Evaluation of Fine-mesh Intake Screen System for the Diablo Canyon Power Plant

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Introduction

This report provides an evaluation of a fine-mesh screening concept under consideration as an alternative cooling system technology at the Diablo Canyon Power Plant (DCPP) by Bechtel Power Corp. in support of the California State Water Resources Control Board Once-Through-Cooling (OTC) Policy Nuclear-Fueled Power Plant (NFPP) Special Studies. This evaluation focuses on the potential biological efficacy of the proposed fine-mesh screening system at reducing impingement mortality and entrainment (IM&E) based on Tenera Marine Biologist's decades of professional consulting experience on environmental issues associated with west coast power plant once-through cooling, including the system currently in-use at Diablo Canyon.

Existing Intake Screening System

The existing vertical traveling screens at DCPP use 9.5 mm (3/8 inch) mesh screen panels for screening out debris that could occlude the plant condenser tubes. The current screen system is oriented perpendicular to the intake flow, and has no provisions for fish survival or return. Although the power plant has a very high capacity factor and a seawater intake design volume of 9.58 million m^3 per day (2,530 mgd), it has the lowest impingement biomass per million gallons circulated of all the coastal plants in California using once-through cooling (Appendix 1; Table E1-2), demonstrated during studies completed in 1975–1977 and 1985–1986 (summarized in Appendix 2). There are several reasons why the impingement rate is so low at DCPP including the design of the intake which included fish impingement reduction features, the enclosure of the intake structure in a relatively confined engineered cove, the location of the intake along an exposed section of coastline, and the fishes primarily found in the geographic location of the plant in central California north of Point Conception. During the studies, the largest proportion of the total estimated annual biomass of 322 kg (710 lbs) of fish was from slower swimming thornback rays (*Platyrhinoidis triseriata*). The slow swimming speeds and large surface area of thornbacks and other skates and rays make these specific fishes more susceptible to becoming trapped against the intake bar racks and traveling screens. The largest numbers of fishes impinged were young-of-year or juvenile olive/yellowtail rockfish (*Sebastes serranoides* / *S. flavidus*), which have weaker swimming abilities than adults of the species. Of the 84 olive/yellowtail rockfish measured during the 1985–1986 study, 75 (89%) were juveniles less than 15 cm (6 in.) in length. Similarly, the only specimen of cabezon (*Scorpaenichthys marmoratus*), a common rocky reef fish in central California, collected during the study was a juvenile less than 8 cm (3 in.) in length. The large percentage of smaller, juvenile stage fishes and the low numbers of adults in the impingement totals at the DCPP indicates that most fishes common to the location are at low risk to impingement at the plant intake.

As a result of the low impingement risk, any changes to the intake screening system at DCPP would largely need to address impacts due to entrainment of small fish eggs and larvae, and other invertebrate plankton through the existing 9.5 mm (3/8 inch) mesh screen.

Proposed Fine-mesh Screen System Design

The alternative intake technology being evaluated for implementation at DCPP is fine-mesh traveling screens that would be mounted parallel to the intake flow using a dual flow design that will increase the effective surface area of the screens. The proposed mesh size is 1 mm x 6 mm (0.04 in. x 0.24 in.) woven stainless steel. The increased screen area due to the dual flow design will result in a decrease in the estimated through-screen velocity from the current velocity of approximately 0.6 m/s (1.95 f/s) at Mean Sea Level (MSL) to 0.3 m/s (1.0 f/s). A wedgewire screen (WWS) system option is also being considered that is a passive intake screening technology designed to reduce impingement and entrainment through the use of reduced screen slot sizing, low approach and through-screen velocities, and sweeping water currents that may move organisms and debris off and away from the screens. If properly designed, there should be limited or no impacts to larger organisms due to impingement when implementing a WWS system. Fine-mesh screens are one component of an entire system that actively removes organisms from the source water as they are impinged on the screens and then transports them, generally via a screen-wash and return system, back to the source water body. Organisms impinged by fine-mesh screens will include larger organisms similar to the organisms described in Appendix 2, as well as smaller organisms such as fish eggs and larvae that would normally be entrained through larger sized screen mesh.

Since the design of the current intake system results in relatively low levels of impact to larger impingeable organisms, the design of the fine-mesh system should focus on reducing the mortality of smaller organisms such as fish eggs and larvae that are currently entrained. The capture, removal, and return system stages all induce stress on the organisms that are initially impinged by the screening technology, and therefore, such systems need to be designed to reduce stress, and potentially mortality, at each operating stage. The system description proposed by Bechtel for the DCPP intake attempts to address these issues by including the following:

- Running the traveling screens continuously to reduce the amount of time the organisms spend impinged on the screen. This also reduces the amount of debris impinged on the screens. As debris occludes the screens the through screen velocity at the open portions of the overall screening unit increases, thereby increasing the chances of entrainment or damage to fragile organisms or life stages (King et al. 1978 and Tathum et al. 1978 as referenced in Jenks 2003).
- Increasing the screen speed to, again, reduce impingement time and to reduce the period of retention in the screen bucket. This also reduces the amount of debris on the screen or in the bucket.
- The addition of fish buckets to the screens so that the organisms will drop, via gravity, from the screen into water filled buckets or trays upon leaving the cooling source water column as the screens rotate upward.
- The use of a low pressure screen-wash to gently remove organisms from the tilted/inverted buckets into the return trough and piping.
- The use of a high pressure screen-wash system following removal of the organisms to remove remaining debris that could occlude the screens and increase through screen velocity.
- Providing a return system that has a minimum of turns and is as short a run to the source water as possible.

One issue not addressed by the Bechtel design concept however is the need to control the growth of fouling organisms within the return system. Fouling organisms, such as barnacles and mussels, will result in physical damage to organisms passing through the system. The fouling organisms will also extensively prey on small fish eggs and larvae, and invertebrate plankton passing through the system.

Fine-mesh Screen System Efficiency

There are two aspects to assessing the efficiency of a fine-mesh screen at reducing IM&E: 1) reduction in entrainment through the use of a smaller screen mesh, and 2) determining the survival of organisms impinged on the screens then returned. Potential survival needs to be determined for those larger organisms impinged on the existing conventional traveling screens, termed “impingeables” in the proposed Federal 316(b) Rule, as well as smaller organisms that would have previously been entrained, termed “converts” in the proposed Federal Rule which would be impinged on the alternative traveling screens. These two aspects are discussed in the following sections.

A significant difference in screen technology application also exists that should be considered in this assessment. The design and application of modular WWS is intended to take advantage of sweeping current influences in the source water surrounding the deployed modules to aid in reduction of initial screen impingement, and to some extent facilitate escape of organisms following impingement. For inshore fine-mesh screen applications the potential effects of sweeping currents are not a significant consideration. The current nearest the intake withdrawal point will generally be in one dominant direction; into and through the screen. Organisms larger than the screen slot size entrained in the cooling flow incapable of escape will almost certainly encounter the screen surface and either be impinged on or pushed through the screen. Once impinged, the organism will likely remain pinned to the screen surface by the uni-directional flow unless removed following screen rotation to a wash and return system.

Entrainment Reductions

Estimates of the expected effectiveness of different size mesh openings at reducing entrainment of fish larvae via exclusion were provided in a previous report (Tenera 2013). The estimates specific to DCPP in that report were based on data collected from an entrainment study conducted at the plant in 1996–1999. Since most of the body parts of fish larvae are soft and easily compressible at the early stages of development when they are susceptible to entrainment, and the head capsule has harder cartilage and bone that is not compressible, the width and depth of the head capsule corresponding to specific length classes of larvae was used to estimate the proportion of each length class entrained. The smallest dimension (width or depth) of the head capsule was used to represent the minimum size larva that could pass through a rectangular mesh or WWS slot opening. The report did not provide any assessment of the survival or viability of larvae following possible screen impingement.

Entrainment estimates and detailed length frequency data for seven taxa of larval fishes were presented in **Tables 5** and **7** in Tenera (2013). These seven included the five taxa with the highest estimated entrainment for the two annual periods during the study. The estimated reductions in entrainment for an opening of 1 mm (0.04 in.) in **Tables 8** and **9** in Tenera (2013), would need to be adjusted to account for the 1 mm x 6 mm (0.04 in. x 0.24 in.) rectangular fine-mesh screen opening. The slot openings on WWS are sufficiently long to allow the passage of any larval fish with head capsule dimensions smaller than the slot width. The 1 mm x 6 mm (0.04 in. x 0.24 in.) rectangular fine-mesh screen opening would however only allow for passage of fish less than a certain length. Offsetting this, the water velocity through the screen would be expected to push/pull easily compressible smaller larval fish through the opening even if they are somewhat longer than 6 mm (0.24 in.). 10 mm (0.39 in) was selected in this assessment as the length of larvae that could reasonably be pushed/pulled by the cooling water flow through the 6 mm (0.24 in.) long rectangular mesh opening.

As shown in **Table 7** in Tenera (2013), the number of larvae from the seven taxa that were greater than 10 mm (0.39 in.) was not large (**Table 1**). The resulting effects of considering both head capsule dimension and larval length in estimating entrainment of kelpfishes, monkeyface pricklebacks, and anchovies are shown in Tables **2–4**. By assuming that all larvae longer than 10 mm (0.39 in.) would not be entrained through a 1 mm x 6 mm rectangular fine-mesh screen slot, the effective reductions in entrainment for these three taxa increase only slightly for kelpfishes and monkeyface pricklebacks, but from 9.0 to 15.8 percent for anchovies. All of the larvae not entrained through the screen would be impinged. The population level reductions (larval population surviving to 20-25 mm) shown in **Table 9** in Tenera (2013), would also need to be adjusted to count only larvae greater than 10 mm (0.39 in.) for kelpfishes, monkeyface pricklebacks, and anchovies, but would only be applicable to these and other fishes that survived impingement and were returned alive to the source water.

Table 1. Percentage of larval measurements greater than 10 mm notochord length (NL) for seven taxa of larval fishes collected during entrainment sampling at DCPP from October 1996 through June 1999. Percentages summarize data presented in Table 7 of Tenera (2013).

Taxa	Percent of Measured Larvae >10 mm NL
sculpins	<0.1
rockfishes	0.0
kelpfishes	2.4
monkeyface prickleback	2.8
anchovies	15.8
cabezon	0.0
flatfishes	0.0

Table 2. Larval entrainment estimates by length for kelpfish larvae with estimated reductions for 1 mm (0.04 in.) wedgewire screen and fine-mesh screen with a mesh opening of 1 mm x 6 mm (0.04 in. x 0.24 in.). The estimates for fine-mesh screen were adjusted to account for fishes larger than 10 mm (0.39 in.) in length that would not likely be entrained through the rectangular mesh.

Length (mm)	Number for Length	Percent for Length	Probability of Entrainment	Annual Entrainment Estimates		Annual Entrainment Estimates 1 mm WWS		Annual Entrainment Estimates 1 x 6 mm fine-mesh	
				1997–1998	1998–1999	1997–1998	1998–1998	1997–1998	1998–1999
2	1	0.0	1	16,639	12,382	16,639	12,382	16,639	12,382
3	7	0.1	1	116,470	86,676	116,470	86,676	116,470	86,676
4	285	3.9	1	4,741,982	3,528,936	4,741,982	3,528,936	4,741,982	3,528,936
5	1,938	26.4	1	32,245,474	23,996,766	32,245,474	23,996,766	32,245,474	23,996,766
6	2,332	31.8	1	38,801,056	28,875,365	38,801,056	28,875,365	38,801,056	28,875,365
7	1,499	20.4	0.998	24,941,159	18,560,966	24,891,277	18,523,844	24,891,277	18,523,844
8	664	9.1	0.954	11,047,985	8,221,802	10,539,778	7,843,599	10,539,778	7,843,599
9	307	4.2	0.747	5,108,029	3,801,345	3,815,698	2,839,605	3,815,698	2,839,605
10	125	1.7	0.426	2,079,816	1,547,779	886,002	659,354	886,002	659,354
11	72	1.0	0.213	1,197,974	891,521	255,169	189,894	0	0
12	40	0.5	0.098	665,541	495,289	65,223	48,538	0	0
13	13	0.2	0.041	216,301	160,969	8,868	6,600	0	0
14	17	0.2	0.017	282,855	210,498	4,809	3,578	0	0
15	2	0.0	0.007	33,277	24,764	233	173	0	0
16	2	0.0	0.003	33,277	24,764	100	74	0	0
17	4	0.1	0.001	66,554	49,529	67	50	0	0
18	5	0.1	0	83,193	61,911	0	0	0	0
19	6	0.1	0	99,831	74,293	0	0	0	0
20	5	0.1	0	83,193	61,911	0	0	0	0
21	6	0.1	0	99,831	74,293	0	0	0	0
22	1	0.0	0	16,639	12,382	0	0	0	0
23	1	0.0	0	16,639	12,382	0	0	0	0
24	0	0.0	0	0	0	0	0	0	0
25	0	0.0	0	0	0	0	0	0	0
			Totals	**121,977,076**	**90,774,143**	**116,388,842**	**86,615,434**	**116,054,374**	**86,366,527**
			Percent Reductions			**4.6%**	**4.6%**	**4.9%**	**4.9%**

Table 3. Larval entrainment estimates by length for monkeyface prickleback larvae with estimated reductions for 1 mm (0.04 in.) wedgewire screen and fine-mesh screen with a mesh opening of 1 mm x 6 mm (0.04 in. x 0.24 in.). The estimates for fine-mesh screen were adjusted to account for fishes larger than 10 mm (0.39 in.) in length that would not likely be entrained through the rectangular mesh.

				Annual Entrainment Estimates		Annual Entrainment Estimates 1 mm WWS		Annual Entrainment Estimates 1 x 6 mm fine-mesh	
Length (mm)	Number for Length	Percent for Length	Probability of Entrainment	1997–1998	1998–1999	1997–1998	1998–1999	1997–1998	1998–1999
3	3	0.1	1	60,396	64,844	60,396	64,844	60,396	64,844
4	5	0.1	1	100,660	108,074	100,660	108,074	100,660	108,074
5	27	0.5	1	543,565	583,598	543,565	583,598	543,565	583,598
6	591	10.0	1	11,898,035	12,774,302	11,898,035	12,774,302	11,898,035	12,774,302
7	3,560	60.2	0.992	71,670,060	76,948,418	71,096,700	76,332,831	71,096,700	76,332,831
8	1,056	17.9	0.946	21,259,434	22,825,149	20,111,424	21,592,591	20,111,424	21,592,591
9	352	6.0	0.831	7,086,478	7,608,383	5,888,863	6,322,566	5,888,863	6,322,566
10	150	2.5	0.655	3,019,806	3,242,209	1,977,973	2,123,647	1,977,973	2,123,647
11	76	1.3	0.468	1,530,035	1,642,719	716,056	768,793	0	0
12	48	0.8	0.312	966,338	1,037,507	301,497	323,702	0	0
13	20	0.3	0.198	402,641	432,294	79,723	85,594	0	0
14	10	0.2	0.122	201,320	216,147	24,561	26,370	0	0
15	5	0.1	0.074	100,660	108,074	7,449	7,997	0	0
16	4	0.1	0.044	80,528	86,459	3,543	3,804	0	0
17	1	0.0	0.026	20,132	21,615	523	562	0	0
18	0	0.0	0	0	0	0	0	0	0
19	0	0.0	0	0	0	0	0	0	0
20	0	0.0	0	0	0	0	0	0	0
21	0	0.0	0	0	0	0	0	0	0
22	0	0.0	0	0	0	0	0	0	0
23	0	0.0	0	0	0	0	0	0	0
24	0	0.0	0	0	0	0	0	0	0
25	1	0.0	0	20,132	21,615	20	22	0	0
			Totals	**118,960,221**	**127,721,405**	**112,810,990**	**121,119,296**	**111,677,617**	**119,902,451**
			Percent Reductions			**5.2%**	**5.2%**	**6.1%**	**6.1%**

Table 4. Larval entrainment estimates by length for anchovy larvae with estimated reductions for 1 mm (0.04 in.) wedgewire screen and fine-mesh screen with a mesh opening of 1 mm x 6 mm (0.04 in. x 0.24 in.). The estimates for fine-mesh screen were adjusted to account for fishes larger than 10 mm (0.39 in.) in length that would not likely be entrained through the rectangular mesh.

				Annual Entrainment Estimates		Annual Entrainment Estimates 1 mm WWS		Annual Entrainment Estimates 1 x 6 mm fine-mesh	
Length (mm)	Number for Length	Percent for Length	Probability of Entrainment	1997–1998	1998–1999	1997–1998	1998–1999	1997–1998	1998–1999
2	97	3.8	1	4,083,262	123,184	4,083,262	123,184	4,083,262	123,184
3	914	36.2	1	38,475,273	1,160,723	38,475,273	1,160,723	38,475,273	1,160,723
4	665	26.3	1	27,993,497	844,509	27,993,497	844,509	27,993,497	844,509
5	162	6.4	1	6,819,468	205,730	6,819,468	205,730	6,819,468	205,730
6	53	2.1	1	2,231,061	67,307	2,231,061	67,307	2,231,061	67,307
7	38	1.5	1	1,599,628	48,258	1,599,628	48,258	1,599,628	48,258
8	56	2.2	1	2,357,347	71,117	2,357,347	71,117	2,357,347	71,117
9	73	2.9	1	3,072,970	92,705	3,072,970	92,705	3,072,970	92,705
10	69	2.7	1	2,904,588	87,626	2,904,588	87,626	2,904,588	87,626
11	66	2.6	0.997	2,778,302	83,816	2,769,967	83,564	0	0
12	53	2.1	0.956	2,231,061	67,307	2,132,894	64,345	0	0
13	37	1.5	0.803	1,557,533	46,988	1,250,699	37,731	0	0
14	29	1.1	0.530	1,220,769	36,828	647,008	19,519	0	0
15	27	1.1	0.268	1,136,578	34,288	304,603	9,189	0	0
16	31	1.2	0.109	1,304,960	39,368	142,241	4,291	0	0
17	27	1.1	0.037	1,136,578	34,288	42,053	1,269	0	0
18	21	0.8	0.011	884,005	26,669	9,724	293	0	0
19	19	0.8	0.003	799,814	24,129	2,399	72	0	0
20	23	0.9	0.001	968,196	29,209	968	29	0	0
21	18	0.7	0	757,719	22,859	0	0	0	0
22	12	0.5	0	505,146	15,239	0	0	0	0
23	12	0.5	0	505,146	15,239	0	0	0	0
24	12	0.5	0	505,146	15,239	0	0	0	0
25	13	0.5	0	547,241	16,509	0	0	0	0
			Totals	**106,375,289**	**3,209,133**	**96,839,651**	**2,921,462**	**89,537,095**	**2,701,158**
			Percent Reductions			**9.0%**	**9.0%**	**15.8%**	**15.8%**

Impingement Survival

The larvae that would not be entrained through the 1 mm x 6 mm (0.04 in. x 0.24 in.) rectangular fine-mesh screen panels would be impinged. The total efficiency of the fine-mesh screening system needs to account for the survival of impinged “converts”, as well as other organisms that may become impinged on the screens. While juvenile and adult fish may be hardy enough to survive the capture, remove, and return system, larval fish can be quite fragile. There are a few studies on larval fish survival on fine-mesh traveling screens. Most of these studies were conducted on the east coast or on lakes and rivers and, while not directly applicable to DCPP due to the differences in species, do provide information on the levels of survival following impingement expected for fishes at different stages of development. There was also a study conducted in Redondo Beach to evaluate several intake technologies, including fine-mesh screens, using west coast species of fish (LMS 1981). The results of these studies are summarized below relative to the fine-mesh screen technology proposed for DCPP.

One study using fish larvae was done at the Indian Point Generating Station, located on the Hudson River in New York, which used a conventional vertical traveling screen modified to use 2.5 mm (0.10 in.) mesh screen panels and fish buckets (Ecological Analysts 1979). Tests involved releasing hatchery reared striped bass yolk-sac larvae (mean length 5 mm [0.20 in.]) in front of the continuously operating traveling screen. A net was placed at the end of a short “fish return trough” to retrieve larvae collected by the system. Of 38,700 larvae released only 835 (2.2 percent) were recovered and none of those were alive. While it is apparent that the vast majority of the larvae were entrained rather than impinged by the screen, it is not apparent whether more larvae would have survived if impinged on a smaller mesh screen. Additional data from the site on actual impingement of naturally occurring striped bass resulted in the collection of 15 larvae which were all dead, and 34 juveniles, with a survival rate of 60 percent after 96 hours.

Laboratory testing done by EPRI (2006) on impingement survival on fine-mesh screens used juvenile and young-of-the-year fish ranging from 27–148 mm in length. Therefore, due to the size range which is much larger than those observed at DCPP, the results are not directly pertinent to evaluating impingement survival of larvae at DCPP, but the results did show an increase in survival with increasing length of the fish. Data on impingement survival on fine-mesh screens reported by McLaren and Tuttle (2000) were also largely collected from juvenile and adult fishes and showed considerable variation in survival among species and life stages. The only data collected on larval survival was for post-yolk sac stage rainbow smelt which had a 96 hour survival rate of 26.9 percent following impingement.

The studies done on west coast species of fish were conducted at a laboratory in Redondo Beach, CA in a flume designed to evaluate various combinations of flow, screen mesh size, and periods of impingement exposure (LMS 1981). Fishes involved in the testing included topsmelt (*Atherinops affinis*), California grunion (*Leuresthes tenuis*), northern anchovy (*Engraulis mordax*), giant kelpfish (*Heterosticchus rostratus*), white croaker (*Genyonemus lineatus*), and shadow goby (*Quietula y-cauda*). Most of the testing was done on larger larvae that verify the results from testing conducted by EPRI (2006), showing high survival for larvae greater than 12 mm in length. The one species in the LMS testing that showed very low survival was northern anchovy, which the authors indicated was not able to tolerate the stress resulting from the spray wash and air exposure of the collection system. Survival of anchovy larvae immediately following treatment was high (>90%), but few northern anchovy survived to 24 hrs, and none survived to 96 hrs. Although the analysis for DCPP shows that anchovy have large larvae that would benefit from the installation of fine-mesh screens, there may be very low survival for any anchovy larvae following impingement.

Survival was improved for other species with survival increasing with the size of the larvae. For example, California grunion used in the testing ranged in size from 9.0 to 18.3 mm (0.35 to 0.72 in.) with adjusted mean survivals for small, medium, and large larvae of 42, 59, and 80 percent, respectively. Grunion larvae hatch from eggs buried in the sand on the beach and are likely better adapted to survive harsh treatment than anchovy larvae which hatch from eggs in the water column.

Conclusions

The purpose of installing fine-mesh screens at DCPP is largely to reduce the effects of entrainment as the existing levels of impingement at the plant are very low. Based on the available information from entrainment studies at DCPP and studies of fine-mesh performance, the expected benefits from the screens would be minimal. The entrainment studies at DCPP show that the vast majority of the fishes entrained were very small and based on other studies, the probability of these larvae surviving impingement, screen-wash systems, and fish return would be very low. Northern anchovy was the only fish taxa entrained with large numbers of larvae greater than 10 mm, and the expected survival of the larvae for this species would be very low based on the results of the LMS (1981) studies at Redondo Beach. The LMS (1981) studies also showed that survival of larger larvae for some fishes could be quite high, but ultimately was highly dependent on the length and development stage of the fish.

Although the population level benefits of protecting later stage larvae increases exponentially with the age of the fish, there does not seem to be any evidence that large numbers of late stage larvae are entrained at DCPP. The survival rates of juvenile and adult fish following impingement on a fine-mesh screen system such as that described in the Bechtel report would be expected to be considerably higher, although species specific tests have not been conducted. However, past impingement studies conducted at DCPP have shown that even with the current traveling screens the collection of juvenile and adult fish is minimal (Appendix 2).

In general, fish survival on fine-mesh screen systems increases as the size of the fish increases (juveniles and adults fare better than larval stages), but impingement of the larger life stages at DCPP is not a major concern. By reducing the mesh size of the traveling screen system installed at the DCPP intake larval fish will be impinged that are currently entrained, but the probability of their survival, even with fish buckets and a return system, is low.

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Appendix 1: Impingement Summary for California Power Plants

There are 14 coastal power plants in California with 17 separate intake structures that have some level of fish impingement due to intake operations. Some plants now operate only intermittently, such as Morro Bay Power Plant, and therefore have much lower impingement rates compared to historical levels when at least one of the units was operating at all times. **Table A1-1** presents information on fish impingement based on recent studies conducted at each facility. Some facilities such as Alamitos Generating Station (AGS) have multiple units but a single combined estimate for total impingement, while other plants, such as Moss Landing Power Plant, are listed with separate estimates for unit pairs sharing common intake systems. The estimates are based on pump flows from 2000-2005. AGS had the highest annual fish impingement of the 17 facilities evaluated (81,422 lb), while Redondo Units 5&6 had the lowest (77 lb). Total impingement is affected by annual variations in operating characteristics of a facility and the abundance of source water fish populations.

There is considerable variation surrounding most estimates because the impingement of several large rays or sharks, for example, can result in high total biomass estimates when extrapolated over the days between surveys when no samples were collected. For the most part, however, the rankings reflect the relative magnitude of impingement among plants based on their operating characteristics and locations.

Diablo Canyon Power Plant (DCPP), although having the highest design flow of all the plants (2,528 mgd), ranked 13th out of 17 intakes in terms of annual fish biomass impingement (710 lb). It also had the lowest rate of impingement per volume of water pumped (.0009 pounds per million gallons). This would be due to a combination of its location on the outer coast where there are generally lower concentrations of small schooling fishes as occur in embayments, and a shoreline intake design that has a large cross-sectional area resulting in relatively low intake approach velocities. **Table E1-2** presents a more detailed accounting of total impingement for all California coastally-sited plants and lists mortality from both normal operations and heat treatment operations. Many facilities no longer use heat treatment for control of biofouling on the intake tunnel walls, but those that do , such as Scattergood Generating Station, can incur a significant fraction of the total mortality from these operations.

Table A1-1. Annual impingement estimates including data from heat treatments for fish numbers and biomass (lb) from California coastal power plants sorted by total estimated biomass for actual flows. Data from Appendix D in Final Substitute Environmental Document for Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling, California State Water Resources Control Board, May 4, 2010.

				Design Flow		Actual Flow	
Rank	**Power Plant**	**Design Flow (mgd)**	**Average Flow (mgd) based on 2000-2005 data**	**Total # Estimate**	**Total Biomass (lb) Estimate**	**Total # Estimate**	**Total Biomass (lb) Estimate**
1	San Onofre Nuclear Generating Station Units 2&3	2,437	2,294	1,424,047	34,563	1,341,195	32,802
2	Scattergood Generating Station	495	309	201,646	18,827	145,635	13,285
3	Encina Power Plant	857	621	286,815	12,502	233,923	10,292
4	Ormond Beach Generating Station	685	521	31,531	5,858	27,259	4,876
5	Moss Landing Power Plant Units 6&7	865	387	565,390	9,071	253,067	4,060
6	Harbor Generating Station	108	59	19,508	6,399	10,666	3,498
7	Huntington Beach Generating Station	514	179	104,840	5,895	54,924	3,112
8	Mandalay Generating Station	253	234	73,697	2,779	67,934	2,562
9	Alamitos Generating Station Units 1-6	1,273	815	81,419	3,514	52,106	2,249
10	Morro Bay Power Plant	668	257	85,315	3,419	32,763	1,313
11	El Segundo Generating Station Units 3&4	399	265	4,057	1,345	2,983	1,012
12	Redondo Generating Station Units 7&8	675	254	6,669	2,266	2,983	967
13	Diablo Canyon Power Plant	2,528	2,287	5,330	785	4,821	710
14	Moss Landing Power Plant Units 1&2	361	193	76,526	762	40,816	406
15	Haynes Generating Station	968	258	66,901	1,462	17,838	390
16	El Segundo Generating Station Units 1&2	207	69	1,074	359	556	182
17	Redondo Generating Station Units 5&6	217	51	613	282	159	77
	Totals	**13,511**	**9,051**	**3,035,380**	**110,089**	**2,289,628**	**81,795**

Table A1-2. Annual impingement estimates for fish numbers and biomass (lb) from California coastal power plants. Estimated mortality from normal operations and heat treatments are shown separately. Table 2a from Appendix D in Final Substitute Environmental Document for Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling, California State Water Resources Control Board, May 4, 2010.

					Annual Normal Operations Impingement				Heat Treatments (HT)			Total Estimated Impingement			
Plant	Design Flow (mgd)	Average Flow (mgd) based on 2000-2005 data	Average # fish per million gal	Average Biomass (lbs) fish per million gal	Based on Count and Design Flow	Based on Biomass (lbs) and Design Flow	Based on Count and Average Flow	Based on Biomass (lbs) and Average Flow	Average # per HT	Average Biomass (lb) per HT	Average Number of HT per year (2000-2005)	Design Flow Total # Estimate	Design Flow Total Biomass (lb) Estimate	Actual Flow Total # Estimate	Actual Flow Total Biomass (lb) Estimate
Alamitos Generating Station Units 1&2	207	121							n/a	n/a	n/a				
Alamitos Generating Station Units 3&4	392	281	0.1750*	0.0076*	81,419	3,514	52,106	2,249	n/a	n/a	n/a	81,419	3,514	52,106	2,249
Alamitos Generating Station Units 5&6	674	413							n/a	n/a	n/a				
Diablo Canyon Power Plant	2,528	2,287	0.0058	0.0009	5,330	785	4,821	710	n/a	n/a	n/a	5,330	785	4,821	710
El Segundo Generating Station Units 1&2	207	69	0.0103	0.0035	779	265	260	89	227	72.18	1.3	1,074	359	556	182
El Segundo Generating Station Units 3&4	399	265	0.0220	0.0068	3,209	995	2,136	662	229	94.60	3.7	4,057	1,345	2,983	1,012
Encina Power Plant	857	621	0.6128	0.0256	191,824	8,016	138,932	5,806	15,832	747.70	6	286,815	12,502	233,923	10,292
Harbor Generating Station	108	59	0.4945	0.1622	19,508	6,399	10,666	3,498	n/a	n/a	n/a	19,508	6,399	10,666	3,498
Haynes Generating Station	968	258	0.1893	0.0041	66,901	1,462	17,838	390	n/a	n/a	n/a	66,901	1,462	17,838	390
Huntington Beach Generating Station	514	179	0.4079	0.0227	76,582	4,270	26,666	1,487	5,887	338.70	4.8	104,840	5,895	54,924	3,112
Mandalay Generating Station**	253	234	0.7940	0.0299	73,497	2,771	67,733	2,553	143	5.90	1.4	73,697	2,779	67,934	2,562
Morro Bay Power Plant	668	257	0.3497	0.0140	85,315	3,419	32,763	1,313	n/a	n/a	n/a	85,315	3,419	32,763	1,313
Moss Landing Power Plant Units 1&2	361	193	0.5804	0.0058	76,526	762	40,816	406	n/a	n/a	n/a	76,526	762	40,816	406
Moss Landing Power Plant Units 6&7	865	387	1.7895	0.0287	565,390	9,071	253,067	4,060	n/a	n/a	n/a	565,390	9,071	253,067	4,060
Ormond Beach Generating Station**	685	521	0.0711	0.0164	17,806	4,094	13,534	3,112	3,050	392.00	4.5	31,531	5,858	27,259	4,876
Redondo Generating Station Units 5&6	217	51	0.0075	0.0034	593	268	139	63	10	7.32	2	613	282	159	77
Redondo Generating Station Units 7&8	675	254	0.0240	0.0085	5,913	2,084	2,227	785	158	37.90	4.8	6,669	2,266	2,983	967
San Onofre Nuclear Generating Station Unit 2	1,219	1,139	1.5787	0.0335	1,405,342	29,854	1,322,490	28,094	2,494	627.80	7.5	1,424,047	34,563	1,341,195	32,802
San Onofre Nuclear Generating Station Unit 3	1,219	1,154									7.8				
Scattergood Generating Station	495	309	0.8226	0.0814	148,840	14,727	92,829	9,185	10,155	788.40	5.2	201,646	18,827	145,635	13,285
Totals	**13,511**	**9,051**			**2,824,776**	**92,756**	**2,079,024**	**64,462**				**3,035,380**	**110,089**	**2,289,628**	**81,795**

n/a = not applicable

* = does not include data from two large impingement events following heavy rain that were not representative of normal operations

** = impingement rates from NPDES data for 2000 through 2005 reported on an October to September annual cycle

Appendix 2: Summary of DCPP Impingement Studies

Two impingement studies have been completed at DCPP. The first was conducted from December 1975 to June 1977, before commercial operation began, but the sampling was not regularly scheduled during that period (Behrens and Larsson 1979). The second study was conducted on a regular schedule from April 1985 through March 1986 (Tenera 1988 and Tenera 1998). Impingement occurs when fishes, invertebrates, algal fragments and other material are too large to pass through the DCPP traveling screen 3/8 inch mesh and is held onto the screen by the pressure of the intake water flows.

The first study (Behrens and Larsson 1979) was conducted to provide the U.S. Nuclear Regulatory Commission with information about the species composition, abundance, and biomass of fishes and macroinvertebrates that were impinged on the facility's traveling screens. Samples were collected infrequently from December 1975 through February 1976 (referred to as Phase 1) and then routinely from January through June 1977 (referred to as Phase 2). Pump testing and mechanical issues affected the schedule of sample collection during this study. Unit 1 was sampled throughout the entire period while Unit 2 sampling did not begin until February 1977. All fishes and macroinvertebrates were identified to the lowest possible taxonomical level and then all the fishes and selected invertebrates (shrimp, crabs, octopus, squid, gastropods, and urchins) were measured and weighted. Their analysis included all fishes and those macroinvertebrates that had commercial fishery value or significant ecological importance.

Sampling consisted of removing and processing all impinged material from the collection sumps that accumulated during a 24-hour period. During Phase 1, 39 samples were collected (37 24-hour samples, one 72-hour sample, and one 7-day sample), for a total of 47 24-hour periods being observed for Unit 1. Phase 2 consisted of a total of 120 samples (90 from Unit 1 and 30 from Unit 2). Similar to Phase 1, some of the sampling efforts in Phase 2 were conducted over 72-hour periods, resulting in a total of 164 24-hour periods observed between the two units.

A total of 284 fishes (including sharks, rays, and skates) comprising 49 species from 27 families was impinged in all of the sampling efforts combined. **Table A2-1** presents a summary of the number and weight of the impinged fishes collected per month. The numbers and weight of the collected fishes were also adjusted by the volume of water during the sample periods to calculate an estimate of the mean number and weight (grams [g]) of fishes impinged per million m^3 of water pumped through the plant. During most of this study's sampling there was generally only one CWP in operation because the plant had yet to produce electricity. However, the authors noted that even when both units were in operation, impingement rates were still low. The monthly mean number of fishes per million m^3 varied from 0.08 to a maximum of 1.0, while the weight in grams varied from 7.8 g (0.02 lb) to 131.2 g (0.29 lb) (**Table A2-1**). The most abundantly impinged species were blue rockfish (*Sebastes mystinus* – 33 individuals), kelp surfperch (*Brachyistius frenatus* – 33 individuals), and striped surfperch (*Embiotoca lateralis* – 27 individuals), comprising 32.7% of the total fish catch. These fishes were generally young-of-the-year or 1–2 year old individuals. Other species varied in abundance from 1–14 individuals. Eighteen species had only a single occurrence in the samples.

The species with the highest collected biomass for both phases combined were striped surfperch (8,952 g [19.7 lb]), Pacific electric ray (*Torpedo californica* – 3,400 g [7.5 lb]), gopher rockfish (*Sebastes carnatus* – 2,191 g [4.8 lb]), kelp surfperch (1,807 g [4.0 lb]) and cabezon (*Scorpaenichthys marmoratus* – 1,554 g [3.4 lb]) (**Table A2-1**). The weight of these five species comprised about 66.7% of the total weight of the impinged fishes collected during both phases. Using the estimates for mean number and weight, and the DCPP calculated total daily volume when all four pumps are operating (9.45 million m^3/day), it is estimated that during this period the annual maximum total number of fishes impinged would have been 1,594, with a weight of 188.8 kg (416.2 lb), based on the data collected during 1975 and 1977.

Table A2-1. Number and weight of all fishes impinged at Diablo Canyon Power Plant during sampling from December 1975 to June 1977. Mean number and weight are based on values per million m^3 of water pumped through the plant. Data from Behrens and Larsson (1979), Table 4.

				Mean values / million m^3		
Month	**# 24-hour samples**	**Volume pumped (million m^3)**	**Total # fish**	**Mean # fish**	**Mean weight (g)**	**Mean weight (lb)**
Dec 1975	16	145	41	0.28	n/r	n/r
Jan 1976	16	142	26	0.18	7.77	0.02
Feb 1976	15	106	9	0.08	6.34	0.01
Jan 1977	17	49	33	0.67	131.24	0.29
Feb 1977	48	107	71	0.66	99.20	0.22
Mar 1977	41	75	49	0.65	80.56	0.18
Apr 1977	29	73	26	0.36	23.80	0.05
May 1977	26	70	20	0.28	22.70	0.05
Jun 1977	3	6	6	1.00	66.17	0.15
		Average	**31**	**0.46**	**54.72**	**0.12**

n/r – data not recorded

A total of 150 taxa of macroinvertebrates were found in the impinged material, with the highest numbers and biomass from kelp crab (*Pugettia producta*) and Pacific rock crab (*Cancer antennarius*). **Table A2-2** presents a monthly summary of the number and weight of these two species collected plus the values per million m^3 of water flow. The kelp crabs generally were 60-80 mm in carapace width (adults) while the rock crabs were generally less than 20 mm in carapace width (juveniles). The monthly average number and weight of kelp crabs based on the collected data were estimated to be 0.6 individuals weighing 72.9 g (0.16 lb) while rock crabs were 0.1 individuals weighing 9.8 g (0.02 lb). When these values were combined with the maximum circulating water flow (9.45 million m^3/day) it is estimated that a total of 2,100 kelp crabs weighing 248.3 kg (547.4 lb) and 456 rock crabs weighing 33.7 kg (74.1 lb) would have been impinged if all four CWPs had operated continuously for an entire one-year period. A few other small crabs were impinged but they were not added into the total due to their low numbers and weights. A total of twelve octopus (*Octopus* spp.) and eight squid (*Doryteuthis opalescens*) were impinged during this study but their weights were not consistently recorded and are not presented in the current report.

Table A2-2. Number and weight of kelp crab and Pacific rock crab impinged at Diablo Canyon Power Plant during sampling from December 1975 to June 1977. Mean number and weight are based on value per million m^3 of water pumped during sample collection. Values calculated from data presented in Behrens and Larsson (1979), Table 4.

	Kelp Crab					Pacific Rock Crab				
Month	**#**	**Total Weight Impinged**	**Mean #**	**Mean wt. (g)**	**Mean wt. (lb)**	**#**	**Total Weight Impinged**	**Mean #**	**Mean wt. (g)**	**Mean wt. (lb)**
Dec-75	79	n/r	n/r	n/r	n/r	20	n/r	0.14	n/r	n/r
Jan-76	98	11,222	0.69	79	0.17	19	901	0.13	6	0.01
Feb-76	58	7,493	0.55	70.7	0.16	30	2,867	0.28	27	0.06
Jan-77	40	5,640	0.82	115.1	0.25	5	554	0.1	11	0.02
Feb-77	80	10,821	0.75	101.1	0.22	12	1,131	0.11	11	0.02
Mar-77	48	7,023	0.64	93.6	0.21	5	777	0.07	10	0.02
Apr-77	29	2,522	0.4	34.5	0.08	6	8	0.08	<1	<0.01
May-77	30	2,505	0.43	35.8	0.08	19	868	0.27	12	0.03
Jun-77	4	404	0.67	67.3	0.15	0	–	–	–	–
Average	**52**	**5,954**	**0.61**	**74.7**	**0.16**	**13**	**888**	**0.13**	**9.8**	**0.02**

n/r – data not recorded

The second impingement study was conducted from April 1985 through March 1986 (Tenera 1988; Tenera 1998). Sampling also occurred during several days in February 1985 through March 1985 and these data are included here to calculate impingement rates using the largest possible sample size. During this study Unit 2 was undergoing its final construction and pump testing, which limited the number of days when its pumps were fully operational. In addition, Unit 1 underwent equipment repairs during the study, which caused the pumps or traveling screens to be out of service on some of the scheduled sampling days. Unit 1 was sampled a total of 51 days while Unit 2 was sampled 24 days.

A total of 62 taxa of fishes, sharks, and rays were impinged during the 1985 to 1986 sampling (**Table A2-3**). The most abundant taxa impinged from April 1985 through March 1986 were olive/yellowtail rockfish (*Sebastes serranoides* / *flavidus* – 86 individuals) and thornback ray (*Platyrhinoidis triseriata* – 57 individuals). The Chondrichthyes taxa that contributed the most to the impinged biomass were thornback ray (27.7 lb) and Pacific electric ray (*Torpedo californica* – 6.7 lb), while the bony fish taxa that contributed the highest impinged biomass were plainfin midshipman (*Porichthys notatus* – 3.8 lb) and Pacific mackerel (*Scomber japonicus* – 3.4 lb). When the biomass for both units and all fishes, sharks, and rays are combined, it was estimated that there was a total biomass impinged of about 0.83 lb per billion gallons. Average annual impingement estimates at DCPP, based on impingement rates calculated just the surveys conducted from April 1985 through March 1986 and reported in Exhibit 1 for design and average flows for the years 2000-2005, resulted in the following estimates:

- Design flow: 5,330 fishes annually with a biomass of 785 lb (356 kg)
- Actual flow: 4,821 fishes annually with a biomass of 710 lb (322 kg)

Table A2-4 presents a summary of the number and biomass of select macroinvertebrates impinged during the 1985-1986 study. Pacific rock crab had the greatest number and biomass of the select macroinvertebrates and kelp crab had the second greatest biomass. Annual entrainment estimates were not calculated for the macroinvertebrates.

Table A2-3. Total abundance and weight (g), and average biomass (lb per billion gal flow) of impinged fishes at Diablo Canyon Power Plant during 1985–1986. Abundance and weight are totals for the sampling periods; biomass is average from 51 samples collected at Unit 1 and 24 samples at Unit 2.

Taxon	Common Name	Unit 1 Sample Count	Unit 2 Sample Count	Unit 1 Sample Weight (lb)	Unit 1 Sample Weight (lb)	Unit 1 Impingement Rate lbs per 10^9 gallons	Unit 2 Impingement Rate lbs per 10^9 gallons	DCPP Impingement Rate lbs per 10^9 gallons
Bony Fishes								
Scomber japonicus	pacific mackerel	2	2	1.764	1.613	0.02866	0.08440	0.05653
Sebastes serranoides	olive rockfish	4	5	0.783	1.237	0.01272	0.09391	0.05332
Porichthys notatus	plainfin midshipman	11	8	2.325	1.448	0.03777	0.04838	0.04308
Xystreurys liolepis	fantail sole	9	0	1.912	0	0.03137	0	0.01568
Embiotoca jacksoni	black surfperch	3	0	1.790	0	0.02909	0	0.01454
Sebastes serranoides / flavidus (juv.)	olive/yellowtail rockfish (juv.)	54	22	0.625	0.417	0.01042	0.01828	0.01435
Sebastes mystinus	blue rockfish	2	3	0.692	0.373	0.01124	0.01428	0.01276
Sebastes atrovirens	kelp rockfish	2	0	0.939	0	0.01525	0	0.00763
Gibbonsia spp.	kelpfish spp.	12	5	0.355	0.161	0.00577	0.00602	0.00590
Syngnathus spp.	pipefish	12	6	0.343	0.109	0.00557	0.00588	0.00573
Hexagrammos decagrammus	kelp greenling	1	0	0.315	0	0.01038	0	0.00519
Hyperprosopon argenteum	walleye surfperch	2	3	0.051	0.228	0.00082	0.00763	0.00423
Pleuronichthys verticalis	hornyhead turbot	0	1	0	0.160	0	0.00825	0.00413
Embiotoca lateralis	striped surfperch	2	0	0.399	0	0.00648	0	0.00324
Cymatogaster aggregata	shiner surfperch	14	0	0.387	0	0.00630	0	0.00315
Sebastes atrovirens (juv.)	kelp rockfish (juv.)	4	3	0.182	0.048	0.00373	0.00161	0.00267
Chromis punctipinnis	blacksmith	1	1	0.092	0.088	0.00189	0.00295	0.00242
Atherinops affinis	topsmelt	1	2	0.024	0.122	0.00039	0.00408	0.00224
Chromis punctipinnis (juv.)	blacksmith (juv.)	2	1	0.149	0.059	0.00242	0.00196	0.00219
Brachyistius frenatus (juv.)	kelp surfperch (juv.)	5	3	0.104	0.064	0.00169	0.00214	0.00191
Sebastes flavidus	yellowtail rockfish	1	0	0.216	0	0.00352	0	0.00176
Seriphus politus	queenfish	2	7	0.018	0.089	0.00029	0.00298	0.00164
Artedius lateralis	smoothhead sculpin	8	3	0.096	0.028	0.00168	0.00145	0.00156
Artedius corallinus	coralline sculpin	8	2	0.164	0.014	0.00266	0.00046	0.00156
Lepidopsetta bilineata	rock sole	0	1	0	0.087	0	0.00290	0.00145
Orthonopias triacis	snubnose sculpin	5	4	0.064	0.050	0.00104	0.00167	0.00136
Pleuronichthys coenosus	c-o turbot	1	0	0.165	0	0.00267	0	0.00134
Anoplarchus purpurescens	high cockscomb	2	2	0.058	0.051	0.00095	0.00172	0.00133

(table continued)

Table A2-3 (continued). Total abundance and weight (g), and average biomass (lb per billion gal flow) of impinged fishes at Diablo Canyon Power Plant during 1985–1986. Abundance and weight are totals for the sampling periods; biomass is average from 51 samples collected at Unit 1 and 24 samples at Unit 2.

Taxon	Common Name	Unit 1 Sample Count	Unit 2 Sample Count	Unit 1 Sample Weight (lb)	Unit 1 Sample Weight (lb)	Unit 1 Impingement Rate lbs per 10^9 gallons	Unit 2 Impingement Rate lbs per 10^9 gallons	DCPP Impingement Rate lbs per 10^9 gallons
Sebastes rastrelliger	grass rockfish	1	0	0.154	0	0.00251	0	0.00125
Aulorhynchus flavidus	tubesnout	7	6	0.032	0.051	0.00052	0.00176	0.00114
Zaniolepis latipinnis	longspine combfish	0	1	0	0.064	0	0.00213	0.00107
Embiotoca unidentified	surfperch unidentified	4	0	0.114	0	0.00185	0	0.00092
Embiotoca lateralis (juv.)	striped surfperch (juv.)	1	1	0.021	0.022	0.00035	0.00148	0.00092
Engraulis mordax	northern anchovy	0	1	0	0.053	0	0.00176	0.00088
Sebastes spp. (juv.)	rockfish spp. (juv.)	6	3	0.047	0.014	0.00078	0.00096	0.00087
Cymatogaster aggregata (juv.)	shiner surfperch (juv.)	3	0	0.081	0	0.00131	0	0.00065
Oxyjulis californica	senorita	0	1	0	0.035	0	0.00118	0.00059
Microstomus pacificus	Dover sole	1	0	0.072	0	0.00117	0	0.00059
Brachyistius frenatus	kelp surfperch	1	0	0.072	0	0.00117	0	0.00058
Oxylebius pictus	painted greenling	1	0	0.064	0	0.00105	0	0.00052
Sebastes mystinus (juv.)	blue rockfish (juv.)	3	1	0.026	0.015	0.00048	0.00051	0.00050
Citharichthys stigmaeus	speckled sanddab	5	0	0.056	0	0.00095	0	0.00048
Chilara taylori	spotted cusk-eel	1	0	0.052	0	0.00085	0	0.00043
Apodichthys fucorum	rockweed gunnel	1	1	0.019	0.011	0.00030	0.00036	0.00033
Gobiesox maeandricus	northern clingfish	2	1	0.006	0.017	0.00009	0.00057	0.00033
Sebastes melanops (juv.)	black rockfish	1	1	0.009	0.007	0.00014	0.00050	0.00032
Sebastes carnatus (juv.)	gopher rockfish	2	1	0.018	0.004	0.00030	0.00029	0.00030
Micrometrus minimus	dwarf surfperch	1	1	0.017	0.009	0.00028	0.00030	0.00029
Agonopsis sterletus	southern spearnose	0	1	0	0.017	0	0.00057	0.00029
Xiphister spp.	prickleback spp.	0	2	0	0.008	0	0.00054	0.00027
Amphistichus argenteus	barred surfperch	2	0	0.022	0	0.00036	0	0.00018
Oligocottus rubellio	rosy sculpin	2	0	0.020	0	0.00033	0	0.00017
Sebastes paucispinis (juv.)	bocaccio	2	0	0.017	0	0.00028	0	0.00014
Symphurus atricaudus	California tonguefish	2	0	0.015	0	0.00024	0	0.00012
Hexagrammos decagrammus (juv.)	kelp greenling (juv.)	1	0	0.013	0	0.00021	0	0.00011

(table continued)

Table A2-3 (continued). Total abundance and weight (g), and average biomass (lb per billion gal flow) of impinged fishes at Diablo Canyon Power Plant during 1985–1986. Abundance and weight are totals for the sampling periods; biomass is average from 51 samples collected at Unit 1 and 24 samples at Unit 2.

Taxon	Common Name	Unit 1 Sample Count	Unit 2 Sample Count	Unit 1 Sample Weight (lb)	Unit 1 Sample Weight (lb)	Unit 1 Impingement Rate lbs per 10^9 gallons	Unit 2 Impingement Rate lbs per 10^9 gallons	DCPP Impingement Rate lbs per 10^9 gallons
Scorpaenichthys marmoratus (juv.)	cabezon (juv.)	1	0	0.011	0	0.00018	0	0.00009
Ulvicola sanctaerosae	kelp gunnel	1	0	0.007	0	0.00014	0	0.00007
Phanerodon furcatus	white surfperch	1	0	0.008	0	0.00013	0	0.00006
Cottidae unidentified	sculpin unidentified	2	0	0.008	0	0.00013	0	0.00006
Oligocottus maculosus	tidepool sculpin	1	0	0.007	0	0.00011	0	0.00006
Liparis mucosus	slimy snailfish	1	0	0.007	0	0.00011	0	0.00005
Artedius creaseri	roughcheek sculpin	1	0	0.005	0	0.00009	0	0.00004
Artedius notospilotus	roughhead sculpin	1	0	0.005	0	0.00008	0	0.00004
Pleuronectidae unidentified	turbot unidentified	1	0	0.004	0	0.00008	0	0.00004
Sebastes jordani (juv.)	shortbelly rockfish	1	0	0.004	0	0.00006	0	0.00003
Bony Fish Totals		**231**	**106**	**15.021**	**6.775**	**0.25139**	**0.32387**	**0.28763**
<u>**Sharks and rays**</u>								
Platyrhinoidis triseriata	thornback	24	33	10.757	16.956	0.17672	0.58950	0.38311
Torpedo californica	Pacific electric ray	11	5	4.850	1.841	0.08017	0.09015	0.08516
Hydrolagus colliei	ratfish	3	1	2.754	1.834	0.04475	0.06129	0.05302
Urobatis halleri	round stingray	0	1	0	0.897	0	0.02998	0.01499
Raja binoculata	big skate	3	2	0.189	0.162	0.00307	0.00541	0.00424
Sharks and Rays Totals		**41**	**42**	**18.550**	**21.691**	**0.30471**	**0.77633**	**0.54052**
All Fishes Totals		**272**	**148**	**33.571**	**28.466**	**0.55609**	**1.10020**	**0.82815**

Table A2-4. Number and weight of selected macroinvertebrates impinged at Diablo Canyon Power Plant during the 1985–1986 study.

Taxon	Common name	Number	Weight (lb)	Weight (g)
Cancer antennarius	Pacific rock crab	1,245	17.38	7,884
Scyra acutifrons	sharpnose crab	1,119	10.04	4,556
Strongylocentrotus purpuratus	purple sea urchin	697	7.50	3,404
Pugettia richii	cryptic kelp crab	654	7.28	3,301
Pugettia producta	northern kelp crab	424	14.00	6,351
Octopus spp.	octopus	252	9.00	4,081
Farfantepenaeus californiensis	yellowleg shrimp	64	4.63	2,102

The bar racks effectively exclude all fishes that cannot fit through the open space between the bars, which are set on approximately 7.6-cm (3-in.) centers. In the forebays, between the bar racks and the traveling screens, there are many fishes that are apparently too large to swim back between the bars. Divers have observed these fishes and large macroinvertebrates, such as adult Pacific rock crabs, freely moving around in the forebay area during pump operation. Divers have videotaped a 15 cm (6 in.) painted greenling (*Oxylebius pictus*) swimming in the forebay and stopping on the traveling screen cross members before swimming away. Figure E4-1 shows an adult rockfish in front of a traveling screen during full operation of the pumps. There are also many fishes, especially young-of-the-year rockfish in spring and summer, that have been observed swimming immediately outside of the bar racks. Some larger sharks and rays that were impinged were too large to swim through the bar racks and may have been living inside the forebays for an extended period prior to being impinged. The cause of death could not be determined when they were removed from the impinged material.

A comparison of the data from the two studies at DCPP shows that the impingement rates for both the number and weight of fishes was relatively low. The highest number and weight of impinged fishes, sharks, and rays was during the 1985–86 study, with an estimated total annual biomass for full operation over an entire year of 356 kg (785 lb).

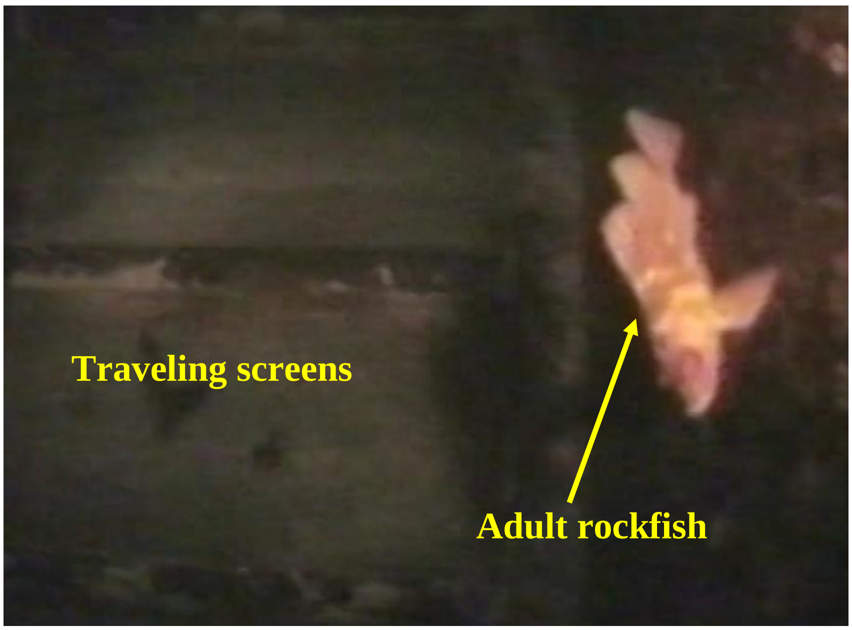

Figure A2-1. Adult rockfish swimming inside the forebay in front of a stationary traveling screen at the Diablo Canyon Power Plant during full operation of the CWS pumps.

References

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