Report on the causes of low fish standing stock at Wheeler North Reef and possible solutions for remediation

SAN ONOFRE NUCLEAR GENERATING STATION (SONGS) MITIGATION PROGRAM

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By

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SUMMARY

The Wheeler North Reef was constructed by Southern California Edison (SCE) and its partners as partial mitigation for the adverse effects of the San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 on living marine resources. Results from the first six years of independent monitoring show that the Wheeler North Reef has consistently failed to meet the performance standard for fish standing stock. Results of analyses of time series data of fish biomass indicate that the current size (173.8 acres) and configuration (low relief reef with an average of 47.6 % coverage of rock) is insufficient to consistently meet the requirement for a minimum fish standing stock of 28 US tons. If the performance standards are not met, then the SONGS permit enables the Executive Director to require SCE to perform remediation, which may require constructing additional reef. Monitoring data collected at the Wheeler North Reef since 2000 were used determine the area of different configurations of new reef needed for remediation. Results from these analyses indicate that the area of additional reef needed for the Wheeler North Reef to meet the performance standard for fish standing stock with a 90% degree of certainty ranged from 30 - 175 acres depending on the rock coverage and vertical relief of the new reef added for remediation.

BACKGROUND

A condition of the SONGS Coastal Development Permit issued by the CCC required studies of the effects of the operation of Units 2 and 3 on the marine environment offshore from the San Onofre Nuclear Generating Station and mitigation of any of its adverse impacts. Impact assessment studies conducted by the Marine Review Committee found that the discharge of cooling water from SONGS Units 2 and 3 resulted in the loss of 200 acres of a medium to high density kelp bed and its associated community. As a result of these impact studies, the CCC added conditions to the SONGS permit to mitigate these adverse impacts that required SCE and its partners to construct a 300-acre kelp reef as in-kind mitigation for the loss of giant kelp forest habitat (Condition C). The 1991 conditions also required SCE and its partners to provide the funds necessary for CCC to contract marine scientists to perform technical oversight and independent monitoring of the mitigation projects (Condition D).

After extensive review of new analyses of SONGS' impacts to the San Onofre Kelp Forest, the CCC approved amended conditions in April 1997 that revised the kelp mitigation requirement in Condition C to require SCE to construct an artificial reef large enough to sustain 150 acres of medium to high density kelp, 28 tons of reef fish, and a kelp forest community that is similar to natural reefs in the region. The CCC noted that to accomplish this goal, a reef larger than 150 acres might be required. In addition, SCE was required to fund a marine fish hatchery. The CCC also confirmed in April 1997 its previous finding that independent monitoring and technical oversight were required in Condition D to ensure full mitigation under the permit.

Performance standards for reef substrate, giant kelp, fish, and the benthic community of algae and invertebrates specified in Condition C are used to evaluate the success of the artificial reef in meeting the intended goal of replacing the kelp forest resources

damaged or lost as a result of SONGS operations. Monitoring that is independent of the permittee is done in accordance with Condition D of the SONGS permit to: (1) determine whether the performance standards established for Condition C are met, (2) determine, if necessary, the reasons why any performance standard has not been met, and (3) develop recommendations for appropriate remedial measures. The performance standards fall into two categories: absolute standards, which are measured only at the artificial reef and require that the variable of interest attain or exceed a predetermined value, and relative standards, which require that the value of the variable of interest on the artificial reef be similar to that measured on natural reference reefs.

The values of the absolute performance standards pertaining to giant kelp and reef fish standing stock are linked to the magnitude of SONGS impacts on these resources as determined by the impact assessment studies conducted by the Marine Review Committee. Annual evaluation of these performance standards is based on the greater value obtained from either: (1) data collected at the artificial reef that year, or (2) a four-year running average calculated from data collected at the artificial reef for that year and the previous three years. A running average recognizes that short-term fluctuations in giant kelp and fish are the norm, and it is used to allow excess kelp or fish in good years to be used as mitigation to compensate for occasional years when values for the kelp or fish are below those required by the performance standards.

The relative performance standards are intended to ensure that the ecological structure and functions of the artificial reef are similar to those of natural reefs in the region. Their evaluation is based solely on a four-year running average calculated from data collected at the artificial reef for that year and the previous three years. To receive mitigation credit for a given year the artificial reef must meet all four absolute performance standards, and at least as many of the 11 relative performance standards as the lowest performing reference reef.

Under Condition C, an artificial reef would be constructed in two phases, an initial small experimental reef (~22 acres) and a subsequent mitigation reef that is large enough to meet the 150-acre kelp and 28-ton fish standing stock requirements. The purpose of the Phase 1 Experimental Reef was to determine which combinations of substrate type and substrate coverage would most likely achieve the performance standards specified in Condition C. The design of the Phase 2 Mitigation Reef was to be based on the results of the Phase 1 Experimental Reef.

Construction of the Phase 1 Experimental Reef was competed in August 1999 and five years of post-construction monitoring were completed in December 2004. All reef designs tested showed considerable promise in meeting many of the performance standards established for the mitigation reef, with reefs having a higher coverage of hard substrate tending to outperform those with lower coverage for several aspects of the kelp forest community. These findings formed the basis of the Executive Director’s determination that: (1) the mitigation reef should be built of quarry rock or rubble concrete having dimensions and specific gravities that are within the range of the rock and concrete boulders used to construct the Phase 1 Experimental Reef, and (2) the percent of the bottom covered by quarry rock or rubble concrete on the mitigation reef should average at least 42%, but no more than 86% (the range of low to high coverage

tested in Phase 1). The Commission concurred with the Executive Director's determination for the type and percent cover of hard substrate on October 12, 2005.

Construction of the Phase 2 Mitigation Reef was completed in September 2008. It was designed as 18 low relief rock polygons ranging in area from 1.35 to 38.88 acres for a total reef area of 152 acres, of which only 130 acres met the minimum requirement of 42% rock coverage. The combined area of the Phase 1 and Phase 2 reefs (officially known as the Wheeler North Reef) totaled ~177 acres, however only 155 of these acres met the Permit requirement for a 150 acre artificial reef that averaged at least 42% cover of rock. Consequently, only the 155 acres that met that averaged 42% cover of rock are used to judge the relative performance standards established for the Wheeler North Reef. In contrast, the total area of the Wheeler North Reef is used to judge the absolute performance standards for giant kelp and fish standing stock.

CURRENT STATUS OF THE PERFORMANCE OF THE WHEELER NORTH REEF

In 2013 the Wheeler North Reef met three of the four absolute standards and as many relative standards as the lowest performing reference reef[1]. It failed to meet the performance standard that requires the standing stock of reef fish at the artificial reef to be at least 28 US tons (Figure 1). Preliminary analysis of data collected during the 2014 surveys show a marked increase in the standing stock of reef fish at Wheeler North Reef and elsewhere in the region. Despite this large regional increase, the Wheeler North Reef still fell short of the 28 ton standard.

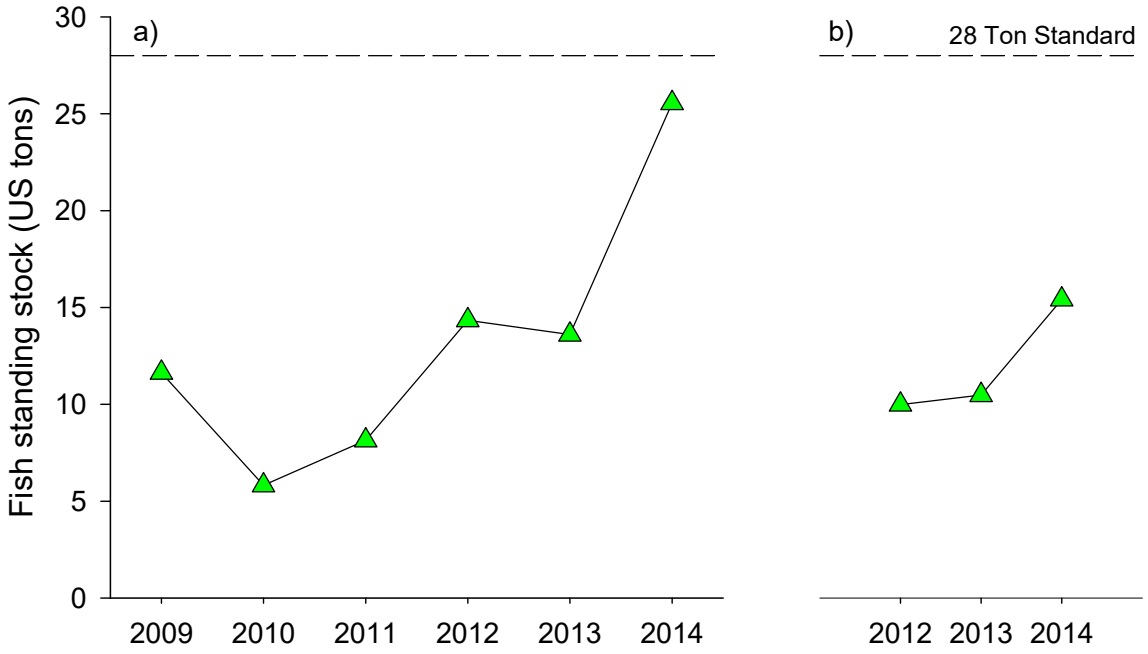

Figure 1. Estimated standing stock of fish at Wheeler North Reef (a) annual values for 2009 - 2014 and (b) 4-year running average.

[1] Reed, D. C., S.C. Schroeter, M. H. Page. 2013 Annual report of the Status of Condition C: Kelp Reef Mitigation. San Onofre Nuclear Generating Station (SONGS) mitigation program. Report to the California Coastal Commission. June 2014. 68 pp. http://marinemitigation.msi.ucsb.edu/documents/artificial_reef/annual_monitoring_reports/2013_annualreport-SONGS_kelp_reef_mitigation.pdf

Fulfillment of the SONGS reef mitigation requirement will occur when the number of years of mitigation credit accrued by the Wheeler North Reef equals the total years of operation of SONGS Units 2 & 3, including the decommissioning period to the extent that there is continuing discharge of cooling water. Operation of Units 2 and 3 began in 1983 and 1984, respectively. Both reactors were shut down in January 2012 due to excessive wear in the cooling tubes of the steam generators, and in June 2013 both units were permanently retired. Full retirement of the units prior to decommissioning is expected to take several years in accordance with customary practices; actual decommissioning will take many years until completion. Although Units 2 and 3 have been permanently shut down, SONGS still circulates ocean water within the plant to cool the spent fuel, and thus continues to discharge cooling water. Thus the number of years of mitigation credit that the Wheeler North Reef must obtain to fulfill the requirements of Condition C of the SONGS coastal development permit is 30 years and counting. As of 2014 the Wheeler North Reef had not earned any years of mitigation credit (Table 1). The reason for this has been its failure to meet the absolute performance standards for giant kelp in the first year (2009) and for fish standing stock in all six years.

Year	Mitigation credit	Reason for no mitigation credit
2009	No	Kelp & fish standing stock too low
2010	No	Fish standing stock too low
2011	No	Fish standing stock too low
2012	No	Fish standing stock too low
2013	No	Fish standing stock too low
2014	No	Fish standing stock too low
TOTAL	**0 years**	
Mitigation Target	**30 years (minimum)**	

Table 1. Summary of the mitigation credit earned by the Wheeler North Reef

Despite the above noted deficiency in the performance with respect to fish standing stock the Wheeler North Reef has shown promise in meeting many of its objectives. For example, it consistently met the absolute performance standards pertaining to hard substrate and lack of invasive species in each of the first five years of monitoring (2009 – 2013) and the absolute standard for giant kelp in in all but the first year of monitoring. Moreover, the overall performance of Wheeler North Reef with respect to the relative performance standards has been similar to that of the natural reference reefs.

REASONS FOR FAILURE TO MEET THE PERFORMANCE STANDARD FOR FISH STANDING STOCK

The standing stock of fish on a reef is influenced by a wide variety of factors including ocean climate, fishing pressure, and the physical attributes of the reef, such as its footprint area, rock coverage and topography. The most recent surveys show that the Wheeler North Reef has experienced a slight decrease in its footprint area and a slight increase in its percent cover of hard substrate relative to its as-built condition. Thus the best estimate of the present configuration of the Wheeler North Reef is ~174 acres of low relief rock that covers on average 48% of the bottom. The Wheeler North Reef was designed to be low relief to mimic natural reefs in the region, including the reef at San Onofre that was damaged by SONGS' operations. Low relief reefs in many areas are also more likely to support giant kelp, which was a major objective of the mitigation project. A critical issue in assessing the long-term performance of the Wheeler North Reef is whether its present configuration is sufficient to sustain at least 28 tons of fish over the long term. Information obtained from monitoring initiated in 2000 for Phase 1 of the reef mitigation project provides a reasonably long-term perspective for evaluating this issue.

Time series data from the Phase 1 rock modules collected from 2000 to 2014 are the most useful for evaluating the effects of rock coverage on the standing stock of reef fish because they include estimates of fish biomass for different coverages of rock over a relatively long time period. We used these data to calculate the annual mean biomass of reef fish per unit area of reef for modules with low (41%), medium (63%), and high (81%) rock coverage. Mean fish biomass per unit area for each of the three rock coverages were scaled up to 174 acres to obtain a time series of the estimated fish standing stock for 174-acre reefs with low, medium or high rock coverage. Results from this analysis show that the ability of a 174 acre reef to support a fish standing stock of at least 28 tons increased with increasing rock coverage (Figure 2). The fish standing

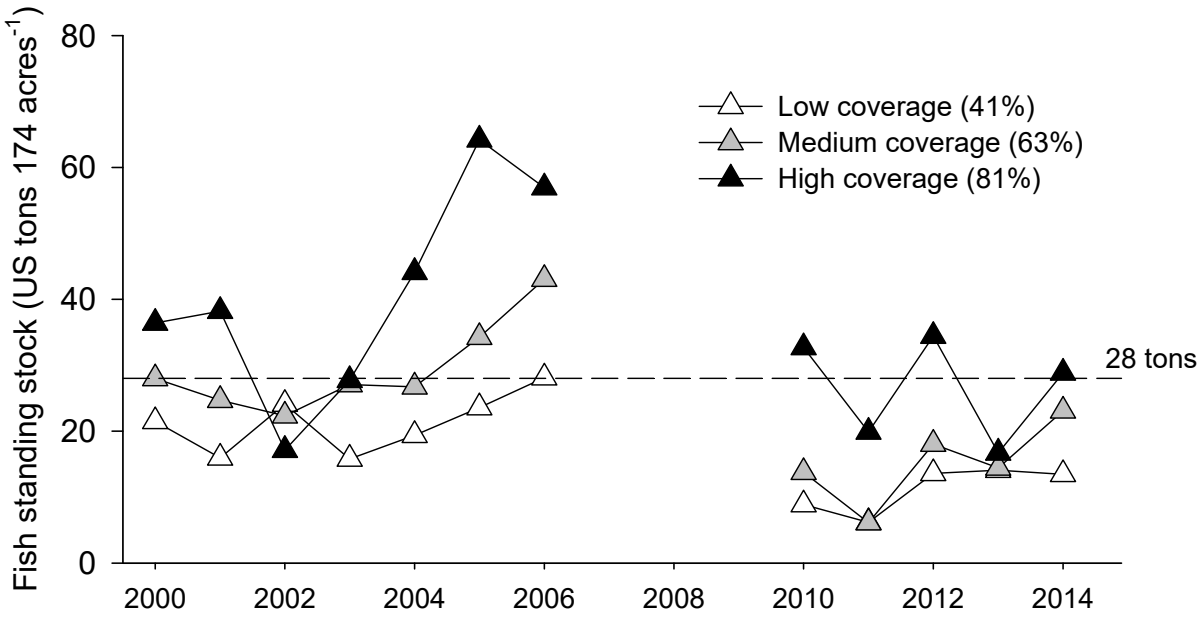

Figure 2. Estimated standing stock of kelp bed fish per 174 acres for the three coverages of rock tested on the Phase 1 modules of Wheeler North Reef.

stock of a 174 acre reef with low rock coverage would have supported 28 tons of fish in only 1 of 12 years. In contrast, a 174 acre reef with high rock coverage would have supported at least 28 tons of fish in 8 of 12 years. A 174 acre reef with medium rock coverage was intermediate in its ability to provide for fish as it would have supported 28 tons or more in 3 of 12 years.

The standing stock of reef fish at the Wheeler North Reef also was compared to that of at the San Mateo and Barn to examine the capacity of natural low-relief (< 1 m tall) reefs to sustain a fish standing stock of at least 28 tons. This also was done using annual monitoring data collected since 2000. The rock coverages at Barn and San Mateo (52% and 47%, respectively) are very similar to that at Wheeler North Reef (48%), however, their footprint areas (328 and 282 acres, respectively) are considerably larger than that of Wheeler North Reef (174 acres). Therefore, we scaled values of fish standing stock at Barn and San Mateo two different ways: (1) to their actual footprint area, and (2) to the footprint area of Wheeler North Reef. Results of this analysis show that when scaled to their actual size Barn and San Mateo frequently supported a fish standing stock of at least 28 tons (i.e., 7 of 13 years for Barn and 5 of 13 years for San Mateo; Figure 3). However, when scaled to the size of Wheeler North Reef Barn and San Mateo rarely supported a fish standing stock of 28 tons (i.e., 2 of 13 years for Barn and 3 of 13 years for San Mateo).

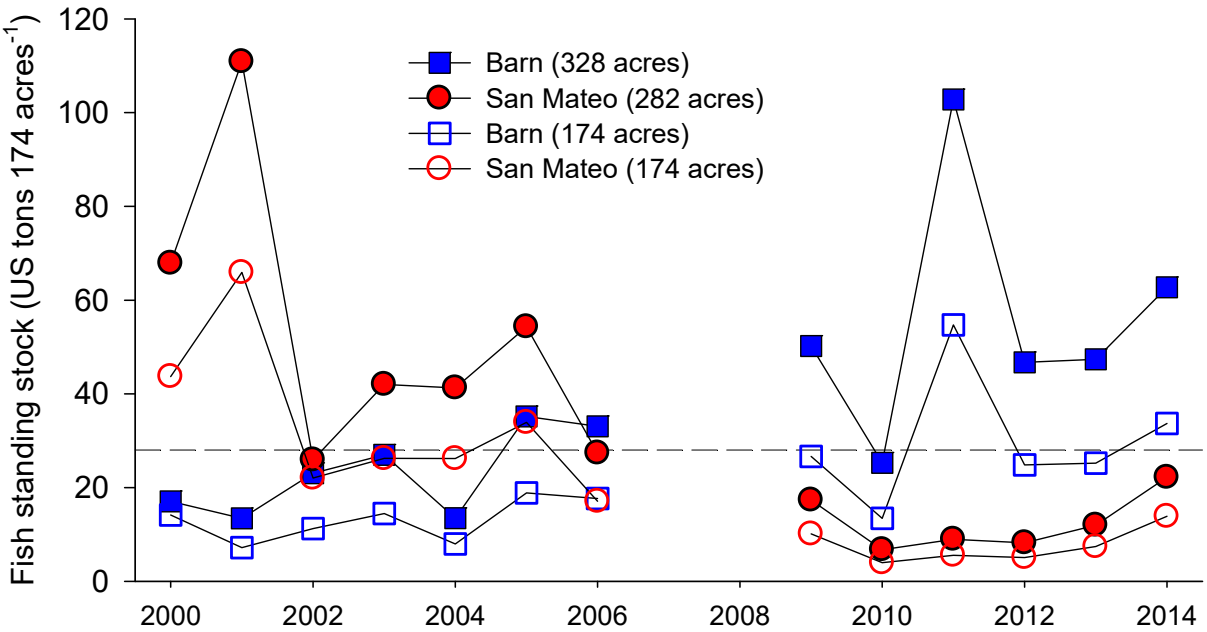

Figure 3. Estimated standing stock of kelp bed fish at Barn and San Mateo. Values are given for the actual size of each reef (328 and 282 acres, respectively) and for each reef scaled to the size of the Wheeler North Reef (i.e., 174 acres).

Collectively, these results suggest that the present size (174 acres) and configuration (48% cover of low relief rock) of the Wheeler North Reef is not sufficient to consistently support 28 tons of reef fish. This finding is notable and indicates that remediation in the

form of additional reef is needed for the Wheeler North Reef to consistently meet its current mitigation requirements over the long term.

ESTIMATES OF ADDITIONAL REEF NEEDED FOR REMEDIATION

Determining the area and bottom coverage of new reef needed for remediation requires realistic estimates of the future performance of the existing 174 acre Wheeler North Reef with respect to fish standing stock, as well as the performance of the additional reef added as remediation. The time series data of fish biomass from the Phase 1 Reef are arguably the most useful data available for predicting the future capacity of an expanded Wheeler North Reef to sustain fish biomass because they: (1) include data for reefs with different rock coverages, (2) contain data collected in 12 years over a 15 year period, which is the longest time series of fish standing stock available, and (3) encompass a broad array of environmental conditions and a wide range of inter-annual variation in the standing stock of fish, which can be expected at Wheeler North Reef in the future.

The general approach used to determine the area of different configurations of new reef needed for remediation consisted of combining the expected future standing stock of the existing 174 acre Wheeler North Reef with the expected future standing stock of fish supported by new acreage of reef added as remediation. The data collected from the seven modules of the Phase 1 Reef with low rock coverage from 2000 -2014 were used to produce a time series of annual estimates of the tons of fish that will be supported by the existing174 acre Wheeler North Reef in the future. Because the rock coverage of the existing low coverage rock modules differed slightly from that of the existing Wheeler North Reef (41% vs. 48%) fish biomass data from the Phase 1 rock modules were adjusted to 48% rock coverage prior to analysis using the relationship between rock coverage and fish biomass density observed during Phase 1.

The adjusted mean and standard deviation of fish biomass density for the existing Wheeler North Reef were used in a Monte Carlo simulation to estimate the standing stock of reef fish that would be supported by the existing 174 acre Wheeler North Reef over the long term with 90% probability (based on the upper 90% confidence limit) using either an annual or 4-year running average, which ever was highest. This estimated standing stock was 15.5 tons. Annual and 4-year running averages of fish standing stock from each of the three rock coverages of the Phase 1 rock modules (low, medium and high) were bootstrapped 1000 times to produce a distribution of the acreage required to produce the additional 12.5 tons needed for a combined standing stock of 28 tons. These distributions were used to determine the 90% probability (based on the upper 90% confidence limit) that the annual or 4-year running average of additional reef acreage (which ever was lowest) for a given reef configuration, when combined with the expected future standing stock of the existing Wheeler North reef, would meet the 28-ton performance standard for fish standing.

Increased certainty that remediation would be successful in meeting the 28 ton standard for fish standing stock could be obtained by increasing this probability above 90%. Doing so would result in increasing the area of additional reef needed for remediation, while decreasing the certainty below 90% would reduce the area of additional reef needed for remediation. These probabilities are based on the assumption that the

standing stock of fish supported by different coverages of rock on the artificial reef in the past is a good predictor of what different coverages of rock on the Wheeler North Reef will support in the future.

The estimated number of acres of various configurations of new reef that are needed for the Wheeler North Reef to meet the performance standard for fish standing stock with a 90% annual probability are provided in Table 2. These results show that remediation involving the addition of low relief, low rock cover reef will require nearly twice as many acres as remediation using low relief, high cover rock (175 acres vs. 90 acres).

Configuration of new reef to be added for remediation	Additional acres needed to support 28 tons of fish
Low relief (< 1 m), high rock cover (81%)	90
Low relief (< 1 m), medium rock cover (63%)	110
Low relief (< 1 m), low rock cover (41%)	175

Table 2. The number of acres of new reef needed for the Wheeler North Reef to have a 90% probability of meeting the 28 ton performance standard for fish standing stock in a given year for different configurations of new reef using Phase 1 as the data source. Phase 1 data were collected from 2000-2014 on 40 m x 40 m low relief rock modules that consisted of low, medium or high rock cover.

Although high relief reefs are known to support more fish biomass than low relief reefs with comparable rock coverage, high relief was intentionally not considered in the design of either phase of SONGS reef mitigation because the intent of the mitigation was to construct a reef that mimicked the type of low relief boulder habitat that was damaged in the San Onofre kelp forest by SONGS' operations. However, because the existing Wheeler North Reef is currently meeting all the performance standards except the one pertaining to fish standing stock, remediation for low fish biomass that involves the addition of high relief reef would be acceptable, and could have advantages in terms of reducing the footprint area, and potential costs and impacts of reef construction.

Because high relief was not considered in the initial design of Wheeler North Reef there are no time series data of fish biomass for high relief reefs available for estimating their efficacy in remediation. To address this deficiency we collected fish biomass data on seven occasions during the summer and early fall of 2014 in areas of high relief (2-3 m tall) with high rock cover (100%) and in adjacent areas of low relief (< 1 m tall) with low to medium rock cover (55%) at two natural reefs in the San Clemente region near the Wheeler North Reef (Two Man Reef and Monument Point). These data were used to calculate a ratio in fish biomass between low relief, 55% rock cover reefs and high relief, 100% rock cover reefs. This ratio was applied to the Phase 1data and analyzed using the methods described above to estimate the additional area of high cover, high relief reef needed for the Wheeler North Reef to have a 90% probability of meeting the 28 tons standard for fish standing stock. This analysis indicated that 30 additional acres of high relief reef would be needed for remediation (Table 3).

Configuration of new reef to be added for remediation	Additional acres needed to support 28 tons of fish
High relief (2.5 m), high rock cover (100%)	30

Table 3. The number of new acres of high relief high rock coverage reef needed for the Wheeler North Reef to have a 90% probability of meeting the 28 ton performance standard for fish standing stock in a given year as estimated using data from Phase 1 (2000-2014). Estimates are based on a fish biomass ratio of low relief, 55% rock cover / high relief, 100% rock cover obtained from repeated sampling of two natural reefs near Wheeler North Reef in summer 2014 (n= 7 sample dates).

Annual time series data of fish biomass in areas of low and high relief from 2002-2014 are available for Naples Reef off Santa Barbara via the Santa Barbara Coastal Long Term Ecological Research Project. We used these data as a measure of comparison for the data that we collected at Two Man Reef and Monument Point in 2014 (see Appendix 1 for details).

Data on fish biomass collected from low and high relief areas of natural reefs in the San Clemente region revealed that the fish biomass in areas of low relief with 55% cover of rock averaged 16.5 % of that at adjacent areas of high relief with 100% cover of rock (Figure 4a). The ratio of fish biomass between areas of low and high relief at these reefs varied slightly over time ranging from of 0.1 to 0.26. By comparison the mean ratio of

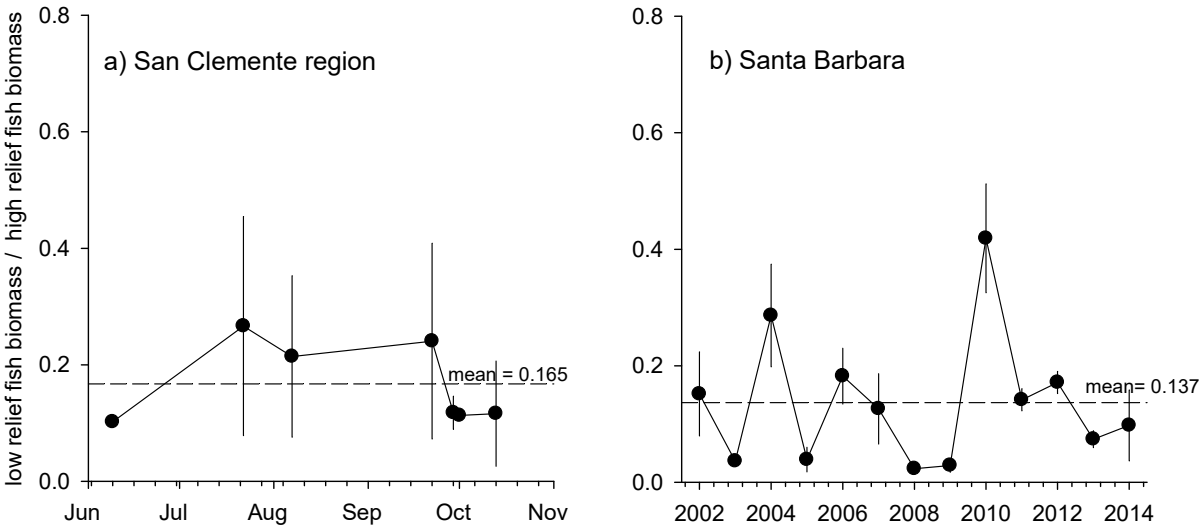

Figure 4. Mean (+/- SE) ratios of fish biomass between low relief and high relief reefs near: (a) San Clemente and (b) Santa Barbara. Data for San Clemente are the mean ratios of two reefs (Two Man Reef and Monument Point) measured on 7 dates during 2014. Data for Santa Barbara are the mean ratios of 7 high relief areas to 1 low relief area at Naples Reef. Values for low relief at Naples Reef were normalized to 55% to match the mean rock cover of low relief areas at Two Man Reef and Monument Point.

fish biomass between areas of low and high relief at Naples Reef near Santa Barbara varied more substantially among years (0.03 to 0.42; Figure 4b). However, its ratio averaged 0.137 over the 13 year study period, which is remarkably similar to the average ratio of the two reefs in the San Clemente region. This reinforces the assumption that the data on fish biomass collected in 2014 in areas of low and high relief at the two natural reefs near Wheeler North Reef provide a reasonable basis for estimating the standing stock of fish that would be supported by high relief reef used in remediating the low biomass of fish at Wheeler North Reef.

Remediation involving the addition of high relief reef that is 2.5 m tall and covers 100% of the bottom would require about 6 times more rock than a comparable area of low relief reef that is 1 m tall and covers 41% of the bottom ((100%/41%) * (2.5 m /1 m) = 6.1). However, results from the above analyses indicate that a high relief reef would support on average about 6 times more fish biomass than a comparable area of low relief reef (175 additional acres of low relief low rock cover needed to support 28 tons of fish compared to 30 acres of high relief high cover rock = 175/30 = 5.8). Thus the amount of fish biomass supported per unit volume of rock is likely to be roughly similar between a low relief, low rock cover reef and a high relief, high rock cover reef.

There are other elements besides the amount of rock needed when considering remediation that involves the addition of new reef. For example, there are physical limitations to the number of acres of new artificial reef that can be added to the existing lease site. The programmatic environmental impact report (PEIR) developed in 1999 for the construction of the SONGS mitigation reef identified a total of 356 acres within the designated lease site that were suitable for artificial reef construction[2]. Thus the most new reef that can be added to the existing 174 acre Wheeler North Reef as per the PEIR is 182 acres. Moreover, the largest artificial reef evaluated in the PEIR was 277.6 acres. Thus under the existing regulations, remediation designs that involve adding more than 182 acres would require one or more additional lease sites to fulfill the requirement for artificial reef mitigation, while remediation that involves adding more than 103.6 acres (= 277.6 – 174) would require additional environmental impact studies. For these reasons remediation involving the addition of high relief reef may be advantageous in terms of construction planning, impacts, and cost.

[2] Resource Insights. Final Program Environmental Impact Report for the construction and management of an artificial reef in the Pacific Ocean near San Clemente, California. May 1999.
http://marinemitigation.msi.ucsb.edu/documents/artificial_reef/sce_reports/programatic_eir4SONGS_reef_vol1-may1999.pdf

Appendix 1

Data from a 13-year time series of fish biomass density at Naples Reef off Santa Barbara, CA were used as a measure of comparison for differences observed in fish biomass between low and high relief reefs near San Clemente in summer 2014. The number, size and species identity of reef fish at Naples Reef have been recorded annually in summer since 2002 by the Santa Barbara Coastal Long Term Ecological Research project (http://sbc.lternet.edu/cgi-bin/showDataset.cgi?docid=knb-lter-sbc.17). Data at Naples Reef are collected within eight permanent transects using methods very similar to those employed at Wheeler North Reef by the SONGS mitigation monitoring project. Seven of the transects are located in areas of high relief (2-3 m tall) bedrock that covers 100% of the bottom. The remaining transect is located in an area of low relief cobble that covers 85% of the bottom.

Because the percent cover of rock in the low relief area at Naples Reef differed from that at the two natural reefs near San Clemente (85% vs. 55%) we converted the fish biomass data from the low relief area at Naples Reef to that expected for low relief with 55% cover of rock. This was done using the relationship between fish biomass density and rock cover collected at the 92 transects at Wheeler North Reef during 2009-2013 (Fig. A1.1).

We calculated the ratio of fish biomass density of each high relief transect at Naples Reef to that of the low relief transect (adjusted to 55% cover rock) for each year in the time series. We used this annual average to calculate the overall mean low relief (55% rock coverage) to high relief (100 % rock coverage) biomass ratio for Naples Reef for the entire time series (n = 13 years). This value was compared to that estimated for the two natural reefs near San Clemente sampled during the summer of 2014.

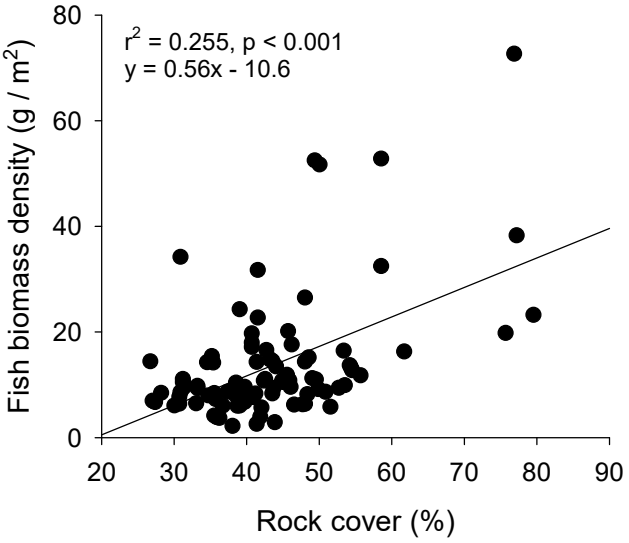

Figure A1.1. The relationship between the percent cover of rock and the biomass density of reef fish on Wheeler North Reef for the period 2009-2013. Data represent the mean value for a transect averaged over all years. N = 92 transects.