%, *APF* = 5% of 100 km or 5 km

Application of APF

- Requires determining area of adult habitat in extrapolated source water
  - Example – along 100 km of coast there may only be 20 km of rocky reef supplying KGB rockfish larvae. APF is % of 20 km – not 100 km.
- May not be applicable to all habitats and species – open water pelagic habitat

Application of APF

- Scale and context is important
- Two fishes have estimated entrainment losses (P_M) of 1%
  - Case 1: northern anchovy has estimated source water of 1,000 km^2, results in APF = 10 km^2
  - Case 2: kelp bass occupying kelp habitat around intake of 1 km^2, results in APF = 0.01 km^2 – could be of greater concern if kelp habitat limited

Conclusions

- Important to apply flexible, site-specific approach to assessment
- Entrainment effects best evaluated using empirically based source water body information and the *ETM* model
- Assessing IM&E not critical with performance-based standards or mandated BTA technology standards, but
- These regulatory approaches do not account for the huge variation in potential impacts among power plants

Questions?

J. Steinbeck, J. Hedgepeth, P. Raimondi, G. Cailliet, and D. Mayer. 2007. Assessing power plant cooling water intake system entrainment impacts. California Energy Commission. Report CEC-700-2007-010.

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