Notes on the South Bay Power Plant (SBPP) 316 a & b application

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Aim: to identify the main ecological issues arising from the 316 a & b reports by South Bay Power Plant.

Pisces Conservation Ltd. reviewed the studies prepared by Duke entitled South Bay Power Plant Cooling Water System Effects on San Diego Bay (Volume I and II). Specifically, Pisces was asked to review whether the studies justify findings for compliance under section 316(a) and (b) – new and old rules – of the Clean Water Act. In this document we highlight areas of concern that we identified from the Duke 316 studies.

The EPA has long recognised that some habitats are far more sensitive than others to the effect of cooling water extraction, and has noted the particular vulnerability of estuaries and the littoral zone.

A key aspect of any argument in favour of closed-cycle cooling or other technology must be the reduction of the ecological impacts caused by direct cooling. It is therefore essential that those favouring the introduction of new technologies establish that the existing direct-cooled power plant does have a detrimental effect. To some extent this is clear as we have direct observational evidence of entrainment and impingement mortality and the effect of the discharge on the localised environment. However, the spatial extent of the impact and the longer-term effects on populations are less clear as the biological studies have not been undertaken in a way that is likely to reveal them. However, as will be developed below, there are reasonable grounds for suspecting that the impact may have been greater than the negligible levels claimed.

The evidence in favour of an appreciable effect is reviewed below.

Executive Summary

This report presents a response to Duke South Bay Power Plant (SBPP)'s 316 (a) and (b) reports in the context of actual and potential damage to the ecosystem of San Diego Bay. In our opinion SBPP does not meet the standards required for 316(a) and either the new or the old 316 (b) regulations.

The SBPP extracts a significant portion of the volume of the South San Diego Bay each day (approximately 20%), and is capable of extracting the entire seawater contents of San Diego Bay in approximately 62 days.

We demonstrate that SBPP has had and is having an Adverse Environmental Impact and has failed on most of the steps required to avoid an Adverse Environmental Impact as defined by the EPA.

Impacts of the SBPP are related to a) impingement of animals on filter screens; b) entrainment in the cooling water flow; c) temperature of outfall water; d) biocide content of outfall water; d) leachate content of outfall water; e) collection of dead animals; f) attraction of predators & scavengers; g) oxygen content of outfall water; and h) increased sediment load.

About 10% of the eelgrass in the Bay has already been lost and it is likely that a larger area still is growing and reproducing sub-optimally. Eelgrass is a very important component of the Bay ecosystem both in terms of habitat creation and food provision, especially for endangered least terns *Sterna antillarum* and halibut *Hippoglossus stenolepsis*.

The distribution and abundance of nematode and oligochaetes indicates that the ecosystem near the outfall already has reduced biodiversity and is highly stressed. As much as 27% of some larval fish are currently entrained by the SBPP – impacts of this magnitude are unsustainable.

Chlorine biocide concentrations well below permitted levels are known to damage bacterial and photosynthetic activity and to kill or suppress reproduction in zooplankton.

Detrimental impacts on the populations of a species can have ramifications for all the other species that interact with them, be they prey, predator, parasite or competitor. These effects might not be directly or easily quantifiable.

This report also refutes the often-quoted concept of surplus production – that natural populations exhibit a huge potential to sustain cropping and therefore can withstand the losses caused by the operation of the plant. We maintain that this argument fallaciously rests on principles developed in agricultural and domestic scenarios and have no relevance in nature where natural variability plays a central part in determining populations.

We conclude that SBPP is not in compliance with 316(a) and (b) – old and new rules – of the Clean Water Act.

Ability to meet New 316 (b) Requirements

To meet the new 316 b regulations for existing facilities, the applicant can either demonstrate that certain performance standards are reached or alternatively a site-specific determination can be undertaken to demonstrate BTA.

Performance Standards.

(1) You must reduce your intake capacity to a level commensurate with the use of a closed-cycle, recirculating cooling system; or
(2) You must reduce impingement mortality of all life stages of fish and shellfish by 80 to 95 percent from the calculation baseline if your facility has a capacity utilization rate less than 15 percent, or your facility's design intake flow is 5 percent or less of the mean annual flow from a freshwater river or stream; or
(3) You must reduce impingement mortality of all life stages of fish and shellfish by 80 to 95 percent from the calculation baseline, and you must reduce entrainment of all life stages of fish and shellfish by 60 to 90 percent from the calculation baseline if your facility has a capacity utilization rate of 15 percent or greater and withdraws cooling water from a tidal river or estuary, from an ocean, from one of the Great Lakes, or your facility's design intake flow is greater than 5 percent of the mean annual flow of a freshwater river or stream; or
(4) *If your facility withdraws cooling water from a lake (other than one of the Great Lakes) or reservoir: (i) You must reduce impingement mortality of all life stages of fish and shellfish by 80 to 95 percent from the calculation baseline; and (ii) If you propose to increase your facility's design intake flow, your increased flow must not disrupt the natural thermal stratification or turnover pattern (where present) of the source water, except in cases where the disruption is determined by any Federal, State or Tribal fish or wildlife management agency(ies) to be beneficial to the management of fisheries.*

(Federal Water Pollution Control Act, as amended though PL 2002)

In the case of the SBPP proposal, if the performance standard approach is chosen then they must either reach closed-cycle levels of impact or reduce impingement mortality by 80 to 95 % and reduce entrainment of all life stages of fish and shellfish by 60 to 90 %.

Site-Specific Determination of Best Technology Available.

(1) If you choose this alternative you must demonstrate to the Director that your costs of compliance with the applicable performance standards in paragraph (b) of this section would be significantly greater than the costs considered by the Administrator when establishing such performance standards,

or that your costs would be significantly greater than the benefits of complying with such performance standards at your site.

(2) *If data specific to your facility indicate that your costs would be significantly greater than those considered by the Administrator in establishing the applicable performance standards, the Director shall make a site specific determination of best technology available for minimizing adverse environmental impact that is based on less costly design and construction technologies, operational measures, and/or restoration measures to the extent justified by the significantly greater cost. The Director's site-specific determination may conclude that design and construction technologies, operational measures, and/or restoration measures in addition to those already in place are not justified because of significantly greater costs.*

(3) *If data specific to your facility indicate that your costs would be significantly greater than the benefits of complying with such performance standards at your facility, the Director shall make a site-specific determination of best technology available for minimizing adverse environmental impact that is based on less costly design and construction technologies, operational measures, and/or restoration measures to the extent justified by the significantly greater costs. The Director's site-specific determination may conclude that design and construction technologies, operational measures, and/or restoration measures in addition to those already in place are not justified because the costs would be significantly greater than the benefits at your facility.*

Based on the data presented in the Duke studies, we conclude that the SBPP fails to meet the performance standard approach since the plant is not operating at closed-cycle levels of impact or reducing their impingement mortality by 80 to 95 % and reducing entrainment of all life stages of fish and shellfish by 60 to 90 %. As a result, we assume that in order for SBPP to come into compliance, it will have to seek a site-specific determination of best available technology.

Ability to Meet Old 316(b) Requirements

U.S. EPA provided notes on how to assess an intake under the old 316(b) rules. (Quotes in this section are taken from Guidance For Evaluating The Adverse Impact Of Cooling Water Intake Structures On The Aquatic Environment: Section 316(B) P. L. 92-500 U.S. Environmental Protection Agency, 1977). If the intake is shown to have a high impact on the environment as argued above, and as outlined in the EPA definition of an Adverse Impact, then steps must be taken to reduce its impact.

Adverse Environmental Impact

Adverse aquatic environmental impacts occur whenever there will be entrainment or impingement damage as a result of the *operation of a specific cooling water intake structure. The critical question is the magnitude of any adverse impact. The magnitude of an adverse impact should be estimated both in terms of short-term and long-term impact with reference to the following factors:*

(1) *Absolute damage (# of fish impinged or percentage of larvae entrained on a monthly or yearly basis);*
(2) *Percentage damage (% of fish or larvae in existing populations which will be impinged or entrained, respectively);*
(3) *Absolute and percentage damage to any endangered species;*
(4) *Absolute and percentage damage to any critical aquatic organism;*
(5) *Absolute and percentage damage to commercially valuable and/or sport fisheries yield; or*
(6) *Whether the impact would endanger (jeopardize) the protection and propagation of a balanced population of shellfish and fish in and on the body of water from which the cooling water is withdrawn (long term impact*

The loss of a significant percentage of a critical organism such as eelgrass is covered by section 4 of the above. The loss of a large proportion of some species of fish is covered section 2. This report will detail evidence of these losses, and others that the Duke studies failed to identify, in later sections.

In the event of an Adverse Environmental Impact, a series of steps to undertake is provided, in order to ensure compliance.

- *The first step should be to consider whether the adverse impact will be minimized by the modification of the existing screening systems.*
- *The second step should be to consider whether the adverse impact will be minimized by increasing the size of the intake to decrease high approach velocities.*
- *The third step should be to consider whether to abandon the existing intake and to replace it with a new intake at a different location and to incorporate an appropriate design in order to minimize adverse environmental impact.*
- *Finally, If the above technologies would not minimize adverse environmental impact, consideration should be given to the reduction of intake capacity which may necessitate installation of a closed cycle cooling system with appropriate design modifications as necessary.*

In our assessment, the SBPP fails on most of these steps. First, the existing screening system is the only feasible one considering the large volumes of water passing through the system. Fine mesh and wedgewire screens are probably impractical with this volume and in this situation. Second, the fact that the screens are not rotated continuously (section 4.2.1 paragraph 2 SBPP Cooling water systems effects on San Diego Bay. volume II) means that the survival probability of any impinged fish returned to the discharge canal will be lower than is technically possible. Finally, the intake velocity and position of the intake are fundamental design parameters of the system and could only be altered by using less cooling water or reengineering the intake configuration.

Later in the guidance notes the EPA refers to 'habitat formers' and describes them as "critical to the structure and function of the ecological system".

> *Habitat formers are plants and/or animals characterized by a relatively sessile life state with aggregated distribution and functioning as:*
>
> *1. a live and/or formerly living substrate for the attachment of epibiota;*
> *2. either a direct or indirect food source for the production of shellfish, fish, and wildlife;*
> *3. a biological mechanism for the stabilization and modification of sediments and contributing to processes of soil buildings;*
> *4. a nutrient cycling path or trap; or*
> *5. specific sites for spawning, and providing nursery, feeding, and cover areas for fish and shellfish.*

It is our assessment, which will be detailed in later sections of this Report, that the impact that the SBPP has on the eelgrass in the bay impinges on its functioning under section 3.

The EPA also refers to High Potential Impact Intakes:

> *High potential impact intakes are those located in biologically productive areas or where the volume of water withdrawn comprises a large proportion of the source water body segment or for which historical data or other considerations indicate a broad impact.*

Again this definition is applicable to SBPP, which is capable of taking a significant proportion of the water in the Bay through its intake each day.

From the above points it is our assessment that SBPP does not comply with the old 316(b) regulations.

Impacts Related to Effluent Discharge

To assess the impact of the intake and outfall of SBPP in relation to the 316 (a) and (b) regulations many factors must be taken into account.

It is normally the case that onshore outfalls such as that used at the SBPP have a greater impact than offshore outfalls because the warm and sometimes chlorinated effluent stream is more likely to impact the benthic community. There is a number of ways in which an effluent discharge influences the receiving water and seabed. The most important of these potential effects are itemised below:

- The warming (and rapid cooling when the plant ramps up and down) effect on benthic communities.
- The effect of chlorine and chlorination products on benthic and planktonic organisms.
- The effect of the 'rain' of dead and damaged animals that have been entrained or broken up by the cooling water system on the receiving ecosystem.
- The attraction of predatory and scavenging organisms into the outfall region.
- Changes in water quality linked to differences in nutrient levels, pollutants, salinity etc. between the water in the intake and outfall areas.
- The impact of outfall canals and structures.
- The impact of general reduced water quality e.g. reduction in dissolved oxygen, increased sediment load and leachates from cooling water system.

From the studies undertaken and reported by Duke, it is difficult to assess the impact of the effluent discharge on the local ecosystem because no data are presented on the state of the communities prior to the establishment of the outfall. Thus the only means available to detect ecological impacts is the detection of trends with distance from the outfall. This approach is problematic, however, as other uncontrolled physical factors, such as water exchange with the open sea and other anthropomorphic effects, will also be changing with distance. The result is that only large, visually apparent, effects are likely to have been detected. This problem is particularly apparent in the beach and offshore benthic samples where variation in animal abundance and diversity linked to natural changes in the substrate may mask any trend linked to distance from the outfall. All that can really be stated with certainty is that the sampling stations show considerable variability and that sampling stations nearest to the outfall are different from some of those that are further away. There are however indications that sampling stations closest to the outfall differ in animal composition from all others.

Duke Study Fails to Fully Assess the Impact of Chlorine in Discharge

It is concluded in the Duke studies that the phytoplankton community will not be impacted by contact with the effluent plume because of the temperature tolerance of the species present. This may or may not be true. However, no consideration is given to other properties of the plume, in particular the presence of chlorine biocide. Residual chlorine in the discharge will be allowed up to the permitted concentration of 0.2 mg/l (milligrams per litre). Davis & Coughlan (1978) demonstrated that photosynthetic activity was considerably reduced at residual chlorine levels well below 0.2 mg/l and concluded that bacterial activity was suppressed at chlorine levels below detection levels. While chlorination will only be intermittent, there will be periods when the effluent will impact the local phytoplankton community.

Similar concerns to those expressed above for the phytoplankton also apply to the zooplankton. Zooplankton show severe metabolic and reproductive suppression after exposure to chlorine at levels as low as 0.01 mg/l in seawater (Goldman et al. 1978). Davis & Coughlan (1978) reported that 48 hr after exposure to a concentration between 0 and 0.25 mg/l, 22 % of adult copepods were dead.

The larvae of oysters are also known to be vulnerable to low levels of chlorine. Chlorine concentrations of 0.05 mg/l caused about 50% of Pacific oyster, *Crassostrea gigas*, larvae to develop abnormally (Bamber & Seaby, 1997). The larvae of American oysters have a 48h LC50 (the concentration at which 50% of the animals die) of less than 0.005 mg/l (Mattice & Zittel, 1976).

Effect on the Fish Fauna of the Discharge Area.

The data presented by the Duke studies suggest that the outfall is influencing fish abundance. In the zone close to the discharge point, the studies pointed out the abundance of fish was higher than that observed at control stations. The study stated that itt was dominated by large numbers of juvenile slough and deepbody anchovy.

The aggregation of fish in the vicinity of outfalls, however, is a commonly observed feature usually linked to the presence of food in the form of debris from impinged animals and dead, injured or disorientated plankton that have passed through the station. The currents produced by cooling water discharges also offer a situation where faster swimming predatory fish can hold an appreciable advantage over their prey. This is not to say that these fish themselves will not be harmed by temperature changes near the outfall as the plant goes on- and off-line.

Duke Study Understates Impact of Copper in Discharge

Copper, even at low discharge levels, bioaccumulates from the environment into higher animals. Copper from the SBPP is released by leaching from the condenser tubes from units 3 and 4. Unit 1 is a high performance stainless steel containing alloying elements of chromium, molybdenum and nickel. Unit 2 condenser tubing is aluminum brass, and Units 3 and 4 have copper-nickel tubing. Any copper release is likely to stay within the bay and accumulate through the food web.

Duke Study Fails to Adequately Assess Impact of Severe Eelgrass Damage

To be in compliance with 316(b), both old and new editions, there must be no significant degradation of the environment. The operation of SBPP has resulted in the loss of 10% of the eelgrass in the Bay.

Eelgrass is very efficient at converting solar energy into plant tissue. During this process it concentrates numerous elements that occur at low concentrations. With its high productivity and rapid growth, eelgrass forms the food-base for fish, shellfish and waterfowl in shallow seas, as plankton does for marine life in deeper waters.

The thermal and chemical impact of the SBPP has reduced the amount of eelgrass present in the bay.

From Fact Sheet for Public Tentative Order No. R9-2004-0154 NPDES Permit No. CA0001368:

> *"The predicted turbidity effects of the SBPP cooling water flows suggests that the SBPP, operating at maximum cooling water circulation rates (i.e. 601.13 MGD) would preclude eelgrass from approximately 104 acres of south San Diego Bay. At the mean summer 2003 operating conditions of 441 mgd, the SBPP is predicted to preclude eelgrass from approximately 71 acres of south San Diego Bay through its cooling water discharge effects on naturally-generated turbidity."*

This loss represents about 10% of the eelgrass habitat of the entire bay. If the power plant is excluding eelgrass totally from an area there must be a much larger area that is growing sub-optimally. The loss and sub-optimal growth of eelgrass within the bay is likely to impact on the community structure as a whole.

The loss of the eelgrass from an area will significantly change the environment and the community of organisms living in that area. In an Order issued by the California Regional Water Quality Control Board, San Francisco Bay Region they state:

> *Eelgrass beds are important components of estuarine ecosystems, and have declined from historical levels both globally and in the San Francisco Bay. Eelgrass restoration projects should therefore be encouraged in the region in order to increase water clarity, reduce erosion, provide nurseries for fish, and increase habitat for invertebrates, in shallow water coastal habitats.*

This indicates that the State has recognised the importance of eelgrass and where possible are working to increase the total overall area of this ecotype.

Diane Gussett from the Port Townsend Marine Science Center in Washington (www.ptmsc.org/html/eelgrass.html) summarises the importance of eelgrass in modifying the habitat. It:

- *Creates a highly structured habitat from loose and shifting sands.*
- *Softens the impact of waves and currents, stabilizing the shoreline and providing a calm space where organic matter and sediments are deposited.*
- *Provides shelter and protection from predators for many juvenile fish and shellfish of ecological, commercial and recreational importance.*

- *Absorbs and concentrates nutrients from the sea and transfers them to the sediment or to animals.*
- *Decomposes into an important part of the food web for the coastal marine ecosystem.*
- *Provides diverse habitats.*
- *Provides an important pathway for food for both local and distant communities*

This natural modification of the environment, caused by the growth of eelgrass, results in an increase in productivity. Bare sand has a lower diversity and a lower abundance of fish than sites with eelgrass present (Murphy *et al,* 2000). It is not only fish that can benefit from the presence of eelgrass. The leaves, stems, roots and rhizomes provide multiple habitats and support a great variety of animals living in, above, and under but not directly feeding on, the eelgrass. Much of the production used by the community living on and around the eelgrass not only consumes the eelgrass but also consumes the epiphytic covering of algae and bacteria. The health of this layer is also important to the productivity of the eelgrass beds. This layer is vulnerable to pollution, both thermal and chemical.

One of the main functions of eelgrass is the production of detritus. The eelgrass fragments are ingested and egested several times, each time becoming smaller and therefore available to a different part of the food chain. The nutrition obtained by the animals consuming these fragments is derived both from the plant itself and the microbial colonisation of the fragments.

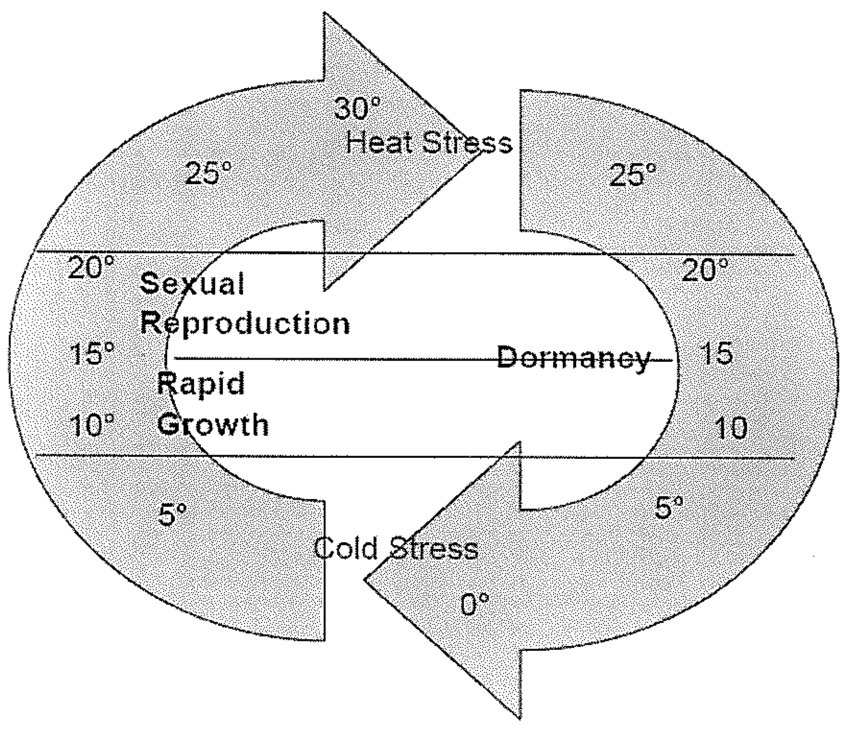
In 1930 and 31 much of the Atlantic Coast eelgrass population was killed by wasting disease. The effects were dramatic and wide-ranging:

> *To appreciate the ecological importance of seagrasses, consider the sudden disappearance of eelgrass beds along the Atlantic coast during the 1930s. An epidemic infestation of the parasitic slime fungus (Labyrinthula), called "wasting disease," literally destroyed the rich eelgrass meadows, the results of which were catastrophic. Populations of cod, shellfish, scallops and crabs were greatly diminished, and the oyster industry was ruined. There was also a serious decline in overwintering populations of Atlantic brant. Areas formerly covered by dense growths of eelgrass were completely devastated and beaches which had been protected from heavy wave action were now exposed to storms. Without the stabilizing effects of eelgrass rhizomes, silt spread over gravel bottoms used by smelt and other fish for spawning. This resulted in a decline in waterfowl populations that fed on the fish. Without the filtering action of eelgrass beds, sewage effluent from rivers caused further water pollution, thus inhibiting the recovery of eelgrass.*

(From http://waynesword.palomar.edu/seagrass.htm a web site run by Professor Armstrong at Life Sciences Department of Palomar College)

Studies into the effects of temperature on eelgrass have a long history. As early as the 1920s studies were performed analysing the life cycle of eelgrasses and the effect of temperature.

> *Based on Setchell's field observations, the relationship between temperature and phenotypic status is given in Figure 2. Field collections were frequently made through 1923-24 at Kiel and Paradise Coves (Setchell 1929). This investigation convinced Setchell that temperature was the primary controlling factor in eelgrass reproduction. In essence, he argued that as temperatures warmed in spring, vegetative growth (and seedling germination began). When temperature reached 15° C sexual reproduction was initiated. Growth slowed as water temperature increased and prolonged exposure to 30° C could result in shoot mortality. Setchell was struck by the fact that as temperatures cooled, the plants did not respond by resuming growth but rather became dormant and did not exhibit a growth response until the following spring and associated temperature increase (Setchell 1929). Phillips et al. (1983) concluded that while water temperature was a factor there were other factors controlling eelgrass phenology[1], a position that is widely accepted but untested, although the influence of photoperiod is a likely candidate in this regard.*



[1] **Phenology** is the study of the annual cycles of plants and animals and how they respond to seasonal changes in their environment.

***Figure 2**. Graphic illustration of Setchell's topology describing the relationship between temperature and eelgrass phenology (Re-drawn from Setchell 1929).*

(From the Office of Response and Restoration website http://response.restoration.noaa.gov/cpr/watershed/sanfrancisco /sfb_html/pdfs/projectreports/partnership_seagrassrev_fin.pdf)

The most notable aspect of this description is that eelgrass does not return to growth and reproduction after being subjected to heat stress. It is therefore likely that eelgrass which has been stressed by the SBPP thermal outfall will not reproduce.

In 1986 Marsh *et al.* measured the changes in eelgrass photosynthesis and respiration rates at 8 temperatures between 0 to 35C. He found that 5C was the optimum temperature for the growth of eelgrass. At 30C the respiration rate of the eelgrass exceeded the rate of photosynthesis resulting in negative growth. These experiments were done in clear water. In turbid water, such as is now found in the South Bay, the rate of photosynthesis will be reduced. Hence the switch point between positive and negative growth will occur at lower temperatures. For example,

> *Bulthuis (1987) examined the effect of temperature on seagrass photosynthesis rates at low light levels. He showed that optimum temperature for photosynthesis in* Heterozostera tasmanica *decreased from 35° C at light saturation to 5° C at reduced light levels.*

(From http://www.epa.gov/region1/braytonpoint/pdfs/BRAYTONchapter6.PDF – including Marsh *et al* 1986 reference.)

Although Bulthuis was working on an Australian species, it is likely that a similar compensation point (where photosynthesis equals respiration) will apply for North American species.

In conclusion, eelgrass is a habitat-modifying species. As such it has a very significant effect on the habitat and community of the Bay. It creates organic material that in turn supports a complex food web of detritivores and consumers. It is used for shelter by many fish species, and is an important food and habitat for birds.

It is affected by temperature and suspended solids; large areas have been lost due to the operation of the SBPP. Other areas may be growing less well than they would without the effect of the power plant. The ramifications of this loss are complex and difficult to quantify.

Benthic Studies Are Crucial to Determining Ecological Impact of SBPP

SBPP has affected the benthos in the Bay. It has had effects that are measurable and are likely to be affecting the production of the habitat in the vicinity of the power plant.

The high biomass of nematodes and oligochaetes in the benthic samples around the outfall of the plant indicates that the system is highly stressed. Dominance by nematode and oligochaetes is usually a sign of organic enrichment and subsequent low oxygen (due to high levels of bacterial respiration). Diversity increases (i.e. the relative importance of these worms decreases) with distance down the discharge channel.

It is known that low diversity habitats with high abundance of pollution-tolerant species such as nematodes and oligochaetes are a sign of a disturbed or polluted environment. See table below.

Table 1. Potential indicators of benthic stress.

Non-Disturbed Environments:	
Environmental Characteristics	**Biological Characteristics**
- Low Total Organic Carbon (<1%)	- High number of species
- High RedOx potential (positive Eh values)	- High Diversity (H')
- Low porewater sulfide (< 0.01 mg/L unionised H_2S)	- High total faunal abundance
- Low porewater ammonia (< 0.2 mg/L unionised ammonia N)	- High biomass
- High bottom water dissolved oxygen (> 5 mg/L)	- High species evenness/low dominance
- Low measures of sediment contamination:	- High Nos. of long-lived/equilibrium & pollution- sensitive species
- Low chloroform extractable bitumen (< 1 mg/g)	- Low Nos. of opportunistic and pollution-tolerant species
- Individual chemical concentrations less than sediment quality guideline values (ERM, PEL values).	- Higher ratio of filter feeders to carnivores and deposit-feeders
	- Higher multi-metric benthic index score
	- Diverse age-class structure
- Low mean ERM quotient (< 0.01)	- Low incidence of morphological anomalies
- No sediment toxicity in standard bioassays with ambient amphipod	- Higher ratio of crustaceans to polychaetes and molluscs
	- Low abundance/biomass ratio
	- Low abundance/ species ratio
	- Low incidence of internal parasites (esp. molluscs)
Heavily Disturbed Environments:	
Environmental Characteristics	**Biological Characteristics**
- High Total Organic Carbon (> 3%)	- Low number of species
- Low RedOx potential (negative Eh values)	- Low Diversity (H')
- High porewater sulfide (> 0.05 mg/L unionised H_2S)	- Low total faunal abundance
- High porewater ammonia (> 0.4 mg/L unionised ammonia N)	- Low biomass
- Low bottom water dissolved oxygen (< 2 mg/L)	- Low species evenness/high dominance
- High measures of sediment contamination:	- Low Nos. of long -lived equilibrium & pollution-sensitive species
- High chloroform extractable bitumen (>10 mg/g)	- High Nos. of opportunistic and pollution-tolerant species
- Individual chemical concentrations greater than sediment quality guideline values (ERM, PEL values)	- Lower ratio of filter feeders to carnivores & deposit-feeders
	- Lower multi-metric benthic index score
	- High incidence of morphological anomalies
- High mean ERM quotient (> 0.1)	- Lower ratio of crustaceans to polychaetes and molluscs
- Significant sediment toxicity	- High abundance/biomass ratio
	- High abundance/ species ratio
	- High incidence of internal parasites (esp. molluscs)
	- Higher incidence of younger forms
	- Presence of beggiatoa-like mats
	- High incidence of imposex
	- Abnormal occurrence of infauna relative to sediment depth (high density of deep burrowing fauna on surface).

Note: Other features to consider include:

1. Abiotic factors to help interpretation of data on biological and environmental (stressor) variables such as grain size, C/N ratios, chlorophyll a/phaeopigment ratios, and acid volatile sulfides.
2. Seasonality.

(From Intergovernmental Oceanographic Commission - technical series. *Ad Hoc* Benthic Indicator Group, Results of Initial Planning Meeting, Paris, France 6-9 December 1999)

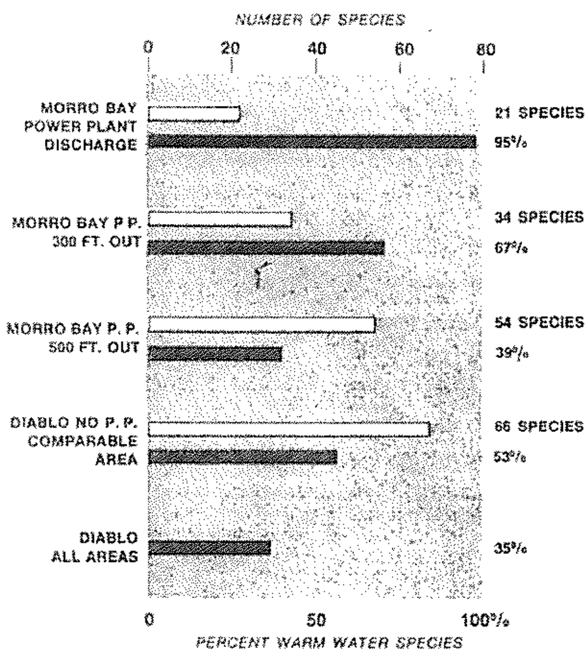
The SBPP power plant will cause a reduction in diversity in several ways. The outfall could eliminate species that:

1. cannot withstand the temperatures found in the area impinged by the outfall.

2. cannot withstand the lower oxygen levels in the area, caused by a) the elevated temperatures and b) the "rain" of dead and dying organisms released by the plant by entrainment and plant washing.
3. cannot withstand the elevated suspended solids found in the area
4. are killed by the presence of biocides in the outfall water
5. are killed by other chemicals leaching from the plant.

Even if species can live within this zone, they might be living sub-optimally and possibly not be able to reproduce. Often, where the temperature of the water is below the thermal death point of the organism, it can have deleterious effects such as increasing growth rates, prolonging the growth season, causing earlier breeding (Barnett, 1971) or causing avoidance behaviour (Naylor, 1965).

Other outfalls have been shown to reduce the diversity of the invertebrates found in the sediments. For example at Morro Bay, California, the number of invertebrates was identified from the discharge zone and at 300 and 500 feet from the end of the discharge. This was compared to a control site along the coast. The control site had 66 species present. The samples from Morro Bay had 21, 34 and 54 species - respectively. Interestingly, 95 % of the species found in the samples closest to the discharge were identified as warm water species (See figure below from Adams, 1969).



INVERTEBRATES COLLECTED AND IDENTIFIED AT MORRO BAY POWER PLANT AND AT DIABLO (NO POWER PLANT)

A Very High Percentage of the Volume of the Bay Affected

In the old regulations, specific mention was made of an intake that "*comprises a large proportion of the source water body segment.*" This is obviously the case for SBPP.

A high percentage of the volume of the water in zone 4 is potentially passed through the power plant. The volume of zone 4 (the zone in which the plant is operating) is 20,410,508 m^3. SBPP, when operating at full capacity, uses 1,580m^3 per minute. In one day the plant uses (60*24*1580) 2,275,200 m^3. This is 11% of the water in zone 4 per day. The volume of the entire San Diego bay is 140,612,092m^3, which means that the plant is utilising 1.6% of the bay per day. The plant could pass the equivalent of the entire bay thorough the cooling water system every 62 days, or about 6 times a year.

SBPP give the average water flow during December 1998 to September 2003 as 425,056m^3. This still represents 2% of the southern bay per day. This number has to be treated with caution as the figure 2.1.2 in 316b report from SBPP shows that the plant operates at or near full capacity for quite long periods. Since planktonic stages in fish are fairly short lived the effect on some species might be greater that the 2% figure suggests. For a more accurate figure it would be necessary to determine the actual flows during the period during which each species is vulnerable to entrainment.

Impingement and Entrainment

The SBPP intake within San Diego Bay acts as a suppressor on the ecosystem, continually removing and killing a wide variety of organisms. Because intakes tend to kill disproportionately large numbers of small animals and juveniles, they tend to impoverish the standing crop in the lower trophic levels towards the base of the ecosystem. The ecosystem in the vicinity of an intake gradually distorts under this unnatural mortality. Given sufficient time, an un-natural equilibrium community adapted to the artificial conditions may develop. However, this may take many years, and other changes are also probably occurring simultaneously. There are no data sets presented by the Duke studies that attempt to quantify the extent of these changes.

Within a restricted water body, such as San Diego Bay, where the plant can utilise the total volume of water in the bay every 60 days, impingement and entrainment mortality has the potential to reduce the local population by a significant amount.

The potential for local impoverishment is most clearly seen in the analysis of Duke's entrainment data. The numbers of fish entrained represent a considerable part of the local population. The Duke studies estimate that the proportion of the larval gobies entrained by the power station varied between 21-27%, Longjaw mudsucker 17-50 %, Anchovy complex 7-10%, Silverside about 14% and combtooth blennies about 3%. In the earlier studies, the total loss of eggs and larvae was estimated at about 12% of the total source stock.

Natural populations cannot remain unaffected by extra mortalities of these magnitudes when applied on a continuous basis. The percentage loss for some species is so large that, in our assessment, they can never be considered acceptable. The ETM calculations demonstrate that, for some species, a high proportion of the local fish larvae are entrained and probably killed by the power station. It is well established that such loss rates can impact populations, even of short-lived, high-fecundity species such as gobies.

It is clear that the entrainment and impingement mortality rates observed would not allow isolated populations within San Diego Bay to maintain their size. SBPP is causing the South Bay to act as a trap that kills animals recruited from the ocean beyond. While many of the animals killed are derived from populations that extend beyond the bay, it should be noted that many of the fish killed by the cooling water system are typical members of the San Diego Bay community. Thus it is quite possible that the present cooling water system has reduced the size of the local fish and crustacean population by a significant amount

Duke Study Does Not Adequately Assess Impact to Non-commercial and Non-target Fish

Only a small fraction of the life forms present in a water body are normally given a monetary value. Yet almost all the species present in the water column or living on the river or seabed in the vicinity of an outfall will be impacted by a direct cooled power plant. Most are not fished or sold in any form and are not of immediate value as tourist features, as may be the case for an elephant seal colony or turtle breeding beach. In general somewhere in the region of about 1 in every 100 species can be assigned a monetary value. The question is how should we consider the worth of the other 99%, many of which are small or even microscopic.

The interdependence of species, and the fact that all species can be viewed as interconnected units within a food web, immediately suggests that the economically important species are dependent upon the existence of many other species either directly because they are their food or indirectly because they help to create some aspect of the habitat that is essential for their existence.

Perhaps the most clear cut, but unusual, situation would be where clear dependence can be shown between two species such that a dependent species that has an economic value cannot exist without another supporting species. With this type of situation the supporting species can be assigned a value as a resource base for the economically important species. Given sufficient ecological knowledge it would be possible to calculate how many of the economically important species would be lost if the resource base was diminished in size.

Because almost all the commercially important fish and crustaceans are predators that feed on a variety of prey and can often be quite flexible in their feeding behaviour such a simple relationship will not generally be the case. However, as the vast majority of species with no economic value can be placed towards the foot of the trophic pyramid, they can be viewed collectively as the resource base upon which the economically important species depend.

Such an approach suggests how we might give a value to the majority of species. Suppose that an estuary has 20 species that can be given a commercial value and these 20 have a production of say 50 kg per hectare per year and this is supported by an ecosystem that achieves a maximum annual standing crop of say 50,000 kg per hectare. Then we might roughly state that 1000 kg of standing crop of all species is needed to produce 50 kg of commercially important species. Then if entrainment reduces the standing crop by say 10% we can conservatively assume that this will result in a proportionate reduction in the commercial species of 10%. Once such a rough relationship is established we can then give a monetary value to any loss to the ecosystem.

Some measure of the likely loss of standing crop of plankton can be gained from simple modelling. We can model the plankton community using say a logistic equation such that in the absence of the power plant the population would be at carrying capacity. Then given a daily mortality rate determined by the proportion of the total volume of the habitat that is pumped via the plant the fractional reduction below carrying capacity that results can be estimated.

While the approach outlined above might be used to estimate the overall value of the resource in terms of its food value to economically important species this does not represent the full value of species lost by entrainment and impingement. Unquantifiable losses include the following.

- Loss of recycling efficiency and the loss of nutrients and materials to the local ecosystem. Damage to ecosystems typically results in a loss of ecological efficiency and the release of materials that would have been retained within the ecosystem. Thus a river or estuary may export to the ocean more resources than would have been the case if the ecosystem had been undamaged.
- Power plant mortality will tend to favour short-lived species at the expense of long-lived forms. This tends to produce a bias in favour of more 'weed-like' life forms. The naturally occurring species towards the top of the food chain such as striped bass are typically adapted to live in climax ecosystems in which short-lived species are less dominant. Further, the bias produced may result in a loss of biodiversity resulting in a less stable ecosystem.
- Damage and alteration to the ecosystem may allow the invasion of unwelcome aliens. In particular, fasting growing invasive species that have adapted to man-made or disturbed habitats may reach pest levels. It is notable that most of the alien species that have become established in the Hudson estuary for example are invasive 'weeds' suggesting that human disturbance may be implicated in allowing them to become established.
- Damage to ecosystems may increase the risk of the development of organisms dangerous to human health. Water bodies receiving heated effluent have been closed to water sports because of the risk of pathogens. Red tides may become more frequent and toxic in highly disturbed and unnatural waters. This can increase the costs associated with environmental monitoring and the processing costs of drinking water.

In addition to the costs that may accrue we can also view the ways in which the ecosystem as a whole can offer us services. Some of the most important are listed below.

- Recycling of human waste. This is probably the most important service that is offered by waters close to human habitation.
- Demobilisation and detoxification of chemical waste products. The living world is involved in both the breakdown and locking away within the

sediments of dangerous metals, petroleum products and a vast range of chemical wastes and products.

- The stabilisation and accumulation of sediments. Without vegetation soft sediments would be far more mobile resulting in increased turbidity and sedimentation of channels.
- Support to the terrestrial ecosystem. In many localities there can be a major re-exportation of biomass from water to the land via insects and other invertebrates but also via fishing birds and mammals. Thus the presence of a diverse and rich aquatic fauna can enhance the health of the associated terrestrial flora and fauna.

Finally the presence of rare species, or species naturally at very low numbers, are by nature, overlooked by most impingement and entrainment studies. These studies are usually comparatively short in length, only 1 or 2 years, and usually only sample for short time within that period. At SBPP entrainment was sampled for 24 hours monthly for one year and then bimonthly for the second, while the fish impingement was sampled for 24 hours once every two weeks. The chance, therefore, of catching a rare species that occurs in very densities is very low.

Surplus Production Does Not Discount for Data Showing Loss of Production and High Mortality Rates for Larval Fish

The operation of the SBPP results in a loss of production, either by removal from the system or by organisms living and growing sub-optimally. The Duke studies discount this loss as being surplus production and, as such, conclude that the loss has no effect on the environment. The concept of surplus production is based on the view that the entrained organisms and particularly larval fish were in most cases never going to become adults and that their loss is therefore of no significance. This argument is used to state that the SBPP has no effect on the environment and hence there is no breach of the regulations.

It has long been recognised that man is able to deplete the natural populations of mammals, birds and migratory fish. A generally held view is that a serious decline is usually linked to the harvesting of numbers greater than the population can sustain, but, with suitable restraint, a harvesting level can be found that is sustainable in the long-term. The portion that can be taken without reducing the population is thought of as surplus production.

To some extent the idea has origins in agriculture. Each year a certain proportion of the production must be kept aside as seed for the next year, the rest is the surplus that can be consumed. Until recently the assumed availability of surplus production in wild as well as domestic populations was never given serious scientific scrutiny. By the 19th century it was clear that the eggs and larvae of fish must suffer high mortalities and few of the offspring could ever reach adulthood otherwise they would exhaust the resources upon which they rely. Therefore there was a self-evident surplus.

One reason why the concept of surplus production was widely accepted was that it fitted with the prevailing 19th and early 20th century views of natural selection, the struggle for existence. Many young are produced but only a few will survive, the rest are just victims of the struggle. It should also be remembered that until the 20th century religious beliefs frequently held that the world had been created with a surplus of fruits for man to exploit. This view is still prevalent in some regions.

The important point to note is that when questioning the validity of surplus production we question a long respected paradigm. The basic mistake that many people make is to assume that wild populations can be exploited in similar fashion to domestic plants and animals. They forget that in agricultural practice we assiduously nurture and protect the surplus production, whereas in the wild this would be eroded by natural losses. Furthermore we are unconcerned about the fate of the majority of species in the previously established ecosystem.

The concept of surplus production was first used in fisheries science by Graham in 1935. If fish were to be harvested without a decline in their population there needed to be greater spawning capacity within the population than was required to maintain the population. Given the extremely high fecundities of many fish, where the annual egg production of a single female can range from thousands to millions, this seemed self-evident. Biologists could also point to examples of populations where overcrowding resulted in considerable damage to the reproductive output of the weak or unlucky. For example, salmon have been observed to destroy redds (nests of eggs buried under the gravel on the stream bed) from earlier spawning in years when numbers of returning fish were high. Another example might be the smothering of herring eggs by the eggs of later arrivals on the spawning grounds. Under such conditions it seemed obvious that some of the adults could be removed without harming the reproductive output of the population.

Note that at the core of the surplus production concept lie assumptions about the importance of the population, rather than individual, and an emphasis on the stability of the natural world. The fate of the individual is unimportant – it does not matter which fish dies or lives provided there is sufficient reproductive capacity left. Secondly, those that favour the concept of surplus production generally argue that the natural variability of the world does not require the surplus production from good years to compensate for the poor years when there may be almost total breeding failure. The fact that surplus production arguments do not take account of environmental variability was one of the key features noted by Boreman (2000) in his critique.

Surplus production would not have developed into a fisheries concept if it had not been for the development of density-dependence theory. This theory was developed as an explanation for the stability and continued existence of natural populations. It was realised in the 1930s that populations would continue to fluctuate unless their survival and birth rates varied with the size of the population. Density-dependence allowed the development of a modified view of surplus production - that it was no longer just the excess young that could not be supported to adulthood produced in any particular year, it could be a larger part of the population providing that those that remained after harvesting could respond by either having a higher fecundity or survival rate. Such arguments were used to justify ever increasing exploitation of marine fish populations. They were also used by power plant operators to defend the destruction of millions of young fish and other aquatic organisms.

The development of fisheries models has been completely anthropocentric. We know of no model that asks what yield we can take that not only protects the population but also avoids harming the natural predators of a fish. It should always be remembered that it is not only the abundance of the prey that can affect a predator but also the size distribution. Almost all predators have a favoured size of food. However, it is clear that the disproportionate harvesting of particular age groups is the norm and will result in a change in the population age structure even if total numbers remain stable.

Thus, if a population can support additional anthropogenic mortality it may still damage the predators. No fish or other biological resource can be harvested at zero cost to the ecosystem. In this sense there cannot be any such thing as surplus production. That the no cost view is commonplace is certainly suggested by the descriptive terms and statements of some who have argued that power plants cannot harm fish populations and natural communities. Goodyear (1977) referred to 'excess production' and Watt (1968) to 'wastage'. Here we see a different viewpoint being introduced. The animals that can be harvested are an excess or natural wastage that, if not killed, would in some way be flushed from the system. Their arguments are based on the premise that the fish killed by impingement and most importantly entrainment are of no worth, either to man or other organisms within their ecosystem. John Boreman (2000) has, by taking an ecosystem approach, shown the fallacy of this argument.

"If a surplus is being removed by power plant operations, then something else in the ecosystem is being out-competed."

This is an important point that has frequently been lost during studies of density-dependence in fish. The focus of the population modeller tends to be the maintenance of adult numbers within the population under study. No consideration is given to the maintenance of the predators that normally feed upon the fish if man does not take them. Mayers & Worm (2003) discuss the recent large declines in the abundance of top predators including piscivorous fish, mammals and reptiles because of overfishing. They estimated predator levels at only 10% of undisturbed levels.

Density-dependent arguments are concerned with the stability and continued existence of a target population as mortality and natality changes. They can say nothing about the overall ecological health of a system subjected to greatly increased mortality rates from power plants and other cooling water intakes. A core aspect of density-dependent control theory is that the agents of density-dependent control are almost always living organisms. This is because only living entities can respond to the size of the prey population by growing or shrinking in abundance. A change in the response of the controlling species that is proportional to the size of the controlled population is an essential pre-requisite for density-dependent control. This observation brings out clearly the point made by Boreman (2000). If a power plant is killing large numbers of a small fish, say the anchovy, then the animals that would normally control the population by predation or competition will respond to the reduced abundance of anchovy. The predators must decline in abundance or move away while their competitors may increase in numbers as they exploit the vacated space. Thus, the existence of surplus production and density-dependence implies that there are inter-species dependencies and relationships and further implies that these species must respond not only to direct entrainment and impingement losses but also to those of their prey.

The only situation in which the predators and competitors would not express the losses to a prey population would be if the loss were tiny and hidden within the random variation that all populations exhibit.

Hidden within the adult equivalent approach to assessment of power station losses there is also a surplus production argument. Just because only a small number of the young will live to adulthood does not mean that these young over their brief lives might not contribute to the maintenance of predators and other organisms that can take advantage of their presence. The weakness of the adult equivalent argument can be easily seen by analogy. A hundred tons of rice might be required to give sufficient energy to take 5 humans from birth to age 70. However, during a famine this quantity of rice might sustain 2000 people for sufficient time to ensure their survival until the next harvest. If the rice store were to burn down during a famine, who would equate the loss to 5 human equivalents?

The fact that almost all exploited fish populations have declined indicates that the amount of surplus production that can be taken by man may be much less than has frequently been assumed. While the destruction of some populations is easy to understand as a simple uncontrolled scramble for a limited resource, it is disheartening to note that even managed fisheries have collapsed. The reason for this is essentially because we have misunderstood (overestimated?) the amount of density dependent compensation within the population. The history of management failure and the frequently observed strong recovery when fishing pressure or mortality rates are reduced gives clear examples of the exaggerated density-dependent response. A good example is the striped bass in the River Hudson. It was argued in the 1970s and early 1980s that the population was under density-dependent control and thus reduced mortality would not allow the population to increase. It was effectively saturating its environment. Yet the closure of this fishery resulted in a 15-fold increase in abundance.

In conclusion, the only theoretical basis for surplus production is the observation that some populations in some years produce an excess of young that cannot hope to survive. These young can be harvested without affecting the size of the adult population. A key aspect that surplus production arguments never consider is the between-year variation in survival and thus production. Some fish may depend on occasional highly favourable years when they can produce so many young that they saturate the appetites of the predators and create a strong cohort that will sustain the population for many years. An example of such a fish is the striped bass. Further, harvesting may result in the exclusion of some predators from the resource. The weakness of surplus production pleading can be exposed by the following arguments:

1. Despite the outward appearance of stability in the marine and freshwater environment, fish live in highly variable environments and this is not considered in the models. When variability is introduced into models the predicted surplus production is often much reduced or non-existent.

2. Surplus production only exists in a model that includes man and the target population. When we harvest, the natural predators are, to some extent, denied a food resource.
3. A high proportion of exploited populations are much reduced or in decline. Any reduced survival in these populations must be reflected in reduced adult numbers.
4. The existence of density-dependent control does not imply that there must be surplus production as is often assumed. We must separate the two concepts or we will find ourselves arguing against the established scientific paradigm. Density-dependent control comes about because species are held within a matrix of active and potential controls based on their predators, prey, parasites and diseases. This network of interactions is maintained in part by the consumption of the focal species. If we take a harvest then this control network is disrupted. Thus our harvesting does to some extent break the very density-dependent relationships that the proponents of surplus production claim. The end result of anthropogenic mortality is known, it is ecological degradation.

Another Fallacy of the Theory of Surplus Production – What Feeds on Larval Fish?

The concept of surplus production is based on the view that the entrained organisms and particularly larval fish were in most cases never going to become adults and that their loss is therefore of no significance. This will not be the case if their loss denies other organisms this food resource. Below we consider what organisms feed on larval and small fish. Many organisms feed on larval fish and eggs. Some species actively seek out larval fish while others are indiscriminate feeders that take them as part of their general diet.

Planktiverous fish such as the clupeids (anchovy, alewife, shad) filter food from the water as they pass through. Some of these species simply filter everything in a certain size range. In others there is evidence that they can discriminate as to which of the small organisms they will take. Filter feeders will generally predate in approximate proportion to the density of the food in the water. Alewife, for example, have been found to have selected larval fish and eggs in their diet as juveniles as they grow they become more omnivorous. The Bay anchovy, an abundant fish in the Hudson, has also been found to feed on larval fish. It is a regular but minor part of their diet (Fish and Wildlife Service, 1989).

Small white perch feed almost exclusively on fish eggs at times when eggs are abundant in the water. (Fish of the Great Lakes, Wisconsin Sea Grant). This indicates that they are actively predating this food resource. The diet of young of year striped Bass (*Morone saxatilis*) was studied in the Hudson between 1993 and 1997 (Hurst and Conover, 2001). It was found to comprise between 2 to 8 % fish. These are likely to include larval fish and eggs. Small predatory fish will take eggs and larvae in large numbers. Species such as stickleback are voracious predators on plankton.

Other groups of organisms also eat larval fish and. Jellyfish, for example, have been observed to feed extensively on larval fish and eggs. In a study in Chesapeake bay

Rilling and Houde (1999) noted that ctenophores, a type of small jellyfish, were voracious predators of larval and egg of the bay anchovy: -

> *"Results of mesocosm experiments (Cowan and Houde, 1993) have indicated that up to 20–40% of bay anchovy eggs and larvae in Chesapeake Bay during the peak spawning season may be consumed daily by jellyfish. Purcell et al. (1994) analyzed jellyfish gut contents and estimated that these predators could account for up to 21% of the daily egg mortality and 41% of the larval mortality of bay anchovy in Chesapeake Bay. In site-specific studies, Dorsey et al. (1996) estimated that jellyfish accounted for 0–35%/d of egg mortality, and from 0 to 15%/d of yolksac larval mortality."*

To give some indication of the wide range of animals that will feed on the eggs and larvae of fish we reproduce below the results of a major study on predation on the Grand Banks (Madin *et al.*, 1999) (Table 1~~Table 1~~). Many of these organisms, or closely related forms will occur in the region. In a study investigating the predation mortality of a wide range of marine animals Madin *et al* (1999) found that many organisms feed on larval fish. Table 1~~Table 1~~ show a reduced version of their table showing only the species and groups where larval fish or eggs were mentioned.

Table 1 Predator Occurrence Prey Feeding Data (modified from Madin *et al* 1999)

Cnidarians	Hydroid/ jellyfish		
Clytia gracilis (hydroids)	Often very abundant on crest	Nauplii, Copepods, Fish larvae	F, T responses, selectivity on copepod eggs & nauplii, rates on cod larvae (GLOBEC data)
Cyanea capillata	Patchy occurrence	Copepods, Fish eggs	Rates, selectivity on copepods (literature data)
Other hydromedusae	Variable occurrence, rarely dense	Copepods, Fish larvae	Rates on fish larvae from gut contents, experiments (literature data)
Ctenophores	Jellyfish		
Bolinopsis infundibulum	Patchily abundant on flank, hard to quantify	Copepods, Fish larvae	Rates on copepods from gut contents (GLOBEC data)
Pleurobrachia pileus	Patchily abundant in spring	Copepods Fish larvae	Rates on copepods from gut contents (GLOBEC data), F and T responses (literature data)
Euphausiids	Crustacean		
Euphausii krohnii	Patchily abundant	Copepods Fish larvae	Estimate from other species (literature data)
Isopods	Crustacean		
Cirolana polita	Demersal, in water column at night	Copepods, Larval fish?	Rates on nauplii, copepods from experiments (GLOBEC data)
Fishes			
Clupea harengus	Briefly abundant during migratory passage	Copepods, larval fish	Rates on copepods, fish larvae from gut contents (COP-GLOBEC data),
Scomber scombrus	Briefly abundant during migratory passage	Copepods, larval fish	Rates on copepods, fish larvae from gut contents (COP-GLOBEC data),

As can be seen from this table several species of hydroid, crustacean, jellyfish and fish were observed to feed on larval fish and eggs.

No assessment was made in the 316 studies of any interactions resulting from the loss of entrained organisms.

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