Diablo Canyon Power Plant
Independent Scientist's Recommendations to the Regional Board Regarding "Mitigation" for Cooling Water Impacts

July 27, 2005

Goal: The goal of the independent scientists is to provide the Regional Board with our best professional judgment regarding environmentally beneficial projects (type of projects, scale, and balance) that might be funded as part of PG&E's Diablo Canyon Power Plant permit.

The independent scientists work with the technical workgroup. The technical workgroup consists of Regional Board staff, the Board's independent scientists, PG&E staff, and PG&E's consultants. The recommendations in this paper reflect the best professional judgment of the Regional Board's independent scientists, and are not necessarily the opinion of PG&E.

The Regional Board's Independent scientists on this project are:

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All costs in this white paper are as of July 2004

EXECUTIVE SUMMARY

As directed by the RWQCB, the independent scientists considered mitigation alternatives for addressing cooling water impacts at DCPP, with specific direction to consider Marine Protected Areas, artificial reefs, the uncertainty regarding impacts and mitigation measures, performance monitoring for any mitigation projects, thermal effects mitigation projects, and a reduced thermal effects monitoring program.

This report considers several types of mitigation projects with respect to entrainment and thermal effects, including:

Creating offshore reef habitat
Establishment of marine reserves (Marine Protected Areas)
Terrestrial conservation easement (RWQCB/PG&E settlement)
Fish hatchery work
Restoration of marine habitat
Use of PG&E lab facilities (RWQCB/PG&E settlement)
Abalone Research (RWQCB/PG&E settlement)
Central Coast Ambient Monitoring Program (RWQCB/PG&E settlement)
CALCOFI work (ocean monitoring/research)
State Parks Docent Program (Thermal effects)

We also recommend a modified thermal effects monitoring plan.

Our recommendations/conclusions are:

- Regarding **entrainment**, three mitigation options are applicable in this case: artificial reefs, establishment of Marine Protected Areas, and the terrestrial easement described in the RWQCB/PG&E settlement.
- Artificial reefs would provide the most direct compensation for entrainment losses. The best current estimate of the area of artificial reef required would be between 85 and 200 hectares (210 to 500 acres). The cost of constructing the artificial reefs is estimated to be between $10.6 million (for 85 hectares) and $26 million (for 200 hectares). These estimates are based on extensive artificial reef mitigation research done at the San Onofre Nuclear Generating Station (SONGS). Note that the cost estimate does not include performance monitoring (a requirement in the SONGS mitigation).
- Permanent preservation of marine habitat via establishment of marine reserves would also provide mitigation for entrainment losses, but marine reserves are likely to benefit only harvested species, which constitute only a portion of those entrained. There might also be some benefit with regard to species harvest via by-catch.
- We recommend that the terrestrial easement be part of the settlement agreement, and conclude that both options we were directed to evaluate, establishment of Marine Protected Areas or creation of an artificial reef on the central coast, could provide a level of compensation for entrainment at DCPP. We discuss the issues around the establishment of Marine Protected Areas in detail in this paper, including the

process for implementation, likelihood of success, and costs. This paper also details the scale, cost, and benefits of artificial reefs as mitigation for entrainment impacts.

- Fish hatchery work, physical restoration of marine habitat, and CALCOFI research funding are not currently recommended as projects.
- Use of the PG&E lab facilities (RWQCB/PG&E settlement) is not mitigation for impacts, and is not recommended.
- The abalone research project (RWQCB/PG&E settlement), as currently proposed, is unlikely to provide any mitigation benefit for either entrainment or thermal impacts, and is not recommended.
- The Central Coast Ambient Monitoring Program (CAMP) funding (RWQCB/PG&E settlement) is an important program, but general ambient monitoring is not mitigation for impacts. We recommend that funds be directed toward performance monitoring as part of any implemented mitigation projects, and that the performance monitoring be overseen by independent scientific experts from the relevant fields of study.
- The States Park Docent Program is unlikely to provide mitigation for either Entrainment or thermal effects if it was in conjunction with opening access to restricted areas. There could be some value associated with this program if it was applied to access control in existing marine parks.
- Regarding **thermal effects**, there are three applicable mitigation options: Marine Protected Areas, the terrestrial easement, and passive restoration of intertidal areas (chiefly through a docents program). Marine Protected Areas would include intertidal and shallow subtidal areas (the same type of habitat affected by the thermal discharge). The terrestrial easement provides permanent protection for a relatively large amount of intertidal habitat (relative to the amount of intertidal habitat impacted by thermal effects). Again, we recommend that the terrestrial easement be included in the settlement. Also, intertidal areas are degraded in some State Park areas on the Central Coast due to public access (trampling). Funds could be directed to a docent program designed to minimize this impact.

The benefits, costs, and likelihood of success for the recommended projects are discussed in this report.

DISCUSSION

1.0 Boundaries, Understandings

The independent scientists' recommendations are made within these boundaries/understandings:

1. The independent scientists will not address policy or legal issues. The independent scientists will make realistic, defensible recommendations based on science.
2. It may not be possible to mitigate or compensate for all environmental losses due to entrainment and/or the thermal discharge. For example, hundreds of species are entrained, and it is infeasible to replace these entrained organisms on a one for

one basis. Therefore, projects are considered that provide a benefit to habitat known to be critical to impacted species (which should help replace some of the losses).

3. The geographic scale from which entrainment losses occur is relatively large. Proposed projects in response to entrainment losses are therefore considered on a similar scale.
4. The geographic scale of the thermal effects is more local. Projects related to thermal effects are therefore considered on a local scale. The thermal effects of concern are those that are above and beyond the predicted effects considered in State Water Resources Control Board Order No. 83-1.
5. Research or surveys are also considered. For some projects, research or surveys are needed before the actual project can begin or to track impacts over time.
6. The independent scientists will scale, balance, and cost projects to the extent possible, with consideration for the major limitations involved. In many cases, costs are likely to be an unknown and only gross estimates will be made.
7. The independent scientists will consider the uncertainties associated with the power plant impacts and potential projects to allow comparison between likely impacts and likely benefits.
8. The independent scientists' recommendations are based on current knowledge of local conditions, the marine environment and scientific literature. The basis of these recommendations is a consideration of potential projects that would benefit the marine environment (but not necessarily directly replace losses).
9. The independent scientists will also recommend a thermal effects monitoring program sufficient to follow biological communities over time (likely to be much less comprehensive than the current program).

2.0 Uncertainties Regarding Entrainment Losses and Projects

Evaluation of the impacts resulting from entrainment requires a basic understanding of the typical life history of most marine species, together with an understanding of the complexity in conducting an entrainment study.

Most nearshore marine species have a "complex" or "bipartite" life history. This means that the life of a species is divided into at least two distinct phases: a dispersing larval stage followed by a typically reef resident adult stage. Note that even those species without a reef resident stage typically have lower dispersal in the adult stage than in the larval stage. Relatively much is known about the duration of the dispersing stage (especially for fish, because otoliths can be used to determine the larval period). By contrast, almost nothing is known about the distance over which larvae may disperse. Most estimates of the geographic scale of larval dispersal come from coupled oceanographic-life history models, which (essentially) estimate larval dispersal as the distance a passive particle would be transported (over a set number of days) due to net movement of the prevailing water mass. Here, a set number of days represents the larval period prior to entrainment. Consultants contracted by PG&E (Tenera) were able to calculate a distribution of dispersal distances prior to entrainment for all target species.

Larval size as a proxy for days in the plankton, this distribution could then be used to estimate the geographic range of impact and the intensity of impact as a function of distance from the intake. For the species evaluated in the 316b study the geographic range of impact was often very large, (see Table 1, below) usually with the intensity at any given location being fairly low. By itself, this does not mean that the impact was small, instead it simply means that the impact was spread over a wide geographic area.

Entrainment studies are difficult to conduct for many reasons, including:

1. The large spatial and temporal scales over which impacts may occur
2. The massive sampling effort required
3. The difficulty in identifying species
4. Evaluating assumptions that must be made to fully parameterize the "effects" model (i.e. the model used to determine loss rate)
5. Evaluating the effects of variability

RWQCB staff and the Regional Board's independent scientists have concluded that entrainment losses cause an impact (essentially decreased numbers of larvae), but estimates of total impact (direct effects) have fairly large uncertainty (but not larger than is typical in impact studies of this complexity). If fact, we consider the recent entrainment study done at DCPP to be the finest ever done for power generating facilities in the State of California. Reducing the uncertainty would take many years and cost tens of millions of dollars, but the resulting estimates are likely to still have very large errors. This problem has no financially practical solution.

The benefits of projects to enhance the environment may also be difficult to measure. Hence, the independent scientists have endeavored to propose those projects that are likely to either provide substantial value per dollar spent or that can be most accurately evaluated.

3.0 Potential Projects Regarding Entrainment Losses

The independent scientists may consider any potential projects to benefit the marine environment; however, the Regional Board specifically directed us to further consider marine reserves and the overall uncertainty associated with "mitigating" impacts.

Projects considered:

Creating offshore reef habitat (artificial reefs)
Establishment of marine reserves (Marine Protected Areas)
Terrestrial conservation easement (RWQCB/PG&E settlement)
Fish hatchery work
Restoration of marine habitat
Abalone Research (RWQCB/PG&E settlement)
Use of PG&E lab facilities (RWQCB/PG&E settlement)

Central Coast Ambient Monitoring Program (RWQCB/PG&E settlement)
CALCOFI work (ocean monitoring/research)

3.1 Artificial Reef Habitat as Compensation for Entrainment Losses

Key conclusions

1) *An artificial reef of sufficient size and with appropriate design and placement could compensate for the majority of impacts associated with entrainment at DCPP.*
2) *Based on Empirical Transport Models (ETM) and estimates of rocky reef habitat in the source water body the estimated range of reef sizes sufficient to compensate for entrainment losses is between 85 (low end) and 412 hectares (high end). Based on information we currently have we have concluded that the most reasonable range is between 85 and 200 hectares.*
3) *As of July 2004, The estimated cost for the construction of an artificial reef ranged from 10.6 million (85 hectares) to 26 million (200 hectares) dollars (cost of transportation of material could cause these estimates to increase).*
4) *The cost associated with the construction of the artificial reef is the single best estimate of the value of the lost resources. If the reef is of sufficient size and of proper design, it has the potential to compensate for almost all entrainment impacts measured and unmeasured.*

Background

Diablo Canyon Power Plant entrains well over 30 billion planktonic forms per year. The reported value (30 billion larvae, based on estimated entrainment for sampled species including all larval stages of crabs and fish, PGE 316B Demonstration) is a vast underestimate of the true number entrained as only a very small subset of entrainable organisms were assessed. For example, no estimates were made for most invertebrates, any algae and marine plants, or any holoplankton. By contrast, entrainment of fish larvae was well characterized. For coastal intakes it has been difficult to develop mitigation strategies that have the potential to compensate for losses due to entrainment. In part this is due to the difficulty in establishing a loss basis (e.g. adult stock) that could be used as a currency for comparing mitigation alternatives. It is also difficult because restoration activities that are used in estuarine and freshwater system are infeasible when losses are mainly to open coast species. Here we evaluate artificial reef habitat that: (1) has the potential to scale directly with a reasonable estimate of impact (larval loss), (2) provides a robust method to value the loss resources (important in the new 316B context), and (3) may compensate for most losses (both measured and unmeasured).

Approach

The basic approach is to estimate the amount of new reef habitat that would be required to produce the juveniles lost to entrainment. Table 1 below shows the estimates for entrainment at DCPP for a series of target fish taxa. Target taxa are defined as the subset of all taxa for which entrainment was estimated and for which a calculation of ecological loss was attempted. Three such measures were used. Fecundity Hindcast (FH) and Adult

Equivalent Loss (AEL) estimate are based on the idea of hindcasting or projecting larval losses to adult stock. The third method, based on a modified Empirical Transport Model (ETM) produces an estimate of proportional mortality (Pm), which is an estimate of the larvae at risk of entrainment, that were entrained. Those larvae at risk of being entrained are considered to be in the source water body, defined as the geographic area from which entrained larvae could have come. The estimate of source water body is based on the period of vulnerability of the larval form (species specific) coupled with an estimate of oceanographic currents that transport the larvae along the coast. By example, an estimate of Pm could be: 10% of larvae of species A in an area stretching 100 km along the coast were lost due to entrainment. Of the three methods the independent scientists agreed that the ETM approach was the most reliable and reasonable approach for the analysis done at DCPP. Hence, our approach here is to determine the amount of habitat that would be required to produce the juveniles lost to entrainment, based on ETM calculations. The table below (Table 1) shows the estimates of adjusted annual entrainment ($\hat{E}_{Adj-T}$) for Analysis Periods 1 (October 1996–September 1997), 2 (October 1997–September 1998), and 3 (July 1997–June 1998) for the 14 target fish taxa collected and analyzed at DCPP (for reference, the Brown Rock Crab and Slender Crab were also evaluated. The combined estimated annual entrainment for these two species was > 27 billion larvae between December 1996 and November 1997).

Table 1: Estimated entrainment for target fish species (PG&E, 316b Demonstration) for Analysis Periods 1 (October 1996–September 1997), 2 (October 1997–September 1998), and 3 (July 1997–June 1998).

Taxon	Analysis Period	Adjusted Annual Entrainment $\hat{E}_{Adj-T}$
Pacific sardine	1.	8,470,000
	2.	22,600,000
	3.	22,600,000
Northern anchovy	1.	136,000,000
	2.	376,000,000
	3.	377,000,000
KGB rockfish complex	1.	275,000,000
	2.	222,000,000
	3.	222,000,000
Blue rockfish complex	1.	84,040,000
	2.	33,800,000
	3.	33,900,000
Painted greenling	1.	24,200,000
	2.	9,610,000
	3.	12,100,000
Smoothhead sculpin	1.	57,700,000
	2.	115,000,000
	3.	129,000,000
Snubnose sculpin	1.	110,000,000
	2.	83,500,000
	3.	105,000,000
Cabezon	1.	51,900,000
	2.	36,300,000
	3.	36,300,000
White croaker	1.	305,000,000
	2.	440,000,000
	3.	447,000,000
Monkeyface prickleback	1.	83,100,000
	2.	61,500,000
	3.	60,200,000
Clinid kelpfishes	1.	181,000,000
	2.	308,000,000
	3.	458,000,000
Blackeye goby	1.	128,000,000
	2.	109,000,000
	3.	128,000,000
Sanddabs	1.	7,160,000
	2.	1,540,000
	3.	6,610,000
California halibut	1.	8,260,000
	2.	15,700,000
	3.	15,500,000

All but five of the species shown above are associated with rocky reefs, primarily shallow ones. The exceptions are sanddabs, California halibut and white croaker, which typically are associated with sandy substrates, and Pacific sardines and northern anchovies, which are more pelagic species. Indeed the majority of all species for which entrainment was calculated are associated (as adults) with rocky reefs. Moreover it is extremely likely that this is also true for unmeasured species except holoplankton.

This is important because it strongly supports the idea that creation of new rocky habitat could compensate for most entrainment losses. The logic of this argument follows. Recall that the estimate of losses based on the ETM model are depicted as the proportion of larvae lost to entrainment that came from the source water body. Essentially this means that larvae were produced in the source water body, or at least had been produced nearby and reached the source water body while still larvae. Note, that this does not necessarily have to be true if very early larval stages were not vulnerable. However it is true that the source water body for a given species will be of the same dimensions regardless of the window of vulnerability so long as the duration of vulnerability is the same. Therefore it follows that since the species are reef residents as adults, larval production is a function of the amount of reef available. A simplifying assumption (that will be assessed later in this document) is that artificial reefs support similar densities of adults as do natural reefs. By knowing the amount of reef available in the source water body we can calculate the amount of new reef that would be required to produce larvae equal to those lost to entrainment. For example, assume that 10% of species A larvae in an area 100 miles along shore by 2 miles cross shore (the source water body for this example) are lost to entrainment. Further assume that within the source water body there are 3,000 acres of reef. It follows that if, somehow, 300 acres of new reef appeared of quality equal to that of average natural reef, there would be additional larvae produced equal to those lost to entrainment (3,000 acres x 10%).

An underlying assumption of our interpretation of ETM calculations is that Pm estimates for individual species represent replicate observations that can be used to come up with an overall estimate of larval loss. This means that an individual Pm value really is meaningful only as it contributes to the overall estimate. We have decided that the average Pm value calculated across sampling periods and species is the most reliable estimate of the true impact. This approach has another valuable attribute. The average Pm calculated across all appropriate target species should be a reliable estimate of the impact to non-targeted species because it is an estimate of the expected Pm across independent, replicate and representative observations.

Pm estimates, as noted, above are only informative when placed in the context of source water body. Therefore we calculated two parameters for use in determining the size of an artificial reef. First, average Pm as discussed above. Second, average source water body calculated for the same species and sampling periods as done for Pm.

In these calculations we used all target fish species except those associated with sandy habitats as adults. The results of these calculations are shown in the table below.

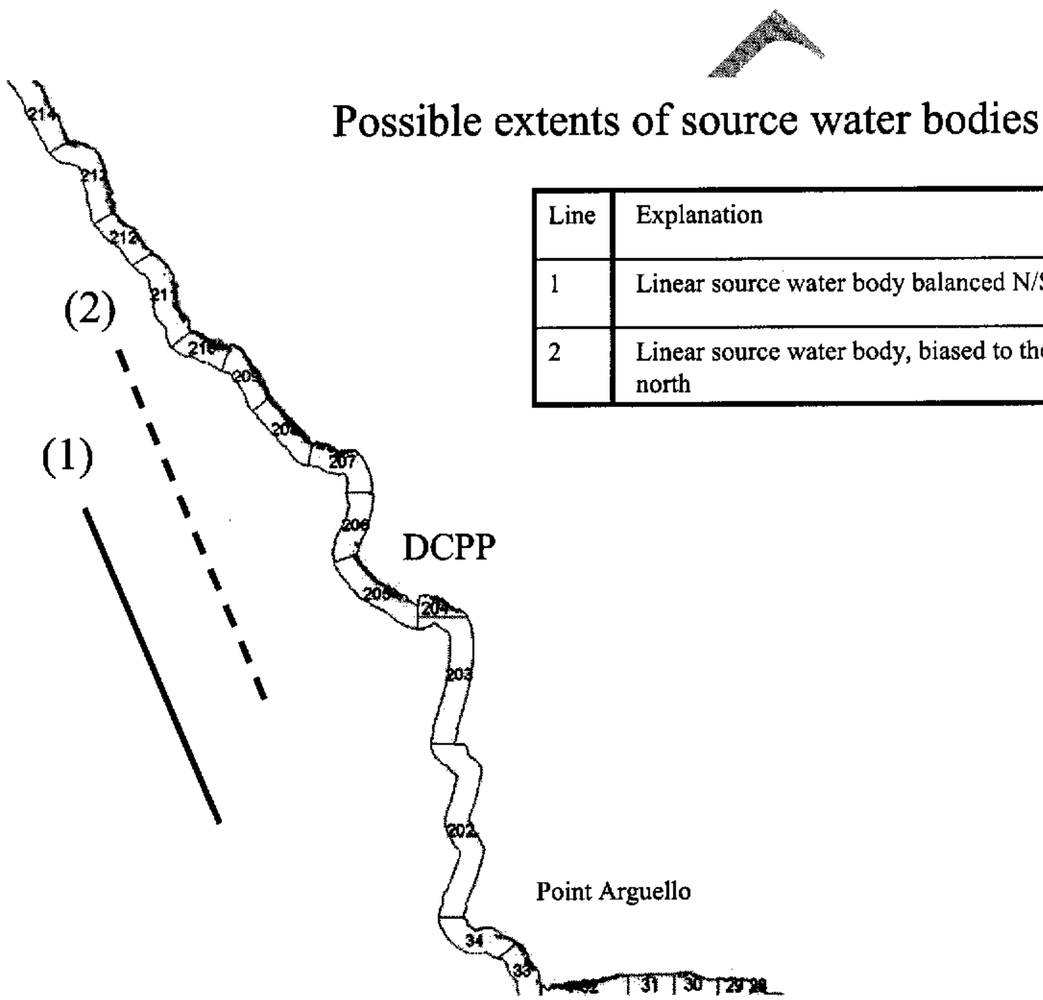
Table 2: Estimates of duration at risk, mortality rate and source water body for target species (PG&E, Revised 316b Demonstration Results: as of June 30, 2005). Larval mortality rates (Pm) based on maximum period of larval risk (defined in 316B document)

Taxa	Adult Habitat	Sample Period	Duration at Risk (Days) - Maximum Length	Mortality rate (Pm)	Source water body, alongshore distance over which Pm can be calculated (km)	Ratio of extrapolated source water to sampled source water (1/Ps)
Smoothhead sculpin	Rocky	97-98	35	11.39%	120.41	6.92
		98-99	35	22.57%	88.57	5.09
Monkeyface prickleback	Rocky	97-98	25	13.76%	106.31	6.11
		98-99	25	11.76%	105.79	6.08
Clinid kelpfishes	Rocky	97-98	32	18.94%	99.88	5.74
		98-99	32	24.97%	76.21	4.38
Blackeye goby	Rocky	97-98	5	11.51%	28.54	1.64
		98-99	5	6.54%	21.92	1.26
Cabezon	Rocky	97-98	8	1.11%	41.06	2.36
		98-99	8	1.52%	33.23	1.91
Snubnose sculpin	Rocky	97-98	42	14.94%	105.79	6.08
		98-99	42	31.02%	91.35	5.25
Painted greenling	Rocky	97-98	24	6.26%	88.22	5.07
		98-99	24	5.58%	77.26	4.44
KGB rockfishes	Rocky	97-98	16	3.88%	67.16	3.86
		98-99	16	4.80%	76.21	4.38
Blue rockfish	Rocky	97-98	13	0.41%	47.15	2.71
		98-99	13	2.77%	52.72	3.03
[redacted]						
	Averages for Rocky reef			**10.76%**	**73.77**	
	Averages for all targeted fish species			**8.59%**	**70.34**	

The best estimate of Pm for reef associated species is 10.76%. Note that this value represents the best single estimate of Pm. In more recent analyses for other plants we have also estimated a confidence interval for Pm estimates. This allows a calculation of how uncertainty in calculations of Pm could affect estimation of impact. Such a calculation was not done for the revised estimates of Pm for DCPP. Because all of the species considered above are nearshore taxa we assume an offshore distance equal to that of the 316B study grid =3 kilometers. Hence, the average source water body is an area 74 kilometers alongshore by 3 kilometers offshore.

The next step is to determine the area of rocky reef within the source water body (henceforth ASWB, *average source water body*). This is difficult for two reasons. First there has been no comprehensive examination of rocky reef habitat along the California Coast. Second, the position of the ASWB is somewhat unclear. We have concluded that the most reasonable ASWB's are linear alongshore areas that are either centered at or that has their southern limit near to DCPP (Figure 1):

Figure 1: Possible extents of source water bodies, overlaid on map showing kelp coverage. Distance of lines offshore is simply to avoid overlap. All ASWB's are assumed to extend from the shoreline to 3 km offshore.

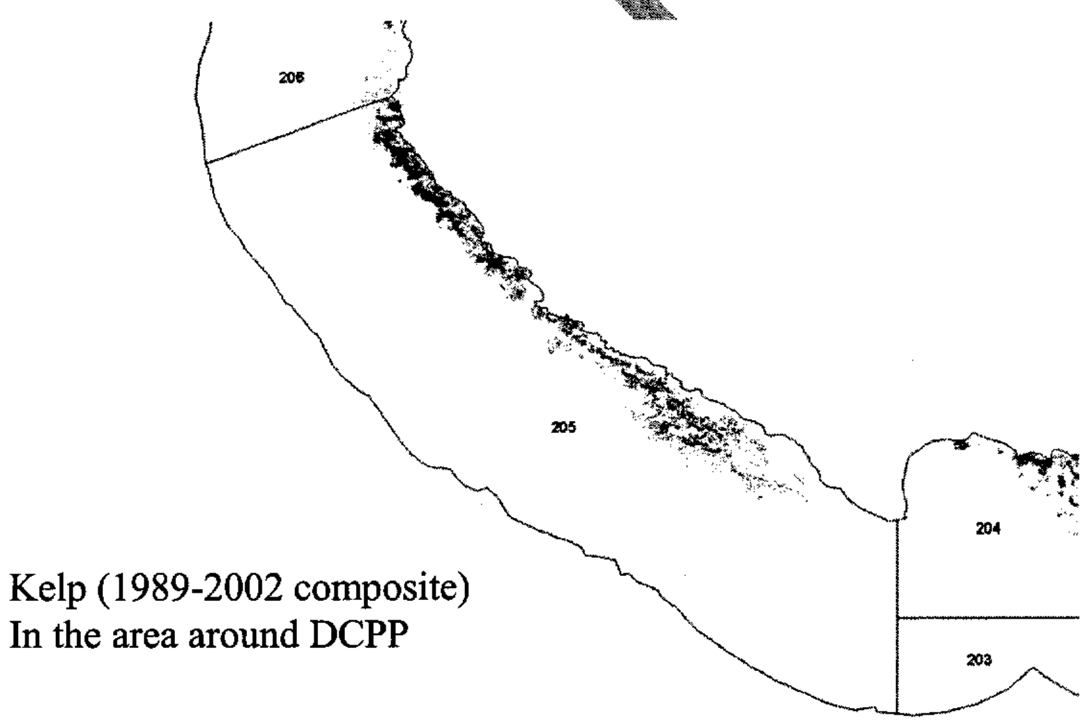


Line	Explanation
1	Linear source water body balanced N/S
2	Linear source water body, biased to the north

Based on current measurements and the configuration of the coastline, the lines above represent the range in reasonable ASWB's. It is clear from the discussion is the 316B document that source water body was estimated as linear multiples of the sampling grid. Therefore, lines 1 and 2 are the most appropriate estimates of the ASWB. The difference between them is in their orientation with respect to DCPP. ASWB 1 has the assumption that transport is equally likely from the north or south. ASWB 2 has the assumption that transport is more likely from the north.

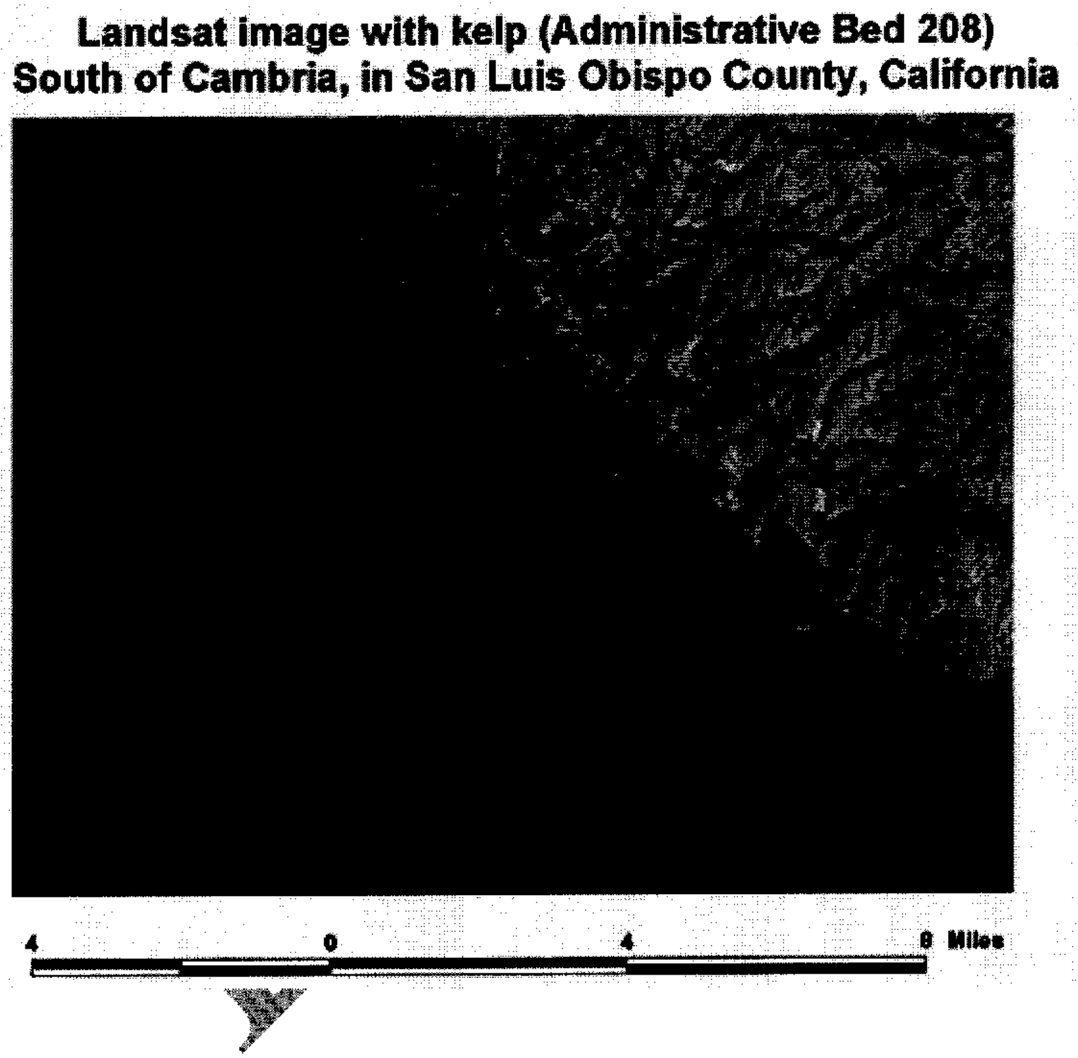
Estimation of the amount of rocky reef is difficult, as noted above. However, we think that there is an approximation that makes sense. Along the central coast most rocky reef habitat that occurs between the 5 and 30 meters depth is likely to support *Macrocystis*. (Indeed many of the affected species are primarily found in kelp forests). Therefore, we can estimate at least the rocky habitat in that depth range by calculating the area covered in kelp. Kelp area varies from year to year with environmental conditions; hence the best estimate of rocky reef in the 5-30 meter depth range would come from an integration of areas covered by kelp over a series of years. Such data exist and are available in GIS format through California Fish and Game. Using the integrated kelp maps (1989-2002) we were able to determine the area of kelp (hence rocky reef in the 5-30 meter depth range) for all ASWB's shown in Figure 1 (the brown areas in figure 1 represent areas that had kelp at least at some point in the period 1989-2002). A blow up of State kelp bed 205 (offshore of DCPP) is shown in Figure 2 to indicate the detail present in the maps.

Figure 2: Kelp area in kelpbed 205



Clearly there are rocky areas that do not support kelp. These can be categorized as either being inshore from the kelp bed or offshore. Inshore approximation is easier using the logic that if there is a kelp bed offshore and rocky intertidal areas in shore, the area in between is likely to also be rock. Offshore rocky reefs are more difficult to quantify. As an example of the former condition we show figure 3. In this figure the area of kelp forest is clearly delineated and there is a margin that has no kelp between the bed and the coast. This is area that is likely to have rocky habitat.

Figure 3:



We took the approach of using a multiplier to bracket the likely rocky reef areas per ASWB's. The lower limit of the multiplier is 1, which would mean that there is no rocky area other than that associated with kelp. We used a multiplier of 2 to yield an upper limit of the amount of rocky habitat. This is based on inshore rocky areas that can be approximated and ones outside of kelp beds (here the approximation is based on knowledge of the few areas where most rocky reefs are known). In the end the upper limit is based on best professional judgment.

Our best estimate of the range in area of artificial reef necessary to compensate for entrainment impacts to rocky reef species is 85 – 400 hectares (approximately 200-1000 acres).

Table 3: Area of kelp per average source water body (2 projections) and the amount of artificial reef required to compensate for entrainment impacts to rocky reef organisms.

Line	Kelpbeds	Explanation	Area (hectares)	Multiplier	PM estimate	Art Reef habitat (hectares)
1	202-208	Straight balanced N/S	792	1	0.1076	85.21
2	205-210	Linear source water body, biased to North	1916	1	0.1076	206.16
1	202-208	Straight balanced N/S	792	2	0.1076	170.42
2	205-210	Linear source water body, biased to North	1916	2	0.1076	412.32

Quality of artificial reef

One obvious assumption of the calculations shown above is that an artificial reef will be as productive as the average natural reef. This is an important assumption, particularly since some artificial reefs that have been evaluated have been shown to be biologically different from natural reefs. Probably the best examination of this question is an ongoing study of artificial reef design being carried out by the California Coastal Commission as part of the mitigation for San Onofre Nuclear Power Generating Station (SONGS). This work has been done near San Clemente and is called San Clemente Artificial Reef (SCAR). In that study two substrate types and three levels of cover were manipulated (see table 4). For each combination of treatments seven 40 x 40 meter replicate reefs were established in 1999. In addition two natural reefs have been sampled since 1999.

Table 4: Reef type, and cover at SCAR (average values over the period 2000-2003). Cover refers to the cover of rocky substrate.

Reef Type	Substrate Type	Cover of Hard Substrate (category)	Average cover
Artificial	Rock	Low	59%
Artificial	Rock	Medium	69%
Artificial	Rock	High	85%
Artificial	Concrete	Low	51%
Artificial	Concrete	Medium	56%
Artificial	Concrete	High	80%
Barn Kelp (Natural)	Rock		52%
San Mateo (Natural)	Rock		46%

The SCAR study was developed to test various reef designs and was done in anticipation of the build out of the full mitigation reef and in recognition that artificial reef performance has been variable. The following figures come from the 2004 annual report, which compares the performance of SCAR to that in natural reference reefs (Barn Kelp and San Mateo Kelp). The basis for the comparisons is the operating permit for SONGS, which requires that the ecological performance at the build out reef be similar to natural reefs in the region. Only data for fish species are shown, however data have been collected for invertebrates and algae as well.

Figure III.19. Change in the mean density of resident kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

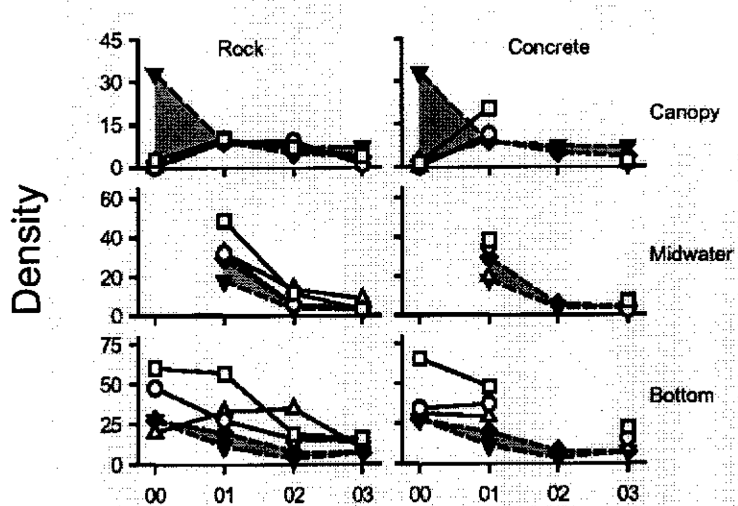


Figure III.20 Change in the number of species of resident kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

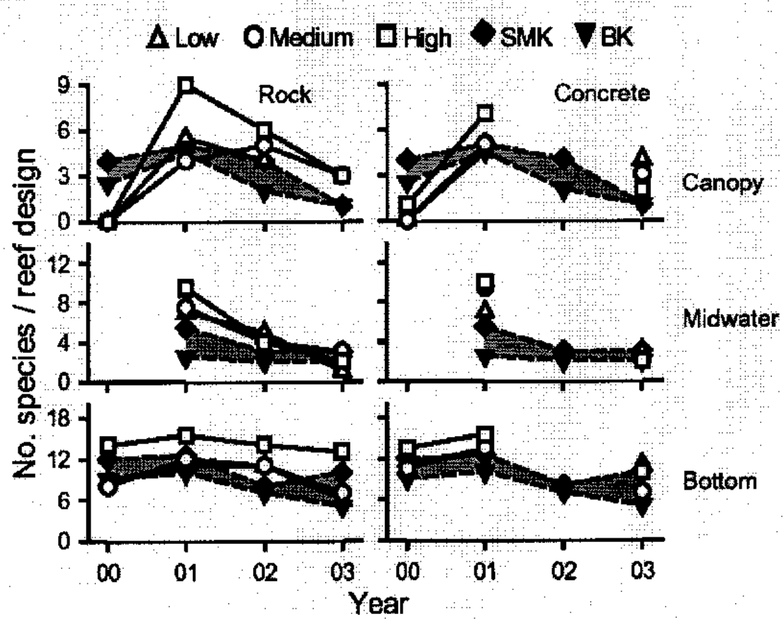


Figure III.21. Percent similarity in the assemblages of resident kelp bed fish between the six artificial reef designs and the mean of the reference reefs Barn (BK) and San Mateo (SMK) (open symbols and solid lines) and between BK and SMK (closed symbols and dashed lines).

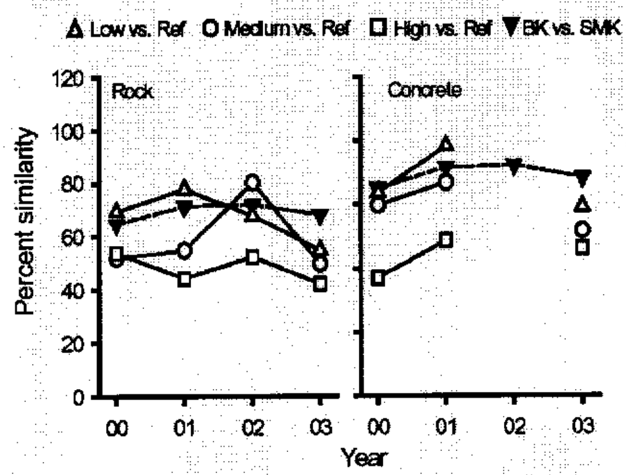


Figure III.22 Change in the mean density of young-of-year kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

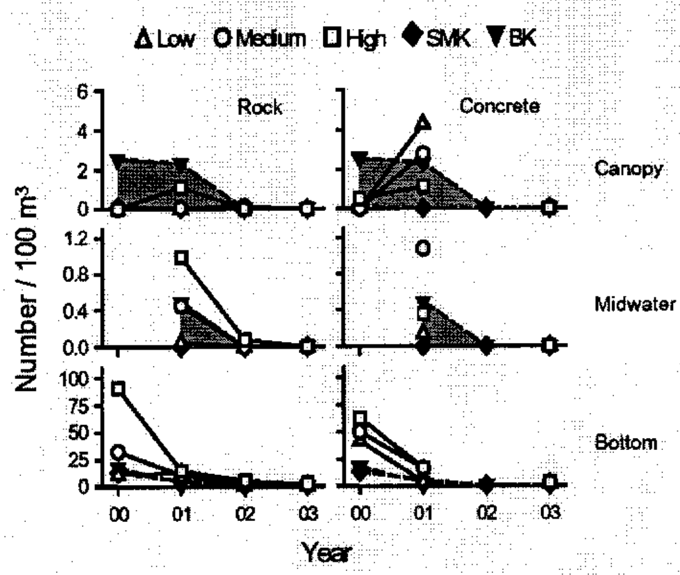


Figure III.23. Change in the number of species of young-of-year kelp bed fish over time at the bottom, mid depth and surface canopy for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). Values within the dashed grey areas are within the range of SMK and BK suggesting that they are similar to natural reference reefs in the region.

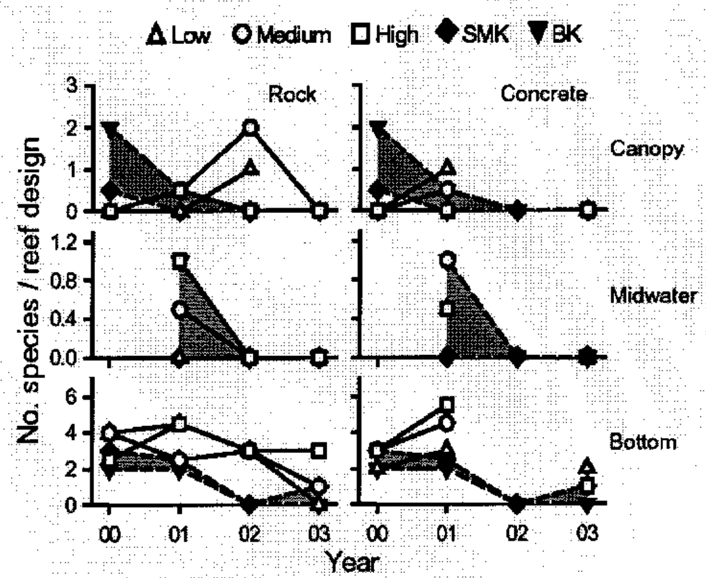
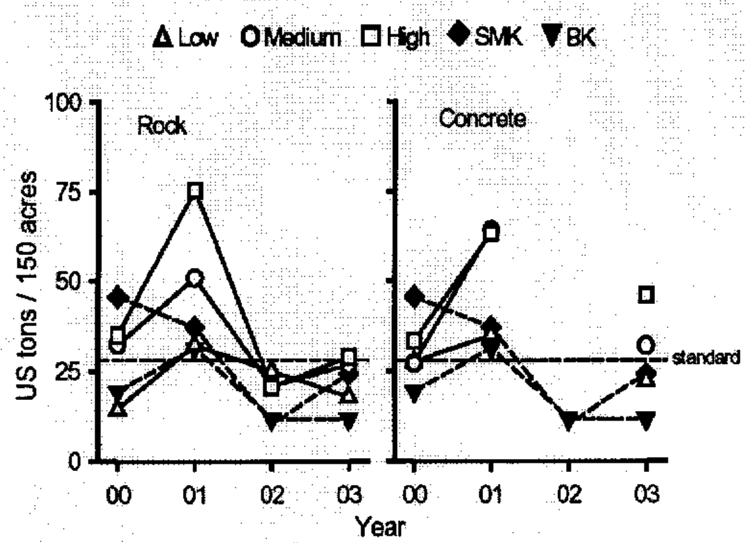


Figure III.24. Change in the projected standing stock of kelp bed fish over time for artificial reef designs with different substrate types (rock and concrete) and bottom coverages (low medium and high) and for the reference reefs at San Mateo kelp bed (SMK) and Barn kelp bed (BK). The dashed horizontal line indicates the permit standard of 28 tons for the 150 acre mitigation reef. See text for how projections were made.



For all the comparisons made artificial reefs performed at least as well as natural ones. Importantly, there was often an effect of cover of hard substrate but even "low" cover reefs performed comparably to natural ones. Therefore we conclude that it is reasonable to assume that a properly constructed artificial reef will be at least as productive as a natural one.

Figure 4: Photo from artificial reef at SCAR

Cost of an artificial reef

The cost of an artificial reef (here we consider only rock – not concrete) is driven in large part by three criteria: (1) quantity of rock (which is manifested as cover and depth), (2) precision in placement of rock, and (3) the distance that the rock has to be transported. We used CCC data from SCAR to come up with estimates of costs for a build out reef for

DCPP mitigation. The total cost of the reef construction at SCAR was $2,600,000. The total acreage is ~22 acres. In total there are 56 modules that are 40 x 40 meters. Hence, the estimated cost per acre based on this is $118,182. The average cover (of rock) per reef is 70%. Conversations with Hany Elwany (who helped engineer SCAR) indicate that: (1) cost is directly related to the cover. (2) There would be an estimated 40% decrease in cost associated with the build out of a large reef because of the lessened need for precise deposition and coverage. Hence a 50% reduction in cover would lead to an estimated 50% reduction in cost. Unfortunately we have little information on the average cover of hard substrate in a rocky reef. For the two reference reefs used in the SONGS study the cover averaged about 50%. Using this as the basis for a build out reef coupled with a cost reduction associated with a reduced need for precise placement of rock, the cost drops to approximately $50,000 per acre or $125,000 per hectare. The estimated costs of the possible reefs are shown in Table 5. Note that the cost may be greater than this value depending on the cost associated with transport of rock. We are awaiting a more detailed cost estimate from Connolly-Pacific (who is the contractor for the SCAR reef).

Table 5: Estimated costs (July 2004) of artificial reefs based on ASWB's (see table 3). All costs are based on reefs with 40-50% cover of hard rock and a cost savings associated with low precision-placement of rock (see text)

Line	Kelpbeds	Explanation	Area (hectares)	Multiplier	PM estimate	Art Reef habitat (hectares)	Cost @ $125 per hectare
1	202-208	Straight balanced N/S	792	1	0.1076	85.21	$10,651,250
2	205-210	Linear source water body, biased to North	1916	1	0.1076	206.16	$25,770,000
1	202-208	Straight balanced N/S	792	2	0.1076	170.42	$21,302,500
2	205-210	Linear source water body, biased to North	1916	2	0.1076	412.32	$51,540,000

The range in estimated costs for the build out of an artificial reef is $10.6 to $50 million, with the latter being the upper limit. We think the appropriate reef size for mitigation is between 85 and 200 hectares and would cost between $10.6 and $26 million. Note that: (1) this does not include any costs associated with performance monitoring of the reef (a requirement in the SONGS mitigation); and (2) costs may be higher depending on transportation (of rock) costs.

The costs associated with the construction of an artificial reef, while substantial, are much less than they would be if SCAR had not been implemented. An artificial reef used to mitigate the entrainment effects at DCPP would greatly benefit from lessons learned at SCAR study in the planning, permitting, design, construction and evaluation phases of the reef.

Valuation

One of the most difficult things about establishing a value associated with entrainment is that for most of the affected species there is no obvious way to estimate a true value. Most of these species have no commercial value and direct estimates of ecological value are essentially impossible. Moreover, most entrained species are not even sampled leading to immensely increased valuation uncertainty, at least using traditional methods.

By contrast, we believe (as admitted non-economists) that the costing of an artificial reef represents the most relevant value of the resources lost to entrainment. While some sandy bottom or deep-water species have larvae that are lost to entrainment, the vast majority are associated with fairly shallow rocky reefs; exactly of the kind of habitat provided by an artificial reef. An artificial reef, of sufficient size and of proper design therefore has the potential to compensate for almost all entrainment impacts. This makes intuitive sense as the artificial reef is in essence replacing a natural reef of similar size from which nearly all resources save substrate have been lost. Therefore the cost of a compensatory artificial reef may be the most relevant and straightforward estimate of the value of the lost resources. Based on this logic, the value of resources lost to entrainment at DCPP is estimated at between $10.6 and $26 million (as of July 2004).

Some Final Remarks

1) The artificial reef proposed in this document is based on the idea that it would NOT be a Marine Protected Area. If the artificial reef were designated as a "no take" marine reserves then the projected size and cost of the reef would decrease. It is difficult to determine at this point by how much (although we could do this with some additional study). Recall though that very few of the affected species are regularly harvested and protection from extraction would likely benefit only those species. We think the overall size and cost would decrease approximately 20% or less if the artificial reef were designated as a "no take" marine reserve.
2) The most problematic parameter used to calculate reef size is the multiplier used to estimate the amount of rocky reef that is not associated with kelp. It is likely that we could come up with a better estimate than "2" with some additional research, but given the information we currently have we have concluded that a reasonable upper limit for the multiplier is 2.
3) The cost projected for the reef does not include any costs associated with monitoring for performance.
4) Artificial reefs cannot be located in all sandy locations. The work done in preparation for the SONGS reef could be used to help locate suitable sites.
5) There are few data available for establishing the percent cover of rock in natural reefs. Estimates used in calculating the cost of the DCPP artificial reef are based on 50% cover of rock, which is the average for two reference reefs used in the SCAR study. It is possible that the value for typical reefs along the San Luis Obispo coastline have greater or less cover. This would affect the cost of the reef.

3.2 Marine Reserve Areas as Compensation for Entrainment Losses: Given the characteristics of entrainment impacts, such as relatively large uncertainty (or confidence intervals), large geographic area of influence, potential ecosystem level impacts, and the infeasibility of replacing all entrainment losses, the benefits and flexibility of marine reserves are attractive and could provide a level of mitigation for entrainment. There are several potential benefits of marine reserves, including permanent overall conservation of resources, increased density of fish, increased size, and increased larval productivity, relative to non-reserve areas. It is important to note that the degree of benefit (other than conservation) is determined by the amount of "take" (fishing pressure) occurring in the area prior to the reserve being established. Additionally, marine reserves may benefit both entrained and thermally impacted species. Accordingly, the independent scientists considered the pros and cons of marine reserves (in and of themselves) and their applicability to entrainment losses and thermal effects. This option is applicable in this case, and is discussed in detail below.

Potential Benefits of Marine Protected Areas

There are two general classes of benefits that may be obtained by the establishment of marine reserves: fisheries management and conservation. With respect to fisheries management there are again two classes of benefit: spillover effects and enhanced production of larvae that will be exported to other reefs. Spillover effects result when abundance within a reserve builds to the point that individuals "spill over" to adjacent exploited areas. Larval export is thought to occur through enhanced fecundity in Marine Protected Areas. This can result from either increasing the abundance of formerly exploited species or through increased individual size (leading to non-linear increases in fecundity), or both. The degree of benefit from spillover effects and enhanced production of larvae are relative to the amount of exploitation that occurred prior to establishment of the Marine Protected Area.

The benefits afforded via conservation are considered to be less speculative. Conservation benefits result from a return to a more pristine ecosystem, and permanent protection of the ecosystem. In contrast, entrainment losses are temporary. Therefore, it is reasonable to conclude that the long-term benefits of marine reserves are greater than the temporary impact of entrainment.

The potential benefits of Marine Protected Areas are supported by many scientists who believe that reserves provide a reliable management tool for the long-term protection of marine resources. There is scientific evidence that marine reserves provide major benefits for both fisheries management (although this is controversial) and particularly conservation (see references listed at the end of this paper).

Other important considerations are:

1. Certain benefits derived from marine reserves are likely to be dispersed over a large geographic scale, similar to the area from which entrainment losses occur.
2. There is legislation requiring the establishment of Marine Protected Areas, which includes marine reserves. The State budget situation temporarily stalled the agency process, but the California Department of Fish and Game (DFG) currently has limited funding to implement the marine reserve process. Other groups are interested in pursuing the Marine Protected Area process and can provide matching funds, as discussed below.
3. The broad scientific support and existing legislation suggests that Marine Protected Areas, including marine reserves will eventually be established throughout California if adequate funding is provided and the essential tasks are completed (discussed below).

4. The costs associated with establishing and maintaining Marine Protected Areas are likely to be relatively low compared to the permanent benefits derived (discussed below).
5. The benefits of marine reserves are permanent, and will likely be manifested throughout the ecosystem. By contrast, entrainment losses are temporary.
6. There are few data (habitat surveys) on which to base the appropriate size and location of marine reserves in the Central Coast area. Identifying those areas likely to provide the maximum benefit (habitat surveys) coupled with a post-establishment performance monitoring are necessary components of a marine reserves project.
7. There are limited scientific data on the benefits of marine reserves in California. The data that do exist suggest that the "restoration" type benefits provided are related to the level of regional exploitation (exploitation of resources prior to the reserve being established). Most of the research is associated with the Channel Islands (which shows evidence of ecosystem level benefits). Some research exists for the Big Creek Ecological Reserve, where there was no detectable benefit, most likely because the area was not heavily fished prior to the reserve being established (that is, the area was relatively pristine prior to the reserve being established, so no biological changes were detected). However, the conservation benefit of permanently protected resources at Big Creek remains.
8. The Regional Board has no authority to establish marine reserves, but can work with other groups on a process for establishing a reserve, or multiple reserves, on the Central Coast.
9. Marine reserves do not directly address entrainment losses for all species. Some taxa are likely to benefit, while others may not.
10. For marine reserves to be effective there is a need for stricter and more extensive management and enforcement. Thus, support for these activities should be considered.
11. Surveys to measure the efficacy of the marine reserves should use the recently-derived PISCO/CRANE SCUBA survey methodology (http://www.piscoweb.org/research/community/subtidal/index.html) for areas accessible to divers and the protocols recently used the Delta submersible in the Big Creek Ecological Reserve at deeper depths than SCUBA (Yoklavich et al. 2002) is presently capable of surveying. The underlying hypotheses to be tested are:

    a. Density is greater in reserve than non-reserve areas
    b. Individual size is greater in reserve than non-reserve areas
    c. Production of larvae per unit area is greater in reserve than non-reserve areas

    With respect to entrainment losses the key hypothesis is item c., however, it is also the most difficult and expensive to measure. Hypotheses a. and b. are often used in functions as proxies for fecundity (larval production) and may be of greater practical value because of cost benefits.

12. Another associated program to "buy out" the nearshore fishing permits of local fishermen would help make the possibility of having additional catch and effort

adjacent to marine reserves less likely. It would also benefit the local fishing industry by replacing at least some of the income they would have made by fishing in the nearshore habitat affected by the power plant.

13. Implementation of marine reserves requires several critical steps, including gathering information on habitats (habitat surveys), a socio-economic study, post performance monitoring, and a dedicated process managed by professionals with adequate funding, as discussed later in this paper under Process for Establishing Marine Protected Areas.

Applicability of Marine Protected Areas to Entrainment Losses

As noted above, entrainment losses may occur over a large area, on the order of hundreds of kilometers of coastline or hundreds of square kilometers of ocean habitat. Note that when the spatial extent of the impact is large the intensity tends to be low (also note the reverse is often true). Importantly, the estimated area is different for each species. Certain benefits of marine reserves also may occur over a similar geographic scale. These benefits would mainly result from increased export of larvae from protected areas.

Although the ecological effects of entrainment losses cannot be precisely identified or measured, staff and the Regional Board's independent scientists have concluded that entrainment losses affect the overall ecosystem (essentially lowering larval production, with uncertain secondary effects). Properly placed and designed marine reserves should increase or maintain larval production, thereby offsetting (to some extent – on a species-specific basis) entrainment and contribute to the restoration and maintenance of natural ecosystems that would otherwise be impacted by other anthropogenic pressures.

The match (entrainment losses to marine reserves) is clearly not perfect; indeed, Marine Protected Areas would benefit some entrained species, but not all. In addition, certain species not subject to entrainment might also be enhanced (e.g. surfperch which do not produce larvae). It is possible that predation pressure on some nearshore fish taxa may increase in reserve areas due to more abundant and larger forage species that prey on nearshore taxa (although the resulting ecosystem within reserves would likely be a more "natural" system). The overall effect of marine reserves is to benefit the marine ecosystem on a large scale; this approach avoids micromanagement of individual species or groups of taxa (as would be the case with fish hatcheries or small scale habitat work).

Another consideration is the real-world likelihood of actually establishing marine reserves. If a potential project is impossible to implement, the project has no real value. Marine reserves have been established by the Fish and Game Commission, and there is legislation requiring the establishment of additional reserve areas (Shelley Bill: Marine Life Protection Act). Accordingly, establishment of Marine Protected Areas on the Central Coast is a realistic option.

The independent scientists considers it unreasonable to expect PG&E to solely fund a Marine Protected Area process for the entire State of California. We think it would be more reasonable for PG&E to contribute funds toward a Marine Protected Area process focused on the Central Coast. Regional Board staff and the Board's independent scientists think PG&E's contribution would be scaled to the Area of Production Foregone (Area of Production Forgone is a way of expressing the entrainment impact in area of habitat, as discussed in the next section), plus consideration for the uncertainty related to the 316b study and the imperfect match between mitigation and entrainment loses.

Scaling Marine Reserve Habitat to Entrainment Losses

Entrainment losses are difficult to interpret in a simple currency. Entrainment losses are the product of both an affected area and an estimate of the intensity of impact over that area. One way to simplify the currency is through the use of "Area of Production Forgone," as discussed in Dr. Raimondi's testimony to the Regional Board for the July 10, 2003 hearing. Area of Production Forgone is the theoretical amount of habitat that would be necessary to produce the entrainment losses. The best estimate comes for calculations similar to those established for the artificial reef, as discussed above. As opposed to those calculations here we included sandy habitat species and came up with a source water body of an area 70 km long and again 3 km wide (see table 2). In addition, the average loss rate of larvae over all targeted species, is estimated at 8.59% (see table 2). The product of these terms is the area of *new* habitat that would be required to offset the entrainment losses; here an area 6 km along shore by 3 km offshore. This hypothetical area would be comprised of the same mixture of sandy and rocky habitat as the source water body. Clearly the additional larval contribution from marine reserve designation would not be the same as that from entirely new habitat, hence a multiplier needs to be used to scale the contribution. For example if the reserve was expected to produce 20% more larvae than a non reserve, then an area 30 km (6/0.2) by 3 km would be required to produce the number of larvae lost to entrainment. [note there is another way to calculate area required. This would rely on estimates of species specific larval production per area. These values could then be used with entrainment estimates and estimates of reserve effect (the additional contribution caused by reserve status) to produce reserve area needed. However, we have few good estimates of larval production per unit area].

In scaling the mitigation to entrainment impacts (Area of Production Forgone to marine reserve area), four main factors should be considered:

1. There is uncertainty in the entrainment study (as with any such study), and there are no practical means of reducing the uncertainty.
2. The conversion of entrainment losses to Area of Production Forgone is not exact; it provides an <u>indication</u> of applicable scale.
3. The reserve effect (in terms of additional larval production) is unknown and would need to be estimated (probably through models)
4. There are no practical means for directly mitigating or compensating for all entrainment losses; only partial mitigation is possible.

5. Marine reserves will not replace entrainment losses, but will provide the benefits discussed in the Potential Benefits of Marine Reserves, above.

Given the above factors, Regional Board staff and the independent scientists think that if marine reserves are the preferred option, it is reasonable to err on the side of over-mitigating for the entrainment losses. This can be accomplished by leveraging mitigation funds and cooperating with a larger, regional effort to establish Marine Protected Areas on the Central Coast, which is discussed in the next section.

The actual benefit to impact ratio would depend on the ambient and/or future level of impact to the protected areas that would be reduced. Marines reserves established in an area that is highly impacted would provide the greatest benefits (by eliminating the impact). It is important to note that the benefits are not strictly "replacement" of larval losses. Rather, the benefits result from general improvement to the ecosystem (see discussion of these benefits, above) and permanent resource protection.

Process for Establishing Marine Reserves

Establishing marine reserves on the Central Coast will require a comprehensive approach, sound management, and assistance from leading experts in the various fields of study. To this end, Regional Board staff and Dr. Raimondi met with the Resources Legacy Foundation Fund (RLFF), a non-profit organization whose mission is to conserve or restore natural landscapes, protect and enhance marine systems, and preserve wildlands and wilderness. RLFF is currently implementing the California Coastal and Marine Initiative (CCMI), a re-granting program of the David and Lucile Packard Foundation. The goal of the CCMI is to ensure the health and resilience of California's coastal and marine environment through ecosystem-based conservation and management. A key component of this goal is to focus intensively on the Central Coast, with the intention of creating significant, tangible, and permanent ecosystem benefits in this specific region. The goal of the CCMI should directly coincide with mitigation goals for Diablo Canyon. .

The Regional Board could establish a working relationship with RLFF to develop a proposal for establishment of marine reserve areas on the Central Coast. This proposal would be presented to the California Fish and Game Commission. RLFF has indicated that they may provide matching funds toward this effort. The major steps involved in developing a marine reserves proposal to the California Fish and Game Commission would be:

1. The Regional Board enters into an agreement with RLFF, establishing goals, tasks to achieve the goals, responsibilities, matching funds, etc. (similar to the Memorandum of Agreement between the Regional Board and the Elkhorn Slough Foundation).
2. Regional Board and RLFF establish a process for developing the Marine Protected Area proposal. The process should include a mechanism for participation by other agencies and parties.

3. Regional Board and RLFF establish an estimated schedule for developing the proposal (a multi-year schedule is certain).
4. Regional Board and RLFF implement the tasks necessary to develop the proposal, which could include:
    a. Habitat surveys necessary to design a preferred reserve size and layout, and possible alternative designs.
    b. A socio-economic study for the preferred reserve design(s), as well as options to mitigate local impacts to the fishing community.
    c. A stakeholder process to gain public input on the final design.
    d. A CEQA (or functional equivalent) document for consideration by the Department of Fish and Game and a public participation process (including a scope of work and budget).
    e. A performance monitoring plan.

5. Regional Board and RLFF form an advisory group, including independent scientists, to guide the design, implementation, and evaluation of the marine reserve areas. Measures of success for the marine reserves should include:
    a. Providing resources that have been lost as a result of impacts at DCPP
    b. Increased number and size of fish
    c. Conservation benefits

The Boards independent scientists recommend performance monitoring to evaluate the effectiveness of any marine reserves that are established. The cost for such monitoring will scale with the size of the reserve. Costs are discussed in the next section. An adaptive management approach is needed to increase the likelihood of success.

The independent scientists also recommend that all surveys and research funded by the Diablo Canyon settlement be overseen and managed by an independent panel of scientists with experience in the relevant field of study.

Costs Associated with Establishing Marine Protected Areas

The estimated costs for developing a marine reserve proposal for the Fish and Game Commission include planning and design (initial habitat surveys, a socio-economic study, etc.), local projects (relief for fisherman, permit buyouts, etc.), process management (coordination, agency outreach, drafting reports etc.), and patrolling/management of the reserves for a limited time after they are established. Based on discussions with RLFF, we estimate the cost of these tasks to be less than $10 million (probably $6 to $8 million).

In addition, performance monitoring should be required. Costs associated with performance monitoring for 316b purposes, based on other similar work at SONGS, will likely be based on a variable effort. The purpose of performance monitoring is to determine whether the size and density of fish taxa are greater in the reserve versus no-reserve areas. The first year will be more comprehensive than subsequent years (prior to reserve being established), followed by reduced monitoring for a number of years, with another more comprehensive effort at the end of the period. One possible scenario based on CFG CRANE survey methods could be:

Year 1:	$150,000
Year 2:	$75,000
Year 3:	$75,000
Year 4:	$75,000
Year 5:	$75,000
Year 6:	$75,000
Year 7:	$75,000
Year 8:	$75,000
Year 9:	$75,000
Year 10:	$150,000
Total	**$900,000**

These costs are estimates based on the work done at PISCO (UC Santa Cruz), which use methods that are the BASIS of CRANE surveys, and are in 2004 dollars.

These estimates assume that the 316b performance monitoring will be coordinated closely with existing efforts to minimize costs. Also, monitoring will be done on a limited spatial scale to minimize costs, and will serve as a proxy for other reserve areas.

The number and size of reserves in the proposal is not expected to have a large linear effect on the total project cost estimate because the same tasks must be done whether the proposal calls for one or multiple reserves, or various size reserves.

Note that additional funds would be necessary over the long term to oversee and patrol the marine reserves. However, this relatively minor cost would eventually be borne by the Department of Fish and Game.

Regional Board/PG&E settlement calls for the following (among other things):

Dedicated Fund for Projects:	$4,050,000
CCAMP Funding:	$1,500,000 (150,000/year for ten years)
Abalone Research Funding:	$ 350,000
Use of Lab Facilities:	$ 150,000 ($100,000 start-up plus $5,000/yr/10 yrs)
Total:	$6,050,000 (2004 dollars)

The $6.05 million listed above could be directed toward development of marine reserves on the Central Coast. RLFF has indicated that they may provide matching funds up to $2.5 million. If these matching are provided, the total, $8.55 million, would likely cover the total cost of developing a comprehensive proposal for the Fish and Game Commission (including all of the elements mentioned above).

Practicality of Establishing Marine Protected Areas

The practicality or real-world likelihood of establishing Marine Protected Areas can be considered on three levels:

1. Likelihood of developing a scientifically and legally defensible proposal.
2. Likelihood of the Fish and Game Commission adopting the proposal, or some variation of the proposal.
3. Likelihood that the Marine Protected Areas accomplish what is intended (performance criteria).

There are no guarantees of success with any option; however, the practicality and likelihood of success on all three levels above is high relative to other projects. This assumes that the performance criteria are carefully crafted and recognize the limitations (only some species will benefit from marine reserves) and strengths (conservation benefits) of Marine reserves. This is because there is precedent for establishing Marine Protected Areas in California, there is strong scientific support for the establishment of marine reserves particularly for conservation, and with the exception of artificial reefs, no other restoration option offers these strong points (nexus, benefits, feasibility, and scientific support).

3.3 Terrestrial Conservation Easement

With respect to marine habitat, the conservation easement defined in the RWQCB/PG&E settlement provides benefits mainly to intertidal taxa via permanent resource protection (while power plant effects are temporary). From a quantitative perspective, the marine benefits of the conservation easement cannot be realistically scaled to entrainment impacts, and the benefits provided would only apply to intertidal taxa. From a qualitative perspective, many species affected by the power plant (entrainment and thermal effects) use this intertidal habitat, so there is a direct nexus. Protection of this intertidal habitat is accomplished by preventing future degradation. Dr. Raimondi's testimony to the Regional Board for the July 10, 2003 hearing discusses the types of intertidal degradation that can occur in unprotected intertidal areas, as illustrated by the University of California's PISCO monitoring program. Where access is allowed, such as at Montana De Oro State Park, intertidal degradation includes decreases in habitat forming species, such as foliose algae, and decreases in density and diversity of associated intertidal taxa. The easement will prevent these types of impacts from occurring. The easement includes 5.7 miles of coastline (measured along the coastline contour, not line of site). This is a relatively large amount of habitat that will be permanently protected. The amount of habitat protected, and the nexus between the intertidal zone and the power plant impacts makes this project appropriate, though not quantitatively scalable to entrainment losses. The easement offers major ecological benefits and should be included in the settlement agreement.

3.4 Fish Hatchery: This option would only potentially benefit one, or perhaps very few, species, would not benefit the overall marine environment, would likely be very costly, and would potentially mitigate entrainment losses to only a fraction of the hundreds of species that are entrained. There are also significant issues with respect to the benefits and impacts of fish hatcheries, such as the introduction of diseases and degradation of natural genetic stocks. Hence, a fish hatchery does not seem to be defensible project for mitigation of entrainment losses, although there may be value in an experimental approach with a few defined and economically important species.

3.5 Restoration of Marine Habitat: Restoration of marine habitat of the sort that would lead to enhanced larval production of affected species is not available on the Central Coast. The nearshore habitats of such species are not in need of restoration (from a physical perspective – but see section on marine reserves, above). That is, from a practical perspective we cannot identify areas of ocean habitat where "restoration" would increase larval productivity. There are examples of degraded ocean habitat in other areas, such as the so-called "dead zones" where pollution runoff from terrestrial sources accumulates in the benthic environment, usually offshore from the mouths of major tributaries like the Mississippi River. The solution to these problems is to minimize pollutant runoff, which will allow the degraded areas to recover over time; there is no practical "restoration" type work that could be implemented to correct the problem. In addition, there are no large-scale degraded areas of ocean habitat off the Central Coast of California (in the relevant geographic area for this case). Therefore, ocean habitat restoration is not applicable in this case.

3.6 Abalone Research (RWQCB/PG&E Settlement): Research to develop disease resistant abalone is speculative at best, and even if successful, would benefit only one species. Abalone are probably not impacted by entrainment, but are impacted by the thermal discharge. The independent scientists do not recommend this type of research as mitigation for thermal impacts. However, other projects intended to enhance black abalone populations could be possible. In addition, research or projects directly intended to help restore red abalone populations (that were impacted by thermal discharge) might also be possible and supportable.

3.7 Use of PG&E Lab Facilities (RWQCB/PG&E Settlement): The use of PG&E's lab facilities by county educational organizations may be beneficial to the community, but it is not mitigation for impacts. There is no nexus to the impacts, or relevant benefit to the environment. This project is not recommended. Note that we have recently been informed that the lab facilities are being torn down.

3.8 Central Coast Ambient Monitoring Program Funding (RWQCB/PG&E Settlement): The Central Coast Ambient Monitoring Program (CCAMP) appears to be an important and useful program for the Regional Board. However, general ambient monitoring is not mitigation for impacts. We do not recommend ambient monitoring as mitigation. We do recommend adaptive performance monitoring, with oversight by independent experts from the relevant fields of study, for any implemented mitigation projects. Adaptive performance monitoring would be done to answer specific questions or address specific hypothesis that determine the degree of success for mitigation projects. Performance monitoring can be expensive, and given its importance in this case, should take precedence over ambient monitoring. CCAMP may provide the organizational structure to manage the adaptive performance monitoring, as long as independent experts from the relevant fields of study oversee the work.

3.9 CALCOFI Program: The California Oceanic Cooperative Fisheries Investigations (CalCOFI) are a unique partnership of the California Department of Fish and Game, the NOAA Fisheries Service and the Scripps Institution of Oceanography. The organization was formed in 1949 to study the ecological aspects of the collapse of the sardine populations off California. Today its focus has shifted to the study of the marine environment off the coast of California and the management of its living resources. CALCOFI is the longest running oceanographic and near shore monitoring program in California. Data collected in these surveys have been used to detect long-term change in zooplankton communities, icthyoplankton spatial patterns and detailed current patterns. The CALCOFI program is costly and the State is not providing funding at anywhere near historic levels. While this program is certainly a worthy effort, the data collected are mainly from much further offshore than the estimated area of entrainment influence, and, as a research project, there is no mitigation or restoration nexus to the power plant impacts. This option is therefore not recommended.

Comparison of All Projects

All options should be considered relative to each other for perspective. Table 7 lists all options and their relative rankings with respect to nexus, availability, likelihood of success, relative benefit, and relative cost. Artificial Reefs are the highest ranked project.

Table 7: Matrix Showing Relative Ranking of Potential Entrainment Mitigation Projects Based on Best Professional Judgment

Project	Nexus	Availability	Relative Likelihood of Success	Overall Relative Benefit	Relative Cost
Offshore Reefs	High	High	High	High	High
Marine Protected Areas	High	High	High*	High**	Moderate
Terrestrial Reserve (intertidal zone protection)	Medium	High (certain)	High (certain)	Medium	Low
Fish Hatchery	Low	Low	Low	Low	High
Physical Restoration of Marine Habitat	Unknown	None	Unknown	Unknown	Unknown
Abalone Research	Low	Low	Low***	Low	Low
PG&E Lab Facilities	None	Low (access)	Unknown (access)	Low	Low
RWQCB CCAMP	Low	High (certain)	High (certain)	Low	Low
CALCOFI Research	Low	High	High	Low	High
Technology Alternatives******	High	None	None	High	Extreme

*assumes that success criteria are crafted with an understanding of the limitations of marine reserves as mitigation for entrainment impacts for non-harvested species
** assumes benefit for conservation is included in calculation
*** for black abalone
**** as discussed in 316B

4.0 Potential Projects Related to Thermal Impacts

4.1 Marine Reserves: The discussion above regarding marine reserves applies here because intertidal and shallow subtidal habitats (such as those affected by the thermal discharge) would be protected. The only practical way to scale the benefits to the impacts is by comparing the amount of habitat affected by the thermal plume to the amount of similar habitat protected in a marine reserve. The thermal discharge impacts a relatively small amount of intertidal and shallow subtidal habitat compared to what would be protected in a marine reserve. The marine reserve would not necessarily replace losses caused by the thermal discharge, but would protect the intertidal and shallow subtidal habitat that supports the thermally impacted taxa.

4.2 Terrestrial Conservation Easement: The Regional Board/PG&E conservation easement would provide permanent protection for 5.7 miles of intertidal habitat against future degradation, which is direct mitigation for many thermal impacts in the intertidal zone. Given current plans, degradation of intertidal habitat would come mainly from public access. Recently PG&E has entered into an agreement with the California Coastal Commission that will open access to areas north of DCPP (the same area designated in the easement. The access rules are not fully understood at the time of writing this document, and the value of the easement as a mitigation alternative is uncertain until we are able to assess the implication of the agreement with the CCC.

4.3 State Parks Docent Program: The Regional Board directed the independent scientists to consider mitigation projects that would provide more immediate benefits than the conservation easement. This would require "restoring" degraded nearshore marine habitat. As noted above, the University of California's PISCO program illustrates intertidal degradation in areas with major public access, such as State Parks. A State Parks docent program may help reduce degradation in these areas by using field-based volunteers to educate and monitor visitors. This would be a "passive" restoration approach, rather than active, physical restoration. This effort could be scaled to the area of thermal impact by including a similar amount of habitat in the docent program. Reduced degradation may be observed over time via existing PISCO sampling. The relative cost of a docent program should be low, consisting mainly of training for volunteers.

The drawback of this type of program is that even with field docents, the areas may continue to be degraded simply because visitation is high. Concentrating visitors in specific areas acts to limit the spatial extent of degradation while allowing the public to experience the resource first hand, and would be preferred to an 'open access' policy.

5.0 Thermal Effects Monitoring

The Regional Board directed the independent scientists to develop a reduced thermal effects monitoring program. As discussed above regarding other programs (CALCOFI and CCAMP), monitoring does not mitigate for impacts. Therefore, staff and the independent scientists do not recommend that thermal effects monitoring be considered "mitigation" for impacts. However, a reduced thermal effects monitoring program could be useful to detect major biological changes above and beyond the impacts documented to date. The purpose of a reduced program would <u>not</u> be to continue verifying <u>known</u> changes, but to detect major additional changes, such as large shifts in algae, invertebrates, and fish, and detect diseases or other major ecological events, outside of Diablo Cove. Accordingly, the independent scientists recommend implementation of a modified thermal effects monitoring program at intertidal and subtidal stations.

6.0 Other Considerations

The independent scientists also considered additional projects/issues that do not directly mitigate impacts, but may be useful, including:

1. Allow access to the conservation easement for the purpose of monitoring intertidal areas. This will be necessary if a Marine Protected Area is established offshore of the easement.
2. The thermal effects in Diablo Cove and the vicinity provide a valuable opportunity for marine research projects; however, access must be approved by PG&E (and possibly federal agencies for security reasons). The independent scientists recommend allowing qualified researchers access to Diablo Cove and the vicinity, including boat launching in the Cove and maintenance of physical access ways (present roads and stairways) to rocky intertidal areas used in PG&E thermal effects studies.

7.0 CONCLUSIONS

We conclude that the most direct mitigation for entrainment losses would be provided by artificial reef habitat. As currently estimated, this alternative would require 85 to 200 hectares, at a cost of $10.6 to $26 million. This is also the best estimate for the "value' of the entrainment losses. We realize that the cost of an artificial reef is not equivalent to the "value" of entrainment losses as estimated from a resource economy model. However, creation of artificial reef habitat would be *direct* mitigation for entrainment losses, and the estimated scale and cost is based on comprehensive research done at SONGS using independent scientific oversight. This type of habitat-based valuation method is also similar to the approach used by the Regional Board at the Moss Landing and Morro Bay Power Plants.

Marine reserves would also provide major benefits to the marine ecosystem, but are more difficult to scale to entrainment impacts. The cost for developing a Central Coast marine reserve proposal to the Fish & Game Commission, in compliance with CEQA and the Marine Life Protection Act, would cost less than $10 million (likely between $6 and $8 million). This effort would include several major tasks such as a habitat survey, a socio-economic study, performance monitoring, local project funding, and a public input process.

We recommend that the conservation easement be included in the settlement agreement because it provides protection for a significant amount of nearshore marine habitat, which is directly scalable to the thermal effects, and partially related to entrainment losses. Also, intertidal areas are degraded in some State Park areas on the Central Coast due to public access (trampling). Funds could be directed to a docent program designed to minimize this impact. We recommend that this project be considered, but secondary to the terrestrial easement.

Other elements of the settlement agreement are not currently recommended (but some could be with further explanation, such as abalone research), because they do not provide mitigation for impacts or direct protection of the marine environment.

Selected references for Marine Reserves, with emphasis on West Coast

Airamé, S., J. E. Dugan, K. D. Lafferty, H. M. Leslie, D. A. McArdle, and R. R. Warner. Applying ecological criteria to marine reserve design: a case study from the California Channel Islands. Ecological Applications 13 (Supp.): S170-S184.

Allison, G., S. Gaines, J. Lubchenco, and H. Possingham. 2003. Ensuring persistence of marine reserves: Catastrophes require adopting an insurance factor. Ecological Applications in press

Bergen, L.K and Carr, M.H. 2003. Science as a catalyst for policy: Informing the development of marine reserves. Environment. 45:8-19.

Berkeley, Chapman, and Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85:1258-1264.

Carr, M., J. Neigel, J. Estes, S. Andelman, R. R. Warner, and J. Lagier. Comparing marine and terrestrial ecosystems: implications for the design of coastal marine reserves. Ecological Applications 13 (Supp.): S90-S107.

Carr, M.H. and Raimondi, P.T. 1999. Marine protected areas as a precautionary approach to management. California Cooperative Oceanic Fisheries Investigations Reports. 40:1-6.

Caselle, J. E., S. L. Hamilton, and R. R. Warner. The interaction of retention, recruitment, and density-dependent mortality in the spatial placement of marine reserves. Gulf and Caribbean Research 14: 107-118.

Gaines, S. D., B. Gaylord, and J. Largier. 2003 Avoiding current oversights in marine reserve design. Ecological Applications. In press.

Halpern, B., and R. R. Warner. Matching marine reserve design to reserve objectives. Proceedings of the Royal Society B 270:1871-1878. DOI 10.1098/rspb.2003.2405

Palumbi, S.R., S. D. Gaines, H. Leslie, and R. R. Warner. New wave: high-tech tools to help marine reserve research. Frontiers in Ecology and Evolution 1:73-79.

Roberts, C., S. Andelman, G. Branch, R. Bustamante, J. C. Castilla, J. Dugan, B. Halpern, K. Lafferty, H. Leslie, J. Lubchenco, D. McArdle, H. Possingham, M. Ruckelshaus, and R. R. Warner. Ecological criteria for evaluating candidate sites for marine reserves. Ecological Applications 13 (Supp.): S199-S214.

Roberts, C., G. Branch, R. Bustamante, J. C. Castilla, J. Dugan, B. Halpern, K. Lafferty, H. Leslie, J. Lubchenco, D. McArdle, M. Ruckelshaus, and R. R. Warner. Application of ecological criteria in selecting marine reserves and developing reserve networks. Ecological Applications 13 (Supp.): S215-S228.

Shanks, A.L, Grantham, B. and Carr, M.H. 2003. Propagule dispersal distance and the size and spacing of marine reserves. Ecological Applications 13:S159-169.

Yoklavich, M., G. Cailliet, R.N. Lea, H.G. Greene, R. Starr, J. de Marignac, and J. Field. 2002. Deepwater habitat and fish resources associated with the Big Creek Marine Ecological Reserve. CalCOFI Reports, 43:120-140.

Also see http://www.pewoceans.org/reports/pew_marine_reserves.pdf , which is a PEW commission report on the utility of Marine Reserves

The Science of Marine Reserves, PISCO – a web page devoted to bringing forward current scientific information on the utility, and design of Marine Reserves: http://www.piscoweb.org/outreach/pubs/reserves/