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# Benefits Valuation Study for Diablo Canyon Power Plant

## Final Report

**Prepared for:**

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**February 21, 2005**

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September 9, 2005 Meeting
PG&E Diablo Canyon Power Plant

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# 1. OVERVIEW AND EXECUTIVE SUMMARY

Cooling water intake structures (CWIS) are regulated under Section 316(b) of the Clean Water Act. This statute directs the United States Environmental Protection Agency (EPA) to assure that the location, design, construction, and capacity of CWIS reflect the best technology available (BTA) for minimizing adverse environmental impact (AEI). EPA is developing national performance standards for CWIS in three phases. The Phase II Rule, which was promulgated in July 2004,[1] applies to existing electric generating plants with significant cooling water intake capacity and requires these plants to reduce impingement mortality and entrainment (I&E) of aquatic organisms according to national standards.[2] In developing the Phase II Rule, EPA included two conditions under which a facility may be allowed a site-specific determination of standards.[3] One such condition occurs when the costs of compliance are significantly greater than the associated economic benefits. The regulatory requirements for demonstrating this condition include the submission of three studies: the Cost Evaluation Study, the Benefits Valuation Study, and the Site-Specific Technology Plan.

Triangle Economic Research (TER) has prepared this Benefits Valuation Study (BVS) report for Pacific Gas and Electric Company's (PG&E's) Diablo Canyon Power Plant (DCPP or Plant). In preparing this report, we followed EPA's benefit valuation methodologies developed for the Phase II Rule, and incorporated site-specific I&E information developed by Tenera Environmental. We also include information from EPA's I&E reduction benefits studies for Northern California and for all California (EPA 2003; EPA 2004).

The major findings of the BVS include the following:

- The annual baseline losses for 16 representative indicator species (RIS) of fishes and shellfishes are in the range of $18,635 to $34,206, with a mean

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[1] The Phase II Rule is being judicially challenged by environmental and industry groups. The appeal is currently pending in the U.S. Court of Appeals, Second Circuit. The Phase II Rule has not been stayed pending appeal, and therefore is currently effective.

[2] Impingement occurs when fish and aquatic species become trapped on equipment at the entrance of the cooling system. Entrainment occurs when aquatic organisms, eggs, and larvae are taken into the cooling system, through the heat exchangers, and discharged back into the waterbody.

[3] A site-specific determination implies less stringent reduction standards.

of $26,412. The RIS account for approximately 70 percent of the fishes and shellfishes that are entrained.

- The annual benefits of reducing impingement mortality by 80 to 95 percent and entrainment by 60 to 90 percent for the RIS range from $13,280 to $27,220, with a mean of $19,863.[4]
- The present value of economic benefits from compliance to 2023 for RIS species ranges from $167,661 to $343,655.[5,6]
- The present value of economic benefits from compliance to 2053 for RIS species ranges from $281,342 to $576,667.[6,7]
- The annual benefits of reducing impingement mortality by 80 to 95 percent and entrainment by 60 to 90 percent for all species (including the additional 30 percent of forage fish larvae not specifically evaluated during the 316(b) Demonstration Study) range from $18,971 to $38,886. The present value of economic benefits from compliance to 2023 for all species ranges from $239,516 to $490,936. The present value of economic benefits from compliance to 2053 ranges from $401,917 to $823,809.[6]
- The annual benefits of eliminating all I&E (including the additional 30 percent of forage fish larvae not specifically evaluated during the 316(b) Demonstration Study) range from $26,621 to $48,866. The present value of economic benefits from eliminating all I&E until 2023 ranges from $336,098 to $616,934. The present value of economic benefits from eliminating all I&E until 2053 ranges from $563,986 to $1,035,240.[6]
- The species with the highest economic impacts are California Halibut, Brown Rock Crab, and Kelpfish.
- Recreational fishing accounts for 56 percent of the total economic impacts.
- Impingement accounts for only about 2 percent of all economic impacts.
- Under EPA guidance, nonuse benefits should not be monetized in this case, and in any event are likely to be minimal.

The foregoing economic impact estimates are conservative because:

- We assume that aquatic populations do not biologically compensate for I&E impacts.
- We assume that no organisms survive entrainment.

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[4] The Phase II Rule states that a facility must reduce impingement mortality by 80 to 95 percent and entrainment by 60 to 90 percent to be in 316(b) compliance.

[5] The NRC licenses for Units 1 and 2 at the DCPP expire in 2022 and 2024, respectively. We therefore assumed full operations of both units until 2023 to facilitate this analysis.

[6] We use a 3-percent discount rate for recreational and forage values, a 7-percent discount rate for commercial values, and assume immediate compliance with the Rule.

[7] A final decision has not been made to seek renewal of the NRC licenses. We have assumed for analytic and illustrative purposes only that the Plant will continue to operate until 2053.

- We assume that the availability of forage species limits populations of commercially and recreationally valuable species.
- We assume that 316(b) compliance is instantaneous.

# 2. BACKGROUND

Estimating the economic benefits of reducing I&E at existing CWIS requires quantifying all beneficial ecological outcomes and assigning appropriate monetary values. Estimating economic benefits in this context is challenging because it requires first linking reductions in I&E to ecosystem changes and then linking ecosystem changes to the resulting changes in quantities and values for the associated environmental goods and services that ultimately are linked to human welfare (EPA 69 *Fed. Reg.* 41,655, July 9 2004). This section provides background on the DCPP's potential ecological impacts and the ecological and economic methodologies used by EPA for assessing the benefits of I&E reductions in the Phase II Rule.

## 2.1 Ecological Endpoints

Tenera Environmental conducted the Plant's 316(b) entrainment study from October 1996 through June 1999 and submitted a final report in March 2000 (Tenera Environmental 2000). The entire study was conducted under the auspices of an Entrainment Technical Work Group (ETWG) that was assembled by the California Regional Water Quality Control Board, Central Coast Region (RWQCB), to assist their staff in assuring the adequacy of the study's design and implementation. The ETWG was composed of PG&E and their consultants, the RWQCB and their consultants, a consultant to the League for Coastal Protection, the California Department of Fish and Game, and the EPA.

The process of identifying organisms for assessment at DCPP included a consideration of guidelines presented in the original 316(b) directive developed by EPA's (1977) draft *Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500.* Based on this guidance, the following criteria were used to select the target organisms:

- Organisms that were representative, in terms of their biological requirements, of a balanced, indigenous community of fish, shellfish, and wildlife;
- Commercially or recreationally valuable species (e.g., among the top ten species landed – by dollar value);
- Threatened or endangered species;

- Species critical to the structure and function of the ecological system (i.e., habitat formers);
- Species potentially capable of becoming localized nuisance species;
- Species necessary in the food chain for the well-being of those species identified in the first four bullets above;
- Species meeting any of the foregoing criteria with potential susceptibility to impingement and/or entrainment.

In addition to those EPA standards, the ETWG included three additional criteria:

- Organisms capable of being identified to the species level;
- Organisms that are entrained in sufficient abundance to allow for a robust impact assessment;
- Organisms whose adult and larval populations can be demonstrated to be local (i.e., not a deep-water species whose larvae drifted ashore).

These additional criteria were important in contributing to the level of confidence in the estimates of entrainment effects. The most important criterion was abundance; therefore, the assessment was based only on the most abundant organisms. The organisms meeting the criteria included 14 species of larval fishes, 2 species of larval *Cancer* spp. crabs, and larval sea urchins. The ETWG determined the final list of species included in the assessment based mainly on data collected during this study and the criteria listed above. The 14 fishes accounted for the predominant species and for approximately 70 percent of the total number of larval fishes collected from the entrainment samples. The remaining 30 percent of the larval fishes were a mix of recreational, commercial, and forage species.[8]

The ETWG reviewed other potential target organism groups for possible inclusion in the assessment, but those groups were intentionally excluded from the Study. For example, the ETWG decided not to include phytoplankton, zooplankton, and algal spores in the assessment due to their large populations, and in the case of phytoplankton and zooplankton, their short generation times. EPA has previously expressed similar views with respect to phytoplankton and zooplankton (EPA 1998). In sum, it was readily apparent that the DCPP's intake would only have negligible, localized impacts on these organisms.

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[8] The remaining 30 percent are valued in this analysis.

Fish eggs and larvae from several commercially important invertebrates such as clams and abalone were also excluded from the assessment by the ETWG, in part because they are small and difficult to identify to the species level. More importantly, there was a very low likelihood that any abalone larvae would be entrained, and there is no suitable substrate for the settlement of Pismo clams near the DCPP. Fish eggs were excluded because most of the fishes at issue have egg stages that are not likely to be entrained: i.e., either they are demersal/adhesive eggs or they are internally fertilized and extrude free-swimming larvae. EPA has previously expressed a similar view with respect to fish eggs (EPA 1998). Young squid were not analyzed because they are competent swimmers immediately after hatching, and therefore would have a low probability of entrainment.

In fact, as the ETWG itself found appropriate for the DCPP, most ecological assessment endpoints for 316(b) studies include only fish and shellfish species (EPA 1998). Indeed, the other organisms entrained have no measurable value other than potential nonuse value (see discussion below). Not surprisingly, EPA itself limited its Phase II benefits valuation to fish and shellfish.

Tenera Environmental developed the impingement data used in this BVS based on a study conducted from April 1985 to March 1986 (Tenera 1988). Their study indicated that impingement by the CWIS' traveling screens was so minor that detailed analysis was not necessary. Nevertheless, we include impingement estimates in this BVS.

## 2.2 Identifying Ecological and Economic Impacts

In theory, it should be possible to quantify ecosystem changes from I&E impacts through direct observation of ecosystem changes and statistical isolation of the influence of water withdrawal. In practice, however, efforts of this nature have failed to identify a significant relationship between the volume of cooling water withdrawn and the status of local fish populations (EPRI 2003). The problem with this approach lies in the large *natural* population fluctuations that are typical for aquatic organisms.

Faced with this situation, EPA expended considerable effort developing methodologies to quantify the impacts of I&E.[9] Over the course of developing its methodologies, EPA made substantial improvements in identifying theoretically appropriate methods for measuring benefits, and TER now believes that EPA has developed a reasonable approach for evaluating the ecological impacts of I&E.[10] In the final Phase II Rule, we believe EPA also identified a reasonable approach for evaluating the economic impacts of I&E on commercial and recreational species. Accordingly, the approach used for evaluating impacts from I&E to commercial and recreational species in this report generally follows that of EPA's most recent analysis.[11]

In that analysis, EPA estimated a national total of $83 million in annual benefits that could be achieved by reducing the I&E of commercial and recreational species. The EPA estimate does not include the value of impacts to forage species or organisms that are not directly recreationally or commercially valuable. This BVS, however, does value forage species impacts using the methodology described in EPA's final Phase II Rule (EPA 2004, Chapter A5: I&E Methods). In the assessment, we assume that populations of recreational and commercially valuable species are limited due to availability of forage populations.[12] Accordingly, lost forage species are valued in terms of the larger populations of recreational and commercial fish that they would have supported had the forage species not been impinged or entrained.

## 2.3 I&E, Fishing, and Population Growth

Evaluating the economic impacts of I&E requires understanding the potential ecological effects of I&E. To do so, we characterize a fishery using the growth and population model developed by Schaefer (1954, 1957). This model recognizes that most fish stocks follow a population-dependent growth pattern, as illustrated in Figure 1.

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[9] TER has been substantially involved in the evaluation of the methods developed by EPA. See Bingham, Mohamed, and Desvousges (2003) and Desvousges, et al. (2002).

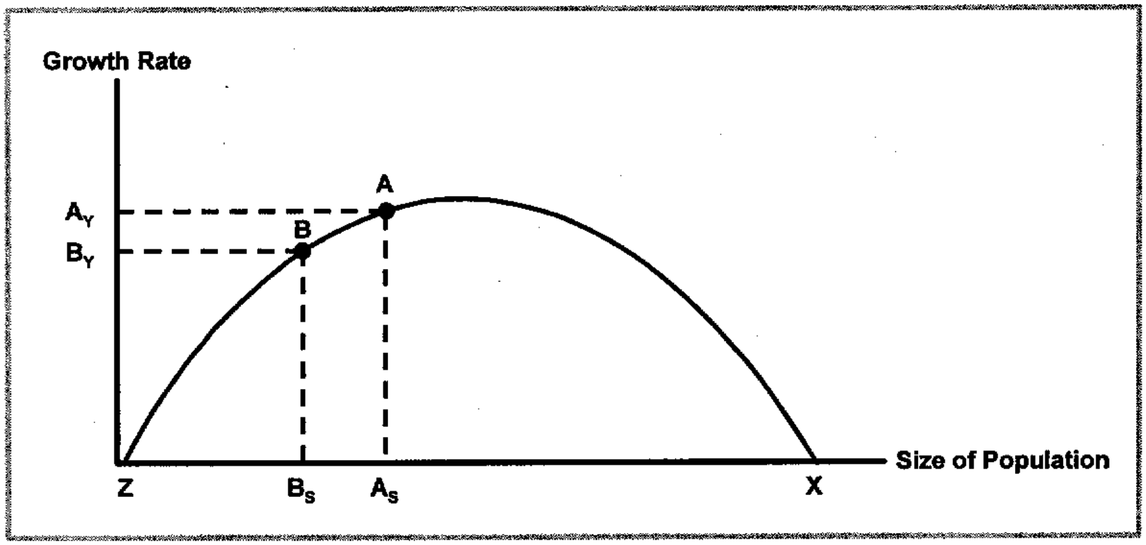
[10] There are shortcomings with EPA's approach, which likely tend to overstate benefits. For example, EPA has been criticized for not considering the ability of aquatic populations to offset I&E impacts through higher productive and survival rates.

[11] The only significant exception is in our analysis of commercial impacts, where we employ an approach that EPA has acknowledged is more theoretically appropriate and that returns higher economic impact estimates.

[12] If this is not the case, our assessment provides overestimates of economic losses.

Figure 1 depicts the relationship between the growth in fish stock on the vertical axis and the size of the fish population on the horizontal axis.[13] Point A is the starting population, which includes I&E and fishing impacts. It would be possible to sustain the population at $A_s$ if the total impacts were equal to the growth in the fish population ($A_y$). For example, if the growth rate is 10 percent per year ($A_y$) and the starting population is 100 fish ($A_s$), then it would be possible to harvest 10 fish per year, starting at the end of the first year, without affecting the size of the population. Point B illustrates the results of overharvesting due to increased I&E and fishing impacts on the fish population. The lower population level ($B_s$) and corresponding lower growth rate ($B_y$) indicate that the number of harvested fish is now greater than the growth in the population. If overharvesting persists in this manner, the fish population will continue to decline.

**Figure 1**
**Fishing and I&E Impacts on Population**



In the Phase II Rule, EPA mentions that secondary effects of I&E include decreased recruitment, decreased fishing yields, and reduced ecosystem productivity (Chapter A1: Risk Assessment Framework). However, EPA does not account for these potential secondary effects in their national benefits analysis.

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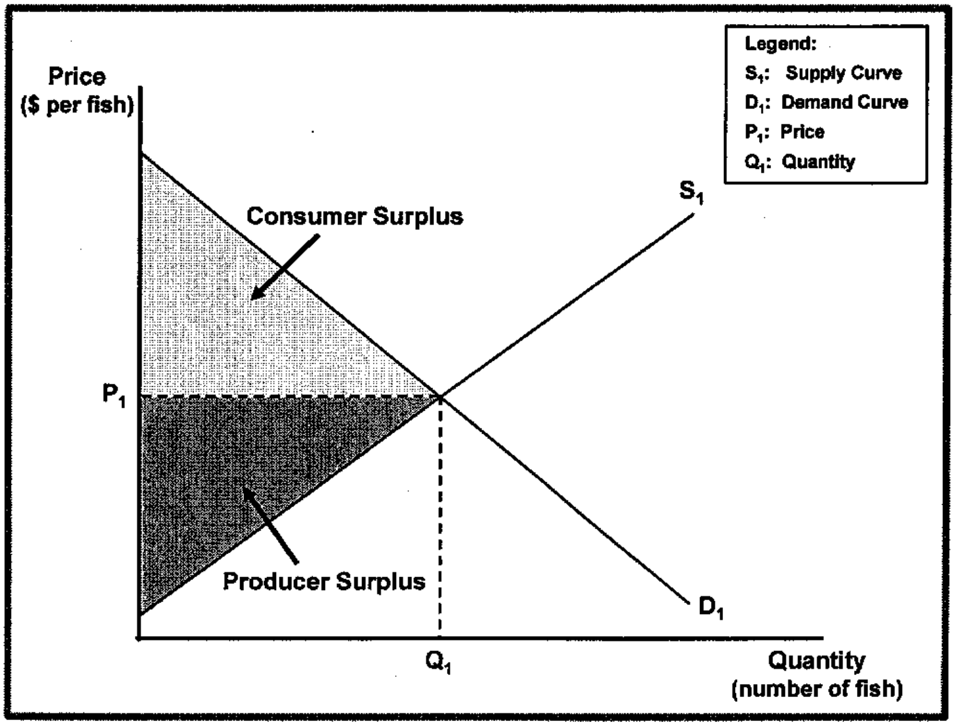
[13] X represents the carrying capacity of the fish population in a state of *natural or stable equilibrium*. The carrying capacity is the maximum fish population that can be sustained in the absence of the fishery and I&E. If the fish population exceeds X, natural mortality rates increase such that the fish population returns to the natural equilibrium. Z is the minimum viable population or the point of extinction.

## 2.4 Fishery Valuation Overview: Use Values

Unlike traditional physical and financial assets, natural resources such as fisheries are generally owned by the public. Although the values of publicly owned resources are not directly revealed in a marketplace, resource economists have well-established methodologies for measuring fishery value. Over a particular time period, the value of a fishery is equal to the difference between the cost of harvesting fish and the value of the fish harvested.

Figure 2 shows how a commercial fishery's value is determined in a hypothetical market for harvested fish.[14] In this figure, the price of fish is on the vertical axis and the quantity of fish harvested is on the horizontal axis. The supply curve ($S_1$) represents how many fish the producers are willing to supply at a given price. The demand curve ($D_1$) corresponds to the maximum cost per fish that consumers are willing to pay for different quantities of harvested fish. The demand curve slopes downward to indicate that the value of each fish drops as the quantity of fish in the market increases.

**Figure 2**
**Hypothetical Fishery Market**



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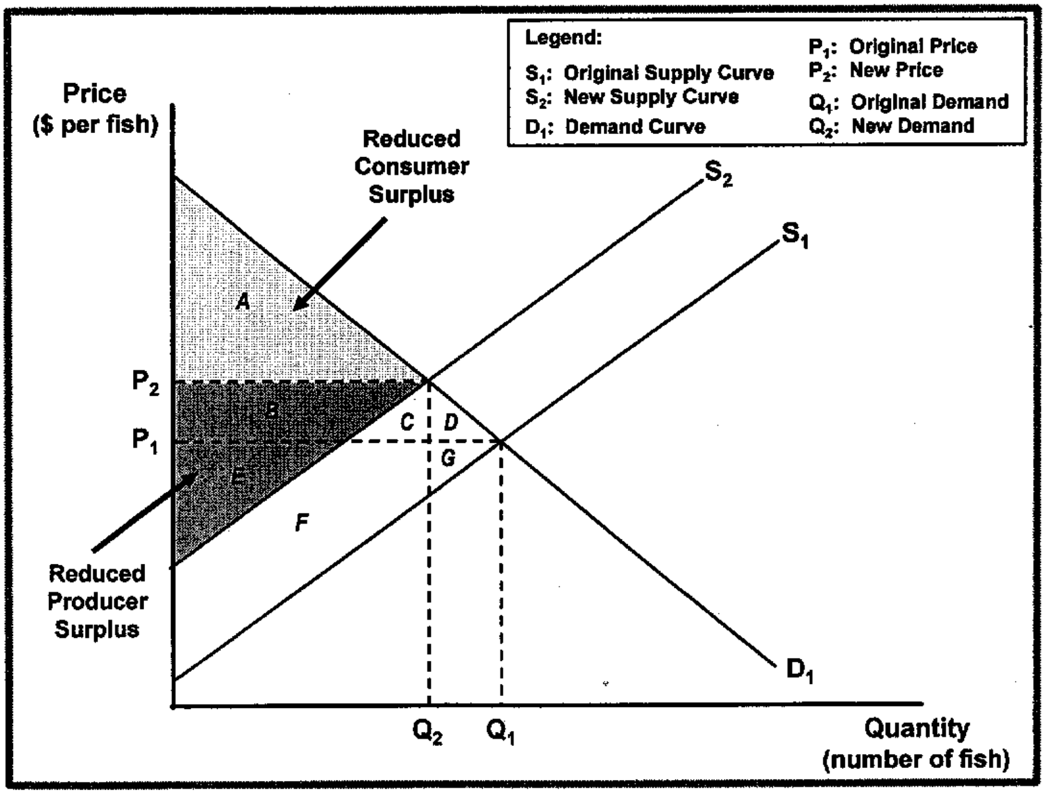
[14] A value for recreational fisheries can be derived using a similar approach.

The value of this fishery is equal to the difference between the cost of harvest (area above the supply curve) and the value of the fish harvested (area below the demand curve). Graphically, this is shown in the shaded areas of Figure 2. Note that the value of the fishery is the sum of producer and consumer surplus. Producer surplus is the difference between the costs that fishermen incur to harvest the fish (as represented by the supply curve) and the market price ($P_1$). In Figure 2, producer surplus is the darker shaded area between the supply curve and the market price. Consumer surplus is the difference between the maximum price that consumers are willing to pay for harvested fish (as represented by the demand curve) and the market price ($P_1$). In Figure 2, consumer surplus is the lightly shaded area between the demand curve and the market price. This simple framework also provides the necessary background for evaluating how a change in abundance affects the value of a fishery, as seen in Figure 3.

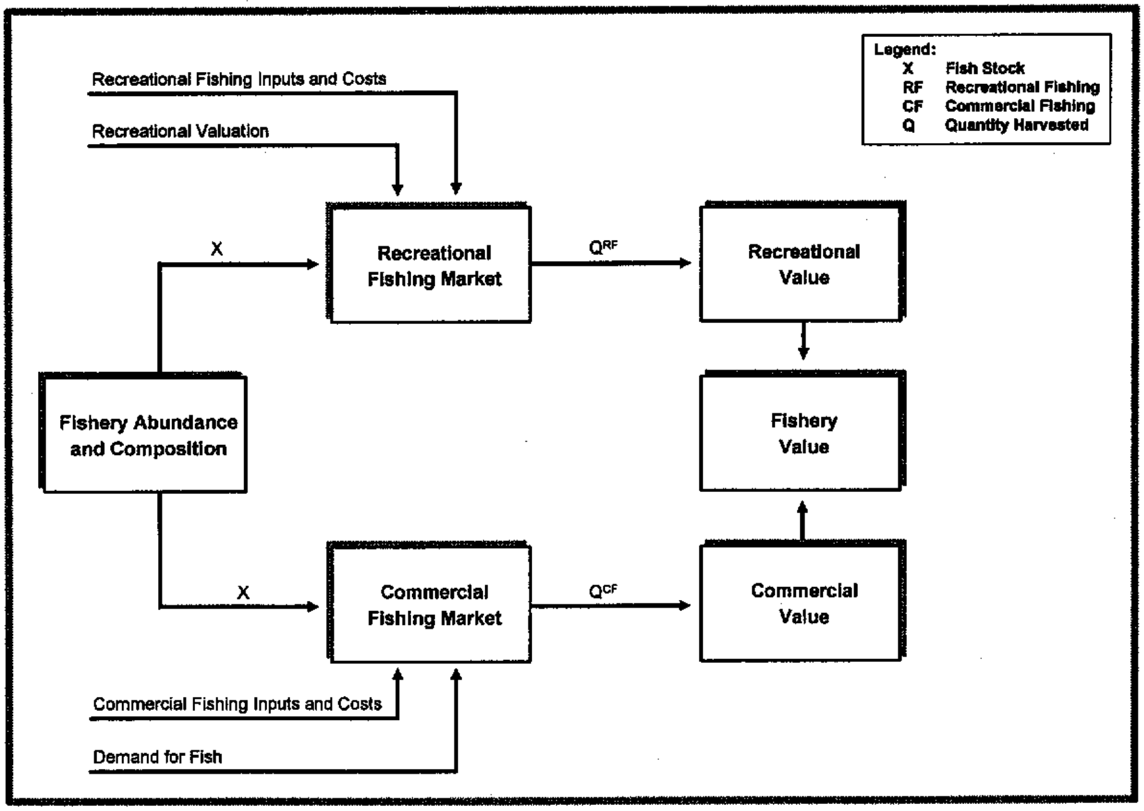
**Figure 3**
**Effect of a Decline in Abundance**



Other things equal, a decline in abundance will increase the cost of harvesting fish. In the supply and demand framework of Figure 3, increased costs are represented by an upward shift of the supply curve. The market determines the decline in the quantity of fish harvested ($Q_1$ to $Q_2$) by the intersection between the new supply curve ($S_2$) and the demand curve ($D_1$). The intersection also leads to an increase in price ($P_1$ to $P_2$). The respective change in price and quantity reduces the value of the fishery. The changes in price and quantity affect both the producers and the consumers. Because of the decrease in the abundance of the fishery, producer surplus decreases from the sum of Areas E, F, and G to the sum of Areas E and B. The reduced consumer surplus is the darker shaded consumer surplus or the value of the fishery as it declines from the sum of Areas A, B, C, and D to lightly shaded Area A.

Although Figures 2 and 3 depict the fishery as a single market, the overall value of the fishery actually depends on two markets: a commercial fishing market and a recreational fishing market. Figure 4 depicts the association between the abundance of a fish stock, commercial and recreational fishing markets, and the economic value of a fishery.

**Figure 4**
**Relationship between Fishery Abundance and Value**



Both the commercial and recreational fishing markets depend on the determinants of supply and demand to establish price and quantity. The abundance of fish within the fishery is an important factor for the value of these fishing markets. For example, in the commercial fishery, a decline in abundance means commercial fishermen will expect to catch fewer fish with the same amount of effort (i.e., commercial fishing inputs and costs). The higher cost of catching fish will result in smaller harvests for commercial fishermen. The reduction in harvested fish will reduce the value of the commercial fishery. In the recreational fishing market, decreased catch rates at some sites leads to less satisfaction with trips to those sites. In addition, some recreational anglers choose to fish elsewhere and take trips of lower value. Others substitute lower-valued activities.

## 2.5 Overview of EPA Case Studies for California and the ASA 2003 Study for the DCPP

This section summarizes the two EPA regional studies we use in our analysis—the Northern California and California studies—and ASA's prior study. EPA conducted the Northern California study for the Phase II Rule Notice of Data Availability (NODA) and the California study for the final Phase II Rule (Part B: California regional studies).

### *2.5.1 Northern California Regional Study*

The Northern California Regional Study area is equivalent to the Northern California National Marine Fisheries Statistics (NMFS) region, which extends from Point Conception north to the Oregon border. According to EPA, of the eight power plants in this region, six withdraw water from estuaries and two withdraw cooling water from the Pacific Ocean. Fisheries in this area are managed by the Pacific Fishery Management Council (PFMC) and the California Department of Fish and Game (CDFG). The PFMC governs recreational and commercial fisheries in federal waters from 3 to 200 nautical miles off the coasts of Washington, Oregon, and California, while the CDFG manages fisheries within 3 nautical miles off the coast of California. In EPA's estimation, this region provided annual recreational benefits of $663,965 from I&E reductions and commercial benefits of $19,514 in 2002 dollars (assuming a 3-percent discount rate). In the NODA, EPA did not present nonuse estimates for the Northern California region. DCPP is included in this region.

### 2.5.2 *California Regional Study*

This regional study includes 20 facilities that are in-scope for the Phase II Rule. Of the 20 facilities, 8 are located in northern California and 12 are located in southern California. Eight of the 20 facilities withdraw cooling water from an estuary or tidal river and 12 withdraw water from the Pacific Ocean. DCPP is in northern California and withdraws cooling water from the Pacific Ocean. EPA lists DCPP's 2001 capacity at 2,300 MW and the 2001 net generation at 18,077,713 MWh. For all of California, EPA estimates commercial benefits from the Phase II Rule in 2002 dollars at a low estimate of $0 or a high estimate of $0.52 million and recreational benefits at $2.45 million (assuming a 3-percent discount rate). EPA does not estimate nonuse or forage impacts in this regional study.

### 2.5.3 *ASA Consulting 2003 Benefit Valuation Study for DCPP*

ASA Consulting performed a benefits valuation study for DCPP based on an 80-percent reduction in the entrainment estimates developed by Tenera Environmental (the same ones used in this BVS). ASA did not separately value the benefits of impingement reduction, as we did here, and based its analysis on EPA's then-existing guidance, some of which was later changed in the final Phase II Rule when promulgated in July 2004. For example, ASA used EPA's then-proposed rule of thumb for estimating nonuse values at 50 percent of the estimated recreational fishing value. In its forage species valuation, ASA used a range of trophic transfer efficiencies that EPA was then considering, but subsequently changed. Other differences from this study include the fact that ASA did not place a value on crabs and used a range of commercial fishing exploitation rates (10 to 40 percent) that is different from the rates assigned in this BVS. Table 1 shows ASA's estimated annual benefits of an 80-percent entrainment reduction for the 14 species of larval fishes.

**Table 1**
**ASA's Estimate of Annual Benefits of an 80-Percent Entrainment Reduction**

| Category | Lower Bound (2001 $) | Upper Bound (2001 $) |
|---|---|---|
| Commercial Fishing | $0 | $25,177 |
| Recreational Fishing | $782 | $33,322 |
| Forage Species | $582 | $35,487 |
| Nonuse Value | $391 | $16,661 |
| **Total** | **$1,755** | **$110,647** |

Assuming 2 percent (upper bound values) and 7 percent (lower bound values) discount rates and assuming that the cooling towers would be in operation beginning in 2008, ASA estimated the net present value (NPV) of the benefits to be $11,045 to $1,334,030 in 2001 dollars, assuming Plant closure in 2023. Assuming Plant closure in 2023, and "grossing up" the benefits by another 30 percent to conservatively account for the 30 percent of the fish species not evaluated in the 316(b) Demonstration Study, ASA estimated that the NPV ranges from $15,786 to $1,905,757 in 2001 dollars, of which $3,517 to $424,587 was nonuse. Assuming Plant closure in 2053, ASA estimated that the NPV ranges from $22,800 to $4,195,663 in 2001 dollars, of which $5,080 to $934,760 was nonuse.

# 3. BENEFITS VALUATION STUDY

The BVS requires that a facility use a comprehensive methodology to fully value the impacts of I&E at its site and the benefits of complying with the applicable performance standards. In addition, the Phase II Rule requires that the benefit study include (EPA 2004):

- Description of the valuation methodologies for commercial, recreational, and ecological benefits (including any nonuse benefits, if applicable).
- Documentation of the basis for any assumptions and quantitative estimates.
- An analysis of the effects of significant sources of uncertainty on the results of the study.
- If requested by the Director, a peer review of the items submitted in the BVS.
- Narrative description of any non-monetized benefits if the facility were to meet the applicable performance standards and a qualitative assessment of their magnitude and significance.

Each section below presents the details of the analysis.

## 3.1 Description of Valuation Methodologies

In this subsection, we present our valuation methodologies for estimating the benefits of I&E reduction at DCPP for commercial, recreational, and ecological benefits. We specifically followed the methodology of EPA's final Phase II Rule national 316(b) benefits analysis, except for the approach EPA used in estimating commercial impacts. For commercial impacts, we employed a methodology more conservative than EPA's.[15] The following sections provide an overview of the valuation methodologies and their application at DCPP.

### *3.1.1 Overview of EPA's Phase II Rule Benefit-Estimate Methodology*

Figure 5 depicts the approach used to evaluate the biological effects and economic benefits of reducing entrainment for commercial, recreational, and forage species. The sections following Figure 5 describe each step. The approach used to assess the biological effects and economic benefits of reducing impingement for commercial, recreational, and forage species is very similar; therefore, we did not

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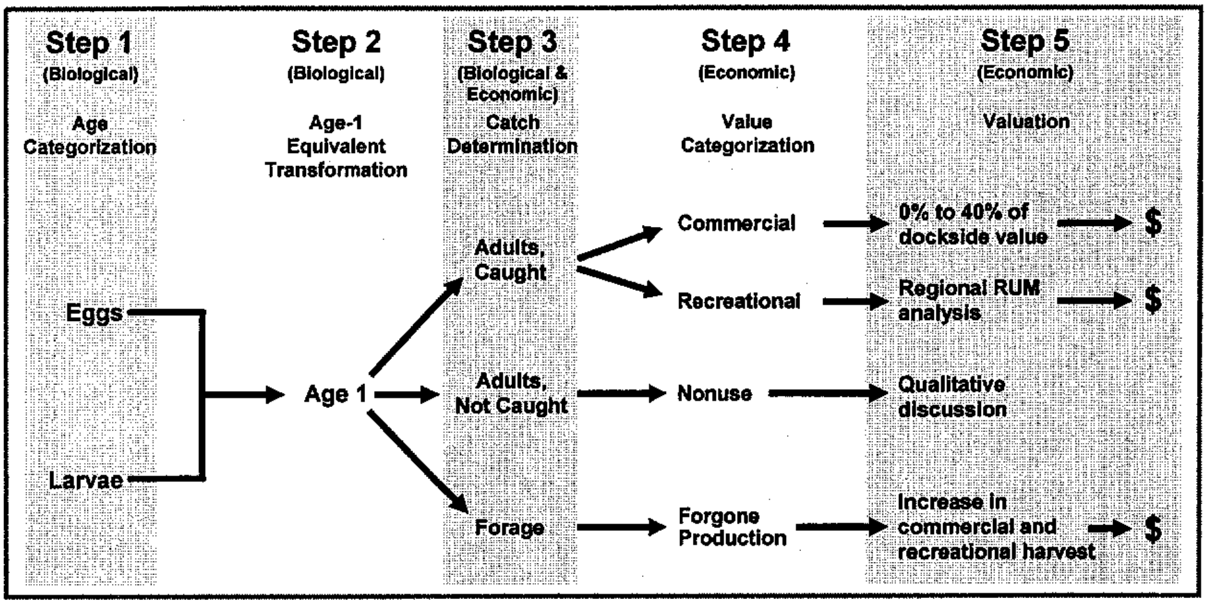
[15] This methodology is described below and results in higher estimates than EPA's method for estimating commercial impacts.

describe each step again with respect to impingement. The only difference between the entrainment analysis and the impingement analysis is that juvenile, Age 1, and Age 2 fish are impinged, whereas eggs and larvae are entrained.

**Figure 5**
**Steps in EPA's Valuation Process for Determining the Economic Value of Reductions in Entrainment**



## Step 1: Categorize Entrained Fish

Step 1 categorizes entrained fish by life stage and species. Appropriate age categorization is an important factor in estimating biological effects and economic benefits appropriately. This is true because younger fish equate to fewer Age-1 equivalents than older fish and vice versa.

## Step 2: Transform Entrained Fish into Age-1 Equivalents

In Step 2, we use cumulative survival rates from each age category (eggs and larvae) to Age 1 fish to determine the expected number of Age-1 equivalents associated with entrainment. We follow EPA's calculations for determining the cumulative survival rates as outlined in Chapter A5: I&E Methods (Part A: Evaluation Methods of the regional studies).

## Step 3: Determine Number of Fish Caught

After converting entrained fish into Age-1 equivalents, we employ natural and fishing mortality parameters to determine the number of each harvested species that will be caught over the lifespan of the fish. Species that are not harvested recreationally or commercially are categorized as forage fish.

## Step 4: Determine Value Categorization

In Step 4, we determine how many of the harvested fish will be caught recreationally and how many will be caught commercially. This determination is based on the recreational/commercial breakdowns employed in EPA's California and Northern California regional studies.

## Step 5: Determine the Value of Fish that Would Be Produced through I&E Reductions

After completing Steps 1 through 4, we value the additional fish production that would be achieved through I&E reductions. TER values fish that are caught recreationally by transferring parameters from appropriate random utility models (RUMs) employed in EPA's analysis. A RUM uses anglers' site choices to evaluate the importance of factors that influence an angler to visit a site. When correctly applied, random utility analysis is the best method for valuing I&E reduction impacts on recreational fishing.[16] In our analysis, the transferred RUM parameters measure the marginal value of catching an additional fish.

In the Phase II Rule, EPA estimated commercial benefits as 0 to 40 percent of gross revenue (increased landings from I&E reductions multiplied by the dockside price). However, we do not follow EPA's commercial valuation procedure in this BVS. We determine commercial impacts by using the percent increase in commercial landings and the percent change in dockside value based on the assumption that the price elasticity of demand is –1.[17] For example, if the percent increase in commercial landings from reducing I&E is 10 percent and the price elasticity of demand is –1, then

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[16] RUMs are recognized in the DOI regulations (43 *CFR* §11.83) as an appropriate method for quantifying recreation service losses in natural resource damage claims. Currently, the RUM is the most widely used model for quantifying and valuing natural resource services. RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985), as well as more recently in environmental and resource economics.

[17] The price elasticity of demand measures the percent change in price for a 1-percent change in quantity.

the percent decrease in the dockside value is 10 percent. To estimate commercial impacts, the new dockside value ($/lb.) is multiplied by the increase in commercial landings (lbs.). TER's method for evaluating commercial impacts is economically sound and results in higher estimates than EPA's method. Thus, our commercial impacts are conservative compared to EPA's. For example, applying EPA methodology results in commercial impacts of $0 to $3,426 for entrainment and $0 to $17 for impingement, whereas TER estimation methods result in commercial impacts of $7,930 for entrainment and $52 for impingement at DCPP.

Forage species are valued in terms of forgone production of recreational and commercial species. Following EPA's methodology in the Phase II Rule as outlined in Chapter A5: I&E Methods (Part A: Evaluation Methods of the regional studies), we applied a net trophic transfer efficiency rate of 2.5 percent to lost biomass of all forage species. This approach uses two distinct estimates of trophic transfer efficiency rates within two kinds of food web pathways: (1) the portion of forage production with a high trophic transfer efficiency because it is directly consumed by harvested species and (2) the portion of forage production with a low trophic transfer efficiency rate that is not consumed directly by harvested species but reaches harvested species indirectly through other parts of the food web.

This approach monetizes all direct and indirect fishery losses.[18] Uncaught recreational and commercial fish do not have a traditional use value and are therefore categorized as having potential nonuse value. However, the number of fish not valued is small.[19] For example, in the NODA (p. 13,567), EPA stated that "Unharvested recreational and commercial fish represent 0.77 percent of the total age one equivalent impingement and entrainment losses." For this reason, nonuse impacts are minimal at DCPP.

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[18] Direct losses reflect I&E of harvested species; indirect losses reflect I&E of forage species that support these recreationally and commercially desirable fish.

[19] The number of uncaught fish varies by species and depends upon pressure and expected lifespan.

### *3.1.2 Applying EPA Benefit-Estimate Methodology to DCPP Using Site-Specific Information*

In this section we calculate the biological effects and economic benefits of I&E reductions at DCPP, employing the methodologies described above and site-specific information from several sources. The analysis incorporates information from:

(1) EPA's 2003 Northern California benefits study (recreational and commercial species classification and life history parameters as indicated in Appendix C of this report)

(2) EPA's 2004 California benefits study (RUM parameters, recreational and commercial species classification, and life history parameters as indicated in Appendix C of this report)

(3) Tenera's I&E study for the DCPP (Tenera Environmental 2000).

Table A.1 in the appendix provides the list of species that are potentially impinged, annual impingement estimates, and the potential biological and economic effects of this annual impingement for DCPP. Table A.2 reports the same information for entrained organisms. Table A.3 combines both types of information and reports I&E estimates for DCPP.

#### Step 1: Categorize Impinged and Entrained Organisms

Step 1 categorizes impinged and entrained organisms by life stage and species. We obtained annual I&E estimates from documents that DCPP submitted to EPA (Diablo_Input.xls in EPA NODA Docket #OW-2002-0049). We first grouped some of the species together to simplify the analysis. For example, we grouped all the rockfish species together.

To determine the percentage of Age 1 and Age 2 fish impinged we applied percentages by species from appropriate EPA case studies. In our analysis, we do not categorize any impinged fish as Age 0/juvenile because there were no juveniles or Age 0 fish impinged in the relevant EPA case studies. For example, we assumed that 68 percent of pipefish impinged at DCPP were Age 1 and the remaining 32 percent were Age 2 based on the impingement of northern pipefish at the Seabrook and Pilgrim facilities.

To determine the percentage of eggs and larvae entrained, we relied primarily on the DCPP 316(b) Demonstration Report (Tenera Environmental 2000), a memorandum from Chris Ehrler at Tenera Environmental, and consultations with John Steinbeck at Tenera Environmental. For many entrained species, we realized that only larvae can be entrained. For example, rockfish are live bearers and gobies have adhesive eggs. For all the other species (California halibut, Northern anchovy, Pacific sardine, sanddabs, and white croaker), if no information was available, we assumed that the ratio of eggs to larvae was 50:50, which increased the entrainment estimates for these five species by 100 percent.[20]

In order to estimate egg entrainment, we conservatively assumed a 1:1 eggs-to-larvae entrainment ratio. An example, for northern anchovy, showed less risk. We used instantaneous mortality (M) rates of 0.191 $d^{-1}$ for eggs and 0.114 $d^{-1}$ for larvae. Using an entrainment duration for eggs of 3.5 days and for larvae of 70 days, combined with natural mortality and exponential survival, we calculated that at the end of 3.5 days 1,000,000 eggs would become 512,000 larvae. Then using these two numbers as $N_0$, we calculate that the ratio of integrals of egg and larval distributions is the expected power plant entrainment fraction for eggs. The integral is computed as:

$$N = \int_0^t N_0 e^{-Mt} dt = \left. \frac{N_0 e^{-Mt}}{-M} \right|_0^t \quad (1)$$

Integration resulted in 2.55 million eggs and 4.49 million larvae, i.e., a 0.558:1 estimated entrainment ratio, thus showing a higher risk to larvae attributable to the prolonged susceptibility.

## Step 2: Transform Impinged and Entrained Organisms into Age-1 Equivalents

To convert impinged and entrained organisms into Age-1 equivalents, we relied primarily on the life history parameters reported in EPA's Northern California and California regional studies. Appendix C lists all the life history parameters we incorporated and their sources. As can be seen there, all of the life history parameters

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[20] John Steinbeck at Tenera Environmental consulted with TER on this assumption.

used were developed by EPA for use in its own benefits studies. For some species, we did not have a perfect match and we transferred the life history parameter from the most similar species based on consultations with John Steinbeck at Tenera Environmental. The fishes in this category consist of nearshore forage species.

To convert an Age-2 fish to Age-1 equivalents, we multiplied the number of Age 2 fish by the inverse of the survival rate from Age 1 to Age 2. We applied the cumulative survival rate from eggs to Age 1 to convert eggs to Age-1 equivalents and the cumulative survival rate from larvae to Age 1 to convert larvae to Age-1 equivalents. The following definitions are important in understanding these calculations.

| | |
|---|---|
| **Natural mortality (M):** | The instantaneous rate of natural (not fishing or I&E) death. Natural mortality (M) changes over an organism's lifetime and generally decreases with age. It is represented by species/life stage-specific parameters or equations. |
| **Total mortality (Z):** | Mortality attributed to both fishing and natural causes. (Froese and Pauly 2004). It is the combined rate or sum of natural mortality and mortality attributable to commercial and recreational fishing pressure. Total mortality (Z) is defined as: $Z = M + F$, where M is the natural mortality rate and F is the rate of recreational and commercial fishing mortality. |
| **Survival Rate (S):** | The fraction of an age class that will survive to enter the next age class stage. Survival rate (S) is defined as: S = exponent $^{(-z)}$, where Z is the total mortality rate (Ricker 1975). |
| **Cumulative Survival Rate (CS):** | Cumulative Survival rate from age entrained to Age-1 Equivalent as detailed in the Phase II Rule (EPA 2004). |

## Step 3: Determine Number of Fish Caught

After converting impinged and entrained organisms into Age-1 equivalents, we employ the natural and fishing mortality parameters detailed in Appendix C to determine the number of each species that will be caught. Once again, EPA developed all of these parameters for use in its own benefits studies, including the Northern California Study and the California Regional Study. The remaining fish that are not categorized as either recreationally or commercially important species are categorized as forage species. For the California Regional Study, EPA estimated that harvested recreational and commercial species accounted for 4.8 percent of all Age-1 equivalents.

### Step 4: Determine Value Categorization

In Step 4, we determine which of the caught fish will be caught recreationally and which will be caught commercially. To determine the recreational/commercial breakdown between species that are caught both recreationally and commercially at DCPP, we employ data from the 316(b) Demonstration Study, EPA's California and Northern California regional studies, and the California Department of Fish and Game website. For example, we estimated that 62 percent of all cabezon caught is commercial and the remaining 38 percent is recreational based on landings data reported by the California Department of Fish and Game.

### Step 5: Determine the Value of Fish Produced as a Result of I&E Reductions

After completing Steps 1 through 4, we value the increased fish production that would result from I&E reductions. TER values fish that were caught recreationally at DCPP by transferring parameters from EPA's California Regional RUM Study. We determine commercial impacts by incorporating 20-year National Marine Fisheries Statistics (NMFS) landings data and most recent dockside prices with the method outlined in the previous section. We value forage species using EPA's production forgone method detailed in Chapter A5: I&E Methods (Part A: Evaluation Methods of the regional studies). Forage species account for 93.8 percent of total current I&E expressed as Age-1 equivalents at DCPP.

### 3.1.3 Detailed Description of Valuation Process Using Brown Rock Crab

This section provides a detailed description of the valuation process using brown rock crab as an example. The discussion provides information on the equations, parameters, and assumptions employed to estimate the recreational and commercial benefits from reducing brown rock crab entrainment. Brown rock crab was chosen for this example because the value of the losses due to DCPP entrainment was larger than any of the other organisms included in the assessment.

## Step 1: Categorize Entrained Brown Rock Crabs

Brown rock crab is a type of cancer crab. According to the 316(b) Demonstration Study (p. 5-21), cancer crabs carry eggs in a mass under their abdominal flap. Therefore, no eggs are entrained. Brown rock crabs have six larval stages—zoea 1 through zoea 5 and megalops. In our analysis, the entrained brown rock crabs (average of 1997 and 1998 data) are classified as zoea 1 through zoea 5 and megalops. In addition, we incorporated information from the 316(b) Demonstration Study to determine the percent allocation by life stage for entrained brown rock crabs (Table 2).

**Table 2**
**Percent Allocation by Life Stage for Entrained Brown Rock Crabs**

| Life Stage | Number Entrained (in millions) | Percent |
|---|---|---|
| Zoea 1 | 17,950.00 | 67.70% |
| Zoea 2 | 4,175.00 | 15.75% |
| Zoea 3 | 3,570.00 | 13.46% |
| Zoea 4 | 723.00 | 2.73% |
| Zoea 5 | 57.24 | 0.22% |
| Megalops | 40.50 | 0.15% |
| **Total** | **26,515.74** | **100.00%** |

## Step 2: Transform Entrained Brown Rock Crabs into Age-1 Equivalents

To transform the entrained brown rock crabs into Age-1 equivalents, we estimate the cumulative survival rate from each of the six larval stages to Age 1 using the life history parameters in Table C.3 in Appendix C, the percent allocation by life stage for entrained brown rock crabs in Table 2, and Equations 2 to 4 presented below. This step results in 5.1 million Age-1 equivalents.[21]

$$Z = M + F \qquad \textbf{(2)}$$

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[21] TER confirmed this estimate of Age-1 equivalents with John Steinbeck at Tenera Environmental. John Steinbeck also estimated 5.1 million Age-1 equivalents from the entrained brown rock crabs using the Adult Equivalent Loss (AEL) method.

where:

$Z$ = the total instantaneous mortality rate
$M$ = natural (nonfishing) instantaneous mortality rate
$F$ = fishing instantaneous mortality rate

$$S = e^{(-Z)} \tag{3}$$

where:

$S$ = the survival rate as a fraction

$$S_{j,1} = S_j^* \prod_{i=j+1}^{jmax} S_i \tag{4}$$

where:

$S_{j,1}$ = cumulative survival from stage j until Age 1
$S_j$ = survival fraction from stage j to stage j + 1
$S_j^*$ = $2S_j e^{-\log(1+S_j)}$ = adjusted $S_j$
$j_{max}$ = the stage immediately prior to Age 1

## Step 3: Determine Number of Brown Rock Crabs Caught

In this step, we convert the 5.1 million Age-1 equivalents into the number of caught crabs employing the natural and fishing mortality parameters in Table C.3 in Appendix C. We determined that brown rock crabs are first caught when they are Age 3 or Age 4. We estimate the cumulative survival rate from Age 1 to Ages 3 and 4 and estimate that approximately 6,343 brown rock crabs would be caught recreationally and commercially.

## Step 4: Determine Value Categorization

According to the California Department of Fish and Game website, brown rock crab is caught commercially and recreationally. Based on the available commercial landings data and the recreational crabbing information, we assumed that 75 percent of the caught brown rock crabs would be caught commercially and the remaining 25 percent would be caught recreationally. This step results in an estimate of 1,586 brown rock crabs caught recreationally and 4,758 brown rock crabs caught commercially.

### Step 5: Determine the Value of Brown Rock Crabs Produced as a Result of Entrainment Reductions

TER values fish that were caught recreationally at DCPP by transferring parameters from EPA's California Regional RUM Study. For brown rock crabs, we estimate a recreational value of $0.49 per crab. Thus, the recreational value of lost brown rock crabs is approximately $771. The recreational benefits of 316(b) compliance from entrainment reduction range from about $463 (60 percent of total value) to $694 (90 percent of total value). In our analysis, we estimate benefits from entrainment reduction using the 60 to 90 percent compliance range.[22]

We determine commercial impacts by using the percent increase in commercial landings and the percent change in dockside value based on the assumption that the price elasticity of demand is –1. For brown rock crabs, we looked at the 1981 to 2002 NMFS commercial landings data for crabs.[23] The commercial landings data are reported in pounds. To estimate the percent change in quantity due to entrainment reduction, we determine the lost commercial pounds. John Steinbeck (Tenera Environmental) stated that the average weight of an adult male brown rock crab is 0.45 kg and the average weight of an adult female brown rock crab is 0.34 kg. To convert to pounds the 4,758 brown rock crabs that would be caught commercially, we multiplied by the average weight of an adult male and female brown rock crab (0.395 kg or 0.871 lbs.). We estimate lost commercial yield from entrainment for brown rock crabs at 4,143 pounds. We estimate that the average commercial landings from 1981 to 2002 for California are 161,623 pounds. The average per-pound value for 2002 was $0.94. The expected increase in landings is 2.56 percent.[24] Given that the assumed price elasticity of demand is –1, the expected decrease in price from the increase in quantity is 2.56 percent. The per-pound price for brown rock crab adjusts to $0.91. We estimate the total commercial impacts for brown rock crab at $3,784. Thus, the

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[22] Similarly, in our analysis, we estimate benefits from impingement reduction using the 80- to 95-percent compliance range.

[23] Source: http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html

[24] (4,143/161,623) * 100 = 2.56 percent.

commercial benefits of 316(b) compliance from entrainment reduction range from about $2,271 (60 percent of total value) to $3,406 (90 percent of total value).

## 3.2 Analysis of the Effects of Uncertainty

There are numerous sources of uncertainty that may lead to imprecision or bias in benefit estimates in this analysis as well as EPA's analysis. Using Finkel (1990), EPA classifies uncertainty into two general types (EPA 2002):

- The first is structural uncertainty, which reflects limited understanding of the appropriate model and relationships among model parameters. Structural uncertainty is an unresolved issue that is inherent in this assessment and all such evaluations that require simplifying complex natural processes.
- The second is parameter uncertainty, which reflects imprecision in the specific numeric values of model parameters.

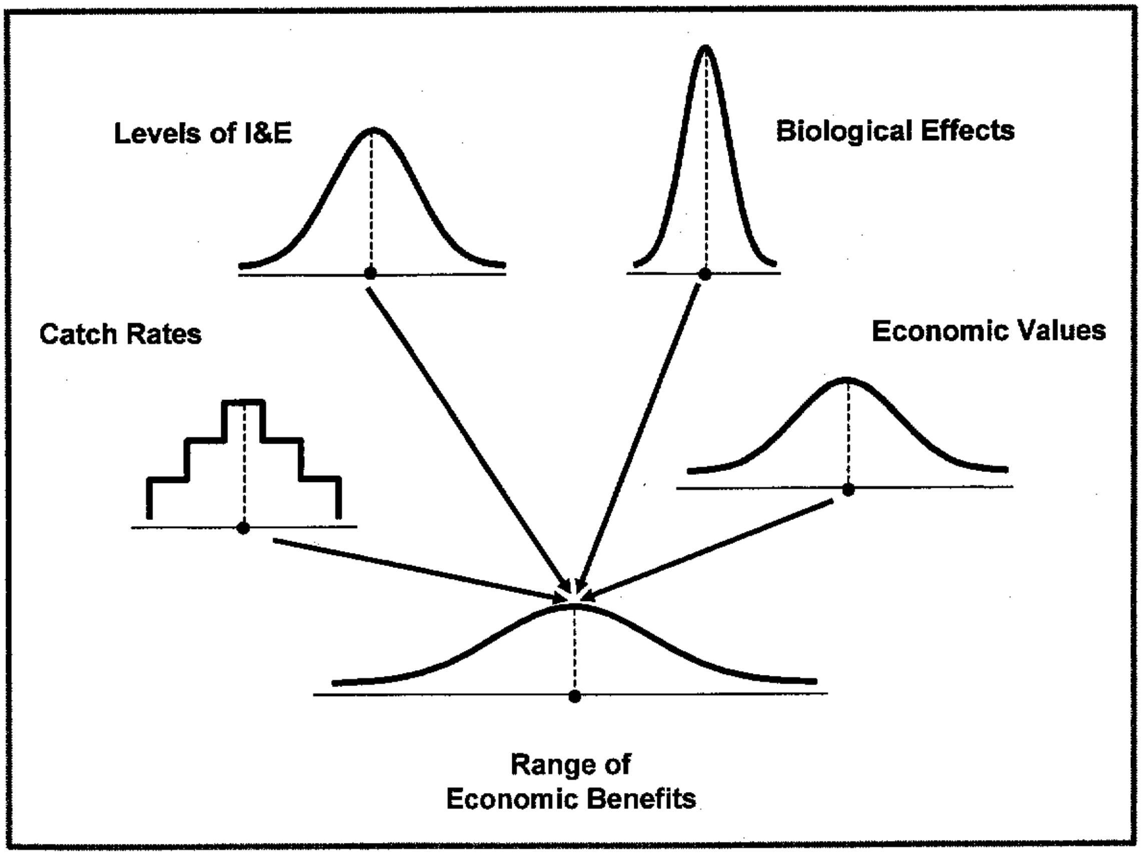
EPA believes that structural uncertainties will generally lead to inaccuracies, rather than imprecision, in economic and biological impact estimates (EPA 2004). EPA does not offer support for this contention. However, in practice, our ability to evaluate such uncertainties is limited. Accordingly, the uncertainty analysis conducted for this effort focuses primarily on parameter uncertainty.

We use a Monte Carlo analysis to quantify the effects of uncertainty on benefits, as recommended by EPA. The Monte Carlo analysis combines and calibrates the inputs from the known and unknown factors to account for the uncertainty of unknown factors in developing the range of 316(b) compliance benefits. The Monte Carlo analysis uses estimated ranges from each unknown factor, randomly selects a value from the range of each factor, and then combines the estimates within the framework of EPA benefit estimation methodologies and 316(b) compliance requirements. The resulting combination of the various inputs creates a range of compliance benefits.

The Monte Carlo analysis repeats this process of drawing from the various factor distributions 10,000 times, each time drawing randomly from the designated ranges of values for calculating biological impacts and economic benefits in a 316(b) framework. Each repetition produces a different estimate of compliance benefits. The resulting distribution of outcomes from the 10,000 draws produces the range of potential 316(b) compliance benefits.

Figure 6 provides an illustrative example. The example presents the process of determining the range of economic benefits associated with reducing I&E. Economic benefits are one component of the larger Monte Carlo analysis depicted in Figure 6. The figure shows that several different components determine the economic benefits associated with reductions in I&E: the current level of I&E, the biological effects associated with the current level of I&E (i.e., how many fish are lost because of the current I&E), the effect of reduced fish populations on catch rate, and the economic values associated with changes in catch rates. The illustration associated with each component shows that there is a range associated with each component and the ranges may have different properties. For example, the range on the levels of I&E may be a typical bell curve, whereas the range associated with catch rates may be more like a series of steps.

**Figure 6**
**Example of Monte Carlo Analysis**



As Figure 6 shows, the Monte Carlo analysis draws from each element influencing economic benefits to determine the range of economic benefits. For example, in one draw, the analysis may draw a low estimate from the range of current levels of I&E, but then draw a high estimate from the biological effect and catch rate and a mid-level estimate from economic benefits. Putting all four of these estimates together produces one estimate of economic benefits. The analysis then draws again. This time it may draw a mid-level estimate from each element. The process is repeated 10,000 times to produce the range of economic benefits.

Appendix B presents a detailed discussion of our Monte Carlo analysis and the specific uncertainty parameters we employ. In our uncertainty analysis, we attempted to account for parameter uncertainty as recommended by EPA. We incorporate uncertainty parameters to account for:

- Biological/Life History—natural mortality rates
- Stock characteristics—fishing mortality rates
- Ecological system—fish community composition and abundance
- Economic value of lost fish—recreational and commercial values
- Compliance levels—performance standard ranges.

Table 3 presents the results of our Monte Carlo analysis. The lower bound and upper bound values represent the 95-percent confidence interval. We provide uncertainty estimates for RIS I&E losses, all I&E losses (including the additional 30 percent of forage fish larvae not specifically evaluated during the 316(b) Demonstration Study), and the benefits of 316(b) compliance (80- to 95-percent impingement reduction and 60- to 90-percent entrainment reduction).[25] In addition, Table 3 lists the present value estimates in 2002 dollars for the benefits of 316(b) compliance until plant termination in 2023 and for an extension to the existing permit up to 2053.[26]

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[25] To estimate all I&E losses, we "gross up" the RIS losses by multiplying by (100/70).

[26] We apply a 3-percent discount rate for recreational and forage values and a 7-percent discount rate for commercial values.

**Table 3**
**Results of Uncertainty Analysis for Diablo Canyon Using Monte Carlo Simulation**

| Estimate | Mean | Standard Deviation | Lower Bound | Upper Bound |
|---|---|---|---|---|
| Baseline I&E (RIS species) | $26,412 | $4,732 | $18,635 | $34,206 |
| Baseline I&E (all species) | $37,731 | $6,760 | $26,621 | $48,866 |
| Benefits of Compliance (RIS species) | $19,863 | $4,207 | $13,280 | $27,220 |
| Benefits of Compliance (all species) | $28,376 | $6,010 | $18,971 | $38,886 |
| Benefits of Compliance in 2023 (RIS species) | $250,772 | $53,114 | $167,661 | $343,655 |
| Benefits of Compliance in 2023 (all species) | $358,246 | $75,877 | $239,516 | $490,936 |
| Benefits of Compliance in 2053 (RIS species) | $420,806 | $89,127 | $281,342 | $576,667 |
| Benefits of Compliance in 2053 (all species) | $601,151 | $127,324 | $401,917 | $823,809 |

## 3.3 Results

In our analysis, TER accounts for 100 percent of the impinged organisms. As Table A.1 shows, impingement impacts at DCPP are minimal. The annual economic value of all species lost to impingement is $537 in 2002 dollars. The annual economic benefits of 316(b) compliance from impingement reduction range from about $430 (80 percent of total impingement impacts) to $510 (95 percent of total impingement impacts). Recreational impacts account for 90 percent of total impingement impacts. The main species for impingement are rockfish, surfperch, sanddabs, and sole.[27]

Table A.2 presents entrainment impacts at DCPP for the RIS species. The annual economic value of RIS species lost to entrainment is $25,595 in 2002 dollars. The RIS species account for only 70 percent of all entrainment. To estimate the economic value of all species lost to entrainment, we multiply the economic impacts for the RIS species by (100/70). Thus, the economic value of all species lost to entrainment is $36,564. The annual economic benefits of 316(b) compliance from entrainment reduction range from about $21,939 (60 percent of total entrainment impacts) to $32,908 (90 percent of total entrainment impacts). Recreational impacts account for 55 percent of total entrainment impacts, while commercial impacts account

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[27] These species account for 96 percent of all total economic impacts from impingement.

for 31 percent. The main species for entrainment are California halibut, brown rock crab, kelpfishes, and sanddabs.

Table A.3 presents I&E impacts at DCPP. The annual economic value of all impinged organisms and the RIS species lost to entrainment is $26,132 in 2002 dollars. To estimate the economic value of all species lost to I&E, we multiply the economic impacts by (100/70). This is a good approximation as impingement accounts for only 2 percent of the total impacts. Thus, the economic value of all species lost to I&E is approximately $37,331. The annual economic benefits of 316(b) compliance from I&E reduction range from about $22,369 (minimum compliance, i.e., 80 percent of total impingement impacts and 60 percent of total entrainment impacts) to $33,418 (maximum compliance, i.e., 95 percent of total impingement impacts and 90 percent of total entrainment impacts). Recreational impacts account for 55 percent of total I&E impacts while commercial impacts account for 31 percent. The main species for I&E are California halibut, brown rock crab, kelpfishes, and sanddabs.

Tables A.1, A.2, and A.3 present point estimates. In our Monte Carlo analysis, we attached uncertainty estimates to various parameters and assumptions. The annual economic value of all I&E impacts ranges from $26,621 to $48,866 in 2002 dollars. The annual benefits of 316(b) compliance range from $18,971 to $38,886.

Table 4 compares the results of our analysis with ASA's study. We present the undiscounted annual benefits of compliance (because the two studies do not use the same discount rates), the impacts each study measured, the reduction criteria each study applied, and any assumptions necessary to make the comparison. As Table 4 shows, TER's estimates fall within the range of ASA's estimates.

### Table 4
### Comparison of Compliance Benefits across Studies

| Study | Measured Impacts | Economic Benefits Lower Bound | Economic Benefits Upper Bound | Reduction Criterion | Assumptions/ Limitations |
|---|---|---|---|---|---|
| TER | Recreational, Commercial, and Forage I&E Impacts | $18,971 | $38,886 | 80% to 95% for impingement, 60% to 90% for entrainment. | Assumes EPA life history parameters are correct. |
| ASA | Recreational, Commercial, and Indirect Use Entrainment Impacts[a] | $1,949 | $134,266 | 80% for entrainment of 14 RIS fish species (excludes brown rock crabs and slender crabs). | Divided by 0.7 to estimate benefits for all entrainment. |

[a] We exclude nonuse impacts from ASA's estimates to make them more comparable to our estimates.

In EPA's estimation, the Northern California region provided annual economic benefits of $683,479 in 2002 dollars (assuming a 3-percent discount rate).[28] For California, EPA estimated annual economic benefits from the Phase II Rule in 2002 dollars at $2.97 million (assuming a 3-percent discount rate).[29] Because of information constraints, it is difficult to separate out the DCPP's contributions to EPA's Northern California and California Regional Studies. Nevertheless, it can be seen from Table 5 that our estimates for the DCPP alone are generally within the range of EPA's benefit estimates over these wider regional areas.

### Table 5
### Comparison of Compliance Benefits across TER and EPA Studies[a]

| Study | Number of Facilities | Economic Benefits (2002 $) |
|---|---|---|
| TER | 1 | $20,424 |
| Northern California | 8 | $683,479 |
| California | 20 | $2,970,864 |

[a] We incorporate only upper-bound commercial benefit estimates for the EPA studies. For the TER study, we present the undiscounted point estimates with no uncertainty attached to the values.

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[28] This estimate includes recreational benefits of $663,965 and commercial benefits of $19,514.

[29] This estimate includes recreational benefits of $2.45 million and upper bound commercial benefits of $0.52 million.

# 4. NONUSE VALUES

As part of the BVS, the 316(b) rule also requires that the benefits assessment consider the nonuse benefits associated with reductions in I&E (EPA 2004 p. 41,647). People hold nonuse values for a resource that are independent of their use of the resource. That is, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist. As the rule points out, the economic literature commonly refers to these two components of nonuse values as "bequest" (or "altruistic") values and "existence" values, respectively (EPA 2004 p. A9-3).[30]

Currently, the only method available for estimating nonuse values is survey-based elicitation. However, the reliability of this approach for estimating these impacts is questionable. For example, the contingent valuation literature has long noted and thoroughly documented the difference between people's stated intentions and actual behaviors. This difference between intentions and behavior is called hypothetical bias. Researchers in the natural resource arena recognized hypothetical bias more than 20 years ago, defining it as the "potential error due to not confronting an individual with a real situation" (Rowe, d'Arge, and Brookshire 1980).

Such difficulties have limited the possibilities for directly eliciting nonuse values in this context with an original survey. In fact, because of conceptual and empirical challenges, the Agency decided in the final rule that "...none of the available methods for estimating either use or nonuse values of ecological resources is perfectly accurate; all have shortcomings" (EPA 2004 p. 41624). More importantly, EPA decided that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004 p. 41624).

As a result of this conclusion, EPA provides guidance in the rule as to how each facility should address the nonuse values associated with reductions in I&E. This

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[30] The only distinction between bequest and altruistic values is whether one values uses of the resource by one's progeny or other people. Thus, both concepts are often combined under either one of the two terms.

section begins by presenting the methods EPA evaluated in its assessment of nonuse values and discussing their relevance for this assessment. The section then presents EPA's guidelines in the Final Phase II Rule for addressing nonuse values and describes how we have used those guidelines to assess the nonuse values associated with reductions in I&E at DCPP.

## 4.1 EPA Approach: Proposed Rule

In the proposed rule, EPA presented three potential approaches for quantifying nonuse values. These include the Habitat Replacement Cost (HRC) method, the Societal Revealed Preference (SRP) approach, and the Fisher-Raucher approximation. After public comment and further review EPA repudiated these methods. The following sub-sections describe each approach.

### *4.1.1 Habitat Replacement Cost Method*

In the Proposed Rule, EPA presented two cost-based methods for approximating benefits. For the HRC method, the costs estimated by EPA are the total costs of restoring habitats so that they produce ecological services equivalent to those expected from technological alternatives.[31] Numerous reviewers commented that these costs are not benefits. Rather, they are alternative costs for achieving the objectives of the proposed regulation. Mitigation approaches such as stocking and habitat restoration may be acceptable alternatives to technology installation. However, the cost of such alternatives bears no implicit relationship to the benefits of reducing I&E. Therefore, it is important not to confuse this method of mitigation scaling with measuring the benefits of the mitigation.

Appropriate economic measures of benefits require that they be based on the willingness-to-pay principle, and HRC is not based on this principle. In many cases, the cost of developing a resource can substantially exceed the resource's value. Although EPA extensively evaluated HRC during its development of the Phase II rule, EPA ultimately decided that the HRC method should not be used as a means of estimating

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[31] Although the Phase II Rule for existing facilities allows the use of restoration measures to achieve compliance with either national or site-specific standards, a similar provision was found to be invalid in the Phase I regulations for new facilities by the U.S. Court of Appeals, Second Circuit. Environmental groups and six States contesting the Phase II regulation are again challenging the validity of restoration in the Phase II regulation, which is being heard by the same Circuit Court of Appeal.

benefits due to "limitations and uncertainties regarding the application of this methodology" (*Fed. Reg.*, Volume 69, No. 131, p. 41,625). Accordingly, the HRC approach is not employed in this assessment.

### 4.1.2 Societal Revealed Preference Method

The second cost-based methodology employed by EPA in the Proposed Rule is called Societal Revealed Preference (SRP). Rather than using the cost of a hypothetical alternative, SRP uses historical costs under prior government mandates to measure benefits. Like the HRC method, this cost-based approach has no foundation in economic theory and is not accepted by economists as a legitimate method of empirical valuation. In fact, the SRP method is a corrupted application of the legitimate revealed preference method. An essential characteristic of revealed preference analysis and not SRP is that willingness to pay is revealed by those who are doing the paying. The SRP methodology takes the fact that a program exists as evidence that its benefits exceed its costs. EPA removed the disputed results of the SRP analyses from its benefits estimates for the final rule. Accordingly, the SRP method is not employed in this assessment.

### 4.1.3 Fisher-Raucher Approximation

For the Proposed Rule analysis, EPA also presented the Fisher-Raucher or "50 percent" rule. This approach approximates nonuse values at 50 percent of recreational use values. The approximation is derived from a comparison of use and nonuse values for water quality improvements.[32] The 50-percent rule is inappropriate in this context because there is no reason to believe that the ratio of nonuse to use benefits from water quality improvements could be applied to the environmental improvement from reductions in I&E. Moreover, because use values for fish often arise from their *consumption*, there is no conceptual reason to believe that there is a positive association between use and nonuse values in this context. EPA does not employ the 50-percent rule in its final analysis and this approach is not employed in this assessment.

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[32] Fisher, A. and R. Raucher. 1984. Intrinsic benefits of improved water quality: Conceptual and empirical perspectives. *Advances in Applied Micro-Economics.* 3:37–66.

## 4.2 EPA Approach: Notice of Data Availability (NODA)

EPA used two approaches to evaluate nonuse values in the NODA. These include a revised form of the HRC method and the Production Forgone method. After public comment and further review EPA repudiated the revised HRC method. The Production Forgone method is included in EPA's final benefits analysis but not quantified in dollar terms because of time constraints. The following sub-sections describe each approach.

### *4.2.1 Revised Habitat Replacement Cost*

In the NODA, EPA presented a "revised HRC" methodology that evaluated nonuse benefits based on estimated willingness to pay values for the resource improvements that would be achieved by equivalent restoration. It was based on a transfer approach that combines an estimate of the amount of habitat required to offset I&E losses by means of wild fish production with a benefits transfer estimate of willingness to pay for aquatic habitat preservation/restoration.

This approach is fundamentally flawed for a number of reasons (Bingham, Desvousges, and Mohamed 2003). A theoretical shortcoming of this approach is that there is no good reason to presume that willingness to pay values for habitat restoration are an appropriate proxy for either the total value or the nonuse value of the fishery resources that would be preserved due to reduced I&E. EPA does not employ this revised HRC approach in its final analysis and this approach is not employed in this assessment.

### *4.2.2 Production Forgone*

When calculating benefits for the NODA, EPA valued forage fish based upon their value as inputs to recreational and commercial stocks. The Production Forgone methodology recognizes that the value of forage species is through indirect use rather than nonuse. This methodology passes the biological effects of increased biomass availability through trophic levels until it reaches commercially and recreationally valuable species. At this point, catch changes and recreational and commercial values are calculated. Although commenters disagreed on certain assumptions, the approach was generally accepted.[33] Valuing forage losses in this manner accounted for nearly all biomass but led to only marginally higher estimates of economic impacts to recreational and commercial fishing.[34] This analysis employs EPA's production forgone methodology as presented in the NODA. The resulting benefits estimates account for nearly all lost fish and shellfish biomass.[35]

## 4.3 EPA Approach: Final Rule

EPA ultimately determined that none of the available methods for estimating nonuse values were appropriate for inclusion in the final rule. Thus, in the absence of impacts to populations or threatened and endangered species, EPA decided to "rely on a qualitative discussion of nonuse benefits."

## 4.4 Qualitative Discussion of Nonuse Values for Diablo Canyon

As the previous section shows, EPA examined a variety of methods to quantify the nonuse values associated with reducing I&E. Based on this examination EPA, "determined that none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004 p. 41,624). EPA then provided guidance in the final rule as to how each facility should assess the nonuse benefits associated with reductions in I&E.

This section provides the assessment of nonuse benefits for Diablo Canyon. Section 4.4.1 begins by presenting the specific guidance EPA provides in the rule. Section 4.4.2 uses that guidance to present the results of the assessment of nonuse benefits for Diablo Canyon.

### *4.4.1 EPA Guidance on Assessing Nonuse Benefits*

In the final Phase II Rule, EPA provides the following guidance on how to assess the nonuse benefits associated with reductions in I&E (EPA 2004 p. 41,647–41,648):

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[33] For example, Barnthouse (2002) indicates that the transfer efficiency is not correct.

[34] The recreational and commercial fishing mortality rates specified by EPA indicate that very few of these fish are expected to die naturally. Valuing forage fish in terms of production forgone added less than 20 percent to total losses.

[35] According to EPA calculations, approximately 99 percent of Age-1 equivalents are forage fish. All of these fish are valued in this analysis using the Production Forgone methodology.

- Nonuse benefits may arise from reduced impacts to ecological resources that the public considers important, such as threatened and endangered species. Nonuse benefits can generally only be monetized through the use of stated preference methods. When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information.
- In cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, nonuse benefits should be monetized.[36]
- In cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not necessary.

The DCPP 316(b) Study demonstrated that the Plant's CWIS does not have any effect on any threatened or endangered species, that the Plant has only relatively minor impacts on commercially and recreationally important species, and that the most significant impacts were to three species of nearshore forage species having no direct commercial or recreational value. There also are no identified problems with the maintenance of community structure in the vicinity of the DCPP. Based on these results and the guidance presented above, there is no need to monetize nonuse values in this study.[37] We therefore provide a qualitative description below.

### *4.4.2 A Qualitative Description of Nonuse Values for Diablo Canyon*

The original concept of nonuse values is credited to Krutilla (1967), who argued that individuals do not have to be active consumers of unique, irreplaceable resources in order to derive value from the continuing existence of such resources. He wrote that "when the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals" (p. 779).

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[36] In cases where harm cannot be clearly explained to the public, monetization is not feasible because stated preference methods are not reliable when the environmental improvement being valued cannot be characterized in a meaningful way for survey respondents. [Note that this footnote is in fact part of the quoted EPA text.]

[37] The production forgone methodology is employed to account for indirect use rather than nonuse impacts.

Krutilla's argument has two crucial components. First, nonuse values are related to unique resources. Second, nonuse values are related to the continuing existence of a resource. Thus, it follows from Krutilla that common resources that suffer from limited injury do not generate significant nonuse values.

This perspective has pervaded the economic literature in the years since Krutilla introduced it. The extensive economic literature on nonuse values emphasizes the relationship between the existence of nonuse values and the uniqueness of the resource in question and the irreversibility of the loss or injury (Freeman 1993). Freeman summarizes this relationship in the economic literature in the following example:

> ...economists have suggested that there are important nonuse values in ...preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes (p. 162).

As Freeman's example illustrates, common resources (i.e., resources that are not unique) that do not experience irreversible losses are not likely to generate significant nonuse values, if any at all. Such is the case with respect to the effects of I&E at DCPP.

First, the DCPP 316(b) Study demonstrated that the Plant's CWIS does not have any effect on any threatened or endangered species. This is important because of the relationship between the uniqueness of the resource, the irreversibility associated with changes to the resource, and the extent of potential nonuse values. Because there are no threatened and endangered species associated with I&E at the Plant, the species being impinged and entrained are not a unique resource and the effect on the resource is not irreversible. Therefore, the nonuse values associated with reducing I&E at the site are small, if anything at all.

Moreover, EPA's guidance on nonuse values is that monetization is not necessary "in cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species..."

(EPA 2004 p. 41,648). Therefore, it is not necessary to attempt to quantify whether there are any nonuse benefits associated with reducing the I&E at the Plant.

Second, the Plant has relatively minor impacts on commercially and recreationally important species, and the most significant impacts were to three nearshore forage species having no direct commercial or recreational value. To account for these lost forage species, the analysis values them in terms of forgone production of recreational and commercial species. This methodology passes the biological effects of increased biomass availability through trophic levels until it reaches traditionally valuable species. At this point, catch changes and recreational and commercial values are calculated. EPA performed these calculations in the benefits assessment of the Phase II NODA. Although commenters disagreed on certain assumptions, the approach was generally accepted.[38] By valuing forage species through the production forgone methodology, this BVS has monetized all meaningful I&E impacts at DCPP.

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[38] For example, Barnthouse (2002) indicates that the transfer efficiency is not correct.

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# Appendix A

## Impingement and Entrainment Estimates

## Table A.1
## TER's Estimates of Total Impingement Losses at Diablo Canyon Power Plant Using Actual Data

| Species | Impingement (# of organisms)[a] | Age-1 Equivalents[b] | Recreational Value[c] |  | Commercial Value[d] |  |  | Forage Value[e] |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Forgone Recreational Yield (# of fish) | Recreational Loss ($) | Forgone Commercial Yield (lbs) | Commercial Catch Value ($/lb) | Commercial Loss ($) | Pounds of Fish | Commercial and Recreational Species Forgone Value ($) |
| Pipefish | 296 | 402 | — | — | — | — | — | 6.07 | $0.17 |
| Rockfish | 1,141 | 1,278 | 64 | $89.36 | 24.2 | $0.87 | $21.15 | — | — |
| Greenling | 14 | 33 | — | — | — | — | — | 0.12 | $0.00 |
| Sculpin | 323 | 519 | — | — | — | — | — | 1.98 | $0.06 |
| Surfperch | 370 | 445 | 165 | $229.74 | — | — | — | — | — |
| Kelpfish | 161 | 389 | — | — | — | — | — | 1.48 | $0.04 |
| Gunnell | 29 | 75 | — | — | — | — | — | 0.29 | $0.01 |
| Sole | 78 | 105 | 8 | $67.18 | 23.2 | $0.36 | $8.44 | — | — |
| Plainfin Midshipman | 200 | 565 | — | — | — | — | — | 2.15 | $0.06 |
| Queenfish | 121 | 121 | 7 | $9.30 | 13.4 | $0.77 | $10.37 | — | — |
| Other (Sanddab) | 373 | 446 | 11 | $88.90 | 30.8 | $0.39 | $12.00 | — | — |
|  | **3,106** | **4,378** | **254** | **$484.00** | **92** |  | **$52.00** | **12** | **$0.34** |

**Total Losses: $537**

[a] Raw impingement numbers from Diablo_Input.xls in EPA NODA Docket (#OW-2002-0049).

[b] Age-1 equivalent transformation based upon EPA method and life history parameters from the Northern California and California Regional Studies. Raw impingement numbers increase when converted to Age-1's because many fish are impinged at older ages.

[c] Recreational numbers calculated using EPA method and California random utility model parameters.

[d] Commercial numbers calculated using EPA method and 1981 to 2002 National Marine Fisheries Statistics data.

[e] Forage pounds and values calculated using EPA's commercial production forgone method. We convert lost recreational and commercial fishery values to forage species-specific values.

## Table A.2. TER's Estimates of Total Entrainment Losses at Diablo Canyon Power Plant Using Actual Data

| | | | Recreational Value[c] | | Commercial Value[d] | | | Forage Value[e] | |
|---|---|---|---|---|---|---|---|---|---|
| Species | Entrainment (# of eggs/larvae)[a] | Age-1 Equivalents[b] | Forgone Recreational Yield (# of fish) | Recreational Loss ($) | Forgone Commercial Yield (lbs) | Commercial Catch Value ($/lb) | Commercial Loss ($) | Pounds of Fish | Commercial and Recreational Species Forgone Value ($) |
| Blackeye Goby | 118,500,000 | 309,726 | — | — | — | — | — | 600.87 | $6.79 |
| Blue Rockfish Complex | 58,920,000 | 362 | 16 | $22.87 | 7.9 | $1.22 | $9.66 | — | — |
| Brown Rock Crab[f] | 26,465,790,000 | 5,057,594 | 1,586 | $771.17 | 4,143.0 | $0.91 | $3,784.17 | — | — |
| Cabezon | 44,100,000 | 297 | — | — | — | — | — | 50.14 | $0.57 |
| California Halibut | 17,970,000 | 8,526 | 1,406 | $11,902.92 | 924.0 | $2.97 | $2,745.10 | | — |
| Clinid Kelpfishes | 275,062,500 | 75,716,670 | — | — | — | — | — | 288,480.51 | $3,258.33 |
| KGB Rockfish Complex | 248,500,000 | 1,528 | 101 | $140.27 | 14.3 | $4.66 | $66.40 | — | — |
| Monkeyface Prickleback | 72,300,000 | 18,016 | 363 | $176.36 | 2.7 | $4.03 | $10.89 | — | — |
| Northern Anchovy | 384,000,000 | 20,902 | — | — | 2,896.2 | $0.05 | $155.11 | — | — |
| Pacific Sardine | 23,302,500 | 159,655 | — | — | 22,124.2 | $0.05 | $1,005.75 | — | — |
| Painted Greenling | 16,905,000 | 4,653,453 | — | — | — | — | — | 17,729.65 | $200.25 |
| Sanddabs | 6,525,000 | 5,640 | 133 | $1,125.06 | 389.3 | $0.39 | $151.80 | — | — |
| Slender Crab[f,g] | 429,440,000 | 95,395 | 120 | $58.18 | — | — | — | — | — |
| Smoothhead Sculpin | 86,350,000 | 21,517 | — | — | — | — | — | 81.98 | $0.93 |
| Snubnose Sculpin | 96,750,000 | 24,109 | — | — | — | — | — | 91.85 | $1.04 |
| White Croaker | 558,750,000 | 8 | 0 | $0.43 | 0.9 | $0.87 | $0.75 | — | — |
| | **28,903,165,000** | **86,093,398** | **3,725** | **$14,197.00** | **30,502.0** | | **$7,930.00** | **307,035.00** | **$3,468.00** |

**Total Losses: $25,595**

[a] Raw entrainment numbers from Diablo_Input.xls in EPA NODA Docket (#OW-2002-0049).

[b] Age-1 equivalent transformation based upon EPA method and life history parameters from the Northern California and California Regional Studies. Raw entrainment numbers decrease when converted to Age-1's because many eggs and larvae would not reach Age 1.

[c] Recreational numbers calculated using EPA method and California random utility model parameters.

[d] Commercial numbers calculated using EPA method and 1981 to 2002 National Marine Fisheries Statistics data.

[e] Forage pounds and values calculated using EPA's commercial production forgone method. We convert lost recreational and commercial fishery values to forage species-specific values.

[f] Entrainment estimates for brown rock crab and slender crab include all larval life stages. We verified the number of Age-1 equivalents with John Steinbeck at Tenera Environmental.

[g] We use EPA's designation that slender crab is a recreationally valuable species.

## Table A.3. TER's Estimates of Total Impingement & Entrainment Losses at Diablo Canyon Power Plant

| Species | Impingement & Entrainment (# of organisms /eggs-larvae)[a] | Age-1 Equivalents[b] | Recreational Value[c] | | Commercial Value[d] | | Forage Value[e] | |
|---|---|---|---|---|---|---|---|---|
| | | | Forgone Recreational Yield (# of fish) | Recreational Loss $) | Forgone Commercial Yield (lbs) | Commercial Loss ($) | Pounds of Fish | Commercial & Recreational Species Forgone Value ($) |
| Blackeye Goby | 118,500,000 | 309,726 | — | — | — | — | 600.87 | $6.79 |
| Blue Rockfish Complex | 58,920,000 | 362 | 16 | $22.87 | 8 | $9.66 | — | — |
| Brown Rock Crab[f] | 26,465,790,000 | 5,057,594 | 1,586 | $771.17 | 4,143 | $3,784.17 | — | — |
| Cabezon | 44,100,000 | 297 | — | — | — | — | 50.14 | $0.57 |
| California Halibut | 17,970,000 | 8,526 | 1,406 | $11,902.92 | 924 | $2,745.10 | — | — |
| Kelpfish | 275,062,661 | 75,717,059 | — | — | — | — | 288,482.00 | $3,258.37 |
| KGB Rockfish Complex | 248,500,000 | 1,528 | 101 | $140.27 | 14 | $66.40 | — | — |
| Monkeyface Prickleback | 72,300,000 | 18,016 | 363 | $176.36 | 3 | $10.89 | — | — |
| Northern Anchovy | 384,000,000 | 20,902 | — | — | 2,896 | $155.11 | — | — |
| Pacific Sardine | 23,302,500 | 159,655 | — | — | 22,124 | $1,005.75 | — | — |
| Painted Greenling | 16,905,000 | 4,653,453 | — | — | — | — | 17,729.65 | $200.25 |
| Sanddabs | 6,525,373 | 6,085 | 143 | $1,213.96 | 420 | $163.80 | — | — |
| Slender Crab[f,g] | 429,440,000 | 95,395 | 120 | $58.18 | — | — | — | — |
| Smoothhead Sculpin | 86,350,000 | 21,517 | — | — | — | — | 81.98 | $0.93 |
| Snubnose Sculpin | 96,750,000 | 24,109 | — | — | — | — | 91.85 | $1.04 |
| White Croaker | 558,750,000 | 8 | 0 | $0.43 | 1 | $0.75 | — | — |
| Pipefish | 296 | 402 | — | — | — | — | 6.07 | $0.17 |
| Rockfish | 1,141 | 1,278 | 64 | $89.36 | 24 | $21.15 | — | — |
| Greenling | 14 | 33 | — | — | — | — | 0.12 | $0.00 |
| Sculpin | 323 | 519 | — | — | — | — | 1.98 | $0.06 |
| Surfperch | 370 | 445 | 165 | $229.74 | — | — | — | — |
| Gunnell | 29 | 75 | — | — | — | — | 0.29 | $0.01 |
| Sole | 78 | 105 | 8 | $67.18 | 23 | $8.44 | — | — |
| Plainfin Midshipman | 200 | 565 | — | — | — | — | 2.15 | $0.06 |
| Queenfish | 121 | 121 | 7 | $9.30 | 13 | $10.37 | — | — |
| | 28,903,168,106 | 86,097,776 | 3,979 | $14,682.00 | 30,594 | $7,982 | 307,047.00 | $3,468.00 |

**Total Losses: $26,132**

[a] Raw impingement/entrainment numbers from Diablo_Input.xls in EPA NODA Docket (#OW-2002-0049).

[b] Age-1 equivalent transformation based upon EPA method and life history parameters from the Northern California and California Regional Studies. Raw impingement numbers increase when converted to Age-1's because many fish are impinged at older ages. Raw entrainment numbers decrease when converted to Age-1's because many eggs and larvae would not reach Age 1.

[c] Recreational numbers calculated using EPA method and California random utility model parameters.

[d] Commercial numbers calculated using EPA method and 1981 to 2002 National Marine Fisheries Statistics data.

[e] Forage pounds and values calculated using EPA's commercial production forgone method. We convert lost recreational and commercial fishery values to forage species-specific values.

[f] Entrainment estimates for brown rock crab and slender crab include all larval life stages. We verified the number of Age-1 equivalents with John Steinbeck at Tenera Environmental.

[g] We use EPA's designation that slender crab is a recreationally valuable species.

# Appendix B

## Detailed Monte Carlo Analysis

# Ranges Applied to Impingement and Entrainment Parameters in the Monte Carlo Analysis

TER includes a Monte Carlo analysis in our 316(b) benefit analysis to account for uncertainty existing in current data and/or estimation methods. A Monte Carlo Analysis treats each parameter as a mean and creates a distribution around the mean by using specified percent ranges.[39] Our Monte Carlo simulates the benefit calculation process 10,000 times using randomly chosen values from each parameter's distribution. Output of the Monte Carlo is a range of benefit values around our calculated mean that accounts for uncertainty. This appendix reports the ranges we apply to each parameter in the Monte Carlo analysis.

## *B.1 Number of Organisms/Eggs and Larvae Impinged and Entrained*

Because fish populations fluctuate from year to year, we attach a range to our estimated number of organisms impinged and number of eggs and larvae entrained. Including this range around the actual number of organisms impinged and entrained accounts for uncertainty in fish community composition and abundance (uncertainty in the ecological system).

**Entrainment:** We use DCPP entrainment data from Diablo_Input.xls in the NODA Docket (#OW-2002-0049). The estimates we use are an average of 1997 and 1998 plant data. We calculate and apply the percent range of each entrained species between 1997 and 1998 to total egg and larvae estimates. The ranges we apply vary from a low of 4 percent for brown rock crabs to a high of 69 percent for sanddabs. Ranges for all DCPP entrained species are shown in Table B.1.

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[39] Ranges are applied to both ends of a mean. A range of 4 percent translates to an 8-percent range around the mean.

**Table B.1**
**Ranges for Entrainment Estimates**

| Entrained Species | Range |
|---|---|
| Blackeye Goby | 8% |
| Blue Rockfish | 43% |
| Brown Rock Crab | 4% |
| Cabezon | 18% |
| California Halibut | 31% |
| Clinid Kelpfish | 26% |
| KGB Rockfish | 11% |
| Monkeyface Prickleback | 15% |
| Northern Anchovy | 47% |
| Pacific Sardine | 45% |
| Painted Greenling | 43% |
| Sanddabs | 65% |
| Slender Crab | 42% |
| Smoothhead Sculpin | 33% |
| Snubnose Sculpin | 14% |
| White Croaker | 18% |
| Average | 29% |

**Impingement:** We use DCPP impingement data from Diablo_Input.xls in the NODA Docket (#OW-2002-0049). Impingement data are available for only one year, 1998. We calculate the average percent range for all entrained species between 1997 and 1998 (29 percent) and apply it to total numbers of impinged organisms. Because we have only one year of impingement data, we are unable to calculate ranges by species.

## *B.2 Recreational and Commercial Species Life Stage Survival Rates*

The life history parameters we use to calculate Age-1 equivalents are transferred from EPA case studies. In some cases, we transfer life history parameters from a similar species or an aggregate species group to DCPP species. The ranges we apply to life stage survival rates are based upon the quality of the match between DCPP species and EPA case study species life histories. Table B.2 reports the criteria we use to assign ranges to recreational and commercial species transfers. Table B.3 presents the EPA species and sources we transfer to DCPP recreational and commercial species as well as the percent ranges applied to the transferred parameters. These ranges account for uncertainty as suggested by EPA:

- Biological/Life History—natural mortality rates
- Stock characteristics—fishing mortality rates.

**Table B.2**
**Uncertainty Applied to EPA Transfers**

| Criterion Number | Transfer Criterion | Standard Deviation Applied |
|---|---|---|
| 1. | Exact Species Transfer | 0.0% |
| 2. | Different Species Transfer, Similar Life History Match | 5.0% |
| 3. | Aggregate Group Transfer, One Exact Species Match | 5.0% |
| 4. | Aggregate Group Transfer, Similar Life History Match | 7.5% |
| 5. | Different Species Transfer, Best Available Match | 10.0% |

## Table B.3
## Recreational and Commercial EPA Species Transfers

| | Species | EPA Species Transfer | Life History Basis | EPA Source[a] | Standard Deviation Applied | Criterion Number[b] |
|---|---|---|---|---|---|---|
| Entrained Species | Blue Rockfish Complex | Rockfish | Blue Rockfish | NCCS | 5.0% | 3 |
| | KGB Rockfish Complex | Rockfish | Blue Rockfish | NCCS | 7.5% | 4 |
| | Brown Rock Crab | Rock Crab | Brown Rock Crab | NCCS | 0.0% | 1 |
| | Slender Crab | Rock Crab | Brown Rock Crab | NCCS | 5.0% | 2 |
| | California Halibut | California Halibut | California Halibut | NCCS | 0.0% | 1 |
| | Monkeyface prickleback | Other Forage Fish | Multiple species | CRS | 5.0% | 2 |
| | Northern Anchovy | Anchovies | Northern Anchovy | NCCS | 0.0% | 1 |
| | Pacific Sardine | Herrings | Pacific Herring | NCCS | 0.0% | 1 |
| | Sanddabs | Flounders | Speckled Sanddab | NCCS | 5.0% | 3 |
| | White Croaker | Drums/ Croakers | White Croaker | NCCS | 0.0% | 1 |
| Impinged Species | Rockfish | Rockfish | Blue Rockfish | NCCS | 5.0% | 3 |
| | Surfperch | Surfperches | Walleye Surfperch | NCCS | 5.0% | 2 |
| | Queenfish | Drums/ Croakers | White Croaker | NCCS | 5.0% | 2 |
| | Sole | Flounders | Multiple species | CRS | 5.0% | 2 |
| | Other (Sanddab) | Flounders | Multiple species | CRS | 10.0%[c] | 5 |

[a] NCCS = Northern California Case Study from EPA NODA Docket.

CRS = California Regional Study from EPA Regional Analysis Document for the Final Phase II Rule.

[b] The criterion number matches the criterion transfer and standard deviation from Table B.2.

[c] 10.0% was used for "Other (Sanddab)" because this category includes species other than Sanddab.

### *B.3 Commercial and Recreational Species Life Stage Breakdown*

**Entrainment:** One-half of DCPP species entrained lay adhesive eggs (monkeyface prickleback), are livebearers (rockfish), or carry eggs in abdominal flaps (crabs) and are not entrained during the egg life stage. Therefore, entrainment of these species is 100 percent larvae; we apply no uncertainty to their life stage breakdown. We assume a 50-percent breakdown between eggs and larvae for remaining entrained species (California halibut, Northern anchovy, Pacific sardine, sanddabs, and white croaker) based on best available data. We apply a 5-percent range to the egg/larvae breakdown for these species to account for the uncertainty of the estimate.

**Impingement:** We estimate the breakdown of impinged organisms into percent Age-1 fish and percent Age-2 fish based on EPA case-study impingement data combined with species-specific life history parameters. Since the breakdown is based upon transferred data, we apply a 5-percent range to the assumed age of impinged organisms.

### *B.4 Commercial and Recreational Species Values*

**Commercial Values:** To calculate DCPP commercial species per-pound values, we use NMFS commercial fishery data from Northern California. We calculate the species-specific average commercial price per pound using catch data from 1981 to 2002 and 2002 price per pound. Taking the average value over a large timeframe includes the natural variations that occur in commercial prices. Because of the quality of our commercial value data, we apply a 0 percent range to these values.

**Recreational Values:** To calculate DCPP recreational species per-fish values, we use estimated changes in DCPP catch rates and values from EPA's California Regional RUM Study. We account for uncertainty in these non-fixed values by applying a 2.5-percent range to all per-fish recreational values. This step accounts for uncertainty in the economic value of lost recreational fish.

## B.5 Forage Species Calculations

Most life history parameters that we transfer to DCPP forage fish are from the "Other Forage Fish" of the California Regional Study. We calculate recreational and commercial production forgone from entrainment and impingement of forage fish using EPA's recreational and commercial species parameters. Because of the uncertainty of the numbers of forage fish impinged and entrained, EPA's "Other Forage Fish" composition, and their recreational and commercial species parameters, we apply a 29-percent range to the final entrainment and impingement forage values calculated. The range of entrainment estimates between 1997 and 1998 is 29 percent. We apply the 29-percent range to the values of the species listed in Table B.4, which presents the EPA species and sources we transfer to DCPP forage species.

**Table B.4**
**Forage EPA Species Transfers**

| | Species | EPA Species Transfer | Life History Basis | EPA Source[a] |
|---|---|---|---|---|
| Entrained Species | Blackeye Goby | Gobies | Blackeye Goby | NCCS |
| | Cabezon | Cabezon | Cabezon | NCCS |
| | Painted Greenling | Other Forage Fish | Multiple Species | CRS |
| | Smoothhead Sculpin | Other Forage Fish | Multiple Species | CRS |
| | Snubnose Sculpin | Other Forage Fish | Multiple Species | CRS |
| | Clinid Kelpfishes | Other Forage Fish | Multiple Species | CRS |
| Impinged Species | Pipefish | Chain Pipefish | Chain Pipefish | NARS |
| | Greenling | Other Forage Fish | Multiple Species | CRS |
| | Sculpin | Other Forage Fish | Multiple Species | CRS |
| | Kelpfish | Other Forage Fish | Multiple Species | CRS |
| | Gunnell | Other Forage Fish | Multiple Species | CRS |
| | Plainfin Midshipman | Other Forage Fish | Multiple Species | CRS |

[a] NCCS = Northern California Case Study from EPA NODA Docket.
CRS = California Regional Study from EPA Regional Analysis Document for the Final Phase II Rule.
NARS = North Atlantic Regional Study from the EPA NODA Docket.

## B.6 Compliance Range

Under EPA's Final Phase II Rule, DCPP must reduce its entrainment levels 60 percent to 90 percent and its impingement levels 80 percent to 95 percent from calculation baseline. We include these compliance ranges in Monte Carlo analysis. We report a compliance benefit range that estimates benefits ranging from minimum compliance (60 percent entrainment and 80 percent impingement mortality reduction) to maximum compliance (90 percent entrainment and 95 percent impingement mortality reduction).

# Appendix C

## Life History Parameters

## Table C.1
## Blackeye Goby
## (Transferred from "Gobies" of Northern California Case Study, Table 2-11: Based on Blackeye Goby)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 1.0000 | 0.000 | 0.00 | 0.00 | 1.0000 | 0 | 0.0000115 |
| Larvae | 2 | 0.0031 | 5.766 | 0.00 | 5.77 | 0.0062 | 0 | 0.0000190 |
| Juvenile | 3 | 0.4185 | 0.871 | 0.00 | 0.87 | 0.5901 | 0 | 0.0001690 |
| Age 1 | 4 | 0.3329 | 1.100 | 0.00 | 1.10 | 0.4995 | 0 | 0.0019400 |
| Age 2 | 5 | 0.3329 | 1.100 | 0.000 | 1.10 | 0.4995 | 0 | 0.0041400 |
| Age 3 | 6 | 0.3329 | 1.100 | 0.000 | 1.10 | 0.4995 | 0 | 0.0076300 |
| Age 4 | 7 | 0.3329 | 1.100 | 0.000 | 1.10 | 0.4995 | 0 | 0.0310000 |
| Age 5 | 8 | 0.3329 | 1.100 | 0.000 | 1.10 | 0.4995 | 0 | 0.0810000 |

## Table C.2
## Blue/KGB Rockfish Complex (entrainment)/Rockfish (impingement) (Transferred from "Rockfish" of Northern California Case Study, Table 2-17: Based on Blue Rockfish)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Larvae | 1 | 0.0024 | 6.040 | 0.00 | 6.04 | 0.0048 | 0 | 0.000181 |
| Juvenile | 2 | 0.0013 | 6.650 | 0.00 | 6.65 | 0.0026 | 0 | 0.007600 |
| Age 1 | 3 | 0.8065 | 0.215 | 0.00 | 0.22 | 0.8929 | 0 | 0.044400 |
| Age 2 | 4 | 0.8065 | 0.215 | 0.00 | 0.22 | 0.8929 | 0 | 0.150000 |
| Age 3 | 5 | 0.7703 | 0.261 | 0.00 | 0.26 | 0.8702 | 0 | 0.308000 |
| Age 4 | 6 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 0.25 | 0.458000 |
| Age 5 | 7 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 0.5 | 0.689000 |
| Age 6 | 8 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 0.75 | 0.878000 |
| Age 7 | 9 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.050000 |
| Age 8 | 10 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.210000 |
| Age 9 | 11 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.340000 |
| Age 10 | 12 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.460000 |
| Age 11 | 13 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.550000 |
| Age 12 | 14 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.630000 |
| Age 13 | 15 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.700000 |
| Age 14 | 16 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.750000 |
| Age 15 | 17 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.800000 |
| Age 16 | 18 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.830000 |
| Age 17 | 19 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.860000 |
| Age 18 | 20 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.880000 |
| Age 19 | 21 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.900000 |
| Age 20 | 22 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.920000 |
| Age 21 | 23 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.930000 |
| Age 22 | 24 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.940000 |
| Age 23 | 25 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.950000 |
| Age 24 | 26 | 0.7703 | 0.131 | 0.13 | 0.26 | 0.8702 | 1 | 1.950000 |

## Table C.3
## Slender/Brown Rock Crab
## (Transferred from "Rock Crab" of Northern California Case Study, Table 2-16: Based on Brown Rock Crab)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 1.0000 | 0.000 | 0.000 | 0.00 | 1.0000 | 0 | 0.000000151 |
| Zoea. 1 | 2 | 0.2060 | 1.580 | 0.000 | 1.58 | 0.3416 | 0 | 0.000027900 |
| Zoea. 2 | 3 | 0.3875 | 0.948 | 0.000 | 0.95 | 0.5586 | 0 | 0.000155000 |
| Zoea. 3 | 4 | 0.3875 | 0.948 | 0.000 | 0.95 | 0.5586 | 0 | 0.000445000 |
| Zoea. 4 | 5 | 0.3875 | 0.948 | 0.000 | 0.95 | 0.5586 | 0 | 0.000956000 |
| Zoea. 5 | 6 | 0.2837 | 1.260 | 0.000 | 1.26 | 0.4419 | 0 | 0.000059800 |
| Megalopae | 7 | 0.0993 | 2.310 | 0.000 | 2.31 | 0.1806 | 0 | 0.000134000 |
| Age 0/Juvenile | 8 | 0.0880 | 2.430 | 0.000 | 2.43 | 0.1618 | 0 | 0.000019200 |
| Age 1 | 9 | 0.0880 | 2.430 | 0.000 | 2.43 | 0.1618 | 0 | 0.289000000 |
| Age 2 | 10 | 0.0880 | 2.430 | 0.000 | 2.43 | 0.1618 | 0 | 0.654000000 |
| Age 3 | 11 | 0.0880 | 2.430 | 0.000 | 2.43 | 0.1618 | 0 | 1.260000000 |
| Age 4 | 12 | 0.0880 | 1.820 | 0.610 | 2.43 | 0.1618 | 0.5 | 1.970000000 |
| Age 5 | 13 | 0.0880 | 1.820 | 0.610 | 2.43 | 0.1618 | 1 | 2.550000000 |
| Age 6 | 14 | 0.0880 | 1.820 | 0.610 | 2.43 | 0.1618 | 1 | 3.000000000 |

# Table C.4
## Cabezon
## (Northern California Case Study, Table 2-4)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.7498 | 0.288 | 0.000 | 0.288 | 0.8570 | 0 | 0.00000043 |
| Larvae | 2 | 0.0025 | 6.000 | 0.000 | 6.000 | 0.0049 | 0 | 0.00060500 |
| Juvenile | 3 | 0.0014 | 6.600 | 0.000 | 6.600 | 0.0027 | 0 | 0.00825000 |
| Age 1 | 4 | 0.8659 | 0.144 | 0.000 | 0.144 | 0.9281 | 0 | 0.16900000 |
| Age 2 | 5 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 0.5 | 1.06000000 |
| Age 3 | 6 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 3.26000000 |
| Age 4 | 7 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 4.72000000 |
| Age 5 | 8 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 5.30000000 |
| Age 6 | 9 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 6.13000000 |
| Age 7 | 10 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 6.78000000 |
| Age 8 | 11 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 7.37000000 |
| Age 9 | 12 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 8.76000000 |
| Age 10 | 13 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 9.23000000 |
| Age 11 | 14 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 10.50000000 |
| Age 12 | 15 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 12.00000000 |
| Age 13 | 16 | 0.7498 | 0.144 | 0.144 | 0.288 | 0.8570 | 1 | 13.70000000 |

## Table C.5
## California Halibut
## (Northern California Case Study, Table 2-5)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.8001 | 0.223 | 0.000 | 0.22 | 0.8890 | 0 | 0.000000548 |
| Larvae | 2 | 0.0015 | 6.500 | 0.000 | 6.50 | 0.0030 | 0 | 0.000004440 |
| Juvenile | 3 | 0.2187 | 1.520 | 0.000 | 1.52 | 0.3589 | 0 | 0.017000000 |
| Age 1 | 4 | 0.8353 | 0.180 | 0.000 | 0.18 | 0.9102 | 0 | 0.130000000 |
| Age 2 | 5 | 0.8353 | 0.180 | 0.000 | 0.18 | 0.9102 | 0 | 0.739000000 |
| Age 3 | 6 | 0.8353 | 0.180 | 0.000 | 0.18 | 0.9102 | 0 | 1.940000000 |
| Age 4 | 7 | 0.8353 | 0.180 | 0.000 | 0.18 | 0.9102 | 0 | 3.870000000 |
| Age 5 | 8 | 0.8353 | 0.180 | 0.000 | 0.18 | 0.9102 | 0 | 6.210000000 |
| Age 6 | 9 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 8.890000000 |
| Age 7 | 10 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 12.200000000 |
| Age 8 | 11 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 15.300000000 |
| Age 9 | 12 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 18.900000000 |
| Age 10 | 13 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 21.300000000 |
| Age 11 | 14 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 23.800000000 |
| Age 12 | 15 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 26.600000000 |
| Age 13 | 16 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 28.600000000 |
| Age 14 | 17 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 30.700000000 |
| Age 15 | 18 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 33.000000000 |
| Age 16 | 19 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 35.300000000 |
| Age 17 | 20 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 37.700000000 |
| Age 18 | 21 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 40.200000000 |
| Age 19 | 22 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 42.900000000 |
| Age 20 | 23 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 45.700000000 |
| Age 21 | 24 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 48.500000000 |
| Age 22 | 25 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 51.500000000 |
| Age 23 | 26 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 54.700000000 |
| Age 24 | 27 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 57.900000000 |
| Age 25 | 28 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 61.300000000 |
| Age 26 | 29 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 64.800000000 |
| Age 27 | 30 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 68.400000000 |
| Age 28 | 31 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 72.200000000 |
| Age 29 | 32 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 76.100000000 |
| Age 30 | 33 | 0.5599 | 0.180 | 0.400 | 0.58 | 0.7179 | 1 | 80.100000000 |

## Table C.6
## Clinid Kelpfishes (entrainment)/Kelpfish (impingement)
## (Transferred from "Other Forage Species" of California Regional Study, Table B1-39)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.3535 | 1.04 | 0.00 | 1.04 | 0.5223 | 0 | 0.0000000186 |
| Larvae | 2 | 0.0005 | 7.70 | 0.00 | 7.70 | 0.0009 | 0 | 0.0000015800 |
| Juvenile | 3 | 0.2753 | 1.29 | 0.00 | 1.29 | 0.4317 | 0 | 0.0004810000 |
| Age 1 | 4 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0038100000 |
| Age 2 | 5 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0049600000 |
| Age 3 | 6 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0050500000 |

## Table C.7
## Gunnell
## (Transferred from "Other Forage Fish" of California Regional Study, Table B1-39)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.3535 | 1.04 | 0.000 | 1.04 | 0.5223 | 0 | 0.0000000186 |
| Larvae | 2 | 0.0005 | 7.70 | 0.000 | 7.70 | 0.0009 | 0 | 0.0000015800 |
| Juvenile | 3 | 0.2753 | 1.29 | 0.000 | 1.29 | 0.4317 | 0 | 0.0004810000 |
| Age 1 | 4 | 0.1979 | 1.62 | 0.000 | 1.62 | 0.3304 | 0 | 0.0038100000 |
| Age 2 | 5 | 0.1979 | 1.62 | 0.000 | 1.62 | 0.3304 | 0 | 0.0049600000 |
| Age 3 | 6 | 0.1979 | 1.62 | 0.000 | 1.62 | 0.3304 | 0 | 0.0050500000 |

## Table C.8
## Monkeyface Prickleback
## (Transferred from "Other Forage Fish" of California Regional Study, Table B1-39)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(−Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.3535 | 1.04 | 0.00 | 1.04 | 0.5223 | 0 | 0.0000000186 |
| Larvae | 2 | 0.0005 | 7.70 | 0.00 | 7.70 | 0.0009 | 0 | 0.0000015800 |
| Juvenile | 3 | 0.2753 | 1.29 | 0.00 | 1.29 | 0.4317 | 0 | 0.0004810000 |
| Age 1 | 4 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0038100000 |
| Age 2 | 5 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0049600000 |
| Age 3 | 6 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0050500000 |

## Table C.9
## Northern Anchovy
## (Transferred from "Anchovies" of Northern California Case Study, Table 2-1: Based on Northern Anchovy)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(−Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.5122 | 0.669 | 0.00 | 0.669 | 0.6774 | 0 | 0.00000138 |
| Larvae | 2 | 0.0003 | 7.990 | 0.00 | 7.990 | 0.0007 | 0 | 0.00110000 |
| Juvenile | 3 | 0.1200 | 2.120 | 0.00 | 2.120 | 0.2143 | 0 | 0.02200000 |
| Age 1 | 4 | 0.4819 | 0.700 | 0.03 | 0.730 | 0.6504 | 0.5 | 0.04080000 |
| Age 2 | 5 | 0.4819 | 0.700 | 0.03 | 0.730 | 0.6504 | 1 | 0.05290000 |
| Age 3 | 6 | 0.4819 | 0.700 | 0.03 | 0.730 | 0.6504 | 1 | 0.06090000 |
| Age 4 | 7 | 0.4819 | 0.700 | 0.03 | 0.730 | 0.6504 | 1 | 0.06840000 |
| Age 5 | 8 | 0.4819 | 0.700 | 0.03 | 0.730 | 0.6504 | 1 | 0.07630000 |
| Age 6 | 9 | 0.4819 | 0.700 | 0.03 | 0.730 | 0.6504 | 1 | 0.07890000 |

## Table C.10
## Pacific Sardine
## (Transferred from "Herrings" of Northern California Case Study, Table 2-12: Based on Pacific Herring)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.7945 | 0.230 | 0.00 | 0.23 | 0.8855 | 0 | 0.0000039 |
| Larvae | 2 | 0.0100 | 4.610 | 0.00 | 4.61 | 0.0197 | 0 | 0.0000609 |
| Juvenile | 3 | 0.4805 | 0.693 | 0.04 | 0.73 | 0.6491 | 0 | 0.0126000 |
| Age 1 | 4 | 0.5102 | 0.473 | 0.20 | 0.67 | 0.6757 | 0 | 0.0408000 |
| Age 2 | 5 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 0.5 | 0.1280000 |
| Age 3 | 6 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.1670000 |
| Age 4 | 7 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.2110000 |
| Age 5 | 8 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.2580000 |
| Age 6 | 9 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.2880000 |
| Age 7 | 10 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.3300000 |
| Age 8 | 11 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.3450000 |
| Age 9 | 12 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.3530000 |
| Age 10 | 13 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.3640000 |
| Age 11 | 14 | 0.6225 | 0.274 | 0.20 | 0.47 | 0.7673 | 1 | 0.3750000 |

## Table C.11
## Painted Greenling (entrainment)/Greenling (impingement)
## (Transferred from "Other Forage Species" of California Regional Study, Table B1-39)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.3535 | 1.04 | 0.00 | 1.04 | 0.5223 | 0 | 0.0000000186 |
| Larvae | 2 | 0.0005 | 7.70 | 0.00 | 7.70 | 0.0009 | 0 | 0.0000015800 |
| Juvenile | 3 | 0.2753 | 1.29 | 0.00 | 1.29 | 0.4317 | 0 | 0.0004810000 |
| Age 1 | 4 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0038100000 |
| Age 2 | 5 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0049600000 |
| Age 3 | 6 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0050500000 |

## Table C.12
## Pipefish
## (Transferred from "Chain Pipefish" of North Atlantic Regional Study, Table C1-21)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.1003 | 2.300 | 0.000 | 2.30 | 0.1822 | 0 | 0.0000007730 |
| Larvae | 2 | 0.0907 | 2.400 | 0.000 | 2.40 | 0.1663 | 0 | 0.0000122000 |
| Juvenile | 3 | 0.4001 | 0.916 | 0.000 | 0.92 | 0.5715 | 0 | 0.0078500000 |
| Age 1 | 4 | 0.4724 | 0.750 | 0.000 | 0.75 | 0.6416 | 0 | 0.0151000000 |
| Age 2 | 5 | 0.4724 | 0.750 | 0.000 | 0.75 | 0.6416 | 0 | 0.0180000000 |
| Age 3 | 6 | 0.4724 | 0.750 | 0.000 | 0.75 | 0.6416 | 0 | 0.0212000000 |
| Age 4 | 7 | 0.4724 | 0.750 | 0.000 | 0.75 | 0.6416 | 0 | 0.0247000000 |
| Age 5 | 8 | 0.4724 | 0.750 | 0.000 | 0.75 | 0.6416 | 0 | 0.0285000000 |

## Table C.13
## Plainfin Midshipman
## (Transferred from "Other Forage Species" of California Regional Study, Table B1-39)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.3535 | 1.04 | 0.00 | 1.04 | 0.5223 | 0 | 0.0000000186 |
| Larvae | 2 | 0.0005 | 7.70 | 0.00 | 7.70 | 0.0009 | 0 | 0.0000015800 |
| Juvenile | 3 | 0.2753 | 1.29 | 0.00 | 1.29 | 0.4317 | 0 | 0.0004810000 |
| Age 1 | 4 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0038100000 |
| Age 2 | 5 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0049600000 |
| Age 3 | 6 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0050500000 |

## Table C.14
## Smooth/Snubnose Sculpin (entrainment)/Sculpin (impingement)
## (Transferred from "Other Forage Fish" of California Regional Study, Table B1-39)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.3535 | 1.04 | 0.00 | 1.04 | 0.5223 | 0 | 0.0000000186 |
| Larvae | 2 | 0.0005 | 7.70 | 0.00 | 7.70 | 0.0009 | 0 | 0.0000015800 |
| Juvenile | 3 | 0.2753 | 1.29 | 0.00 | 1.29 | 0.4317 | 0 | 0.0004810000 |
| Age 1 | 4 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0038100000 |
| Age 2 | 5 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0049600000 |
| Age 3 | 6 | 0.1979 | 1.62 | 0.00 | 1.62 | 0.3304 | 0 | 0.0050500000 |

## Table C.15
## Sole
## (Transferred from "Flounders" of California Regional Study, Table B1-15)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Eggs | 1 | 0.8001 | 0.223 | 0.000 | 0.22 | 0.8890 | 0 | 0.00000030300 |
| Larvae | 2 | 0.0019 | 6.280 | 0.000 | 6.28 | 0.0037 | 0 | 0.00121000000 |
| Juvenile | 3 | 0.3198 | 1.140 | 0.000 | 1.14 | 0.4846 | 0 | 0.00882000000 |
| Age 1 | 4 | 0.5472 | 0.363 | 0.240 | 0.60 | 0.7073 | 0.5 | 0.06720000000 |
| Age 2 | 5 | 0.3399 | 0.649 | 0.430 | 1.08 | 0.5074 | 1 | 0.22600000000 |
| Age 3 | 6 | 0.2859 | 0.752 | 0.500 | 1.25 | 0.4447 | 1 | 0.55300000000 |
| Age 4 | 7 | 0.2859 | 0.752 | 0.500 | 1.25 | 0.4447 | 1 | 1.13000000000 |

## Table C.16
## Speckled/Pacific Sanddabs (entrainment)/Sanddab (impingement)
## (Transferred from "Flounders" of Northern California Case Study, Table 2-10: Based on Speckled Sanddab)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.8001 | 0.223 | 0.000 | 0.223 | 0.8890 | 0 | 0.00000030 |
| Larvae | 2 | 0.0019 | 6.280 | 0.000 | 6.280 | 0.0037 | 0 | 0.00121000 |
| Juvenile | 3 | 0.3198 | 1.140 | 0.000 | 1.140 | 0.4846 | 0 | 0.00882000 |
| Age 1 | 4 | 0.5461 | 0.363 | 0.242 | 0.605 | 0.7064 | 0.5 | 0.06720000 |
| Age 2 | 5 | 0.3393 | 0.649 | 0.432 | 1.081 | 0.5066 | 1 | 0.22600000 |
| Age 3 | 6 | 0.2856 | 0.752 | 0.501 | 1.253 | 0.4444 | 1 | 0.55300000 |
| Age 4 | 7 | 0.2856 | 0.752 | 0.501 | 1.253 | 0.4444 | 1 | 1.13000000 |

### Table C.17
### Surfperches
### (Transferred from "Surfperches" of Northern California Case Study, Table 2-23: Based on Walleye Surfperch)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Juvenile | 1 | 0.5712 | 0.560 | 0.000 | 0.56 | 0.7271 | 0 | 0.0044300 |
| Age 1 | 2 | 0.7558 | 0.280 | 0.000 | 0.28 | 0.8609 | 0 | 0.0429000 |
| Age 2 | 3 | 0.5712 | 0.280 | 0.280 | 0.56 | 0.7271 | 0.5 | 0.1250000 |
| Age 3 | 4 | 0.5712 | 0.280 | 0.280 | 0.56 | 0.7271 | 1 | 0.2030000 |
| Age 4 | 5 | 0.5712 | 0.280 | 0.280 | 0.56 | 0.7271 | 1 | 0.2610000 |
| Age 5 | 6 | 0.5712 | 0.280 | 0.280 | 0.56 | 0.7271 | 1 | 0.3000000 |
| Age 6 | 7 | 0.5712 | 0.280 | 0.280 | 0.56 | 0.7271 | 1 | 0.3240000 |

### Table C.18
### White Croaker (entrainment)/Queenfish (impingement)
### (Transferred from "Drums/Croakers" of Northern California Case Study, Table 2-8: Based on White Croaker)

| Life Stage | Life Stage Sequence | Survival by Stage Fraction (S=exp(–Z)) | Natural Mortality Rate (M) | Fishing Mortality Rate (F) | Total Mortality Rate (Z) | Adjusted S | Fraction Vulnerable to Fishery | Weight (lb.) |
|---|---|---|---|---|---|---|---|---|
| Egg | 1 | 0.6065 | 0.500 | 0.000 | 0.5 | 0.7551 | 0 | 0.000000722 |
| Larvae | 2 | 0.0100 | 4.610 | 0.000 | 4.6 | 0.0197 | 0 | 0.000004640 |
| Juvenile | 3 | 0.0000 | 13.800 | 0.000 | 13.8 | 0.0000 | 0 | 0.000212000 |
| Age 1 | 4 | 0.6570 | 0.420 | 0.000 | 0.4 | 0.7930 | 0 | 0.120000000 |
| Age 2 | 5 | 0.6570 | 0.420 | 0.000 | 0.4 | 0.7930 | 0 | 0.156000000 |
| Age 3 | 6 | 0.7342 | 0.210 | 0.099 | 0.3 | 0.8467 | 0.5 | 0.195000000 |
| Age 4 | 7 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.239000000 |
| Age 5 | 8 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.287000000 |
| Age 6 | 9 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.340000000 |
| Age 7 | 10 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.398000000 |
| Age 8 | 11 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.458000000 |
| Age 9 | 12 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.519000000 |
| Age 10 | 13 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.584000000 |
| Age 11 | 14 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.648000000 |
| Age 12 | 15 | 0.6570 | 0.210 | 0.210 | 0.4 | 0.7930 | 1 | 0.723000000 |