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Assessment of Once-Through Cooling System Impacts to California Coastal Fish and Fisheries

December 2007

Assessment of Cooling Water Intake Structure Impacts to California Coastal Fish and Fisheries

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EXECUTIVE SUMMARY

This report provides a technical review of the current status of information relative to the effects of once-through cooling (OTC) and cooling water intake structures (CWIS) on California coastal fisheries. The purpose of this report is to provide technical information to help inform California regulatory agencies and stakeholders currently deliberating the need for, and nature of, any California 316(b) regulatory structure that may differ from the Federal §316(b) Phase II Rule (Phase II Rule). On June 13, 2006, the California State Water Resources Control Board (SWRCB) issued a draft §316(b) scoping policy (Draft California Policy) outlining a proposed California regulatory structure that was significantly more stringent than the Phase II Rule (SWRCB 2006).

Unlike the Federal Phase I Rule for new facilities, the Phase II Rule was not based on use of closed-cycle cooling. Rather the Environmental Protection Agency (EPA) based the Rule's performance standard ranges on a suite of alternative fish protection technologies and operational standards. These technologies were discussed in a Technical Development Document (USEPA 2004). The Draft California Policy, while retaining performance ranges, required that facilities meet the high end of the performance standard range, although for entrainment, this could be achieved by meeting the low end of the range with technologies and using restoration to make up the difference. However, no analysis of what alternative fish protection technologies could achieve in California's coastal waters was conducted. Additionally, the Draft California Policy called for protection of zooplankton in addition to fish and shellfish. None of the technologies EPA considered were designed to protect zooplankton. The Draft California Policy provided no discussion of technologies that could provide such protection in California. For California's generating facilities, the Draft California Policy's requirements were so limiting that for most facilities few options exist besides either converting facilities to closed-cycle cooling at a cost of billions of dollars or retiring facility/generating units. In addition, the Draft California Policy does not consider that closed-cycle cooling causes its own adverse social and environmental impacts such as increased plant air emissions and the resulting decreases in local air quality. It has the potential to significantly impact energy supply by reducing energy production at existing operating facilities and/or through forcing early facility retirement. It is therefore important to consider the nature of the adverse environmental impacts from existing generating facilities before implementing a State 316(b) Policy.

The Draft California Policy did not provide any technical basis for deviating from EPA's nearly 10-year effort to establish the Phase II Rule. A recent California Energy Commission (CEC) report (York and Foster 2005) on power plant environmental issues included a general discussion of the current status of California's coastal fisheries, pointing out that many species are in decline; however, the information in the report has practical limitations. The report expressed concern that OTC was a factor in the declines. One of the stated goals of the report was to "Quantify and interpret, to the extent allowable by available data, the water uses and ecological effects of once-through cooling" (York and Foster 2005). The report provides quantitative information on cooling water use and discusses studies used to assess impacts. The report has practical limitations, however. For example, concern over projected impacts is discussed in terms of permitted (maximum) rather than actual cooling water flows and the analysis includes facilities that have since been, or soon will be, retired. The report contains little information on

the quantification of ecological impacts. For these impacts, the report bases estimates of entrainment losses on coastal wetland acreage production. Such estimates are not particularly useful for addressing entrainment losses for offshore species that do not rely on coastal wetlands for spawning. Furthermore, the analysis does not attempt to quantify OTC impacts relative to other human-induced impacts. A major conclusion of the report is the need for additional OTC impacts research due to uncertainties associated with potential impacts.

This EPRI report expands upon the CEC report by providing a discussion of OTC impacts that includes mitigative factors such as compensation and comparisons to fishery impacts. It also provides current information on OTC use and fish protection measures implemented by California's facilities. Included in this discussion is a review of the historical information on velocity cap effectiveness as well as results of new studies conducted in 2006/2007. These data indicate that velocity caps not only meet the Phase II Rule's performance standard range, but that for the dominant species impinged, achieve the upper end of that range.

Although it is acknowledged that the ability to quantify impingement and entrainment losses relative to population level impacts with any degree of precision is limited, there is an extensive body of empirical information to help inform the nature and magnitude of these losses. A quantitative examination of entrainment impacts is provided for CWIS located within both lagoons and embayments based on historical and recently collected data from South Bay Power Plant, Encina Power Station and Moss Landing Power Plant. Results of these data analyses determined that 95% of entrainment losses were to commonly occurring forage species (e.g., gobies) not subject to commercial or recreational fishing. Further, the numbers of the locally resident species in the vicinity of CWISs were determined to be similar to the numbers associated with similar habitat areas without OTC facilities. Research indicates that behavior of these dominant entrained species minimizes the risk of adverse OTC impacts.

A similar quantitative examination of entrainment impacts for open ocean coastal environments can be based on long-term data from the Diablo Canyon Power Plant. This analysis suggests that localized impacts due to OTC are even less likely in open ocean coastal environments than in coastal lagoons and embayments due to the large volume of water in the coastal current relative to the volume circulated through the power plant.

The number and biomass of impingement losses at California OTC facilities have been generally acknowledged to be low. Diablo Canyon, the single largest OTC facility in the State impinges an estimated 1,600 lb of fish per year. Diablo Canyon has a shoreline intake structure located in a manmade cove, and in 2003 was determined to be effectively in compliance for impingement from a §316(b) standpoint. A contributing factor to low impingement at other OTC facilities is use of offshore velocity caps. San Onofre Nuclear Generating Station has the highest impingement rate, but also uses an effective fish collection and return system in addition to an offshore velocity cap.

This report provides a discussion of other sources of empirical evidence relative to OTC that includes compensatory mechanisms, use of cooling water on confined cooling waterbodies such as cooling lakes, as well as results of studies conducted in oceans and estuaries located on the east coast. These sources of information suggest that should use of OTC be eliminated immediately, no significant benefits to California's coastal fisheries may occur.

In January 2007, the Second Circuit Court issued its decision (Decision) on the Phase II Rule litigation. The result of that Decision was to remand significant portions of the Rule back to EPA. As a result, EPA is withdrawing the Phase II Rule in its entirety and directing EPA regions and states to implement §316(b) on a Best Professional Judgment (BPJ) basis until the litigation issues are resolved. This report should provide useful empirical evidence to inform that judgment.

CONTENTS

1
INTRODUCTION

The need for review of once-through cooling (OTC) impacts in California has been a major topic of discussion between a number of State Agencies, stakeholders, and owners and operators of the State's steam electric generating stations. These discussions are the result of the issuance of the new §316(b) Phase II Rule by EPA on July 9, 2004. Prior to this, OTC for existing facilities was considered a preferred method of cooling for California's coastal power plants[1] and industrial water supply is one of the beneficial uses of the State's waters that must be protected under the Basin Plans issued by the Regional Water Quality Control Boards (RWQCB).[2] The California Energy Commission (CEC) for a number of years has required mitigation for cooling water intake structure (CWIS) impacts associated with new construction or re-powering projects that propose use of OTC. Recent California discussions of OTC impacts for existing facilities began in June 2005 when the CEC issued a staff report on issues and impacts associated with OTC use by California's power plants (York and Foster 2005). During the same timeframe, the SWRCB held series of stakeholder meetings to discuss issues and the need for a new State 316(b) Policy. The State Water Resources Control Board (SWRCB) issued a proposed statewide 316(b) Policy in June 2006 (Draft California Policy). The Draft California Policy set requirements for 316(b) in California that went beyond the requirements in the EPA's Phase II Rule. Additionally the California State Lands Commission has issued an updated OTC policy (April 2006) and the California Ocean Protection Council (OPC) has initiated a study of alternative fish protection control technologies.

Federal and Proposed California 316(b) Regulatory Requirements

The Draft California Policy, justified with no new scientific or technological information, establishes performance standards for reducing impingement mortality and entrainment at the maximum end of the federal Rule range. The Phase II Rule, over a fact-finding and development period that spanned nearly a decade, established an impingement mortality reduction standard of 80%–95%. In contrast, the Draft California Policy requires a 95% impingement reduction that must be achieved with technologies and/or operational measures with no allowance for use of restoration. For entrainment, the Phase II Rule requires a 60%–90% reduction while the Draft California Policy requires 90%, using technological and operational controls, unless it is not feasible, in which case a minimum reduction of 60% must be achieved using technological and operational measures and the remainder achieved through restoration. Further, the Draft California Policy requires entrainment reductions for zooplankton in addition to fish and shellfish. Currently, none of the alternative fish protection technologies considered by EPA in the Federal rulemaking are designed to protect zooplankton. As discussed in Appendix A, even

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[1] California State Water Resource Control Board. 1975. Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling. June, 1975.

[2] California Regional Water Quality Control Board, Los Angeles Region. 1994. Water Quality Control Plan: Los Angeles Region. Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties. Adopted by the California Regional Water Quality Control Board, Los Angeles Region on June 13, 1994.

for fishes and shellfishes there are limited opportunities for use of alternative fish protection technologies and/or operational measures in California coastal waters.

In January 2007, the Second Circuit Court issued its decision on the Phase II Rule in a lawsuit brought by the Hudson Riverkeeper. This decision remanded significant portions of the Phase II Rule to EPA. Important aspects of the Phase II Rule affected by the Decision included:

- Remanding to EPA the determination of Best Technology Available (BTA). EPA was directed to clarify the basis for the determination that closed-cycle cooling was not BTA and that the "best performing" rather than the most cost effective technology in the performance standard range must be used;
- A determination that restoration measures were not BTA and could not be used;
- A determination that environmental benefits could not be considered in establishing BTA;
- Remanding to EPA the Cost-Cost Test due to failure to propose the details for public review and comment prior to inclusion in the Rule; and
- Remanding to EPA the Technology Installation and Operation Plan, also for failure to allow for public review and comment.

As a result of the decision, EPA has withdrawn the Phase II Rule in its entirety and has directed that EPA regions and delegated states implement §316(b) on a Best Professional Judgment (BPJ) basis until the litigation issues are resolved.[3]

An important feature of the Phase II Rule retained in the Draft California Policy was not a litigation issue. It allows facilities to take credit for cooling water intake system design and/or operational measures that provide the benefit of fish protection or restoration measures put in place to offset impingement or entrainment losses. As discussed later in this report, most of California's coastal power plants have employed such measures either for impingement and/or entrainment.

The result, and perhaps unintended consequence, of the Draft California Policy's requirements is that most of California's facilities would need to retrofit with wet or dry closed-cycle cooling systems or significantly reduce flow and generation capacity to comply (see Appendix A). A recent study completed by EPRI (EPRI 2007) indicates this would result in expenditures of billions of dollars to comply and/or facility retirements that would result in a significant reduction in the State's reserve generation capacity necessary to meet peak energy demand. There is not a large reserve capacity of energy in California, as documented in comments on the Draft California Policy submitted to the SWRCB from other State Agencies including the CEC and California Independent System Operator (Cal ISO). The problems of energy supply in California were also expressed in articles in USA Today (7/24/2006 and 7/29/2006) and other news publications during the record-setting heat wave in the latter part of August 2006, which severely strained the State's reserve electric energy supply.

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[3] Federal Register, 7/9/07, Vol. 72, No. 130, pgs 37107-37109.

In its decision, the Second Circuit Court noted that there were three factors that EPA could use in the determination of whether closed-cycle cooling is BTA for existing facilities. These three factors are:

- Whether or not facilities can reasonably bear the cost of the technology;
- Impacts to energy production and supply; and
- Adverse impacts associated with the technology.

Considering the Draft California Policy's high cost of compliance and potential energy supply impacts to consumers (as recognized by the Second Circuit Court), insufficient information was provided in either the Draft California Policy or the CEC report (York and Foster 2005) to support these stringent requirements. The information that was provided largely consisted of qualitative statements with no quantitative assessments provided about the expected changes in California's fisheries that would result from the multi-billion dollar investment required by the Draft California Policy. The qualitative concerns expressed in the CEC report and/or Draft California Policy included:

- The decline of the world's oceanic biological resources in general and California's coastal resources in particular,
- The cooling water withdrawal of billions of aquatic organisms,
- The majority of impacts are to early life stages of fishes and shellfishes,
- Cumulative impacts, and
- Impacts to primary and secondary producers such as zooplankton.

The purpose of this report is to provide California's stakeholders with information on the impacts to coastal fishes and fisheries of OTC to assist in better understanding the nature and magnitude of fishery changes that might be achieved by reducing OTC at steam electric generating stations. This should allow for more informed decision making in the context of California's limited technological options for CWIS compliance. This is especially true for entrainment reduction options.

Two issues have been raised relative to OTC. The first is effects resulting from fish passage through, or entrapment inside, the CWIS, while the second is exposure to elevated temperatures in the thermal discharge. Cooling water intake structure impacts are regulated under §316(b) of the Clean Water Act and the Federal Rule. Thermal discharges are regulated under the State Thermal Plan. The Clean Water Act contains a unique variance provision within §316(a) that allows facilities a variance from the thermal standards, including the mixing zone standard, if it can be demonstrated that an alternate standard will ensure protection of a balanced population of fish and wildlife. Information discussed in this paper is limited to only CWIS impacts.

This report contains five additional sections. Section 2 of this report discusses the nature of CWIS impacts and the current OTC facilities operating in California. Section 2 also includes a short discussion of any technologies and/or operational measures employed at these facilities or use of restoration measures to address OTC impacts. Section 3 focuses on OTC impacts in California, based on currently available information. Section 4 provides a general discussion of

California’s OTC impacts that includes information from other portions of the U.S. as a means of placing California observed impacts in perspective. Section 5 provides the summary and conclusions regarding OTC based on the information discussed in the other sections of this report. The literature references used in this report are found in Section 6.

2

THE NATURE OF COOLING WATER INTAKE STRUCTURE IMPACTS AND CALIFORNIA'S ONCE-THROUGH COOLING FACILITIES

This section provides a discussion of the nature of cooling water intake structures (CWIS) and California's coastal generating stations that use once-through cooling (OTC).

2.1 Impingement and Entrainment

There are several non-thermal effects to aquatic organisms that can result from OTC. Facilities with OTC are designed with screening systems that prevent objects too large to pass through the cooling water condenser tubes from damaging or blocking the condenser tube sheet face. Fishes and other organisms that become trapped on the screens are referred to as impinged organisms and the process as impingement (Figure 2-1). Generally the screens are designed to rotate (traveling screens) so that debris or fish on the screens can be removed. While the mesh size of the screening material can vary, most facilities are designed with 3/8-inch (approx 1-cm) mesh screens. Fish and shellfish during their early life stages are small enough to pass through the traveling screens where they are exposed to mechanical stress, heated water and sometimes biocides (used intermittently). The small fishes and other organisms that pass through the traveling screens are referred to as entrained organisms and the process as entrainment (Figure 2-1).

Six California facilities are located along the ocean in areas with sandy beaches and have offshore intake structures with intake tunnels to convey water to the onshore power plant. Fishes and shellfishes can enter the intake tunnels and inhabit embayment areas in front of the traveling screens. In order to control biofouling organisms that colonize the intake tunnel walls and other surfaces, these facilities periodically "heat treat" by circulating warmer discharge water back through the cooling water intake system. This exposes the biofouling organisms to heated water in order to remove these organisms from the tunnel walls. Any fishes in the intake embayment area and the intake tunnels can suffer mortality as a result of exposure to the heat treatment process unless they move back out the intake tunnel. Typically the tunnels are heat treated every six to eight weeks as necessary during periods of high fouling.

The EPA Phase II Rule is based on the assumption that all entrained organisms are killed. However, facilities were to be allowed to propose entrainment survival studies under the Cost-Benefit Test to document survival in estimating the economic environmental benefit of meeting the entrainment performance standard. Under the Court Decision, however, use of the specific Cost-Benefit Test is no longer allowed. EPRI prepared a summary of entrainment survival studies conducted at a number of facilities (EPRI 2000) that showed significant entrainment survival in some species. This is not likely to be the case for the facilities with offshore intakes and discharges due to the longer transit times required for organisms to pass through these systems and predation of biofouling organisms on entrainable life stages within the system. As discussed for impingement, the Phase II Rule's performance standard is based on actual impingement mortality since many of the nation's facilities are equipped with fish return systems that return impinged fishes alive to the source waterbody. This is generally not the case in California due to the long transport distances required for most facilities. An important exception is the San Onofre Nuclear Generating Station, which does employ a fish collection and return system for reduction of impingement mortality.

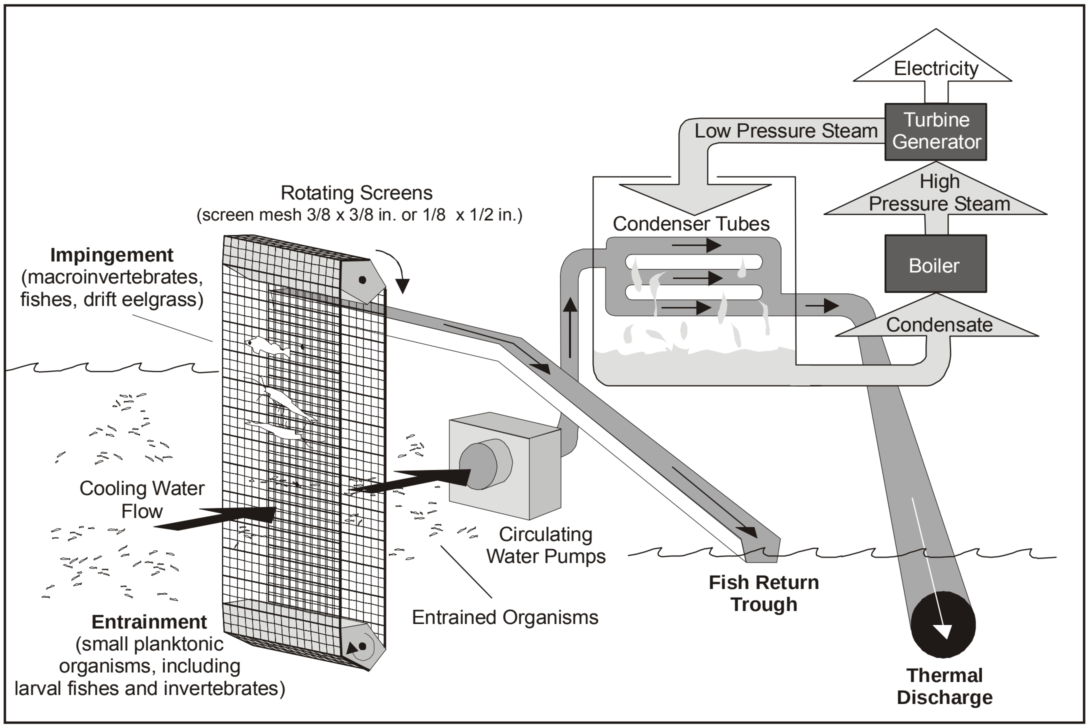


Figure 2-1. Diagram showing entrainment and impingement at OTC facilities.

2.2 California's Coastal Once-through Cooling Facilities

There are currently 16 operating fossil fuel and two nuclear fuel generating facilities using OTC in California (Table 2-1). Their locations are shown in Figure 2-3. As noted in Table 2-1, one facility has been retired (Hunters Point), retirement plans have been announced for the South Bay Power Plant, and several facilities have been retrofitted or are undergoing retrofits that will not utilize OTC. These include the Long Beach Generating Station that has been retrofitted with simple cycle units that do not employ steam condenser cooling, the Humboldt Bay Power Plant that is undergoing a retrofit to diesel generator units that will be completed in 2009 and will not utilize OTC, and plans have been announced to replace El Segundo Generating Station Units 1 and 2 with new air-cooled units. As shown in Table 2-1, approximately one-third of the OTC flow is used by California's two baseloaded nuclear facilities. These two facilities provide electric power generation to meet a significant portion of the day-to-day energy requirements of the State. The vast majority of the fossil fueled facilities in contrast, are not baseloaded and many of these generating units operate as peaking facilities, operating for only a small portion of the year when energy is in greatest demand (generally occurs during the warmer summer months) or when the baseloaded nuclear units are taken out of service for maintenance.

Additionally, facilities tend to have diel peaks with higher demand during the day and reductions in demand at night, especially in summer when afternoon temperatures are highest.

Ten of the 18 currently operating facilities in California have taken some action to reduce the potential effects of OTC using either flow reductions, technologies, restoration measures, or some combination of these options. The specific measures are briefly summarized in Table 2-2 and in the remainder of this section.

2.2.1 Flow Reductions

The EPA Phase II Rule describes flow reductions as one of the most significant actions to reduce both impingement and entrainment. However, as discussed in Section 1, if this action involves replacement of OTC with closed-cycle cooling, this alternative either has a very high economic cost and/or energy penalty associated with it. However, both the Contra Costa and Pittsburg power plants have implemented substantial flow reductions through a combination of unit retirements, use of closed-cycle cooling, and installation of variable speed drive pumps (Mirant Delta LLC 2006 a, b). Flow reductions were first used at these facilities to reduce potential impacts to a recreationally important species (striped bass) in the San Francisco Bay Delta. Currently, additional use of these variable speed drives reduces potential impacts to listed species. This is further discussed in Section 4.

2.2.2 Use of Velocity Caps for all of California's Offshore Intake Structures

All of the facilities with offshore intakes (El Segundo, Huntington Beach, Ormond Beach, Redondo Beach, Scattergood and San Onofre) employ velocity caps on the intake pipes that have been demonstrated to reduce impingement of fishes to levels that meet the Phase II Rule performance standards. One of the first facilities to employ a velocity cap was the Huntington Beach Generating Station (Weight 1958). The velocity cap at Huntington Beach was installed during construction of the plant after results from model studies for that facility and full-scale tests at the El Segundo Generating Station showed that a velocity cap would be effective in reducing impingement (Weight 1958). The model studies were done using a 16-in. pipe in a 5 ft x 7 ft tank. Results of these studies showed that even small fishes that could avoid being pulled into the pipe when a velocity cap was in place were pulled into the pipe when the velocity cap was removed. These model studies (Schuler 1974) were followed by full-scale tests at El Segundo where impingement from July 1956 through June 1957 prior to velocity cap installation was compared with impingement from July 1957 to June 1958 after the velocity cap was installed. Total impingement between the two periods was reduced from 272.2 tons to 14.95 tons—a reduction of 95%. The results of both the model studies and the full-scale tests at El Segundo were presented in the Proceedings of the American Society of Civil Engineers (Weight 1958). The shortcomings of this study were that data on species composition were not available and the comparison was between two several month periods during which fish composition could change. Therefore, there is some uncertainty related to the contribution of these differences to the reduction in impingement observed when the velocity cap was present.

Table 2-1. California's power plants employing once-through cooling technology listed in SWRCB staff's 316(b) Proposed Policy (SWRCB 2006).

California Once-through Cooling Power Plants Listed in CEC June 2005 Staff Report	Owner and/or Operator	Facility Flow (mgd)	Comments
		Fossil Fueled Facilities	
Alamitos	AES[1]	1,181	
Contra Costa	Mirant[2]	440	
El Segundo	NRG[3]	606	Air-cooling planned for Units 1 and 2 replacement units.
Encina	NRG	857	Planned retirement of Units1-3 and replacement with air-cooled units.
Harbor	LADWP[4]	108	
Haynes	LADWP	1,014	
Humboldt Bay	PGE[5]	0	Retrofitting to diesel generating units that will be completed in 2009 and not utilize OTC. Until completion the existing units are operating at a low capacity.
Hunters Point	PGE	0	Retired
Huntington Beach	AES	514	Offshore Intake
Long Beach	NRG	0	Refurbished with simple cycle units not utilizing OTC.
Mandalay	Reliant[6]	254	
Morro Bay	Dynegy[7]	668	
Moss Landing	Dynegy	1,224	
Ormond Beach	Reliant	685	Offshore Intake
Pittsburg	Mirant	506	
Potrero	Mirant	226	
Redondo Beach	AES	891	Offshore Intake
Scattergood	LADWP	495	Offshore Intake
South Bay	Dynegy	601	Planned Retirement
Subtotal Fossil		**10,223**	
Nuclear Facilities			
Diablo Canyon	PGE	2,500	
San Onofre	SCE[8]	2,335	Offshore Intake
Subtotal Nuclear		4,835	
Total Facilities		**15,058**	

1. AES Southland
2. Mirant California
3. NRG Energy
4. Los Angeles Department of Water and Power
5. Pacific Gas and Electric Company
6. Reliant Energy
7. Dynegy
8. Southern California Edison

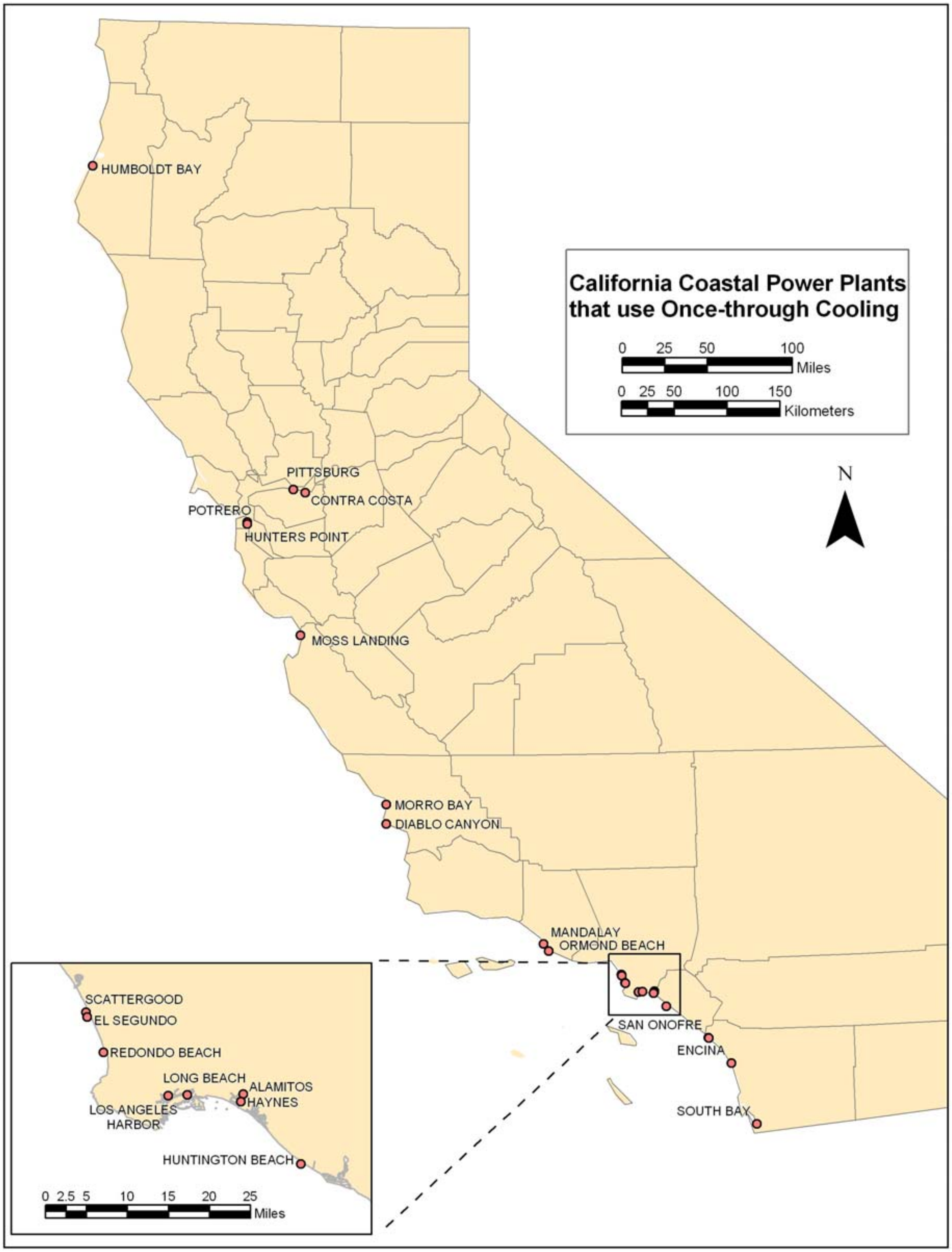


Figure 2-2. Location of facilities in California using once-through cooling.

Table 2-2. Currently planned or implemented technologies, operational measures, or restoration measures at California generating stations using once-through cooling.

California-Once-through Cooling Power Plants	Comments
Contra Costa	Flow reductions for fish protection have already been implemented sufficient to comply with the federal Rule for entrainment. These reductions have been achieved through a combination of actions that include unit retirements, installation of variable speed drive pumps, and a reduction in flow.
El Segundo	Use of submerged offshore intake with a velocity cap for impingement.
Huntington Beach	Use of submerged offshore intake with a velocity cap for impingement. Use of restoration measures to offset entrainment losses for Units 3 and 4.
Morro Bay	Detailed plan of restoration measures including benefits and cost evaluations to offset entrainment losses adopted by Central Coast RWQCB for re-powering project.
Moss Landing	Use of restoration measures to offset entrainment losses fully and successfully implemented through Elkhorn Slough Foundation.
Ormond Beach	Use of submerged offshore intake with a velocity cap for impingement.
Pittsburg	Flow reductions for fish protection have already been implemented sufficient to comply with the federal Rule for entrainment. These reductions have been achieved through a combination of actions that include unit retirements, installation of variable speed drive pumps, a reduction in flow, and use of closed-cycle cooling.
Redondo Beach	Use of submerged offshore intake with a velocity cap for impingement.
Scattergood	Use of submerged offshore intake with a velocity cap.
San Onofre	Use of restoration measures for entrainment, use of submerged offshore intake with a velocity cap to reduce impingement and fish return system for fishes avoiding velocity cap protection. Aquaculture and stocking of white seabass to offset intake effects.

The second study done in 1979–1980 (Johnson et al. 1980) was much more extensive and was carried out by a team of researchers from the University of Washington College of Fisheries. This study, which was summarized in the Huntington Beach Proposal for Information Collection (AES Huntington Beach 2005), may be the most comprehensive evaluation of velocity cap effectiveness ever conducted. During this study impingement and source water data on individual species were collected and the results were reported in several University of Washington technical reports (Thomas et al. 1979, Thomas et al. 1980a, Thomas et al. 1980b, Thomas et al. 1980c, Thomas et al. 1980d). The results were also published in an Institute of Electrical and Electronics Engineers journal (Thomas and Johnson 1980) and hydroacoustic methods presented at a Scientific Committee on Oceanic Research meeting (Thorne 1980).

In order to control biofouling California's facilities with offshore intakes and velocity caps have the ability to reverse flow. In this process the cooling water flow is reversed such that cooling water is taken in through the discharge pipe water and the thermally heated water is discharged through the intake pipe. Since the discharge pipe is not equipped with a velocity flow reversal it provides a means to estimate velocity cap effectiveness. Flow reversal studies were conducted at four different power plants over a year that consisted of a series of field trials, with the majority of the trials occurring at Huntington Beach. The seven trials at Huntington Beach resulted in 123 hourly estimates of impingement and source water fish abundances with 70 observations at full flow with the velocity cap in place. This was the control condition, and the results were used to compare impingement and source water abundances under several other plant operating conditions. Source water abundances of fishes were estimated using hydroacoustic sampling that was supplemented with net sampling to verify the composition of the acoustic targets. Gill nets were also positioned at different depths in the water column to determine the vertical distribution of the different species. Data were collected with the plant under full operation in reverse flow (without velocity cap). Although the plant now rarely operates under full load, the flows used in the study would be the maximum possible under present conditions.

A smaller number of test runs were also done during the study to compare entrapment and vulnerability at full and reduced flow. Vulnerability of several species was decreased under reduced flow conditions, but the reductions were not significant for white croaker (*Genyonemus lineatus*) and northern anchovy (*Engraulis mordax*).

The study had several unique features that improved the ability to measure the effectiveness of the velocity cap. First, unlike the 1950s study, test conditions were evaluated for a few hours or days and then were changed to evaluate another set of test conditions. This ensured that fish composition and source water abundances did not change dramatically between tests. Secondly, the intake tunnels were cleared of fishes between observations by injecting chlorine at the upstream end of the screenwell in concentrations that forced the fishes towards the traveling screens. This clearing of the intake tunnels ensured that a complete count of fish entrapment was completed during each trial. In addition, several trials of each test condition were conducted over the course of the study to ensure that seasonal differences in ocean conditions and fish composition were taken into account. Finally, the entrapment data were combined with estimates of source water fish populations in the vicinity of the intakes to calculate estimates of entrapment vulnerability. The source water population estimates were made using net and hydroacoustic sampling. This enabled the effects of the velocity cap to be evaluated independently of offshore population abundances. The statistical technique for adjusting the entrapment rates was to calculate the ratio of the number of fish entrapped by the intake to the numbers of fishes in the source water in the vicinity of the intake (E/B). This ratio was used to estimate the relative vulnerability of fishes to entrapment by the intake. All of these study measures greatly improved the ability of the study to evaluate the effectiveness of the velocity cap and produced a study that would be very difficult to improve upon.

The use of the vulnerability ratio (E/B) in assessing differences among treatments had additional benefits that increased the statistical power to determine if there was a significant decrease in the vulnerability of fishes to impingement in the control condition with the velocity cap. The ratio of vulnerability resulted in a measure that adjusted the impingement data for the abundances of fishes in the source water during each observation to ensure that any differences in impingement were the result of the presence or absence of the velocity cap and not differences in source water abundances. This decreased the variation among observations within a treatment, which contributed to the ability to detect differences among treatments. The use of the E/B ratio and the large number of replicates of each treatment increased the statistical power of the study to detect any differences due to the velocity cap.

The final report presented results both for total impingement of all fish species combined and three individual fish species: queenfish (*Seriphus politus*), white croaker, and northern anchovy. Similar to the period of study in 1979 and 1980, queenfish and white croaker were the most abundant fishes in the impingement sampling conducted from July 2003 through July 2004, and northern anchovy was the fourth most abundant species. These three species, accounted for almost 85% of the total impingement during the 2003–2004 period. The recent Huntington Beach IM&E Characterization Study report (MBC and Tenera Environmental 2005) also included appendices with data and analyses for other fishes that were identified as important species. Except for silversides, these 13 other species were collected in relatively small numbers. There were large numbers of silversides collected during the 1979–1980 study, but they were mostly collected in the source water sampling, and were only collected from impingement sampling during reverse flow operations in the absence of the velocity cap. Although not analyzed in the report due to the absence of normal operations data for comparison, the results for silversides probably represented the best example of the effectiveness of the velocity cap. Silversides are primarily distributed in the surface layers where they are less likely to be pulled into the system during normal operations with a velocity cap. In the absence of a velocity cap the intake draws water vertically from surface layers resulting in greater impingement of silversides.

The vulnerability ratios from the study present the measure of effectiveness for the velocity cap (Figure 2-3). Based on the results, the difference in vulnerability at full flow with the velocity cap and full flow without the velocity cap was highly significant**.**

In summary, the results from the 1979–1980 studies provide a measure of the effectiveness of velocity caps as a technology for reducing impingement mortality. The use of data from the 1979–1980 velocity cap study is useful for informing the EPA Phase II Rule since the Rule allows use of historical data to estimate the calculation baseline. This study was well designed and was probably the most extensive evaluation ever conducted on the effectiveness of velocity caps in reducing impingement mortality. The study was conducted by independent researchers from the University of Washington and results published in a professional journal and presented at a scientific conference. Salient points of the study are summarized below:

- The study collected data on both impingement and source water abundances. This allowed impingement abundances to be adjusted so that the results reflected differences due to the presence or absence of the velocity cap and not to differences in source water abundances.

- The three species analyzed in detail were identified as key species because they comprised very large percentages of the total impingement. These three species were also identified from the recent impingement mortality study in 2003–2004 as comprising a very large percentage of total impingement. The Phase II Rule, in terms of the calculation baseline, requires making estimates for the species most susceptible to impingement and these three species at Huntington Beach have been documented in the 2003–2004 study as the most susceptible species.

- The results of the 1979–1980 study were consistent with the overall results of an earlier comparison from 1957–1958 such that the effectiveness of the velocity cap has been determined to meet the impingement mortality performance standard in two independent studies.
- Results for silversides from the 1979–1980 study show how the velocity cap functions in reducing impingement, and how its use can result in the large decreases observed in total impingement during the 1957–1958 study.
- For all species combined (effectiveness can vary with species) the results indicate an average reduction of 82% in biomass in terms of effectiveness.

The study would be extremely difficult to repeat today, due to the permitting requirements for the destructive sampling methods used for the source water populations and the chemical methods (chlorine injections) used to clear the tunnels of fishes between hourly observations.

As recently as October 2006–January 2007, a series of reverse flow studies were initiated at the Los Angeles Department of Water and Power's Scattergood Generating Station. These studies employed the same study design used in the previous reverse flow studies and continued to document the effectiveness of this technology in reducing fish impingement. During these studies without the velocity cap, a total of 639,712 fishes were impinged compared to 18,732 impinged fishes with the velocity cap—a reduction of over 97%. The dominant impinged species in this study were Pacific sardine (*Sardinops sagax*), a commercially important species, and topsmelt (*Atherinops affinis*), which together accounted for over 96% of all fishes impinged. References on velocity cap studies are provided in the literature cited section (Section 6) of this paper.

Table 2-3. Entrapment concentrations for total fishes at the Huntington Beach Generating Station during the 1979 and 1980 velocity cap studies (from Thomas et al. 1980d), Table 3, p. 18).

Year	Velocity Cap Present	Time	Entrapment Concentration (kg/hr)	Effectiveness
1979	No	Day/Night 18-hr	20.45	
1979	Yes	Day/Night 18-hr	1.97	90%
1979	No	Night	32.93	
1979	Yes	Night	15.53	53%
			Average:	**72%**
1980	No	Day	47.2	
1980	Yes	Day	0.65	99%
1980	No	Night	52.99	
1980	Yes	Night	6.78	87%
			Average:	**93%**
			Overall:	**82%**

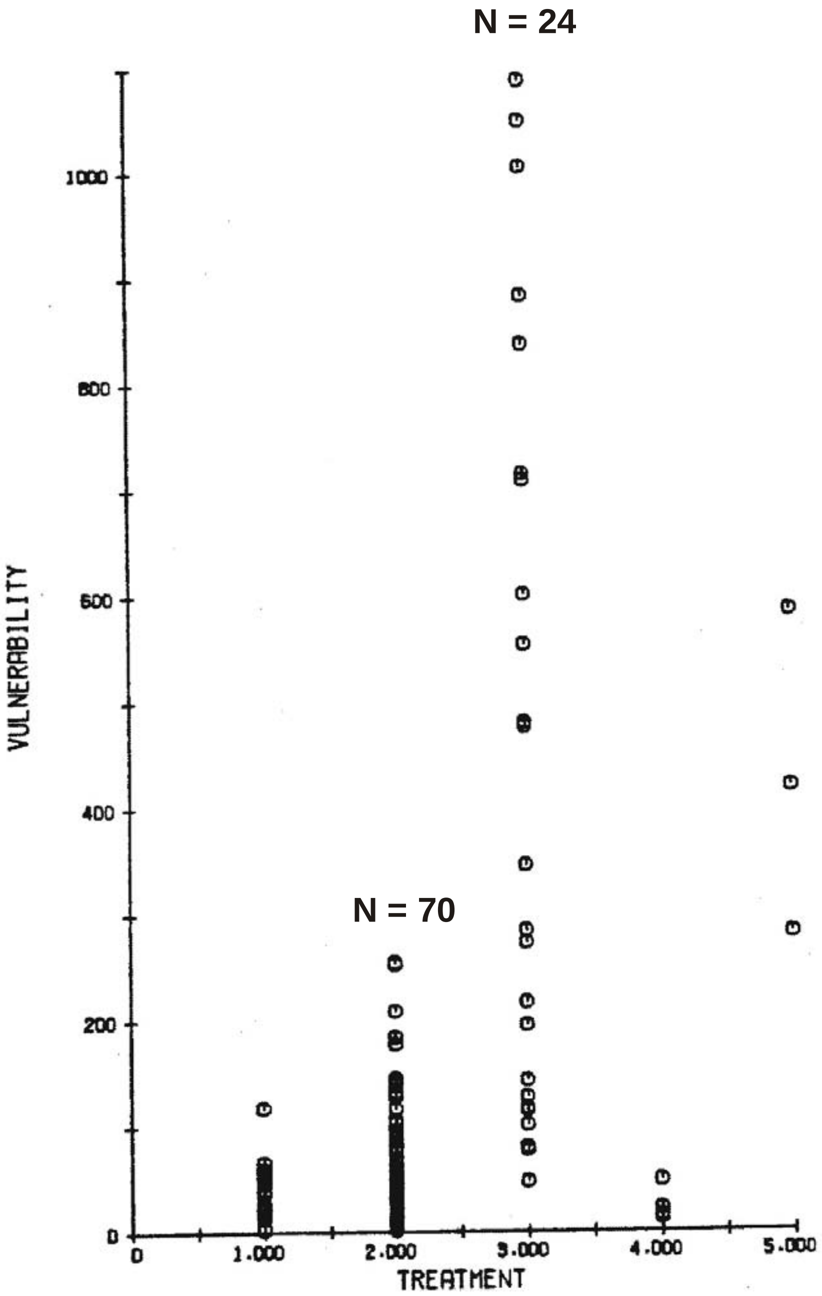


Figure 2-3. Vulnerability (E/B x 10^4) for all species combined by treatment. Plant operational treatment: 1 = reduced-flow with-cap; 2 = full-flow with-cap; 3 = full-flow without-cap; 4 = reduced-flow without-cap; and 5 = tunnel swapping, i.e., the transition period between reversed and normal flow directions. The primary focus of the studies was comparisons of treatments 1 vs. 2 and 2 vs. 3 and as a result there were few observations for Treatment 4. The data were collected at Huntington Beach in 1979 and 1980 (from Thomas et al. 1980d; Figure 6 p.14).

2.2.3 Fish Collection and Return System

In addition to using a velocity cap, Southern California Edison installed a fish collection and return system at the San Onofre Nuclear Generating Station to further reduce impingement. This system works by using angled screens and louvers, sometimes in combination with heated water, to move fishes in the intake screen wells into an area where they are collected in a large fish collection tray. The tray relocates the collected fishes into a conduit for return back to an offshore location in the ocean. This system has been shown to be very effective (Love et al. 1989). Studies have indicated that this system has reduced impingement mortality by 71.6% in terms of abundance and 89.2% in terms of biomass (MBC 2007). In addition, both the Huntington Beach and Redondo Beach power plants have used fish rescue and return procedures to reduce impingement mortality (MBC 2006a). However, fish rescue efforts have been less successful with only a 3.7% survival rate at Redondo Beach and less than 1% at Huntington Beach.

2.2.4 Use of Restoration Measures

Wetland restoration has been the primary method used by the California Energy Commission (CEC), California Coastal Commission (CCC) and California Regional Water Quality Control Boards (RWQCB) to require compensation for entrainment losses for new generation construction or re-powering. CCC required the San Onofre Nuclear Generating Station and CEC required the Huntington Beach, Morro Bay, and Moss Landing power plants to construct and/or restore coastal wetlands as a licensing condition for project approval. Coastal wetlands are an important source of habitat for many fish species and these habitats have additional functional environmental value that includes providing habitat for wildlife, including threatened and endangered bird species, as well as improving water quality. Details of these projects are readily available for San Onofre (San Dieguito River Park Staff 2000); for Huntington Beach (MOU 2007); for Morro Bay (CEC 2004) and for Moss Landing (CEC 2000). While the Court Decision determined that restoration measures cannot be used for §316(b) compliance, the projects have or will be completed as part of the California licensing requirements for construction or re-powering at these facilities.

3 EFFECTS OF ONCE-THROUGH COOLING ON CALIFORNIA FISH AND FISHERIES

In this section, the effects of entrainment and impingement on California coastal fish and fisheries due to once-through cooling (OTC) are presented. A discussion of entrainment is provided first, since it is currently viewed as the more significant effect of power plant OTC and is the more costly to address through use of technologies and/or operational measures.

3.1 Entrainment

3.1.1 Effects on Phytoplankton and Zooplankton

The entrainment performance standard for entrainment reduction in the EPA Rule focuses on addressing impacts to fish and shellfish rather than lower tropic levels such as phytoplankton and zooplankton. There are several reasons why there is a low potential for impacts to phytoplankton and zooplankton and why it made sense for EPA to focus on effects on fish and shellfish. EPA recognized the low vulnerability of phytoplankton and zooplankton in its 1977 draft §316(b) guidance (USEPA 1977). The reasons include the following:

- The extremely short generation times—on the order of a few hours to a few days for phytoplankton and a few days to a few weeks for zooplankton;
- Both phytoplankton and zooplankton have the capability to reproduce continually depending on environmental conditions; and
- The most abundant phytoplankton and zooplankton species along the California coast have populations that span the entire Pacific, or in some cases all of the world's oceans. For example, *Acartia tonsa,* one of the common copepod species found in the nearshore areas of California has a distribution that includes the Atlantic and Pacific coasts of North and South America and the Indian Ocean.

Relative to the large abundances of phytoplankton and zooplankton, larval fishes make up a minute fraction of the total numbers of organisms present in seawater. They are more susceptible to entrainment effects for the following reasons:

- Unlike phytoplankton and zooplankton that have longer reproductive seasons; fishes have much shorter spawning seasons. For many fish species, spawning occurs only once during the year;
- Unlike phytoplankton and zooplankton that may be distributed over large oceanic areas, most fishes are restricted to the narrow shelf along the coast, and in some cases have specific habitat requirements that further restrict their distribution; and
- Unlike many phytoplankton and zooplankton species, there is a greater likelihood of mortality due to entrainment of larval fishes, since many lower trophic level organisms are not soft bodied (e.g., diatoms) as is the case for finfishes and are better able to tolerate passage through cooling system.

The low potential for impacts on phytoplankton and zooplankton has been supported by studies at many East Coast facilities. For example, field and laboratory studies of entrainment effects on phytoplankton and zooplankton were conducted at the Roseton, Indian Point, and Bowline Point plants on the Hudson River during the 1970s (Central Hudson et al. 1977). Thermal tolerance studies showed that mortality of most species was less than 10%, except at high discharge temperatures that would only occur during the summer months. Field studies conducted at all three plants demonstrated no differences in microbial respiration, primary production, or zooplankton concentrations between locations near the intake structures (near-field) and locations outside the influence of the intakes (far-field).

The State of Maryland's comprehensive program on the environmental effects of power plants concluded the following:

".. that phytoplankton and zooplankton were very variable, with greatest reductions found in the summer and at plants where chlorine was used as a biocide to keep condenser tubing from being fouled. We found that phytoplankton and zooplankton populations recovered rapidly from power plant related mortalities and stresses, such that nearfield effects could not be detected except in special circumstances" (Maryland Power Plant Research Program 1986).

3.1.2 Analytical Approach to Assessing Entrainment Effects

From a theoretical standpoint, the best approach to evaluate potential environmental effects of OTC, and consequent environmental benefits by reducing or eliminating OTC, would be to compare data on fish and shellfish populations from a source water area before power plant operation to source water data for several years during operation. Entrainment and impingement losses would be measured concurrently. Ideally, data would also be available over the same time period from a similar coastal area without a power plant because many factors can affect population abundances, and these data would help in determining if the changes observed during plant operation were due to the effects of the cooling water intake or due to other natural or anthropogenic factors. Although this approach would provide a strong scientific case for determining cooling water intake effects, such data are not available from any location in California.

A less rigorous approach would be to collect entrainment and impingement data from a single power plant over time and then determine if any long-term changes could be attributed to effects of the cooling water intake system. This approach is much more problematic since it is necessary and difficult to estimate and separate out potential entrainment and impingement effects from all the other possible sources of change, natural or otherwise. Such data, for impingement only, are available from a few plants such as the San Onofre and Huntington Beach facilities in southern California. There are no long-term studies of entrainment in California. Therefore, effects of entrainment can only be examined using results from studies at power plants that were generally conducted during a single year and in a few cases comparing these results with data from more recent studies. An exception is the monitoring at the Contra Costa and Pittsburg power plants that was focused specifically on striped bass larvae and occurred only during the time of year when the larvae are present in the San Francisco Bay Delta system (USEPA 2002).

The information in Appendix B compares past and current §316(b) studies at California coastal power plants and is based on information provided in a recent CEC report reviewing cooling water intake system effects in California (York and Foster 2005). The information from the CEC report was supplemented with additional information on the methods used by referencing the original sources. The information in Appendix B shows that there are few power plants with recent cooling water studies that can be compared with previous data. Comparisons between current and previous studies are also complicated by inadequate or insufficient data from previous studies, as described in the CEC review. For example, although entrainment data were collected at a few facilities, the original operator of the majority of the power plants in southern California, Southern California Edison Co. (SCE), used data from these representative plants to characterize entrainment at other facilities rather than conducting site-specific studies. This same approach was used for the Morro Bay Power Plant in central California by Pacific Gas & Electric Co (PG&E). As a result, in some cases the historical studies include entrainment data from only a few plants presumed to be representative of the others.

Despite these shortcomings in the available data, entrainment was identified in the CEC review as the major impact due to OTC in California, but the historical record shows that this claim is based on studies from very few facilities. In addition, there are no studies on the effects of OTC that include long-term entrainment data and concurrent data from comparable coastal areas without power plants. Studies recently completed at many of the facilities in California will provide updated characterizations on the effects of OTC in California and more importantly, provide results that can be compared to previous results from the same facilities. Currently, this type of comparison for entrainment can only be done for South Bay in San Diego Bay and Encina in Carlsbad where the methodologies are comparable between the original studies and the recent studies. Although recent entrainment studies were also done at the Diablo Canyon (Tenera Environmental 2000a) and Moss Landing power plants (Tenera Environmental 2000b), entrainment estimates from the previous studies were calculated from samples collected at the discharge where abundance of larval fishes and other organisms would be expected to be reduced by biofouling organisms in the cooling water system. The same would be true of a recent entrainment study completed at the Potrero Power Plant in San Francisco Bay; the 1978–1979 Potrero entrainment data were also collected at the discharge. At the time this report was prepared, comparisons between historical and recent entrainment studies were available only for the South Bay and Encina facilities and therefore comparisons are limited to only those two plants.

Although there were few plants where comparisons between historical and recent larval entrainment rates could be made, long-term monitoring data on source water populations were available from several locations that provide indirect evidence regarding cooling water intake system (CWIS) entrainment and impingement effects. The first study was a five-year study of fish populations in San Diego Bay (Allen 1999) that sampled many of the same species that were collected in high abundance in the entrainment studies at the South Bay Power Plant. A summary of the results from this study is incorporated into the discussion of the entrainment studies at the South Bay plant in south San Diego Bay, which is presented in the next section. The second set of source water data is from ichthyoplankton sampling that was done in the 1970s in Elkhorn Slough at the same source water stations recently sampled as part of the Moss Landing entrainment studies. The results from this comparison support results from recent studies in Agua Hedionda Lagoon in Carlsbad, California for the Encina Power Station showing the importance of habitat in sustaining fish populations. This is supported by long-term data collected at King Harbor, Redondo Beach. This study of the fishes of King Harbor has been conducted since 1974 and is one of the longest term studies of fishes available from California. The intakes for the Redondo Beach Generating Station are also located in King Harbor making this data set particularly pertinent. Data on adult fish abundance from King Harbor are compared with data from the Channel Islands where no power plant is located and other impacts, including fishing pressure, should be reduced relative to King Harbor. Finally, results from long-term monitoring of adult fish populations in the vicinity of the Diablo Canyon Power Plant that were collected as part of the receiving water monitoring on the effects of the cooling water thermal discharge are presented. This is an area of central California that has a relatively low human population density and where a recent study (Stephens et al. 2006) has shown that populations of most nearshore fishery species are at sustainable harvest levels.

3.1.3 South Bay Power Plant Entrainment Study Comparisons

Plant Description

The South Bay Power Plant is located on the southeastern shore of San Diego Bay in the city of Chula Vista, approximately 10 miles north of the U.S.-Mexican border (Figure 3-1). South Bay consists of four steam turbine generating units with a combined capacity of 723 megawatts. South Bay uses the waters of San Diego Bay for cooling of its four electric generating units with two circulating water pumps supplying each unit. Individual pump output varies between units, ranging from 39,000 gallons per minute (gpm) to 68,400 gpm based on the manufacturer's pump performance estimates. The volume of cooling water circulated through the plant is dependent upon the number of pumps in operation, but with all pumps in operation, the cooling water flow is 417,400 gpm or 601 million gallons per day (mgd). After passing through the plant, the cooling water is returned to the bay through a discharge channel.

The intake structure is generally similar to other coastally-sited plants in California with onshore intakes, although each power plant has a unique configuration dependent on local geographic constraints. The South Bay intake consists of three separate screenhouses for its four units situated at the terminus of a dredged intake channel bounded by a constructed berm to the south and mudflats to the north. Cooling water for the plant enters the screenhouses through stationary bar racks that prevent larger organisms such as marine mammals and sea turtles from entering the system and also screen out any large debris that could damage the traveling water screens and circulating water pumps located behind the racks (Figure 3-2). The cooling water system is equipped with one traveling water screen for each pump. The plant uses vertical "through flow" traveling screens with a mesh size of either 3/8 inch square or 1/8 by 1/2 inch rectangular. Debris is impinged upon the screen mesh and carried upward, out of the water, with the ascending panels.

Environmental Setting

San Diego Bay is the largest estuary between San Francisco Bay and Baja California. The bay is relatively long and narrow, 15.5 miles in length and 0.6–2.4 miles wide, forming a crescent shape parallel with the coast between the city of San Diego to the north and Coronado Island/Silver Strand to the south. The bay is separated into two distinct topographic regions: the outer bay, which is generally narrow and deep, and the inner bay below the Coronado Bridge (Figure 3-1), which is wide and shallow. Exchange with the ocean is limited to a single channel at the mouth.

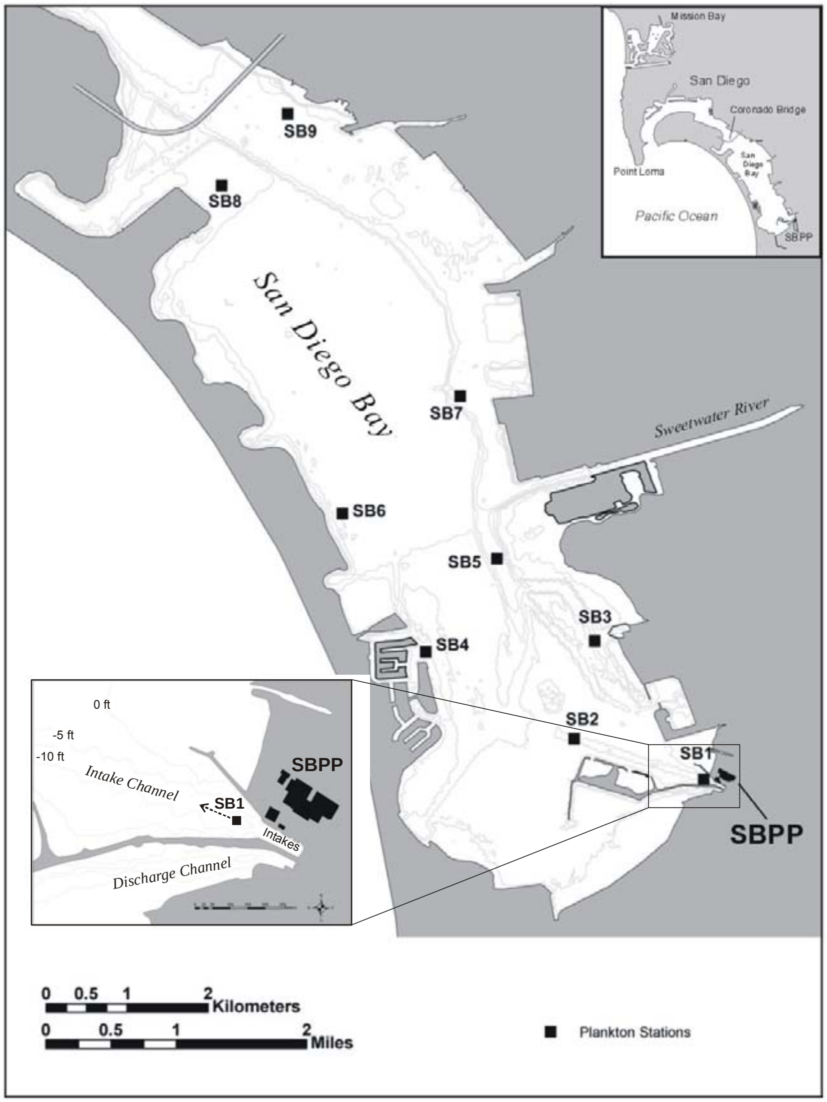


Figure 3-1. Location of South Bay Power Plant on San Diego Bay. Entrainment (SB1) and source water plankton stations (SB2–SB9) were sampled during 2001 and 2003 studies. Upper inset shows the entire bay. The lower inset shows the entrainment station in relation to SBPP with the direction and approximate length (330 ft [100 m]) of plankton tows.

Figure 3-2. South Bay Power Plant showing the intake screenhouse for Units 1& 2.

South Bay Power Plant is located along the southeastern shoreline of San Diego Bay, near the only remaining portions of natural estuarine habitats. The area is relatively shallow (<12 ft), and is characterized by warm water temperatures and sluggish tidal currents. The aquatic habitats in the vicinity of the power plant are characteristic of a protected inshore marine environment. Because of the low volume of freshwater inflow, the plant and animal communities are typical of marine and higher salinity estuarine environments. Aquatic habitats include submerged subtidal areas, eelgrass beds, mudflats, and salt marshes. Salt evaporation ponds located adjacent to the southernmost reach of the bay provide important habitat for shorebirds and migrating waterfowl.

The location of the power plant in the far end of San Diego Bay has important implications in calculating the source water for the power plant cooling water system. Computing the source volume required a compilation of areas and volumes below fixed elevations and an analysis of currents and tidal dispersion for the south part of San Diego Bay. The analyses of current patterns and tidal dispersion showed that the south part of the bay (south of the Coronado Narrows) acted as a closed system for the purposes of modeling larval entrainment. As a result, fish larvae in this confined body of water are subject to entrainment for extended periods increasing the possibility of measurable effects on fish populations.

Fish Communities

Allen (1999) conducted a study of the fishes of San Diego Bay from July 1994 through April 1999. Different types of collection gear were used to allow for sampling in all of the available habitat types throughout the bay. The gear included large and small seines, square enclosures, purse seines, and beam and otter trawls. Allen (1999) divided the bay into four ‘ecoregions’ with the power plant being located in the ‘south region’. In this region, the abundance of fishes was dominated by slough anchovy (*Anchoa delicatissima*) (66%), topsmelt (14%), arrow goby (*Clevelandia ios*) (3%), round stingray (*Urolophus halleri*) (3%), northern anchovy (2%), and shiner surfperch (*Cymatogaster aggregata*) (2%). Sample biomass was dominated by round stingray (37%), spotted sand bass (*Paralabrax maculatofasciatus*) (13%), bay ray (*Myliobatis californica*) (10%), barred sand bass (*Paralabrax nebulifer*) (8%), slough anchovy (8%), and topsmelt (7%). The total standing stock biomass of the fishes in the south ecoregion was estimated at 174,000 lb. Allen (1999) also found that the fish composition and relative abundance in this area was similar to an earlier study conducted in 1988–1989 (SDUPD 1990).

A study of the fish community in the power plant discharge channel was conducted quarterly from April 1997 through January 2000 (Merkel and Associates 2000). Over 176,000 individuals representing 38 species were collected during this study. Numerically, the catch was dominated by slough anchovy (91.4%), followed by deepbody anchovy (*Anchoa compressa*) (1.4%), round stingray (1.1%), and topsmelt (1.0%). Concentration and biomass varied between the two discharge stations and also between seasons and years.

Both of these studies did not adequately sample mudflats that are present along two-thirds of the shoreline of the south bay and are absent only along the western shore. The largest expanse of mudflat habitat in the region extends from the southern boundary of Emory Cove around the south end of the bay to the power plant site. Mudflats are rich in organic matter and support a diverse assemblage of invertebrates. An extensive assortment of birds and fishes utilize this abundant invertebrate fauna as a primary food source. Several species of gobies occupy burrows in the mud and they were the dominant fish larvae collected during both the original and recent entrainment studies.

1979-1980 Entrainment Study Summary

Entrainment studies were previously conducted at South Bay Power Plant from February 1979 through February 1980 as part of the plant's initial §316(b) Demonstration requirement (SDG&E 1980a). Pumps were used to sample plankton at the intake structure and plankton nets towed from a boat were used at four source water stations in south-central and southern San Diego Bay.

The study was focused on "critical taxa" that included 14 groups of invertebrates and fishes. The fish larvae included anchovies, silversides, gobies, black croaker (*Cheilotrema saturnum*), California halibut (*Paralichthys californicus*), and diamond turbot (*Hypsopsetta guttulata*). Estimates of total annual entrainment were much greater for gobies than any of the other taxa (Table 3-1).

Table 3-1. Total annual entrainment estimates for "critical" fish larvae from 1979–1980 reported in the South Bay Power Plant §316(b) Demonstration Study (SDG&E 1980a).

Critical Taxa	Annual Entrainment Estimate
Goby species complex	2,200,000,000
Anchovy species complex	180,000,000
Silverside species complex	14,000,000
Diamond turbot	1,400,000
California halibut	420,000
Black croaker	41,000

Source water sampling was done at one station near the plant (near-field) and at three stations further north of the plant (far-field) (one located 2.5 miles north and two located 4.8 miles north). Statistical comparisons of abundances for the "critical taxa" showed no statistically significant differences in larval concentration between near-field and entrainment stations, but overall species composition and abundance at the near-field station was different from the far-field stations, as would be expected based on the differences in habitat and closer proximity of the far-field stations to the bay entrance.

The study used a stock assessment model similar to the Empirical Transport Model (*ETM*) used in the more recent study at the power plant and in studies at other California power plants. The model and data from the 1979−1980 §316(b) study at the plant presented in MacCall et al. (1983) is one of the papers that formed the basis for the implementation of the *ETM* modeling approach in other studies in California. Comparisons of entrainment losses and source water abundances using this model showed that entrainment resulted in an estimated loss of approximately 12% of the source water standing stock of larvae. The study concluded that reductions in larval fish populations caused by entrainment through the South Bay plant's cooling water system had no significant ecological effects on populations of juveniles or adults in San Diego Bay. This conclusion was largely based on the fact that effects were mainly confined to fishes that were not targeted by commercial or recreational fishing and therefore would be better able to sustain the estimated levels of entrainment mortality.

2001 Entrainment Study Summary

Entrainment and source water sampling was conducted monthly from January 2001–January 2002 and bi-monthly from December 2002–October 2003. This was done to provide a complete year of data in 2001 (including January 2002) to describe seasonal differences in species abundances, and a comparison year in 2003 (including December 2002) to describe inter-annual variability. While the results from the sampling in 2003 were expected to confirm the initial entrainment assessment, it was recognized that the bi-monthly sampling would affect estimates for species with short larval durations that do not have extended spawning periods. Therefore, this summary only presents results from the monthly sampling in 2001.

Sample collection methods were similar to those developed and used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) in their larval fish studies (Smith and

Richardson 1977) but modified for sampling in the shallow areas of south San Diego Bay where depths can be less than 6 ft during low tides. Entrainment samples were collected from a single station (SB1; Figure 3-1) located in the power plant intake channel by towing a bongo frame with two 2.33 ft diameter openings each equipped with 335-µm (0.013 in.) mesh plankton nets and codends. Because the intake channel was bounded by a separation dike to the south and a shallow mudflat to the north, and there was a constant current flow toward the intake structure, it was assumed that all of the water sampled at the entrainment station would have been drawn through the plant's cooling water system. Entrainment samples were collected over a 24-hour period, with each period divided into six 4-hour sampling cycles. Two replicate tows were collected consecutively at the entrainment station during each cycle. Source water samples at Stations SB2–SB9 (Figure 3-1) were collected from the same vessel during the remainder of each cycle using the same gear and sample volume used for entrainment samples.

During the 2001 monthly sampling, 23,039 larval fishes from 20 taxonomic categories were collected from the entrainment station (SB1) (Table 3-2). Using maximum design flows, the total annual entrainment of all larval fishes was estimated to be 2.42 x 10^9. Entrainment samples were dominated by unidentified gobies in the *Clevelandia ios* arrow goby, *Ilypnus gilberti* cheekspot goby and *Quietula y-cauda* shadow goby (CIQ) species complex. They comprised 76% of the total estimated entrainment and together with anchovies comprised greater than 95% of the total estimated entrainment. No endangered or threatened fish or invertebrate species were collected at entrainment or source water stations during either study period. Only 17 larvae from California halibut and other commercial or recreational fishery species were collected during the study and these fishes comprised less than 0.1% of the total estimated entrainment. For this reason, no commercially or recreationally important fishes were evaluated in detail for entrainment effects. Based on estimated entrainment the following five groups of fishes were evaluated for entrainment effects:

- CIQ goby complex (comprised of arrow, cheekspot and shadow goby),
- longjaw mudsucker (*Gillichthys mirabilis*),
- anchovies,
- silversides, and
- combtooth blennies.

Table 3-2. Total annual entrainment estimates of fishes and target invertebrates at South Bay Power Plant based on monthly larval concentrations (sampled at Station SB1 from February 2001–January 2002) and design maximum circulating water flows. The survey periods used in the entrainment estimates varied in duration accounting for the differences for fishes with the same number of larvae collected.

Taxon	Common Name	Total Larvae Sampled	Estimated Total Annual Entrainment	Standard Error
Fishes				
CIQ goby complex	gobies	17,878	1,830,898,760	21,724,769
Anchoa spp.	bay anchovies	4,390	514,808,619	5,071,239
Hypsoblennius spp.	combtooth blennies	226	22,334,999	258,893
Gillichthys mirabilis	longjaw mudsucker	249	21,953,225	405,184
Atherinopsidae	silversides	140	14,521,485	384,593
Syngnathus spp.	pipefishes	101	10,013,128	329,781
Acanthogobius flavimanus	yellowfin goby	19	2,260,696	89,422
Strongylura exilis	California needlefish	8	740,045	26,934
Sciaenidae	croakers	6	706,220	38,208
Hyporhamphus rosae	California halfbeak	3	346,465	34,112
Genyonemus lineatus	white croaker	3	340,216	22,636
Hypsopsetta guttulata	diamond turbot	3	277,819	15,795
Engraulis mordax	northern anchovy	3	269,386	30,975
Ruscarius creaseri	roughcheek sculpin	2	214,553	2,914
Odontopyxis trispinosa	pygmy poacher	2	214,553	2,914
Gobiesox spp.	clingfishes	2	179,103	22,315
Cheilotrema saturnum	black croaker	1	137,775	24,745
Lepidogobius lepidus	bay goby	1	113,911	20,459
Typhlogobius californiensis	blind goby	1	107,251	20,268
Paralichthys californicus	California halibut	1	89,571	17,914
	Total Fishes	**23,039**	**2,420,527,779**	
Cancer crabs				
Cancer antennarius	brown rock crab larvae	1	99,567	18,816

South Bay Power Plant Entrainment Impact Discussion

Of the five fishes analyzed in detail for the entrainment assessment, complete life history information for demographic model estimates were only available for the CIQ goby complex, while limited life history information for anchovies and silversides allowed calculation of a demographic model that estimated the reproductive capacity of adult females lost due to entrainment. The demographic models allowed estimates of the numbers of adult gobies represented by the larval losses due to entrainment, and these ranged from 1,579,926 to 2,169,562 adults. Allen's (1999) study of the fishes of San Diego Bay provided information that was used to estimate that the average population of CIQ gobies in the South Bay source water for the 1995–1999 period was 10.6 million. This estimate was based on an average concentration of approximately 5.0 gobies per m^2 at intertidal stations in the south part of the bay where the plant is located. Estimates of equivalent adults lost due to entrainment of larvae from the 2001 data under maximum design flows, were equivalent to the loss of 15–21% of the average standing stock estimated from Allen's 1995–1999 data.

The other approach used for assessing the South Bay data was the Empirical Transport Model (*ETM*), which uses the estimates of the number of larvae entrained and the number in the source water to calculate mortality due to entrainment and the total loss from the larval population over the year. The upper range of the percentage loss to the estimated adult standing stock of gobies from the demographic model was 21%, the same estimate of proportional loss to the larvae calculated using the *ETM*. The estimates of the average annual losses of 12% and losses during peak periods of abundance of 28% from the previous study also bound the *ETM* estimates from the 2001 study. The close estimates of entrainment mortality between studies, and the agreement between multiple assessment models all provide assurance that the assessment of entrainment effects for this group of fishes is reasonably accurate.

The previous §316(b) demonstration concluded that these levels of entrainment losses should have no measurable effect on the overall goby population in south San Diego Bay. This conclusion is especially valid for fishes like gobies that appear to be well-adapted to habitats with strong tidal currents. Brothers (1975) calculated that tidal exchange alone in Mission Bay, a few miles north of San Diego Bay, would result in a larval survival rate of only 0.02% over a 15-day period, but his data showed survival rates of 0.8 to 1.7% over a two-month period. He concluded that the larvae are probably capable of some behavior that orients them to areas with reduced tidal exchange that increases their survival. In addition to the similarity in the estimates of entrainment effects between the 1979–1980 and 2001 studies, the estimated number of larvae entrained annually, 2.2 billion compared to 1.8 billion larvae in 1979–1980, were also very similar given the potential differences in operation of the cooling water system between the two years and potential for large variation among years in larval production. While this type of comparison cannot be used to determine the long-term effects of entrainment by South Bay's cooling water system since there are no data from before plant operation for comparison, it does indicate that no large-scale declines in the adult spawning stock have occurred over the time period between the two studies. The presence of a stable adult population of gobies in the vicinity of the power plant is supported by Allen's (1999) abundance data for gobies that showed increases through time during his 5-year study. The same life history adaptations of gobies that help populations survive in estuarine conditions with strong tidal export may also moderate the population effects of chronic low-level entrainment mortality.

Similar detailed comparisons are not possible for the other fishes, but entrainment estimates for silversides from the 2001 study are almost identical to the estimate from the 1979–1980 study, and estimates of anchovy entrainment from the 2001 study are much greater than the previous estimates from the 1979–1980 study. Although many factors affect the abundances of fish populations in south San Diego Bay over the 20 years between these studies, the comparisons for these fishes and the results for gobies do not show lower abundances that might be expected if entrainment losses to the larvae were impacting adult populations.

3.1.4 Encina Power Station

Plant Description

The Encina Power Station (Encina) is a fossil-fueled steam electric power generating station that began operation in 1954. Encina is located in the City of Carlsbad, California, adjacent to the Agua Hedionda Lagoon on the Pacific Ocean and approximately 30 miles north of the City of San Diego (Figure 3-3). Cooling water is withdrawn from the Pacific Ocean via the Agua Hedionda Lagoon. The power plant consists of five steam turbine generating units and a small gas turbine unit with a combined capacity of 939 MWe. The combined cooling and service water design flow is 857 mgd at full operating capacity. After passing through the plant, the heated seawater is discharged to the ocean through a shoreline forebay and conveyance channel (Figure 3-4).

Cooling water for all five steam-generating units is supplied through a common intake structure located at the southern end of the outer segment of the lagoon, approximately 2,800 ft from the opening of the lagoon to the ocean. Seawater entering the cooling water system passes through metal trash racks on the intake structure and into two 12 ft wide tunnels that further split into four 6 ft wide inlet tunnels. Vertical traveling water screens are positioned upstream of the cooling water pumps to prevent fishes and debris from entering the cooling water system and potentially clogging the condensers.

Environmental Setting

The aquatic environment in the vicinity of the power plant consists of Agua Hedionda Lagoon and its seasonal tributaries, and the open coastal waters of the Pacific Ocean. Agua Hedionda Lagoon is a coastal lagoon system consisting of three interconnected segments situated at the seaward end of the Agua Hedionda Creek drainage (Figure 3-3). Historically, the lagoon was a natural, seasonal estuary characterized by frequent closings of the lagoon mouth, especially in summer months. The lagoon was first dredged from 1952 to 1954 in order to increase the lagoon volume to provide a cooling water source for the power plant, thereby establishing a permanent opening and tidal connection with the nearshore coastal waters. The present lagoon system consists of three basins: the outer, middle, and inner lagoons. The outer lagoon is connected to the Pacific Ocean through an inlet channel formed by two jetties.

The coastal region where Agua Hedionda Lagoon is located is part of the Southern California Bight whose nearshore is punctuated by headlands and submarine canyons. The Southern California Bight extends from Point Conception south to Cabo Colonet in Baja California about 120 miles south of the U.S.-Mexico border. The inlet to the lagoon serves as the source of coastal oceanic water for cooling the power plant. In general, this water flows through the outer lagoon to the power plant and to the middle and inner lagoons during flood tide, while the lagoon itself is the source of cooling water during slack and ebb tidal conditions. Despite the relatively short residence time of “old water” in the lagoon, large populations of resident fishes are present.

The primary source waterbody for extracting Encina cooling water is the outer lagoon. However, because of the large tidal exchange rate between the outer lagoon and nearshore coastal waters, and also the contiguous tidal connections with the middle and inner portions of Agua Hedionda Lagoon, these waters are also part of the greater source water for the power plant. One of the most recent comprehensive studies on the biological characteristics of the lagoon was done by MEC Analytical Systems (1995) in preparation for potential dredging within the lagoons. An earlier comprehensive study of lagoon and nearshore biological resources was done by SDG&E (1980b) for the original Encina §316(b) demonstration done in 1979–1980.

Agua Hedionda Lagoon contains several highly productive habitats that are favorable for the growth of early stages of fishes and invertebrates. Habitats include open water, sand and mud substrates, eelgrass, rock revetment, pilings, and aquaculture grow-out floats. Utilization of the lagoon is variable among species. There are permanent residents that utilize particular habitats in the lagoon for resting, feeding and spawning throughout their lifetime. There are also transient species whose adults use the lagoon for spawning seasonally and whose young subsequently utilize the area as a nursery ground.

Fish Communities

A study by Horn and Allen (1976) showed that the number of fish species in Agua Hedionda Lagoon (55 species) was similar to that of other embayments of similar size examined in southern and central California. A total of 79 fish species was collected during the original SDG&E (1980b) impingement study, which included additional sampling in the lagoon using an otter trawl. Other bays examined by Horn and Allen (1976) were: Anaheim Bay with 59 species, Alamitos Bay with 43 species, Elkhorn Slough with 69 species, Bolinas Lagoon with 41 species, and Newport Bay with 78 species. The lagoon is primarily a marine environment but can be influenced by seasonal freshwater inflows mainly from December–April.

Additional fish surveys were done by MEC (1995) using several types of sampling gear including otter trawl, beam trawl, and beach seine. A total of 35 species of fishes was found during the 1994 and 1995 sampling. The middle and inner lagoons had more species and higher abundances than the outer lagoon. During the 1995 survey, only four species were collected in the outer lagoon, compared to 14 and 18 species in the middle and inner lagoon, respectively. The sampling did not include any surveys of the rocky revetment lining the outer lagoon that would have increased the abundance and number of species collected. Silversides (Atherinopsidae) and gobies (Gobiidae) were the most abundant fishes collected. Silversides, including jacksmelt (*Atherinopsis californiensis*) and topsmelt, occur in schools in shallow waters where water temperatures are warmest and these were most abundant in the shallower middle and inner lagoons. Gobies were most abundant in the inner lagoon, which has large shallow mudflat areas that are their preferred habitat. The species composition generally reflected the open tidal exchange conditions with nearshore coastal waters, especially in the outer lagoon; some of the more abundant marine species included spotted sand bass, barred sand bass, queenfish, shiner surfperch, giant kelpfish (*Heterostichus rostratus*), California halibut, and diamond turbot.

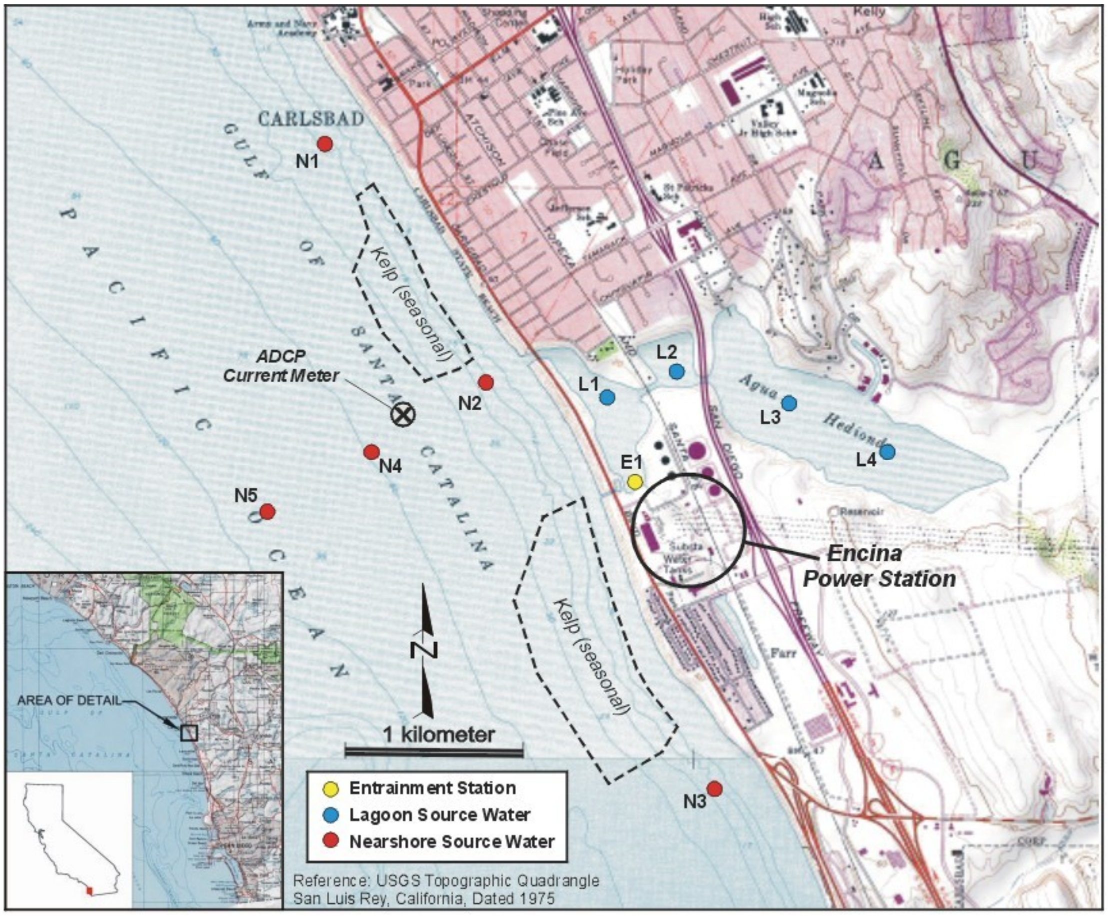


Figure 3-3. Locations of Encina Power Station and entrainment and source water plankton stations sampled during 2004–2005 studies (Tenera Environmental *in prep*.).

Figure 3-4. Encina Power Station cooling system intake and shoreline discharge.

1979-1980 Entrainment Study Summary

A one-year entrainment and source water characterization study was conducted at Encina beginning in 1979. Plankton samples were collected monthly at five offshore stations using 505- and 335- micron (0.02 and 0.01 in.) mesh nets attached to a 2 ft diameter bongo net system. Collections were made monthly in the middle and inner segments of the lagoon and every two weeks in the outer lagoon. Entrainment samples were also collected every two weeks using a plankton pumping system in front of the intakes. Although most samples were collected during daylight hours some samples were occasionally taken in the evening or early morning hours.

Anchovies were the most abundant larval forms in both the source water and entrainment samples, followed by croakers and sanddabs (Table 3-3). There were fewer fish eggs and more goby larvae in the entrainment samples whereas kelp bass (*Paralabrax clathratus*) and sand bass larvae were substantially more abundant in the combined source water samples from the lagoon and offshore. Overall the average composition between the entrainment and source water data sets was very similar for the ten most abundant taxa. Only English sole (*Parophrys vetulus*), were among the top ten entrainment taxa not represented in the top ten source water taxa.

Entrainment losses were calculated for each two-week sampling interval by multiplying the average plankton concentrations at the intake by the volume of cooling water drawn through the plant during that period. Annual estimates of the abundance of ichthyoplankton entrained through the power plant ranged from 4.15 to 6.66 billion individuals per year depending on the mesh used in the sampling. Fish eggs comprised 98% and 86% of the total annual ichthyoplankton entrainment for the two estimates.

Table 3-3. Average annual concentrations during 1979 of the ten most abundant larval fish taxa in source water and entrainment samples collected at the Encina Power Station.

Common Name	Taxon	Source Water concentration (mean # per 100 m^3)	Entrainment concentration (mean # per 100 m^3)
anchovies	Engraulidae	952.7	855.2
croakers	Sciaenidae	341.7	400.6
sanddabs	*Citharichthys* spp.	73.2	82.7
fish eggs	unidentified fish egg	33.8	20.2
gobies	Gobiidae	29.2	42.9
silversides	Atherinopsidae	8.3	10.8
wrasses	Labridae	6.4	4.0
combtooth blennies	*Hypsoblennius* spp.	6.1	5.7
sea basses	Serranidae	5.1	0.9
rockfishes	*Sebastes* spp.	2.8	2.5
English sole	*Parophrys vetulus*	0	1.9

Entrainment impacts were assessed by qualitative comparisons of entrainment losses to the estimated numbers of larvae in nearby source waters, comparisons of additional power plant mortality to natural mortality rates, entrainment probabilities based on current studies, and primary productivity studies. It was concluded that the entrainment of 18 million fish larvae and eggs daily was small compared to the egg and larval concentrations measured in monthly plankton tows in the source waterbody and amounted to about 0.2% of the plankton available within one day's travel time by current transport from the power plant. With natural mortality rates assumed to be 99% for egg and larval stages of most marine fish species, the authors of the report concluded that the additional mortality from the power plant was not significant.

2004–2005 Entrainment Study Summary

A total of 20,601 larval fishes representing 41 taxa was collected from the entrainment station (Station E1 in Figure 3-3) during 13 monthly surveys in the 2004–2005 sampling period (Tenera Environmental *in prep* – report being prepared for submittal to San Diego Regional Water Quality Control Board). Gobies (a complex of three species termed the CIQ goby complex) and blennies comprised over 90% of all specimens collected, with anchovy larvae the third most abundant taxon at approximately 4%. Most of the larvae collected from the entrainment samples did not have direct recreational or commercial fishery value, and those with fishery value were in low abundance. Only a single Cancer crab megalops larva was identified from the entrainment samples.

The CIQ goby complex were collected in the highest numbers in the entrainment samples (Table 3-4). This species group has no commercial or recreational value but plays an important role in the lagoon ecosystem as potential forage for predators. Highest concentrations of larval gobies occurred in the inner lagoon and lowest concentrations in the nearshore areas outside of the lagoon. Monthly concentrations were typically several hundred per 100/ m^3 in the inner and middle lagoon segments and over 100/100 m^3 in the outer lagoon. Similar but slightly lower concentrations were measured in the earlier §316(b) study done in 1979–1980 (SDGE 1980b), with goby concentrations averaging almost 50/100 m^3 in samples from the lagoon. The higher concentrations in the recent studies are noteworthy since infilling of the middle and inner lagoon segments and development of sandbars at the western edge of the inner lagoon (MEC 1995) have probably resulted in a reduction in total habitat area in recent years.

Encina Power Station Entrainment Impact Discussion

The comparison on the abundance of larval gobies between the two studies does not provide any evidence that they are substantially affected by the cooling water intake system that removes a substantial percentage of the larval population. Even with a substantial fraction of the source larval production lost due to entrainment, the lagoon habitat appears to sustain a large population of gobies and other fishes, as evidenced by the large larval concentrations that are over 70 times that of the nearshore source water.

Table 3-4. Average annual concentrations of larval fishes at entrainment station for Encina Power Station from sampling conducted during 2004–2005. Fishes presented are for comparison with data collected during 1979 study (Table 3-3).

Taxon	Common Name	Average Concentration (per 100 m^3)
Gobiidae (CIQ complex)	gobies	222.29
Other gobies		
Typhlogobius californiensis	blind goby	2.47
Acanthogobius flavimanus	yellowfin goby	1.44
Gillichthys mirabilis	longjaw mudsucker	0.21
Hypsoblennius spp.	blennies	110.77
Engraulidae	anchovies	13.43
Hypsypops rubicundus	garibaldi	4.10
Atherinopsidae	silverside	0.92
Citharichthys spp.	sanddabs	0.22
Paralabrax spp.	sea basses	0.19
Sciaenidae	croakers	0.19
Other croakers		
Roncador stearnsi	spotfin croaker	
Genyonemus lineatus	white croaker	0.83
Seriphus politus	queenfish	0.70
Cheilotrema saturnum	black croaker	0.03
Menticirrhus undulatus	California corbina	0.02
Labridae	wrasses	0.02
Other wrasses		
Oxyjulis californica	señorita	0.01

In a lagoon or bay such as Agua Hedionda that is significantly affected by tidal exchange, many of the larvae produced by adult fishes in the lagoon are inevitably lost to the system due to export by outgoing tidal currents. A hydrodynamic study showed that the entire volume of the lagoon was turned over within 6.3 tidal cycles or 3.2 days, which, in the absence of behavioral mechanisms to allow larval retention, would result in the loss of all of the goby larvae from the lagoon before they developed to the stage when they recruit into their adult habitat, a period of about 60 days (Brothers 1975). Fishes and other organisms that inhabit lagoons with strong tidal currents have behavioral adaptations that cause larvae to migrate toward the bottom or move to areas with less current and minimize export (Brothers 1975) or, in larger systems, have mechanisms that allow some larvae to return to the estuary after a period of development in offshore waters. In addition, results of detailed hydrodynamic modeling of tidal processes indicate that exchange rates can vary considerably within the lagoon (Fischer et al. 1979), especially in the middle and inner segments where the majority of the goby habitat is located. Larvae that are transported into coastal waters can provide genetic exchange between estuarine areas along the coast by moving back into bays with incoming tidal currents. However, these exported larvae probably experience much higher mortality rates in the open ocean than those that are retained in their natal estuaries. Although the Encina intake and discharge increases the export rate of larvae from the lagoon over natural transport, it mainly affects the outer lagoon where larvae are less abundant, and many of these larvae would be lost to the system even under natural conditions.

Determining the actual effects of larval losses on adult goby populations assumes that there is available habitat to support the additional production in the source water, which is not usually the case for substrate-oriented or territorial species such as gobies. In contrast, species that live in open water environments, such as anchovies, are generally not limited by habitat availability but by other factors such as food availability, oceanographic conditions, or predation. In Agua Hedionda Lagoon where there is a limited amount of benthic habitat, density-dependent mortality may be a substantial factor affecting post-settlement recruits (Brothers 1975). Studies of adult goby populations in the lagoon (Appendix C) done in connection with the 2004–2005 study showed large decreases in the numbers of juvenile gobies from spring (54/m^2) through summer (10/m^2). The increasing mean length in the population between the two sampling periods reflected the high mortality rate on juvenile gobies recruiting into the mudflat habitat. This shift in abundance and size was also shown in a previous study on the fishes in Agua Hedionda Lagoon (MEC 1995). The average concentration of CIQ gobies of all sizes was 24.3/m^2, which yields an estimate of almost 100,000/acre resulting in a rough estimate of 4.5 million CIQ gobies in the shallow areas of the middle and inner lagoons, not including habitat exceeding -4 ft MLLW (mean lower low water) or the deeper habitat in the outer lagoon.

The limited habitat area in the lagoon coupled with the short generation times of gobies (1-3 years) explains why the population concentrations are similar to other small lagoons in southern California that have no additional mortality from OTC systems. Steele et al. (2006) sampled several of the small lagoons in San Diego County, including Batiquitos, Los Penasquitos, San Dieguito, and San Elijo lagoons, using the same enclosures used in the Encina supplemental study. They reported an average concentration of CIQ gobies from all of their sampling of 25.8/m^2. The goby concentrations from Steele et al. (2006) and the Aqua Hedionda studies are much higher than values reported from other studies because of the increased efficiency of the sampling enclosures used in these studies.

The importance of available habitat as the limiting factor in these fish populations is further shown by the results for blennies, a group of small fishes that live in crevices in rocks and the spaces within and between mussels, barnacles and other components of the fouling community that form on rocks, piers, and other structures. The aquaculture floats in the outer lagoon that are used to culture mussels and oysters, and the rock revetments around the lagoon provide extensive potential habitat area for blennies. The increase in the aquaculture operations since the 1979 studies helps explain the increase in concentrations measured in the outer lagoon between the two studies. Concentrations exceeded 100/100 m^3 during the 2004–2005 study (Table 3-4), but averaged only 6.7/100 m^3 during the 1979 study (Table 3-3). The comparison with previous study results for blennies contrasts with the results for gobies that showed only slightly increased concentrations in the recent study. Whereas the habitat for gobies has declined slightly since the previous study, the habitat for blennies has increased significantly due to the placement of artificial habitat in the outer lagoon.

3.1.5 Summary of South Bay and Encina Entrainment Studies

In discussing the potential effects of OTC on fish populations the primary consideration is the life history of species in the community. Although the results discussed from these two cooling water intake system studies focused on species potentially affected by entrainment, it is important to note that several fish species in south San Diego Bay, Agua Hedionda Lagoon, and nearshore coastal areas have early life stages that are not susceptible to entrainment. Live-bearers, such as surfperches and some sharks and rays, produce young that are fully developed and too large to be affected by entrainment. Data from Allen (1999) show that live-bearers together comprised nearly 40% of the estimated fish biomass in the San Diego Bay. Another common species in both south San Diego Bay and Agua Hedionda Lagoon, striped mullet (*Mugil cephalus*), also is not susceptible to entrainment because it spawns offshore and only the juveniles and adults subsequently utilize bay habitats. From the standpoint of impingement effects, one of the most abundant groups of species in protected bays and estuaries, gobies, are generally not susceptible to impingement after transformation to the juvenile life stage because they are bottom-dwelling species that typically do not move up into the water column. Even fish species that swim in the water column are generally not susceptible to impingement effects as they mature because they are able to swim against the slow approach velocity of the cooling water inflow. For example, at the South Bay Power Plant intakes it was not uncommon to see small schools of adult striped mullet swimming directly in front of the intakes and not being impinged during times when circulating water pumps were operating.

Other important considerations in assessing the effects of power plant cooling water systems are the habitats and hydrodynamics of the source waterbodies used for cooling. The source waters for the South Bay and Encina power plants are two examples where large impacts due to OTC might be expected. In the case of the South Bay Power Plant, the source water of south San Diego Bay is functionally a closed system where outside sources have less potential for replenishing larvae lost due to entrainment thereby increasing the potential for population impacts. In the case of the Encina Power Station, the source water volume of Agua Hedionda Lagoon is small relative to the volume of cooling water withdrawals, which also increases the potential for population impacts.

While it is impossible to make definitive statements regarding power plant impacts to these populations because of the numerous factors affecting fish abundances, the results from these two studies and associated studies do not provide evidence that OTC has negatively affected fish populations in either location. The resident goby populations that are most susceptible to the effects of entrainment seem to be thriving in both locations. The large numbers of small gobies available to recruit into available mudflat habitat in Agua Hedionda Lagoon is evidence that these populations are more likely to be limited by available habitat and not by the supply of larvae that might be reduced through entrainment. Studies show that these species are well adapted to living in an environment where strong tidal currents can result in transport of larvae into nearshore areas where they are unable to survive. The dependence on habitat as the limiting factor for these populations is supported by results from the Encina study for blennies showing large order of magnitude increases in larval abundance over time as more habitat for the adults of this group of fishes was created in the lagoon. The relationship between changes in available habitat and larval production is further supported by studies of fish larvae from Elkhorn Slough presented in the following section.

3.1.6 Ichthyoplankton Studies in Elkhorn Slough and Moss Landing Harbor

Elkhorn Slough is a shallow tidal embayment and seasonal estuary that borders Monterey Bay and provides habitat for at least 65 species of fishes (Yoklavich et al. 1991). The slough entrance from the ocean is a constructed boat harbor where the cooling water intake for the Moss Landing Power Plant (Moss Landing) is also located (Figure 3-5). The main channel of Elkhorn Slough extends approximately 6 miles inland and is intersected by a network of tidal creeks. Yoklavich et al. (1992) sampled the seasonal abundance and distribution of larval fishes in Elkhorn Slough from 1974–1976, and Tenera Environmental (2000) conducted a similar study in 1999–2000. Both studies used similar sampling methods to collect larvae. The two studies were largely comparable but some of the results were potentially affected by small differences in the methods used by each study. These differences are discussed in detail in Appendix D.

Larval fish samples were collected at several stations along the length of Elkhorn Slough ranging from the shallow (-10 ft MLLW) inland station at Kirby Park to the deeper (-23 ft MLLW) ocean entrance of the slough at the mouth of Moss Landing Harbor (Figure 3-5). Stations common to both studies were Kirby Park (KP), Dairies (DR), Harbor Bridge (HB), and Harbor Mouth (HE). The locations of the KP and DR stations were largely the same for both studies. Two basic types of apparatus were used to collect samples from a small boat: 1) a bow-mounted single-hoop push net, and 2) a stern-mounted dual-hoop tow net ("bongo"). Details on the sampling are provided in Appendix D.

The changes in ichthyoplankton between the two studies show large increases in concentrations of larvae from fishes that are slough residents (Table 3-5), the fishes that would be expected to be most affected by entrainment from Moss Landing. The large increase in larval abundances from slough resident fishes was mostly attributed to increases in arrow goby abundance, one of the species in the CIQ goby complex. Although there was a large increase in arrow goby abundance between studies there was also a decrease in the abundance of longjaw mudsucker larvae, another species of goby. There are numerous factors that could have caused the differences between studies, including the retirement of Moss Landing Units 1-5 in the mid 1990s that discharged into the slough (Figure3-5). The changes in composition with the shift in dominance from longjaw mudsucker and arrow goby is more likely due to a change in habitat type and quality in Elkhorn Slough throughout the 1980s and 1990s.

Enlargement of the Moss Landing Harbor area and a series of dike and levee failures in the 1980s significantly increased the tidal prism, current velocities, and circulation throughout Elkhorn Slough resulting in accelerated bank erosion, deeper and wider channels, increased area of mudflats, and thinning of salt marsh vegetation (Malzone and Kvitek 1994). This likely reduced the area of preferred habitat of the longjaw mudsucker, which is largely distributed among shallow channels of tidal marshes. The same conditions may have favored arrow goby, which have broader habitat requirements and occur on mud substrates throughout the slough. The increases in both larval concentrations and numbers of taxa during the 15-year period between studies would not be expected if the increased larval mortality due to entrainment was affecting fish populations in Elkhorn Slough.

The Central Coast Regional Water Quality Control Board Staff Report on the Moss Landing Power Plant National Pollutant Discharge Elimination System (NPDES) Permit from May 15, 2003 included a review of the long-term studies on the fish fauna of Moss Landing Harbor and Elkhorn Slough by researchers at the Moss Landing Marine Laboratories which stated that "…*in general, the species composition and overall densities of the dominant fish larvae appear to have remained fairly similar, with some species of fish larvae being considerably more abundant in 1999–2000 than in previous decades. The main categories of* *fish larvae exhibiting higher densities were gobies, the Pacific herring, Pacific sand lance, staghorn sculpin, white croaker, true smelts, and blennies.*" In regards to the observed changes in larval fish composition, the staff report further stated that "*…the intakes for that plant are in Moss Landing Harbor, and there is no evidence that water from Elkhorn Slough specifically was entrained in sufficient volume to cause these changes in the ichthyofauna.*"

Table 3-5. Classification of larvae by abundance and composition (number of taxa) in Elkhorn Slough based on typical adult occurrence. Occurrence categories from Yoklavich et al. (1991, 1992).

Adult Occurrence	Percent by Abundance		Percent by Taxa Composition	
Category	1974–1976	1999–2000	1974–1976	1999–2000
Marine	6.7	4.7	53.6	35.1
Marine immigrant	34.7	10.3	21.4	21.6
Slough resident	56.1	82.4	21.4	35.1
Partial resident	0.9	1.6	3.6	5.4
Freshwater	0.0	0.2	0.0	2.7

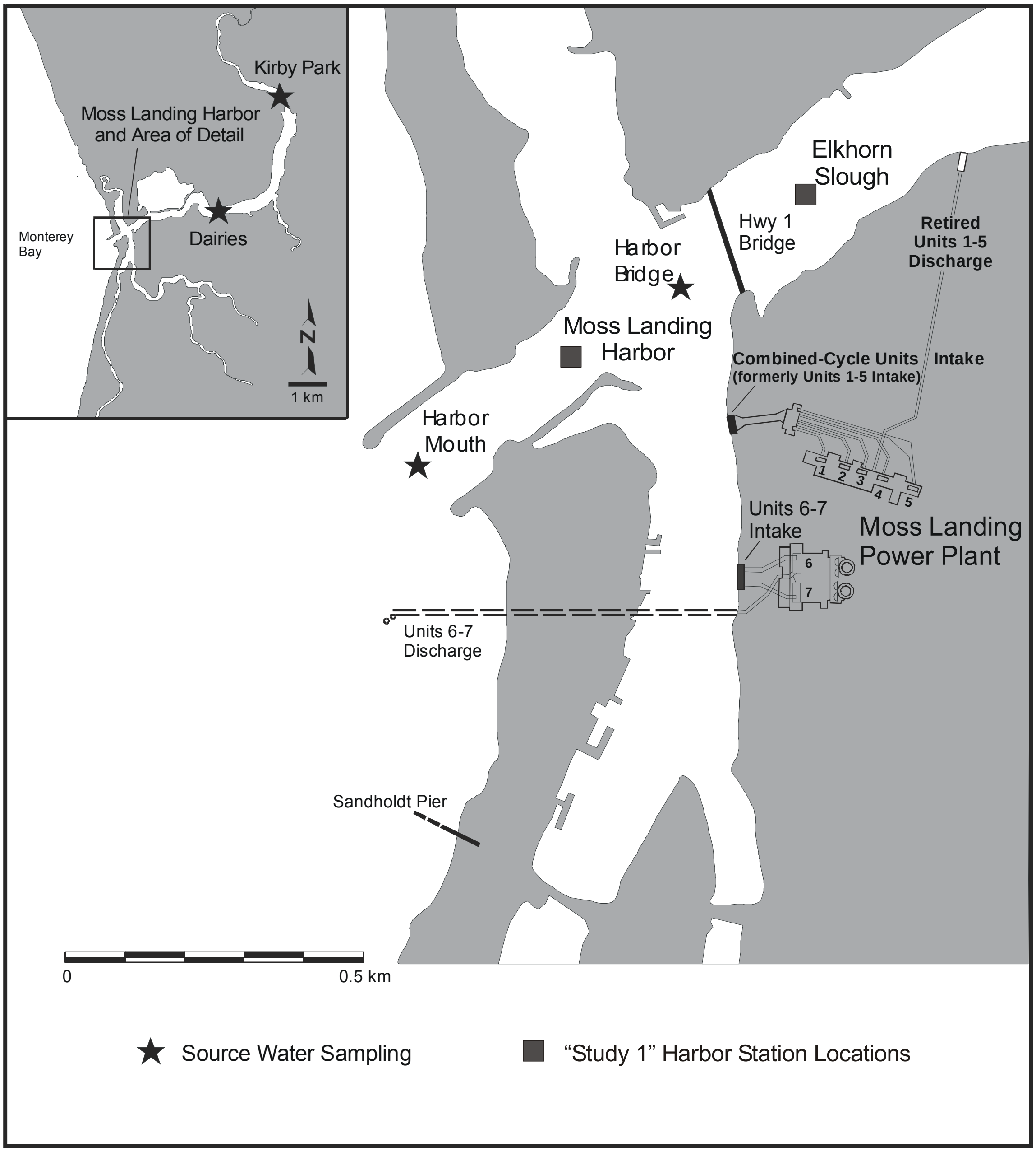


Figure 3-5. Elkhorn Slough and Moss Landing Harbor larval fish sampling locations in relation to the Moss Landing Power Plant. Retired units were operating as part of the OTC system during the 1974-1976 study but not during the 1999-2000 study.

3.1.7 Other Ichthyoplankton Studies in Coastal Lagoons and Embayments

The importance of available habitat as a factor controlling populations is particularly acute in many fishes in the tropics on coral reefs. One of most abundant fish larvae entrained at Encina Power Station was the garibaldi, a conspicuous orange damselfish that is the California state fish. The damselfishes are one of the most prominent groups of fishes on coral reefs throughout the tropics. The garibaldi is abundant throughout southern California and normally occupies rocky habitat in nearshore areas out to depths of 100 ft, but in Agua Hedionda Lagoon occurs along the rock revetment surrounding the outer lagoon. In these habitats the adult garibaldi maintain and defend a territory which includes a shelter hole, grazing area, and for some males, a nest site (Clarke 1970). The garibaldi also occurs in other harbor areas including King Harbor in Redondo Beach where long-term monitoring of fishes has been conducted by the Vantuna Research Group since 1974 (Pondella and Stephens 1994, Stephens et al. 1994). The cooling water intakes for the Redondo Beach Generating Station are also located in King Harbor. These and other long-term data on coastal fishes were recently summarized as part of a California Department of Fish and Game statewide monitoring study (Tenera Environmental 2006a).

Results for garibaldi abundance from diver transect surveys at King Harbor and from the Channel Islands National Park monitoring program are provided because, similar to gobies, it is a fish 1) with strong habitat dependence, 2) that is not subject to fishing pressure since it is protected from sport and commercial fishing, and 3) that has larvae that are subject to entrainment. The results from the two monitoring programs show very similar abundances for garibaldi over the time period from 1985–2003 when the two data sets can be compared (Figure 3-6). Since garibaldi is not fished, one of the primary differences between the two areas where the data were collected is the presence of the intakes for the Redondo Beach Generating Station. An entrainment study for the Redondo Beach Generating Station was recently completed, but regardless of the levels of entrainment estimated for garibaldi it appears that the additional larval mortality due to entrainment have had no effect on adult population levels. This is not unexpected since, as discussed by Clarke (1970), garibaldi populations are more likely limited by food supply or by the minimal space requirements for nesting males.

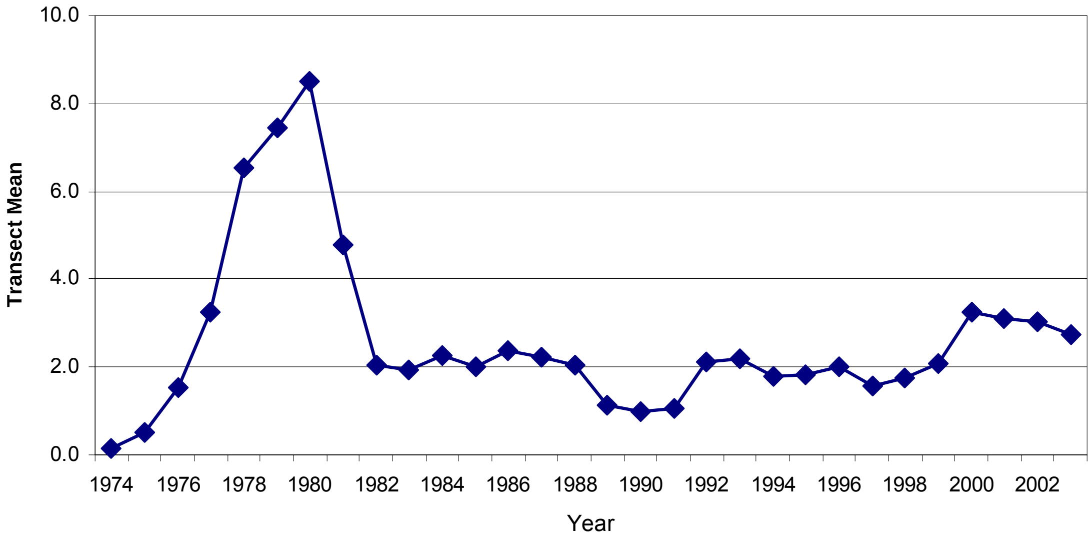
3.1.8 Conclusion on Effects of Entrainment on Fishes in California Coastal Lagoons and Embayments

Entrainment studies at power plants located in coastal lagoons and embayments have consistently shown that the large percentage of entrained larvae are from resident fishes that are important components of the ecosystem largely as a forage base for other organisms. At both the South Bay and Encina power plants the larvae from these species accounted for over 90% of the total larvae entrained. These fish populations do not experience additional mortality due to fishing as adults and therefore may be less affected by the additional mortality due to entrainment at the larval stage. It is also instructive to focus on these fishes rather than the larger more conspicuous commercial and recreational species because the potential effects of entrainment should be greater to resident species and any potential effects on adult populations are not masked by the additional mortality due to fishing. The commercial and recreational important species from these studies are typically entrained in very low numbers, and since these species are typically not resident in the immediate source water for power plant cooling, the larvae lost due to entrainment represent a much smaller percentage of the source of larvae available to the population.

The enclosed nature of the source waters for power plants located in coastal lagoons and embayments would seem to result in a potential for larger impacts due to entrainment, but independent studies on fishes from San Diego Bay, Agua Hedionda Lagoon, and Elkhorn Slough all show that the populations of the fishes in these locations are similar to other estuarine areas without power plants. Research shows that many of these species have behavioral adaptations to living in an environment where large tidal currents have the potential to remove the majority of the early life stages before they develop to an age where they can move into their adult habitats.

The results from these studies also show that availability and quality of habitat are probably the most important factors in sustaining the fish populations most susceptible to entrainment effects of OTC. For this reason, a State policy that focuses on restoration will provide much more benefit to the biological resources of the State than reducing or eliminating the use of OTC by California's power plants.

a) King Harbor



b) Channel Islands East (Anacapa and Santa Cruz Islands)

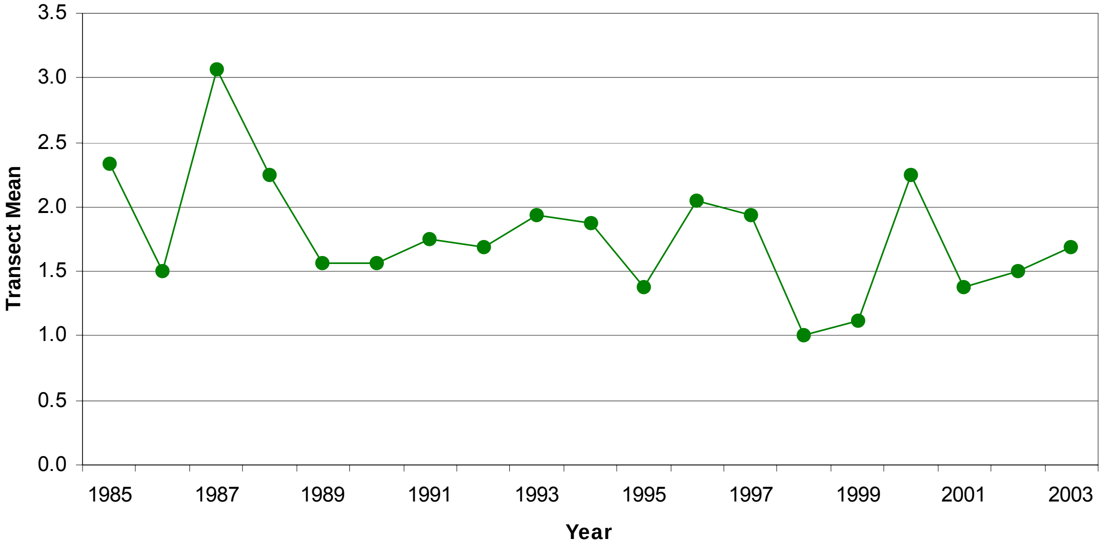


Figure 3-6. Average annual abundance of garibaldi along benthic fish transects sampled at a) King Harbor, Redondo Beach, CA, and b) the Channel Islands National Park at Anacapa and Santa Cruz Islands. Data summarized as part of a California Department of Fish and Game statewide monitoring study (Tenera Environmental 2006a).

3.1.9 Effects of Entrainment on Fish Populations from Open Coastal Habitats

Studies at most of the power plants located on the open coast have only recently been completed in response to the new Phase II §316(b) regulations and the data from these are currently being analyzed. While these results will provide a more complete picture of entrainment effects on coastal fish populations there are data from the Huntington Beach Generating Station and Diablo Canyon Power Plant that can be used to examine effects on open coastal habitats.

The Huntington Beach Generating Station is located along the open coast in Orange County. Entrainment and impingement studies were recently completed in response to requirements of a permit from the California Energy Commission for re-powering and operating Units 3 and 4, which were retired from service in 1995 (MBC and Tenera Environmental 2005). Regular impingement sampling at the facility has been done for many years and represents one of the best long-term impingement data sets in southern California. The results from the impingement studies are provided in Section 3.2, while the results of the entrainment studies are presented in the following paragraphs.

The study to examine entrainment effects included sampling in the immediate proximity of the cooling water intake, which was done at least monthly from September 2003–August 2004. During each sampling event, two replicate tows at the entrainment station were collected four times per 24-hr period—once every six hours. The sampling was conducted offshore (within 100 m) of the submerged intake structure (Figure 3-7) using an oblique tow that sampled the water column from approximately 13 cm off the bottom and then back to the surface. Six source water stations upcoast, downcoast, and offshore from the entrainment station were also sampled at least monthly (Figure 3-7) using the same procedures used for the entrainment sampling. Samples were returned to the laboratory and processed using the same procedures described for the South Bay and Encina studies.

A major difference between the results for the coastal site at the Huntington Beach Generating Stations and the enclosed bays sites for the Encina and South Bay power plants is the much lower numbers of larvae entrained. Even though the cooling water flows for South Bay are much less than Huntington Beach, the total annual entrainment of fish larvae was much larger (2.4 billion vs. 345 million [Table 3-6]). The difference for the larger Encina plant was even greater. The most abundant fish larvae collected at Huntington Beach were gobies that occur in the nearshore ocean after being transported out from spawning locations in nearby harbors and wetlands. These larvae have been transported out of their native habitats and only function as a food source for larger open coastal fishes. The fate of goby larvae is similar to other larvae such as lampfish, which are deep-water fishes that are transported onshore from their normal habitat. These species are typically not the focus of detailed analysis in these studies because they represent larvae that are not in their native habitats and their loss would represent very little risk to their source populations.

The total annual entrainment estimates of important nearshore fishes such as queenfish and other croakers, California halibut, and sea basses were very low (Table 3-6) relative to the numbers entrained from the examples of the power plants located in coastal lagoons and bays. Another way to place the low numbers into context is based on the reproductive capacity, or fecundity, of a species. For example, the estimated entrainment for California halibut larvae of five million larvae is only about 2% of the estimated lifetime fecundity of 233 million eggs from one female (estimated from data in MacNair et al. 2001). Similarly, the estimated entrainment for white croaker of 17.6 million larvae equals the total lifetime fecundity (2.3 million eggs from data in Love et al. 1984) of approximately eight females. Demographic modeling of the entrainment effects, which would extrapolate the numbers of larvae entrained to an equivalent number of adults, was not done for these species, but based on these comparisons the number of adult equivalents lost due to entrainment would be very small.

The low potential for impacts from Huntington Beach Generating Station is primarily based on the Empirical Transport Modeling (*ETM*) results, which was the primary approach for analyzing data from the entrainment and source water stations and was also used for the South Bay and Encina power plant studies. The proportional mortality due to entrainment estimated using the *ETM* was based on the maximum cooling water volume for Huntington Beach and a sampled source water volume of 239 billion gallons. Based on these estimates, the Huntington Beach plant entrains 0.2% of the sampled source water per day. The estimated impacts for the species analyzed were all very low with the largest estimate for northern anchovy representing the loss of approximately 1.2% of the source population of larvae (Table 3-7). Estimated effects from the *ETM* were even less when the potential source population was increased to include offshore areas.

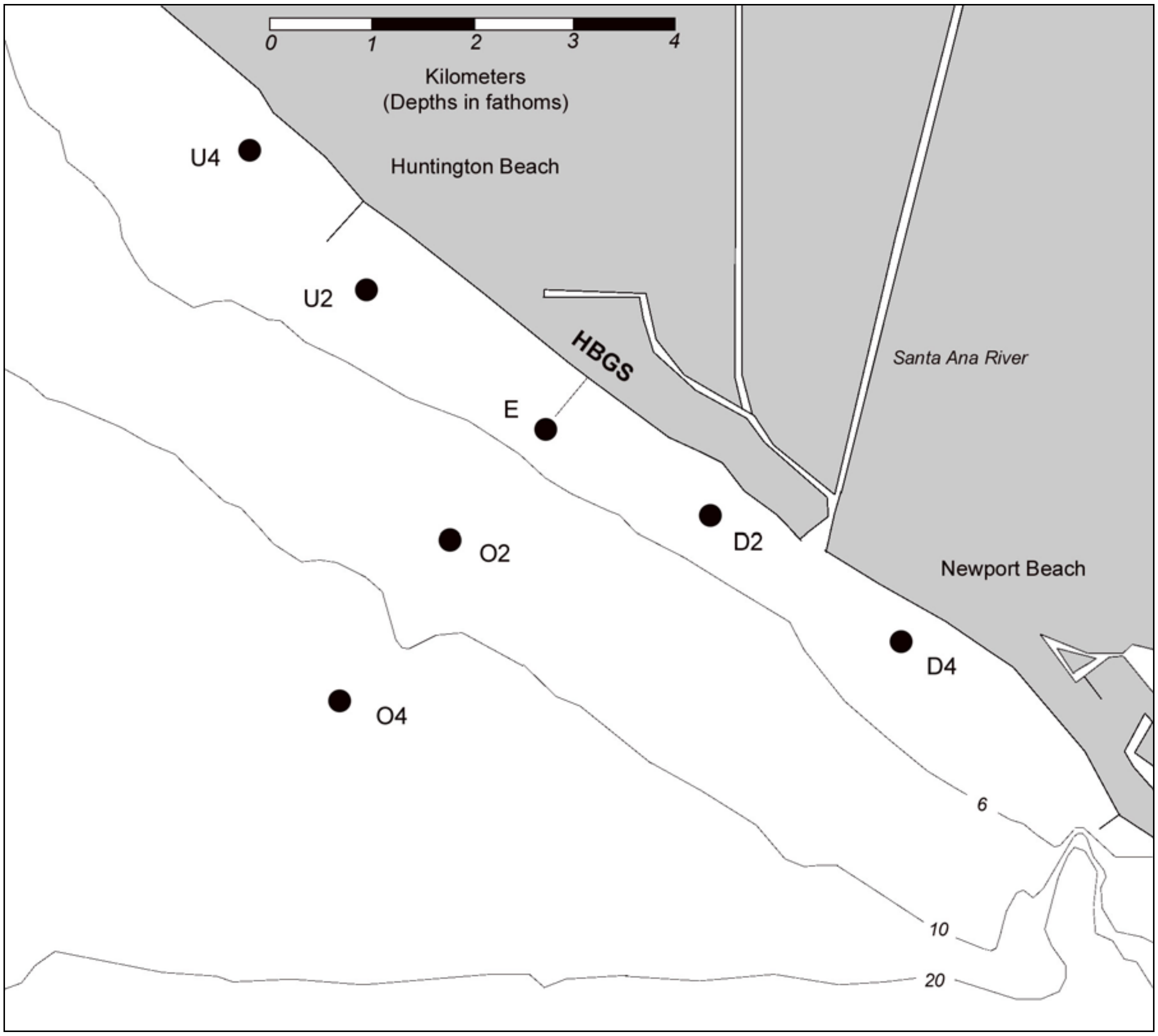


Figure 3-7. Location of Huntington Beach Generating Station (HBGS) entrainment (E) and source water sampling stations (U4, U2, D2, D4, O2, and O4), where U, D, and O designate stations upcoast, downcoast and offshore of the intake, respectively. Also shown are the 6-fathom (11-m), 10-fathom (18-m), and 20-fathom (36-m) isobaths.

Table 3-6. Larval fishes collected during 45 surveys from September 2003–August 2004 at the Huntington Beach Generating Station entrainment station in order of total estimated entrainment.

	Taxon	**Common Name**	**Sample Count**	**Percent of Total**	**Cumulative Percent**	**Mean Density (#/1000m3)**	**Total Estimated Entrainment**	**Entrainment Std. Error**
1	Gobiidae (CIQ complex)	gobies	2,484	36.95	36.95	151.56	113,166,834	6,568,091
2	*Roncador stearnsi*	spotfin croaker	912	13.57	50.51	53.07	69,701,589	8,636,383
3	Engraulidae	anchovies	1,209	17.98	68.50	74.46	54,349,017	4,355,775
4	*Seriphus politus*	queenfish	306	4.55	73.05	18.17	17,809,864	2,415,487
5	*Genyonemus lineatus*	white croaker	446	6.63	79.68	28.14	17,625,263	1,491,336
6	*Xenistius californiensis*	salema	153	2.28	81.96	7.70	11,696,960	5,186,479
7	Sciaenidae	croaker	244	3.63	85.59	14.73	10,534,802	1,004,033
8	*Hypsoblennius* spp.	blennies	166	2.47	88.06	10.28	7,165,513	580,175
9	*Cheilotrema saturnum*	black croaker	96	1.43	89.48	5.41	7,128,127	1,481,158
10	*Hypsopsetta guttulata*	diamond turbot	87	1.29	90.78	5.28	5,443,118	476,544
11	*Paralichthys californicus*	California halibut	98	1.46	92.24	6.40	5,021,168	447,516
12	Atherinopsidae	silverside	97	1.44	93.68	5.98	3,654,229	577,117
13	*Menticirrhus undulatus*	California corbina	43	0.64	94.32	2.33	2,809,417	807,329
14	*Paralabrax* spp.	sand bass	48	0.71	95.03	2.93	2,793,730	518,724
15	*Citharichthys* spp.	sanddabs	31	0.46	95.49	2.15	1,913,607	314,973
16	*Hypsypops rubicundus*	garibaldi	43	0.64	96.13	2.44	1,622,966	776,711
17	*Oxyjulis californica*	senorita	27	0.40	96.53	1.66	1,190,449	311,376
18	*Sphyraena argentea*	California barracuda	14	0.21	96.74	0.79	1,133,103	258,040
19	Pleuronectidae	flounders	17	0.25	97.00	1.02	982,419	131,877
20	*Umbrina roncador*	yellowfin croaker	24	0.36	97.35	1.63	962,905	266,187
21	*Gillichthys mirabilis*	longjaw mudsucker	20	0.30	97.65	1.29	834,682	155,798
22	*Lepidogobius lepidus*	bay goby	18	0.27	97.92	1.16	683,887	161,835
23	Syngnathidae	pipefishes	17	0.25	98.17	0.91	591,496	353,236
24	*Leptocottus armatus*	Pacific staghorn sculpin	16	0.24	98.41	0.97	584,664	115,109
25	*Pleuronichthys ritteri*	spotted turbot	12	0.18	98.59	0.75	561,958	87,434
26	*Triphoturus mexicanus*	Mexican lampfish	8	0.12	98.71	0.51	536,324	95,606
27	*Acanthogobius flavimanus*	yellowfin goby	15	0.22	98.93	0.88	522,589	176,940
28	*Diaphus theta*	California headlight fish	11	0.16	99.09	0.63	486,274	110,942
29	Myctophidae	lanternfishes	6	0.09	99.18	0.39	423,578	94,314
30	Haemulidae	grunts	5	0.07	99.26	0.28	368,219	121,028
31	*Atractoscion nobilis*	white seabass	5	0.07	99.33	0.29	347,306	114,685
32	*Gibbonsia* spp.	clinid kelpfishes	10	0.15	99.48	0.55	341,921	87,691
33	*Pleuronichthys verticalis*	hornyhead turbot	3	0.04	99.52	0.17	198,470	52,984
34	*Sardinops sagax*	Pacific sardine	4	0.06	99.58	0.25	166,724	117,891
35	*Peprilus simillimus*	Pacific butterfish	2	0.03	99.61	0.14	138,138	56,479
36	*Semicossyphus pulcher*	California sheephead	2	0.03	99.64	0.13	129,222	52,033
37	*Stenobrachius leucopsarus*	northern lampfish	3	0.04	99.69	0.21	111,109	46,395
38	Labrisomidae	labrisomid kelpfishes	3	0.04	99.73	0.18	108,964	58,784
39	*Halichoeres semicinctus*	rock wrasse	1	0.01	99.75	0.06	97,344	45,888
40	Paralichthyidae	lefteye flounders & sanddabs	2	0.03	99.78	0.12	95,195	45,031
41	*Medialuna californiensis*	halfmoon	2	0.03	99.81	0.13	77,804	58,815
42	*Scomber japonicus*	Pacific mackerel	2	0.03	99.84	0.10	61,004	32,608
43	Scorpaenidae	scorpionfishes	1	0.01	99.85	0.09	50,467	38,150
44	*Symphurus atricauda*	California tonguefish	1	0.01	99.87	0.07	42,344	32,009
45	*Strongylura exilis*	California needlefish	1	0.01	99.88	0.07	40,637	30,719
46	*Oxylebius pictus*	painted greenling	1	0.01	99.90	0.07	40,289	30,456
47	*Typhlogobius californiensis*	blind goby	1	0.01	99.91	0.06	36,976	27,951
48	*Merluccius productus*	Pacific hake	1	0.01	99.93	0.06	33,954	25,667
49	*Coryphopterus nicholsi*	blackeye goby	1	0.01	99.94	0.06	33,202	25,099
50	Agonidae	poachers	1	0.01	99.96	0.05	30,817	23,295
51	*Ruscarius creaseri*	rouchcheek sculpin	1	0.01	99.97	0.05	30,813	23,293
52	Pleuronectiformes	flatfishes	1	0.01	99.99	0.05	30,192	22,823
53	Cottidae	sculpins	1	0.01	100.00	0.05	28,990	21,914
			6,723			**406.91**	**344,570,635**	

Table 3-7. Summary of Empirical Transport Model (*ETM*) estimates of proportional mortality (P_M) from entrainment by the Huntington Beach Generating Station cooling water system. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the estimate.

Taxon	Estimated Annual Entrainment	P_M Alongshore Extrapolation	P_M Offshore +Alongshore Extrapolation
CIQ goby complex	113,166,834	1.0% (60.9 km)	1.0%
northern anchovy	54,349,017	1.2% (72.0 km)	0.7%
spotfin croaker	69,701,589	0.3% (16.9 km)	0.3%
queenfish	17,809,864	0.6% (84.9 km)	0.5%
white croaker	17,625,263	0.7% (47.8 km)	0.4%
black croaker	7,128,127	0.1% (19.4 km)	<0.1%
blennies	7,165,513	0.8% (12.8 km)	0.3%
diamond turbot	5,443,118	0.6% (16.9 km)	0.3%
California halibut	5,021,168	0.3% (30.9 km)	<0.1%
rock crab megalops larvae	6,411,171	1.1% (26.5 km)	0.8%

A way to place the Huntington Beach Generating Station entrainment losses for species targeted by commercial fishing into context is to use the results of the *ETM* modeling to extrapolate the percentage losses to the larvae to adults of fishery size. This approach assumes that the losses of larvae are not compensated by increased survival of the remaining larvae due to decreased competition for food and other resources and that the entire adult population has equal chance of being caught. The two species discussed above, California halibut and white croaker, are part of the local commercial fishery. The California Department of Fish and Game reports the catch of commercial fish by areas referred to as "catch blocks". In the case of Huntington Beach, the relevant block comprises an area 6 square miles directly offshore from the power plant (Block 738). The losses to the fishery are calculated by multiplying the annual fishery value of reported landings in that catch block by the estimated value of P_M for each species. For halibut, the fishery value from Block 738 was $18,245 in 2003 and $5,483 in 2002. The alongshore P_M estimate of 0.3% (Table 3-7) translates to values of $55 and $16 in 2003 and 2002, respectively. For white croaker, the fishery value was $9,783 in 2003 and $11,755 in 2002. The alongshore P_M estimate of 0.7% (Table 3-7) translates to values of $68 and $82 in 2003 and 2002, respectively. Northern anchovy are also fished commercially off Huntington Beach. The projected ex-vessel value of northern anchovy lost as a result of larval entrainment using the same approach totaled $181 and $153 in 2003 and 2002, respectively using fishery values from the same catch block of $15,094 in 2003 and $12,784 in 2002. These estimates represent maximum losses because fisheries science is clear that compensation does occur in early life stages of such species.

The estimated effects of entrainment on source water populations of larvae off Huntington Beach are less than estimated effects from the examples previously presented for South Bay and Encina power plants. One of the primary reasons for the differences is the type of habitat found in the vicinity of the South Bay and Encina intake structures. The Encina and South Bay entrainment studies were conducted in estuarine areas that have very limited source waterbodies relative to the open coastal source water for Huntington Beach. The smaller volume of the source waterbodies for these plants contribute to higher proportional entrainment estimates relative to Huntington Beach which is a homogeneous, gently sloping, sandy environment that extends for several miles north, south and offshore of the intake. This homogeneous environment probably results in a more uniform distribution of larvae throughout the sampling area. This may have contributed to average daily estimates of proportional entrainment that closely approximated the volumetric ratio of the cooling water to the sampled source water volume of 0.2% for several of the more abundant larvae and averaged 0.2%, the volumetric ratio, for all of the fishes analyzed.

3.1.10 Long-term Monitoring of Fish Populations from Open Coastal Areas

There are several sources of long-term data on fish abundances in California, but most of these are from areas of the State where large populations and associated industrialization, land-use practices, and fishing pressure result in multiple impacts that are difficult to separate from the effects of OTC and make the effects of OTC difficult to determine. In addition to human-induced impacts, changes have also occurred due to larger-scale climatic changes that resulted in a regime shift to warmer average seawater temperatures that began during the 1976–1977 El Niño (Holbrook et al. 1997).

The ecosystem changes were particularly evident in the Southern California Bight where reduced primary and secondary productivity associated with the regime shift led to large impacts on population abundances and trophic structure in nearshore benthic communities within the Bight (Holbrook et al. 1997). Holbrook et al. (1997) showed that the diversity and abundance of fishes with more northerly distributions have declined in the Southern California Bight since the advent of this warmer water regime. Furthermore, these assemblages have shown a shift in the dominant species away from more northern distributed taxa and toward more southerly distributed taxa that are presumably more tolerant of warm water. Similar trends were also observed further north at Santa Cruz Island where populations of surfperches, the standing stock of their crustacean prey, and the biomass of understory macroalgae all declined by approximately 80%. Holbrook et al. (1997) hypothesized that fish abundance declined as a result of declining recruitment that became insufficient to compensate for losses of older age classes. This is termed “recruitment overfishing” and was defined by Gulland (1983) as limiting the amount of larvae a population produces by taking primarily older, more fecund adults and leaving young, less fecund individuals. Recruitment levels of surfperches fell more than one order of magnitude over two decades. The abundance trends were correlated with broad indicators of Bight-wide productivity of the coastal marine ecosystem; namely the biomass of zooplankton in the California Current (Holbrook et al. 1997).

As a result of the multiple sources of impacts in southern California and other areas of the State, the long-term monitoring of fish populations in central California near the Diablo Canyon Power Plant provides a unique set of data that can be used to evaluate the potential effects of OTC on adult fish populations (Tenera Environmental 1998, 2002, 2006a, 2006b). These data were collected as part of the receiving water monitoring required under the plant’s NPDES permit for monitoring the effects of the thermal discharge. They were collected from a control area that does not experience increases in seawater temperature due to the plant’s discharge. The data from Diablo Canyon are unique for several reasons. First, the data were collected over a period of 30 years starting in 1976, ten years before the plant began operation, and have continued through the present. Secondly, the data are collected from a remote area of the open coast that is subject to less fishing pressure than other areas of the State. The data are also unique because of several characteristics of Diablo Canyon. The plant is located on a pristine section of open coast between Morro Bay and Avila Beach in San Luis Obispo County. The plant is a two-unit, nuclear-powered, steam-turbine power plant with a rated output of 2,200 MWe with a cooling water intake volume of 2.5 billion gallons per day, the largest in the State. Commercial operation of Unit 1 began in May 1985 and Unit 2 in March 1986. The plant has operated at very high capacity factors since it began operating. Therefore, in addition to the unique nature of the study, Diablo Canyon has the largest cooling water volume in the State and has been operating almost continuously since 1986. The cooling water volumes and plant operating characteristics increase the potential for impacts to local fish populations which would otherwise be very difficult to detect due to the diluting effects of ocean currents which result in low levels of proportional mortality over large areas of coastline.

The results of the Diablo Canyon monitoring indicate little change during plant operation in the number of species collected at a sampling location outside the influence of the plant's thermal discharge (Figure 3-8). The abundances of adult fishes with entrainable larvae[4] show relatively stable levels during plant operation through 1992 (Figure 3-9). Abundances decreased between 1992 and 1993 and have remained fairly stable through 2005. The reasons for the decrease in abundance may be related to prolonged El Niño conditions during the 1991–1993 period. El Niño conditions persisted through the late winter and spring of 1992 which probably affected recruitment for a large number of species. This is supported by the decline between years that coincides with the 1997 El Niño that produced the warmest temperature anomalies recorded since 1950. In addition, the early and mid-1990's saw the advent of trap fishing along the central coast of California (Bloeser 1999) that resulted in declines in cabezon (*Scorpaenichthys marmoratus*), rockfishes and greenling and has been identified as a cause of declines in adult abundances in other areas (Starr et al. 1998). Regulation of the live fish fishery began in the late 1990s and boating in the waters around Diablo Canyon, including the control study area, is now restricted due to heightened security following the terrorist events of September 2001. This discussion highlights the difficulty and potential pitfalls of attributing changes in fish abundances to any specific factor. Although entrainment effects might be expected to occur as a long-term declining trend in abundance, environmental variability and fishing impacts are such that the effects of entrainment cannot be determined.

The health of nearshore fish populations around Diablo Canyon is supported by recent analysis of recreational fishery data showing that the stocks in central California have not experienced the same declines seen elsewhere in the State (Stephens et al. 2006). Data from the local recreational partyboat fishery show very little change in fishing success over the period from 1980–2005 (Figure 3-10). The species examined for this analysis included the same group of rockfishes analyzed for the Diablo Canyon entrainment study, including the kelp-grass-black and yellow group of rockfishes that had the highest overall estimated entrainment. Dotson and Charter (2003) also show an increase in commercial partyboat fishing success in central California relative to southern California ports (Figure 3-11).

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[4] Note. The graph does not include surfperches, sharks, and rays which all give birth to young that are not subject to entrainment.

The results from the monitoring data collected at the plant and results from independent studies are unable to identify any effects on adult fishes that are targeted by the partyboat fishery.

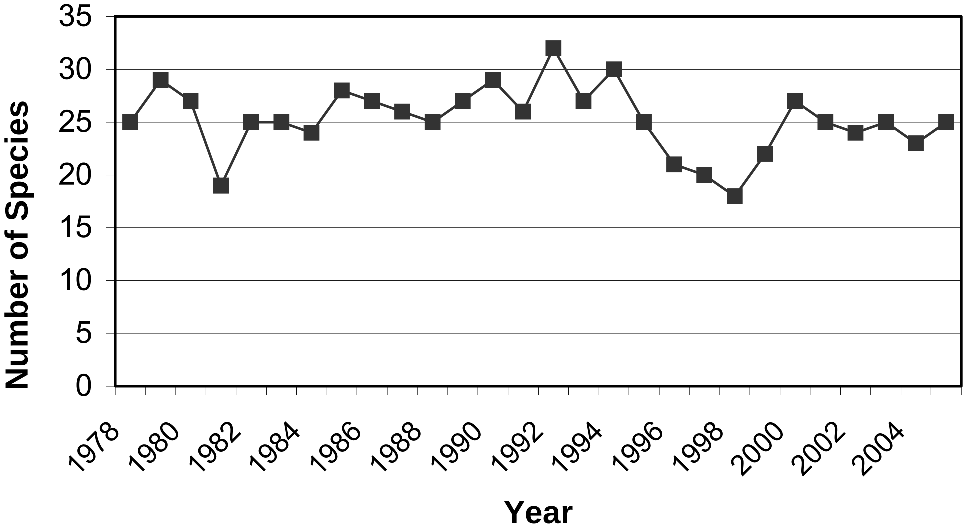

Figure 3-8. Total number of fish species based on annual average abundances from 1978 through 2005 along three transects (50 m long x 2 m wide) laid along the bottom in the control area for the receiving water monitoring at the Diablo Canyon Power Plant. Numbers do not include juveniles and young-of-the-year fishes. Data from Diablo Canyon Power Plant receiving water monitoring program summarized in Tenera Environmental (2006a).

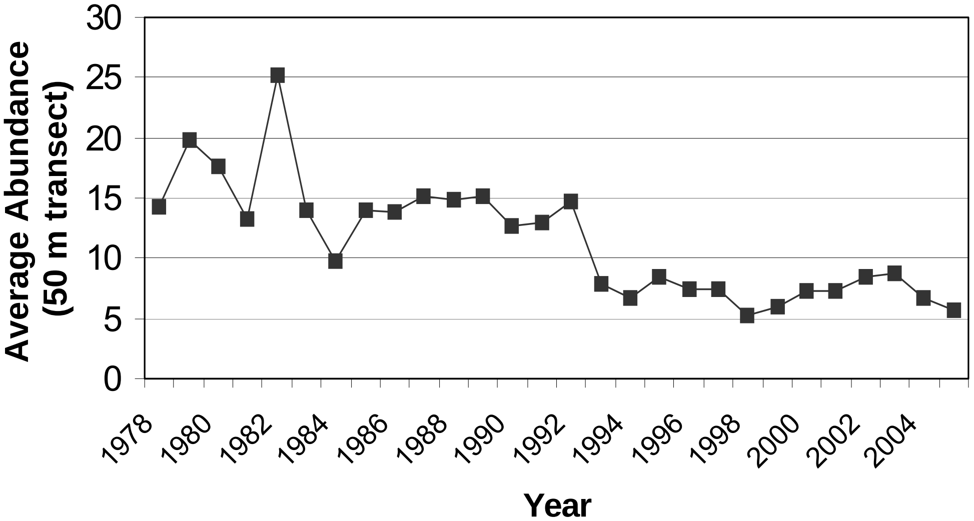

Figure 3-9. Total average annual abundance of adult fishes (juveniles and young-of-the-year removed) with entrainable egg and larval stages in studies from 1978–2005 along three transects (50 m long x 2 m wide) in the control area for the receiving water monitoring at the Diablo Canyon Power Plant. Numbers do not include señorita, which is a midwater species which can be observed along the benthic transects. Data from Diablo Canyon Power Plant receiving water monitoring program summarized in Tenera Environmental (2006a).

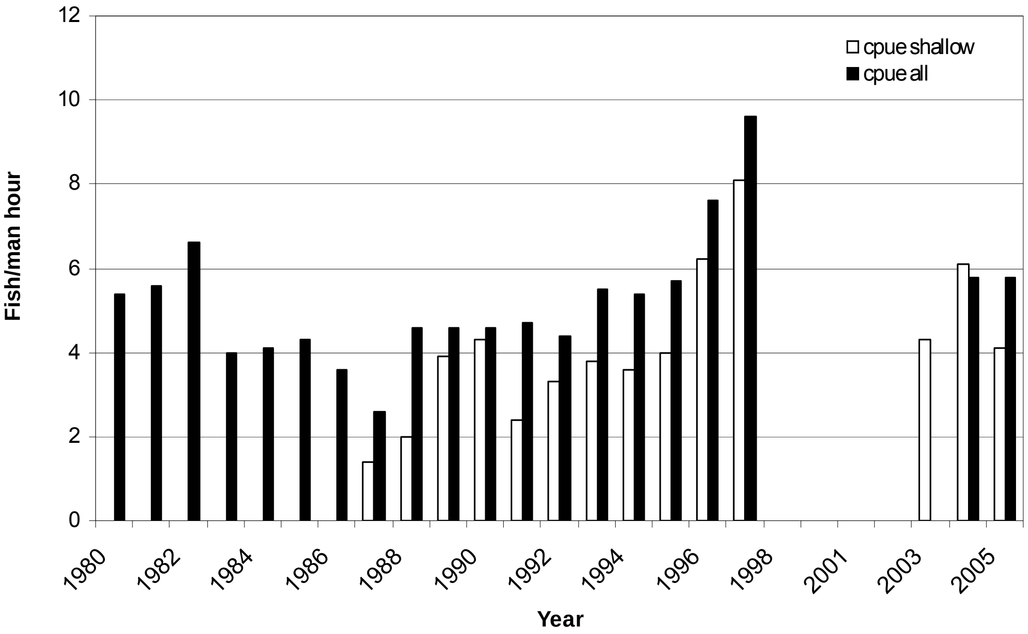

Figure 3-10. Partyboat catch per unit effort (number of fishes per fisher per hour) for eleven rockfishes and two greenling species from ports on the south Central Coast, 1980–2005 from the following sources: 1980–1997 California Department of Fish and Game and 2003–2005 California Polytechnic State University (from Stephens et al. 2006). Data from 1998–2002 collected by Pacific Fisheries Management Commission were not available.

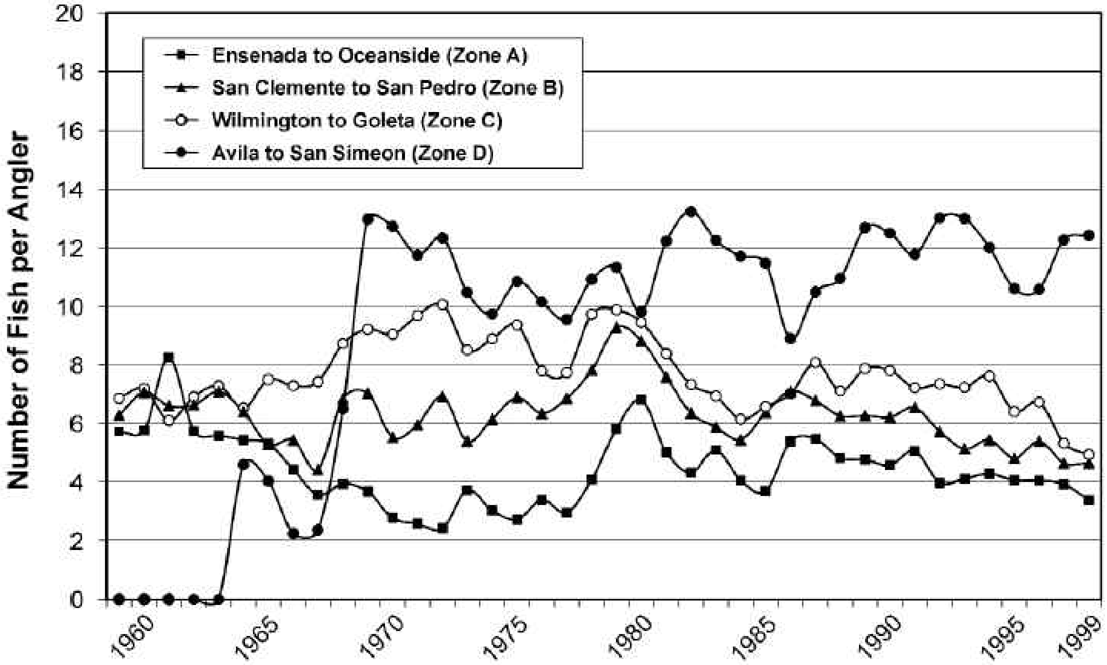

Figure 3-11. Annual average commercial passenger fishing vessel (CPFV) catch per angler by geographic zone 1959 to 1998. (Figure 3 from Dotson and Charter 2003). The Diablo Canyon Power Plant is located north of Avila Beach in Zone D.

3.1.11 Entrainment Conclusion for Open Coastal Systems

Power plants utilizing OTC in open coastal environments have far less potential for population-level effects on fish populations than power plants located in coastal lagoons and embayments. The potential source water utilized for cooling at plants like Huntington Beach and Diablo Canyon includes large areas of coastline. As a result, the proportional losses due to entrainment at power plants located on the open ocean are typically much smaller than the losses from plants located in coastal lagoons or embayments. In open coastal environments any larvae lost due to entrainment are replaced by larvae transported by ocean currents. The species along the open coast also have large geographic distributions that may extend for hundreds of miles along the coast. All of these factors contribute to a low potential for entrainment at these plants to cause any localized effects on fish populations.

3.2 Impingement

Unlike most power plants located in marine and estuarine environments on the East Coast, the numbers of fishes impinged at most of California's power plants utilizing OTC is relatively low. This is documented from the results of recent studies at power plants in central California, and also in statements from Central Coast Regional Water Quality Control Board (RWQCB) staff. For example, regarding the Morro Bay Power Plant the following statement was included in the reissuance of the NPDES Permit:

"The evidence supports the conclusion that impingement impacts of the Project are not significant either in the absolute sense or relative to the existing plants."[5]*;"*

and impingement at the Diablo Canyon Power Plant was evaluated as follows:

"Regarding impingement of adult fish in the intake structure, the number of fish lost per year is so minor (a few hundred fish per year) that intake structure modifications or operational changes are not necessary. These losses are already minimized pursuant to Clean Water Act Section 316(b)."[6]

These statements are especially valid for power plants in the central California region administered by the Central Coast RWQCB because they all have shoreline intakes with conventional bar racks and 3/8-inch mesh traveling screens. The plants either do not heat treat their intake tunnels or heat treat very infrequently due to their current operating characteristics. A plant like Diablo Canyon, situated on the open coast, has very low impingement due to the low intake velocities and strong swimming ability of the fishes of the open exposed coastal waters. Total annual impingement of fishes at Diablo Canyon is the approximate equivalent of the fishes caught during four recreational fishing party boat trips. Other plants have similarly low levels of impingement. In southern California, plants with offshore intakes are fitted with velocity caps. Studies done at the Huntington Beach and Ormond Beach power plants in late 1970s and early

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[5] Central Coast Regional Water Quality Control Board. Draft Waste Discharge Requirements. Order No. R3-2004-0028 NPDES No. CA0050610 For Duke Energy, Morro Bay, Morro Bay Power Plant, Units 1 and 2. December 2, 2004.

[6] Central Coast Regional Water Quality Control Board. Staff testimony for regular meeting of July 10, 2003 Pacific Gas and Electric Company's Diablo Canyon Power Plant renewal of NPDES Permit. Prepared on June 6, 2003

1980s showed that the velocity caps reduce impingement by more than 90%. Recent studies conducted in 2006 at the Scattergood Generating Station demonstrated performance can exceed 95%. Table 3-8 shows the weight of impinged fishes during normal operations at several California coastal power plants based on actual flow through the cooling water system during the studied years unless otherwise noted.

Table 3-8. Annual weight of impinged fishes based on actual flows. (Note: Table is based on representative facilities and does not include impingement during heat treatments).

Power Plant	County	Study Year	Maximum Intake Volume (mgd)	Type of intake	Estimated annual weight (lb) impinged
Moss Landing	Monterey	1979–1980	1,412	shoreline	10,000
Morro Bay	San Luis Obispo	1999–2000	670	shoreline	2,500
Diablo Canyon	San Luis Obispo	1985–1986	2,500	shoreline	1,600
El Segundo	Los Angeles	1999–2004	399	offshore	500
Huntington Beach	Orange	1979–2004	241[1]	offshore	3,500
Harbor	Los Angeles	1978–1979	241[2]	shoreline	6,200
Haynes	Los Angeles	1978–1979	1014[3]	shoreline	3,000
Scattergood	Los Angeles	1978–1979	495[4]	offshore	6,940
Encina	San Diego	2002–2003	857	shoreline	5,000[5]– 8,000[6]
South Bay	San Diego	2002–2003	601	shoreline	1,200

[1] Average flow during the studied years
[2] Current maximum flow is 108 mgd
[3] Current maximum flow. Average capacity factor during study was 46%
[4] Current maximum flow. Average capacity factor during study was 58%
[5] Weight based on actual annual cooling water flow during the study
[6] Weight based on maximum annual cooling water flow

3.2.1 Facilities and Data

The following section discusses long-term impingement data from the following three power plants:

- *Ormond Beach Generating Station* (Ventura County)—1990–2005 normal operation and heat treatment impingement data (MBC 2006b). Monthly normal operation impingement data were extrapolated based on cooling water volumes to obtain annual normal operation impingement estimates. Annual impingement totals were calculated by summing the extrapolated normal operation and heat treatment impingement totals.
- *Huntington Beach Generating Station* (Orange County)—1979–2005 normal operation and heat treatment impingement data (MBC 2006a, c). Normal operation impingement data were collected approximately weekly from 1979–1993, and monthly thereafter, except in 2003–2004 (weekly). Normal operation impingement data were extrapolated based on cooling water volumes to obtain annual normal operation impingement estimates. Annual impingement totals were calculated by summing the extrapolated normal operation and heat treatment impingement totals.
- *San Onofre Nuclear Generating Station* (San Diego County)—1995–2003 normal

operation and heat treatment impingement data at Units 2 and 3 (SCE 1996–2004). Normal operation impingement data were collected monthly from 1994–1998, and quarterly from 1999–2003. Normal operation impingement data were extrapolated based on cooling water volumes to obtain annual normal operation impingement estimates. Annual impingement totals were calculated by summing the extrapolated normal operation and heat treatment impingement totals.

All three facilities are located in southern California. No long-term data were available from any of the plants located in central or northern California, but as presented in the introduction to this section, the design of the intake structures at those plants results in generally lower impingement than the offshore intakes at these three facilities. All three of these facilities have offshore intakes with velocity caps that help reduce impingement.

The results from the impingement sampling at these three facilities were compared with recreational and commercial fisheries data available from several sources. The comparisons focus on three fish species: queenfish, white croaker, and northern anchovy. These three species have been historically dominant in impingement samples at most coastal generating stations in southern California. The annual impingement totals for northern anchovy are only compared with the commercial fishing landings combined from San Diego and Los Angeles ports. Since commercial landings are reported by weight, the comparison is done using impingement biomass. The sport and commercial landings data for white croaker and queenfish are sometimes combined. Therefore the impingement numbers and biomass data for these two species were also combined for comparison with the sport and commercial catch, respectively.

3.2.2 Analysis of Northern Anchovy

Northern anchovy accounted for approximately 3% of the 139 million lb (63 million kg) of seafood products landed in California waters from Los Angeles Area ports and had the fourth highest landings after market squid (50%), Pacific sardine (37%), and Pacific chub mackerel (5%). Landings for northern anchovy ranged from a high of 251 million lb (114 million kg) in 1975 to a low of 14,000 lb (6,500 kg) in 1930 (source: Southwest Fisheries Science Center Live Access server http://las.pfeg.noaa.gov:8080). Over the time period from 1980–2005 there were very large landings from 1980–1982, with a large reduction in total catch following the 1983 El Niño which continued through the late 1990s with some recovery following the large El Niño ocean warming event in 1997 (Figure 3-12). Northern anchovy is considered a colder-water species that typically occurs in water temperatures from 54 to 71°F (Leet et al 2001), which helps explain the decline in catch during the warmer oceanic regime present during much of the 1980s and 1990s.

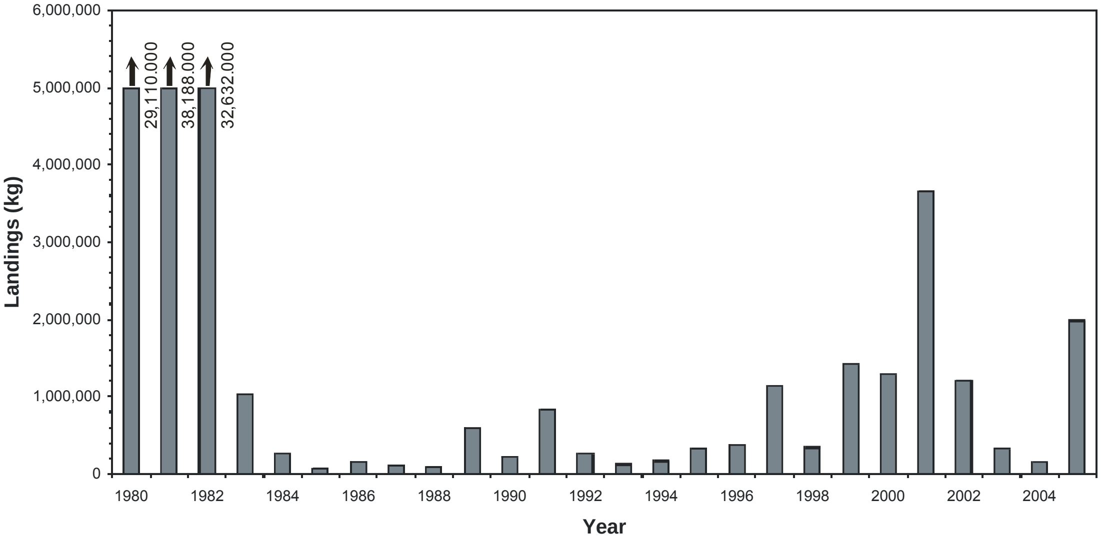

Figure 3-12. Total annual commercial landings for northern anchovy totaled from Los Angeles and San Diego area ports from 1980–2005. Data sources: Southwest Fisheries Science Center Live Access Server (http://las.pfeg.noaa.gov:8080) and Pacific States Marine Fisheries Commission PacFIN web site (http://www.psmfc.org/pacfin).

Impingement at the three facilities was highest at San Onofre for the 1994–2004 period (average of 9,900 lb [4,500 kg]) and could be several orders of magnitude greater than the levels at Huntington Beach and Ormond Beach (Figure 3-13). Annual totals at San Onofre averaged less than 1% of the total annual commercial landings data from Figure 3-12. The levels of impingement at these and other California coastal power plants represent only a minute fraction of the total central subpopulation of northern anchovy, which was estimated in 1994 to have a total biomass of 432,000 tons (392,000 metric tons [MT]) (Leet et al. 2001). The population based on commercial fisheries landings has increased since 1994 (Figure 3-12).

The largest historical commercial landings occurred during the 1970s while the power plants in California were operating (Figure 3-14). There was also a large market for northern anchovy that was reduced to fish meal (Leet et al. 2001). This market disappeared with the decline in the population largely due to environmental factors associated with increased water temperatures (Leet et al. 2001). These fluctuations are characteristic of a fishery resource that is largely dependent on market forces and environmental factors.

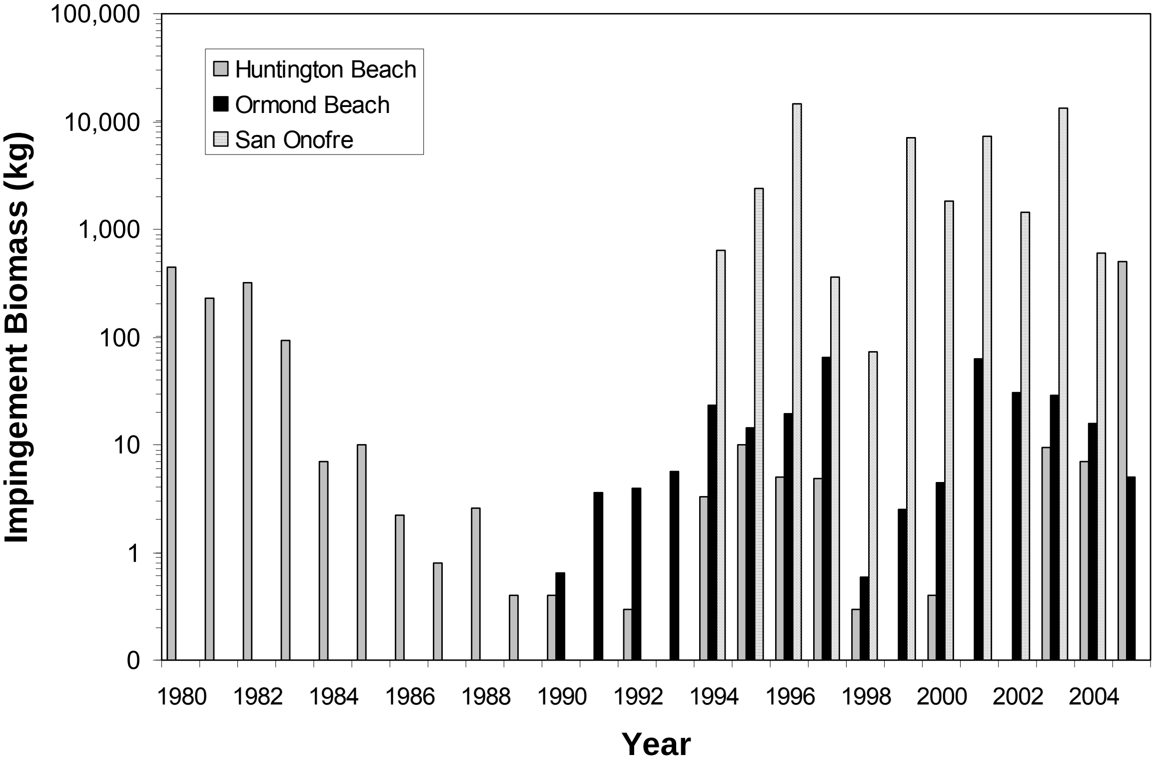

Figure 3-13. Total annual impingement biomass of northern anchovy at the Huntington Beach, Ormond Beach, and San Onofre power plants. Data only available from San Onofre for 1994–2004 and for Ormond Beach from 1990–2005. Note the use of log scale on y-axis.

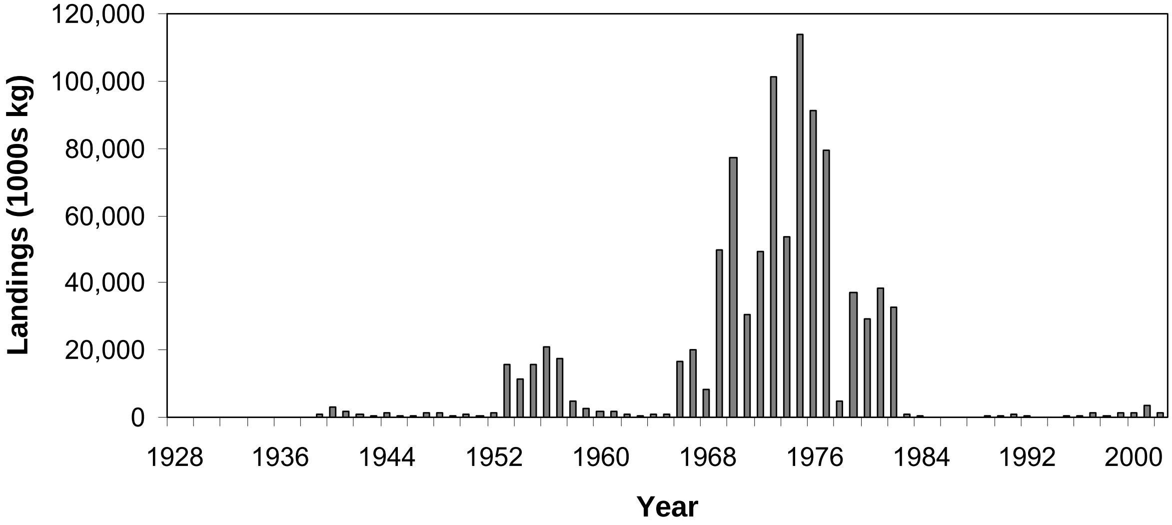

Figure 3-14. Commercial landings for northern anchovy totaled from Los Angeles and San Diego area ports from 1928–2001. Data sources: Southwest Fisheries Science Center Live Access Server (http://las.pfeg.noaa.gov:8080).

3.2.3 Analysis of White Croaker and Queenfish

White croaker and queenfish are both members of a family of fishes known commonly as croakers (Family Sciaenidae). White croaker is a component of both the sport and commercial fisheries in southern California. An increase in commercial landings during the 1970s has been attributed to the increase in the Southeast Asian population that settled in coastal areas and earned a living as gillnet fishers by exploiting an underutilized resource (Leet et al. 2001). Decreased landings through the 1990s correspond to overall declines in several species of nearshore croakers, including white croaker and queenfish, observed in an analysis of impingement data from southern California power plants (Herbinson et al. 2001). They analyzed data through 1999 and noted that the declines were coincident with major El Niño events in 1982–1983, 1986–1987, and 1997–1998. Although declines in the recreational catch for white croaker may be correlated with these El Niño events, the commercial catch also shows a large increase following the 1982–1983 event (Figure 3-15). Overall, the declines in white croaker recreational and commercial catch, especially in the late 1990s, show the same patterns described by Herbinson et al. (2001). No recreational or commercial fishing data are presented for queenfish, which has not comprised a frequent or substantial portion of the recreational or commercial catch.

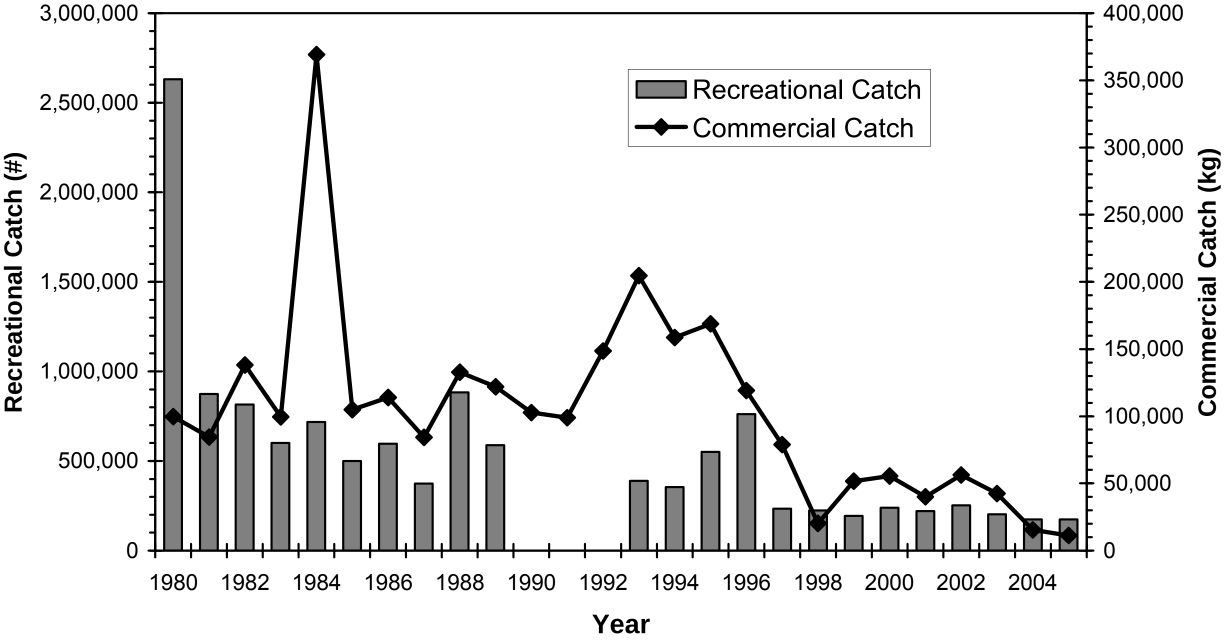

Figure 3-15. Total annual recreational and commercial landings for white croaker totaled from Los Angeles and San Diego area ports from 1980–2005. Data sources: Southwest Fisheries Science Center Live Access Server (http://las.pfeg.noaa.gov) and Pacific States Marine Fisheries Commission PacFIN (http://www.psmfc.org/pacfin) and RecFin (http://www.psmfc.org/recfin) web sites. Data on sport catch not available for 1990–1992 period due to suspension of data collection.

Although queenfish is not an important fishery resource, it was much more abundant than white croaker in the impingement collections. For the periods presented in Figure 3-16, impingement of white croaker was highest at Huntington Beach with an annual average of about 900 lb (410 kg) and lowest at Ormond Beach with an average of about 46 lb (21 kg). For the same time periods, impingement of queenfish was highest at San Onofre with an annual average of about 18,300 lb (8,300 kg) and was lowest at Ormond Beach with an average of about 560 lb (250 kg).

The declines in impingement abundances for these two croakers reported by Herbinson et al. (2001) are noticeable through the 1998 time period they analyzed, but data from more recent years show increases in impingement abundance (Figures 3-16 and 3-17) that are not reflected in the fisheries data. The increases are noticeable in impingement data for both white croaker and queenfish at Huntington Beach where impingement abundances reached their lowest levels in 1999, two years following the 1997 El Niño event. The highest abundances of white croaker impingement during the 1980–2005 period were observed in 2005 along with high biomass levels that have not been recorded since the early 1980s. Based on the analysis of long-term patterns of change in croakers relative to ocean warming events by Herbinson et al. (2001), the increase in white croaker and queenfish may be in response to the prolonged cooler water temperatures that have persisted in the southern portion of the California current since 1999 (Peterson et al. 2006). The changes in abundance appear to fluctuate in response to ocean conditions making it difficult to determine if impingement or entrainment by power plant cooling water systems are affecting these populations, although effects of OTC should occur as a long-term downward trend in abundance or a shift in the baseline population due to the additional mortality to the populations.

3.2.4 Assessment of Impingement Impacts

The data presented in the previous sections for croakers are generally not adequate for assessing the effects of impingement because of the absence of long-term data for these species. One source of long-term data comes from an analysis of recreational fishing trends in Santa Monica Bay for the period 1936–1984 (MBC 1985) (Figure 3-18). There are three coastal generating stations that utilize up to 1.99 billion gallons per day of OTC water in Santa Monica Bay: LADWP Scattergood, NRG El Segundo, and AES Redondo Beach generating stations. Scattergood and El Segundo became operational in the 1950s. Units 1-4 at Redondo Beach became operational in the 1940s, and Units 5&6 became operational in the mid 1950s.

The sport fish catch in Santa Monica Bay increased from the mid-1940s through the early 1970s. From the 1970s–1984, the catch per unit effort (CPUE) decreased, but was still well above 1940 levels. The sport fish CPUE was negatively correlated with water temperature (Spearman rank correlation = -0.486, p=0.01) and transparency (Spearman rank correlation = -0.603, p=0.005), indicating more fish were caught per angler during the cold water, productive periods than during warmer water events. This corresponds to larger regional observations of declines in marine fishes associated with the regime shift of 1977, during which a cooler, high upwelling period was replaced with a warmer, less productive oceanic period in the coastal northeast Pacific (Brooks et al. 2002, Allen et al. 2004, Polovina 2005). Large declines in rockfishes, in particular, were noted in southern California during the shift to warmer conditions, and these declines were reflected in the impingement data from four power plants in the Southern California Bight (Love et al. 1998). Fisheries-independent observations confirmed that the impingement data were representative of the pattern of change in the nearshore environment.

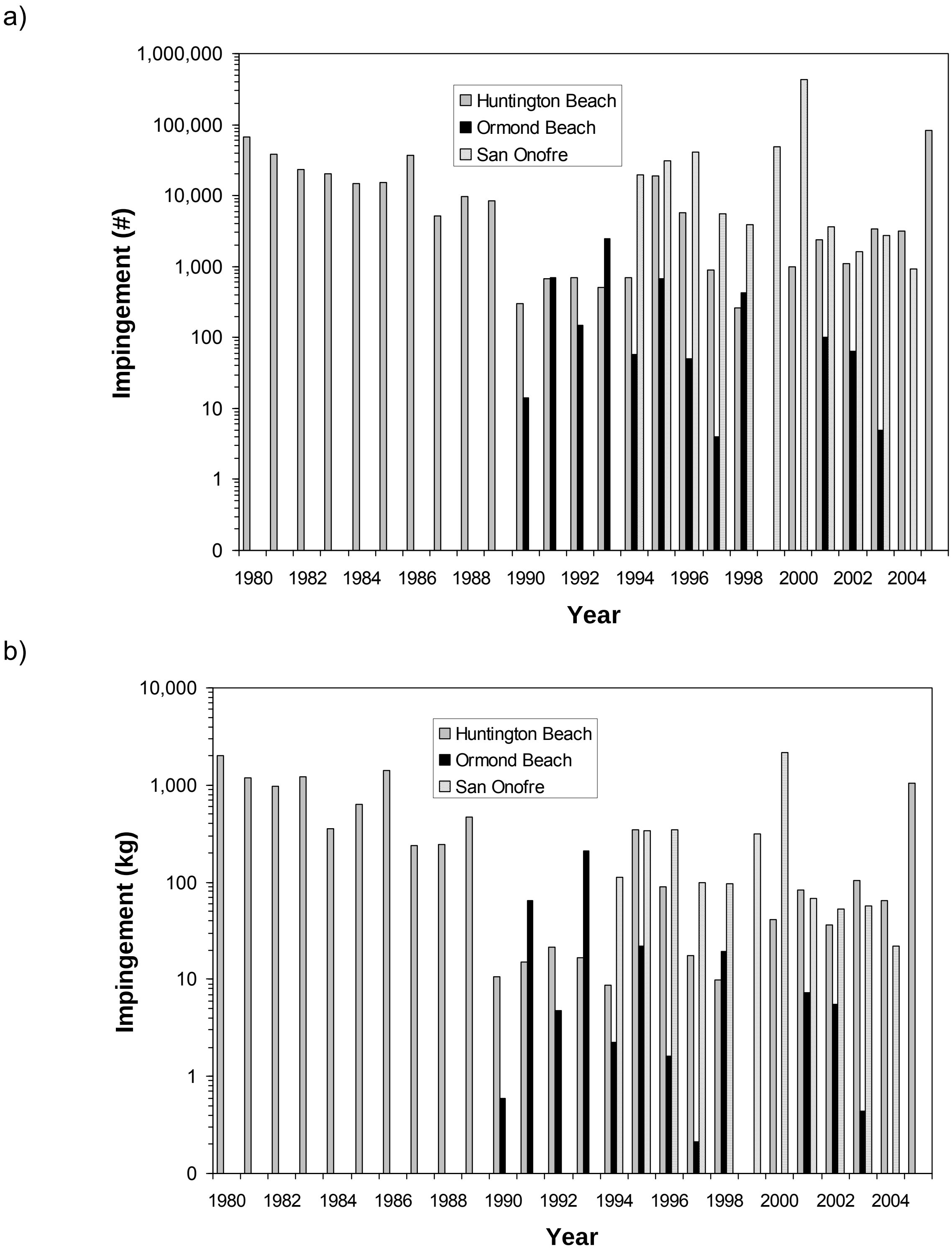

Figure 3-16. Total annual impingement in a) numbers and b) biomass of white croaker at Huntington Beach (1980–2005), Ormond Beach (1990–2005), and San Onofre (1994–2004). Note log scale used for y-axis. Data only available for Ormond Beach from 1990–2005 and for San Onofre from 1994–2004 .

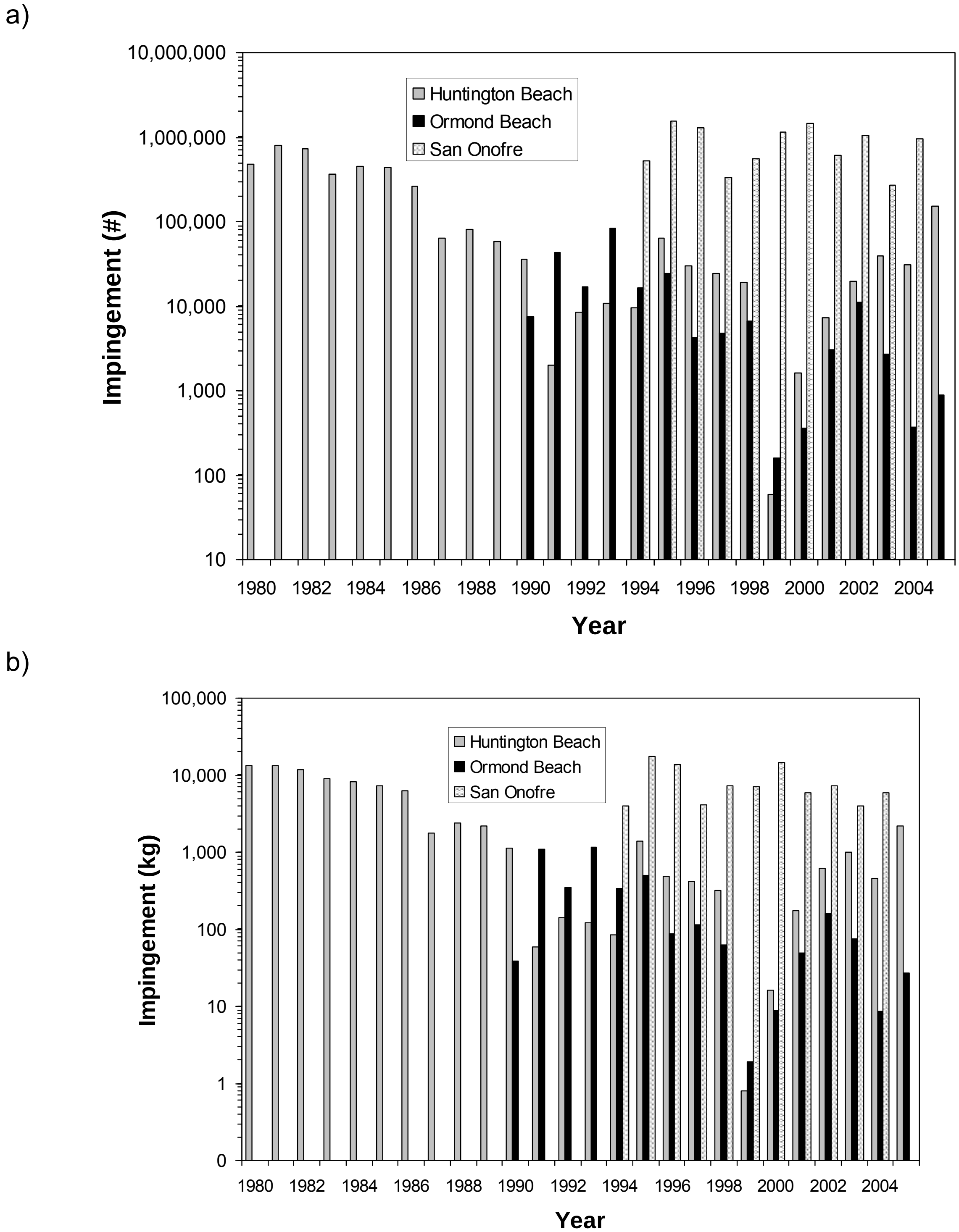

Figure 3-17. Total annual impingement in a) numbers and b) biomass of queenfish at the Huntington Beach (1980–2005), Ormond Beach (1990–2005), and San Onofre (1994–2004). Note log scale used for y-axis. Data only available from Ormond Beach from 1990–2005 and from San Onofre from 1994–2004.

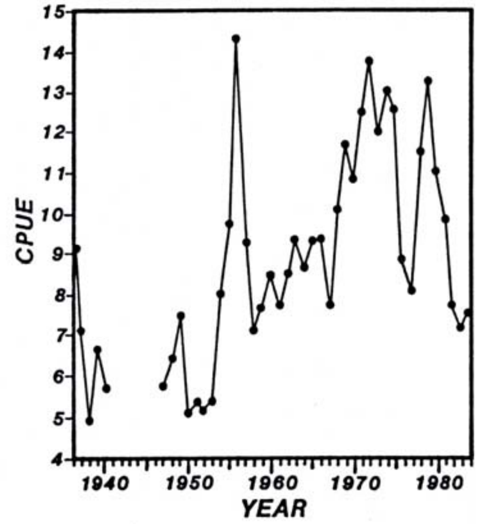

Figure 3-18. Total catch per unit effort for all fishing blocks in Santa Monica Bay, 1936–1984 (from MBC 1985).

3.3 Conclusions on Effects of Once-Through Cooling

The ability to assess the impacts on fish populations of impingement and entrainment due to OTC is very limited, especially in regard to entrainment, which has been identified by California agency staff and environmental groups as a major impact on California fish populations despite the absence of any supporting evidence for such a conclusion. At the time that this report was prepared, only two of the 21 California coastal power plants have comparable entrainment data from historical and contemporary studies. Simple comparisons of the results at both the South Bay Power Plant in San Diego and the Encina Power Station in Carlsbad showed that there was very little change in larval fish abundances over more than a 20-year period between historical and contemporary studies. These comparisons do not provide conclusive evidence for or against entrainment effects because of the numerous factors that could affect larval abundances and composition between the two study periods. Some of the changes observed at Encina Power Station were probably the results of changes in the available habitat around the area of the intake lagoon. The effect of habitat as a major factor is supported by a similar comparison of ichthyoplankton concentrations from studies separated by over 20 years that were conducted in Elkhorn Slough where the Moss Landing Power Plant is located.

If entrainment is a large problem then effects should be detectable in enclosed bodies of water such as San Diego Bay, Agua Hedionda Lagoon, and Elkhorn Slough/Moss Landing Harbor where these three power plants are located, since the cooling water volume of these power plants represents a substantial percentage of the total volume of the waterbody. Many of the fish populations at these locations are limited to the habitats inside these waterbodies where reduced larval supply due to entrainment might be expected to be translated into reduced adult populations. Despite the potential for increased impacts, there was no evidence of entrainment effects found from the comparisons to historical study results at these locations. This is probably due to a combination of factors including behavioral adaptations for species living in habitats with strong tidal currents and limitations on available habitat in these waterbodies for recruitment of late larval and juvenile fishes.

The potential for entrainment effects at power plants on the open coast, such as the Huntington Beach and Diablo Canyon, are much reduced from power plants that draw cooling water from more enclosed waterbodies. The fish populations that are potentially affected by entrainment from these facilities are typically distributed along hundreds of miles of coastline that are connected by coastal currents that help distribute larvae into areas that may have reduced abundances. As a result, there should be very little potential for impacts due to OTC on the open coast. This is supported by the results from long-term monitoring of adult fish populations in the vicinity of the Diablo Canyon Power Plant provided in this section that showed no changes in abundance that could be related to power plant operation.

Fish impingement has been routinely measured for decades at several coastal power plants in southern California, and these data are reported annually as part of their NPDES receiving water monitoring studies. The same core group of fish species continues to be impinged at these power plants, and there is no detectable effect from the operation of the cooling water systems. For species that are harvested commercially, such as northern anchovy, the biomass of fish impinged is orders of magnitude below commercial landings.

The same is true for species that are targeted by recreational fishing. From the mid-1940s to the early 1970s, the sportfish catch per unit effort in Santa Monica Bay more than doubled despite the fact that three generating stations commenced operation during that time period. Analysis of this trend revealed that fish abundance was highly correlated with water temperature and transparency. Similar correlations have been recorded in recent years by many researchers, suggesting regional climatic events play a large role in the fluctuations of fish populations. The trends are not indicative of long-term declines that might be expected if the additional mortality due to cooling water intake systems were affecting these populations.

Although the results presented in this report were limited to a few plants with historical or long-term data that could be used to examine potential changes in fish populations due to OTC, the comparisons do include examples from all of the major coastal intake location configurations in use by facilities throughout California. These include an example from a small lagoon (i.e., Encina inside Agua Hedionda Lagoon), a large bay (i.e., South Bay in San Diego Bay), an open coastal site with a shoreline intake (Diablo Canyon), and an open coastal with an offshore intake (Huntington Beach). While these examples do not provide any evidence of cooling water intake system effects, the absence of long-term data hinders more definitive statements on the effects of OTC.

The absence of any clear evidence of cooling water intake system effects from these studies is consistent with a recent review on population level effects on harvested fish stocks by two EPA scientists (Newbold and Iovanna 2007). They modeled the potential effects of impingement and entrainment (I&E) on populations of 15 fish stocks that are targeted by either commercial or recreational fisheries using empirical data on I&E, life history, and stock size. For 12 of the 15 species, the effects of removing all of the sources of power plant I&E were less than 2.5%. For the other three species, the effects ranged from 22.3% for striped bass (*Morone saxatilis*) on the Atlantic coast to 79.4% for Atlantic croaker (*Micropogonias undulatus*). Their overall conclusions were that population level effects were negligible for many fish stocks but could be severe in some cases. They attributed the absence of large effects for most species to compensatory effects that are probably acting on the populations at some level. If there is strong density dependence acting on these populations at some point during the life stages from the period when they are vulnerable to entrainment as larvae through the age of maturity, then they concluded that there should be very little potential for population level effects due to impingement and entrainment.

Unlike the harvested fishes analyzed by Newbold and Iovanna (2007), the effects of I&E in California would appear to have the greatest potential for detrimental effects for non-harvested fishes in protected waters. There is evidence, at least for gobies, however, that there is strong density dependence during recruitment and low potential for populations level effects. The large impacts for Atlantic croaker from the Newbold and Iovanna study are a result of a high entrainment mortality rate estimated at 43.4%, much higher than west coast species of croakers. The mortality rates for west coast species of croakers are typically much lower and closer in value to the levels that Newbold and Iovanna concluded represented little risk to the populations. Their results indicate the need for site-specific studies of on the effects of cooling water intake systems to determine if some combination of factors including the conditions and species at a site result in large population level effects. If properly designed these studies would help provide more definitive answers on the effects of cooling water intake systems on California fish populations.

4 DISCUSSION

California fisheries are subject to a wide variety of perturbations—both natural and human induced. The correlation of fishery catch trends with changes in environmental factors is one of the most significant and best documented (Jarvis et al. 2004). In terms of human induced impacts, the most significant impact on California's coastal fishes has been commercial fishing. Between 1981–2000, the combined harvest of most commercial species declined by 50%, although there was an overall increase in commercial landings primarily due to increased harvest of small pelagic fishes and squid (Starr et al. 1998). This decline was attributed to reduced populations of many deep-dwelling bottom species caused by high fishing pressure in the 1980s that occurred following overestimates of production for these species. As a result, fishing pressure moved inshore in the early 1990s, but by the end of the decade inshore species began to decline as well. The CEC Staff Report (York and Foster 2005) also documented California's fishery declines. In addition to once-through cooling (OTC), other human induced impacts of concern to nearshore fisheries include habitat modification and loss, introduction of invasive species due to transoceanic shipping, point and non point source water quality impacts, marine construction related to such activities as oil wells and desalination facilities. Each of these human-induced impacts is the result of providing a public benefit. However that impact could be addressed through an investment of public or private economic resources to provide appropriate controls or mitigation to address those uses. In making informed decisions as to appropriate prioritization for use of economic resources when billions of dollars will be required to address these concerns, it is important to consider the cost of the proposed action and anticipated benefit.

As discussed in the Introduction of this report, with EPA's promulgation of the Phase II Rule for cooling water intakes, there has been considerable attention focused on use of OTC by a number of State Agencies in California. Most importantly is the consideration being given by the SWRCB in the ongoing development of a State 316(b) policy, which significantly deviates from the EPA Rule. As discussed in Section 2, the majority of California's coastal OTC generating stations have taken some form of mitigating action in the form of employing some level of fish protection technologies, flow reduction, or compensation for impingement and/or entrainment reduction through planned or implemented restoration projects. These actions reflect the State's focus on protecting coastal fisheries. In implementing a California §316(b) Policy that could result in a requirement to retrofit all OTC facilities with wet or dry closed-cycle cooling, it is important to consider the technical basis of such a policy in light of the costs, the benefits that would be achieved, and the potential impact to energy supply and reliability, as well as the non-aquatic environmental impacts associated with such a policy. However, no technical basis for such a policy has been provided by its advocates. Concerns are expressed primarily in terms of the relatively large volume of water use by OTC facilities. The most significant concern has been for entrainable life stages. A policy urged by some stakeholders in light of fishery declines is use of the precautionary principle. The principle advocates action in the absence of a clear understanding of benefits. However, when the policy results in expenditures of billions of dollars based on technologies that also cause impacts, including fishery impacts, it is important to fully consider the net social and environmental benefit.

In addition to the California case studies and other information provided in Section 3 of this report, a number of factors important to consider in developing a sound §316(b) Policy are offered for consideration.

4.1 Role of Compensation

Despite the large numbers of larval fishes that are entrained, there is no scientific basis in fishery population dynamics or fisheries management policy and practice to expect any significant fish population impacts. More importantly, there is no evidence from previous §316(b) studies or information presented in the Draft California Policy that OTC has caused, or is at present, causing significant adverse effects on California coastal fish populations. Though the absolute numbers of larvae entrained seem enormous, these losses comprise very small fractions of the populations at risk to entrainment. In addition, those early life stages remaining have heightened survivorship following entrainment losses. This is the result of a concept referred to as compensation or "density dependence". This concept is fundamental to the understanding and management of fish and shellfish populations. This compensatory response is the key factor that allows fish populations to maintain themselves when subjected to fishing mortality. It provides a foundation for the understanding of stock dynamics and fishery management. If compensation did not exist, species could not sustain themselves in highly variable natural environments and in the face of long-term anthropogenic stresses, such as mortality from fishing.

Identifying the operation of compensation in fish populations has been a major focus of fishery research for decades (Rose et al. 2001). Examples of compensatory processes include altered competition for food or habitat and preferential targeting of predators on abundant prey species. Even when the specific compensatory mechanisms involved are not known, fisheries scientists can often quantify compensation by analyzing relationships between the abundance of spawning fishes and the resulting number of young fishes produced. Quantitative estimates of compensation are employed in fishery management to protect stocks from over exploitation, to define alternative criteria for optimal utilization, and to guide the course of rehabilitation of depressed stocks. Fisheries managers routinely use quantitative models to perform fish stock assessments, and these stock assessments are the foundation for the setting of fishery limits and quotas. It is recognized that a fish population's compensatory reserve (the amount of loss that can be compensated for by natural processes) varies from year to year such that in some years a species compensatory reserve will be greater than in other years. It is also recognized that species exploited by stresses such as heavy fishing pressure will have a smaller reserve for other sources of mortality than species that are not exploited. Finally, it is also recognized that there are clearly instances where fishery models have overestimated compensatory reserves that have resulted in declines for various species. Nonetheless, the majority of larval fishes entrained in California are in fact unexploited species (e.g., gobies, blennies, topsmelt, etc.) or species that are harvested recreationally but not commercially (e.g., croakers) and appear to have a high compensatory reserve with a few exceptions (e.g., rockfishes at Diablo Canyon).

Specifically, it is important to remember that the numbers of larvae produced by most fishes during their reproductive years as adults can be enormous, but only two of those larvae need to survive to adults to maintain a stable population level. For example, a single California halibut (an exploited species) releases 5–50 million eggs per year over its reproductive life, and a single rockfish may release up to one million larvae per year for several years to decades, depending on the species. These species have evolved to produce prodigious numbers of early life stages because of the risky environment into which they disperse their young. Other species such as gobies produce only a few thousand larvae per year over a much shorter lifespan, but even in these fishes, the total lifetime survival required to maintain the population is quite small. For example, if each female spawns 2,000 eggs over her lifetime, and half of these eggs produce female fish, only 0.1% (2/2,000) of the eggs must survive to sexual maturity to maintain a stable population.

The issue of compensation (density-dependent predation and recruitment) is critical for interpreting impacts of entrainment. The arguments presented by State Water Resources Control Board, California Energy Commission, and California Coastal Commission staff and members of the environmental stakeholder groups do not consider the role of compensation in maintaining these populations. An important example is the observation on gobies from Agua Hedionda Lagoon. In the case of gobies, there appears to be strong density-dependent mortality at the stage when the fishes recruit onto the mudflat habitat they will occupy as adults (Brothers 1975). There is only so much space for goby burrows on the mudflat and all of the juvenile gobies that are unable to find suitable available habitat are probably prey for larger fishes. The adult population of gobies has very little dependence on larval supply, but is very dependent on habitat availability. Similar density dependencies have been shown in other temperate and tropical reef fishes. Estimates of the strength of density dependence are now frequently used to inform fisheries management decisions. Recent stock assessments for cabezon and kelp greenling, prepared for the Pacific Fisheries Management Council, include an explicit model of density-dependent population dynamics (Cope and Punt 2005). Although the relative effects of density dependence have been debated (Rose et al. 2001), there is a strong theoretical basis for its importance.

An equally important statistic from both the past and most recent entrainment studies is that the majority of the larval fishes entrained are from species that are not commercially or recreationally important and therefore are not harvested in a fishery. Since they are not harvested, the low levels of mortality imposed by entrainment are being imposed on populations that are at a level close to the natural carrying capacity of the coastal environment. Therefore, the mortality due to entrainment is not added to mortality from fishing, and it alone likely would not affect such populations. In fact, the loss (or cropping) of early life stages in populations limited by food or space generally leads to faster growth and higher survival of subsequent life stages; another reason why reductions in entrainment losses of larval fishes will not be followed by observable increases in source water populations. An example of a commonly entrained species that is commercially harvested is the northern anchovy. This species has an extensive adult population that covers thousands of square miles of ocean and any impact would be small relative to the population. Other species affected by entrainment have source populations well offshore, and their larvae are transported inshore where they become susceptible to entrainment (sink species). An example would be Mexican lampfish (*Triphoturus mexicanus*), a mesopelagic species that is found in several thousand feet of water.

4.2 Impingement and Entrainment Losses in Context with Fishery Harvests

Whereas fishing pressure as been implicated in population declines there has been no evidence that power plant impingement and entrainment losses have directly caused a measurable impact to an adult fish population. Fishing pressure has resulted in a fishery management decision to reduce fishing that did result in a positive response for that species (e.g., Richards and Rago 1999). Because extensive fisheries data tend to be collected on many harvested species, comparisons of those harvest losses to impingement and entrainment losses can provide a useful basis for comparison. From a population sustainability perspective, the mortality imposed on larval populations by entrainment at OTC power plants is negligibly small compared to mortality levels of concern in fishery management. The fishery often takes reproducing adults whereas entrainment takes early life stages that normally have high mortality. Impingement most often takes juveniles at a pre-reproductive age that also have high natural mortality rates. The California Department of Fish and Game has stated in their Nearshore Fisheries Management Plan (CDFG 2002) that an overfished stock is one that has been reduced to 30% of its unfished biomass and that controls would need to be enacted whenever a stock is reduced to 60% of its unfished biomass. The designs of recent entrainment studies are based on similar principles of fishery management and provide estimates of the numbers entrained (harvested) as percent of the total larvae at risk (i.e. not sexually mature adults) to entrainment (catchable). In these studies, the entrained fractions typically average between 2%–10%. For many species, the average mortality level is much lower. Important differences compared to fishery losses are that the losses are to larvae are potentially compensated for at later life stages. In addition the larval source populations at risk for most species represent only small fractions of the total annual larval production by the adult spawning population. Because most of the spawned larvae are never susceptible to entrainment, the population-level mortality rates are likely to be much smaller than the mortality rates estimated in typical entrainment studies. Even the 2%–10% additional larval mortality resulting from entrainment typically estimated from studies at California power plants on the open coast is very small compared to the fishing mortality that would reduce a fish population to 60% or less of its unfished abundance. For many this scientific fact is difficult to comprehend or is philosophically at odds with their ideas of preservation.

Cabezon and blackgill rockfish (*Sebastes melanostomus*) provide good examples of the very small magnitude of entrainment mortality as compared to fishing mortality. According to Cope and Punt (2005), in the absence of fishing, the spawning stock biomass (SSB) of the southern subpopulation of California cabezon (defined as the population inhabiting the region from Point Conception to the U.S./Baja California border) would be 276 tons (251 metric tons [MT]). Fishing at the maximum sustainable rate permitted by California regulations would reduce SSB to only 121 tons (110 MT). According to Helser (2005), in the absence of fishing, the SSB of the coastwide California blackgill rockfish population would be 10,475 tons (9,503 MT). Fishing at the maximum sustainable rate would reduce SSB to only 4,188 tons (3,799 MT).

Information provided in the cumulative impacts analysis prepared for the Huntington Beach Generating Station Entrainment and Impingement Study (MBC and Tenera Environmental 2005) can be used to compare these impacts to impacts caused by entrainment at all 13 of the power plants located between Point Conception and the U.S./Baja California border. This assessment provides estimates of cumulative fish larval mortality due to the operation of these plants. Key points resulting from this analysis include:

- Depending on the assumptions made concerning the spatial distribution of larvae and the duration of the period in which larvae are susceptible to entrainment, between 0.17% and 4.36% of larvae present in this region could be entrained.

- Using the results provided in the Huntington Beach Generating Station study, Figure 4-1 compares the potential impacts of entrainment on the spawning biomass of cabezon and blackgill rockfish to the impact of harvesting at the maximum sustainable rate, assuming a susceptibility duration of 40 days (the maximum value used in the Huntington Beach study). As shown in Figure 4-1a, fishing at the maximum sustainable rate would reduce cabezon SSB by 155 tons (141 MT) as compared to the unfished population. The additional reduction in cabezon SSB caused by entrainment would be at most 5.3 tons (4.8 MT), assuming that all larvae are restricted to the region within the 115 ft (35 m) depth contour, and only about 1.7 tons (1.5 MT), assuming that larvae can occur out to the 246 ft (75 –m) depth contour.

- For blackgill rockfish (Figure 4-1b), fishing at the maximum sustainable rate would reduce SSB by 6,288 tons (5,704 MT). Entrainment would reduce blackgill rockfish SSB by only a further 90–182 tons (82–165 MT) (1.4%–2.9%), depending on the assumption made about larval distribution. The spawning stock biomass and harvest for this species are applicable to the entire California coast, not just to southern California. If it is assumed that only half of blackgill rockfish larvae are susceptible to entrainment at southern California power plants, then the reduction in SSB due to entrainment would be only 29–57 tons (26–52 MT).

Note that these calculations are conservative and probably overstate the actual impacts of entrainment because they assume that the duration of the period of susceptibility is 40 days (the maximum duration considered in the Huntington Beach Generating Station study), that no larvae occur in water deeper than 246 ft (75 m), and that natural mortality is not density dependent.

The extensive studies conducted at the San Onofre Nuclear Generating Station can also be placed in context with California fishery harvests. Figure 4-2 provides a comparison of San Onofre entrainment and impingement losses with recent fishery harvest information. As shown in the figure for San Onofre, the combined impingement and entrainment biomass is 0.49% of the fishery harvest biomass. The impingement biomass makes up 0.02% of the California fishery harvest and 0.07% of the L.A. County commercial catch biomass. While San Onofre is only one of 12 of the southern California facilities, it impinges 93% of the fishes (York and Foster 2005).

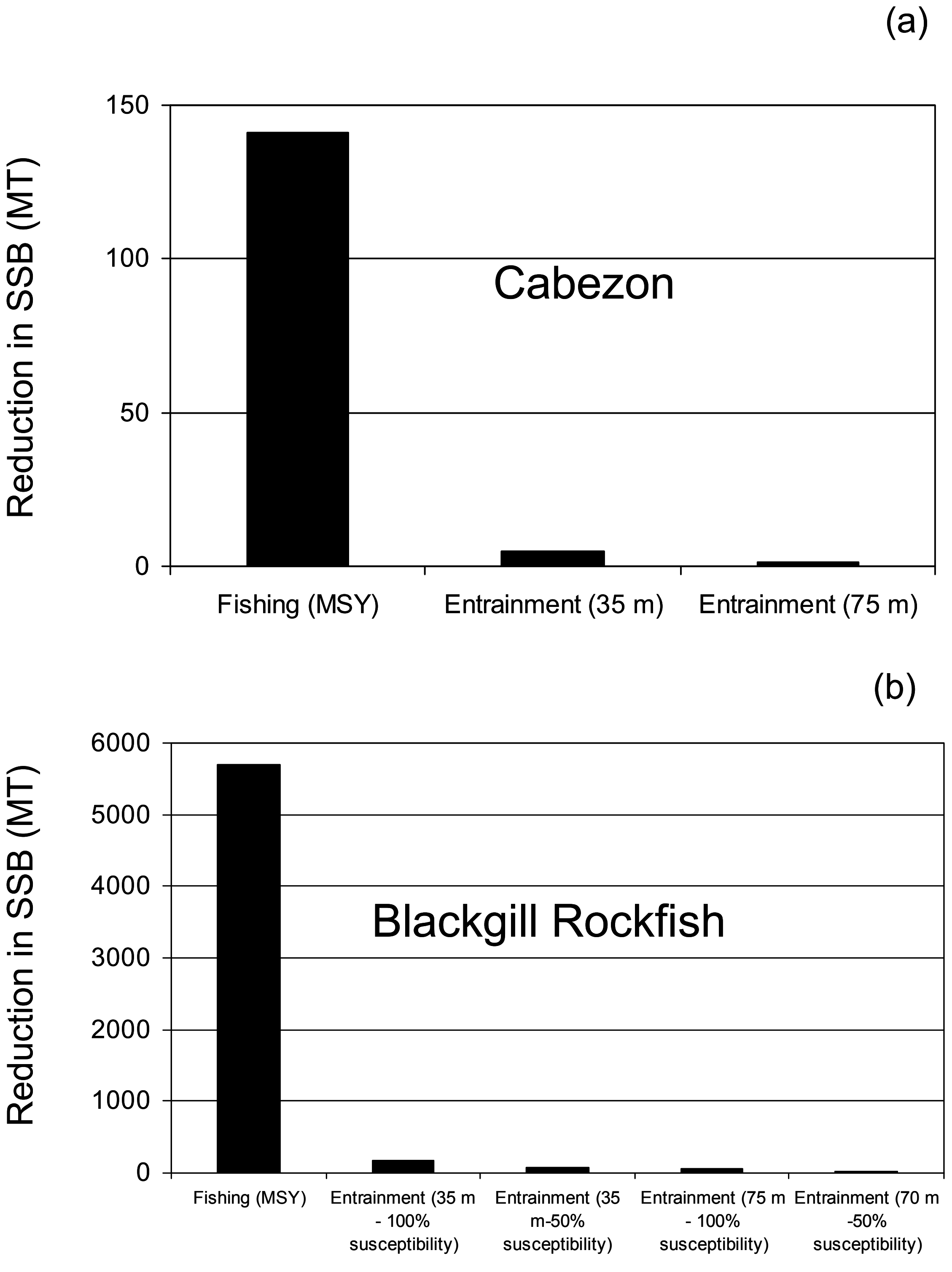

Figure 4-1. Reduction in spawning stock biomass of (a) cabezon and (b) blackgill rockfish caused by fishing (Cope and Punt 2005, Helser 2005) compared to reductions caused by entrainment at southern California once-through cooled power plants.

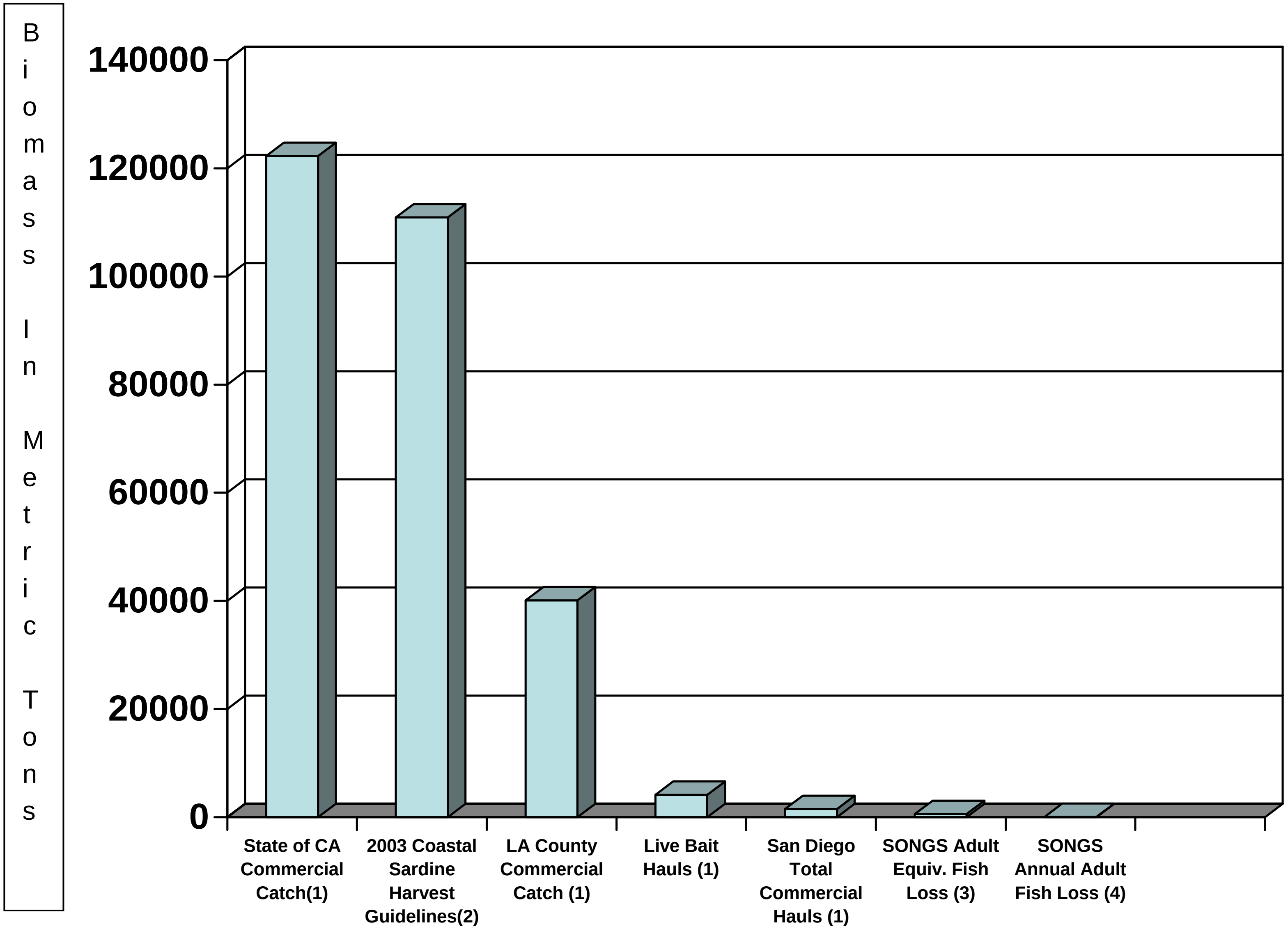

Figure 4-2. Comparison of California recent fishery harvest data (biomass in metric tons) to San Onofre impingement and entrainment losses. Sources of information (1) PacFIN 2003, (2) Hill et al. 2005 (3) MRC 1990, (4) SCE 2007.

4.3 §316(b) Assessment in Maryland

There are several reasons why a good source of OTC impact information relevant for consideration in California comes from Maryland. First, Maryland is located on the Chesapeake Bay, which is considered important for seafood production. It is the largest coastal estuary in North America and supports a large population of fish and shellfish. Second, as is the case in California, many of the commercially harvested species in particular have been in decline. Third, Maryland's OTC generating facilities are primarily located on tidal river estuaries with the exception of the State's single nuclear facility (Calvert Cliffs Nuclear Power Plant), which is located on the main stem of Chesapeake Bay. The relevance is that these facilities in Maryland are located in more enclosed systems compared to California coastal facilities with the exception of California's San Francisco Bay-Delta facilities. As a result of decreased circulation one would expect any impacts of these facilities to be much more visible than along California's coast. Fourth, Maryland has established the Power Plant Research Program (PPRP) within the Maryland Department of Environment. This State Agency is funded via a surcharge on electricity use in the State and functions in a manner similar to the California Energy Commission. It plays a major role in licensing of new generation within the State and responsibilities also include evaluation of power plant impacts. In this capacity it serves as a source of technical information for the Maryland Department of Environment (MDE), which administers the NPDES permit program. The PPRP has conducted millions of dollars of independent research on OTC. In addition, it is charged with conducting the technical review of independent studies conducted by the OTC facilities. Maryland's three largest OTC facilities have each conducted millions of dollars of research to assess their §316(b) impacts. Both PPRP and facility studies have concentrated on impacts to fish and shellfish but studies have included evaluations of impacts to all trophic levels.

The PPRP and its primary technical contractor published a paper on two decades of power plant fishery impact studies (Richkus and McLean 2000). Some of the findings of this assessment were as follows:

- "A relatively recent assessment of trends in important aquatic resources in different segments of the Bay found various long-term trends in the abundance of some of the major species impinged (Richkus et al. 1994), but none that could be linked to impingement effects."
- "…it can be seen that bay anchovies, spot and menhaden, three of the species appearing in greatest numbers in entrainment and impingement estimates for the Chalk Point and Calvert Cliffs power plants over the last several decades, are characterized as being at or above the long-term reference levels established to characterize status. This information further supports the view that power plant effects are not a dominant factor in establishing the status of basin-specific fish stocks."
- To assess entrainment impacts, the PPRP used extensive ichthyoplankton sampling using a stratified random sampling design, combined with a Spawning and Nursery Area of Consequence Model to evaluate impacts to Representative Important Species (RIS). Entrainment losses were estimated for 24 different populations of RIS in the

Potomac River Estuary. The Model was also applied for many of these species to evaluate entrainment impacts to other tidal systems. As a result of these evaluations "…only in the case of PEPCO's Chalk Point Steam Electric Station were entrainment impacts considered to be sufficiently significant to warrant some action being taken by the state." At Chalk Point the species of concern was the Bay anchovy considered important as a forage species. At this plant, use of mitigation to restore several important fish stocks was implemented rather than a requirement for technology solutions since they "…were deemed to be not commensurate with the magnitude and nature of the loss of aquatic resources."

- "…a critical point to be made regarding the regulation of power plants in Maryland is that the regulatory procedures successfully employed to protect the living resources of Maryland's Chesapeake Bay and to allow for the generation of electricity essential to the state's citizens and industry clearly allows for cooling water withdrawal as a valid use of the state's water resources, so long as the consequences of this use is [sic] balanced against other related sources of impacts and the state's overall environmental and social objectives."

The findings of the Maryland PPRP studies are consistent with similar studies conducted in other East Coast estuaries. Scientists have been studying impacts of entrainment and impingement on Hudson River fish populations, and especially on the Hudson River striped bass population, for more than 30 years (Barnthouse 2000). Throughout most of this period, six power plants employing OTC technology were operating and withdrawing more than 5 billion gallons of cooling water per day. In spite of these withdrawals, the abundance of the spawning population of striped bass in the Hudson River increased by more than a factor of 10 over this period. Additionally, similar studies of the striped bass population of the Delaware River have shown that annual production of juvenile striped bass from the Delaware grew from nearly zero in the early 1980s to more than 1,000,000 fish per year by 1990 (Kahn et al. 1998). This exponential population growth has been attributed to improvements in water quality, and occurred despite the operation of the Salem Generating Station (more than 1 billion gallons per day) and other OTC power plants withdrawing water from the Delaware. Analyses of trends in fish community structure and population abundance, supported by modeling of entrainment impacts, demonstrated that OTC operation at Salem has had no adverse impacts on the Delaware estuary (Barnthouse et al. 2002).

4.4 Cooling Lakes and Reservoirs

In one sense, freshwater cooling lakes can be considered one of the most sensitive waterbody types, in terms of susceptibility to OTC impacts. Many of the cooling lakes in Texas, Oklahoma, New Mexico, and other states were constructed specifically for the purpose of providing a source of condenser cooling water for generating stations due to water scarcity. Most of these lakes or reservoirs were subsequently stocked with recreational fishes and some fishes and invertebrate species were introduced in make-up water, which is used to replace evaporative water losses in these lakes. These cooling lakes represent totally isolated systems. There is virtually no means for adult fishes to leave these systems except through recreational harvest or impingement. The introduction or recruitment of new fishes is limited to wet periods of the year when fish eggs and larvae may be introduced into the cooling lake as make-up water withdrawn from nearby rivers is used to maintain water levels in the lake. Additionally, in some cases recreational fishes may be stocked.

In most of these lakes, the OTC condenser flows are quite large relative to the cooling lake water volumes. The result is that the entire volume of the lake, depending on the facility, can pass through the power plant over a period of less than a week to several weeks. One might assume that due to the amount of cooling water used relative to the size of the source waterbody and the enclosed fishery that in such instances very few fishes could survive. On the contrary, most of these cooling lakes and ponds have become very important local recreational sport fisheries. These lakes contain a variety of species such as bass, bluegill (*Lepomis macrochirus*), crappie, and catfish in addition to a forage base that generally consists of threadfin and gizzard shad (*Dorosoma petenense* and *Dorosoma cepedianum*), minnows, and juvenile bluegill or other sunfish. However, it is important to note that only the shad, usually the dominate species, are pelagic spawners that tend to be vulnerable to entrainment.

EPRI conducted a detailed study of a cooling reservoir in Illinois, which included recording water quality conditions (EPRI 1979). In the case of reservoirs, a cooling water impoundment is created by a small river or stream to supply condenser cooling water. EPRI produced a series of four report volumes comparing two similar Illinois reservoirs, one with an OTC system and one without. The results of these studies determined that the OTC reservoir was capable of supporting a viable fishery.

In both the case of the Texas and Illinois reservoirs, pelagic spawning gizzard and threadfin shad are among the species susceptible to impingement and entrainment. These species provide the forage base for recreationally important species.

4.5 Benefits of Cooling Water Flow for Some near Shore Systems

There is a potential ecological benefit of OTC for several California power plants that is frequently not considered. This benefit is provision of hydraulic circulation to a number of tidal rivers or coastal embayments. These facilities include the Alamitos, Haynes, Encina, and South Bay power plants. In the case of Alamitos, in 2006 there was a reduction in use of cooling water. Alamitos withdraws its cooling water from the Pacific through the Los Cerritos Channel. The Channel is lined with wetlands that depend on water circulation to maintain their health. In the absence of operation of the Alamitos cooling water pumps, the only significant flow in the channel occurs during storm events when there is freshwater inflow from the stormwater runoff via the storm channel and some tidal exchange. As a result of Alamitos' reduced flow, concern was expressed over odor problems and bacteria in the Los Cerritos Wetlands. AES Alamitos was contacted with a request to discuss options for maintaining flow in the Channel in order to maintain the health of the Los Cerritos Wetlands even during times when cooling water is not needed by the plant. If Alamitos were to be retrofitted with closed-cycle cooling, the health of the wetland system and its associated productivity would be adversely affected. Similarly, if Encina were to be retrofitted with closed-cycle cooling, there is significant potential for impacts to the Agua Hedionda Lagoon. Haynes Generating Station draws its water in through Alamitos Bay. This water withdrawal, along with tidal flows through Alamitos Bay, has a significant beneficial impact on the health and overall water quality of the bay, which would otherwise exhibit the stagnant characteristics of many backwater harbors with poor circulation. If Haynes or Alamitos Generating Stations were to be retrofitted with closed-cycle cooling, flow into the bay would be significantly reduced, which would result in a reduction in circulation and the health of this aquatic environment. Additionally the OTC water flow from both Alamitos and Haynes is discharged into the San Gabriel River. These discharges make up the majority of the flow in this river. There would be a risk of water quality impairment if the OTC flows were to be eliminated.

4.6 Results of New Impingement and Entrainment Studies for Decision Making

Most of California's OTC facilities were conducting new impingement and entrainment studies in 2006. For a number of facilities, these studies also included the collection of source waterbody data. For most of these facilities, sample processing is now being completed and data are being entered onto databases and verified. The results will be available for analysis and summary in late 2007. Since studies conducted at many of these facilities include source waterbody sampling, the data should allow use of the *ETM* model. These studies will provide additional quantitative information on the current level of entrainment for many of California's facilities to further evaluate the effects of entrainment on marine fish populations and the extent to which any significant adverse impact occurs to the fish populations and fisheries. They will also provide additional information on the expected change in the fisheries that might result from a closed-cycle retrofit based on California's proposed §316(b) Policy.

5 SUMMARY AND CONCLUSIONS

The California State Water Resources Control Board (SWRCB) is currently in the process of determining the need for requirements that go beyond the EPA Phase II Rule requirement to address concerns related to use of once-through cooling (OTC). California currently has 16 fossil and two nuclear generating stations that use OTC. The majority of these facilities currently employ some level of fish protection technology, have reduced use of cooling water flow, and/or addressed entrainment losses through use of mitigation. The six facilities with offshore intakes all employ use of velocities caps that have been shown to provide a significant impingement reduction compared to open-pipe intakes. Recent velocity cap studies indicate a level of performance at the high end of the EPA Phase II Rule's performance standard range for the dominant species impinged.

The EPA Phase II Rule has been remanded back to EPA as a result of the Court Decision. The Phase II Rule would have required all facilities to demonstrate a reduction in impingement and entrainment to meet the 60% to 90% entrainment reduction and 80% to 95% impingement mortality reduction performance standards using one of five compliance options. Based on the Court Decision, facilities will no longer be allowed to use restoration measures for compliance nor will they be able to consider the benefits resulting from technologies and/or operational measures in context with the cost. Until the litigation issues are resolved, either through further litigation and/or EPA revisions to the Phase II Rule, §316(b) is to be administered on a Best Professional Judgment (BPJ) basis. The present responsibility of the California SWRCB is to determine the measures that should be required for California's OTC facilities under BPJ. It is the premise of BPJ that the best technical information related to the issue will be used for decision making.

For entrainment, the Draft California Policy would require most facilities to install closed-cycle cooling to comply. The cost of requiring elimination of OTC through wet or dry closed cycle cooling retrofits is estimated to be in the range of several billion dollars and could result in the retirement of a large number of older units with low capacity utilization that are necessary to provide generation during periods of peak energy demand. To date, no quantitative technical information has been provided to support the nature of the fishery improvements that would be achieved by the Draft California Policy.

The SWRCB has not provided any quantitative technical information to support the nature of the fishery improvements that would be achieved by the Draft California Policy despite the availability of a significant amount of recently collected and existing data documenting the magnitude of impingement and entrainment losses. The absence of any long-term comparative data, including data prior to plant operation, at any power plant makes scientific determination of OTC effects very difficult. These types of data are necessary due to the multiple human (e.g., fishing, pollution, habitat loss, OTC, etc.) and environmental factors (e.g., long- and short-term changes in ocean temperatures, ocean currents, ecosystem interactions, etc.) that are known to affect fish abundances. In the absence of any definitive study, multiple sources of information were presented in this report to determine if there was any available evidence indicating that impingement and entrainment losses were severely impacting California fish populations.

The examples in this report do not indicate that impingement and entrainment losses have severely impacted California fish populations. The examples included comparisons of historic and current levels of impingement and entrainment, comparison of fish abundances in similar habitats with and without power plants, and comparisons to impacts from other human induced pressures such as commercial and/or recreational fishing losses. It was also noted that for the facilities located in embayments and lagoons, OTC may provide a water circulation benefit that contributes to the overall health of these inshore areas. An examination of other sources of information such as compensation, fishery health in enclosed waterbodies, and detailed studies conducted on the East Coast in oceans and estuaries in nearly all instances also supported the conclusions based on the California data.

Therefore, the merits of a large economic investment in closed-cycle cooling and/or reduction in California’s generation reserve capacity are not yet clear and these changes may result in no measurable benefit to California fish populations. Additional information in the form of recent impingement and entrainment data collected at the majority of the OTC facilities along with source waterbody data for many facilities has been collected and analysis of that data may aid SWRCB in establishing a technically and socially sound §316(b) Policy.

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A PROPOSED PERFORMANCE STANDARDS, ALTERNATIVE FISH PROTECTION TECHNOLOGIES, AND OPERATIONAL MEASURES

Fish protection technologies and operational measures are topics for which EPRI has done, and continues to do, extensive research. During the rulemaking for 316(b), EPRI provided numerous documents, comments, and testimony on fish protection technology research. This area of research continues to make up the largest component of the 316(b)-related research in recent years. Comments on California §316(b) Policy's performance standards and implications for available fish protection technologies and operational measures are as follows:

A.1 Technology Performance - General

EPA in the Federal 316(b) Phase II Rule for existing Steam Electric Generation Stations established performance standards to protect fish and shellfish as ranges (i.e. 60%–90% reduction for entrainment and 80%–95% reduction for impingement mortality). These ranges were based on EPA's engineering evaluation of available fish protection technologies (USEPA 2002). The Phase II Rule's preamble points out that due to site-specific constraints there is no single technology applicable for all facilities and that even for a given technology, performance can vary due to the species and life stages, waterbody and other factors. EPA's economic analysis of the Phase II Rule's costs and benefits concluded that use of closed-cycle cooling should not be required everywhere. As a result, EPA established performance standard ranges and compliance options and alternatives that would allow all Phase II facilities to comply with the Rule.

In contrast, the California State Water Resources Control Board's (SWRCB) Draft California Policy requires adherence to specific technologies or numeric standards and limited use of compliance alternatives and options. Further, the entrainment performance standard is applied to zooplankton in addition to fish and shellfish. The only flexibility in compliance allows facilities to demonstrate that if only a 60% reduction can be achieved with technologies, restoration measures can be used to reach the required 90% reduction. However, it is important to note that the demonstration is based on showing that alternatives such as closed-cycle cooling or flow reductions are not feasible. EPA explains the basis for using a performance standard range in the Phase II Rule on page 41598 in the preamble to the Rule. There are a finite set of available technologies to reduce impingement and an even more limited set of alternatives to reduce entrainment. Many technologies would be immediately excluded by the Draft California policy and others will be infeasible for use in California. None of the alternative fish protection technologies evaluated by EPA are designed to protect zooplankton. A review of the issues associated with the technologies and operational measures considered by EPA for application in California's coastal waters is discussed in the comments below.

A.2 Entrainment Technologies

Since entrainment reduction technologies generally address impingement, as well as entrainment, and since entrainment is viewed as the more significant issue in California, these alternatives are considered first. There are basically five alternatives for entrainment reduction considered in the EPA Phase II Rule that are potentially applicable to California's coastal generating facilities. Each of these is briefly discussed.

A.2.1 Aquatic Filter Barrier (AFB)

The Aquatic Filter Barrier is a coarse fabric mesh that is designed to filter out fish eggs and larvae from the withdrawn water. It covers the entire inlet cross section. It works by creating sufficient surface area to generate very low through screen (i.e. filter fabric) velocities. This technology has been deployed in a full-scale manner at only one U.S. facility, the Lovett Generating Station on the Hudson River. Data have not yet been made available to demonstrate the technology can meet the EPA Phase II Rule's entrainment performance standard. The first year the system was deployed, it developed a large tear during the test. In the summer of the second year, water was observed flowing over the top of the AFB. No results have been made available for a full spawning season to fully evaluate performance. Based on the problems with this technology during its deployment in a tidal river, it is not considered to be feasible in open ocean environments. Further, its use is precluded at nearly all, if not all, inshore facilities in California due to the size of the AFB that would be required and the fact that it would present an obstruction to navigation.

A.2.2 Use of Collection and Handling Systems

Traveling screens might be deployed with mesh sizes small enough to exclude larger entrainable organisms, with provision of a return system to the source waterbody. EPRI is conducting evaluations of a number of alternative designs for fine mesh traveling screens, beginning in 2007. However, these systems would effectively be eliminated from consideration under the Draft California Policy. The reason is that it is highly unlikely that some fragile, commonly entrained species (i.e. northern anchovy, sardine, croakers, etc.) would have survival rates that would meet the performance standards even at the lower bound of 60%. southern California Edison (SCE) conducted studies in 1981 (LMS 1981) to evaluate survival rates of entrainable-sized fishes using various mesh sizes and materials as well as variable intake velocities. While the results determined immediate survival rates of up to 80% for hardy species such as California grunion, survival for this species dropped to 47% when handling and transport back to the source waterbody after immediate impingement survival were considered. Survival was much lower for northern anchovy, a fragile species. In this case, immediate survival off the screens was determined to be 40% with no survival when handling was considered. While there may be some improvement in survival based on current improvements in this technology, it is highly unlikely that fragile species will achieve survival rates of the minimum 60% required, let alone the 90% reduction required by the high end of the range. In addition, for many facilities such as Alamitos, Haynes, Huntington Beach, El Segundo, and Scattergood long transport distances (over a mile for some of these facilities) would be required to return impinged or entrained organisms to a location in coastal waters where they would not be subject to re-impingement or re-entrainment. Finally, studies are documenting that the large majority of entrainment losses for California's facilities occur to very early life stages. In many cases, these life stages are smaller than the mesh sizes previously tested or proposed for testing in EPRI 2007 studies.

A.2.3 Narrow Slot Wedgewire Screens

Screens are commercially available that are constructed with wedge-shaped wire having small slots between the wedges. This technology is also designed with a very low through-screen velocity and narrow slot wedgewire screens would automatically meet the proposed impingement standard. They are designed to have a through-slot velocity that would not exceed 0.5 feet per second (fps) (EPA's acceptable intake velocity). However, there are feasibility issues with this technology. The first is marine biofouling. These systems have not been employed at any existing power plants located in marine environments on either the east or west coast. The size and distance of the once-through cooling intake tunnels for many California plants exceed the capacity of the air blast system currently designed to control fouling and debris on the surface of the screen modules. Design changes would be necessary to address fouling both inside the intake tunnels and at the surface of the wedgewire modules. Secondly, for many facilities such as Alamitos and Haynes, the distance required for deployment (i.e. well over a mile) will preclude use of this alternative. Thirdly, for facilities in a closed harbor area, such as the Harbor Generating Station, the technology may have difficulty meeting the performance standard due to the lack of tidal currents to carry entrainable organisms past the screen modules. Studies in a tidal estuarine environment on the East Coast used screen slot widths of 1, 2, and 3 mm. Study results determined that no fish less than 5 mm long were excluded. However, more than 80% of the larger ichthyoplankton were excluded (Weisberg 1987). It is the very small-sized larvae that are dominant in California's entrainment studies, however. Currently a number of California's coastal facilities are evaluating the cost and effectiveness of this technology. The results of these evaluations will be available in the latter part of 2007.

A.2.4 Reduced Use of Cooling Water Pumps

The Phase II Rule used the assumption that a reduction in flow would result in a proportional reduction in entrainment. This could potentially be achieved through two approaches. The first approach would be to reduce the number of pumps in operation on a seasonal or diel basis. The advantage of this approach is that it requires no capital cost. The disadvantage of this approach is that it does not allow any level of precision in terms of the amount of flow reduction as there are normally a limited number of pumps that serve a unit and the pumps are either on or off. The second approach would be to install variable speed drives to allow much greater precision to control the amount of the flow reduction. Such drives were installed at Mirant's Contra Costa and Pittsburg Generating Stations to provide fish protection.

However, this option has the significant disadvantage of potentially reducing the maximum power generation at a facility unless pump use reductions are limited to periods when power demand is low or generation is not required. Nearly all of California's fossil fuel generating units have capacity factors less than 50%. Capacity utilization of these units has been reduced to periods when electric power generation demand warrants generation. The Draft California Policy requires that facilities make their reductions from actual rather than design flow. While many facilities may be able to reduce flow to some extent on a diel or seasonal basis, the benefit from a reduction in actual flow would be limited without a significant reduction in available electric power generation in California during peak power demand. Such a reduction may have significant impacts to the electric generation supply to the grid when most needed .

A.2.5 Closed-Cycle Cooling

Use of wet or dry closed-cycle cooling by definition results in compliance with the EPA Phase II Rule and would also achieve compliance under the Draft California Policy. However, this is by far the most costly technology option as a result of very high capital and operations and maintenance (O&M) costs. EPRI is currently in the process of developing cost estimates for retrofit of California's facilities affected by the State's Draft Policy. Retrofit costs can be significantly higher than the cost of installation of closed-cycle cooling systems at new facilities, depending on the layout of the facility and water piping distances. For some facilities this option may not be available due to space constraints. This option also has the disadvantage of loss of some generation capability as a result of the energy requirements to operate the cooling towers (e.g., pumps and fans) and loss of efficiency as a result of reduced condenser cooling efficiency. These systems also have their own environmental disadvantages that include impacts to air (e.g., air pollution from replacement power at other facilities to offset lost generation), water quality from blowdown in wet systems, salt drift, foam, and noise. Although EPA based the Phase I Rule for new sources on use of closed-cycle cooling, it did not do so for Phase II for existing sources. While EPA evaluated requiring closed-cycle cooling retrofits under three of the options considered for the Phase II Rule (pp. 41605 – 41607) it decided not to base the Rule on this option due to high cost, lack of cost-effectiveness and impacts to national energy supply.

A.3 Impingement Mortality Reduction Technologies

There are more options for protecting larger organisms from impingement and the cost of technologies is generally lower. However, the options provided in the Draft California Policy will present significant issues for most of California's once-through cooling facilities. The following categories of technologies are either not available in California or will not meet the 95% impingement mortality reduction criteria.

A.3.1 Behavioral Devices

Due to the size and swimming ability of most impinged fishes, they are able to detect and respond to lights and sounds. EPRI is currently in the process of conducting tests on these devices in fresh water on the East Coast. It has previously been determined that while some species of fish respond to such devices others do not. In some cases species are attracted to these devices. Testing of various behavioral devices was performed by SCE for the San Onofre Nuclear Generating Station (San Onofre). Results of the light study tests were published in the peer reviewed literature (Jahn and Herbinson 2000). In this study, light was being evaluated for the purpose of improving the effectiveness of the overall SONGS fish impingement protection system. There was some level of response for some species but not the 80% -95% reduction levels in the federal Rule or the Draft California Policy's proposed 95% impingement reduction. Laboratory studies were also conducted on use of acoustic signals at the Redondo Marine Laboratory and made available to the California Coastal Commission for review (Sonalysts, Inc. 1995). These studies focused on a number of offshore species that included northern anchovy, sardines, white croaker, kelp bass, and walleye surfperch. The sound did elicit a response from all five species tested with low frequency sound and responses were achieved at the 95% level for croaker, walleye surfperch, and kelp bass based on their circular swimming pattern in the test device. It is thought that many offshore species may have developed an acoustic response mechanism to combat use of sound by predatory marine mammals that use sound to find prey. While results are promising there are no data for inshore species. There is concern that this technology could have impacts to marine mammals.

A.3.2 Diversion Systems

Such systems take advantage of waterbody flow to guide fishes to a location away from the intake or to an area where they can be collected and transported to a safe area. Rivers are generally the ideal waterbody type for this option due to the continuous unidirectional water current. However, due to slack tides and variable current patterns along the coastline such options are not generally feasible for California's coastal facilities, especially at the 95% performance range.

A.3.3 Fish Collection and Handling Systems

There is currently one fish collection and handling system in operation in California. It is a unique design used in conjunction with an offshore velocity cap and works on an intermittent rather than a continuous basis. It employs use of a fish chase system that uses heat to direct fishes into a collection area where they are collected and discharged back to the ocean. The fishes are thus collected before they are impinged on the traveling screens.

While there are a number of fish collection systems around the U.S. that operate on a continuous basis and collect fishes directly off the traveling screens, there are none in operation in California. The effectiveness of these systems for impingeable life stages varies with species. While these systems may be very effective for some species, due to the presence of fragile species both inshore and offshore, they would not be expected to meet the 95% standard set in the Draft California Policy. In addition, as discussed for the fine mesh version of this technology, for many facilities the long distances required to transport fishes to a location where they will not be subject to re-impingement will result in additional mortality and feasibility issues.

A.3.4 Velocity Reductions

The Draft California Policy alternatives for impingement include reducing impingement mortality by 95%, installing closed cycle cooling or reducing the maximum through screen design flow to not exceed 0.5 fps. There are a limited number of options to meet the 0.5 fps criterion for California's coastal facilities as follows:

- Expand the intake structure to add more traveling screens,
- Install a barrier net,
- Install wide slot wedge-wire screens, and
- Reduce flow

While these options may be feasible for a small number of facilities, for others this level of reduction could only be achieved at costs in the millions of dollars.

A.4 Zooplankton Entrainment Control

The Draft California Policy appears to consider zooplankton entrainment as part of the entrainment community to be protected. It is important to recognize that none of the alternative fish protection technologies that EPA considered in the Phase II Rule are designed to protect zooplankton. Many species of zooplankton are less than a millimeter in size. Thus the only alternative for compliance even to reach the minimum 60% reduction for zooplankton entrainment will be use of flow reduction measures. Specifically facilities will be limited to reducing annual average flows by 60% to 90% or retro-fitting with wet or dry closed-cycle cooling. It is also important to consider that unlike larval fish, zooplankton are encased in chiton exoskeletons (and silicon shells) which provide significant protection from entrainment mortality.

A.5 Summary of Available Technologies Under the Proposal

Under the Draft California Policy, facilities would be left with either significant flow reductions and associated reduction in generation available to meet peak energy demand or use of closed-cycle cooling retrofits. The costs of retrofits, based on currently available estimates for Diablo Canyon and San Onofre will be over a billion dollars each for these facilities alone. Based on recent peak energy demand in California, the Draft California Policy would pose electric power generation supply issues for the State.

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B INFORMATION OF HISTORIC AND RECENT 316(B) COOLING WATER STUDIES AT CALIFORNIA POWER PLANTS UTILIZING ONCE-THROUGH COOLING

Original 316(b) Studies

Power Plant / Location		**Entrainment samples collected with plankton nets or pumps**	**Net mesh size (microns)**	**Target sample volume (m^3)**	**Entrainment sampling frequency**	**Entrainment station location**	**Source water stations sampled**	**Notes**
South Bay Power Plant San Diego Bay	IM&E 1979-80[1] 12 months	pump samples; lowered pump intake during sample collection	202	60	Diel Strategy: monthly day and night samples. Night Strategy: monthly sampling only in the night out of phase with diel sampling. Tidal Series Strategy: every 8 weeks, tidal instead of diel. Collected from surface, mid-depth or bottom during high and low	intake	4 stations in south-central and southern San Diego Bay	entrainment samples collected by pumping water at approx. 2 m^3/minute
Encina Power Station Northern San Diego County	IM&E 1979-80[3] 12 months	paired pumps - one filtered through 335, other into 505.	335 and 505		every 2 weeks at intake structure (pump samples) and in the outer AHL lagoon segment (net samples)	intake	Monthly at 5 offshore stations using 505 and 335 micron nets attached to a 61 cm (23.62 in) bongo net system; monthly in the middle and upper Agua Hedionda Lagoon segments using paired 0.5 m nets with 505 and 335 mesh	mainly daytime sample collection, although some evening and early morning collections
San Onofre Nuclear Generating Station Units 2&3 Northern San Diego County	IM&E 1978-86[5]	Manta, bongo, and Auriga nets		400	Pre-operational (38 sample days), interim (5 sample days), operational (27 sample days), intake loss (6 survey days)	As close as possible to offshore intakes		
Huntington Beach Generating Station Orange County	IM[6]	Ormond Beach and Songs Unit 1 data used to estimate entrainment at HBGS						
Long Beach Generating Station Long Beach Harbor	IM[8]	data from Haynes used for LBGS, and adjusted for flow differences	see Haynes	see Haynes	see Haynes	see Haynes	Biweekly, 46 stations in the Bight, from 8 to 36 m depths	Bongo, manta, and Auriga nets with 335 micron mesh
Haynes Generating Station Alamitos Bay	IM&E 1978-79[9]	day samples from midwater with high volune pump. Night: manta nets at surface, bongo nets midwater and epibenthic bongo at near-bottom	335 for first seven surveys then 202 for rest	2 replicates of about 60	approx. biweekly	at bar racks in marina	1 near-field and 2 far-field stations	Entrainment mortality assessed. Predation by fouling and fish community in canal, and thru plant mortality
Alamitos Generating Station Alamitos Bay	IM 1982[10]	Harbor data used to estimate daily entrainment at Alamitos					Biweekly, 46 stations in the Bight, from 8 to 36 m depths	Bongo, manta, and Auriga nets with 335 micron mesh
Harbor Generating Station Los Angeles Harbor	IM&E 1978-79[11]	day and night samples from midwater with high volume pump. Near-field and far-field stations sampled with manta, bongo, and epibenthic bongo.	335 for first seven surveys, then 202 for remaining	2 replicates of about 60	biweekly	at the bulkhead intake structure	1 near-field and 1 far-field	
Redondo Beach Generating Station Santa Monica Bay	IM&E 1979-80[12]	day and night samples from within intake riser with high volume pump at Units 5&6 and 7&8 intakes.	333	24 replicates of 100 during each 24-hr	monthly	within intake riser	Biweekly, 46 stations in the Bight, from 8 to 36 m depths	Bongo, manta, and Auriga nets with 335 micron mesh
El Segundo Generating Station Santa Monica Bay	IM 1978-1980[13] & 1972-2004[14]	Ormond Beach data used to estimate entrainment at El Segundo						
Scattergood Generating Station Santa Monica Bay	IM&E 1978-79[15]	high volume pump: day and night samples from within forebay (surveys 1-26) and at velocity cap (surveys 8-24)	202		biweekly	forebay and velocity cap	Biweekly, 1 near-field and 2 far-field stations (daylight monthly, nighttime biweekly)	Manta, bongo, and epibenthic bongo nets
Ormond Beach Generating Station Ventura County	IM&E 1978-80[16]	pump at offshore intake riser during each of six periods (two day, two night, one sunrise, and one sunset) over a 24-hr period.	333	24 replicates of 100 during each 24-hr period	monthly	within intake riser	Biweekly, 46 stations in the Bight, from 8 to 36 m depths	Bongo, manta, and Auriga nets with 335 micron mesh
Mandalay Generating Station Ventura County	IM[17]	Data from Haynes used for Mandalay with adjustment for flow differences					Biweekly, 46 stations in the Bight, from 8 to 36 m depths	Bongo, manta, and Auriga nets with 335 micron mesh
Diablo Canyon Power Plant San Luis Obispo County	IM&E 1985-86[18]	pump	335	54	at least weekly	discharge conduit		
Morro Bay Power Plant San Luis Obispo County	IM[20]	No studies at Morro Bay - used Moss Landing entrainment data						
Moss Landing Power Plant	IM&E 1978-80[22]	pump from forebays; top, middle & bottom levels for U1-5 and middle bottom for U6-7	335	assumed 160 per 3-hour cycle	weekly; eight 3-hour cycles	forebays		
Hunter's Point Power Plant San Francisco Bay	IM&E 1978-79[24]							
Potrero Power Plant San Francisco Bay	IM&E 1978-79[25]	pumped from Unit 3 discharge	505 from March-August 1978. Then switched to 335	mean of 159 per each 3-hour collection	weekly (24 hour period), eight 3-hour cycles	discharge		
Pittsburg Power Plant San Francisco Bay-Delta	IM&E 1978-79[27]	One location at U6 discharge	505	pumped at 0.9 m^3/min so about 160 m^3/ 3-hour cycle	typically once per week for 24-hours. During striped bass period (May-July) sampled two 24-hour periods/week	discharge		
Contra Costa Power Plant San Francisco Bay-Delta	IM&E 1978-79[28]	U1-5 and U6-7 discharges	505	pumped at 0.9 m^3/min so about 160 m^3/ 3-hour cycle	typically once per week for 24-hours. During striped bass period (May-July) sampled two 24-hour periods/week	discharge		
Humboldt Bay Power Plant Units 1&2 Humboldt County	IM&E 1979-80[29]	(information incomplete)						

Recent 316(b) Studies

Power Plant / Location		**Entrainment samples collected with plankton nets or pumps**	**Net mesh size (microns)**	**Target sample volume (m^3)**	**Entrainment sampling frequency**	**Entrainment station location**	**Source water stations sampled**	**Notes**
South Bay Power Plant San Diego Bay	IM&E 2001-03[2]	bongo frame	335	60	monthly from Jan 2001-Jan 2002 and bi-monthly from Dec 2002-Oct 2003	near intake	monthly from Jan 2001-Jan 2002 and bi-monthly from Dec 2002-Oct 2003 at 8 stations in south SD Bay	six 4-hour cycles
Encina Power Station Northern San Diego County	IM&E 2004-05[4]	bongo frame	335	60	entrainment and source water sampling was conducted monthly from June 2004 through May 2005 except that two surveys were done in June 2004 separated by a two-week interval	in front of intake	monthly at 5 nearshore and 4 lagoon stations	four 6-hour cycles
San Onofre Nuclear Generating Station Units 2&3 Northern San Diego County	IM&E in progress	bongo and single frame	335	30-40	biweekly/monthly	in-plant (biweekly), and offshore at intake (bongo net) monthly	1 (offshore entrainment)	fish return system entrainment also surveyed biweekly
Huntington Beach Generating Station Orange County	IM&E 2003-04[7]	bongo frame	333	30-40	conducted twice monthly in September and October 2003, weekly from November 2003 through July 2004, and twice during August 2004.	immediate proximity of the cooling water intake	6 stations sampled monthly in September and October 2003, twice per month from November 2003 through July 2004, and once in August 2004	During each sampling event, 2 replicate tows at the entrainment station collected once every 6 hours over 24-hour period
Long Beach Generating Station Long Beach Harbor	not required							
Haynes Generating Station Alamitos Bay	IM&E in progress	single net	335	15-20	every two weeks	at bar racks in marina	monthly surveys at 3 stations in Alamitos Bay and 6 in the nearshore	four 6-hour cycles
Alamitos Generating Station Alamitos Bay	IM&E in progress	single net	335	15-20	every two weeks	in intake canal for U1-4 and U5-6	monthly surveys at 4 stations in Alamitos Bay and 6 in the nearshore	four 6-hour cycles
Harbor Generating Station Los Angeles Harbor	IM&E in progress	bongo frame	335	15-20	every two weeks	near bar racks	monthly surveys at 6 source water stations	four 6-hour cycles
Redondo Beach Generating Station Santa Monica Bay	IM&E in progress	bongo frame	335	15-20	every two weeks	near intake riser	monthly surveys at 7 source water stations (2 in King Harbor and 5 outside the Harbor in the nearshore)	four 6-hour cycles
El Segundo Generating Station Santa Monica Bay	IM&E in progress	bongo frame	335	15-20	once per month	near two intake risers	monthly surveys at 10 source water stations	four 6-hour cycles
Scattergood Generating Station Santa Monica Bay	IM&E in progress	bongo frame	335	15-20	every two weeks	near intake riser	monthly surveys at 10 source water stations	four 6-hour cycles
Ormond Beach Generating Station Ventura County	IM&E in progress							
Mandalay Generating Station	IM&E in progress							
Diablo Canyon Power Plant San Luis Obispo County	E 1996-99[19]	bongo frame	335	40-50	once per week	in front of intake structure	monthly surveys in 64 study grid cells	eight 3-hour cycles
Morro Bay Power Plant San Luis Obispo County	IM&E 1999-2000[21]	bongo frame	335	40	once per week	in front of intake structure	monthly surveys at 3 stations in Morro Bay and 1 station outside the bay in the nearshore	six 4-hour cycles
Moss Landing Power Plant	E 1999-2000[23]; IM in progress	bongo frame	335	40	once per week during the peak larval fish season (November through June) and every other week during the off-peak period	in front of two intake structures	2 samples collected in daylight at each of the 3 stations during one high and one low tide. Sampling at the Entrance station a normal oblique tow. Samples at the Dairies and Kirby Park stations collected using a push net on the surface in front of a movi	six 4-hour cycles
Hunter's Point Power Plant San Francisco Bay	not required							
Potrero Power Plant San Francisco Bay	E 2001-02[26]; IM in progress	bongo frame	335	40	weekly during herring season (mid-Jan to early April 2001 and from Dec 2001- Feb 2002) and monthly the rest of the year	2 stations in front of the intake structure	4 near-field stations and 3 far field stations (same frequency as entrainment stations)	six 4-hour cycles
Pittsburg Power Plant San Francisco Bay-Delta	planned							
Contra Costa Power Plant San Francisco Bay-Delta	planned							
Humboldt Bay Power Plant Units 1&2 Humboldt County	not required							

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C ABUNDANCES OF FISHES ASSOCIATED WITH MUDFLAT HABITATS IN AGUA HEDIONDA LAGOON, SAN DIEGO COUNTY

By Tenera Environmental

October 2005

Summary

Intertidal fishes on mudflat habitat in Agua Hedionda Lagoon were surveyed using small portable enclosures as a sampling tool. Arrow goby (*Clevelandia ios*) was the most abundant species sampled, with average densities approaching 50 per m^2 in spring when juveniles were most abundant. Densities declined and mean size increased during fall. The enclosure sampling method yielded substantially higher densities of gobies than earlier studies using trawl samples.

Introduction

The purpose of this study was to provide improved estimates of adult densities of target fish species in Agua Hedionda Lagoon (AHL), San Diego County, that could be compared to historical density estimates in AHL and estimates from other regional estuarine systems not affected by power plant entrainment. The results provide some context for interpreting calculated larval losses due to operation of the Encina Power Station (EPS) cooling water system.

One approach used to model the effects of larval entrainment mortality on source populations is to calculate adult equivalents based on the abundance of entrained larvae. A comparison of calculated losses to adult standing stock in the source water puts the contribution of power plant mortality into perspective for evaluating potential entrainment effects. Gobies and blennies can be very abundant in southern California bays and estuaries (Allen 1982, 1985) and can produce large numbers of larvae. The larvae from these species can be entrained in high numbers (Tenera 2000, 2001, 2004) resulting in large estimated impacts, even though the additional mortality due to entrainment may have little effect on the local densities of adult populations.

Adult fish densities were quantified in AHL in 1994 and 1995 using beam trawls, otter trawls and beach seines (MEC Analytical Systems 1995). Although 29 species were collected, the methods did not adequately sample intertidal mud and sandflat habitats. The methods used in the earlier surveys likely underestimated the densities of gobies because they can inhabit burrows and may escape capture by traditional net sampling methods. Accurate density information on these small cryptic fishes requires the use of enclosure sampling or use of anesthetic solutions to ensure that all individuals are collected within a specified area.

Sampling Methods

The sampling method targeted gobies and other small fishes that typically reside on the substrate or in burrows on intertidal mud and sandflat habitats. This portion of the study was conducted at stations located in the intertidal zone of the middle and inner AHL (Figure C-1). The outer lagoon was not sampled using this method because almost all of the intertidal zone in the outer lagoon is armored with rock revetment and there is very little intertidal soft substrate habitat. The methods and apparatus used were similar to those used by other researchers sampling fishes elsewhere in southern California salt marshes and tested by Steele et al. (2006). At each of nine sites around the AHL lagoons, a portable circular enclosure (0.43 m^2 [4.74 ft^2]) constructed of 3 mm (1/8 in.) thick plastic sheeting was used to sample the fishes (Figure C-2). Sampling was done during low-tide periods. An average of five haphazardly placed replicates was sampled parallel to shore at each site. Enclosures were placed with a short toss in water depths of approximately 0.25 to 0.75 m (0.8 to 2.5 ft). A hinged sweep net with the hinge positioned in the center of the enclosure was unfolded through the enclosure to capture any fishes. The enclosure was swept on multiple passes until three consecutive passes yielded no fish. A hand-held dip net was then swept within the enclosure to capture any remaining fish. All fish captured were preserved for later identification and measurement in the laboratory.

Results

Cryptic fishes were sampled at nine stations in low intertidal and shallow subtidal areas around the perimeter of AHL using the enclosure method. Stations E6–E9 were sampled during afternoon low tides in May 2005 and Stations E1–E5 were sampled during afternoon low tides in October 2005. A total of 37 enclosure replicates was sampled. Arrow goby (*Clevelandia ios*) was the most abundant species, followed by cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) (Table C-1). Densities of arrow goby were greater during the spring when there was an abundance of recently settled individuals less than 25 mm (1 in.) (Figure C-3).

Table C-1. Density of fishes (number per m^2) from enclosure sampling in middle and inner Agua Hedionda Lagoon.

			Middle Lagoon		**---------------- Inner Lagoon --------------------**						
		Station	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**
		Replicates	5	5	5	5	5	6	7	6	4
		Date Sampled 2005	10/15	10/15	10/15	10/15	10/15	5/15	5/15	5/15	5/15
Taxon	**Common Name**	**Mean**									
Clevelandia ios	arrow goby	**18.37**	9.09	18.18	2.27	4.55	6.82	38.64	25.00	31.82	29.00
Ilypnus gilberti	cheekspot goby	**3.76**	2.27	–	2.27	2.27	–	15.91	–	9.09	2.00
Quietula y-cauda	shadow goby	**2.21**	–	–	–	–	–	6.82	4.55	4.55	4.00
Hypsopsetta guttulata	diamond turbot	**0.76**	–	–	–	–	–	–	2.27	4.55	–
Leptocottus armatus	Staghorn sculpin	**0.76**	–	–	–	–	–	–	6.82	–	–
Citharichthys stigmaeus	speckled sanddab	**0.25**	–	–	–	–	–	–	–	2.27	–
Paralichthys californicus	California halibut	**0.51**	–	2.27	–	2.27	–	–	–	–	–
	Total density:		11.36	20.45	4.55	9.09	6.82	61.36	38.64	52.27	35.00

The habitat area in the inner lagoon that was between the +1 ft and –4 ft MLLW elevations, based on a bathymetric survey in April 1994 was calculated at 39.6 acres, and the area at a similar tidal range in the middle lagoon was 6.2 acres, for a combined area of 45.8 acres. Although gobies are known to inhabit all depths throughout the lagoon, this area was selected because it was the approximate range sampled during the enclosure survey. The average density of CIQ gobies of all sizes was 24.34 per m^2, which yields an estimate of 98,400 per ha. Although it is a rough estimate, at least 4.5 million CIQ gobies inhabited the AHL system, without taking into account habitat exceeding –4 ft MLLW or the habitat of the outer lagoon which, with sandier substrate, does not provide as optimal habitat as the inner lagoon, but is still known from earlier studies (MEC 1995) to support a portion of the local goby population.

Discussion

Accurate estimation of fish abundances requires that the sampling methods used are appropriate for the species under consideration by accounting for such variables as preferred habitat and sampling gear avoidance (Allen et al. 2002). Enclosure sampling is a more efficient method than beach seining for capturing a wide range of size classes, and consequently the density estimates, particularly for juvenile and newly settled recruits, are higher than for traditional sampling. The drawback in using the method is that the total sampling area is generally less than that covered by seining, and the depth range sampled is restricted by the tide level during which the sampling occurs. Steele et al. (2006) noted that the 0.43 m^2 enclosure area adequately sampled arrow goby in southern California estuaries, but that some avoidance of larger specimens of other species may occur, thus underestimating their actual densities.

The sampling conducted in the present study yielded density estimates for gobies that were much greater than those that were developed from earlier sampling in AHL (MEC 1995). For example, arrow goby of all sizes averaged nearly 20 per m^2 across all sampling dates in the inner and middle lagoon shoreline, yielding an estimate of 200,000 per hectare of this species alone. The SDG&E (1980) trawl sampling in the upper lagoon yielded an estimate of less than 2,000 fishes per hectare of all species combined. Although there may have been real differences in densities between the studies, it is clear that the capture of smaller fishes in the enclosures improves the overall characterization of the benthic fish fauna.

Other estuarine areas in southern California have also been sampled using enclosure methods. In nearby Batiquitos Lagoon, 1.0 m^2 square enclosures were one sampling method used to track recovery of fish populations in a restored marsh (Merkel and Associates 2002). Overall fish densities using the enclosure method ranged from 0.35 to 7.82 individuals per m^2 over a four-year period. Allen et al. (2002) used the same enclosure method in San Diego Bay during a 5-year study and recorded overall densities exceeding 6 individuals per m^2 in the intertidal areas of the north-central and south regions. Again this was mostly due to the highly productive habitat in which juveniles and newly-settled recruits, particularly in the spring, comprised most of the specimens. The relatively high overall average of 26 individuals per m^2 in the study at AHL was influenced by the predominantly spring sampling period where densities approached 50 per m^2. Fall densities were approximately 10 individuals per m^2 with an absence of smaller size classes and an increase in mean size of fish sampled.

The enclosure method has been shown to be the best method available for obtaining density estimates of small intertidal fishes in bays and estuaries, especially for gobies that may seek the shelter of burrows and avoid capture from traditional beach seine sampling methods. Repeated seasonal sampling over the same areas in AHL using the enclosure method can identify settlement periods and allow accurate estimates of cryptic fish density.

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Figure C-1. Locations of fish intertidal enclosure samples (E1-E9).

Figure C-2. Investigators sample fishes in mudflat habitat using a circular plastic enclosure and hinged sweep net.

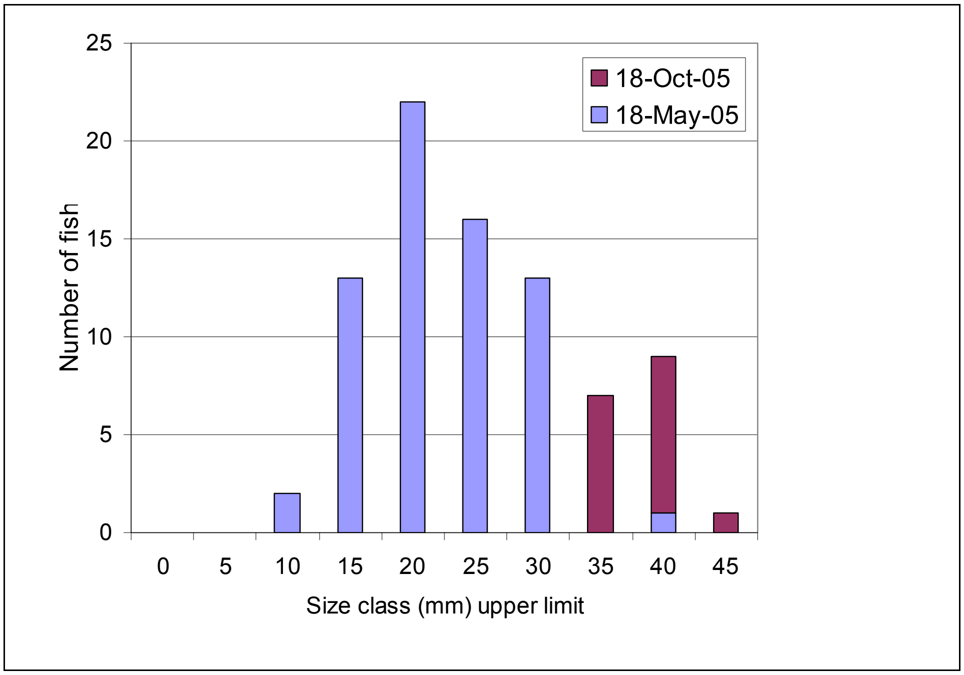

Figure C-3. Size frequency (TL) of arrow goby (*Clevelandia ios*) between spring and fall sampling periods.

D LONG TERM CHANGES IN LARVAL FISH ABUNDANCE IN ELKHORN SLOUGH, 1974 - 2000

By Tenera Environmental

December 2006

Summary

Larval fish concentrations in Elkhorn Slough increased substantially over a 15-year period mainly due to large increases in arrow goby (*Clevelandia ios*), bay goby (*Lepidogobius lepidus*), and Pacific herring (*Clupea pallasii*). Other species declined over the same time period, notably longjaw mudsucker (*Gillichthys mirabilis*), and northern anchovy (*Engraulis mordax*). More individual taxa were recorded in the later study but this may have been due to advancements in larval taxonomy and not necessarily an indication of increased diversity. Large-scale processes including a regime shift to warmer ocean conditions and changes in the hydrology of Elkhorn Slough likely contributed to some of the observed differences in larval fish assemblages.

Introduction

Elkhorn Slough is a shallow tidal embayment and seasonal estuary that borders Monterey Bay and provides habitat for at least 65 species of fishes (Yoklavich et al. 1991). The slough entrance from the ocean is a constructed boat harbor that also serves as a point-source cooling water intake for Moss Landing Power Plant. The main channel of Elkhorn Slough extends approximately 10 km inland and is intersected by a network of tidal creeks. Yoklavich et al. (1992) sampled the seasonal abundance and distribution of larval fishes in Elkhorn Slough from 1974–1976 ("Study 1"), and Tenera (2000) performed a similar study in 1999–2000 ("Study 2"). This paper compares the two studies to examine differences in the relative species composition and seasonal concentrations of larval fishes.

Sampling Methods

Both studies used similar sampling apparatus and methods (towed or pushed plankton nets) to collect larvae. The two studies were largely comparable but some of the results were potentially affected by small differences in the methods used by each study and these are addressed in the results/discussion section.

Station Locations

Larval samples were collected at several stations along the length of Elkhorn Slough ranging from the shallow (- 3 m MLLW) inland station at Kirby Park to the deeper (-7 m MLLW) ocean entrance of the slough at the mouth of Moss Landing Harbor (Table D-1). Stations common to both studies were Kirby Park (KP), Dairy (DR), Harbor Bridge (HB), and Harbor Entrance (HE) (Figure D-1). Kirby Park and Dairy stations were largely the same for both studies. In Study 1 the location of HB was approximately 200 m east of the Hwy. 1 bridge, and in Study 2 was approximately 100 m west of the bridge. Also, the HE station was positioned in the center of the channel directly off the tip of the two jetties in Study 2, but was positioned about 400 m inside the entrance in Study 1. Both stations were located to sample the largely marine-influenced seaward extension of the slough.

Collection Methods

Two basic types of apparatus were used to collect samples from a small boat, 1) a bow-mounted single-hoop pushed net, and 2) a stern-mounted dual-hoop towed net ("bongo"). All samples in Study 1 were collected using the push net, an apparatus which consisted of a 0.5 m diameter, 2.2 m long, 405-micron zooplankton net attached to a frame that was pushed in front of a small boat at a depth of about 1 m. Study 2 used a similar push-net apparatus to sample DR and KP, except that the net mesh was finer (333 microns) and the diameter was larger (0.7 m). The HB and HE stations were sampled with towed bongo nets and sampled the entire water column from near the bottom to the surface. In Study 1 the samples were all collected at or near high tide, but in Study 2 two samples of at least 40 m^3 were collected in daylight at each station during one high and one low tide. Sample volume was measured directly with frame-mounted flowmeters in Study 2, and indirectly in Study 1 by beginning and ending the transects based on shoreline reference marks.

Obliquely towed net samples at the deeper Moss Landing Harbor sampling locations and pushed-net samples at the shallow Elkhorn Slough sampling locations were similarly representative of water column plankton concentrations. The surface samples in Study 1 would probably under-sample some species and over-sample others compared to the obliquely towed nets, but it is probable that these differences could not be statistically detected.

Sampling Frequency

Samples in Study 1 were collected regularly at monthly intervals over a 2-year period from September 1974–September 1976. Therefore the seasonal component of fluctuations in larval abundance was well-documented, as well as some measure of interannual variation. Study 2 samples were also collected monthly, but the study period only extended over nine months beginning in June 1999, and no samples were collected in March, April, or May of 2000. Therefore the spring seasonal values were represented only by a single survey in February 2000.

Species Identification Issues

The level of taxonomic certainty in specimen identifications affected the comparison of overall species richness between the two studies as well as abundances within the same taxon. Not all larval specimens can be identified to the species level, either due to a lack of distinctive morphological characters between similar species, especially at early developmental stages, or less frequently due to damaged specimens. For the most part identifications were consistent between studies, but potential differences in species richness should be examined carefully before conclusions are drawn regarding significant changes over time or between stations.

Specimens identified as "unidentified gobies" in Study 2 were probably almost all *Clevelandia ios*, but were designated as unidentified because newly-hatched specimens do not have sufficient characteristics to differentiate them from two other closely-related species. However, the two other species are not known to occur in Elkhorn Slough, based on previous surveys of adult and juvenile fishes (Yoklavich et al. 1991), whereas *C. ios* was found to be very abundant. Similarly, many of the larval smelt specimens, family Osmeridae, collected in Study 1 were identified as surf smelt (*Hypomesus pretiosus*) but some of the early stage larvae could only be identified to the family level. In Study 2 all smelts were combined into the Osmeridae but were probably largely *H. pretiosus*. These issues were taken into account when comparisons were made between the two studies.

Results and Discussion

Community Composition

During Study 1 a total of 3,645 fish from 29 taxa were collected in 323 samples over a 2-year period. In Study 2, 15,038 fish from 38 taxa were collected in 175 samples over a 9-month period. The total numbers in Study 1 also included an additional station sampled in the slough that was not sampled in Study 2. In both studies the larvae of resident slough species, particularly gobiids, were the most abundant taxa (Table D-1) along with other common species such as northern anchovy and Pacific herring that are classified as marine migrants. Larval abundances increased between study periods at all stations, particularly during spring surveys (Figure D-2). The primary species contributing to the increases during Study 2 was arrow goby and, to a lesser extent, Pacific herring. Arrow goby, a small residential species, replaced longjaw mudsucker, a larger residential goby, as the most abundant larval form in Elkhorn Slough.

The dominance of gobies in the samples, especially during 1999–2000 (Figure D-3), resulted in over 80% of the specimens consisting of slough residents, based on adult classification (Table D-2). Species that migrate between the slough and coastal marine environments, such as Pacific herring, were the next most abundant category in both studies. Species that are considered primarily open coast species were collected mainly at station HE, and there were a few representatives of freshwater species or those considered only partial slough residents.

More taxa were identified from the Study 2 samples (40 taxa) than in the Study 1 samples (30 taxa) (Table D-1). Half of the taxa identified in Study 1 were not observed in Study 2, and conversely over 60% of the taxa identified in Study 2 were not observed in Study 1. Initially it would appear that the community composition changed dramatically during the 15-year period between studies, but some of the differences can be attributed to taxonomic inconsistencies between studies, occurrences of single species, and slight differences in sampling protocols. For example, both studies sampled several species represented by only one or a few specimens, while other differences were simply due to combining some specimens into taxa at the genus level or higher. In addition, refinements in the taxonomy of Pacific Coast larval fishes in the 15-year period between studies resulted in the ability to differentiate the larvae of more species in Study 2. This may have been the reason that bay goby was not reported as a separate species in Study 1, but was relatively abundant in Study 2 despite it's occurrence in samples of adult fishes from Elkhorn Slough in the mid-1970s (Yoklavich et al. 1992). The greater overall number of taxa in Study 2 may also have been affected by the oblique tow methods that sampled the entire water column at the deeper harbor stations. This procedure may have captured some species from deeper strata that were not present in the surface tows sampled in Study 1.

Individual Species Abundances and Distributions

Densities for the most abundant species were presented by season and sampling station in Yoklavich et al. (1991) and for all species in Tenera (2001). In both studies only a few species comprised over 90% of the larvae collected although the relative species composition differed between studies. Confidence in the seasonal estimates of abundance are greater in Study 1 because the sampling occurred over a two-year period compared to nine months in Study 2, and nearly twice the number of samples were collected.

Longjaw mudsucker was the most abundant larval species collected in Study 1. The highest densities were from station KP in summer and fall (Figure D-4). Densities declined rapidly moving from the shallow eastern areas of the slough toward the ocean underscoring the habitat preference of these gobies to the network of smaller tidal channels. Longjaw mudsucker was the fifth most abundant species in Study 2 comprising less than 5% of the specimens collected.

Arrow goby dominated the larval assemblage in Study 2 and increased by an order of magnitude over previous densities measured in Study 1. Highest densities were recorded in spring in Study 2 and summer in Study 1 (Figure D-5). The Kirby Park station had the greatest concentrations of this species in both studies and but high concentrations were also found at stations HB and HE during Study 2. Some of this apparent shift in spatial distribution may have been due to the inclusion of low-tide sampling in Study 2 which captured higher concentrations of the larvae of some residential species that were drawn toward the western reaches of the slough during the ebb tidal phase. A similar study in Morro Bay found that larval fish concentrations were consistently greater during ebb tides, particularly at stations in the interior areas of the bay where concentrations of larval fishes, mainly gobies, were greatest (Tenera 2001). The correlation between larval density and tidal cycles was weaker at stations in the outer areas of Morro Bay and was not apparent at offshore stations.

Northern anchovy comprised 24% of the larvae collected in Study 1 and was present in all seasons (Figure D-6). By 1999-2000 it was only collected during one of the nine surveys conducted and was the fifteenth most abundant species. High concentrations of larvae at both KP and HE during Study 1 showed that it utilized all areas of the slough.

Another open water fish species that was relatively abundant in Study 1 was surf smelt. It showed a strong affinity to station HE (Figure D-7) closest to Monterey Bay which is consistent with the adult distribution along shallow open coastal areas. Overall concentrations declined substantially between studies and there was a strong seasonal component with a winter/spring spawning peak.

White croaker changed little in overall abundance between studies with an average density of 23.5 larvae per 1000 m^3 in Study 1 and 17.5 larvae per 1000 m^3 in Study 2. Adults occur primarily in open coastal habitats from the surf zone to depths of several hundred feet, and its larval distribution in Elkhorn Slough, particularly its absence at station KP, reflects the adult habitat preference (Figure D-8).

Bay goby and combtooth blennies were the third and fourth most common species in Study 2, together accounting for over 10% of the specimens collected and a mean density of over 70 larvae per 1000 m^3, yet neither of these two taxa were identified from samples collected during Study 1. Bay goby was recorded during adult fish studies in Elkhorn Slough during the mid-1970s but combtooth blennies were not (Yoklavich et al. 1991). It is possible that specimens of bay goby from Study 1 were either misidentified as arrow goby, or classified into the unidentified goby or unidentified fish larvae categories, and that the combtooth blennies were classified as unidentified larvae. However, even if this were the case, unidentified larvae accounted for only 1.3% of the total catch in Study 1, so combtooth blennies would appear to have increased substantially between the two sampling periods. This would be consistent with the regime shift to warmer water that began in the late 1970s because combtooth blennies have a southern distribution, and of the three *Hypsoblennius* species recorded from California, the most northerly-distributed species is the bay blenny (*H. gentilis*) which has a recorded northern limit of Monterey Bay (Love et al. 2005). Northern anchovy larvae were abundant throughout Study 1 but scarce in Study 2, and a similar decline in northern anchovy larvae was documented throughout the entire southern California bight from 1975–1998 (CalCOFI 2001).

Conclusions

The decline in longjaw mudsucker and large increases in arrow goby may reflect a change in habitat type and quality in Elkhorn Slough throughout the 1980s and 1990s. Enlargement of the Moss Landing harbor area and a series of dike and levee failures in the 1980s significantly increased the tidal prism, current velocities and circulation throughout Elkhorn Slough resulting in accelerated bank erosion, deeper and wider channels, increased area of mudflats, and thinning of salt marsh vegetation (Malzone and Kvitek 1994). This likely reduced the area of preferred habitat of the longjaw mudsucker which is largely distributed among shallow third-order channels of tidal marshes. The same conditions may have favored arrow goby which have broader habitat requirements and can occur on all mud substrates throughout the slough.

Because of some differences in sampling methods between studies and a limited period of sampling in Study 2 (nine months), there is some uncertainty regarding the nature and magnitude of long-term changes in larval fish populations in Elkhorn Slough. However, a shift in ocean temperature regime and physical changes associated with slough hydrodynamics are consistent with some of the long-term changes observed in the larval fish assemblages. The coincidental long-term effects of Moss Landing Power Plant entrainment mortality on Elkhorn Slough larval abundances cannot be determined based on these comparisons alone.

Appendix D Literature Cited

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Table D-1. Rank abundance of larval fishes in Elkhorn Slough, 1974–1976 and 1999–2000.

Rank 74-76	**Rank 99-00**	**Taxon**	**Common Name**	**74-76 % comp**	**99-00 % comp**
1	5	*Gillichthys mirabilis*	longjaw mudsucker	40.49	4.26
2	15	*Engraulis mordax*	northern anchovy	23.70	0.27
3	1	*Clevelandia ios*	arrow goby	9.68	62.02
4	13	*Hypomesus pretiosus*-Osmeridae	surf smelts	6.04	0.68
5	6	*Leptocottus armatus*	Pacific staghorn sculpin	5.65	4.13
6	10	*Genyonemus lineatus*	white croaker	4.44	1.13
7	2	*Clupea pallasii*	Pacific herring	3.95	8.40
8	28	Unidentified fish larvae	unidentified larval fishes	1.34	0.04
9	-	*Neoclinus uninotatus*	one-spot fringehead	1.15	-
10	-	*Citharichthys* spp.	sanddabs	0.91	-
11	15	Atherinopsidae	silversides	0.85	0.27
12	39	*Ammodytes hexapterus*	Pacific sand lance	0.55	0.02
13	-	Clinidae type I	kelpfish	0.30	-
14	-	Gobiidae type I	goby	0.22	-
14	-	*Sebastes* spp.	rockfishes	0.22	-
16	7	*Stenobrachius leucopsarus*	northern lampfish	0.08	2.44
17	-	*Psettichthys melanostictus*	sand sole	0.05	-
18	9	*Rhinogobiops nicholsi*	blackeye goby	0.03	1.13
18	-	Gobiidae type II	unidentified gobies	0.03	-
18	-	*Clinocottus* sp.	sculpins	0.03	-
18	33	*Gibbonsia* sp.	clinid kelpfishes	0.03	0.03
18	33	*Cebidichthys violaceus*	monkeyface eel	0.03	0.03
18	-	*Sebastes paucispinis*	bocaccio	0.03	-
18	-	*Platichthys stellatus*	starry flounder	0.03	-
18	-	*Lyopsetta exilis*	slender sole	0.03	-
18	-	*Pleuronichthys verticalis*	hornyhead turbot	0.03	-
18	-	*Lipolagus ochotensis*	popeye blacksmelt	0.03	-
18	-	*Oxyjulis californica*	senorita	0.03	-
18	-	*Paralichthys californicus*	California halibut	0.03	-
18	25	*Syngnathus leptorhyncus*	pipefishes	0.03	0.05
-	3	*Lepidogobius lepidus*	bay goby	-	5.29
-	4	*Hypsoblennius* spp.	combtooth blennies	-	5.12
-	8	*Atherinopsis californiensis*	jacksmelt	-	1.37
-	11	Pleuronectidae unid.	flounders	-	0.70
-	12	*larval fish fragment*	unidentified larval fishes	-	0.69
-	14	*Sebastolobus* spp.	thornyheads	-	0.53
-	17	*Cottus asper*	prickly sculpin	-	0.21
-	17	*Tarletonbeania crenularis*	blue lanternfish	-	0.21
-	19	Cottidae unid.	sculpins	-	0.16
-	20	*Pleuronectiformes unid.*	flatfishes	-	0.12
-	21	*Sebastes* spp. VD	rockfishes	-	0.11
-	22	*Artedius* spp.	sculpins	-	0.10
-	23	*Sebastes* spp. V	rockfishes	-	0.09
-	24	*Citharichthys stigmaeus*	speckled sanddab	-	0.06
-	26	*Sebastes* spp.	rockfishes	-	0.05
-	26	*Sebastes* spp. V_De	rockfishes	-	0.05
-	28	*Clinocottus analis*	wooly sculpin	-	0.04
-	28	Clupeiformes	herrings and anchovies	-	0.04
-	33	Paralichthyidae unid.	lefteye flounders & sanddabs	-	0.03
-	33	Chaenopsidae unid.	tube blennies	-	0.03
-	35	Clupeidae unid.	herrings	-	0.02
-	35	*Psettichthys melanostictus*	sand sole	-	0.02
-	35	Bathymasteridae unid.	ronquils	-	0.02
-	35	Hexagrammidae unid.	greenlings	-	0.02
-	35	*Citharichthys sordidus*	Pacific sanddab	-	0.02

Table D-2. Classification of larvae in Elkhorn Slough based on typical adult occurrence. Categories from Yoklavich et al. (1991, 1992).

Adult Occurrence Category	Percent by Abundance		Percent by Taxa Composition	
	1974-1976	**1999-2000**	**1974-1976**	**1999-2000**
Marine	6.7	4.7	53.6	35.1
Marine immigrant	34.7	10.3	21.4	21.6
Slough resident	56.1	82.4	21.4	35.1
Partial resident	0.9	1.6	3.6	5.4
Freshwater	0.0	0.2	0.0	2.7

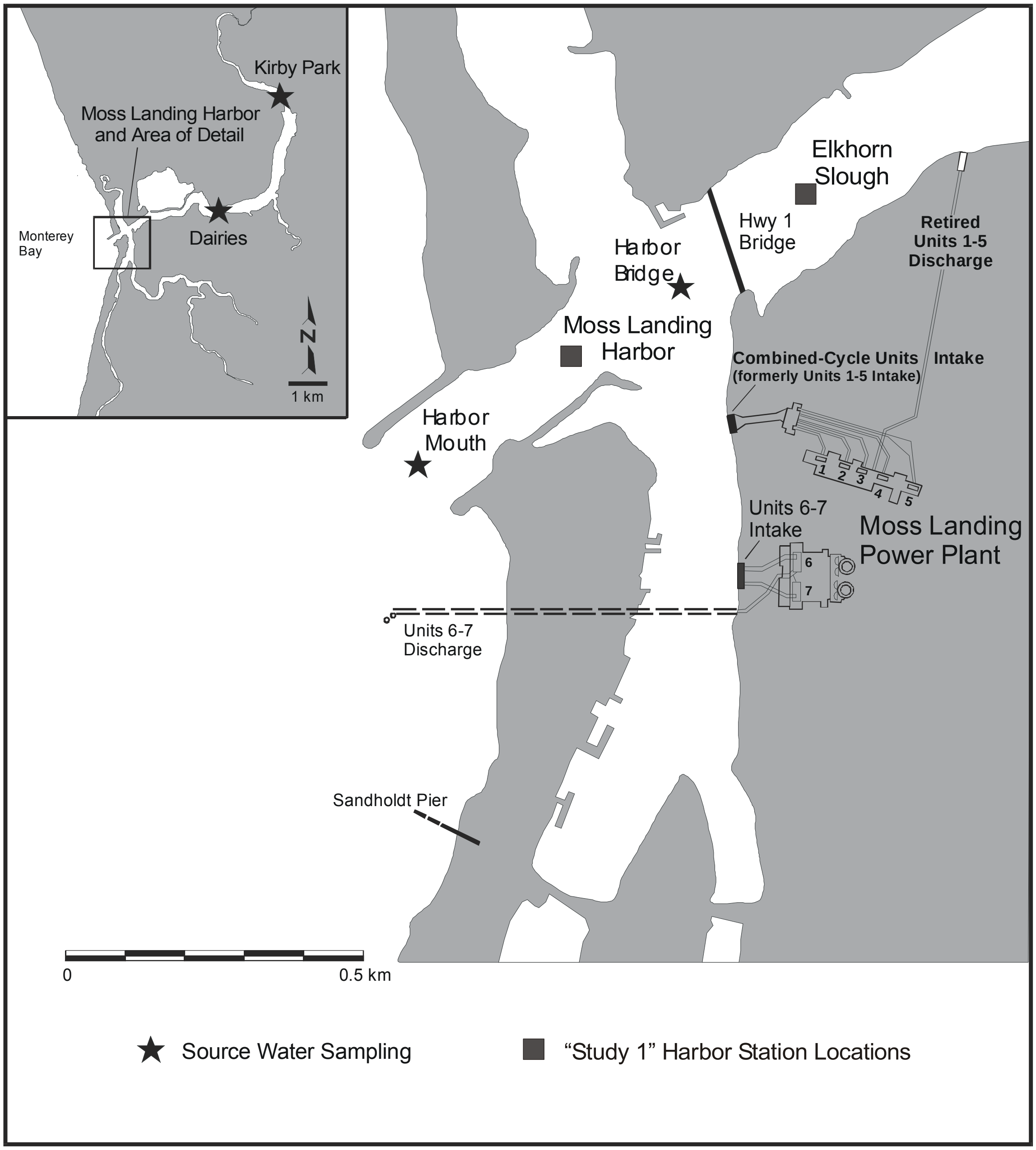
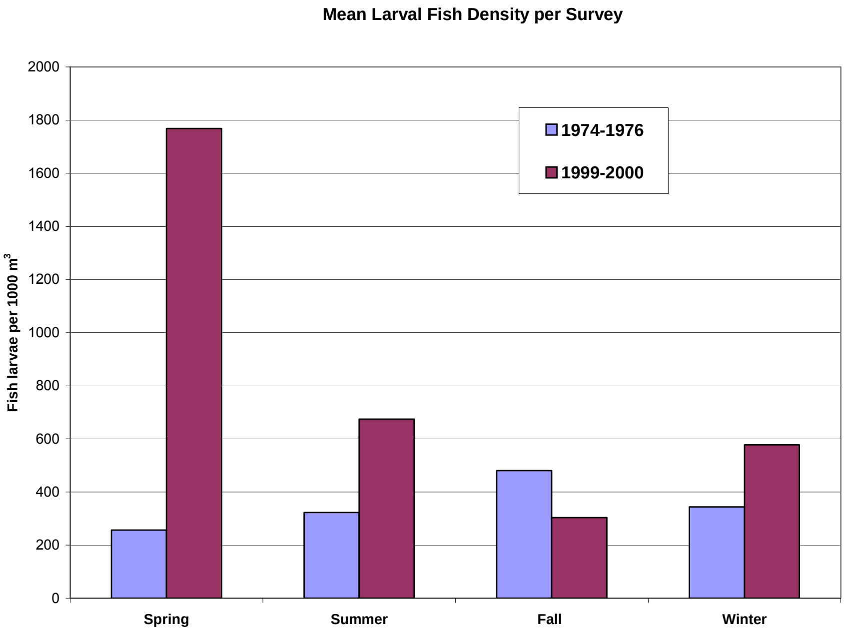


Figure D-1. Elkhorn Slough larval fish sampling locations.



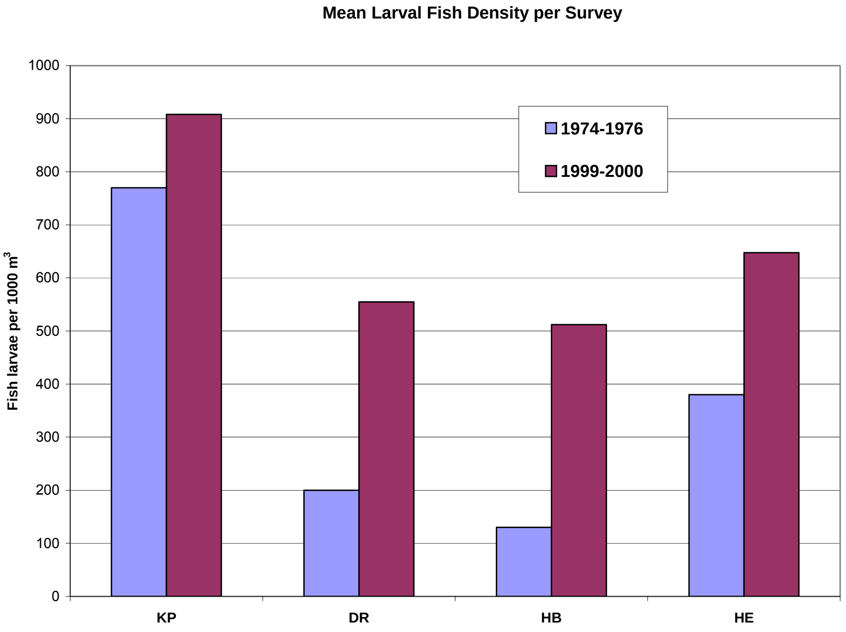
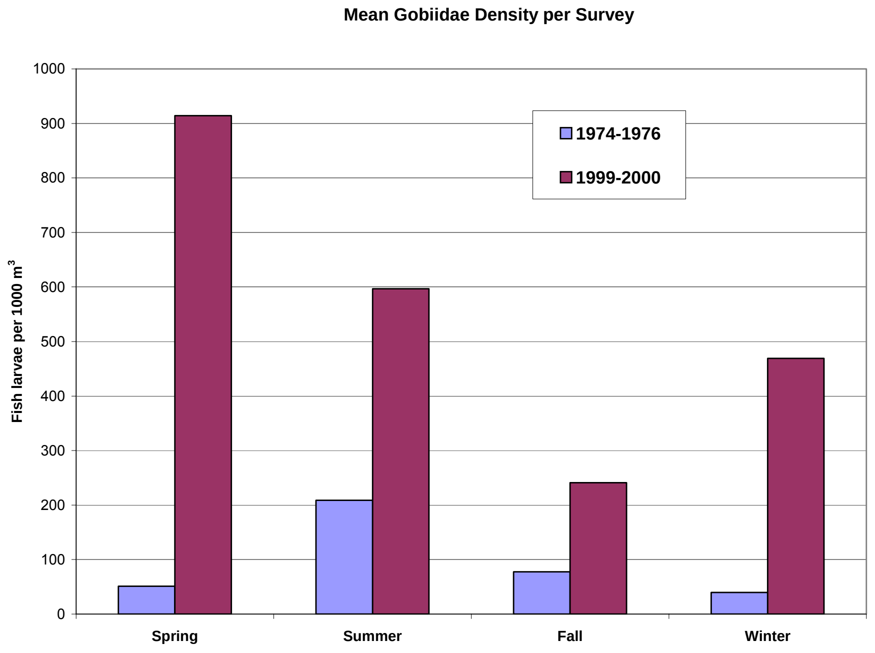


Figure D-2. Total larval density by season and area in Elkhorn Slough.



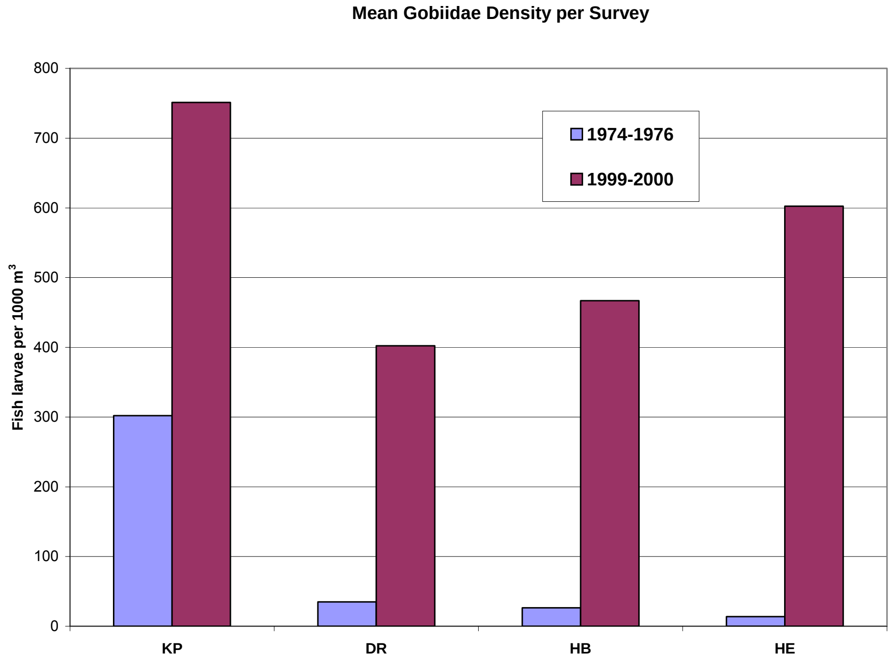
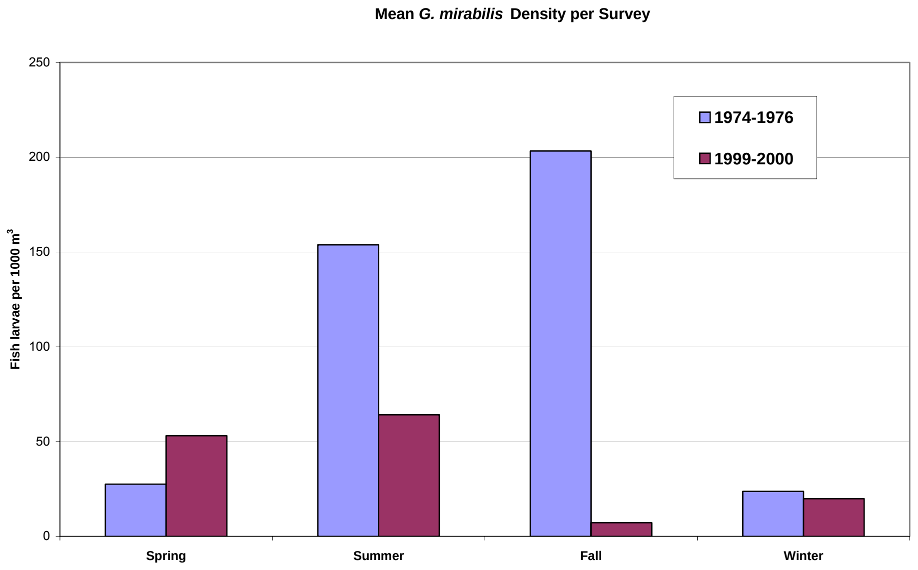


Figure D-3. Total goby density by season and area in Elkhorn Slough.



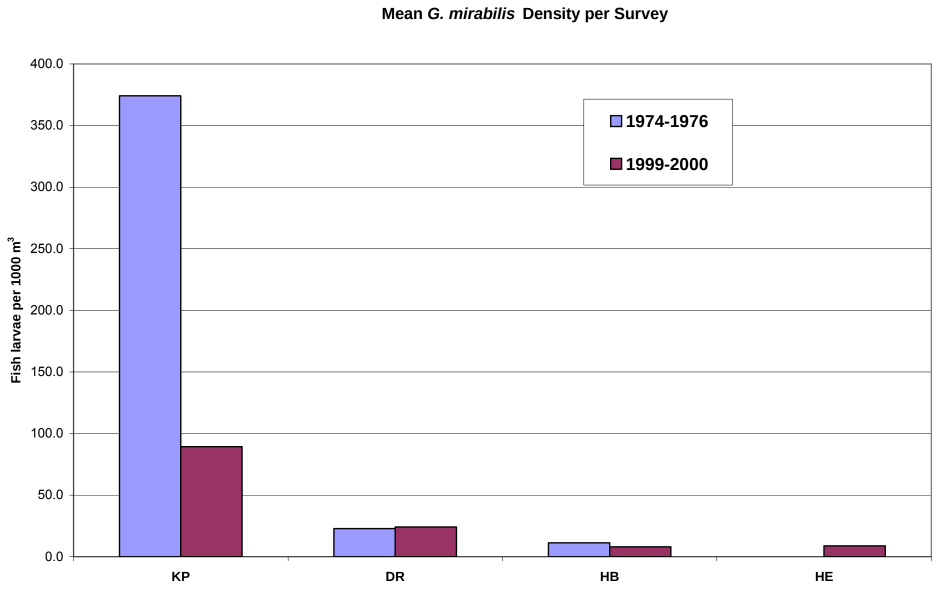


Figure D-4. Longjaw mudsucker density by season and area in Elkhorn Slough.

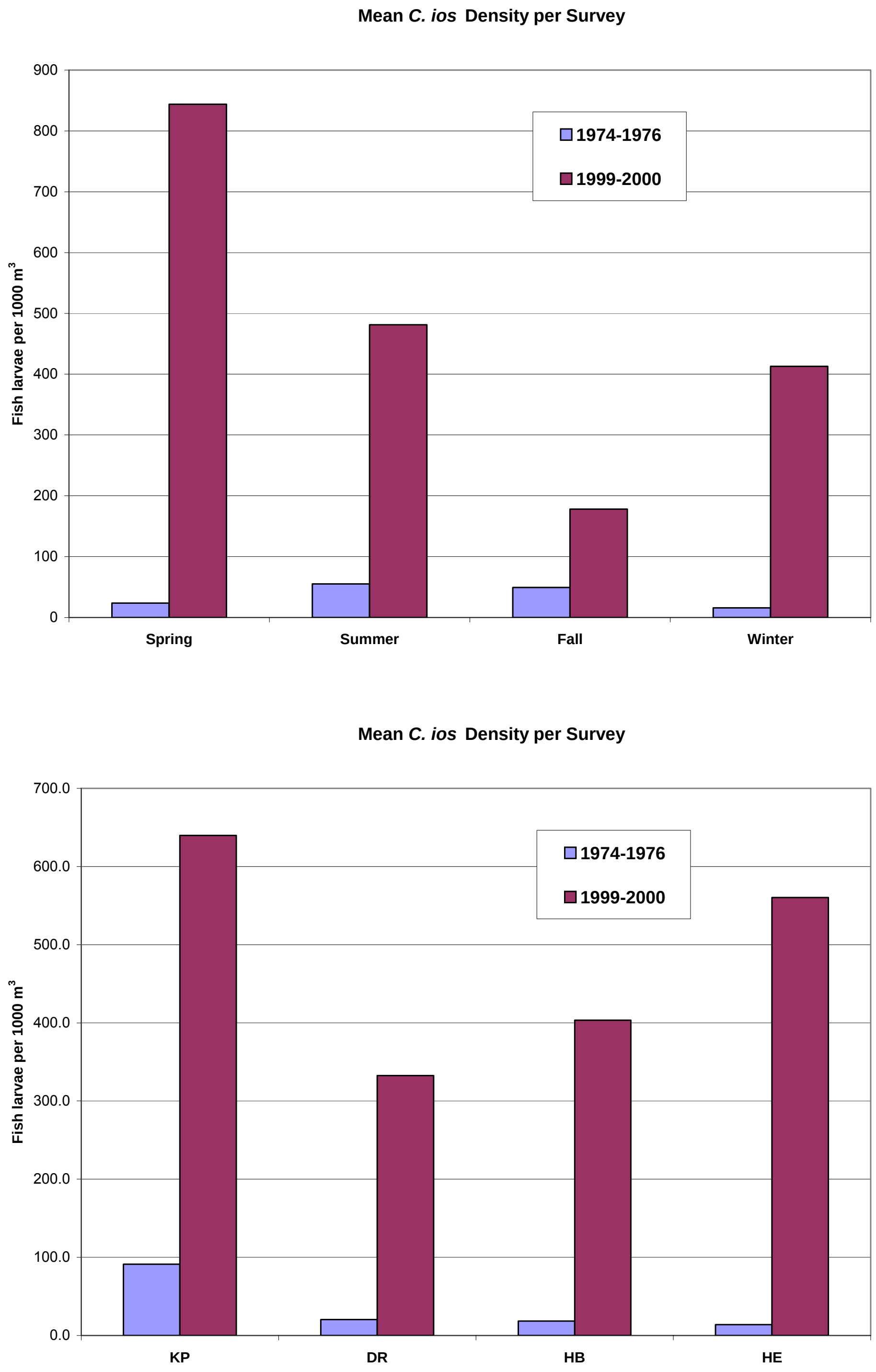


Figure D-5. Arrow goby density by season and area in Elkhorn Slough.

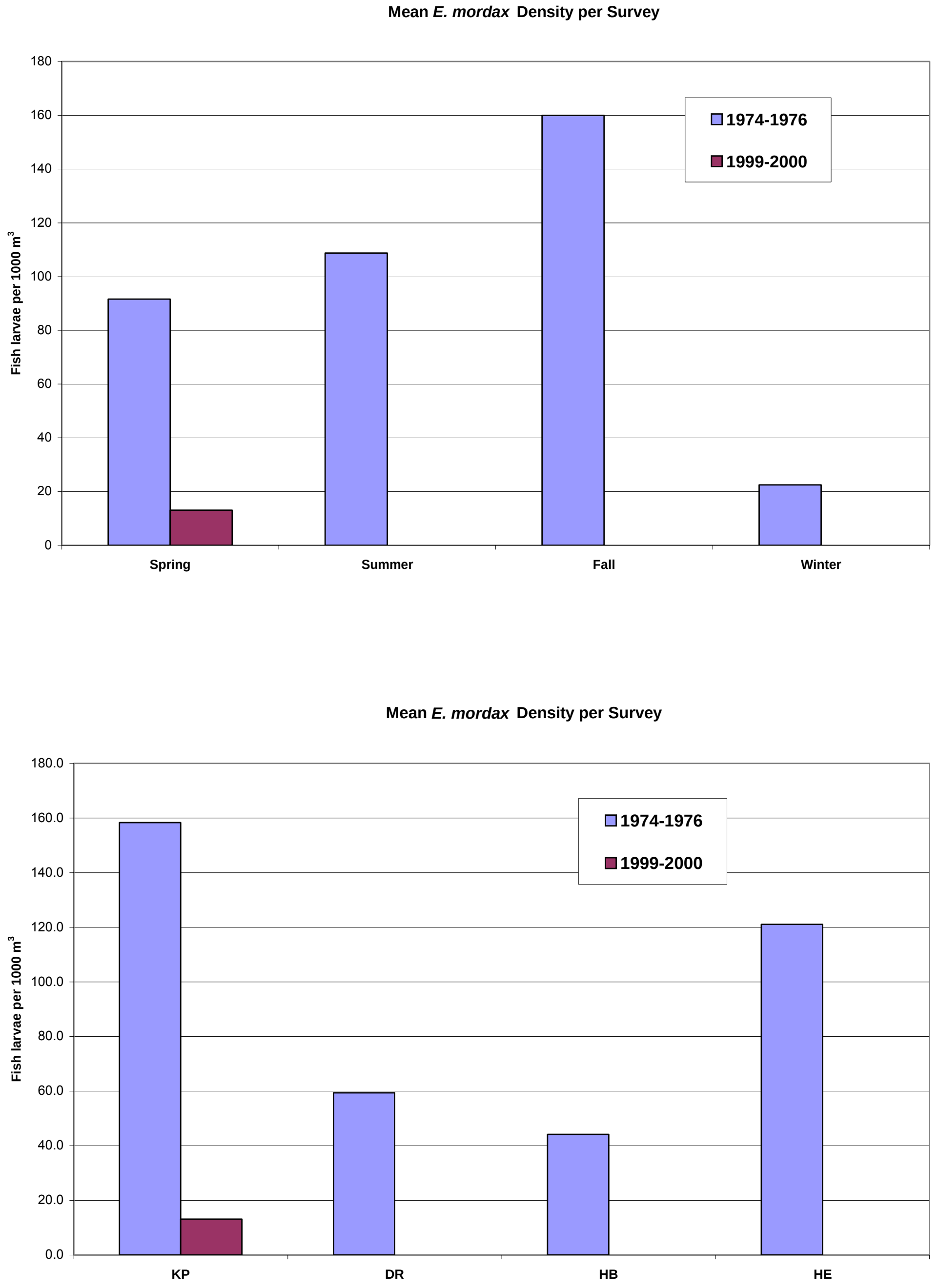
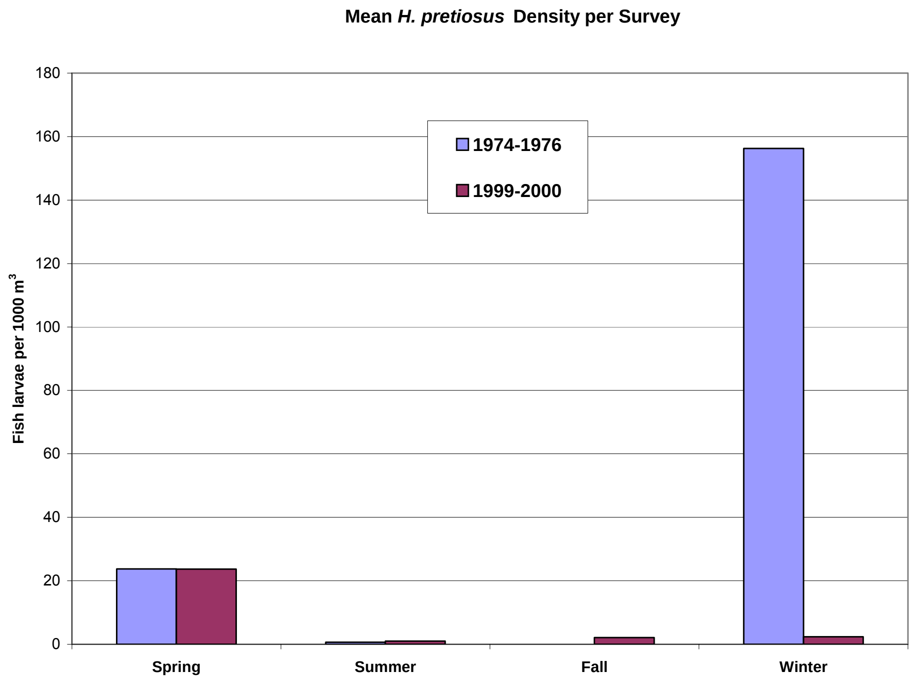


Figure D-6. Northern anchovy density by season and area in Elkhorn Slough.



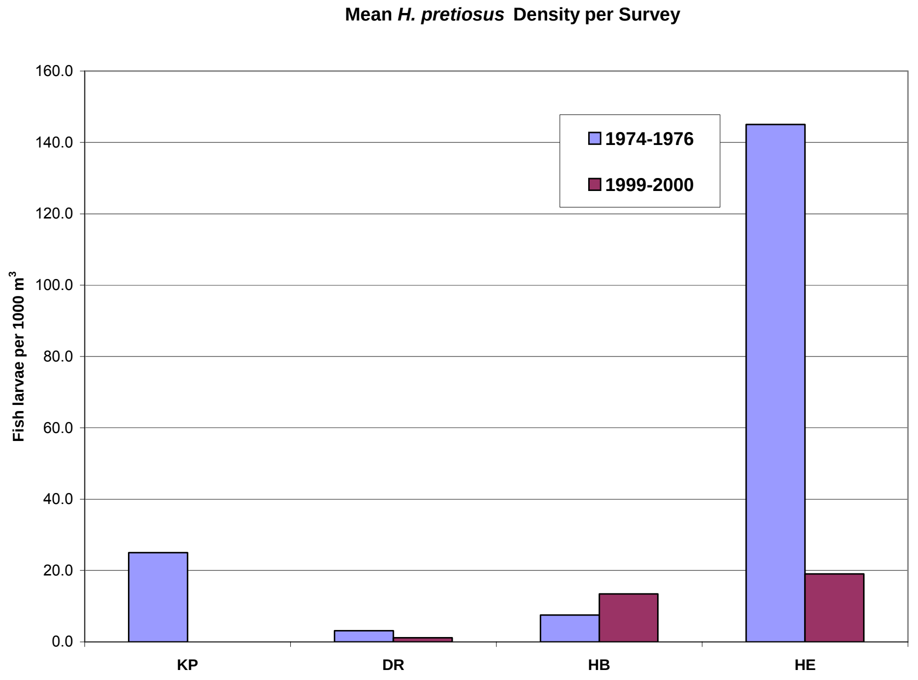
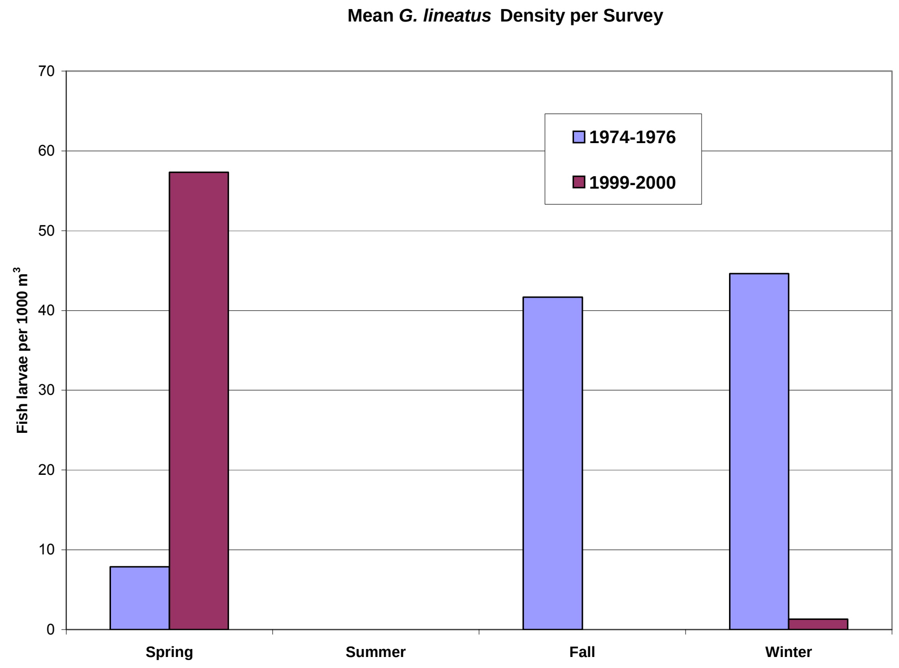


Figure D-7. Surf smelt density by season and area in Elkhorn Slough.



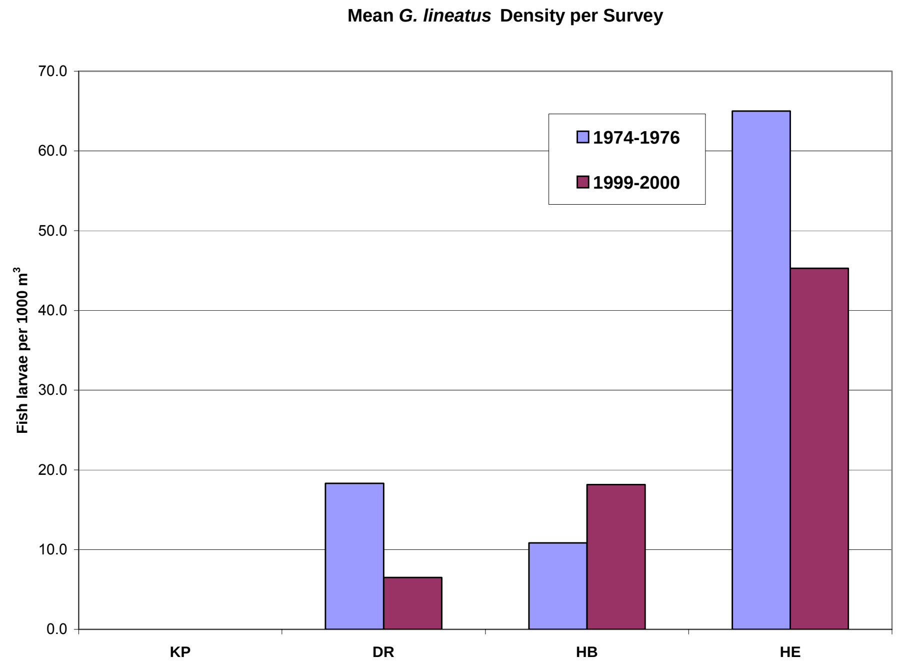


Figure D-8. White croaker density by season and area in Elkhorn Slough.

E PEER REVIEW COMMENTS

EPRI sent out a draft version of the report to the following three peer reviewers:

1. Dr. Alec D. MacCall (Senior Scientist, NMFS/SWFSC/FED, Santa Cruz, CA)
2. Dr. Peter T. Ramondi (Professor with the University of California Santa Cruz)
3. Dr. Charles (Chuck) C. Coutant (Fisheries Consultant; formerly Distinguished Senior Scientist at the Oak Ridge National Laboratory and Past President of the American Fisheries Society)

The major technical comments of each peer reviewer are summarized below along with the nature of the changes made to the report in response to comments.

Dr. Alec MacCall:

- Commented it was “really quite a good report” with the caveat that a number of conclusionary statements appeared to be biased and/or illogical.
- The review did not involve the entire document and comments were focused on Chapter 3 California fishery discussion.
- It was stated that the report seems to draw a “no impact” conclusion no matter what the evidence is, which is pretty much what I would expect from the topic and motivation of the report. In nearly every case, the more accurate conclusion is that available data do not allow a determination of whether or not there is an impact. The comments stated that “In nearly every case a slight change of wording will produce an objectively accurate and acceptable statement, and (in my view) greatly improve the credibility of the report”. A number of specific examples regarding conclusions were provided in the comments.
- There is often confusion between impacts on fishes and impacts on fisheries (beginning with the title of the report, which would more accurately be “...coastal fishes and fisheries”), though the report does try to recognize this distinction.

Dr. Chuck Coutant:

- Commented that the report should be a useful compilation of entrainment and impingement studies at power plants in California.
- Described the technology descriptions in Appendix A as too short to be useful. Comments suggested that each technology be described briefly and include at least one reference. Stated “This report can serve not only as a summary of the authors’ opinions but a guide to pertinent literature for state folks who want to look more deeply. Again, citing EPRI’s previous compendiums of technologies might suffice.”
- Numerous comments were made throughout the document asking for clarifications to be provided as well as editorial comments.
- Regarding the croaker analysis in Section 3.2.3, a comment was made the analysis was not very convincing as the croaker populations are on a downswing at the same time as impingement numbers are in the hundreds of thousands per year. “Therefore the combined effects of fishing, El Nino, and impingement could all contribute to the decline.

El Nino may be causing the minor up and down [something missing?], while overfishing and impingement are baseline losses that result in a lower stable population level. Needs more thought. The logical Santa Monica Bay story doesn't apply to the coastal waters."

- Commented that the compensation discussion was largely qualitative.
- Regarding the discussion of blackgill rockfish, Dr. Coutant pointed out that "the fact that the power plants are reducing fisheries at all, even 26-52 MT is a lot of fish biomass not available for harvest and states "fisheries managers have pushed the so-called sustainable rate of harvest to the razor edge to the point that fish populations are actually declining. When the fisheries models have shown themselves to be not particularly good, should we trust these estimates? This is the sort of question that needs to be answered"
- Questioned the example of lack of impacts in cooling lakes since many of the fish in these lakes are nest builders not vulnerable to entrainment and some that are such as tend to reproduce in coves not in the main cooling-water circuit.

Dr. Peter Raimondi:

- Commented the report was nicely done, but also expressed a number of concerns. The two major disagreements with the findings were in two areas:
    1. The lack of recognition of potential effects except to the target species.
    2. The lack of testable hypotheses to support conclusions.

  In the absence of such information, it is Dr. Raimondi's view that there is no evidence that entrainment does not have an impact an effect on populations or a broader impact on communities. There were a number of comments on these two points inserted throughout the document.
- Felt that the discussion of velocity caps in Section 2.2.2 was good, but also pointed out that in some cases the distance offshore of the intake resulted in the discharge being closer to shore than the intake and that higher fish densities were found nearshore. Also pointed out that velocity cap effectiveness varied by species.
- Commented that the Elkhorn Slough was not a compelling example of the lack of once through cooling impacts in the absence of pre-operational data.
- Took exception to the role played by compensation in tempering fisheries impact noting that compensation is variable from year to year.
- Relative to the discussion on compensation, expressed concern that existing fishery models as used by resource management agencies have done a poor job in protecting fisheries.

Response to comments reflected in the final report

- Nearly all the editorial comments suggested were accepted and changes in the text were made in response to comments on lack of clarity.
- All conclusionary statements were revisited as suggested by Dr. McCall and appropriate wording changes were made in terms of the statement and supporting information.
- The authors agree that compensation, while a well documented biological process, is difficult to quantify, especially in open systems such as oceans. The current text reflects this circumstance. The report also acknowledges that level of compensatory reserve varies with population fluctuations.

- The authors also generally agree that more research is needed to more accurately quantify impacts to fishes and fisheries and this recognition is reflected in the final report. The report points out the extensive entrainment sampling conducted at facilities in the last few years combined with source waterbody sampling could provide current information on this topic.
- Text was added to the report to reflect that velocity cap performance can vary with species, however, no change was made relative to distance from shore as the difference between the thermal discharge distance and intake difference is relatively small.

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