ESTIMATION OF POTENTIAL ECONOMIC BENEFITS OF COOLING TOWER INSTALLATION AT THE DIABLO CANYON POWER PLANT

Final Draft

Prepared for:

Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94105

Prepared by:

ASA Analysis & Communication, Inc.
291 County Route 62
New Hampton, NY 10958

and

Ivar Strand
Professor Emeritus
Department of Agricultural and Resource Economics
2200 Symons Hall
University of Maryland
College Park, MD 20742-5535

April 2003

1. INTRODUCTION

The withdrawal of waters for cooling purposes, including at electric generating facilities, is regulated under Section 316(b) of the Clean Water Act. These cooling water withdrawals are regulated as part of the National Pollutant Discharge Elimination System (NPDES) permitting process administered by the United States Environmental Protection Agency (USEPA). For many states, including California, the administration of NPDES permitting has been delegated to the State. In the late 1970s, USEPA issued regulations relative to §316(b). However, these were challenged on procedural grounds and subsequently withdrawn. On 28 February 2002, the USEPA again proposed regulations for addressing §316(b) requirements (Federal Register 67(69) 9 April 2002). On 19 March 2003, USEPA released a Notice of Data Availability (NODA) regarding these proposed regulations wherein they provide additional thoughts on their economic benefits assessment approach and request additional public comment. USEPA will review all relevant information resulting from this NODA and final regulations are scheduled to be promulgated by 16 February 2004.

As currently proposed, these regulations call for large existing cooling water intakes, including most electric generating facilities, to meet specified target reductions in annual losses resulting from the entrainment and impingement of aquatic organisms. The magnitude of the proposed reduction targets vary depending on the waterbody type used as the source of the cooling water withdrawals. These reductions are to be met through a combination of intake and operational modifications, or through environmental enhancements that can offset the existing losses. However, USEPA also recognized that it was neither appropriate nor prudent to require meeting the proposed reduction targets at each and every cooling water intake. Consequently, they included provisions that allow an existing facility to meet the proposed regulations without modifying the intake or plant operations. Under this option, the owner or operator of the facility would need to demonstrate that either:

- The costs of compliance would be significantly greater than the cost considered in establishing the performance standards: or,

- The costs of compliance would be significantly greater than the benefits of compliance.

Inclusion of these two provisions make it clear that USEPA intended to impose substantial cost burdens only on those facilities where the cost of meeting the proposed performance standards are economically justifiable given the expected biological benefits accrued through reductions in entrainment and impingement. As part of developing these proposed regulations, USEPA prepared extensive supporting documents including case studies wherein they propose methods to estimate the economic benefits that can arise from reductions in entrainment and impingement losses at cooling water intakes (USEPA 2002; 2003).

In March 2000, Pacific Gas & Electric Company (PG&E) submitted a §316(b) Demonstration for the Diablo Canyon Power Plant (DCPP) (Tenera 2000) to the Central Coast Regional Water Quality Control Board (RWQCB), the delegated NPDES regulatory authority. The data collection and analytical methods upon which this Demonstration is based were reviewed and approved by the Entrainment Technical Work Group (ETWG). The ETWG was assembled by the RWQCB and composed of PG&E and their consultants, RWQCB and their consultants, a consultant for the League for Coastal Protection, the California Department of Fish and Game, and the USEPA. The ETWG oversaw study design, data collection and analysis on this project. Using the results of these efforts, PG&E prepared the DCPP Demonstration.

This Demonstration, which was completed well prior to the release of the currently proposed §316(b) regulations by the USEPA, provides estimates of entrainment and impingement losses resulting from cooling water withdrawals at DCPP and includes an assessment of the potential population-level consequences of these losses. Based on this assessment, the Demonstration concluded that the DCPP cooling water intake system is not causing widespread or long-term population level effects on any of the aquatic species that were the focus of the assessment (Tenera 2000). In addition, this Demonstration provides a review of potential intake alternatives that could be considered to reduce the magnitude of entrainment and impingement losses. This review concluded that, although no intake alternatives are necessary to reduce adverse environmental impacts, only one, closed-cycle cooling towers with saltwater makeup water, was even technically feasible at this site. The estimated cost (Net Present Value) for this intake alternative was estimated as $503,000,000. In a subsequent assessment conducted for the Central Coast Regional Water Quality Control Board, Tetra Tech (2002) estimated the Net Present Value of mechanical draft cooling towers at DCPP as $1.3 billion.

The purpose of this report is to provide estimates of the economic benefits of reductions in entrainment losses that could arise from installation of cooling towers at DCPP. This report focuses on the same target aquatic species and should be considered supplemental to the DCPP §316(b) Demonstration previously submitted. The evaluation methods used in this report are consistent with that described in USEPA (2002, 2003) and draw on much of the biological information presented in the Demonstration (Tenera 2000). The estimate of economic benefits contained herein can then be compared to estimated costs for cooling tower installation described above as part of next step in the evaluation process under proposed §316(b) regulations. An earlier draft of this report was review by Stratus Consulting, Inc., consultant to USEPA for the Phase 2 §316(b) Rulemaking (Stratus 2003). Stratus concluded that, "In general, ASA (2002) appears to have appropriately applied EPA's § 316(b) case study methods for evaluating entrainment losses and estimating economic benefits" (p. 6). Other specific comments provided by Stratus, were addressed in this final draft.

2. BACKGROUND

USEPA defines "economic benefits" under § 316(b) as the dollar value associated with the environmental changes that enhance the welfare of individual humans as a result of an alternative intake structure (USEPA 2002). For marketed goods, this value is equivalent to the sum of predicted changes in "consumer and producer surplus". Producer surplus is the difference between the price obtained for a good (e.g., fish) and the cost of producing that commodity. Consumer surplus is the difference between the perceived value of a good or service to the consumer and the cost of acquiring that good or service. Non-marketed goods, such as recreational fishing, normally require using indirect markets, such as travel, to infer their value. In addition to these two types of values that make direct use of the resource, there is a potential for changes to increase the welfare of individuals who do not directly use the resource. These benefits are considered nonuse benefits. Finally, some positive changes in resources such as forage fish might indirectly increase the use and nonuse values even though the resources themselves are not directly used. USEPA defines methods for measuring these four categories of benefit values relevant to § 316(b) regulations for existing facilities: market benefits, nonmarket direct use benefits, indirect use benefits, and nonuse benefits. Each of these four categories are described in more detail below:

1. <u>Market Benefits</u> - Market benefits refer to economic benefits that can be directly measured from data obtained in the marketplace. Changes in the magnitude of commercial fisheries harvest are the principal market benefit relevant to § 316(b) regulations. As reductions in entrainment and impingement losses at cooling water intake structures have the potential to increase stock size, and hence commercial harvests, positive market benefits can accrue from different intake alternatives. Owing to the availability of commercial fisheries economic data, market benefits can be estimated in a straightforward manner and usually offer the least controversial of the benefits categories to estimate.

2. <u>Nonmarket Direct Use Benefits</u> - As the title suggests, this category includes benefits derived through use of the resource that are not reflected in the market for the resource. Relative to §316(b) regulations, the most common benefit that would accrue from reductions in entrainment and impingement would be through increases in recreational fishing opportunities. Increased abundance of adult fish that could result from decreasing entrainment and impingement losses can lead to increased individual fisherman catch rates as well as an increase in the number of fishing trips by fishermen. Unfortunately, benefits from increased recreational use of the resource are not directly reflected in any marketplace. However, USEPA concluded that there is considerable literature to support valuing this benefit through estimation of a fisherman's "willingness to pay" for recreational opportunities. Thus, the nonmarket direct use benefit from recreational fishermen can be defined as the increase in the total "willingness to pay" across all fishermen resulting from any greater recreational opportunities due to reduction in entrainment and impingement losses.

3. <u>Indirect Use Benefits</u> - This category includes benefits that accrue to humans from the use of the resource indirectly. Relative to § 316(b) regulations, the most common indirect benefit that could result from reductions in entrainment and impingement would be through the consumption of aquatic organisms (forage species) by higher trophic levels. These higher trophic levels might include fish that support commercial and recreational fisheries, as well as birds that support enhanced bird watching opportunities.

4. <u>Nonuse Benefits</u> - This category, also known as passive use values, includes all benefits above and beyond any accrued through use of the resource. Most common cited nonuse benefits include bequest and existence values. USEPA acknowledges that these benefits

can only be estimated using contingent valuation methods on a site-specific basis. However to date, no such studies have been conducted. Further, USEPA concluded that such studies are unlikely to be conducted for specific facilities and were not feasible to complete given the time constraints for development of the §316(b) regulations. Recently, USEPA offered several alternative methods to estimate nonuse benefits for comment as part of the §316(b) rulemaking effort (USEPA 2003). However, the preferred USEPA approach will not be known until release of the final §316(b) rules for existing facilities scheduled for February 2004.

The total economic value of the biological benefits provided by reductions in entrainment and impingement is the sum of both the use and nonuse benefits. USEPA (2002, 2003) acknowledges that this value could also be calculated directly from stated preference studies. However, no such studies have been conducted relative to either DCPP or §316(b). In addition, USEPA (2002, 2003) discusses the possible use of habitat replacement costs as a means to estimate total economic value. However, USEPA (2003) acknowledges that habitat replacement costs do not provide estimates of "willingness to pay". Hence they do not provide a basis for a strict interpretation of the benefits of regulatory options (USEPA 2003). For this reason, habitat replacement costs were not used to estimate benefits of cooling tower installation at DCPP. As with the nonuse benefits category, USEPA is considering several alternative methods, however, their preferred approach will not be known until release of the final §316(b) rules in February 2004.

3. ESTIMATION OF BIOLOGICAL BENEFITS OF COOLING TOWERS

The first step in estimating economic benefits is to estimate the magnitude of reductions in entrainment and impingement loss that would results from cooling tower installation at DCPP. These estimates of absolute reductions in loss next need to be converted to a biological currency amenable to the estimation of economic values. It is important to recognize that the procedures used to estimate biological benefits for this assessment, assume that there are no changes in the natural mortality or reproduction rates in any of the species as a result of changes in stock abundance (i.e., density). Such density-dependent changes are believed to operate in most animal populations and serve to regulate overall abundance within a range supportable by available resources. Unfortunately, estimation of the magnitude of potential density-dependent changes is beyond the current state-of-the-science for most of the species considered in this assessment. However to the extent they exist, it is likely that the procedures used in this assessment overestimate the actual biological benefits of cooling tower installation at DCPP.

The DCPP §316(b) Demonstration provides estimates of the entrainment losses expected under normal operations for fourteen target fish taxa (Table 1). These taxa comprised approximately 70 percent of the total number of fish larvae collected in entrainment sampling at DCPP. These taxa were selected by the Entrainment Technical Working Group that over saw the data collection and resulting assessments that were a critical part of the DCPP §316(b) Demonstration (Tenera 2000). The DCPP §316(b) Demonstration also provides estimates of entrainment losses for two species of crab, the brown rock crab (*Cancer antennarius*) and the slender crab (*Cancer* *gracilis*), however neither were included in this analysis.[1] No other species of any significant commercial or recreational importance are expected to be entrained at DCPP in biologically meaningful numbers. This is identical to the approach used in USEPA (2002, 2003). To date, all USEPA efforts related to the Phase 2 §316(b) rulemakeing have focused on fish, and to a lesser extent shellfish with significant commercial and/or recreational importance. The presumption of this approach is that all other species either entrained or impinged are either not economically significant or are addressed as part of the nonuse benefit category.

For each of the target taxa listed above, estimates of the entrainment losses of larvae were calculated for three different analysis periods based on intensive sampling of the cooling water intake:

Period 1 23 October 1996 – 30 September 1997

Period 2 01 October 1997 – 30 September 1998

Period 3 01 July 1997 – 30 June 1998.

These three periods were selected as the basis for impact assessment in the DCPP §316(b) Demonstration (Tenera 2000). Estimates of the number of larvae lost to entrainment at DCPP were then converted to an equivalent number of adults using one of two equivalent loss models, the Fecundity Hindcast model or the Adult Equivalent Loss model (Tenera 2000) for six of the target taxa that have commercial and/or recreational importance, Pacific sardine, northern anchovy, blue rockfish complex, KGB rockfish complex, white croaker, and sanddabs. The magnitude of impingement loss at DCPP was considered to be inconsequential and, hence, was not considered further in the impact assessment.

Installation of cooling towers at DCPP is expected to result in an 80 percent reduction in cooling water flow at this facility (Tenera 2000). Hence, it is reasonable to assume that there would be a coincident 80 percent reduction in the number of larvae of each target taxa entrained at DCPP and number of equivalent adults. Following this logic, estimates of the absolute reductions in equivalent adults expected with the installation of cooling towers at DCPP for each analysis period and for each target taxa were calculated and are presented in Table 2. Also included in this table are estimates of the mean weight of individuals harvested in the recreational fishery. These numbers of equivalent adults can then be used to estimate the economic value of the reductions in entrainment and impingement from the perspective of commercial and recreational use. For the remaining two species with commercial and/or recreational importance, cabezon and California halibut, economic values were directly estimated as described in the next section.

The remaining six target taxa, painted greenling, smoothhead sculpin, snubnose sculpin, monkeyface prickleback, clinid kelpfishes, and blackeye goby, have little or no direct commercial or recreational importance to man. For this analysis, these taxa were treated as

[1] Tenera (2000) estimates the total lost revenue to the fishermen as $1,760 to $2,040 per year for entrainment of brown rock crab. No similar estimate was presented for slender crab. Since the economic parameters for the crab fishery are not available, estimation of market benefits of cooling tower installation on crabs was not conducted.

forage with their primary value to man being as food for other trophic levels. For this group of species, the amount of future production that could have been expected from entrained larvae was estimated using the Production Foregone Model (PFM). The PFM was originally developed by Rago (1984) and further expanded and modified to a length-specific basis by Jensen et al (1988). The PFM was used by USEPA (2002) as their trophic transfer model to estimate the biomass at secondary or tertiary trophic levels that could be supported by individuals entrained or impinged. These equivalent higher trophic level biological benefits can then be converted to an economic benefit by using the methods previously described for commercial and recreational fish.

For this assessment, the PFM was implemented on a length-specific basis following the approach of Jensen et al (1988). This is because ages of the entrained larvae are unavailable and length was used as a surrogate for age. Using this method production foregone for each of the forage species as follows:

$$P_i = \sum_{i=i}^{L} \frac{G_i N_i W_i \left(e^{(G_i - Z_i)} - 1\right)}{G_i - Z_i}$$

where:

P	=	Total production foregone
P_i	=	Production foregone for individual entrained in length interval (i)
G_i	=	Instantaneous growth rate in weight for length interval (i)
N_i	=	Number entrained during length interval (i) (Note: for each subsequent length interval, Ni is reduced by the total survival rate (e^{-Z}).
W_i	=	Average weight of individuals in length interval (i)
Z_i	=	Average instantaneous mortality rate for length interval (i)
m	=	Total number of length interval (i) entrained.
L	=	Final length interval

The total production foregone (P) is then found by summing over all the length intervals that are entrained:

$$P = \sum_{i=1}^{m} P_i$$

This approach is consistent with that used in USEPA (2002). Estimates of the number of each length interval (i) that would not be entrained with the installation of cooling towers were determined for each analysis period and target forage taxa by multiplying the estimated numbers entrained by the fraction of the total entrainment that was of each length interval. This process divided the absolute reductions in entrainment from cooling tower installation into discrete length intervals based on observed length distributions of those entrained. Values for the remaining input parameters to the PFM (G_i, W_i, and Z_i) were estimated from available life history information for each species as detailed in Appendix A.

Estimates of the total production of each target forage fish species were then converted to an equivalent biomass of commercial and recreational species by using the trophic transfer method of USEPA (2002). In their approach, USEPA assumed that 20 percent of the total production would be converted to commercial and recreational fish biomass through a one-step trophic transfer at an average conversion efficiency of 9 percent. The remaining 80 percent would be transferred through a two-step process with an average effective conversion efficiency of 0.9 percent. USEPA has recently indicated they are considering using a single-step process with a transfer efficiency of 0.20. Both assumptions were evaluated in producing the upper and lower bounds for indirect benefits. These transfer assumptions were then used to convert the expected reduction in total forage species production foregone that would result from cooling tower installation at DCPP to an equivalent reduction in the biomass of commercial and/or recreational species that could be supported by this production foregone. Finally, the expected biomass of commercial and/or recreational species was converted to an equivalent number of adults by assuming that all the biomass was converted to California halibut with an average weight of 3.5 kg. Estimates of the equivalent number of predators supportable by this production that could result from the installation of cooling towers at DCPP are presented in Table 3.

4. ESTIMATION OF ECONOMIC BENEFITS OF COOLING TOWERS

Economic benefits (measured in year 2001 $) of cooling towers at DCPP were estimated for each of the four categories following methods suggested in USEPA (2002) as discussed below:

Market Benefits (Commercial Fishing)

The estimation of market benefits involves estimation of the increase in commercial catch that would occur if closed-cycle cooling were installed, and the value that would be added as producer and consumer surpluses resulting from that catch. For taxa with equivalent adult loss estimates, the losses are assumed to be reduced by 80 percent as a result of cooling tower installation. The resulting increases in adult stocks are then assumed to be harvested at two total exploitation rates, 10 percent or 50 percent. These rates bracket the range of exploitation rates, both realized and recommended, for species harvested off the California coast that are listed at the Pacific States Marine Fisheries Commission (PSMFC) website. For this assessment, these rates were chosen as reasonable upper and lower bounds for exploitation of the commercial species addressed herein. (The lower exploitation rate was applied to the lower bound of equivalent adults, and the higher exploitation rate was applied to the upper bound.) The additional catch was then apportioned to the commercial and recreational fisheries according to the California coastal catches for the taxa from 1993-2001 estimated from the PacFin and RecFIN databases. For rockfish, data for all rockfish species combined were used for the apportionment and, due to recent changes in commercial regulations and catches, apportionments were also made on 1999-2001 data only. Finally, the increased commercial catch was multiplied by the mean price in the commercial fishery of this same time period (Table 4) to estimate the total equivalent revenue to the commercial fishermen that would be expected to occur with installation of cooling towers. For rockfish, mean price for 1999-2001 were also used. For cabezon and California halibut, which did not have equivalent adult loss estimates, the total revenue that would accrue to the commercial fishermen was calculated by apportioning the values estimated in Tenera (2000) by the same values used above (80 percent reduction, 10 percent or 50 percent exploitation). These revenue estimates were then divided by the mean price and commercial proportion to estimate the total increase in pounds harvested.

It is important to recognize that this increase in revenue is not equivalent to the total market benefits. To estimate total market benefits, two additional steps are required. The first step is to estimate the producer surplus to the commercial fisherman; that is, the amount of money remaining for the fishermen once the cost of obtaining these fish is removed. For this assessment, we use the approach of USEPA (2002) and assume that the costs of catching the fish are in range of 30 to 60 percent of the total revenue. Subsequently, USEPA (2003) revised this assumption to cost being 60 to 100 percent of total revenue. Following this assumption, the increased revenues estimated above were multiplied by 0.0 and 0.4 to estimate the lower and upper end of the range in increased producer surplus for DCPP. This producer surplus then represents the increased benefit to the individual commercial fishermen resulting from installation of cooling towers. However, the producer surplus is only one portion of the total economic benefits to society as a whole. Other benefits that can result from increased commercial harvests included economic surplus to wholesalers, processors, retailers, and consumers (USEPA 2002). Again following USEPA (2002) methodology, the producer surplus was assumed to be 22 percent of the total market benefit although this percent probably overestimates the change in consumer surplus. Hence, to estimate the total direct market benefits the producer surplus was divided by 0.22 (which is equivalent to multiplying by 4.55). Using this approach, the total increase in direct market benefits resulting from installation of cooling towers at DCPP is expected to be between $0 and $25,177 annually (Table 4).

<u>Non-Market Benefits (Recreational Fishing)</u>

Similar to the Market Benefit calculations, the increased stocks potentially arising from implementing closed-cycle cooling were calculated by determining the expected increased recreational catch and multiplying that catch by estimated values per fish. Estimation of per fish benefits is a difficult process that requires a benefit study, transfer process that used recreational benefit estimates made previously for Southern California and extrapolated to the Diablo Canyon analysis. For this study, the values of fish that are directly targeted by recreational fishing (rockfish and California halibut) were estimated to range from $5 to $25 per fish (Appendix B). Species that are rarely target species, but are caught incidentally, were valued at the average commercial value (Table 5). For cabezon and California halibut, the estimated increase in pounds harvested (Table 4) was converted to numbers by dividing by the mean weight. Total annual non-market benefits expected from cooling tower installation at DCPP are expected to range from $782 to $33,322 (Table 5).

<u>Indirect Use Benefits</u>

USEPA (2002) proposed two general methods to estimate the indirect value of forage species. The first involves conversion of the estimated increase in forage species to an equivalent amount of higher trophic level species. This is accomplished through the use of a trophic transfer model to estimate the transfer efficiency to secondary or tertiary trophic levels. For forage species that support higher-level species with commercial or recreational importance, the equivalent biological benefit at these higher trophic levels can be converted to an economic benefit by using the methods previously described for commercial and recreational fish.

The second method proposed by USEPA to estimate the indirect value of forage species entails use of cost of replacing the individuals through hatchery production. Hatchery replacement costs are derived from data compiled by the American Fisheries Society. These replacement costs per fish are then multiplied by the increase in the number of forage species resulting from the reductions in entrainment and impingement to estimate the total economic benefit from increases in forage species abundance. Unfortunately, as discussed by Strand (2002), the cost of production is a function of the difficulty of rearing and has nothing to do with the economic value of these species. In fact, the cost of production far exceeds the economic value in most cases. If this were not the case then hatchery production of these species would be commonplace. Hence, use of USEPA's second method to estimate indirect use benefits is not supportable (Strand 2002).

For this assessment, the economic evaluation of this benefit category was based on USEPA's first method, a trophic transfer model. Details of the trophic transfer calculations are described in Section 3 and Appendix A. For the economic assessment, we assume that an average of 284 to 2,256 predator fish would be supported by the reduction in production foregone resulting from installation of cooling towers at DCPP (Table 3). Further, we have conservatively assumed that all of reduction in the production foregone would be consumed by California halibut, one of the target species supporting important commercial and recreational fisheries. Following the logic used for this species under the market and non-market direct use benefit calculations, the total annual monetary benefit of reducing entrainment losses of target prey species through installation of cooling towers at DCPP would be expected to range from $504 to $20,006 through market benefits and $78 to $15,480 through non-market benefits. Hence, the total benefits for the installation of cooling towers at DCPP in the indirect use category is $582 to $35,487 per year (Table 6).

Non-Use Benefits

USEPA (2002) proposed three alternate means to estimate nonuse benefits. These include assignment based on use values, benefits transfer, and habitat replacement costs. As previously noted, USEPA is now considering several alternative methods (USEPA 2003). However, the acceptability of these methods has not be finally determined.

Under the first method, USEPA assumes that nonuse benefits are a fixed proportion of the total of the previous three benefits categories. Citing a paper from 1977 relative to water quality improvements, USEPA assumes that the nonuse benefits are 50 percent of the recreational fishing benefit. However, they acknowledge considerable uncertainty in this 50 percent "rule of thumb" and plan to revise this topic and reevaluate this method at some point in the future. However, "In the interim, the Agency will continue to apply the 50 percent rule for this proposed rule, acknowledging the limitations of the approach."

The benefits transfer method attempts to use information from other studies to assign a willingness-to-pay value to all nonuse values for a specific waterbody. However, USEPA appears to conclude that this method might prove difficult to apply relative to cooling water intake structures because there are no studies that directly address the problem. Information to assess non-use benefits using this method is not available for DCPP.

Under the habitat replacement costs methods, USEPA assumes that the nonuse benefit for a resource can be “scaled” by the cost of improving/replacing/enhancing habitat sufficient to generate the magnitude of the biological benefit expected from reducing entrainment and impingement losses. As support for this approach, USEPA cites the case of threatened and endangered species where “…the costs of restoration programs and various resource use restrictions indicate the revealed preference value of preserving the species” (USEPA 2002). Unfortunately, as with using hatchery replacement costs as a measure of forage species benefits, the costs of habitat replacement are merely costs and have little relationship to actual benefits (Strand 2002). How illogical this method is can be illustrated by showing that this method would assign the greatest benefit to cases where habitat restoration is most difficult and costly regardless of the biological benefits of the restoration. Further while the USEPA appears to follow a Natural Resource Damage Assessment (NRDA) process in this method, it is important to recognize that the circumstances are quite different. In NRDA, parties are required to restore the resource and HRC are a cost avoided. With cooling water intake structures, this is not the case. While habitat replacement and/or enhancement are clearly useful resource management tools and could have a role in offsetting cooling water intake losses, the monetary costs of such activities cannot be validly considered as equivalent to the economic benefit of mitigating entrainment and/or impingement losses. Hence for this reason, we do not use habitat replacement costs as a measure of benefits for DCPP.

For the purposes of this assessment, non-use benefits are estimated using the first method from USEPA (2002). Using this method, non-use benefits were assumed to be 50 percent of the recreational fishery benefits. Under this assumption non-use benefits would be expected range from $391 to $16,661 per year (Table 6).

5. TOTAL ECONOMIC BENEFITS

The total economic benefits that would accrue would be the sum of the component benefits described above. In addition, these benefits would accrue annually once cooling towers were completed and in-service, thus the temporal aspects of benefit generation must be considered. However, these benefits would not occur indefinitely, but would end when DCPP ceased operating since at that time entrainment through the present once-through cooling system would also cease. In order to weight properly benefits in the future against present-day costs, it is important to express both costs and benefits in the same monetary time frame. Thus the time series of future benefits were converted to net present value (NPV) in 2001 dollars:

$$NPV_t = \frac{B_t}{(1+r)^{t-t_0}}$$

where NPV_t = net present value of a benefit received in year t
B_t = monetary value of benefit received in year t
r = annual discount rate
t_0 = base year for calculation of net present value = 2001

The total value of the series of future benefits is then the sum of the individual benefits received after each is converted to Net Present Value:

$$NPV_{t_0} = \sum_t NPV_t$$

The series of total annual benefits expected due to implementing cooling towers at DCPP would range from $1,755 to $110,647 per year(Table 6).

To estimate the Net Present Value of the series of annual benefits it was assumed that the cooling towers would be in operation beginning in 2008. This is probably an underestimate of the amount of time it would take to design, obtain permits, construct, and tie-in cooling towers for DCPP. The use of cooling towers is assumed to end in 2023, the mean year of license expiration for the two DCPP units. For purposes of bounding the expected benefits, discount rates of 2 percent (applied to upper bound values) and 7 percent (applied to lower bound values) were used.

Under these assumptions, the Net Present Value (2001) of expected benefits to the target species from implementing closed cycle cooling at DCPP would range from $11,045 to $1,334,030 (Table 7). Since these target species represent approximately 70 percent of the total entrainment of fish larvae, it is reasonable to assume that the overall economic benefits could be estimated by dividing by 0.7 and, thus, range from 15,786 to 1,905,757. Thus, the costs of installing cooling towers at DCPP as estimated in Tenera (2000) would be from approximately 264 to more than 31,000 times the expected economic benefits from reduction in entrainment losses for all fish species over the life of the plant. Using the estimated cooling tower costs from Tetra Tech (2002), the costs-to-benefit ratios would be substantially higher.

REFERENCES

Jensen, A.L., Reider R.H., and Kovalak W.P.. 1988. Estimation of production forgone. N. Amer. J. Fish. Manage. 8:191-198.

Rago, P.J. 1984. Production foregone: An alternative method for assessing the consequences of fish entrainment and impingement at power plants and water intakes. Ecological Modeling. 24:79-111.

Strand, I. 2002. Review of Economic and Benefits Analysis of Proposed Phase II Regulations Associated with Section 316(b) of the Clean Water Act. Comments submitted to USEPA on behalf of the Electric Power Research Institute. 7 August.

Stratus Consulting, Inc. (2003) Review of PGE's Benefits Analysis for the Diablo Canyon Power Plant. Memo to Michael Thomas, California Central Coast Regional Water Quality Control Board, 22 January.

Tenera Environmental Services (Tenera). 2000. Diablo Canyon Power Plant 316(b) Demonstration Report. Prepared for Pacific Gas and Electric Company. March.

Tetra Tech, Inc. 2002. Evaluation of Cooling System Alternatives: Diablo Canyon Power Plant. Draft. Prepared for the California Regional Water Quality Control Board, Central Coastal Region. November.

United States Environmental Protection Agency (USEPA). 2002. Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule. Office of Water. EPA-821-R-02-002. February.

USEPA. 2003. National Pollutant Discharge Elimination System- Proposed Regulations to Establish Requirements for Cooling Tower Water Intake Structures at Phase II Existing Facilities: Notice of Data Availability. Office of Water. April.

TABLE 1 TARGET FISH SPECIES SELECTED FOR THE DCPP §316(b) DEMONSTRATION.

Common Name	Scientific Name
Pacific sardine	*Sardinops sagax*
Northern anchovy	*Engraulis mordax*
Blue rockfish complex[1]	*Sebastes* spp. V/*S. mystinus*
KGB rockfish complex[1]	*Sebastes* spp. V_De/V-D_
Painted greenling	*Oxylebius pictus*
Smoothhead sculpin	*Artedius lateralis*
Snubnose sculpin	*Orthonopias triacis*
Cabezon	*Scorpaenichthys marmoratus*
White croaker	*Genyonemus lineatus*
Monkeyface prickleback	*Cebidichthys violaceus*
Clinid kelpfishes	*Gibbonsia* spp.
Blackeye goby	*Coryphopterus nicholsi*
Sanddab	*Citharichthys* spp.
California halibut	*Paralichthys californicus*

[1] Rockfish larvae were categorized into two distinct pigmentation groups.

TABLE 2 ESTIMATES OF REDUCTION IN EQUIVALENT ADULT LOSSES FOR SIX TARGET FISH TAXA OF COMMERCIAL AND/OR RECREATIONAL IMPORTANCE WITH INSTALLATION OF COOLING TOWERS AT THE DIABLO CANYON POWER PLANT.

	Absolute Reduction in Equivalent Adults[1]			
Taxa	**Period 1 23 Oct 96 – 30 Sep 97**	**Period 2 01 Oct 97 – 30 Sep 98**	**Period 3 01 Jul 97 – 30 Jun 98**	**Mean Weight[2] (lb)**
Pacific sardine	2,104	5,600	5,600	0.18
Northern anchovy	34,560	96,000	96,000	0.13
Cabezon[3]				2.19
KGB rockfish complex	896	724	725	0.45
Blue rockfish complex	282	131	114	1.34
White croaker	8,176	11,808	12,000	1.09
Sanddab	1,896	409	1,752	0.48
California halibut[3]				8.07

[1] 80 percent of the estimated annual losses with once-through cooling
[2] Mean weight in recreational fishery 1993-2001.
[3] Estimates of equivalent adults not available.

TABLE 3 ESTIMATES OF REDUCTION IN LOSSES OF PREDATORY FISH (CALIFORNIA HALIBUT) AS A RESULT OF INCREASED ABUNDANCE OF SIX TARGET PREY FISH TAXA WITH INSTALLATION OF COOLING TOWERS AT THE DIABLO CANYON POWER PLANT.

Prey Taxa	Absolute Reduction in Equivalent Adults of Predator					
	One and Two-Step Transfers Transfer Efficiency = 0.09			One Step Transfer Transfer Efficiency = 0.20		
	Period 1 23 Oct 96 – 30 Sep 97	Period 2 01 Oct 97 – 30 Sep 98	Period 3 01 Jul 97 – 30 Jun 98	Period 1 23 Oct 96 – 30 Sep 97	Period 2 01 Oct 97 – 30 Sep 98	Period 3 01 Jul 97 – 30 Jun 98
Painted greenling	21	9	11	170	68	85
Smoothhead sculpin	1	3	3	9	25	26
Snubnose sculpin	2	2	2	17	14	17
Monkeyface prickleback	221	168	164	1,750	1,335	1,304
Clinid kelpfishes	48	78	114	379	617	903
Blackeye goby	2	2	2	17	15	17
Total	295	261	296	2,342	2,074	2,352
Mean	284			2,256		

TABLE 4 ESTIMATE OF ANNUAL MARKET DIRECT BENEFITS RESULTING FROM INSTALLATION OF CLOSED-CYCLE COOLING AT DIABLO CANYON POWER PLANT.

Taxa	Total Increased Harvest (lbs)		Percent Commercial[3]	Mean Price[4]	Increased Revenue to Fishermen ($)	
	Lower[1]	Upper[2]		$/lb	Lower	Upper
Pacific sardine	39	513	99.94	0.05	2	26
Northern anchovy	450	6,260	99.87	0.07	32	438
Cabezon	350	1,750	56.99		720	3,600
White croaker	529	3,886	56.21	0.65	193	1,420
Blue rockfish	15	190	16-32[5]	0.73-0.97[5]	2	59
KGB rockfish	79	486	16-32[5]	0.73-0.97[5]	9	151
Sanddabs	20	452	94.84	0.36	7	154
California halibut	8	6,618	45.10	2.68	10	8,000
Total	1,489	20,156			974	13,848
Multiplier for Producer Surplus					0. 0	0.4
Producer Surplus ($)					0	5,539
Producer Surplus as proportion of total Market Benefit					0.22	0.22
Total Market Benefit ($)					0	25,177

[1] Lower bound of equivalent adult loss x 80 percent x 10 percent exploitation; converted to weight.
[2] Upper bound of equivalent adult loss x 80 percent x 50 percent exploitation; converted to weight.
[3] Based on 1993-2001 data from PacFIN and RecFIN.
[4] Based on 1993-2001 data from PacFIN.
[5] Based on 1999-2001 data from PacFIN and RecFIN

TABLE 5 ESTIMATE OF ANNUAL NON-MARKET DIRECT BENEFITS RESULTING FROM INSTALLATION OF CLOSED-CYCLE COOLING AT DIABLO CANYON POWER PLANT.

Taxa	Total Increased Harvest (#s)		Percent Recreational[3]	Recreational Value ($/fish)[4]		Increased Benefit to Fishermen ($)	
	Lower[1]	Upper[2]		Lower	Upper	Lower	Upper
Pacific sardine	210	2,800	0.06	0.01	0.01	<1	<1
Northern anchovy	3,456	48,000	0.13	0.01	0.01	<1	1
Cabezon	160	798	43.01	5.00	25.00	343	8,579
White croaker	1,176	8,640	43.79	0.29	0.29	151	1,106
Blue rockfish	11	141	68[5]-84	5.00	25.00	39	2,965
KGB rockfish	72	448	68[5]-84	5.00	25.00	246	9,408
Sanddabs	41	948	5.16	0.17	0.17	<1	8
California halibut	1	820	54.90	5.00	25.00	3	11,255
Total	5,128	62,595				782	33,322

[1] Lower bound of equivalent adult loss x 80 percent x 10 percent exploitation.
[2] Upper bound of equivalent adult loss x 80 percent x 50 percent exploitation.
[3] Based on 1993-2001 data from PacFIN and RecFIN.
[4] Values are the commercial price per pound x mean recreational weight for Pacific sardine, northern anchovy, white croaker, and sanddabs based on 1993-2001 data from PacFIN and RecFIN.
[5] Based on 1999-2001 data from PacFIN and RecFIN

TABLE 6 SUMMARY OF MONETARY BENEFITS FOR 14 TARGET PREY FISH TAXA WITH INSTALLATION OF COOLING TOWERS AT THE DIABLO CANYON POWER PLANT.

Benefit Category	Annual Monetary Benefit ($)	
	Lower Bound	**Upper Bound**
Market Direct Use	0	25,177
Nonmarket Direct Use	782	33,322
Indirect Use	582	35,487
Non-Use	391	16,661
Total	1,755	110,647

TABLE 7 SUMMARY OF MONETARY BENEFITS FOR 14 TARGET PREY FISH TAXA WITH INSTALLATION OF COOLING TOWERS AT THE DIABLO CANYON POWER PLANT.

Year	Annual Benefits ($)		Net Present Value ($)	
	Lower	Upper	Lower[1]	Upper[2]
2001				
2002				
2003				
2004				
2005				
2006				
2007				
2008	1,755	110,647	1,093	96,325
2009	1,755	110,647	1,021	94,436
2010	1,755	110,647	954	92,585
2011	1,755	110,647	892	90,769
2012	1,755	110,647	834	88,989
2013	1,755	110,647	779	87,245
2014	1,755	110,647	728	85,534
2015	1,755	110,647	680	83,857
2016	1,755	110,647	636	82,212
2017	1,755	110,647	594	80,600
2018	1,755	110,647	555	79,020
2019	1,755	110,647	519	77,471
2020	1,755	110,647	485	75,952
2021	1,755	110,647	453	74,462
2022	1,755	110,647	424	73,002
2023	1,755	110,647	396	71,571
Total	28,074	1,770,354	11,045	1,334,030

[1] Assuming a 7 percent annual discount rate.
[2] Assuming a 2 percent annual discount rate.

TABLE 8 COMPARISON OF ESTIMATES OF COMMERCIAL REVENUE LOSSES FOR DCPP WITH USEPA ESTIMATES FOR THE NORTHERN CALIFORNIA REGION. (SOURCE: USEPA 2003, TABLES X-29 and X-30)

Taxa (DCPP / USEPA)	DCPP Economic Benefits Assessment			Northern California Losses due to Entrainment at Estuarine and Ocean Station		
	Estimated Increase in Commercial Catch (lbs)		Revenue per lb ($)	Lost Landings (lb)	Lost Revenue ($)	Revenue per lb ($)
	Lower	Upper				
Pacific Sardine	39	513	0.05	No Data	No Data	No Data
Northern Anchovy / Anchovies	450	6,252	0.07	533	43	0.08
Cabezon	199	997	3.61	204	667	3.27
White Croaker / Croakers[1]	297	2,185	0.65	105	60	0.57
Rockfish	15	216	0.74-0.98	253	140	0.55
Sanddabs / Flounders	18	429	0.36	619	191	0.31
California Halibut	4	2,985	2.68	3,892	9,768	2.51

[1] NODA indicated no losses due to entrainment, so impingement losses substituted to allow calculation of lost revenue per pound.

APPENDIX A
Input Parameters for Production Foregone Model

The Production Foregone Model used to convert losses of prey species to equivalent losses of predator species as part of the economic benefits assessment requires estimates for the following three parameters in addition to estimates of entrainment loss by length interval:

- Instantaneous mortality rate for each length interval (Z_i)
- Instantaneous growth rate for each length interval (G_i)
- Average weight of an individual for each length interval (W_i).

Values for these three parameters for each of the six prey species were developed for this assessment by following the four steps described below:

1. Determine expected lifetime growth curve. An overall growth curve (in length) was determined for each of the six prey species using a two-step process based on available biological information. First, the growth rate from hatching through the end of the larval period (settlement) was described using an exponential model:

$$L_t = L_0 e^{k_l t}$$

where:

L_t = Length in millimeters at time (t)
L_0 = Length in millimeters at hatch (t=0)
k_l = Instantaneous larval growth rate
t = Time in days

The value for k_l was estimated based on available information on the length at hatch and the average length and assumed age at the time of larval settlement.

For the juvenile and adults of each of the six prey species, growth was described using a Von Bertalanffy growth curve (Ricker 1975):

$$L_t = L_\infty \left(1 - e^{-k_o t}\right)$$

where:

L_t = Length in millimeters at time (t)
L_∞ = Maximum length of species in millimeters
k_o = Instantaneous growth rate of juvenile and older individuals
t = Time in days

The value for k_o was estimated based on information on the reported maximum length of the species and any length and age for juvenile and older individuals obtained from available sources.

Information used to estimate the two growth curves for each of the six prey species are in included on Table A-1.

2. Determine the time duration of each length interval. Using the growth curves estimated under step 2, the time required to reach the beginning of each 1-mm length interval was estimated as follows:

   for larvae:

$$t = \frac{\ln\left(\frac{L_t}{L_0}\right)}{k_l}$$

   for juvenile and older individuals:

$$t = -\frac{\ln\left(1 - \frac{L_t}{L_\infty}\right)}{k_o}.$$

   The duration for each length interval (i) was then estimated as the difference between the time to the beginning and the end of each interval:

$$d_i = t_{l+1} - t_l \ .$$

3. Estimate expected lifetime egg deposition for an adult female. Expected lifetime egg deposition is the total number of eggs an average female just entering the adult population can be expected to produce over the rest of her life. The total egg deposition is a function of adult mortality rates and the increase in fecundity with age demonstrated for most fish species. Unfortunately, the life history data necessary to directly estimate lifetime egg deposition are unavailable for any of the six prey species in this analysis. Instead, lifetime egg deposition for each species was approximated using the method presented in Tenera (2000):

$$\text{Lifetime Egg Deposition} = AF \times \frac{(ML - AM)}{2}$$

   Where:

AF	=	Estimated annual fecundity
ML	=	Maximum longevity in years
AM	=	Age at maturity in years.

Values used to estimate expected lifetime egg deposition for each species are presented in Table A-2.

4. <u>Estimate instantaneous mortality rate for each length interval.</u> Mortality for adult (i.e., mature) individuals of all prey species, except monkeyface prickleback, was assumed to be 50 percent per year. Each of these species is relatively small (< 200 mm) and this value is consistent with values reported for other fish species of similar sizes (refs). Monkeyface prickleback is a relatively long-lived species (up to 18 years) and reaches a much larger size (> 600 mm). Further, this species spends most of its life in well-protected areas under rocks and in shallow waters. Hence, it is reasonable to assume that this species would have a substantially lower natural mortality rate as adults. For this assessment, natural mortality for monkeyface prickleback was assumed to be 20 percent per year.

In addition to the assumed adult mortality rates, 50 percent of the eggs were assumed to hatch. This value is on the high side of values reported for other species but consistent with the fact that these prey species typically provide some degree of parental guarding of the eggs. Mortality rates between hatching and age at maturity (i.e., becoming an adult) were then assumed to be an inverse function of the length of the individual following the logic of Ware (1975) and Logan (1985). For this assessment, instantaneous mortality rates were estimated to decline to that of the adult rate at the length of maturity:

$$Z_l = Z_0 \Big/ \left[\frac{(L_m - L_0)}{L_m - l}\right]_a$$

for $I<L_m$, or

$Z_i = Z_a$

for $I>L_m$

where:

Z_l	=	Instantaneous mortality rate for length (l)
Z_0	=	Instantaneous mortality rate immediately after hatch
Z_a	=	Instantaneous mortality rate for adults (= ln(0.5) or ln(0.2))
L_m	=	Length at maturity (mm)
L_0	=	Length at hatch (mm).

Values for L_m and L_0 were obtained from available literature. The average instantaneous mortality rate for each length interval (i) was assumed to be equal to:

$$Z_i = \frac{1}{\sqrt{\left(\frac{1}{Z_l} \times \frac{1}{Z_{l+1}}\right)}}.$$

Using this average instantaneous mortality rate, the total expected survival across a length interval (S_i) can be estimated as:

$$S_i = e^{-Z_{avg} \times D_i}.$$

The total survival across all length intervals from spawning to adult, then defines the number of individuals entering the adult population that would result from the expected lifetime egg deposition of an individual. For this assessment, the values for the initial instantaneous mortality rate at hatch (Z_0) were adjusted such that the number of individuals entering the adult population was 2 – that is the total egg production of one adult female over her lifetime is sufficient to replace herself and a mate. In other words, the population was at equilibrium and, hence, neither increasing nor deceasing over long period of time. Such an assumption was used for estimation of equivalent loss in the DCPP 316(b) Demonstration (Tenera 2000) and in other models for equivalent loss calculations (Horst 1975, Goodyear 1978, Dey 2002).

5. <u>Estimate the instantaneous growth rate and average weight for each length interval.</u> For the production-foregone model, growth is defined in terms of increases in weight. Hence, overall production of the population is defined as the increase in overall biomass available to the ecosystem. Estimation of the instantaneous growth rate begins with conversion of lengths defining the beginning and end of each length interval to weights. This was done using the following length-weight relationships obtained from Cailliet et al. (2000):

Painted greenling	$W = 0.00000356L^{3.221}$
Monkeyface prickleback	$W = 0.0.01289(L/10)^{2.9}$
Clinid kelpfish	$W = 0.00310456(L/10)^{3.243}$.

In all cases, length was defined in millimeters and weight is defined in grams. Length-weight relationships were not available for any of the other three species, smoothhead sculpin, snubnose sculpin, and blackeye goby. For these species, the length-weight relationship for painted greenling was used as a result of similar body morphology.

Using the estimated weight at the beginning and end of each 1-mm length interval, the instantaneous growth rate over the interval (i) can be determined as follows:

$$G_i = \frac{\ln\left(\frac{W_{l+1}}{W_l}\right)}{d_i}$$

where:

G_i	=	Instantaneous growth rate for interval (i)
W_l	=	Estimated weight at beginning of interval (i)
W_{l+1}	=	Estimated weight at end of interval (i)
d_i	=	Estimated duration of interval (i).

Average weights for each length interval (i) were assumed to be the average of the weight at the beginning and end of the length interval.

REFERENCES

Cailliet, G.M, E.J Burton, J.M Cope, L.A. Kerr, R.N. Lea. 2000. The life histories of nearshore fishes of California: a data matrix review of existing literature. Abstract, Western Society of Naturalists. Portland, OR.

Dey, W.P. 2002. Use of equivalent loss models under Section 316(b) of the Clean Water Act. The Scientific World. 2(S1): 254-270.

Goodyear, C.P. 1978. Entrainment Impact Estimates Using the Equivalent Adult Approach. Report No. FWS/OBS-78/65. U.S. Fish and Wildlife Service, Washington, D.C.

Horst, T.J. 1975. The assessment of impact due to entrainment of ichthyoplankton, in: Fisheries and Energy Production: A Symposium (S.B. Saila, ed.), pp. 107-118. D.C. Heath, Lexington, MA.

Logan, D. T. 1985. Environmental variation and striped bass population dynamics: A size-dependent mortality model. Estuaries 8:28-38.

Ricker, W.E., ed. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin 191. Department of the Environment, Fisheries and Marine Service, Ottawa. 382 pp.

Tenera Environmental Services (Tenera). 2000. Diablo Canyon Power Plant 316(b) Demonstration Report. Prepared for Pacific Gas and Electric Company. March.

Ware, D.M. 1975. Relation between egg size, growth, and natural mortality of larval fish. J. Fish. Res. Bd. Can. 32: 2503-2512.

TABLE A-1 – INFORMATION USED TO ESTIMATE GROWTH CURVES FOR SELECTED PREY SPECIES ENTRAINED AT DIABLO CANYON POWER PLANT.

Taxon	Length at Hatch in mm. (L_0)	Length End of Larval Period in mm	Age at end of Larval Period in days	K_l	Maximum Length in mm (L_∞)	K_0
Painted greenling	3.2[1]	15.0[3]	148[8]	0.010439	173[2]	0.000547
Smoothhead sculpin	2.4[1]	11.9[3]	114[9]	0.014044	140[2]	0.000806
Snubnose sculpin	2.6[1]	11.9[3]	114[9]	0.013342	100[2]	0.001151
Monkeyface prickleback	5.7[1]	24.6[3]	88[2]	0.016617	670[2]	0.000554
Clinid kelpfishes	4.1[1]	21.6[3]	70[7]	0.023739	183[5]	0.002139
Blackeye goby	2.0[1]	24.6[3]	75[2]	0.033461	150[2]	0.002686

[1] Estimated based on 2 percentile of larval length from DCPP entrainment sampling (Tenera 2000).
[2] Reported in Tenera (2000).
[3] Based on largest reported in DCPP entrainment collections in Tenera (2000).
[4] Assumed same as smoothhead sculpin.
[5] Mean of values reported for *Gibbonsia* spp. in Tenera (2000).
[6] Estimated from Von Bertalanffy growth curve.
[7] Calculated using larval growth rate for giant kelpfish (0.25 mm/day) reported in Tenera (2000).
[8] Calculated using larval growth rate (0.08 mm/day) reported in Tenera (2000).
[9] Calculated using larval growth rate (0.083 mm/day) reported in Tenera (2000).

TABLE A-2 – INFORMATION USED TO ESTIMATE TOTAL PRE-ADULT MORTALITY FOR SELECTED PREY SPECIES ENTRAINED AT DIABLO CANYON POWER PLANT.

Taxon	Annual Fecundity (AF)	Age at Maturity in yrs. (AM)	Length at Maturity (mm)	Maximum Longevity in yrs (ML)	Lifetime Fecundity (LTF)	Initial Instantaneous Mortality Rate (Z_0)
Painted greenling	20,025[1]	3[2]	78[8]	8[2]	50,063	0.01495073
Smoothhead sculpin	900[4]	0.75[3]	27.5[8]	3[2]	1,013	0.03892967
Snubnose sculpin	700[4]	0.75[5]	27[8]	3[5]	788	0.03570436
Monkeyface prickleback	20,000[6]	5[2]	380[8]	18[2]	130,000	0.01435374
Clinid kelpfishes	5,000[7]	2[2]	145[8]	7[2]	12,500	0.02575072
Blackeye goby	8,062[2]	0.5[2]	45[2]	3.6[2]	12,496	0.12533812

[1] Mid-point of values reported in Tenera (2000).
[2] Reported in Tenera (2000).
[3] Assumed value based on reported maturity within first year of life (Tenera 2000).
[4] Assumed value based on other small sculpin.
[5] Assumed same as smoothhead sculpin.
[6] Assumed value based on range of data reported in Tenera (2000).
[7] Assumed 2 spawns per year and 2,500 eggs per spawn.
[8] Estimated from growth curve.

APPENDIX B
Estimation of the Recreation Value of Target Fishes

Areas of the Pacific Ocean near DCPP are popular for recreational fishing. Unfortunately, information on the actual recreational value for those target taxa that are subject to sport fishing (California halibut, the rockfish complex, cabezon, white croaker, and sanddabs) is limited. However, available information can be used in the sense of a benefit transfer study to estimate a reasonable range in value for the purposes of this assessment.

Hanemann et al. (1980) studied recreational fishing in southern California during the 1980 -1981 period and described the California species harvested, including in area around DCCP. However, this study does not provide specific information regarding the value of a fish. Nevertheless, it does provide information linking the aggregate value of trips and with changes in bottomfish (rockfish and California halibut) catch rates. Their results show that private rental boat trips decrease by 4 percent with a 15-20 percent decrease in the catch rate of bottomfish for a quality elasticity of 0.33. Associated with the changes in trips are changes in aggregate consumers surplus. The average consumer surplus per trip for the baseline was $22.76 whereas the value after a 15-20 percent fall in catch rate was $21.55. Thus, the average loss in consumer surplus per trip was $1.21 for a 15-20 percent decrease in catch rate. The problem with these estimates is that they are based on a travel cost coefficient that is not statistically significant.

Both Hanemann et al. (1980) and Kling and Thomson (1996) provide an alternative to the standard travel cost model by using a random utility (RUM) model. A marginal value per fish per choice occasion can be computed by dividing the coefficient on travel cost (the marginal utility of income) by the coefficient on the catch rate (the marginal utility of catching fish). In essence, this is the amount of money (value) that would make the utility lost from losing the money equal to the utility gained from having more fish. The process assumes that catch rates change by the same amount across all sites.

Hanemann et al. (1980) provide coefficients from the RUM model for catch rates and for one-way distances. Unfortunately, the distance variable was not converted to costs and the coefficients cannot be used to obtain a marginal value of fish.

Kling and Thomson (1996) used data from 1989 and estimated the catch rate for the species that the anglers were actually targeting but the coefficient on catch rate was assumed to be independent of the type of fish. Thus, the value per targeted fish is the same regardless of the species the angler targeted. In a private correspondence, Kling provided the estimates of coefficients (their models A and D , of Table 4) for four different modes of fishing (pier, shore, charter/boat and private boat) and for seven sites within southern California. Model D was the statistically preferred model and Model A was the model that most researchers have used previous to Kling and Thomson (1996).

Using the estimated coefficients for both models, the economic value of additional targeted recreational fish per hour by the different types of trips can be estimated. This is done for Model A in column 4 of Table B-1. The highest value is for the private boat trip whereas the least is for the Party/Charter trips. The weighted average of the values based on the type of trip taken by local residents of the San Luis Obispo area (residents in San Luis Obispo, Santa Barbara, and Ventura Counties) are given in Tables 4a.1-11a-f of Thomson and Crooke (1991). The "representative" or average value per fish per hour is $29.43. When adjusted for the hours fished by anglers in each area, the average value per fish becomes $5.25 in 2001 dollars.

The same process was applied to the statistically preferred model of Kling and Thomson (1996), Model D. This model clustered sites into shore and offshore categories. The catch rate coefficient is provided not on the basis of mode of fishing (as in Model A) but on the basis of offshore and shore sites. Table B-2 of Kling and Thomson provided the information for deriving the value per fish per hour. Because Thomson and Crooke (1991) did not provide the hours fished by the shore/offshore categorization, we assumed that the hours fished per angler trip in each category were 4 hours and estimated a value per fish of $5.74 in 2001 dollars. Because the average hours spent fishing is undoubtedly greater than 4, this estimate is biased upwards.

In addition to these revealed preference studies, Thomson and Crooke (1996) present the results of a contingent valuation question regarding the willingness to pay for an annual sportfishing stamp to increase the harvest rate of California halibut from one fish per five days to one fish per two days (or expected one-half fish per trip). For the aggregate populations of San Luis Obispo/Santa Barbara/Ventura Counties fishing sample, the average willingness-to-pay is in the range of $6-10 per year in 1989 dollars. Unfortunately, we do not know how many more fish an angler is expecting to catch when they provide their willingness-to-pay response. To obtain a conservative estimate of this number, we use the high end ($10) and assume that this increase equivalent to about one-half fish per year. Then, the value per fish becomes $27.60 in 2001 dollars. Because the wording of the question does not suggest how many total fish that the respondent would actually catch, this information is limited at best. However, the report shows that the average angler takes more than five trips per two-month period (Tables 4.1-7b and c) so that the average annual number of trips likely approaches thirty. This would mean that the angler could expect to catch 15 additional fish each year. Therefore, the assumption of an increase of one-half fish increase per year appears quite conservative and the estimate of $27.60 appears quite liberal.

Based on all of the above it appears that a range of $5 to $25 per fish is likely to encompass the value for the fish that actually attract anglers to go fishing or to choose a site to fish. For this assessment, this range could be applied to rockfish, cabezon, and California halibut.

It appears that residents in this area are less likely than most California marine anglers to target species (Table B-3). About one-half of all trips from these residents are not targeting a species (or species group) whereas about one-third of all Californians target species. Species such as white croaker, sanddabs, and cabezon are rarely the direct targets of marine angling trips.

Analysis of the total catch by species reveals that little of the harvest is represented by sanddabs or cabezon (Table B-4). White croaker is slightly more represented, having nearly 10 percent of the harvest in the March/April period. Species in the rockfish group dominate the harvest of residents located in the Counties around DCPP. Given these factors, the value of an additional sanddab and white croaker to a recreational angler is probably quite low. Hence for this analysis, the recreation value of these two taxa was assumed to be equal to commercial price of the fish.

REFERENCES

Hanemann, W. M., T. Wegge, and I. Strand. 1989. Development and Application of a Predictive Model to Analyze the Economic Effects of Species Availability. National Marine Fisheries Service, Southwest Region, Terminal Island CA. Admin. Rpt. SWR 89-02. June.

Kling, C. and C. Thomson. 1996. The Implications of Model Specification for Welfare Estimation in Nested Logit Models. Am. J. Agr. Econ. 78 (February):103-114.

Thomson, C. and S. Crooke 1991. Results of the Southern California Economic Sportfishing Survey. NOAA Technical Memorandum, NMFS, Southwest Fisheries Center, August.

TABLE B-1: RECREATIONAL VALUES OF FISH DEVELOPED USING THE RANDOM UTILITY MODEL, MODEL A, OF KLING AND THOMSON (1996).

Mode of Fishing	Catch Rate Coefficient (Fish/hour)	Travel Cost Coefficient	Value per Fish/hour (2000 dollars)	Percent of Total Local Trips (1989)	Weighted Average Value/Fish /Hour (2000 dollars)	Weighted Average Hours per Angler Trip	Weighted Average Value per Fish
Pier	0.89	-0.061	$22.03	14.7	3.17	6.08	0.52
Shore/ Beach	0.58	-0.061	$14.36	24.9	2.87	4.79	0.56
Private Boat	2.13	-0.061	$52.73	43.7	2.94	6.20	0.43
Party/ Charter Boat	0.80	-0.061	$19.80	16.7	20.45	6.13	3.60
Average Angler Trip					29.43		5.11

TABLE B-2 RECREATIONAL VALUES OF FISH USING RANDOM UTILITY MODEL, MODEL D, OF KLING AND THOMSON (1996)

Mode of Fishing	Catch Rate Coefficient (Fish /hour)	Travel Cost Coefficient	Value per Fish/hour (2001 dollars)	Percent of Total Local Trips (1989)	Weighted Average Value/Fish /Hour (2001 dollars)	Weighted Average Hours per Angler Trip	Weighted Average Value per Fish
Shore Sites	0.47	-0.0394	16.43	45.5	7.26	4	1.81
Offshore Sites	0.81	-0.0394	28.51	55.5	15.06	4	3.77
Average Angler Trip					22.32		5.58

TABLE B-3 TARGETING OF RELEVANT SPECIES ON CALIFORNIA MARINE RECREATIONAL TRIPS, 1993.

Preferred Taxon	Percentage of Santa Barbara, San Luis Obispo, and Ventura County Residents' Marine Trips Targeting[2] Species						Percent Targeting from All California
	Jan/Feb	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec	All Waves
Not targeting	31.5	40.5	60.7	49.0	53.0	49.2	30.0
Targeting bottomfish	0.0	0.0	1.6	0.4	0.2	0.4	8.1
California halibut	2.0	9.3	7.4	11.13	12.2	5.5	5.1
Rockfish	6.0	3.9	5.8	1.6	13.3	15.8	5.7
White croaker	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Cabezon	00	0.5	0.0	2.2	0.0	0.0	0.2
Sanddabs	0.0	0.00	0.07	0.0	0.0	0.0	0.0

[2] Targeting defined as angler reporting that species was the primary species sought.

TABLE B-4 PERCENTAGE OF SANTA BARBARA, SAN LUIS OBISPO, AND VENTURA COUNTY RESIDENTS' MARINE HARVEST REPRESENTED BY SPECIES, BY WAVE.

	Percent of Harvest By Survey Wave					
Taxa	**Jan/Feb**	**Mar/Apr**	**May/Jun**	**Jul/Aug**	**Sep/Oct**	**Nov/Dec**
California halibut	0.5	2.3	2.1	4.1	2.7	1.1
Rockfish	12.6	21.3	24.7	9.6	48.0	54.6
White croaker	5.3	9.2	7.6	8.3	3.3	2.4
Cabezon	0.0	0.6	0.8	0.2	0.9	0.9
Sanddabs	.5	1.9	1.8	0.0	0.6	1.6

TABLE B-1: RECREATIONAL VALUES OF FISH DEVELOPED USING THE RANDOM UTILITY MODEL, MODEL A, OF KLING AND THOMSON (1996).

Mode of Fishing	Catch Rate Coefficient (Fish/hour)	Travel Cost Coefficient	Value per Fish/hour (2000 dollars)	Percent of Total Local Trips (1989)	Weighted Average Value/Fish /Hour (2000 dollars)	Weighted Average Hours per Angler Trip	Weighted Average Value per Fish
Pier	0.89	-0.061	$22.03	14.7	3.17	6.08	0.52
Shore/ Beach	0.58	-0.061	$14.36	24.9	2.87	4.79	0.56
Private Boat	2.13	-0.061	$52.73	43.7	2.94	6.20	0.43
Party/ Charter Boat	0.80	-0.061	$19.80	16.7	20.45	6.13	3.60
Average Angler Trip					29.43		5.11

TABLE B-2 RECREATIONAL VALUES OF FISH USING RANDOM UTILITY MODEL, MODEL D, OF KLING AND THOMSON (1996)

Mode of Fishing	Catch Rate Coefficient (Fish /hour)	Travel Cost Coefficient	Value per Fish/hour (2001 dollars)	Percent of Total Local Trips (1989)	Weighted Average Value/Fish /Hour (2001 dollars)	Weighted Average Hours per Angler Trip	Weighted Average Value per Fish
Shore Sites	0.47	-0.0394	16.43	45.5	7.26	4	1.81
Offshore Sites	0.81	-0.0394	28.51	55.5	15.06	4	3.77
Average Angler Trip					22.32		5.58

TABLE B-3 TARGETING OF RELEVANT SPECIES ON CALIFORNIA MARINE RECREATIONAL TRIPS, 1993.

Preferred Taxon	Percentage of Santa Barbara, San Luis Obispo, and Ventura County Residents' Marine Trips Targeting[3] Species						Percent Targeting from All California
	Jan/Feb	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec	All Waves
Not targeting	31.5	40.5	60.7	49.0	53.0	49.2	30.0
Targeting bottomfish	0.0	0.0	1.6	0.4	0.2	0.4	8.1
California halibut	2.0	9.3	7.4	11.13	12.2	5.5	5.1
Rockfish	6.0	3.9	5.8	1.6	13.3	15.8	5.7
White croaker	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Cabezon	00	0.5	0.0	2.2	0.0	0.0	0.2
Sanddabs	0.0	0.00	0.07	0.0	0.0	0.0	0.0

[3] Targeting defined as angler reporting that species was the primary species sought.

TABLE B-4 PERCENTAGE OF SANTA BARBARA, SAN LUIS OBISPO, AND VENTURA COUNTY RESIDENTS' MARINE HARVEST REPRESENTED BY SPECIES, BY WAVE.

	Percent of Harvest By Survey Wave					
Taxa	Jan/Feb	Mar/Apr	May/Jun	Jul/Aug	Sep/Oct	Nov/Dec
California halibut	0.5	2.3	2.1	4.1	2.7	1.1
Rockfish	12.6	21.3	24.7	9.6	48.0	54.6
White croaker	5.3	9.2	7.6	8.3	3.3	2.4
Cabezon	0.0	0.6	0.8	0.2	0.9	0.9
Sanddabs	.5	1.9	1.8	0.0	0.6	1.6