MONITORING PLAN FOR THE SONGS' REEF MITIGATION PROJECT

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EXECUTIVE SUMMARY

Condition C of the coastal development permit (no. 6-81-330) for the San Onofre Nuclear Generating Station (SONGS) requires Southern California Edison (SCE) and its partners to select a site and construct an artificial reef as partial mitigation for impacts to living marine resources in the San Onofre kelp forest caused by the operations of SONGS Units 2 and 3. The artificial reef is to be located in the vicinity of SONGS (but outside of its influence) with the goal of replacing a minimum of 150 acres (= 60.7 hectares) of kelp forest community that includes 28 tons of reef associated fishes . Mitigation for losses of kelp bed resources through the construction of an artificial reef is to be done in two phases; a five-year experimental phase followed by a mitigation phase having a duration equivalent to the operating life of SONGS Units 2 and 3 (= 32 years). The primary objective of the experimental phase is to determine the substrate types and configurations that best provide adequate conditions for establishing and sustaining giant kelp and other reef-associated biota during the mitigation phase. Data collection on the experimental phase was completed in December 2004, and on October 12, 2005 the California Coastal Commission (CCC) concurred with the CCC's Executive Director's determination for the type and percent cover of hard substrate to be used to build the mitigation reef. Construction of the mitigation phase of the SONGS artificial reef began was completed in September 2008. The combined 177-acre experimental and mitigation reef complex was named in honor of Wheeler North. In July 2020 the construction of a 197.4-acre expansion of the Wheeler North Reef (referred to as Phase 3) was completed in order to ensure that the requirements for fish standing stock and kelp area were met in a timely fashion.

Monitoring by independent contract scientists working for the CCC is being done during the mitigation phase to: (1) determine whether the performance standards established for the mitigation reef 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 SONGS coastal development permit requires the CCC's contract scientists to develop a monitoring plan for the mitigation reef that describes the sampling methodology, analytical techniques and methods for measuring performance of the mitigation reef relative to the performance standards identified in the SONGS coastal development permit. This document serves as that monitoring plan. It contains: (1) a description of the process used to evaluate condition compliance, including a list of the performance standards by which the Wheeler North Reef is judged and the general approach that is used to evaluate its overall success in compensating

for the loss of kelp bed resources caused by SONGS operations, (2) descriptions of the specific sampling methods and analyses that are used to evaluate each of the performance standards, (3) an explanation of how project data are managed, archived and accessed for future use, and (4) a description of how the results from the monitoring program are being disseminated to the CCC, the applicant, and all other interested parties.

This is a living document that will be modified as needed to ensure and maintain rigorous monitoring and evaluation of Condition C in the most cost-effective manner possible. A chronology of changes to the monitoring plan is provided in Appendix 3 of this document.

1.0 INTRODUCTION

Through its 1991 and 1997 coastal permit actions, the California Coastal Commission (CCC) amended Southern California Edison Company's (SCE) coastal development permit for the San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 (permit no. 6-81-330, formerly 183-73, hereafter SONGS permit) to include permit condition C, which requires SCE and its partners to select a site and construct an artificial reef as partial mitigation for the resource losses at the San Onofre kelp bed caused by SONGS's operations[1]. The reef is to be located in the vicinity of SONGS with the goal of replacing a minimum of 150 acres (= 60.7 hectares) of kelp forest community. Condition D of the SONGS permit adopted by the CCC establishes the administrative structure to fund the independent monitoring and technical oversight of the artificial reef mitigation project. Specifically, Condition D: (1) enables the CCC to retain contract scientists and technical staff to assist them in carrying out its oversight and monitoring functions, (2) provides for a scientific advisory panel to advise the CCC on the design, implementation, monitoring, and remediation of the SONGS mitigation projects, (3) assigns financial responsibility for the CCC's oversight and monitoring functions to the permittee and sets forth associated administrative guidelines, and (4) provides for periodic public review of the performance of the SONGS mitigation projects.

Mitigation for SONGS induced losses of kelp bed resources through the construction of an artificial reef is being done in phases, a five-year experimental

[1] The amount of kelp forest habitat lost due to SONGS operations was estimated at 179 acres. To fully mitigate this loss, the CCC required SCE and its partners to build an artificial reef that replaced 150 acres of kelp forest habitat and to establish an interest-bearing account in the amount of $3.6 million for a mariculture/fish hatchery program operated by the State of California through the Ocean Resource Enhancement and Hatchery Program (OREHP). The purpose of this fund was to compensate for losses to the kelp bed community at SONGS that are not mitigated by the artificial reef.

phase followed by a longer mitigation phase that has a minimum duration equivalent to the operating life of SONGS Units 2 and 3 including the decommissioning period to the extent there are continuing discharges. Condition C requires construction of an artificial reef that consists of an experimental reef and a larger mitigation reef. The experimental reef must be a minimum of 16.8 acres (= 6.8 hectares) and the mitigation reef (when combined with the experimental reef) must be of sufficient size to sustain 150 acres (= 60.7 hectares) of medium to high density kelp forest community. The purpose of the experimental reef was to determine which combinations of substrate type and substrate coverage will most likely achieve the performance standards specified in the SONGS permit. The design of the larger mitigation reef was based on the results of the experimental reef (Reed et al. 2005).

The CCC approved the coastal development permit for the construction of the experimental reef (referred to as the Phase 1 Reef) on July 15, 1999. The final plan approved by the CCC was for an experimental artificial reef located off San Clemente, California that tested eight different reef designs that varied in substrate composition (quarry rock or recycled concrete), substrate coverage (targeted 17%, 34%, and 67%), and presence of transplanted kelp. All eight reef designs were represented as individual 40m x 40m modules that were replicated in seven areas (i.e., blocks) for a total of 56 artificial reef modules totaling 24.8 acres (~10 hectares). The Army Corps of Engineers issued its permit on August 13, 1999, and SCE completed construction of the Phase 1 Reef on September 30, 1999.

Five years of post-construction monitoring were completed in December 2004. Results from the five-year experimental phase of the artificial reef mitigation project were quite promising in that all six artificial reef designs and all seven locations (i.e., blocks) tested showed similar tendencies to meet several of the performance standards established for the mitigation reef (Reed et al. 2005). It was concluded from these findings that a low relief concrete rubble or quarry rock reef constructed off the coast of San Clemente, California had a good chance of providing adequate in-kind compensation for the loss of kelp forest biota caused by the operation of SONGS Units 2 and 3. These findings formed the basis of the CCC Executive Director’s determination that: (1) the mitigation reef shall 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 SONGS Phase 1 Reef, and (2) the percent of the bottom covered by quarry rock or rubble concrete on the mitigation reef shall average at least 42%, but no more than 86%. The CCC concurred with the Executive Director’s determination for the type and percent cover of hard substrate on October 12, 2005.

On August 8, 2006, the Commission approved SCE's proposed design for creating a low-profile (< 1 m in height), single-layer artificial reef (referred to as the Phase 2 Reef) of quarry rock distributed on the sea floor in quantities similar to those of the lowest substrate coverage used in the experimental phase of Condition C. On April 17, 2006 the California State Lands Commission acting on a request from SCE adopted a resolution declaring that the SONGS Mitigation Reef complex be named in honor of Dr. Wheeler North.

Construction of the Phase 2 reef was completed in 94 days on September 11, 2008. Approximately 126,000 tons of boulder-sized quarry material were deposited in 18 polygons that collectively covered 152 acres (= 61.5 hectares) of sea floor. When added to the Phase 1 Reef a total of 177 acres (= 71.5 hectares) of reef were constructed. SCE submitted a final construction report detailing the as-built specifications of the Phase 2 Reef to the CCC on September 4, 2008 (Coastal Environments 2008). The Executive Director of the CCC found the Phase 2 reef to be in compliance with Condition C and on January 27, 2009 issued a Notice of Acceptance of SCE's final construction report. In his notice of acceptance, the Executive Director found that the average cover of quarry rock on the Phase 2 reef was slightly below the 42% minimum requirement specified in the SONGS permit. To address this inadequacy, the Executive Director of the CCC accepted a scenario in which 16 of the 18 polygons of the Phase 2 reef comprising ~130 acres (hereafter referred to as primary polygons) were combined with the 24.8 acres of the Phase 1 reef (as determined in 2009, Elwany et al. 2009) to fulfill SCE's permit requirement that they construct a minimum of 150 acres of reef with an average of at least 42% cover. The 22 acres associated with the two Phase 2 polygons not used to meet the 150-acre requirement (hereafter referred to as the Phase 2 the contingency polygons) are used when evaluating the requirements pertaining to giant kelp area and fish standing stock (see section 2.1).

Performance standards for reef substrate, giant kelp, fish, and benthos specified in Condition C are used to evaluate the success of the Wheeler North Reef in meeting the intended goal of replacing the kelp forest resources damaged or lost by SONGS operations. Monitoring independent of the permittee shall be done in accordance with Condition D 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.

Independent monitoring revealed that the Phase 1 and 2 Wheeler North Reef consistently failed to meet the absolute performance standard for fish standing stock (Reed et al. 2015). Results of monitoring showed that the size and rock coverage of the Wheeler North Reef were insufficient to consistently meet the requirement for a minimum fish standing stock of 28 US tons. Based on these analyses the Commission's Executive Director informed SCE, in a letter dated May 24, 2016, that to comply with the mitigation requirements SCE needed to remediate Wheeler North Reef by building new reef acreage that meets minimum size, relief and cover requirements. Monitoring data collected at the Phase I Reef from 2000-2016 were used to determine the area of different configurations of new reef needed for remediation (Reed et al. 2015). On March 7, 2019 the CCC approved SCE's plan to expand the existing 174-acre Wheeler North Reef by creating up to 210 additional acres of low-relief quarry rock reef using up to 175,000 tons of quarried rock (hereafter referred to as Phase 3). Construction of the Phase 3 occurred during the summers of 2019 and 2020 and consisted of 20 polygons encompassing a total of 197.4 acres with an average of 45% cover of quarry rock distributed as a mono-layer on the bottom. Collectively, in 2020 the Phase 1, 2 and 3 reefs encompassed ~373 acres with an average of~ 46% cover of rock.

The SONGS permit requires the CCC's contract scientists to develop a monitoring plan for the Wheeler North Reef that describes the sampling methodology, and analytical techniques and methods for measuring the performance of the mitigation reef relative to the performance standards identified in Condition C. This document serves as that monitoring plan for the Wheeler North Reef.

2.0 EVALUATION OF THE MITIGATION REQUIREMENTS

Condition C of the SONGS permit identifies physical and biological standards that specify how the mitigation reef should perform and the timing and level of monitoring that is needed to evaluate its performance. The performance standards fall into two categories: (1) absolute standards, which are measured at the Wheeler North only and require the variable of interest attain or exceed a predetermined value that is linked to estimated losses in the San Onofre kelp forest caused by SONGS operations, and (2) relative standards, which require that the value of the variable of interest at Wheeler North Reef be similar to that measured on natural reference reefs. Among other things these performance standards require the Wheeler North Reef to support at least 150 acres of medium-to-high density kelp, 28 tons of reef fish, and assemblages of algae, invertebrates and fishes that are similar to nearby natural reference reefs.

Below we provide: (1) a list of the performance standards for the mitigation reef as stated in the SONGS permit, (2) an explanation of how mitigation credit is assigned for the different types of performance standards, (3) a summary of the process used to select the reference reefs used as a measure of comparison in assessing the relative performance standards, (4) a description of methods used to determine whether the Wheeler North Reef and the reference reefs are similar, and (5) a schedule for the monitoring period.

2.1 Performance standards

The following performance standards listed in the SONGS permit will be used to measure the success of the mitigation reef and to determine whether remediation is necessary. Performance standards for (1) Substrate, (2) Kelp bed, (3a) Fish standing stock, and (4c) Undesirable and invasive species are absolute standards; the remaining performance standards pertaining to Fish (3b-e) and Benthos (4a-b) are relative standards.

1. Substrate

    a. The mitigation reef shall be constructed of rock, concrete, or a combination of these materials.

    b. The total area of the mitigation reef (including the experimental reef modules) shall be no less than 150 acres.

    c. At least 42% but no more than 86% of the mitigation reef area shall be covered by exposed hard substrate

    d. At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota.

2. Kelp bed

    The mitigation reef shall sustain 150 acres of medium-to-high density giant kelp. For purposes of this condition, medium-to-high density giant kelp is defined as more than four adult *Macrocystis pyrifera* plants per 100 m^2 of sea floor,.

3. Fish

    a. The standing stock of fish at the mitigation reef shall be at least 28 tons

    b. The resident fish assemblage shall have a total density and number of species similar to natural reefs within the region.

    c. Fish reproductive rates shall be similar to natural reefs within the region.

    d. The total density and number of species of young-of-year fish (fish < 1 year old) shall be similar to natural reefs within the region.

    e. Fish production shall be similar to natural reefs within the region.

4. Benthos

   a. The benthic community (both algae and macroinvertebrates) shall have coverage or density and number of species similar to natural reefs within the region.

   b. The benthic community shall provide food-chain support for fish similar to natural reefs within the region.

   c. The important functions of the mitigation reef shall not be impaired by undesirable or invasive benthic species (e.g., sea urchins or *Cryptoarachnidium*).

2.2 Assigning mitigation credit

Mitigation credit is assigned on an annual basis and the manner in which credit is assigned varies with the different types of performance standards.

Mitigation credit for meeting the absolute performance standards for fish standing stock and giant kelp acreage is based on estimated annual losses of reef fish (i.e., 28 US tons) and giant kelp area (150 acres) and assigned on a cumulative basis. The CCC's rationale for using this approach is that full compensation is to be based on total accrued losses of fish and kelp during the period of SONGS operations rather than for annualized losses. For example, the accrued loss of fish standing stock due to SONGS operations is 896 tons (28 tons x 32 years), Using this approach, the standing stock of reef fish is measured each year and the annual total is added to the cumulative total of previous years. Once a cumulative total of 896 tons is reached, the requirement for mitigation of losses in fish standing stock will be satisfied. Using this same cumulative approach, the mitigation requirement for giant kelp area is satisfied once the Wheeler North Reef has supported a cumulative total 4800 acres of medium-to-high density adult giant kelp (150 acres x 32 years).

Mitigation credit for meeting the absolute performance standards for hard substrate and undesirable and invasive species in any given year is based on the greater value obtained from either: (1) data collected at the Wheeler North Reef that year, or (2) a four-year running average calculated from data collected at the Wheeler North Reef for that year and the previous three years. A running average recognizes that short-term fluctuations in kelp forest biota are the norm, and it is used to allow credit for excess reef biota in good years to compensate for occasional years when values for the biota are slightly below that of the absolute standards.

The evaluation of each relative performance standard is based solely on a four-year running average calculated from data collected at the Wheeler North Reef for that year and the previous three years. An either /or criterion (i.e., using data from either a single year or a running average) is not appropriate in this case because the desired goal for the relative standards is not to achieve a specified value that is linked to estimated losses at the San Onofre kelp forest, but rather to evaluate whether the abundances and numbers of species of kelp forest biota at the Wheeler North Reef are similar to that of the reference reefs. This is best accomplished using a short-term (4-year) running average that accounts for natural variation in time. Natural kelp forests vary greatly in their species composition and abundance and it is likely, that the reference reefs will not consistently meet all the relative standards in a given year. Therefore, to avoid requiring the Wheeler North Reef to perform better than the reference reefs the Wheeler North Reef is required to meet at least as many of the relative standards as the lowest performing reference site (which by definition is an acceptable measure of comparison; see section 2.2 below) in a given year for that year to count towards compliance with Condition C.

The Wheeler North Reef will earn 1 year of mitigation credit for each year that it meets the absolute performance standards for hard substrate and invasive and undesirable species and as many relative performance standards as the lowest performing reference reef. The mitigation requirements for these performance standards will have been met once the Wheeler North Reef attains 32 years of mitigation credit.

2.3 Reference Reefs

Requiring that the value of a resource be similar to that on natural reefs is based on the rationale that to be successful, the mitigation reef must provide the same types and amounts of resources that occur on natural reefs. Resources on natural reefs, however, vary tremendously in space and time. Differences in physical characteristics of a reef (e.g., depth and topography) can cause plant and animal assemblages to differ greatly among reefs while seasonal and inter-annual differences in oceanographic conditions can cause the biological assemblages within reefs to fluctuate greatly over time. Ideally, the biological assemblages on a successful artificial reef should fluctuate in a manner similar to those on the natural reefs used for reference. One way to help ensure this is to select reference reefs that are close to and physically similar to the design of the Wheeler North Reef. The premise here is that nearby reefs with similar physical characteristics should support similar biota, which should fluctuate similarly over time. Thus, in addition to proximity other criteria used to select the reference reefs included that they: (1) not be influenced by the operation of SONGS, (2) be located at a depth similar to the Wheeler North Reef, (3) be primarily low relief, preferably consisting of cobble or boulders, and (4) have a history of sustaining giant kelp at medium to high densities. The criterion that the reference reefs have a history of supporting persistent stands of giant kelp is important because communities on reefs without giant kelp can differ dramatically from those with kelp. Based on these criteria, San Mateo kelp bed (located adjacent to the southern end of the proposed Wheeler North Reef) and Barn kelp bed (located approximately 12 km south of San Mateo kelp bed) were chosen as reference reefs for evaluating the performance of the Wheeler North Reef.

Temporal variability, especially of the sort associated with changes in oceanographic conditions, can be accounted for more easily by sampling the Wheeler North Reef, San Mateo and Barn concurrently. Concurrent monitoring of the mitigation and reference reefs increases the likelihood that regional changes in oceanographic conditions affecting the Wheeler North Reef are reflected in the performance criteria, since nearby San Mateo and Barn will be subjected to similar regional changes in oceanographic conditions.

2.4 Determination of similarity

A requirement of the SONGS permit is that as many of the response variables used to assess the relative performance standards of the Wheeler North Reef (hereafter referred to as “relative performance variables”) be “similar” to those at nearby natural reference reefs. Evaluating whether the performance of Wheeler North Reef is similar to that at the San Mateo and Barn reference reefs requires that the mean (or in some cases the median) value for a given relative performance variable at Wheeler North Reef not be significantly lower than the mean (or median) value at the lower performing of the two reference reefs. We use a one sample, one tailed approach for all comparisons. Significance is determined using an approach that utilizes both a formal probability value (i.e. p-value) and an effect size. This is generally done by means of a t-test except in the case of the performance standards pertaining to fish reproductive rates and food chain support for fish. For these two standards significance is determined by a resampling procedure in which the effect size is calculated as the proportional difference in the medians of the resampled distributions of the Wheeler North Reef and the lower performing reference reef, and the p-value is the percentile in the distribution of the lower performing reference reef that is equal to the median value of the Wheeler North Reef.

The level of certainty in determining whether the Wheeler North Reef meets the performance standards is directly related to sampling effort. Data collected during the experimental Phase 1 of the reef mitigation were used to determine the level of sampling that would likely be needed to detect a 20% deviation from the relative performance standards (i.e., the effect size which is calculated as the proportional difference between the mean values for the Wheeler North Reef and that of the lowest performing reference reef) with 80% power (i.e., the statistical power is calculated as 1- Type II error), using a Type I error (α) = 0.2. Once data have been collected and an effect size for a given relative performance standard is determined, a critical α needs to be assigned in order to evaluate whether the performance standard has been met for the year. The monitoring philosophy adopted for this project is to balance the risk associated with falsely concluding that the performance standard was not met (Type I error = α) with the risk associated with falsely concluding that the standard was met (Type II error =β). The approach used to assign a value to α involves linking it to the effect size. This is done because the importance of correctly determining whether the Wheeler North Reef failed to meet a relative performance standard increases with the magnitude of the difference between Wheeler North Reef and the lowest performing reference reef (i.e., the effect size). If the effect size is small, then it is necessary to apply a correspondingly small value of α in order to be certain that the difference between Wheeler North Reef and the reference reefs is in fact real. Assigning a critical value of α that is too large in this case runs the risk of falsely concluding that the Wheeler North Reef met the performance standard when it did not (Type I error). By contrast if the effect size for a relative performance standard is large, then assigning a critical value of α that is too small runs the risk of falsely concluding that the Wheeler North Reef did not meet the performance standard when it did (Type II error). Thus linking the critical value of α to the effect size reduces the probability of committing a Type I error when the effect size is small, and a Type II error when the effect size is large.

The following rules will be used when assessing whether the Wheeler North Reef meets a given relative performance standard (refer to Figure 3):

1) If $\alpha \leq$ effect size for any α ranging from 0.000 to 0.500, then the Wheeler North Reef will be considered not to have met that performance standard (i.e. it is different from the reference sites) for the period of assessment (α and effect size rounded to three significant figures).
2) If $\alpha >$ effect size for any effect size ranging from 0.000 to 0.500, then the Wheeler North Reef will be considered to have met that performance standard (i.e., it is similar to at least one of the reference sites) for the period of assessment (α and effect size rounded to three significant figures).
3) If the effect size is > 0.500 and α is >0.500 then assessment for the period will be considered inconclusive (α and effect size rounded to three significant figures) and the following steps will be taken:
    a. The sampling design may be revised to increase the statistical power to an expected value of at least 80%. Whether this effort is necessary will be based on the history of the performance of the Wheeler North Reef with respect to the performance standard. For example, if the analyses were conclusive in previous periods, then a

single inconclusive analysis would not be sufficient to invoke a revision of the sampling design.

b. If needed, the revised sampling design will be implemented the following year.
c. If in the following year the standard is met, then the standard will be considered to have been met the previous year as well. If in the following year the standard is not met, then the standard will be considered to not have been met the previous year as well.
d. This process will continue until the standard can be assessed, unless the Commission changes the standard set forth in SONGS permit condition C.

4) Monitoring data will be evaluated annually to determine if changes need to be made to the sampling program to bring it closer to the design objective of detecting a 20% deviation from the performance standards (i.e., the effect size) with an 80% probability (i.e., the statistical power) using a type I error (α) = 0.2.

The following is an example of how these rules are implemented. If the proportional effect size for a given variable was 0.25 (i.e., the mean value at Wheeler North Reef was 75% of the mean value at the lower of the two reference reefs), then a t-test yielding a p-value ≤ 0.25 would indicate the Wheeler North Reef did not meet the performance standard, whereas p-values > 0.25 would indicate that it did meet the performance standard. The rationale for using the lower of the two reference reefs is that both reference reefs are considered to be acceptable measures of comparison for Wheeler North Reef. Hence, if Wheeler North Reef is performing at least as well as one of the reference reefs, it would be judged successful. The scaling of the p-value (α) to the effect size recognizes sampling error when estimating mean values and balances the probability of a Type I error (falsely concluding that Wheeler North Reef is not similar to the reference reefs when it is t) with the probability of a Type II error (falsely concluding that the Wheeler North Reef is similar to the reference reefs when it is not).

To insure that the Wheeler North Reef is not held to a higher standard than the reference reefs the above procedure is also applied to San Mateo and Barn to evaluate whether they would have met the relative performance standards. This is done by treating San Mateo (or Barn) as the mitigation reef and using the Wheeler North Reef and Barn (or San Mateo) as the two reference reefs. The Wheeler North Reef is considered similar to the reference reefs if the number of relative standards met by the Wheeler North Reef is equal to or greater than the number of relative standards met by either San Mateo or Barn.

The above approach ensures that the assessment of similarity is consistent with the SONGS permit requirement that the performance standards be met without the unreasonable requirement that Wheeler North Reef outperform the reference reefs for every performance standard. Importantly, this approach deals realistically with the inherent variability of nature in a manner that best serves the interests of the public and SCE.

2.5 Monitoring period

Condition C of the SONGS permit requires that the SONGS mitigation reef be monitored for a period equivalent to the operating life of SONGS. "Full operating life" was defined to include "past and future years of operation of SONGS Units 2 and 3, including the decommissioning period to the extent that there are continuing discharges." The operation of Units 2 and 3 began in 1982 and 1983, respectively. Both reactors were shut down in January 2012 due to excessive wear in the cooling tubes of the steam generators, and permanently retired in June 2013. At the March 2019 hearing when the CCC approved the Phase 3 Reef expansion as remediation for the Wheeler North Reef's failure to support a fish standing stock of 28 tons the CCC defined the full operating life of SONGS to be the 32-year period spanning the commencement of Unit 2 in 1982 through the end of 2013. The CCC ruled that the accrual of mitigation credit by the Wheeler North Reef would begin upon the installation of the Phase 3 Reef (i.e., 2019).

Monitoring of the performance of the Wheeler North Reef began in 2009 after completion of the construction of the Phase 2 Reef and will continue until: (1) the Wheeler North Reef earns 32 years of mitigation credit for meeting the relative performance standards and the absolute performance standards for hard substrate and undesirable and invasive species, and (2) the Wheeler North Reef accrues mitigation credit for 896 tons of reef fish and 4800 acres of giant kelp. The level of sampling effort may be reduced to annual site inspections, after the Wheeler North Reef has met the relative performance standards and the absolute performance standards for hard substrate and undesirable and invasive species for at least three consecutive years following the construction of the Phase 3 Reef.

Annual site inspections are intended to represent a significant reduction in effort compared to current sampling protocols. An approach under consideration is based on the spatial replication (i.e., number of transects) required to detect a minimum 50% difference between the Wheeler North Reef (Phase 1 and 2 only) and the reference sites with 80% confidence and statistical power. In this way the sampling design for annual site inspections is based on the existing requirements for statistical power and confidence interval (see section **2.4 Determination of similarity**), but with a much reduced ability to detect moderate to small effect sizes. The rationale for this approach is to create a sampling design that is only capable of detecting large differences in the performance of the Wheeler North Reef relative to the reference reefs. This reduced sampling design, when coupled with cumulative monitoring for fish standing stock and kelp area, involves a sampling effort (measured in terms of diver days) that is approximately 15% of the current sampling effort.

As with the existing full scale monitoring, performance evaluation using annual site inspections will require the Wheeler North Reef to meet as many relative standards as the lowest performing reference reef in a given year for that year to count towards mitigation credit. Annual site inspections would continue to be used until either: (1) the mitigation requirement for the relative standards is met (i.e. the number of years of accrued mitigation credit equals the 32 years of SONGS operations), or (2) annual site inspections indicate that the Wheeler North Reef is performing worse than the reference reefs with respect to the relative performance standards. Full scale monitoring would then be restarted in the event that the performance of the Wheeler North Reef falls below that of the lowest performing reference reef for two consecutive years and would continue until the relative performance standards are met for three successive years at which time monitoring would revert to annual site inspections. Before this approach is implemented this monitoring plan will be updated to include the specific methods for annual site inspections and the performance triggers that lead to its implementation or to a return to full scale monitoring.

If the results of annual site inspections show that the Wheeler North Reef fails to meet the performance standards for a period of two consecutive years, then full monitoring may be re-established for those standards that are out of compliance to determine whether non-compliance is an artifact resulting from a reduction in monitoring effort. If resumption of full monitoring leads to the conclusion that the reduction in monitoring was responsible for non-compliance, then monitoring will remain at the full levels for the duration of the project or until the Executive Director of the CCC concludes that reduced monitoring could be reinstituted.

3.0 SAMPLING METHODS AND DATA COLLECTION

3.1 General Sampling Design

The goal of the general sampling design is to provide a cost efficient framework for collecting data that is suitable for accurately determining whether the Wheeler North Reef has met the SONGS' performance standards. To achieve this goal, the sampling design incorporates the following features: (1) spatially distributed sampling to increase accuracy in the characterization of each reef, (2) a method for adaptively altering sampling effort based on the analysis of data collected during previous years, and (3) a strategy for dealing with the potential loss of sampling units at the reference reefs caused by unforeseen events.

3.1.1 Spatial distribution of sampling effort

147 sampling locations, each defined by a fixed 50m x 20m area, were established at the Wheeler North Reef; 12 transects are in Phase 1, 70 in the primary polygons of Phase 2, 12 in the contingency polygons of Phase 2, and 59 in Phase 3 (Figure 1a). An additional 82 transects were established at both San

Mateo and Barn in areas that are known to support persistent kelp; Figures 1b, c). Sampling of the three reefs is done concurrently. Each sampling area is identified by unique differential GPS coordinates that mark the “zero end” of a 50m transect and a compass heading along which divers lay out a 50m measuring tape. A 20m wide swath centered along the 50m transect defines the sample area at each sampling location. Different sized sampling units (e.g., 0.5m^2, 1m^2, 20m^2, and 100m^2) within this sampling area are used to evaluate different performance variables (Figure 2).

The transects on each reef are arranged in pairs with the two transects in each pair spaced 25m apart (Figures 1a -c). The exceptions to this are the single transects located on the Phase 1 and Phase 3 Wheeler North Reef. Pairing of transects is done to increase sampling efficiency. Maps of kelp persistence and hard substrate were used to strategically distribute the 41 transect pairs at San Mateo and Barn across areas of reef known to support giant kelp. Transects at Wheeler North Reef were allocated to the polygons and the existing experimental reef modules in proportion to their area.

3.1.2 Strategy for dealing with unusual events.

An issue that may occur during the course of monitoring the SONGS reef mitigation project is the loss of reef habitat and/or biota at sampling locations on the reference reefs due to unusual or unforeseen events. Such events would render the reference sites to be an inappropriate comparison for judging the performance of the Wheeler North Reef. An example of such an unusual event was the catastrophic loss of kelp forest biota at Barn during the impact assessment phase of the SONGS mitigation project (Bence et al. 1989). The loss of hard substrate due to a rapid influx of sediment caused by the construction of the Interstate-5 freeway was implicated as the cause for the loss of kelp forest resources at Barn during the 1980s (Bence et al. 1989; Kuhn and Shepard, 1984). Because the loss of reef habitat at Barn was substantial and linked to human activities, it was deemed to be an inappropriate reference site for measuring SONGS’s impacts. Consequently, data from Barn were excluded from the analyses of SONGS impacts.

If such unusual events occur at San Mateo and Barn during the monitoring period of the Wheeler North Reef, then the following strategy will be employed:

1. If >50% of the reef habitat at any of the sampling locations on the reference reefs (i.e. the 50m x 20m area defined by a transect) is lost or damaged due to human activities, then that sampling location will be replaced with one that is suitable for use as a reference using the same criteria for transect placement as described above (*3.1.1 Spatial distribution of sampling effort)*.

2. If the amount of suitable reef habitat at San Mateo and Barn declines to less than that of the Wheeler North Reef, then it will be replaced with a different reference reef that contains as least as much area of suitable reef habitat as the Wheeler North Reef.

3.2 Methods used to evaluate the performance standards

Listed below are the approaches that are used to evaluate the performance standards used to judge whether the Wheeler North Reef meets the mitigation requirements of Condition C of the SONGS permit. The general sampling methods follow those used during the experimental phase (Reed et al. 2005), with some modifications.

1. THE MITIGATION REEF SHALL BE CONSTRUCTED OF ROCK, CONCRETE, OR A COMBINATION OF THESE MATERIALS.

Approach: SCE's final design plan for the Wheeler North Reef listed quarried rock as the exclusive building material. University of California Santa Barbara (UCSB) scientists working for the CCC conducted diver surveys and reviewed SCE's final construction report for the Wheeler North Reef (Coastal Environments 2008, 2020) and determined that the material used to construct the Wheeler North Reef conformed to that described in the final design plan. Hence SCE met this performance standard.

2. THE TOTAL AREA OF THE MITIGATION REEF (INCLUDING THE EXPERIMENTAL REEF MODULES) SHALL BE NO LESS THAN 150 ACRES.

Approach: Multi-beam sonar surveys of the Phase 2 portion of Wheeler North Reef were done in 2008 by contractors working under a cooperative agreement with SCE and the CCC immediately after construction of the Wheeler North Reef (hereafter referred to as the as-built sonar survey). Data from the as-built sonar survey were compared to results obtained from the pre-construction multi-beam survey done in 2005 to determine whether the Wheeler North Reef constitutes 150 acres of artificial reef habitat. Analyses of data obtained from these surveys were presented in the final construction report of the Wheeler North Reef (Coastal Environments 2008). UCSB scientists working for the CCC reviewed these data and analyses and determined that the Phase 2 mitigation reef consisted of 152 acre low-profile (<1 m in height) single-layer quarry rock reef arranged in 18 polygons. Because multibeam surveys of the Phase 1 portion of Wheeler North Reef were not done in 2008 bathymetry data of the Phase 1 Reef collected in 2009 were used to estimate the total as-built area of Wheeler North Reef (i.e., Phase 1 + Phase 2) in 2008. Thus the 176.81 acres of mitigation reef (24.79 acres from the Phase 1 as determined from data collected from the 2009 multi-beam sonar survey + 152.02 acres from Phase 2 as determined from data collected from the 2008 as–built multi-beam survey) met this performance standard.

3. At least 42 % but no more than 86% of the mitigation reef area shall be covered by exposed hard substrate

Approach*:* The percent cover of hard substrate on the Wheeler North Reef was measured by UCSB scientists in summer 2008. Five 1m^2 quadrats were uniformly placed along each of the 50m long fixed transects, which were distributed across the polygons and experimental reef modules in proportion to the polygon (or experimental reef module) area (see ***3.1 General Sampling Design*** for details). Percent cover was estimated using a uniform grid of 20 points placed within the 1m^2 quadrats using the same technique employed during the experimental phase of the artificial reef mitigation project. In brief, the observer sighted an imaginary line through each of the points that was perpendicular to the bottom and recorded the substrate type intercepted by the line extending below the point. Substrates were classified as natural or artificial and categorized as bedrock (continuous rocky reef), mudstone, large boulder (largest diameter ≥ 100 cm), medium boulder (≥ 50cm and <100cm), small boulder (≥ 26cm and <50cm), cobble (≥ 7cm and ≤ 25cm), pebble (≥ 2mm and < 7cm), sand (< 2mm), and shell hash. The categories of exposed hard substrate used to assess this standard included only quarry rock in the form of cobble, small, medium and large boulders. Hard substrates covered with a thin layer of silt or sand were noted as being silted (silted artificial substrates are considered available for the attachment of reef biota for the purpose of evaluating performance standard 4 below). Results from diver surveys completed immediately after the construction of the Phase 2 Reef in 2008 showed that the mean percent cover of hard substrate averaged across all Phase 2 primary polygons and Phase 1 modules was 42.3 %, demonstrating that the as-built condition of the Wheeler North Reef met this standard. Moreover, post-construction monitoring of the Phase 3 Reef demonstrated that it also met this standard as its rock coverage averaged 45%.

4. At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota

Approach*:* The total area of the exposed hard substrate (S) that is available for the attachment of reef biota during any given year t is determined as:
$S_t = A_t P_t$,

where A_t is the total area of the footprint of the Wheeler North Reef in year t, and P_t is the proportion of the Wheeler North Reef covered by hard substrate in year t. A_t is determined from backscatter in the most recent multibeam sonar survey using a horizontal grid size of 0.25 meters with an isobath interval of 0.5 meters as described in Elwany et al. 2009. P_t is determined from data collected in diver surveys. The proportion of area covered by hard substrate in the as-built condition in 2008 immediately after construction ($S_0 = A_0P_0$) that is remaining at time *t* can be expressed as S_t/S_0 The value of S_t/S_0 based on the current year or a four-year running average of the current year and the preceding three years (whichever is larger) must be ≥ 0.9 for the Wheeler North Reef to be in compliance with this standard.

The reef footprint area used to evaluate this standard includes the Phase 1 modules and the Phase 2 primary polygons, which collectively met the construction criteria of ≥ 42% cover of rock. The area of the Phase 2 primary polygons in the as-built survey done immediately after construction in 2008 was 130.31 acres (Elwany et al. 2009). Because the footprint area of the Phase 1 modules was not measured during the 2008 as-built survey, their footprint area measured in 2009 (24.79 acres) is used as their footprint area in 2008. Hence the initial footprint area of the Wheeler North Reef that is used to evaluate this performance standard (A_o) is 155 acres. The mean percent cover of rock of this initial footprint area in 2008 (P_0) was 45.6%.

5. THE ARTIFICIAL REEF(S) SHALL SUSTAIN 150 ACRES OF MEDIUM-TO-HIGH DENSITY GIANT KELP.

Approach: The abundance of giant kelp *Macrocystis pyrifera* is monitored by divers once per year in the summer in five replicate 10m x 2m plots arranged at 10m intervals along each of the replicate 50m transects at Wheeler North Reef (Figure 2). For the purpose of this performance standard, medium-to-high density giant kelp is defined as more than four adult plants per 100m^2 of ocean bottom and adult giant kelp plants are defined as having eight or more fronds. The summed total of adult plants in the five 10m x 2m plots provides an estimate of the number of adult plants per 100m^2 at each transect. The proportion of transects with a density > 4 adult plants per 100m^2 is used as an estimate of the proportional area of the artificial reef occupied by medium to high density giant kelp. The total area A_k at Wheeler North Reef occupied by medium to high density giant kelp in a given year is determined as:

$$\mathrm{A}_k = \sum_{i=1}^{n} \left(\frac{N_{ki}}{N_{ri}}\right) * A_i$$

Where n = total number of polygons at the Wheeler North Reef (Phases 1+2+3), A_i is the area of a polygon or module based on the most recent sonar survey, N_{ki} = number of transects on that polygon with >4 plants per 100m^2, and N_{ri} is the total number of transects sampled on that polygon. For the purpose of this calculation all 56 Phase 1 modules are considered to be a single polygon.

Unlike the absolute performance standard for hard substrate, the data used to evaluate the absolute performance standard for giant kelp and fish standing stock (see below) are collected over the entire Wheeler North Reef (Phases 1+2+3).

The reason for this is that the requirement for sustaining 150 acres of giant kelp and a fish standing stock of 28 tons is not tied to a specific coverage of hard substrate.

The value of A_k is calculated each year of the monitoring period and summed to that measured in previous years beginning in 2019. The mitigation requirement for giant kelp area will have been met when the total acres of giant kelp accrued by Wheeler North Reef equals the targeted annual value (= 150 acres) x the total years of operation of SONGS Units 2 & 3 (= 32), which amounts to 4800 acres of medium-high density adult giant kelp.

6. The standing stock of fish at the mitigation reef shall be at least 28 tons

Approach: The standing stock of fish on the Wheeler North Reef is estimated using data on total fish density, individual lengths, and relationships between fish length and mass. Data on fish density and length are recorded on the bottom along replicate fixed transects at the Wheeler North Reef in summer to early autumn of each year. Divers count, identify to species and estimate the total length (to the nearest cm) of each fish observed in a 3m wide x 1.5m high x 50m long volume centered above a measuring tape placed along the bottom of each replicate 50 m transect. For aggregating species such as the blacksmith (*Chromis punctipinnis*) and salema (*Xenistius californiensis*), the number and mean length of individuals in a group are estimated. Cryptic fishes (e.g. cottids, gobies, blennies) are recorded in a 2m wide swath centered along the transect as divers return after completing the sampling of less cryptic fish and in the five 1m^2 quadrats used to sample invertebrates and algae. These data are augmented with data from additional surveys of fish lengths if more information is needed to accurately characterize the population size structures.

Length data are used to assign each fish to one of three life stages (juvenile, subadult, and adult) using data from the literature (e.g. Love 2011) or best professional judgment by reef fish experts (e.g., Milton Love UCSB and Mark Steele CSUN). The biomass of each species within a transect is calculated by multiplying the number of fish in each life-stage by the average weight of the life stage and summing over all life stages Fish weights are estimated from fish lengths using species-specific length- weight regressions obtained either from the literature (Gnose, 1967; Quast, 1968a, 1968b; Mahan, 1985; Wildermuth, 1983; Stepien, 1986; DeMartini et al., 1994, Love 2011) or from data collected as part of this project.

The biomass densities of all species encountered on a transect are summed to produce an estimate of the total biomass of fish within each transect in units of g wet weight m^{-2}. The biomass density of all transects in a polygon are averaged, converted to US tons per acre, and multiplied by the total area of the polygon (in acres) to obtain the standing stock of fish in that polygon. The sampling methods and calculations for determining fish standing stock described above are the same as those used by the Marine Review Committee (MRC, 1989) when they determined that SONGS operations caused a 28-ton reduction in the standing stock of bottom-dwelling kelp bed fish).

The standing stock of fish on all polygons (Phases 1, 2 and 3) is summed to obtain an estimate of the total standing stock of fish at the Wheeler North Reef. For the purpose of this calculation all 56 Phase 1 modules are considered to be a single polygon. The standing stock of reef fish is calculated each year and is added to the cumulative total of previous years. The mitigation requirement for fish standing stock will have been met when the total tons of fish accrued by Wheeler North Reef equals the targeted annual value (i.e., 28 tons) x the total years of operation of SONGS Units 2 & 3 (i.e., 32), which amounts to 896 tons of reef associated fish..

7. THE RESIDENT FISH ASSEMBLAGE SHALL HAVE A TOTAL DENSITY SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Data on the density and lengths of resident fishes in the San Mateo and Barn kelp beds are collected using the same methods described for the Wheeler North Reef above (see approach for performance standard 6). Briefly, all species of resident fish are sampled on the bottom at each of the replicate 3m wide x 1.5m high x 50m long transects at Wheeler North Reef, San Mateo and Barn and in the cryptic fish transects and quadrats to obtain the number of resident fish on each transect. Resident fish are defined here as reef associated species > 1-year-old. Data on fish length are used to classify each individual fish counted as a resident or young-of-year (< 1-year-old) based on published size classes and/or knowledge of local experts. The total density of resident fish for each reef (Wheeler North Reef, San Mateo, and Barn) is calculated as the mean density of resident fish on the bottom averaged over the replicate transects. The four-year running average of the density of resident fishes at the Wheeler North Reef must be similar to that at the reference reefs (as per the methods described Section 2.3 above) for the Wheeler North Reef to meet this performance standard for any given year.

8. THE YOUNG-OF-YEAR FISH ASSEMBLAGE SHALL HAVE A TOTAL DENSITY SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Data on the density of young-of-year fish (defined as reef associated fish that are < 1-year-old) at the Wheeler North Reef and reference reefs are collected during the same surveys done for resident fish. Additional surveys are done if determined necessary for evaluating this performance standard. The approach used for determining whether the density of young-of-year fish on the Wheeler North Reef is similar to that on the reference reefs is the same as that used for evaluating the performance standard pertaining to the density of resident reef fish. The four-year running average of the density of young-of-year fish at the Wheeler North Reef must be similar to that at the reference reefs (as per the methods described Section 2.3 above) for the Wheeler North Reef to meet this performance standard for any given year.

9. THE TOTAL NUMBER OF SPECIES OF RESIDENT AND YOUNG-OF-YEAR FISH SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Species richness (number of species) of resident and young-of-year fish at the Wheeler North Reef and reference reefs are assessed as the mean number of species observed per transect during the same surveys used to estimate resident and young-of-year fish density. The four-year running average of the mean number of species of resident and young-of-year fish combined at the Wheeler North Reef must be similar to that at the reference reefs (as per the methods described Section 2.3 above) for the Wheeler North Reef to meet this performance standard for any given year.

10. FISH REPRODUCTIVE RATES SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Data on per capita egg production of a select group of targeted reef fish species are used to determine whether fish reproductive rates at the Wheeler North Reef are similar to those at San Mateo and Barn for similar sized individuals. Reproduction rates are assessed for selected target species that represent different feeding guilds of reef fishes in southern California and are sufficiently abundant to facilitate collection (Table 1).

Data on per capita egg production (i.e., number of eggs in a clutch) and the proportion of individuals likely to have spawned within 24 hours of collection (as determined by the hydrated status of the eggs) are collected monthly at Wheeler North Reef, San Mateo, and Barn during summer through autumn and used to evaluate this standard. A resampling approach is used to statistically determine whether the Wheeler North Reef met this performance standard for a given year (Appendix 1). This provides a method to estimate the variance and provides a basis for the calculation of a p-value. Because larger individuals tend to produce more eggs, the production of eggs is scaled to the body length and used to obtain a standardized measure of fecundity for each species at each reef.

For each reef, a species-specific estimate of standardized fecundity is combined with a species- specific estimate of the proportion of individuals spawning to obtain a four-year running average of the Fecundity Index that is averaged across all target species in a manner that weights each species and year equally (Appendix 1). The four-year running average of the Fecundity Index for each reef for a given year is calculated as the median of the resampled distribution of the four-year running average for that year. In order for fish reproductive rates at Wheeler North Reef to be considered similar to that at natural reference reefs the four-year running average of its Fecundity Index (based on the current year and the previous three years) must not be significantly lower than that of the reference reef with the lower four-year running average Fecundity Index as per the methods described in Section 2.3.

11. FISH PRODUCTION SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Estimating fish production on a reef is a difficult and potentially expensive task because it requires knowledge (or scientifically defensible assumptions) of the abundance and size structure of the fish standing stock, coupled with size-specific rates of growth, mortality, reproduction, emigration and immigration. For this reason, a great deal of thought has gone into developing a precise and cost-effective way to evaluate this performance standard. The method selected for estimating fish production involves the use of information already being collected on fish abundance and size structure (for performance standards 6, 7, and 9), fish reproductive rates (standard 8), combined with estimates of somatic growth rates obtained from additional otolith studies. Importantly, this method of calculating fish production assumes no net migration (i.e., the immigration of fish to a reef is assumed to be equal to the emigration of fish from a reef). Details of the method are presented in Appendix 2.

Production is estimated for five target species that represent the major feeding guilds of fishes in southern California kelp forests and are common to the study region (Table 1). The annual production calculated for each of the targeted species is averaged to obtain an overall mean and standard error for each of the three reefs (Wheeler North Reef, San Mateo and Barn). The four-year running average of fish production at the Wheeler North Reef must be similar to that at the reference reefs (as per the methods described Section 2.3) for the Wheeler North Reef to meet this performance standard for any given year.

12. THE BENTHIC COMMUNITY (BOTH ALGAE AND MACROINVERTEBRATES) SHALL HAVE COVERAGE OR DENSITY AND NUMBER OF SPECIES SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: The benthic communities at Wheeler North Reef, San Mateo, and Barn are sampled annually in the summer in the areas defined by the replicate 50m x 20m transects at each reef (see ***3.1 General Sampling Design*** for details). Several different sampling methods are used to determine density and percent cover of benthic invertebrates, and understory algae. Abundances of sessile invertebrates and understory algae that are either difficult to distinguish as individuals (e.g. colonial tunicates, foliose red algae) or lay flat on the bottom (e.g., the brown alga *Desmarestia ligulata*) are measured as percent cover in five replicate 1m^2 quadrats located at 10m intervals along each of the eighty-two 50m transects. Percent cover is estimated using a uniform point contact method that consists of noting the identity and relative vertical position of all organisms under 20 uniformly placed points within each quadrat, giving a total of 100 points per transect. Using this method, the total percent cover of all species combined can exceed 100%; however, the maximum percent cover possible for any single species cannot exceed 100%. Large solitary mobile invertebrates (e.g. sea stars, sea urchins, and lobsters) and large solitary understory algae (e.g. palm kelp, *Pterygophora californica*) are counted in the five replicate 10m x 2m plots located at 10m intervals along each 50m transect. Smaller solitary mobile invertebrates (nudibranchs, bivalves, etc.) and algae (small size classes of all kelps) that are numerous and/or time consuming to count in a 1m^2 area are counted in a 0.5m^2 area created by dividing the 1m^2 quadrats in half using a bungee cord stretched across the frame of the quadrat. Percent cover data and count data are both used to determine the mean number of species of understory algae and benthic invertebrates per transect at each reef.

The following components of the benthic community are evaluated separately to determine whether this performance standard is met: (1) the percent cover of algae, (2) the number of species of algae, (3) the percent cover of sessile invertebrates, (4) the density of mobile invertebrates, and (5) the combined number of species of sessile and mobile invertebrates. The four-year running averages of each of these five components of the benthic community at the Wheeler North Reef must be similar to those at the reference reefs (as per the methods described in Section 2.3) in order for the Wheeler North Reef to meet this performance standard for any given year.

12. THE BENTHIC COMMUNITY SHALL PROVIDE FOOD-CHAIN SUPPORT FOR FISH SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Several different approaches could be taken to evaluate the contribution of the benthic community to food-chain support of reef fishes, but the most direct and cost efficient of these approaches involves sampling gut contents in reef fishes that feed on the bottom and are collected for other purposes. Such is the case for the black surfperch and the California sheephead. Both species feed almost exclusively on benthic prey and individuals of these species are collected for purposes of evaluating the performance standards pertaining to fish reproductive rates and fish production. Once collected, black surfperch and sheephead specimens are placed on ice and transported to the laboratory where they are either immediately dissected and processed or frozen for processing at a later date. Sample processing for both species involves removing the entire tubular digestive tracts and weighing the contents, either before or after preservation by fixation in 10% formaldehyde and storage in 70% ethanol. These measurements are used to calculate an index of food chain support (FCS) that is based on the mass of the gut contents relative to the body mass of the fish

FCS = g / (b-(r+g))

Where g = gut content mass, b = body mass, and r = gonad mass.

Because the number of specimens of each species collected inevitably varies between species and among reefs the FCS values must be standardized to ensure each species and reef are weighted equally. To accomplish this standardization, FCS values for each species and reef in a given year are resampled with replacement 100 times (100 being the targeted sample size) and this process is iterated 1000 times. The mean for each iteration is calculated to produce a dataset of 1000 FCS values for each species x reef combination for a given year. For each species and year, we calculate the mean and standard deviation of the FCS values averaged over all 3000 iterations (= 1000 values for 3 reefs). We use these means and standard deviations to calculate the z-scores for each combination of year x species x iteration number for each reef yielding 1000 z-scores for each species x year x reef combination. We then average the z scores of the two species for each of the 1000-year x reef combinations to produce a data set of 1000 standardized FCS values for each reef in any given year.

The four-year running average of the standardized FCS index for each reef is calculated using a four-year mean of each iteration based on the current year and the previous three years producing 1000 values of the four-year average of the standardized FCS index for each reef. The four-year mean of the standardized FCS index for each reef is calculated from the resampled distribution of these 1000 values. The four-year running average of the standardized FCS index at Wheeler North Reef must be similar to that at the reference reefs (as per the methods described in Section 2.3) in order for the Wheeler North Reef to meet this performance standard for any given year.

13. THE IMPORTANT FUNCTIONS OF THE REEF SHALL NOT BE IMPAIRED BY UNDESIRABLE OR INVASIVE BENTHIC SPECIES (E.G., SEA URCHINS OR Cryptoarachnidium).

Approach: Reefs in southern California provide many important ecological functions that pertain to the production of food and the provision of habitat for reef associated species. Undesirable or invasive species have the potential to impair these functions and thus prevent the Wheeler North Reef from attaining its mitigation goal of compensating for the loss of marine resources caused by SONGS operations. Undesirable or invasive reef species may include introduced or non-native taxa such as the green seaweed *Caulerpa taxifolia,* which escaped from the aquarium trade to invade many marine habitats worldwide including some in southern California, and the brown seaweed *Sargassum horneri,* which was accidentally introduced from Asia and has become increasingly abundant at some reefs off southern California. Undesirable or invasive reef species may also include native species when they attain very high abundances. This is the case when dense aggregations of sessile invertebrates such as sea fans monopolize space and exclude other species, or when high densities of sea urchins over graze the bottom and create large deforested areas commonly called sea urchin barrens. Data on the abundance of undesirable and invasive species are collected as part of monitoring done to evaluate the biological performance standards pertaining to the benthic community.

Examples of key ecological functions provided by shallow reefs of southern California include the provision of nursery habitat for fishes, the production of invertebrate prey sufficient to support populations of predatory reef fish, and primary productivity by macroalgae. The first of these two functions are monitored for the purpose of evaluating the performance standards pertaining to the density and number of species of young-of-year fishes and benthic food chain support and thus incur no added cost to evaluate. By contrast, measuring primary productivity by reef macroalgae is very time consuming and is not required for evaluating the performance of Wheeler North Reef. However, more easily measured estimates of frond density can be used to accurately predict net primary productivity by giant kelp (Rassweiler 2018), which constitutes the vast majority of algal biomass on reefs in California (Graham et al. 2007). Data of kelp frond density are routinely measured for the purpose of evaluating the performance standard pertaining to giant kelp.

The evaluation of this performance standard involves a two-step approach. First, the performance of Wheeler North Reef with respect to giant kelp, young-of-year fish and benthic food chain support is used to determine whether the important functions of Wheeler North Reef are impaired. Second, data of the abundance of sea urchins, sea fans and other undesirable or invasive species are used to evaluate whether any impairment in these reef functions result from increases in the abundance of invasive or undesirable species.

4.0 DATA MANAGEMENT

Data management protocols will follow those developed during the experimental phase of the reef mitigation project and are outlined below.

4.1 Daily Field and Data Transfer Procedures

Data management and quality assurance procedures for the artificial reef monitoring begin in the field. Upon completion of each dive, data sheets are checked for completeness and legibility and total counts are tallied for each species. After these field checks are completed, the data sheets are filed into a field binder for transport back to the laboratory. Upon arrival at the laboratory, data sheets are checked into a survey log that contains entries for the observer, date, and survey location. The log is used to verify that all data assignments for a day have been completed, and all field data have been accounted for.

Data consistency is also verified during the check-in procedure, and any anomalies are brought to the attention of the field supervisor. Senior staff members examine the data sheets for possible misidentification of species, missing data values, and invalid counts. The field supervisor decides how to rectify any errors and implements corrective action to avoid repeating mistakes in the field. Such actions have included retaking data, and providing additional field training for investigators.

4.2 Data Entry and Quality Assurance

All SONGS Mitigation Monitoring data are entered and stored in electronic databases based on Structured Query Language (SQL). The project's data entry procedures have been designed to facilitate rapid data entry while continuing to ensure the quality and integrity of the data as they are transformed from physical to electronic form.

The vast majority of monitoring data are entered using custom designed web forms. These web forms provide an intuitive, graphical user interface to the project's databases. Each form mimics the exact layout of the data sheets taken into the field, which allows the individual entering the data to electronically transcribe a sheet without replicating key variable entries, or manipulating columns, rows, or formats. Such tasks are processed on the project's internal web server, which translates the form data into the appropriate format for storage on the project's data servers. In some cases, these forms can reduce the amount of data a user is required to enter by over 100 fields for a single data sheet, which translates to significant time savings.

This entry system also allows the implementation of a multi-tiered checking system. Data entered using the web forms are verified in three distinct phases before any information is considered suitable for the final databases on which all analyses are done.

1. First, database structure (i.e. foreign key constraints) restricts the values that can be entered into a data table (e.g. the observer entry cell contains only valid entries for observer's names).
2. Second, a JavaScript program is incorporated into each web form used to enter data. These programs include a number of checks (e.g. recognizing invalid data lengths, out of range values, and incorrect formats). Failure of one of these checks prevents the form from being submitted, and alerts the user of the error. The system requires errors to be corrected for a form to be successfully submitted.
3. Finally, a third filter occurs on the project's internal web server. After a form is successfully submitted, the web server will check that each data row does not violate any constraint built into the database. If any line of the form fails these tests, the entire form will be rejected until the invalid entry

is corrected.

This three phase checking system has greatly reduced the time required for post-entry data checking procedures by eliminating the most common data entry errors. This system has also substantially reduced the number of data checking programs previously required to find these problems, in some cases by as much as 75%.

Three final steps convert the electronically checked databases into the final databases. First, pairs of investigators manually check each data line of the database tables against the field data sheets for correct values. Second, following the manual check, a series of programs are run on the data to check for consistent values between database tables. For example, sampling dates for a given location are checked against the dates recorded into the sampling log. Any inconsistencies are rectified. Once these checks are complete, the data are transferred to a production database that contains all fully checked and verified data. Data from the production database are merged onto a template that populates the data for zero value observations. The templates also contain all pertinent metadata (variable descriptions and sampling methods), which are checked thoroughly prior to posting. At this stage, databases are considered to be in their final form and suitable for analysis.

4.3 Data Storage and Preservation

After the physical data are entered and checked, each data sheet is scanned and converted into a PDF file for electronic storage. The material sheets are then filed in binders by survey type and year, and then added to the monitoring data library located at UCSB’s SONGS mitigation office and laboratory in Carlsbad, CA. The PDF data sheets are similarly filed in an electronic library located on the project's data servers.

The project employs a highly redundant, multi-server system to ensure maximum data integrity, preservation, and uptime. The system consists of a central data server, and multiple mirror and backup servers located at UCSB’s Carlsbad office, the Marine Science Institute on UCSB’s main campus in Santa Barbara, CA, and geographically distributed cloud storage.

The central server at UCSB’s Carlsbad office acts as the primary management point for all project-related data and files. These files fall into three distinct classes, which are used to determine both the method and format of automated backup and preservation: (1) regular documents (backed up daily in native format), (2) SQL database files (backed up in real time to two mirror servers using native format, and daily to cloud storage in comma delimited text), and (3) statistical and database program files (backed up every hour in native format, and daily to a server on main campus in native format).

Local daily backups are written to a redundant disk array. All valid users for the system can access daily backups of regular documents and statistical or database program files, however, the restoration of SQL database files must be done by a system administrator.

5.0 DISSEMINATION OF RESULTS

The following procedures are followed to ensure efficient and effective communication with SCE, state and federal resource agencies and the general public: (1) CCC contract scientists communicate with SCE and state and federal agencies as needed via phone, email, and face-to face meetings to discuss results and any potential changes in monitoring design, (2) status reports are prepared and submitted to the CCC for public viewing on an annual basis, (3) project related documents are downloadable from the project' s public website (https://marinemitigation.msi.ucsb.edu/index.html), which also provides information on the history, current status, contact information, and other relevant material pertaining to the monitoring of the SONGS reef mitigation project (4) all monitoring data are deposited annually into the Environmental Data Initiative (EDI) repository (https://portal.edirepository.org) after they have been verified and are freely accessible to the public via the project's website or EDI's data portal (using the Key words UCSB SONGS), and (5) as per Condition D of the SONGS permit, duly noticed annual public workshops are convened to review the overall status of the project, identify problems and make recommendations for solving them, and review activities planned for the following year. .

6.0 REFERENCES

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Table 1. Reef fishes used as target species for estimating reproductive rates and fish production.

Common Name	Scientific Name	Mode of Reproduction	Primary Diet
kelp bass	*Paralabrax clathratus*	egg layer (broadcast)	Midwater and benthic fish and invertebrates
señorita	*Oxyjulis californica*	egg layer (broadcast)	Zooplankton & small benthic invertebrates
sheephead	*Semicossyphus pulcher*	egg layer (broadcast)	Hard-shelled benthic invertebrates
blacksmith	*Chromis punctipinnis*	egg layer (demersal)	Zooplankton
black surfperch	*Embiotica jacksoni*	live bearer	Small benthic invertebrates

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Figure 1a. Map of Wheeler North Reef showing the location of the 151 fixed transects (black lines) where monitoring of the performance standards is done. Transects are shown as black lines (n = 12 Phase 1, n = 80 Phase 2, and n = 59 Phase 3)

Figure 1b. Map of the reef at San Mateo showing the location of the 82 fixed transects where monitoring of the performance standards is done. Transects are in pairs and are shown as white lines in the black shaded areas, which denote hard substrate. Depth contours are in meters.

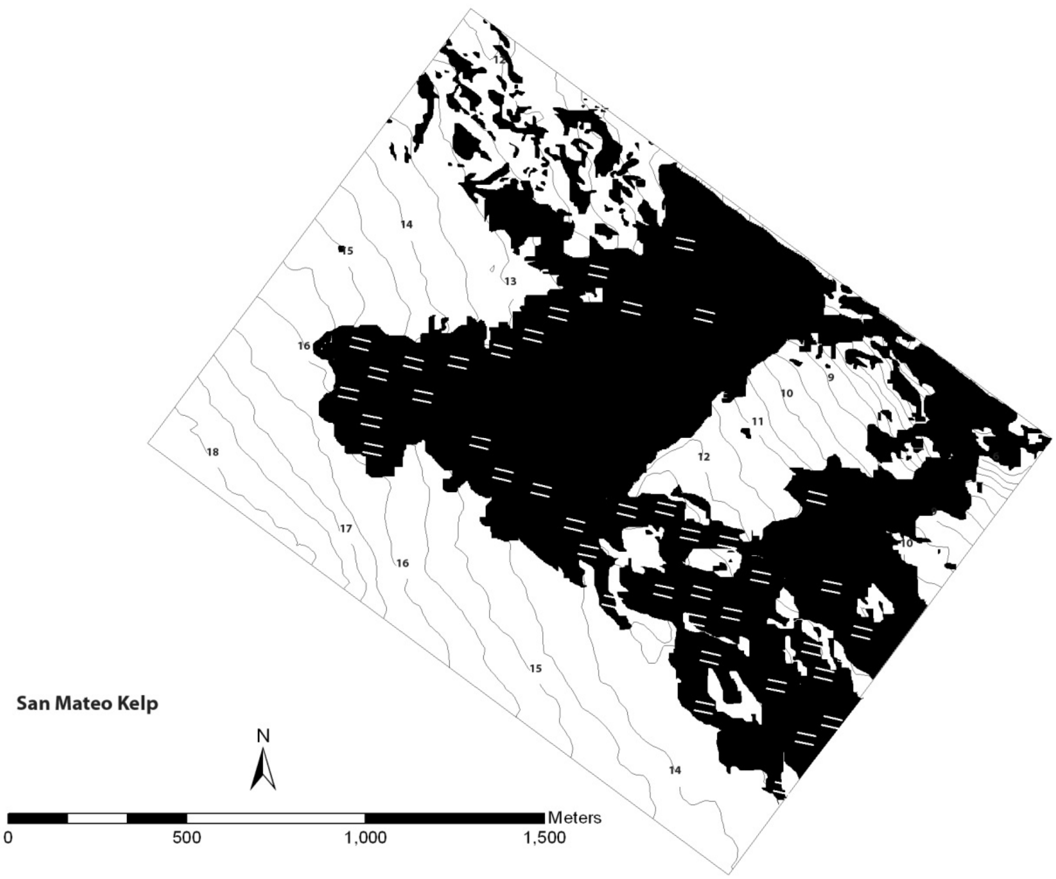


Figure 1c. Map of the reef at Barn showing the location of the 82 fixed transects where monitoring of the performance standards is done. Transects are in pairs and are shown as white lines in the black shaded areas, which denote hard substrate. Depth contours are in meters.

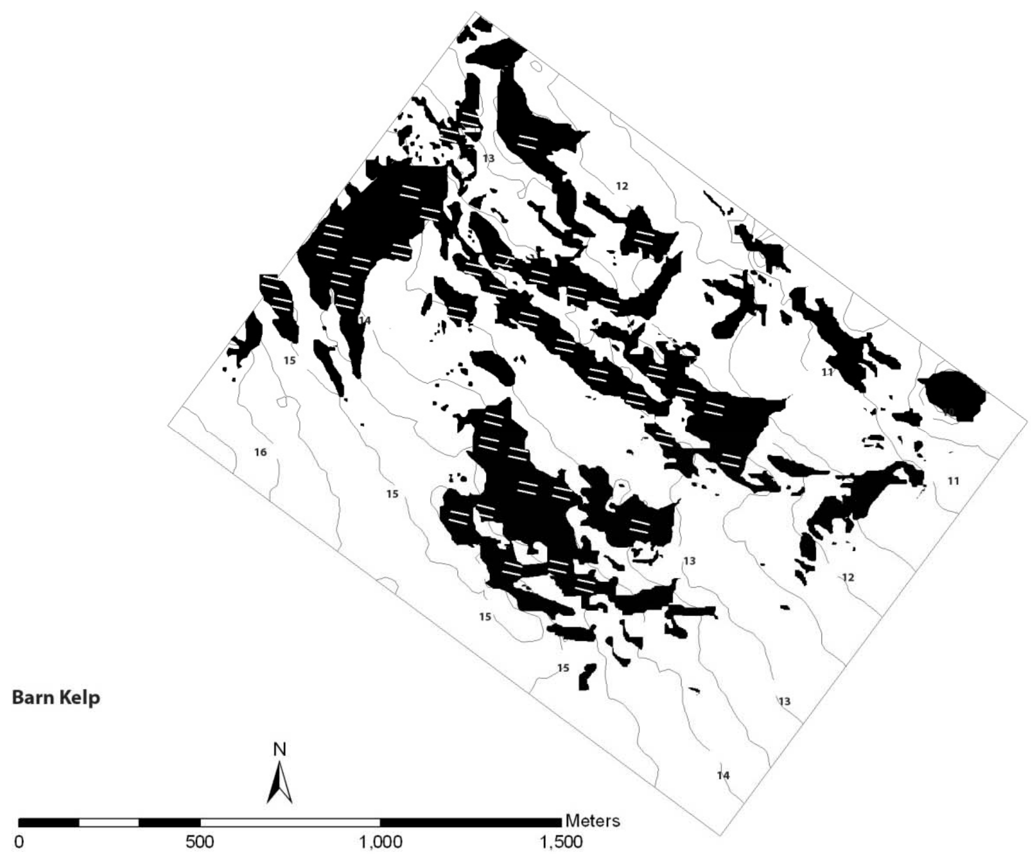


Figure 2. Schematic showing the different sized sampling areas that are used at each of the fixed monitoring stations; including a large 50m x 2m band transect (delineated by dashed lines; five smaller 10m x 2m band transects perpendicular to the main transect and evenly spaced along it; five evenly spaced 1m x 1m quadrats (shaded squares and inset) containing 20 evenly spaced point contact locations and divided into two 0.5 m^2 quadrats.

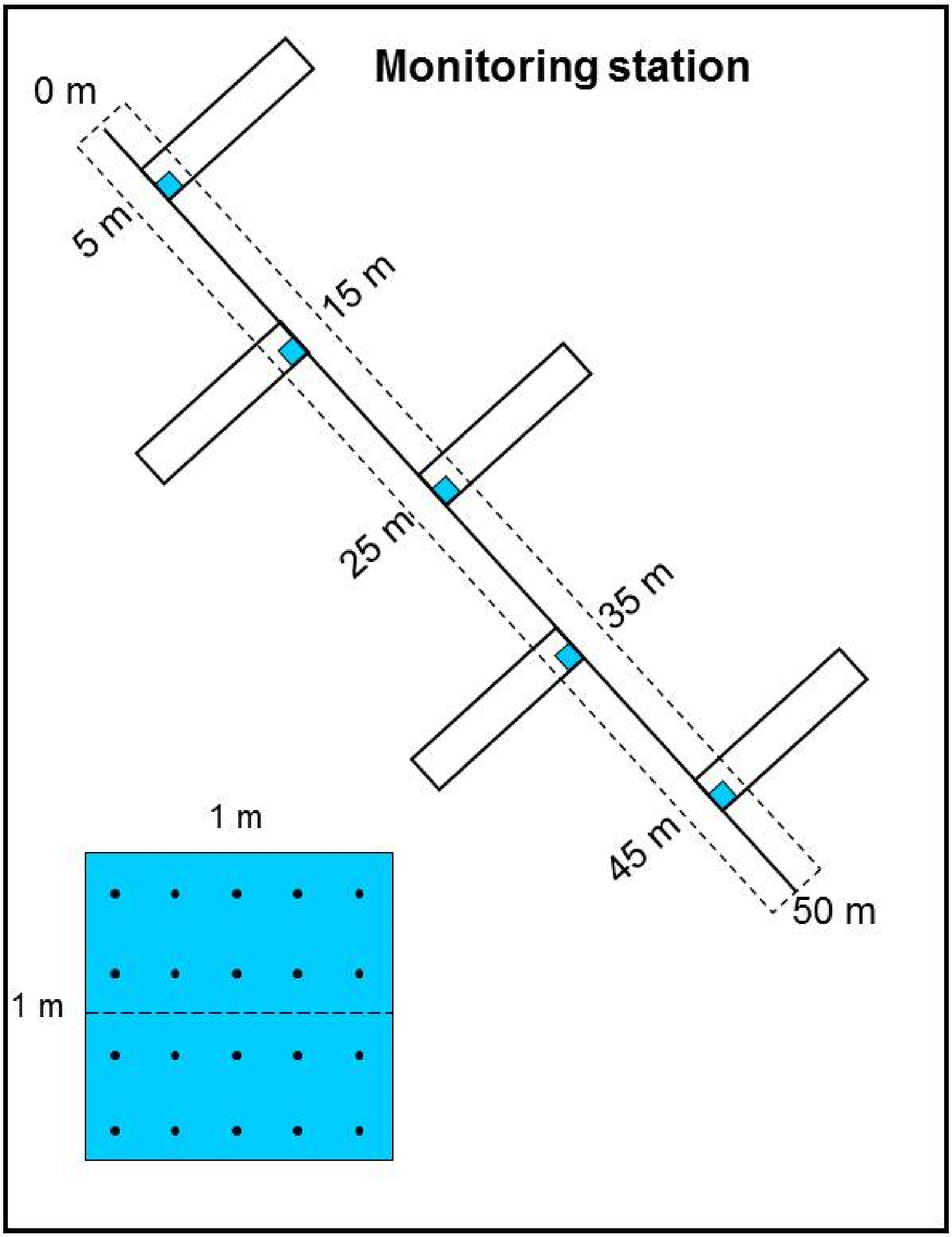
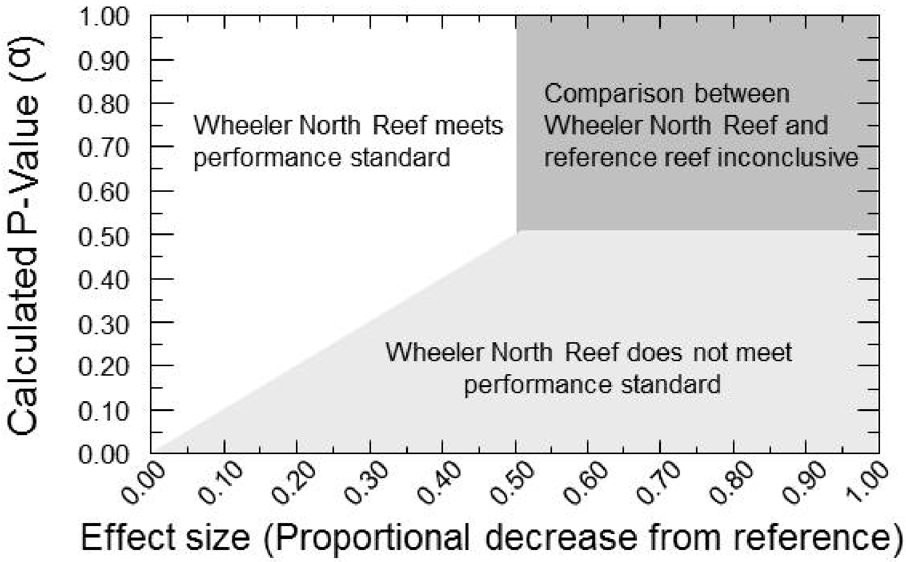


Figure 3. The relationship between effect size and α, and how it is used to determine whether the Wheeler North Reef meets a given relative performance standard.



APPENDIX 1

METHODS FOR ESTIMATING FISH REPRODUCTIVE RATES

General Methods

Individuals of four targeted species (blacksmith, *Chromis punctipinnis;* sheephead, *Semicossyphus pulcher;*, senorita, *Oxyjulis californicus;* and kelp bass, *Paralabrax clathratus*), are collected monthly throughout their reproductive period (May to September) at Wheeler North Reef, San Mateo and Barn via spear and hook and line for the purpose of estimating fish reproductive rates. Like all common egg-laying species at the study sites, the four species targeted for assessing reproductive rates are batch spawners, that is, they spawn multiple batches of eggs throughout a single spawning season.

On the day that a batch of eggs is spawned, the eggs are first hydrated within the ovaries and then ovulated. Hydrated ova appear only within several hours of spawning and are recognized by their relatively large size and translucent appearance. We aim to capture at least 50 females with hydrated eggs in their ovaries from each reef for each year sampled. In the field, the body cavity of each specimen is opened and the sex and stage of development of the ovaries of females is noted. Ovaries are classified based on macroscopic examination as immature/inactive (no obvious oocytes); mature (obvious oocytes but none hydrated); and ripe (hydrated oocytes present). Specimens are kept on ice until they can be processed in the laboratory (no more than 24 h).

In the laboratory, each fish is weighed to the nearest 0.1 gram, and measured for total length and standard length. Sagittal otoliths are removed from each specimen for age and growth analysis needed for evaluating the performance standard pertaining to Fish Production. Ovaries from female fish are removed, blotted dry, weighed to the nearest 0.1 g. Ovary-free body weight is determined by subtracting the ovary weight from the body weight. Ovaries are preserved in 10% formalin for fecundity analysis in the laboratory.

Batch fecundity is estimated using hydrated eggs. It is usually impractical to count all of the hydrated ova within the ovaries of a female, so batch fecundity is estimated from subsamples, and the number of hydrated eggs in these subsamples is extrapolated to the entire ovary pair. The number of hydrated ova in each subsample is counted using a dissecting microscope and the number of hydrated ova is extrapolated to the entire ovary.

Fecundity Index for Egg-laying fish

The Fecundity Index for egg-laying fish is calculated for each reef as the product of batch fecundity and the proportion of individuals that produced eggs. A resampling approach is used to obtain an estimate of the variance of these two variables, which is needed to statistically determine whether the Wheeler North Reef has met this performance standard in a given year.

Estimating Batch Fecundity

Appendix 1: Methods for estimating fish reproductive rates

Larger fish tend to produce more eggs. Therefore, the production of eggs is scaled to body length to obtain a standardized measure of fecundity that takes into account differences in size within a species. Standardization for each species is achieved by dividing the length and fecundity of an individual by the mean length or mean fecundity averaged across all individuals of that species collected at all three reefs. These standardized measurements are used to develop species-specific regression models for each reef in a given year using standardized fecundity as the dependent variable and standardized length as the independent variable. Data used in each regression model are resampled 1000 times using a bootstrap approach (i.e., resampling with replacement) yielding 1000 regression equations. The integrated area under each regression function provides a species-specific estimate of batch fecundity (F_b) across all sizes for a given reef and year.

Estimating the proportion of individuals that produced eggs

The number of individuals of each species that are sampled in a given year (N) and the proportion of them that produced eggs (p) are used in a binomial model to generate 1000 estimates of the number of reproductive individuals in each iteration (k). The proportion of individuals that produced eggs in a given iteration (P_k) is calculated as:

$$P_k = \binom{N}{k} p^k q^{1-k}$$

where q = 1-p.

Calculation of Fecundity Index

The 1000 estimates of F_b generated for each species, reef and year are merged with the 1000 estimates of P_k for each species, reef and year. The product of these two variables yields 1000 estimates of population fecundity (F_p) for each species at each reef for a given year. Values of F_p are then standardized to ensure that each species is weighted equally. This is done by dividing each species-specific value of F_p by the median of the resampled distribution of F_p for that species to produce 1000 cases of standardized fecundity (F_s) for each species at each reef for a given year. Values of F_s are averaged across all target species for which there are data to obtain 1000 estimates of reef fecundity (F_r) for each reef in a given year. The annual estimates of F_r for current year and the preceding three years are averaged by case to produce 1000 estimates of the four-year running average of F_r for a given year. The four-year running average of the Fecundity Index for each reef for a given year is calculated as the median of the resampled distribution of the four-year running average of F_r for that year.

An implicit assumption of using the Fecundity Index to evaluate whether fish reproductive rates at Wheeler North Reef is similar to that at natural reference reefs is that the frequency of spawning for a given species does not vary significantly among the three reefs.

APPENDIX 2

METHODS FOR ESTIMATING FISH PRODUCTION

This document describes the approach that is used to estimate annual production of fish tissue using data on length, density, somatic growth rates, and production of reproductive tissues for a select group of target species. The result is an estimate of production per unit area of reef for each species. The approach is conceptually similar to that used by DeMartini et al. (1994), but differs in the details of the production model and some of methods used to estimate key parameters. This approach to estimating tissue production includes production of both somatic and reproductive tissues. Hence, total production of tissue biomass for a given species is:

$$P_{TOTAL} = P_{St} + P_{Rt}$$

where P_{St} is production of soma and P_{Rr} is production of gonadal tissue over some time period t.

P_{St} is estimated as:

$$P_{S\,t} = \sum_{i=1}^{n} (\overline{N}_{i\,t} \bullet g_{i\,t})$$

where $\overline{N}_{it}$ = mean population density of size class *i, during period t,* and g_{it} is the average growth increment (mass) of individuals in size class *i* over time period t.

P_{Rt} is estimated as:

$$P_{Rt} = P_{Ft} + P_{Mt}$$

where P_{Ft} is production of eggs by females in all size classes and P_{Mt} is production of milt (sperm and semen) by males in all size classes over time period t.

P_{Ft} is estimated as:

$$P_{F\,t} = \sum_{i=1}^{n} (\overline{N}_{F,i\,t} \bullet E_i \bullet w_e)$$

where $N_{F,it}$ = density of females in size class *I during period t; E_i* =mean number of eggs produced by a female in size class *i*; and w_e is the average weight of an egg.

P_M is estimated as:

$$P_{M\,t} = \sum_{i=1}^{n} (\overline{N}_{M,i\,t} \bullet E_i \bullet w_e \bullet r_i)$$

where $N_{M,it}$ = density of males in cohort *i during time t*; and r_i is the ratio of testes weight to ovary weight for males and females in cohort *i*. Thus, milt production, which is not readily measured, is estimated based on the ratio of testes to ovary size.

Appendix 2: Methods for estimating fish production

<u>Parameter estimation</u>

The equations above include several parameters that are estimated using data collected from the three field sites.

N_{it} — The density of individuals in a size class during time t is determined from field surveys of fish density and size structure.

N_{Ft} and N_{Mt} — The density of females and males in each size class during period t is estimated from total densities in field surveys and sex ratios determined from the work on reproductive output.

g_{it} — cohort specific growth increments over period t are estimated for the year preceding capture by back-calculation from otoliths of fishes collected for the work on reproduction and supplemented with collections of juveniles. In brief, somatic growth is estimated from otolith growth for species where clear increments are present and a tight relationship between otolith size and body size exists.

E_i — Per capita egg production is estimated as the product of the batch fecundity and the number reproductive bouts per year.

w_e — Egg weight is estimated from the largest 20% of yolked (but not hydrated) eggs in a large, random selection of ovaries of each species. Egg weight is calculated as egg volume in cc (using measured radius and assuming spherical shape) times a specific gravity of 1.

r_i — Ratio of testes to ovary weights is calculated for each size class from samples collected for the reproduction standard. Only mature, reproductively active fish are used in estimating this ratio; and only females with mature but non-hydrated eggs are used.

APPENDIX 3

CHRONOLOGY OF CHANGES TO THE MONITORING PLAN FOR SONGS' REEF MITIGATION

All changes to the monitoring plan for reef mitigation become effective the date they are implemented and do not affect the assessment of reef performance in previous years

Changes made in February 2013 revision.

1. Changes with respect to how the absolute performance standards are evaluated.

Previous approach: For a given year, each absolute standard is evaluated using data collected at the Wheeler North Reef (WNR) for that year.

New approach: For a given year, the evaluation of each absolute standard will be based on the greater value obtained from either: (1) data collected at WNR that year, or (2) a four-year running average calculated from data collected at WNR for that year and the previous three years.

Rationale for change: Short–term fluctuations in the physical and biological attributes of a kelp forest community are a common feature of natural reefs unaffected by SONGS operations. Assessing the absolute standards using either the current year's value or a four-year running average recognizes that such short-term fluctuations at WNR are to be expected even if it is performing as well as or better than natural reefs in the region. As in the past, all absolute standards must be met in a given year for that year to count towards compliance with Condition C.

2. Changes with respect to how the relative performance standards are evaluated

Previous approach: All relative standards at WNR must be met in a given year for that year to count towards compliance with Condition C. In order for WNR to meet a relative performance standard the value for that standard at WNR must be statistically equal to or greater than the value at the lower of the two reference reefs. In addition, WNR cannot have the lowest value (regardless of statistical significance) for more standards than expected by chance in order for that year to count towards compliance.

New approach: The following changes were made

1) Instead of requiring WNR to meet every relative standard in a given year, it must meet only as many of the relative standards as the lowest performing reference site.
2) A four-year running average calculated from data collected for that year and the previous three years (instead of the mean calculated from data collected only in

that year) will be used to determine whether a performance standard is met in that year.

3) Assessment of the fish community and benthic community of algae and invertebrates is based on an equal (instead of unequal) number of standards pertaining to the fish and benthic communities.
4) The number of species of fish, invertebrates and algae is based on the mean number of species per transect (species density) rather on estimating the total number of species on the reef (species richness) using a two-parameter model two parameter model relating the number of species encountered to the number of transects sampled.

Rationale for change # 1: Analyses of the monitoring data collected to date show that reference reefs would not consistently meet all the relative performance standards required of WNR. Thus requiring WNR to meet all the relative standards each year for that year to count towards compliance with Condition C in effect requires WNR to consistently outperform the reference reefs. By requiring WNR to meet only as many relative standards as the lowest performing reference reefs achieves the desired mitigation goal, which is for WNR to perform as well as the natural reefs in the region chosen as suitable measures of comparison.

Rationale for change # 2: The purpose for the relative standards is to ensure that WNR performs at least as well as the natural reference reefs over the operating life of SONGS. Using a running average rather than a mean value for a given year recognizes that short-term fluctuations in the biological attributes of WNR are to be expected even if it is performing as well as natural reefs in the region. An either /or criteria (i.e., using data from either a single year or a running average) is not appropriate in this case because the desired goal for the relative performance standards is not to achieve a specified value that is linked to estimated losses at San Onofre kelp forest. Instead the purpose of the relative standards is to evaluate whether the abundances and numbers of species of kelp forest biota at the Wheeler North Reef are similar to that of the reference reefs. This is best accomplished using a short-term running average that accounts for natural variation. A running average calculated over four years approaches the desired monitoring goal of being able to reliably detect a 20% difference between WNR and the reference reefs while providing the CCC and SCE with a reasonable time frame for evaluating the performance of WNR.

Rationale for change #3: The relative performance standards described in the SONGS permit do not specify the metrics to be used to evaluate whether the fish and benthic communities are similar to those of the reference reefs. The CCC contract scientists chose to evaluate the performance standards using metrics that best met the intent of the SONGS permit (i.e. similarity with the reference reefs) in the fairest manner possible. The number of standards pertaining to the fish community relative to those pertaining to the benthic community was not critical using the previous approach because all standards had to be met. The number of metrics used to evaluate each relative standard, however, was important because the probability of WNR meeting all the relative standards in a given year diminishes with an increasing number of metrics evaluated. Thus to meet the objectives of Condition C in the fairest manner possible a concerted effort was made to institute the fewest number of metrics in the previous approach. Limiting the number of metrics is not a constraint in the new approach because it requires WNR to meet only as many standards as the lowest performing reference reef. However, implementing the new approach requires a more equitable balance in the number of standards that pertain to the fish and benthic communities, because both are equally important in ensuring that WNR complies with Condition C. Consequently, the ratio of fish standards to benthic standards in the new approach is 5:5 compared to 6:3 in the previous approach (see Table 1).

Rationale for change #4: The two parameter model previously used to estimate species richness of an entire reef required WNR to meet both model parameters (i.e., the slope and asymptote), which in effect resulted in two separate performance standards for species number. Species density is a direct and easily measured estimate of the average number of species per unit area and provides a single measure of the number of species in each of the four groups of organisms targeted in the monitoring plan (i.e., algae, invertebrates, resident fish and young-of-year fish). Thus the use of species density for assessing reef performance resulted in the abundance of individuals having the same weight as the number of species, which is consistent with the intent of the SONGS permit.

Table. 1. Previous and revised relative standards for evaluating the performance of the Wheeler North Reef

	PREVIOUS		**REVISED**
	Benthic Community Standards		***Benthic Community Standards***
1.	Algae + sessile invertebrate cover	1.	Algal cover
2.	Mobile invertebrate density	2.	Algal species richness
3.	Benthic species richness	3.	Sessile invertebrate cover
		4.	Mobile invertebrate density
		5.	Invertebrate species richness
	Fish Standards		***Fish Standards***
1.	Resident fish density	1.	Resident fish density
2.	Resident fish species richness	2.	YOY fish density
3.	YOY fish density	3.	Fish species richness (all ages)
4.	YOY fish species richness	4.	Fish production
5.	Fish production	5.	Fish reproductive rates
6.	Fish reproductive rates		
	Fish + Benthic Community Standard		***Fish + Benthic Community Standard***

1.	Food chain support	1.	Food chain support

Changes made in March 2014 revision.

Revisions reflect recent decisions on the methods used to determine the as-built footprint area of the Phase 1 and Phase 2 portions of Wheeler North Reef that were jointly agreed upon by SCE and CCC contract scientists at a meeting in La Jolla on Sept 24, 2013. Other changes include clarification of methods used to estimate fish biomass and fish reproductive rates (including updating Appendix 1).

Changes made in January 2015 revision.

Revisions reflect changes in the multibeam sonar data used to assess the footprint area of SONGS. Bathymetry data have proven to be more reliable that backscatter data in estimating the area of Wheeler North Reef. Consequently, bathymetry data are now used to determine changes in the footprint area of Wheeler North Reef. The exception is in 2008 when only backscatter data were collected.

Changes made in April 2017 revision.

Revisions were made to the methods used to evaluate the performance standards pertaining to Fish Reproductive Rates and Benthic Food Chain Support. These revisions involved making slight changes to the methods used to calculate standardized Fecundity and the standardized Food Chain Support Index to insure that all species and years were weighted equally when assessing performance.

Changes made in April 2021 revision.

Most notable revisions include changes to accommodate: (1) monitoring of the Phase 3 Expansion Reef constructed as remediation for the failure of the Phase 1 and 2 Reefs to consistently support a fish standing stock of 28 tons and 150 acres of medium-to-high density giant kelp, (2) assignment of mitigation credit for kelp area and fish standing stock on a cumulative basis, and (3) the CCC's decision to define the operating life of SONGS Units 2 and 3 as 32 years for the purpose of mitigating their impacts.