MONITORING PLAN FOR THE SONGS' REEF MITIGATION PROJECT

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EXECUTIVE SUMMARY

The California Coastal Commission (CCC) requires Southern California Edison (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 (SOK) caused by the operation of San Onofre Nuclear Generating Station (SONGS) Units 2 and 3. 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. Mitigation for losses of kelp bed resources through the construction of an artificial reef will 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. 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 the CCC concurred with the Executive Director's determination for the type and percent cover of hard substrate on October 12, 2005. Construction of the mitigation phase of the SONGS artificial reef requirement began on June 9, 2008 and was completed 94 days later on September 11, 2008,

Monitoring by independent contract scientists working for the CCC will be 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 13 performance standards by which the mitigation reef will be judged and the general approach that will be used to judge the overall success of the mitigation project, (2) descriptions of the specific sampling methods and analyses that will be used to evaluate each of the 13 performance standards, (3) an explanation of how project data will be managed and archived for future use, and (4) a description of how the results from the monitoring program will be disseminated to the CCC, the applicant, and all other interested parties.

This monitoring plan is based on SCE's Final Construction Report for the Wheeler North Reef at San Clemente, California (Coastal Environments 2008) which was approved by the Executive Director of CCC on January 27, 2009. 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.

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 two phases, a five year experimental phase (completed in December 2004) followed by a longer mitigation phase (beginning in September 2008) that and has a minimum duration equivalent to the operating life of SONGS Units 2 and 3. 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 and the

[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 150 acre artificial reef.

mitigation reef (when combined with the experimental reef) must be of sufficient size to sustain 150 acres 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 permit. The design of the mitigation reef was based on the results of the experimental reef (Reed et al. 2005).

The CCC approved the coastal development permit for the experimental reef on July 15, 1999 (CDP #E-97-10). 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 (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 22.4 acres. The Army Corps of Engineers issued its permit on August 13, 1999, and SCE completed construction of the experimental reef on September 30, 1999.

Five years of post-construction monitoring were completed by the CCC’s contract scientists 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 nearly equal tendencies to meet 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 has 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 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 experimental artificial reef, and (2) the percent of the bottom covered by quarry rock or rubble concrete on the mitigation reef should average at least 42%, but no more than 86%. The CCC concurred with the Executive Director’s determination for the type and percent cover of hard substrate on October 12, 2005.

On April 17, 2006 the California State Lands Commission acting on a request from SCE adopted a resolution declaring that the SONGS Mitigation Reef be named in honor of Dr. Wheeler North. SCE submitted a preliminary design plan for the Wheeler North Reef to the Executive Director of the CCC on May 12, 2006. The proposed design created a 127.6 acre, low-profile, single-layer reef (< 1 m in height) of Catalina 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. The design consisted of 11 polygons that varied in area from 2.4 to 37.5 acres, which when combined with the 56 experiment modules totaled 150 acres of artificial reef. Four contingency polygons (totaling 22.4 acres) were designed to serve as potential alternative reef construction areas. The construction period was estimated at 100 working days.

On August 8, 2006, the Commission concurred with the Executive Director's determination that the Preliminary Design Plan for the Wheeler North Reef met the requirements of the SONGS permit. SCE submitted a final mitigation plan to the CCC in the form of a coastal development permit application in October 2007. The final plan and coastal development permit application for the construction of the Wheeler North Reef was approved by the CCC on February 6, 2008.

Construction of the Wheeler North Reef was completed in 94 days on September 11, 2008. Approximately 126,000 tones of boulder-sized quarry material were deposited in 18 polygons that collectively covered 152 acres of sea floor. When added to the 22.4 acre experimental reef a total of 174.4 acres of mitigation reef were constructed. SCE submitted a final construction report detailing the as-built specifications of the Wheeler North Reef to the CCC on September 4, 2008 (Coastal Environments 2008). The Executive Director of the CCC found the Wheeler North 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 SCE's Coastal Development Permit. To address this inadequacy the Executive Director accepted a scenario in which 16 of the 18 polygons of the phase 2 reef comprising 130.3 acres (hereafter referred to as primary polygons) are combined with the 22.4 acres of the phase 1 reef 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 21.7 acres in the remaining two polygons (hereafter referred to as contingency polygons) will be included in evaluations assessing compliance of the biological performance standards that pertain to giant kelp and fish standing stock, which are described below (section 2.1).

Performance standards for reef substrate, giant kelp, fish, and benthos specified in Condition C will be 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.

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, 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 the monitoring plan for the Wheeler North Reef (hereafter used to refer to the 174.4 acre reef comprising 22.4 acres of artificial reef constructed during phase 1 and the 152 acres in the primary and contingency polygons constructed during phase 2). It is based on the reef configuration described in SCE's final construction report for the Wheeler North Reef (Coastal Environments 2008).

2.0 EVALUATION OF CONDITION COMPLIANCE

The specific requirements for attaining compliance with Condition C are discussed in various sections throughout the SONGS permit and are summarized in Appendix 1. Condition C 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 require that the variable of interest attain or exceed a predetermined value, and (2) relative standards, which require that the value of the variable of interest 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 fish, and assemblages of algae, invertebrates and fishes that are similar to nearby natural reference reefs. If the Wheeler North Reef does not achieve these standards, then remediation shall occur until the performance standards are met.

In this section of the monitoring plan we provide: (1) a list of the performance standards for the mitigation reef as stated in the SONGS permit, (2) an explanation of the process used to select the reference reefs that will be used as a measure of comparison in assessing the relative performance standards, (3) a description of the method of similarity that will be used to assess compliance of the relative performance standards, and (4) a schedule for the monitoring period.

2.1 Performance standards

The following 13 performance standards listed in the SONGS permit (no.6-81-330) will be used to measure the success of the mitigation reef and to determine whether remediation is necessary. Performance standards 1 through 6 are absolute standards and 7 through 13 are relative standards.

Substrate

1. The mitigation reef shall be constructed of rock, concrete, or a combination of these materials.
2. The total area of the mitigation reef (including the experimental reef modules) shall be no less than 150 acres.
3. At least 42% but no more than 86% of the mitigation reef area shall be covered by exposed hard substrate
4. At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota. The permittee shall be required to add sufficient hard substrate to the mitigation reef to replace lost or unsuitable hard substrate, if at any time the Executive Director determines that more than 10 percent of the hard substrate within the reef has become covered by sediment, or has become unsuitable for growth of attached biota due to scouring, and there is no sign of recovery within three years. The Commission scientists in accordance with Condition D shall initiate surveys to monitor the amount and distribution of exposed hard substrate. These surveys shall begin immediately after construction is complete and continue for at least ten years.

Kelp bed

5. The artificial reef(s) 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, as determined by down-looking sonar surveys or equivalent monitoring techniques in accordance with Condition D. If the average area of medium to high density giant kelp falls below 150 acres, then the reason for this failure shall be determined by independent monitoring overseen by CCC scientists. The permittee shall implement any remedial measures deemed necessary by the Executive Director.

The permittee's remediation requirement shall include the funding of independent studies that are necessary to determine the reasons for lack of kelp coverage as well as feasible corrective action, as determined by the Executive Director. If the failure is due to insufficient hard substrate, the corrective action shall entail the permittee adding more hard substrate to the reef.

If sufficient hard substrate appears to be available but kelp recruitment is low, then corrective action could include the permittee funding independent studies of kelp recruitment that are designed to determine the best method of establishing kelp on the reef. The Executive Director shall determine whether such studies are necessary.

The method determined by the Executive Director most likely to be a successful and reliable corrective action for low kelp abundance shall be implemented by the permittee until kelp coverage meets this performance standard; however, kelp establishment or augmentation methods shall not be required for more than a total of five years. If oceanographic conditions are unfavorable to kelp during part of this period, the Executive Director may defer the effort to establish kelp.

Fish

6. The standing stock of fish at the mitigation reef shall be at least 28 tons
7. The resident fish assemblage shall have a total density and number of species similar to natural reefs within the region.
8. Fish reproductive rates shall be similar to natural reefs within the region.
9. The total density and number of species of young-of-year fish (fish less than 1 year old) shall be similar to natural reefs within the region.
10. Fish production shall be similar to natural reefs within the region.

Benthos

11. The benthic community (both algae and macroinvertebrates) shall have coverage or density and number of species similar to natural reefs within the region.
12. The benthic community shall provide food-chain support for fish similar to natural reefs within the region.
13. The important functions of the reef shall not be impaired by undesirable or invasive benthic species (e.g., sea urchins or *Cryptoarachnidium*).

2.2 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 will help ensure that regional changes in oceanographic conditions affecting the Wheeler North Reef will be reflected in the performance criteria, since nearby San Mateo and Barn will be subjected to similar regional changes in oceanographic conditions.

2.3 Determination of similarity

A requirement of the SONGS permit is that the response variables measured to assess the relative performance standards (hereafter “performance variables”) of the Wheeler North Reef be “similar” to those at nearby natural reference sites. Evaluating compliance with the relative performance standards (i.e., standards 7 through 13) requires the use of an objective approach to determine whether the values of the performance variables are similar between the reference and mitigation sites. A hybrid approach that draws on the strengths of two existing techniques, but minimizes their weaknesses will be used to assess similarity (see Appendix 1 for a detailed description of this approach). The two techniques are called the “Range” test and the “Separate Confidence Interval“ (SCI) test. For the range test, a particular performance variable would be considered similar if its average value at the Wheeler North Reef falls within the range of average values of the reference reefs at San Mateo and Barn. While this is one of the simplest and least ambiguous ways of determining similarity, it has the major limitation of not considering measurement error associated with sampling the reference sites, and is thus likely to underestimate the true range of reference site values for a given performance variable.

Unlike the Range test the SCI test considers measurement error as it assesses similarity by determining whether the average value for a selected variable at Wheeler North Reef falls within the range set by the upper confidence interval of the reference site with the highest average and the lower confidence interval of the reference site with the lowest average. In essence this is a more sophisticated range test that takes into account the inherent natural variability at San Mateo and Barn kelp beds. A limitation that arises if the SCI test is used by itself to evaluate similarity is that it would allow Wheeler North Reef to have a lower mean value than San Mateo and Barn for *every* performance variable and still be in compliance. This clearly is not consistent with the goals of the SONGS permit. For this reason, a Hybrid Approach will be adopted for evaluating similarity that includes two criteria which must be met to conclude that the performance of Wheeler North Reef is similar to that at the San Mateo and Barn reference reefs: (1) the values of the performance variables at Wheeler North Reef must be within the range of the SCI of San Mateo and Barn for all performance variables, ***and*** (2) Wheeler North Reef must not have the lowest value more often than expected by chance alone. Criterion 1 ensures that the values of each performance variable at Wheeler North Reef will be greater than that of the lower confidence limit of the reference site with the lowest value. Criterion 2 ensures that the success of Wheeler North Reef requires it to behave like the reference sites with respect to all the performance variables, eliminating the possibility of concluding that Wheeler North Reef is in compliance when it has the lowest mean value for a disproportionately large number of performance variables.

When applied together, the two criteria of the Hybrid Approach ensure that the assessment of similarity is consistent with the SONGS permit requirement that all performance standards must be met without the unreasonable requirement that Wheeler North Reef outperform San Mateo and Barn for every performance standard. Thus, the Hybrid Approach deals realistically with the inherent variability of nature in a manner that best serves the interests of the public and SCE.

2.4 Monitoring period

Conditions C and D of the SONGS permit describe the monitoring requirements for the Wheeler North Reef which we summarize below. Additional documentation for this summary is provided in Appendix 1.

Fully implemented monitoring of the performance of the Wheeler North Reef will ensue upon completion of its construction and will continue until success is achieved. Success of the Wheeler North Reef requires that (1) all performance standards be met within 10 years after construction is completed, and (2).that all the performance standards have been met each year for three consecutive years. Hence, fully implemented monitoring will last a minimum of 10 years. All years that the Wheeler North Reef is in compliance will count towards the compliance period. The level of sampling effort may be reduced during this phase of monitoring if analyses of the data indicate that compliance of the performance standards can be adequately assessed using less sampling effort. Remediation may be required if the performance standards are not met within ten years and if three consecutive years of compliance has not occurred within 12 years. The Executive Director could prolong this phase of monitoring or reinstate it if necessary following any degradation of the Wheeler North Reef (resulting in a period of non-compliance) or remediation. Monitoring can be reduced to annual site inspections, which will serve to identify noncompliance with the performance standards, when the Wheeler North Reef has been in compliance with permit standards for at least three consecutive years, and evaluated for at least ten years post-construction.

If the Wheeler North Reef is considered unsuccessful within 12 years post-construction, then (at the discretion of the Executive Director) SCE shall fund an independent study to collect information needed to determine what remediation is required. SCE shall be required to implement any remedial measures determined necessary by the Executive Director in consultation with state and federal resource agencies and shall provide funds for independent monitoring that evaluates the success of the required remediation. Remediation monitoring may be different from the compliance monitoring required by the SONGS permit.

If the Wheeler North Reef is in a period of reduced monitoring and falls out of compliance 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 concludes that reduced monitoring could be reinstituted. CCC staff scientists will be responsible for designing and implementing the reduced monitoring program. If resumption of full monitoring leads to the conclusion that non-compliance is due to poor performance of the Wheeler North Reef, then SCE shall be responsible for implementing any remedial measures deemed necessary by the Executive Director including remediation monitoring

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 is in compliance with the SONGS' performance standards. To achieve this goal, the sampling design incorporates the following features: (1) spatially distributed sampling to increase accuracy, (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

Initially eighty two sampling locations, each defined by a fixed 50m x 10m area, will be established on the Wheeler North Reef in the primary polygons, and at San Mateo and Barn in areas that are known to support persistent kelp; Figures 1a-c). An additional 10 sampling locations will be established in the two contingency polygons on Wheeler North Reef. Sampling of the three reefs will be done concurrently. Each sampling area will be 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 10m wide swath centered along the 50m transect will define 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 will be used to evaluate different performance variables (Figure 2; see ***3.2 Methods for assessing the performance standards***). This combined level of effort (246 transects spread across three reefs + 10 transects in the 2 contingency polygons on Wheeler North Reef) is similar to that used during the first year of the experimental phase of the SONGS artificial reef project (n = 242 transects). As was done in the experimental phase of the SONGS reef mitigation project, monitoring data will be analyzed annually to determine whether sampling effort can be reduced or must be increased in order to detect non-compliance of permit standards.

The 82 transects on each reef will be arranged in 41 pairs with the two transects in each pair spaced 25m apart (Figures 1a -c). The 10 transects in the two contingency polygons on Wheeler North Reef will be similarly arranged in 5 pairs. Pairing of transects will be done to increase sampling efficiency. Maps of kelp persistence and hard substrate will be used to strategically distribute the 41 transect pairs at San Mateo and Barn across areas of reef known to support giant kelp. Transect pairs on the Wheeler North Reef will be allocated to the polygons and the existing experimental reef modules in proportion to their area (Table 1).

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, 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 10m 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 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 for assessing the performance standards

The level of certainty in assessing compliance of the SONGS reef mitigation project with the performance standards is directly related to sampling effort. Data collected during the experimental phase 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 the lower 80% confidence limit of the lowest performing reference reef) with an 80% probability (i.e., the statistical power calculated as 1-Type II error) using a Type I error (α) = 0.2 (see Appendix 1). However, in practice, only two of the three parameters (effect size, statistical power and α) can be controlled in a sampling design with a fixed sampling effort. The monitoring philosophy adopted for this project is to balance risk associated with under-performance of the artificial reef with risk associated with making errors in assessment (Type I (α) and Type II (β)). Given that statistical power is directly related to both Type I error (α) and effect size, the decision as to whether the Wheeler North Reef is in compliance with the relative performance standards will be based on a partially linked relationship between effect size and α, which is equal to the calculated p - value from an analysis (Figure 3).

The following rules will be used when assessing compliance of the relative performance standards (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 out of compliance for the period of assessment (α and effect size rounded to three significant figures).

2) If α > effect size for any effect size ranging from 0.000 to 0.500, then the Wheeler North Reef will be considered in compliance 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 variable. 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.

Listed below are the approaches that will be used to evaluate each of the thirteen performance standards that will be used to judge whether Condition C is in compliance with 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. CCC staff scientists conducted diver surveys and reviewed SCE's final construction report for the Wheeler North Reef (Coastal Environments 2008) and determined that the material used to construct the Wheeler North Reef conformed to that described in the final design plan. Hence SCE is in full compliance with 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 Wheeler North Reef were done 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). Results 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 Envrionments 2008). Contract scientists working for the CCC reviewed these data and analyses and determined that the Phase 2 mitigation reef consists of 152 acre low-profile (<1 m in height) single-layer quarry rock reef arranged in 18 polygons. Thus the 174.4 acres of mitigation reef (22.4 acres from the phase 1 + 152 from phase 2) is in compliance with 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 CCC contract 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 will be considered available for the attachment of reef biota for the purpose of evaluating performance standard 4 below). Contract scientists estimated the mean percent cover of hard substrate averaged across all phase 2 primary polygons and phase 1 modules was 42.3 % demonstrating that the Wheeler North Reef is in compliance with this standard.

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* will be determined as:

$S_t = A_t P_t$,

where A_t is the total area of Wheeler North Reef in year *t* (as determined by the methods described for performance standard 2 above) and P_t is the proportion of the Wheeler North Reef covered by quarry rock in year *t* (as determined by the methods described for performance standard 3 above). The proportion of area covered by quarry rock in the as-built condition ($S_0 = A_0P_0$) remaining at time *t* can be expressed as S_t / S_0 The value of S_t / S_0 must be ≥ 0.9 for the Wheeler North Reef to be in compliance with this standard.

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

Approach: The abundance of giant kelp *Macrocystis pyrifera* will be 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 on the Wheeler North Reef (see *3.1 General Sampling Design* for details). 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. Four plants per $100m^2$ was the minimum density of giant kelp used by the Marine Review Committee to estimate the acreage lost due to SONGS operations, and eight or more fronds per plant was the resolution of the down-looking sonar used to measure these losses. The proportion of transects with a mean ≥ 4 adult plants per 100 m^2 (based on the average of the five 10m x 2m plots in each transect) will be 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 of the Wheeler North Reef occupied by medium to high density giant kelp in a given year will be determined as:

$$A_k = (N_k/N_r)*A_r$$

Where A_r is the area of the Wheeler North Reef based on the most recent sonar survey, N_k = number of transects on the Wheeler North Reef with ≥ 4 plants per $100m^2$, and N_r is the total number of transects on the Wheeler North Reef. The value of A_k will be calculated each year of the monitoring period and used to determine whether the Wheeler North Reef is in compliance with this performance standard. If for a given year the value of A_k is ≥ 150 acres then the Wheeler North Reef will be considered to be in compliance with this performance standard for that year. Because the abundance of giant kelp fluctuates naturally from year to year the Wheeler North Reef will also be considered to be in compliance with this performance standard for a given year if the mean value of A_k averaged over that year plus the two preceding years ≥ 150 acres.

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 will be estimated using data on total fish density, individual lengths, and relationships between fish length and mass. Data on fish density and length will be recorded on the bottom along replicate fixed transects at the Wheeler North Reef in late summer to autumn of each year. Divers will count and estimate the total length (to the nearest cm) of each fish observed in a 2m wide x 2m 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 will be estimated. Cryptic fishes such as the blackeye goby (*Rhinogobiops nicholsii*) and the California scorpionfish (*Scorpaena guttata*) will be recorded along the transect as divers return after completing the sampling of less cryptic fish. These data will be augmented with data from additional surveys of fish lengths if more information is needed to accurately characterize the population size structures.

The concentration of bottom-dwelling fish will be estimated in replicate 50m x 2m x 2m transects on the Wheeler North Reef and scaled up to the total area of the reef as determined by the most recent sonar survey. Standing stock will be estimated by converting this scaled up concentration along with length data collected from the replicate 50m x 2m x 2m transects to mass 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) or from data collected as part of this project. These values will be used to estimate the mean mass of all fish species per cubic meter near the bottom and multiplied by the total reef area to obtain an estimate of the mean standing stock of bottom-dwelling fish on the Wheeler North Reef (this same approach was used by the Marine Review Committee when they determined that SONGS operations caused a 28 ton reduction in the standing stock of bottom-dwelling kelp bed fish). If for a given year the mean standing stock of bottom-dwelling fish on the Wheeler North Reef is ≥ 28 tons or the mean fish standing stock of bottom-dwelling fish averaged over that year plus the two preceding years ≥28 tons, then the Wheeler North Reef will be considered to be in compliance with this performance standard for that year.

7. THE RESIDENT FISH ASSEMBLAGE SHALL HAVE A TOTAL DENSITY AND NUMBER OF SPECIES 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 will be collected using the same methods described for the Wheeler North Reef above (see approach for performance standard 6). Briefly, all species of resident fish will be sampled on the bottom at each of the replicate fixed 2m x 2m x 50m transects at Wheeler North Reef, San Mateo and Barn to obtain the number of resident fish on each transect. Resident fish are defined here as reef associated species > 1 year old (the density and number of species of fish ≤ 1 year old will be evaluated in performance standard 9). Data on fish length will be 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) will be calculated as the mean density of resident fish on the bottom averaged over the replicate transects.

Species richness (number of species) of resident fish at the Wheeler North Reef and reference reefs will be assessed in the following manner. Resampling methods will be used to generate 80% confidence intervals for the total number of species observed during dive surveys on each reef. Both the density and species richness of resident fishes on the Wheeler North Reef must be similar to that of the reference reefs (as per the methods described Section 2.3 above) for the Wheeler North Reef to be in compliance with this performance standard.

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

Approach: Data on annual per capita egg production (or embryo production in the case of live-bearers) of a select group of targeted reef fish species will be used to determine whether fish reproductive rates on the Wheeler North Reef are similar to those on San Mateo and Barn for similar sized individuals. We will assess reproduction rates for a group of target species that represent the major feeding and reproductive guilds of fishes on southern California reefs and are sufficiently abundant to facilitate collection (Table 2).

Information on reproductive rates will be collected at Wheeler North Reef, San Mateo, and Barn during summer through fall. The annual mass or number of eggs (or embryos in the case of live bearers) produced per individual (*F*) will be calculated for each female specimen (details of the methods are provided in Appendix 2). The relationship between egg mass (or number) and fish length will be determined using regression models, most likely of the form Log (F) = a +Log (length). Other forms in the same family of models that can be linearized may also be used. If this is not possible, then an approach using the fecundity matrix discussed in Appendix 3 will be employed. Reproductive rates and fish lengths will be normalized within species across reefs using a Z transformation (Z = (observed value – mean $\text{value}_{\text{species } i}$) / standard $\text{deviation}_{\text{species } i}$). Parameter estimates for normalized slopes and intercepts will be averaged across species to produce normalized mean slopes and intercepts for each of the three reefs (Wheeler North, San Mateo and Barn). Fish reproductive rates on the Wheeler North Reef will be considered similar to that on the natural reference reefs if the mean slope and intercept for the relationship between egg mass (or number) and fish length at the Wheeler North Reef are similar to those of the reference reef with the lowest slope and intercept values.

9. THE TOTAL DENSITY AND NUMBER OF SPECIES OF YOUNG-OF-YEAR FISH (FISH LESS THAN 1 YEAR OLD) SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Data on the density and number of species of young-of-year fish at the Wheeler North Reef and reference reefs will be collected during the same surveys done for resident fish. The approach to be used for determining whether the density and number of young-of-year fish on the Wheeler North Reef is similar to that on the reference reefs will be the same as that used for resident fish in performance standard 7. Both the density and species richness of young-of-year fish on the Wheeler North Reef must be similar to that of the reference reefs (as per the methods described Section 2.3 above) for the Wheeler North Reef to be in compliance with this performance standard.

10. 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 that will be obtained from additional otolith studies. Importantly, this method of calculating fish production assumes no net migration. Details of the method are presented in Appendix 3.

Production will be estimated for target species that represent the major feeding guilds of fishes in southern California kelp forests and are common to the study region (Table 2). The annual production for each of the targeted species will be averaged to obtain a representative estimate of the annual fish production *P* (± 80% confidence limits) for each of the three reefs (Wheeler North Reef, San Mateo and Barn). The value of *P* at the Wheeler North Reef must be similar to the reference reefs (as per the methods described in Section 2.3 above) for the Wheeler North Reef to be in compliance with this performance standard.

11. 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 will be sampled annually in the summer in the areas defined by the replicate 50m x 2m transects at each reef (see ***3.1 General Sampling Design*** for details). Several different sampling methods will be 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*) will be measured as percent cover in five replicate 1m^2 quadrats located at 10m intervals along each of the eighty two 50m transects. Percent cover will be 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*) will be counted in the five 10m x 2m plots centered along each 50 m transect. Smaller solitary mobile invertebrates (nudibranchs, bivalves, etc) and algae (small size classes of all kelps) will be 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.

Count data and percent cover data will be combined to determine the total number of species of understory algae and benthic invertebrates on each reef. Resampling methods will be used to generate 80% confidence intervals for the total number of species of understory algae and benthic invertebrates observed on each reef. The following three elements will be used to assess compliance of the Wheeler North Reef with the benthic community performance standard. (1) the combined percent cover of the bottom occupied by algae and sessile invertebrates, (2) the density of mobile invertebrates, and (3) the combined number of species of algae and invertebrates. All three of these elements at the Wheeler North Reef must be similar to the reference reefs (as per the methods described in Section 2.3 above) for the Wheeler North Reef to be in compliance with this performance standard.

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 involves sampling gut contents in reef fishes that feed on the benthos and are collected for other purposes. Such is the case for the black perch (*Embiotica jacksoni*) and the California sheephead (*Semicossyphus pulcher*). Both species feed almost exclusively on benthic prey and will be collected for purposes of evaluating rates of reproduction and growth. Restricting the evaluation of this performance standard to these two species assumes that their feeding activities are broadly representative or other benthic feeding species of kelp bed fish. As noted in Appendix 2, fish collected for evaluation of performance standard 8 will be placed on ice upon collection and transported to the laboratory where they will either be frozen or immediately dissected and processed. Sample processing for both species will involve 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. This performance standard will be evaluated using an index of food chain support (FCS) that is based on the mass of the gut contents relative to body mass

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

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

Because there may be species-specific differences in average feeding success we will normalize our measurements within species using a Z transformation (see performance standard 8) to ensure that our estimates from both species are comparable.

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

Approach: Large increases in the abundance of one or more native or non-indigenous species can have profound adverse effects on important ecological functions that kelp forests provide. For example, dramatic increases in the abundance of native sea urchins can cause them to change their behavior from passive drift feeding to active grazing, which has been shown to greatly reduce the standing crop of vegetation on a reef and the important ecological functions that it provides. The spread of exotic species such as the green alga *Caulerpa* can have similar adverse effects of the ecological functions of an ecosystem by displacing native species and/or altering food webs and energy flow.

Primary production is arguably one of the most important functions of reefs that support giant kelp forests, which are believed to be one of the most productive ecosystems on earth (Mann 2000). The majority of primary production in giant kelp forests is derived from giant kelp itself (R. Miller et al. unpublished data). Unfortunately, quantifying rates of primary production by giant kelp is very labor intensive, requiring frequent sampling to accurately measure high and unpredictable rates of biomass turnover (Reed et al. 2008). Recent studies, however, indicate that annual net primary production of giant kelp in southern California can be accurately estimated from summertime densities of giant kelp fronds ($r^2 = 0.93$, $P < 0.0001$, Rassweiler et al. 2008). Fortunately, sampling the summertime density of giant kelp fronds along the fixed transects at Wheeler North Reef, San Mateo and Barn can easily be done with little added effort, thus providing a reliable and inexpensive estimate of the annual production of giant kelp. The summertime density of kelp fronds is also an important measure of habitat complexity in kelp forests, which is critically important to the recruitment of many species of reef fish that take shelter in the kelp and feed off small crustacean prey that live on it (Carr 1989, 1994). Thus data on the summertime densities of *Macrocystis* fronds is relatively easy to obtain and provides important information for two very important reef functions: (1) net primary production by giant kelp and (2) shelter and living space for a diverse assemblage of reef fishes and their invertebrate prey.

The extent to which sea urchins or other undesirable species impair the primary production and habitat complexity of giant kelp will be determined by comparing summertime densities of kelp fronds at the Wheeler North Reef to that at San Mateo and Barn. If the summertime density of giant kelp fronds at the Wheeler North Reef is significantly less than the mean frond density at the reference reef with the lowest mean value then data on the abundances of potentially invasive and undesirable species will be analyzed to determine whether there is probable cause to implicate them for the lower frond densities observed at the Wheeler North Reef. Ecological functions other than kelp primary production and shelter habitat will be investigated on the Wheeler North Reef if observations indicate that they are being impaired by 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 phase 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 returned to the user alerting him or her of the invalid entry.

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 "live" database that contains all fully checked and verified data.

Data from the live 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, and at the Marine Science Institute on UCSB's main campus in Santa Barbara, CA.

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. These are 1) regular documents (backed up every four hours in native format), 2) SQL database files (backed up in real time to two mirror servers using native format, and once a week to the Marine Science Institute's server on UCSB's main campus in comma delimited text), and 3) statistical and database program files (backed up every four hours in native format, and once a week to server on main campus in native format).

Daily backups are written to a redundant disk array, while weekly backups are written to disk and removable media (tape, DVD). 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 will be followed to ensure efficient and effective communication with SCE, state and federal resource agencies and the general public: (1) CCC contract scientists will 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 will be prepared and submitted to the CCC for public viewing on a regular basis, (3) all monitoring data will be made available upon request as soon as they have been verified, (4) CCC contract scientists will develop and maintain a public website that provides information on the history, current status, and other relevant information pertaining to the monitoring of the SONGS reef mitigation project, and (5) annual meetings will be held with all interested parties.

6.0 REFERENCES

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Table 1. Distribution of monitoring transects on the Wheeler North Reef based on acreage provided in SCE's Final Construction Report for the Wheeler North Reef (Coastal Environments. 2008).

Primary Polygons	**Area (acres)**	**Number of Transects**
1	13.83	6
2	38.88	20
3	6.61	4
4	14.05	8
6	4.24	2
7	6.80	4
8	7.64	4
9	2.52	2
10	3.89	2
11	3.48	2
12	1.35	2
13	2.85	2
14	2.12	2
15	5.54	2
16	11.19	6
17	5.32	2
Contingency Polygons		
5	9.48	4
7a	12.2	6
Experimental Reef Modules	22.4	12
Total	174.4	92

Table 2. Reef fishes being considered 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
barred sand bass	*Paralabrax nebulifer*	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 92 fixed transects where monitoring of the performance standards will be done. Transects are in pairs and are shown as white lines in the primary reef polygons and as black lines in the contingency reef polygons and experimental reef modules. The primary and contingency reef polygons are identified by the numbers shown within them and correspond to the identification numbers shown in Table 1. Depth contours are in meters.

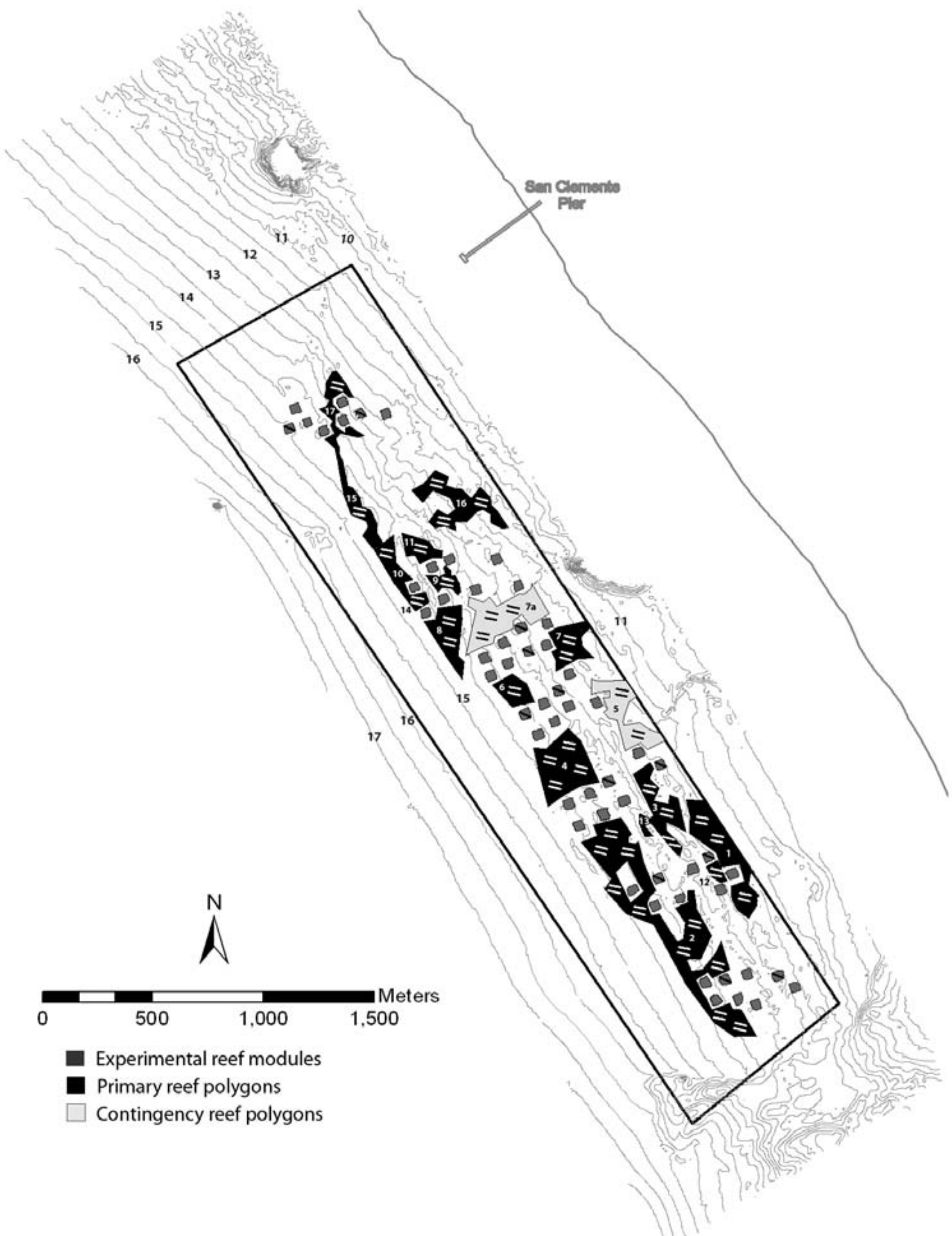


Figure 1b. Map of the reef at San Mateo showing the location of the 82 fixed transects where monitoring of the performance standards will be done. Transects are in pairs and are shown as white lines in the black shaded areas, which denote hard substrate. Depth contours are in meters.

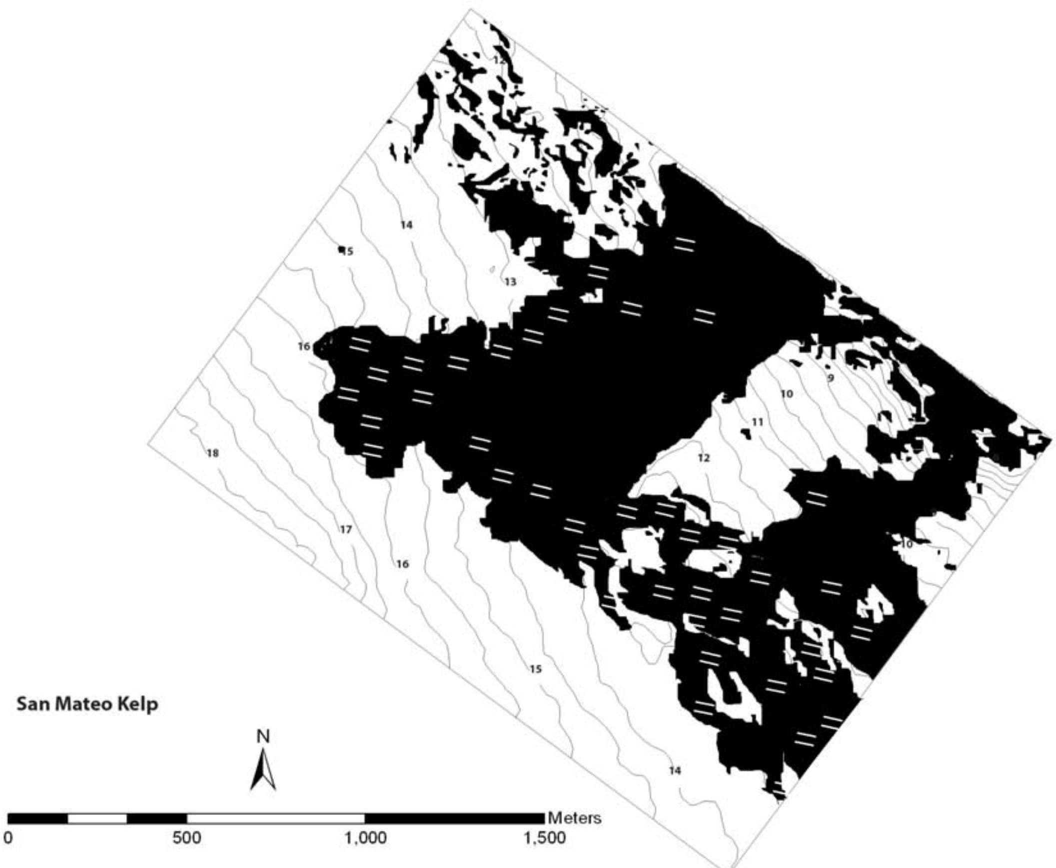


Figure 1c. Map of the reef at Barn showing the location of the 82 fixed transects where monitoring of the performance standards will be done. Transects are in pairs and are shown as white lines in the black shaded areas, which denote hard substrate. Depth contours are in meters.

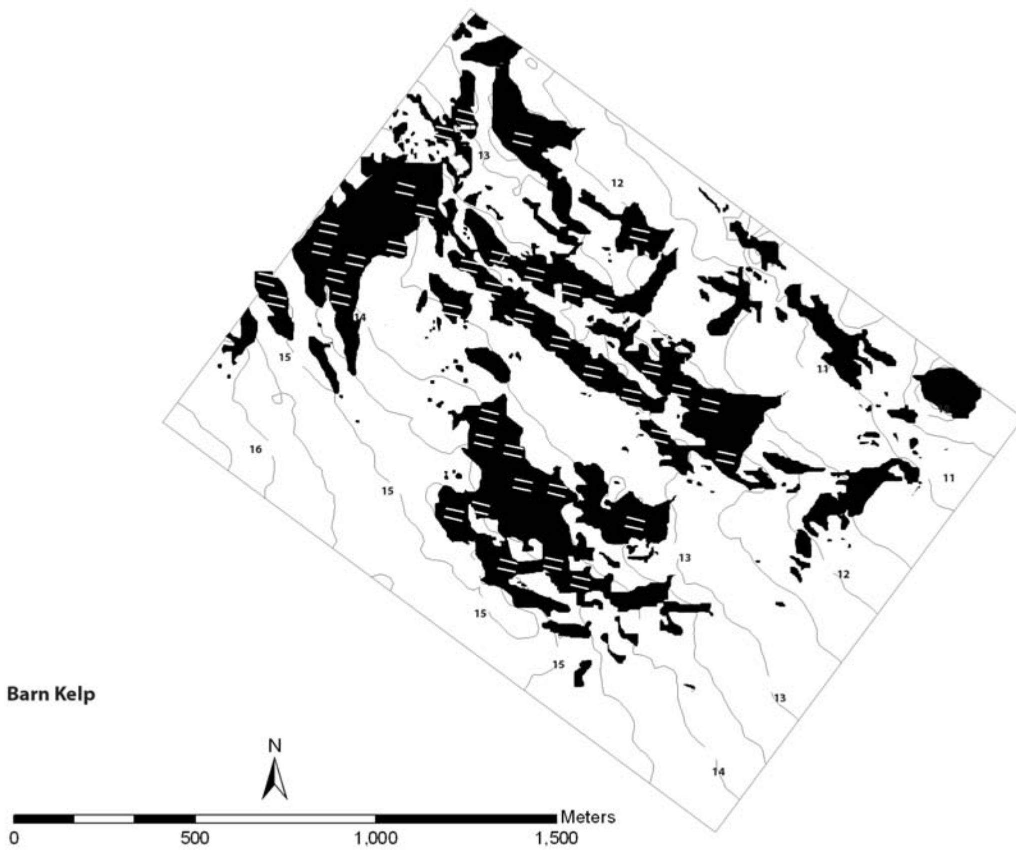


Figure 2. Schematic showing the the different sized sampling areas that will be used at each of the fixed monitoring stations; including a large 50m x 2m band transect (delineated by dashed lines; five smaller 10m x 2m band transects perpendicular to the main transect and evenly spaced along it; five 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.

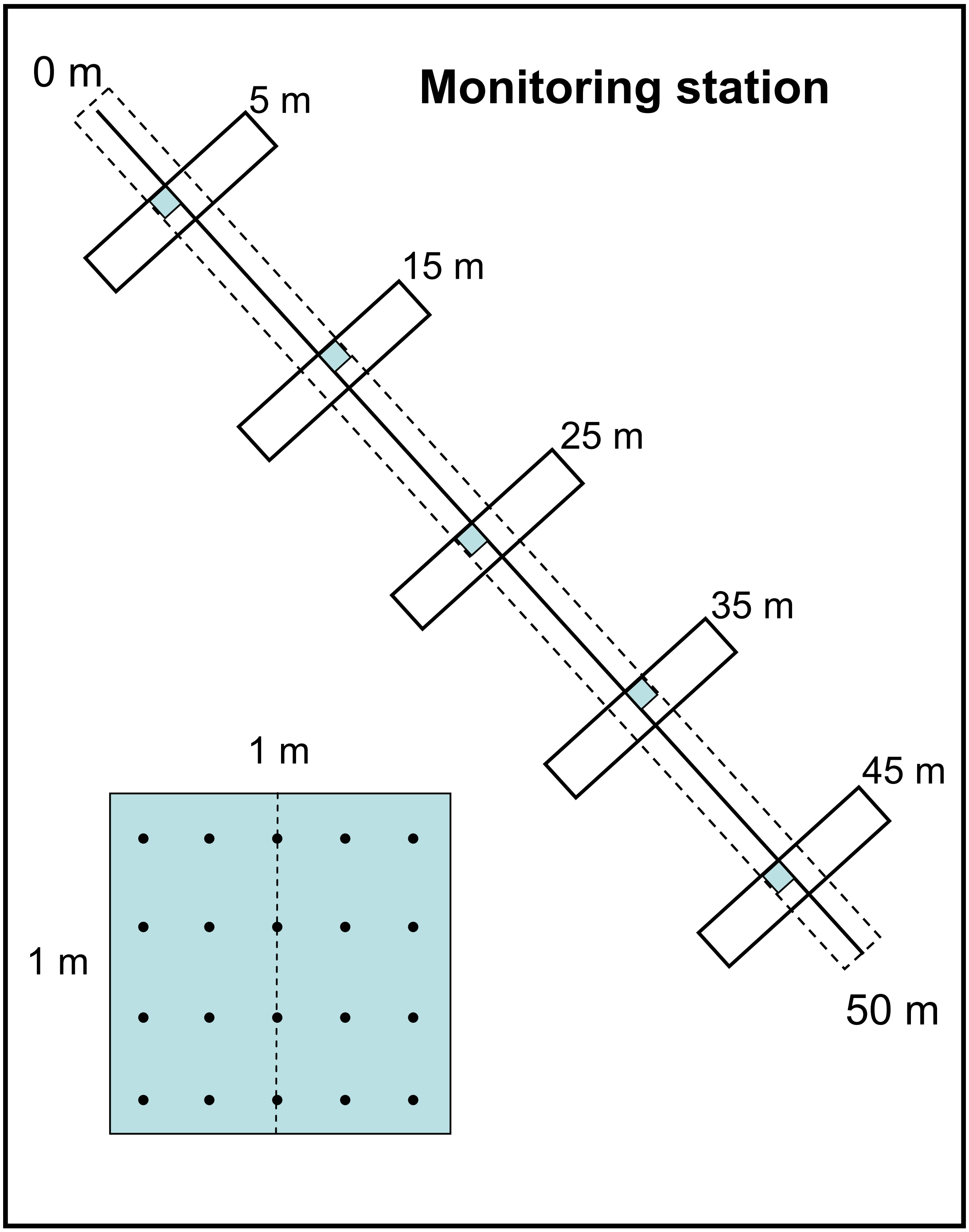
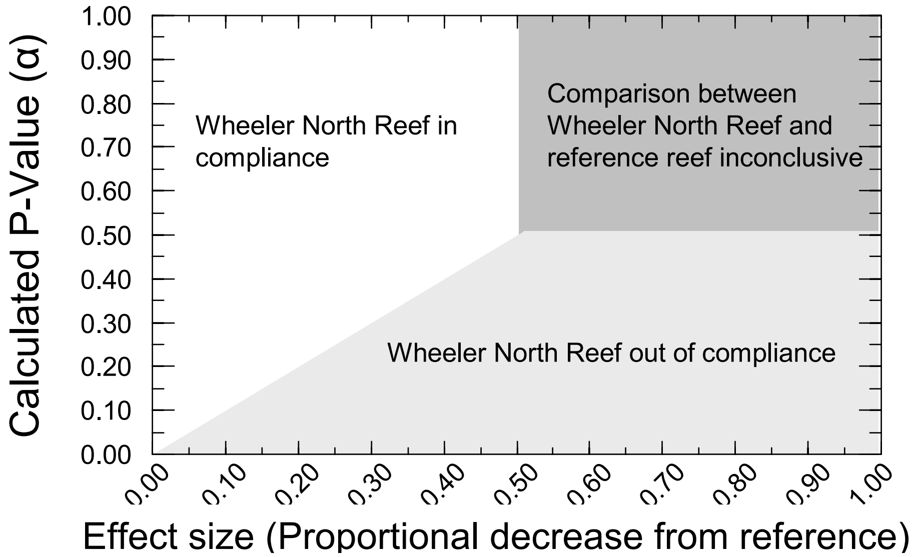


Figure 3. The relationship between effect size and alpha, and how it will be used to determine whether the Wheeler North Reef is in compliance with the relative performance standards



Appendix 1

The Definition of Compliance and the Determination of Similarity in the Context of the SONGS Mitigation Projects

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EXECUTIVE SUMMARY

The California Coastal Commission (CCC) has required Southern California Edison (SCE) and its partners to construct mitigation projects that provide adequate compensation for the loss of marine resources resulting from the operation of SONGS Units 2 and 3. The CCC is responsible for determining whether these projects are successful. Two related issues that reside at the core of this determination are: (1) the level and duration of performance by the mitigation projects that is needed to achieve compliance with specific conditions of the SONGS coastal development permit and (2) a methodological approach to determining whether the mitigation projects are performing similarly to naturally undisturbed reference sites. We address these two issues in the following sections of this document.

I. ASSESSING COMPLIANCE FOR THE SONGS MITIGATION PROJECTS

The conditions of the SONGS coastal development permit (6-81-330-A) were amended in 1991 to mitigate the adverse impacts of the operation of SONGS Units 2 and 3 on the marine environment. The conditions that were amended to the permit require SCE and its partners to (1) create or substantially restore a minimum of 150 acres of southern California wetlands (Condition A), (2) install fish barrier devices at the power plant (Condition B), and (3) construct an artificial reef large enough to sustain 150 acres of medium to high density kelp bed community (Condition C). A fourth condition (Condition D) requires SCE to fund the Commission's oversight of the mitigation and independent monitoring functions identified in and required by Conditions A, B, and C. Physical and biological standards are identified in conditions A and C that specify how the wetland and reef mitigation projects should perform and the timing and level of monitoring that is needed to evaluate their performance. The specific requirements for attaining compliance of these conditions are discussed in various sections throughout the permit. The purpose of this document is to provide SCE with clear and consistent interpretations of key terms in the SONGS coastal development permit, which provide the basis for assessing compliance of SONGS wetland and reef mitigation projects. We identify the specific sections in the permit that provide support for our interpretations, and provide schedules for the different levels of monitoring that are required to determine whether the wetland and reef mitigation projects are in compliance with Conditions A and C.

II. METHODS FOR DETERMINING SIMILARITY BETWEEN THE MITIGATION AND REFERENCE SITES FOR THE PUROPOSE OF EVALUATING COMPLIANCE OF THE SONGS' MITIGATION PROJECTS

A requirement of the SONGS permit is that certain biological attributes (performance variables) of the mitigation sites (i.e., the restored wetland or marine artificial reef) be “similar” to those at nearby natural reference sites. Evaluating compliance with these relative performance standards requires the use of an objective approach to determine whether the values of the performance variables are similar between the reference and mitigation sites. Contract scientists working for the California Coastal Commission were charged with developing that method (Permit No. 6-81-330-A, Condition A.3.4). This document describes the *Hybrid Approach* the contract scientists will use to evaluate similarity between the mitigation and reference sites.

The Hybrid Approach draws on the strengths of two existing techniques but minimizes their weaknesses. The two techniques are called the “Range” test and the “Separate Confidence Interval“ (SCI) test. For the range test, a particular performance variable would be considered similar if the average value at the mitigation site falls within the range of average values at the selected reference sites. While this is one of the simplest and least ambiguous ways of determining similarity, it has the major limitation of not considering measurement error for sampling at reference sites, and is thus likely to underestimate the true range of reference site values for a given performance variable. The SCI test does not have this limitation. It assesses similarity by determining whether the average value for a selected variable at the mitigation site falls within the range set by the upper confidence interval of the reference site with the highest average and the lower confidence interval of the reference site with the lowest average. In essence this is a more sophisticated range test that takes into account inherent natural variability within reference sites. Limitations of the SCI test arise when it is used by itself to evaluate similarity because it would allow the mitigation site to have a lower mean value than all the reference sites for *every* performance variable and still be in compliance. This is not consistent with the goals of the SONGS permit. For this reason, a Hybrid Approach will be adopted for evaluating similarity that includes two criteria that must be met to conclude that the mitigation and reference sites are similar: (1) the values of the performance variables at the mitigation site must be within the range of the SCI of the reference site for all performance variables, ***and*** (2) the mitigation site must not have the lowest value more often than expected by chance alone. Criterion 1 ensures that the values of each performance variable at the mitigation site will be greater than that of the lower confidence limit of the reference site with the lowest value. Criterion 2 ensures that the mitigation site behaves like the reference sites with respect to all the performance variables, eliminating the possibility of concluding that the mitigation site is in compliance when it has the lowest value for a disproportionately large number of performance variables.

When applied together, the two criteria of the Hybrid Approach ensures that the assessment of similarity is consistent with the SONGS permit requirement that all performance standards must be met without the unreasonable requirement that the mitigation project outperform all reference sites for every performance standard. Thus, the Hybrid Approach deals realistically with the inherent variability of nature in a manner that best serves the interests of the public and Southern California Edison.

I. ASSESSING COMPLIANCE FOR THE SONGS MITIGATION PROJECTS

The SONGS coastal development permit (6-81-330-A) requires SCE to create or substantially restore a minimum of 150 acres of southern California wetlands (Condition A), and to construct an artificial reef large enough to sustain 150 acres of medium to high density kelp bed community (Condition C). Physical and biological standards are identified in these conditions that specify how the wetland and reef mitigation projects should perform and the timing and level of monitoring that is needed to evaluate their performance is discussed. The purpose of this document is to provide consistent interpretations of key terms in the SONGS coastal development permit (6-81-330-A), which provide the basis for assessing compliance of SONGS wetland and reef mitigation projects. The specific sections in the SONGS permit that provide support for our interpretations are indicated by numerical superscripts in the text and are referenced below (see p. 6 of Appendix 1, **Permit language supporting CCC staff's interpretations on SONGS project compliance**).

DEFINITIONS

Monitoring Period: Post-construction monitoring will ensue upon completion of the reef construction and wetland restoration[1, 2]. The duration of such monitoring will last for a period not less than the full operating life of SONGS (defined below) plus years monitored without the project attaining compliance with permit standards[2, 3].

Compliance: The condition in which all performance standards are met.

Compliance Period: The number of years that a mitigation project is in compliance. The mitigation requirements will be fulfilled when the compliance period equals the total years of operation of SONGS Units 2 & 3, including decommissioning period to the extent that there is continuing entrainment or impingement or discharge of cooling water[3,4].

MONITORING EFFORT

Mitigation Reef (see Figure 1)

1) *Phase 1: Fully implemented monitoring*: Independent monitoring designed and conducted by CCC staff scientists will be done to evaluate the performance of the mitigation reef[5]. The sampling methodology, analytical techniques, and methods for measuring performance of the mitigation reef relative to the performance standards shall be described in the monitoring plan prepared for the mitigation reef[6]. Monitoring will ensue upon completion of the reef construction[2]. All performance standards must be met within 10 years[7,8]. The project will be considered successful when all the performance standards have been met each year for three consecutive

years[9]. Hence, fully implemented monitoring will last a minimum of 10 years. All years that the project is in compliance will count towards the compliance period. The level of sampling effort may be reduced during this phase of monitoring if analyses of the data indicate that compliance of the performance standards can be adequately assessed using less sampling effort. Remediation may be required if the performance standards are not met within ten years and if three consecutive years of compliance has not occurred within 12 years [10, 11]. Note that the Executive Director could prolong this phase of monitoring or reinstate it if necessary following degradation of the artificial reef (resulting in a period of non-compliance) or remediation[12].

2) *Phase 2: Annual site inspections:* Monitoring can be reduced to annual site inspections[13,14], which will serve to identify noncompliance with the performance standards, when:
   a. The project has been in compliance with permit standards for at least three consecutive years, and
   b. The project has been evaluated for at least ten years post-construction.

The schedule for monitoring the mitigation reef project is shown in Figure 1.

Restored Wetland (see Figure 2)

1) *Phase 1: Fully implemented monitoring:* Independent monitoring designed and conducted by CCC staff scientists will be done to evaluate the performance of the wetland restoration project[5]. A description of the monitoring can be found in the wetland monitoring plan and details of the monitoring effort will be set forth in a work plan[15]. Monitoring will ensue upon completion of wetland construction[16]. Within 4 years of construction, the total densities and number of species of fish, macro-invertebrates and birds shall be similar to the densities and number of species in similar habitats in the reference wetlands[17]. All performance standards must be met within 10 years, which is the same amount of time required for the mitigation reef to meet all of the performance standards[7,8]. The wetland restoration project will be considered successful when all the performance standards have been met for each of three consecutive years[9]. All years that the project is in compliance will count towards the compliance period. Remediation may be required if all the performance standards are not met within ten years and if three successive years of compliance has not occurred within 12 years[18]. Note that the Executive Director could prolong this phase of monitoring or reinstate it if necessary following remediation or degradation of the wetland (resulting in a period of non-compliance)[12].

2) *Phase 2: Scaled back monitoring:* Upon determination that the project has been in compliance for three consecutive years, a scaled back phase of monitoring will ensue[14]. The scaled back monitoring program will be

designed and implemented by CCC staff scientists(5). Reduction in effort will be based on analyses of data collected during the period in which the project was in compliance. Staff scientists will examine these data to determine the minimum effort that would have been necessary to assess compliance during the period**.** All monitoring, whether it is fully implemented or scaled back, must be sufficient for assessing compliance of the performance standards*.*

The schedule for monitoring the wetland restoration project is shown in Figure 2.

Remediation

If the mitigation reef or restored wetland is not considered successful within 12 years post-construction or if the restored wetland has not met the biological community standard by year 4, then (at the discretion of the Executive Director):

1) The permittee shall fund an independent study to collect information needed to determine what remediation is required(19).
2) The permittee shall be required to implement any remedial measures determined necessary by the Executive Director in consultation with state and federal resource agencies and will provide funds for independent monitoring that evaluates the success of the required remediation(10,11,19). Remediation monitoring may be different from the compliance monitoring required by the permit.

If the mitigation reef or restored wetland is in a period of reduced monitoring and if it falls out of compliance for a period of two consecutive years, then to determine if non-compliance is an artifact resulting from a reduction in monitoring effort, full monitoring (Phase1) may be re-established for those standards that are out of compliance. 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 study or until the Executive Director concludes that reduced monitoring could be reinstituted(12). CCC staff scientists will be responsible for designing and implementing the reduced monitoring program(5).

If resumption of full monitoring leads to the conclusion that non-compliance is due to poor performance of the mitigation project then:

1) The permittee shall be required to fund an independent study to collect the information necessary to determine what remediation is needed (19)
2) The permittee shall be required to implement any remedial measures determined necessary by the Executive Director in consultation with state and federal resource agencies and will provide funds for independent monitoring that evaluates the success of the required remediation(10,11,19). Remediation monitoring may be different from the compliance monitoring required by the permit.

Permit (No. 6-81-330-A) language supporting CCC staff's interpretations on SONGS project compliance

1. (III.A.3.4). Upon completion of construction of the wetland, monitoring shall be conducted to measure the success of the wetland in achieving stated restoration goals (as specified in restoration plan) and in achieving performance standards, specified below.

2. (III.B. 2.4). Following completion of construction the mitigation reef shall be monitored for a period equivalent to the operating life of SONGS.

3. (III.A.3.0). Monitoring, management (including maintenance), and remediation shall be conducted over the "full operating life" of SONGS Units 2 and 3**.** Full operating life" as defined in this permit includes past and future years of operation of SONGS units 2 and 3 including the decommissioning period to the extent there are continuing discharges. The number of past operating years at the time the wetland is ultimately constructed, shall be added to the number of future operating years and decommission period, to determine the length of the monitoring, management and remediation requirement.

4. (III.B 2.4). The permittee shall insure that the performance standards and goals set forth in this condition will be met for at least the length of time equivalent to the full operating life of SONGS Units 2 and 3….“Full operating life” as defined in this permit includes past and future years of operation of SONGS Units 2 and 3, including the decommissioning period to the extent there are continuing discharges.

5. (III.C.1.0). Personnel with appropriate scientific or technical training and skills will, under the direction of the Executive Director, oversee the mitigation and monitoring functions identified and required by conditions II-A through C. The Executive Director will retain approximately two scientists and one administrative support staff to perform this function.

This technical staff will oversee the preconstruction and post-construction site assessments, mitigation project design and implementation (conducted by permittee), and monitoring activities (including plan preparation); the field work will be done by contractors under the Executive Director's direction. The contractors will be responsible for collecting the data, analyzing and interpreting it, and reporting to the Executive Director.

6. (III.B.2.4. A monitoring plan for the mitigation reef shall be developed by the Commission staff scientists pursuant to Condition D. The monitoring plan shall be completed within six months of approval of a coastal development permit for the mitigation reef proposed in a final plan developed pursuant to this condition.

The monitoring plan shall provide an overall framework to guide the monitoring work. The monitoring plan shall describe the sampling methodology, analytical techniques, and methods for measuring performance of the mitigation reef relative to the performance standards identified below.

7. (III.B.2.4). The independent monitoring program for the mitigation reef shall be designed to assess whether the performance standards have been met. If these standards are met after ten years following the completion of construction, then monitoring can be reduced to annual site inspections.

8. (III.B.2.4). If the standards listed above are not met within ten years after reef construction, then the permittee shall undertake those remedial actions the Executive Director deems appropriate and feasible.

9. (III.C.3.0). The mitigation projects will be successful when all performance standards have been met each year for a three-year period. The Executive Director shall report to the Commission upon determining that all of the performance standards have been met for three years and that the project is deemed successful.

10. (III.B.2.4). The permittee shall undertake necessary remedial actions based on the monitoring results and annual site inspections for the full operating life of the SONGS Units 2 and 3.

11. (III.B.2.4). If the standards listed above are not met within ten years after reef construction, then the permittee shall undertake those remedial actions the Executive Director deems appropriate and feasible.

12. (III.C.3.0). If subsequent monitoring shows that a standard is no longer being met, monitoring may be increased to previous levels, as determined necessary by the Executive Director.

13. (III.B.2.4). The independent monitoring program for the mitigation reef shall be designed to assess whether the performance standards have been met. If these standards are met after ten years following the completion of construction, then monitoring can be reduced to annual site inspections.

14. (III.C.3.0). If the Commission determines that the performance standards have been met and the project is successful, the monitoring program will be scaled down, as recommended by the Executive Director and approved by the Commission. A public review shall thereafter occur every five years, or sooner if called for by the Executive Director.

15. (III.A.3.1). A monitoring and management plan will be developed in consultation with the permittee and appropriate wildlife agencies, concurrently with the preparation of the restoration plan, to provide an overall framework to guide the monitoring work. It will include an overall description of the studies to be conducted over the course of the monitoring program and a description of management tasks that are anticipated, such as trash removal. Details of the monitoring studies and management tasks will be set forth in a work program.

16. (III.A.3.4). Upon completion of construction of the wetland, monitoring shall be conducted to measure the success of the wetland in achieving stated restoration goals (as specified in restoration plan) and in achieving performance standards.

17. (III.A.3.4.b.1). *Biological Communities.* Within 4 years of construction, the total densities and number of species of fish, macroinvertebrates and birds shall be similar to the densities and number of species in similar habitats in the reference wetlands.

18. (III.A.3.4). The permittee shall be fully responsible for any failure to meet these goals and standards during the full operational years of SONGS Units 2 and 3. Upon determining that the goals or standards are not achieved, the Executive Director shall prescribe remedial measures, after consultation with the permittee, which shall be immediately implemented by the permittee with Commission staff direction. If the permittee does not agree that remediation is necessary, the matter may be set for hearing and disposition by the Commission.

19. (III.B.2.4). Executive Director may also use any other information available to determine whether the performance standards are being met. If information from the annual site inspections or other sources suggests the performance standards are not being met, then the permittee shall be required to fund an independent study to collect the information necessary to determine what remediation is needed. The Executive Director shall determine the required remedial actions based on information from the independent study. The permittee shall be required to implement any remedial measures determined necessary by the Executive Director in consultation with state and federal resource agencies, as well as provide funds for independent monitoring that evaluates the success of the required remediation. As described under the funding option (Condition D) of this permit, the cost of remediation shall not be limited if the permittee elects to implement the mitigation reef.

Figure 1. Idealized monitoring schedule for the mitigation reef showing the minimum time periods for the two phases of monitoring: (1) Fully implemented monitoring and (2) annual site inspection. The actual time periods for each phase may be longer, depending on the performance of the project.

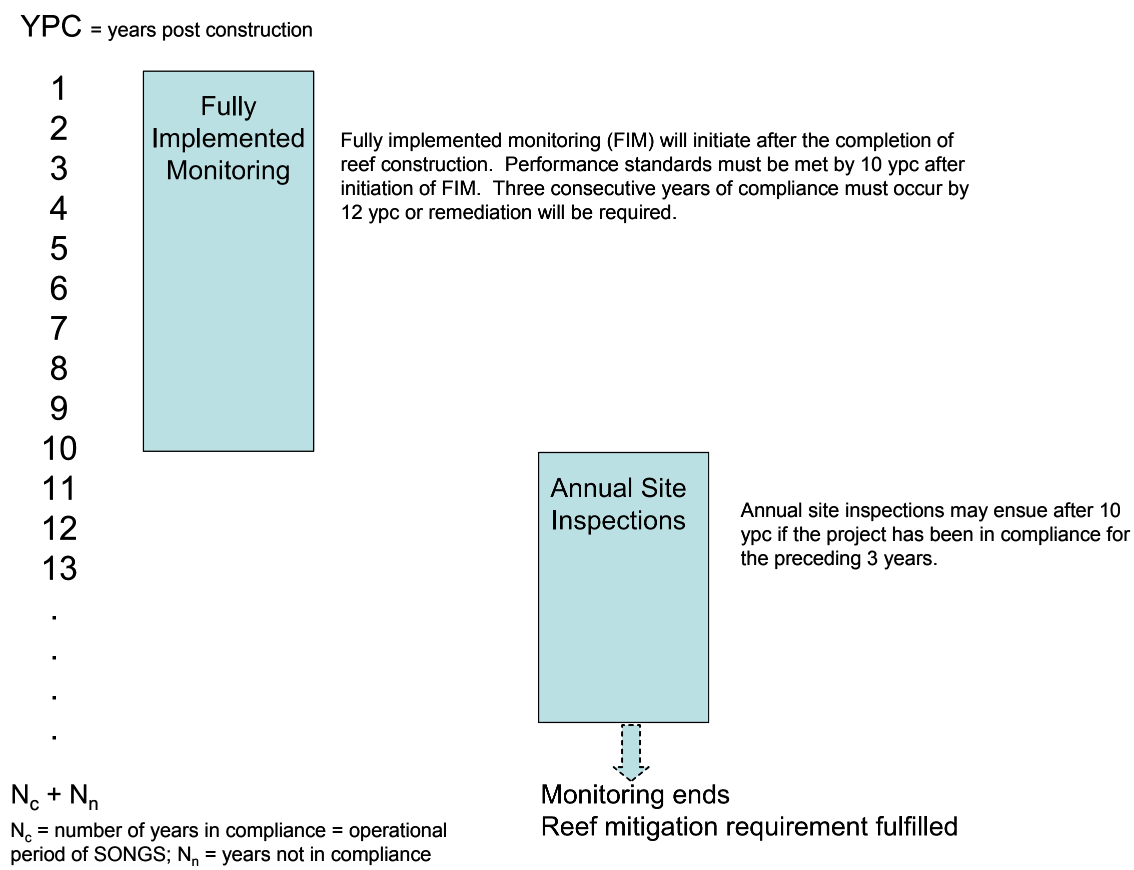
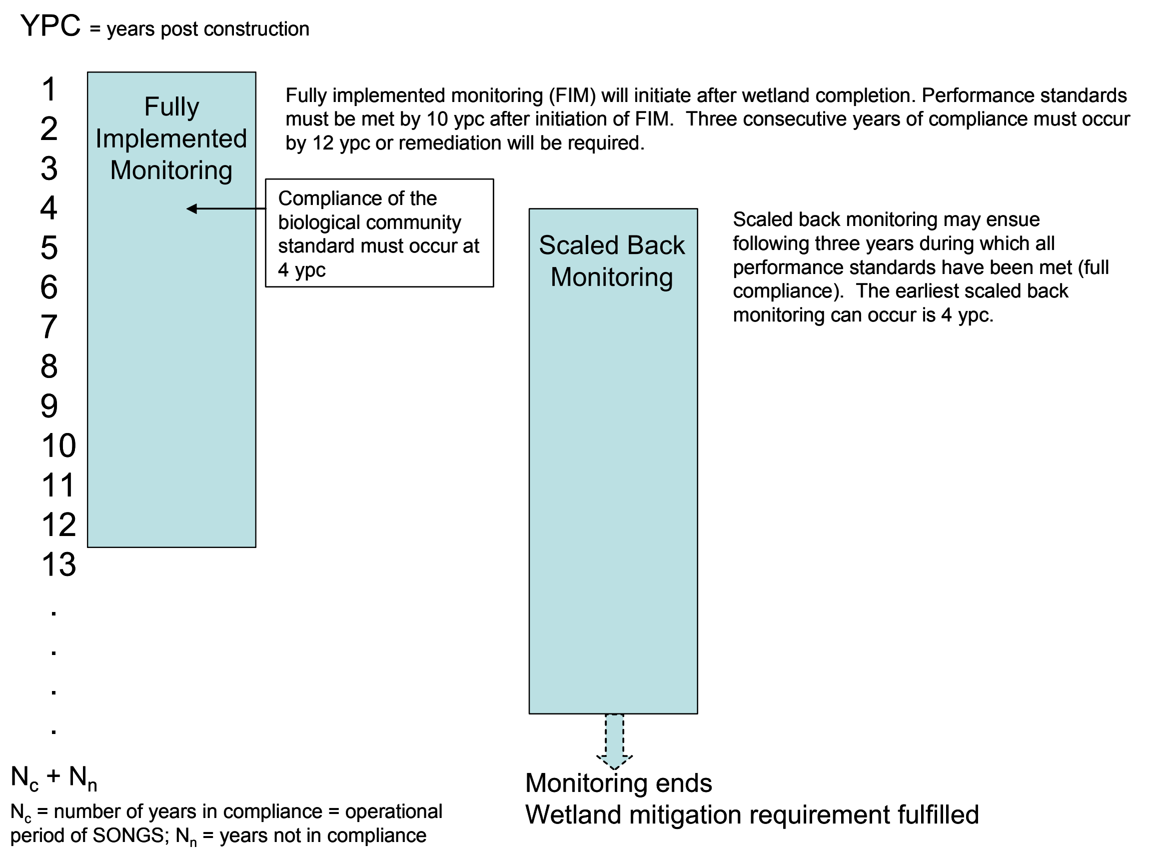


Figure 2. Idealized monitoring schedule for the wetland restoration project showing the minimum time periods for the two phases of monitoring: (1) Fully implemented monitoring and (2) scaled back monitoring. The actual time periods for each phase may be longer, depending on the performance of the project.



II. METHODS FOR DETERMINING SIMILARITY BETWEEN THE MITIGATION AND REFERENCE SITES FOR THE PUROPOSE OF EVALUATING COMPLIANCE OF THE SONGS' MITIGATION PROJECTS

INTRODUCTION

Many of the performance standards used to assess compliance of the SONGS mitigation projects require various attributes of the restored wetland and artificial reef mitigation sites to be similar to those of nearby relatively undisturbed, natural reference sites. The method used for determining similarity between the mitigation and reference sites for these "relative performance standards" is to be specified in a work program developed by contract scientists working for the California Coastal Commission (Permit No. 6-81-330-A, Condition A.3.4). The SONGS permit provides two examples of statistical methods that might be used to determine similarity: (1) the range test (within the range of the means of the reference sites), and (2) the 95% confidence interval (CI) of the mean of the reference sites (Box 1)

Contract scientists working for the Commission used the range test and a confidence interval test (i.e. the 95% CI centered on the mean of the reference sites) to evaluate the performance of the different artificial reef designs tested during the experimental phase of the reef mitigation project (referred to as the Universe Approach and Sample Approach, respectively; Reed et al. 2005). However, use of such range and confidence interval tests for evaluating similarity in the context of SONGS permit compliance may be problematic due to some inherent limitations of these methods, as described below. In the following sections, we describe the conceptual basis of the range and confidence interval tests and discuss their pros and cons for determining similarity in the context of SONGS permit compliance. We conclude by introducing a new approach to determining similarity (the Hybrid Approach) that draws on the strengths of these two methods and minimizes their weaknesses.

Note that the permit requires the mitigation site to be "similar" to reference sites but does not address the issue of the performance variable values being above versus below the values at the reference sites. In the examples given in this document, we focus on mitigation values below the reference values for simplicity, but it is possible that a mitigation site would be judged dissimilar because the value of some attribute was higher than that at the reference sites.

METHODS FOR DETERMINING SIMILARITY

Although the permit mentions two possible approaches that could be used to assess similarity, there are other possibilities. There is a well developed literature concerning methods for assessing similarity of ecological communities. For example, similarity could be assessed using multivariate statistical techniques (such as cluster analysis or non-metric multi-dimensional scaling; see Edwards and Proffitt 2003) or established indices such as the Jaccard Index of Similarity (Jaccard 1901). Most of these approaches focus on assessing the similarity of communities; they evaluate how similar the species identities and abundances are in two or more communities. Because the SONGS performance standards do not require similar communities *per se*, these types of methods are not appropriate for evaluating permit compliance of the SONGS mitigation projects. The most appropriate approaches for SONGS mitigation are based on the range of reference site values or some type of confidence interval around the mean of a reference value (Box 1), and these are discussed below.

Box 1. Confidence Intervals. For practical reasons populations are usually sampled rather than censused to obtain a measure of central tendency of the population such as the mean or median. Sampling error is typically associated with such sample statistics and the use of confidence intervals is a common way to account for such error. A confidence interval is a range of values that has a defined probability of including the sample statistic of interest (e.g. mean). For example, if the 95% confidence interval of the population mean is the interval between 25 and 75, then there is a 95% percent probability that the true population mean (not the sample mean) lies between 25 and 75. Another way to use confidence intervals is to define a range of acceptable values. This is the model used to assess compliance with mitigation standards that are derived from values from reference sites.

Although relatively few published studies address how mitigation sites should be judged relative to reference sites, all of the approaches discussed here have been used previously. For example, Craft et al. (2003) used the range of means of natural wetlands to judge the development of restored wetlands of different ages. Kentula et al. (1993) were early proponents of evaluating restoration success by using reference sites and assessed similarity to reference sites by comparing the mean at a mitigation site to confidence intervals calculated from data collected at *multiple* reference sites (an approach we call the Composite Confidence Interval [CCI]). In this case the restoration was judged to be successful if the mean value of the mitigation site was within the confidence interval of the reference sites. The basis for using such an approach is: (1) the reference sites are considered to be independent replicates of the natural condition, (2) measurements are made with error and, (3) use of the confidence interval based on reference sites as replicates ensures a realistic target for mitigation that accounted for measurement error. Evans and Short (2005) used a version of the CCI, although they evaluated similarity using standard deviations rather than a confidence interval. Proper use of the CCI requires that the confidence interval be calculated around the mean of the reference sites, with replication based on the number of reference sites. When reference sites are few and variable the use of the CCI for assessing similarity is ineffective because it produces undesirably large confidence intervals with the lower limit often close to or including zero. Because of this trait, the unit of replication sometimes has been based on sub samples within sites (e.g. transects) in cases where there have been few reference sites. Such improper use of the CCI makes the invalid assumption that the sub samples are independent of site[2]. The proper use of the CCI for evaluating similarity for the SONGS mitigation projects would result in undesirably large confidence intervals with little power to discriminate because only two or three reference sites are envisioned. For this reason the CCI is not considered a useful approach for determining similarity for the SONGS mitigation projects.

Similarity has also been assessed by comparing the mitigation site mean to the confidence interval calculated from data collected at a *single* reference site (Zedler and Callaway 1999, Burdick et al. 1997). This Separate Confidence Interval (SCI) test was also used by Ambrose et al. (2006) to evaluate similarity at five different mitigation sites, using two reference sites per mitigation site.

The Range test

Use of the Range test to determine similarity relies on comparing the mean values of a performance variable at the mitigation and reference sites. With the Range test, the mitigation site would be considered similar to the reference site for a given performance variable if the mean of the performance variable at the mitigation site were to fall between the means at the reference sites. For example, in Figure 3a the mean of the mitigation site is between the means of the reference sites in scenarios A through E, but not in scenarios F through H. In these hypothetical examples, the mitigation site would be judged to be similar to the reference sites in scenarios A through E and dissimilar in scenarios F through H.

The underlying assumption of the range test is that the selected reference sites represent the full range of suitable sites for evaluating the mitigation project; in other words, the selected reference sites represent the "universe" of possible reference sites. The Range test is one of the simplest and least ambiguous ways of determining similarity between the mitigation and reference sites.

A major limitation of the Range test is that it does not consider sampling and measurement errors within reference sites and thus could underestimate the true range of reference site means for a given variable.

Separate Confidence Interval (SCI) test

Use of the SCI test to determine similarity between the mitigation and reference sites involves calculating separate confidence intervals for each reference site using within-site sub samples as replicates. The range of values

[2] Transects were used as the unit of replication when applying the CCI to evaluate the suitability of different reef designs during the experimental phase of the SONGS reef mitigation program (Reed et al. 2005). This improper usage, however, had no consequences to the recommendations made regarding the suitability of designs for the mitigation reef because conclusions based on the range test and the CCI did not differ.

used to determine similarity for a given performance variable is set by the upper confidence limit of the reference site with the highest mean value for the performance variable and the lower confidence limit of the reference site with the lowest mean value for the performance variable. In essence it requires the mitigation site to perform at least as well (in a statistical sense) as the lowest performing reference site. For example, in Figure 3b (which uses the same set of scenarios as Figure 3a) the mitigation site would be judged similar to the reference sites for all scenarios but G. This result differs from the range test (Figure 3a) in that scenarios F and H would be judged similar by the SCI, but dissimilar by the Range test. Unlike the CCI, the SCI does not assume that all reference sites can be characterized by a single mean value for a given performance variable, nor does it allow the mean value of any reference site to fall outside the range of values used to assess similarity.

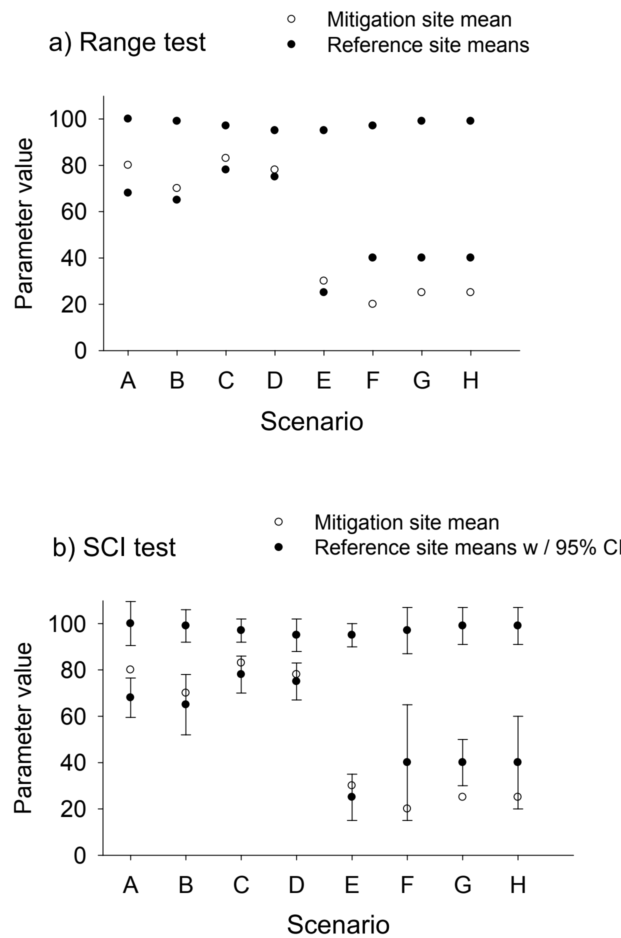


Figure 3. Hypothetical scenarios for determining similarity involving one mitigation and two reference sites using (a) the Range test and (b) the Separate Confidence Interval (SCI) test. The parameter values in (a) and (b) are the same for each scenario.

The issue of statistical power and within-site variability can be critical for decisions regarding similarity when the mean of the mitigation site falls outside the range of the means of the reference sites. For example, in scenarios G and H, the mean values for the reference and mitigation sites are identical, but the variability around the reference site with the lowest mean value differs (variability is greater in scenario H). Consequently the value of the performance variable for the mitigation reef would be judged to be similar to the reference sites for scenario G, but not for scenario H. Factors that increase the SCI of the reference sites, whether due to natural variability or sampling design, will make it easier for a mitigation site whose mean is outside the range of the reference site means to nonetheless be judged similar to the reference sites.

MULTIPLE PERFORMANCE STANDARDS

The examples described above have focused on assessing similarity for a single performance standard. The SONGS permit contains multiple performance standards for both the reef and the wetland mitigation projects, all of which must be met in order for the projects to be in compliance with the SONGS permit (see **I. ASSESSING COMPLIANCE FOR THE SONGS MITIGATION PROJECTS** above).

In evaluating multiple performance standards, consideration must be given to how the means of the mitigation site and reference sites vary due to chance alone. For example, imagine there are three reference sites, all of which are from the same population of sites. If we measure a number of different variables at these three sites, then we would expect that, on average, the mean of any given reference site would have the lowest value for one-third of the variables. We would expect a mitigation site that truly is similar to natural reference sites to have similar performance. It follows that if there were two reference sites and one mitigation site, then one would expect the mitigation site to have the lowest value for one third of the variables if it was similar to the reference sites[3]. Requiring that the value at the mitigation site be higher than any reference site for 100% of the variables would constitute a different and more severe threshold for the mitigation site than for the reference sites. Conversely, allowing a mitigation site to have the lowest value for more than one-third of the variables would likely not result in full compensation for the resources lost due to SONGS operations. Thus, relying solely on the SCI approach to evaluate similarity would be problematic because it would allow the mitigation site to have a lower mean value than all the reference sites for *every* performance variable and still be in compliance. This would not be consistent with the goals of the SONGS permit.

THE HYBRID APPROACH

Because neither the Range nor the SCI tests are satisfactory by themselves for determining similarity for the SONGS mitigation projects, we propose a hybrid approach that avoids the limitations of these tests. The Hybrid Approach requires that the value of the mitigation site be within the range of the SCI of the reference sites for all performance variables ***and*** that it not be the lowest more often than expected by chance alone.

To illustrate this approach, imagine a hypothetical scenario in which the success of a mitigation site is based on nine performance variables and two reference sites. Compliance using the Hybrid Approach would require: (1) the value of the means for all nine variables at the mitigation site be within the SCI of the two reference sites, and (2) that the mitigation site not have the lowest value for more than 1/3 of the variables (in this case, no more than 3 variables). Criterion 1 ensures that the values of all the performance variables at the mitigation site will be greater than that of the lower confidence limit of the mean of

[3] Generally, the probability of the value for a single performance variable being lower at the mitigation site than at any of the reference sites by chance alone will be 1/(x+1), where x is equal to the number of reference sites.

the reference site with the lowest value. Criterion 2 is based on the null hypothesis that the resource value of the mitigation site represents a sample from the same population as the reference sites and that the mitigation site behaves like the reference sites with respect to all the performance variables. If this is true, then in the example above it follows that each of the three sites (i.e., the mitigation site and the two reference sites) has an equal one-third chance of having the lowest value for any performance variable. This criterion eliminates the possibility of concluding that the mitigation site is in compliance when it has the lowest value for a large number of the performance variables. When applied together, the two criteria of the Hybrid Approach guarantee that the assessment of similarity is consistent with the SONGS permit requirement that **all** performance standards be met for the mitigation project to be in compliance without requiring the mitigation site to outperform all the reference sites for every performance variable.

THE IMPACT OF THE SCI ON SAMPLING DESIGN

The use of the SCI as the first criterion in the Hybrid Approach has dramatic and insightful implications for the sampling designs used to assess compliance which stem from the interplay among (1) the size of the confidence interval based on a defined significance level (Type I error = α), (2) the desired statistical power (1-Type II error = 1-β), (3) the percentage difference between the value of a performance variable at the mitigation site and the lowest performing reference site (effect size), and (4) sample size. Generally speaking, for a given sampling effort and target effect size, minimizing the Type I error (i.e., minimizing the chance of incorrectly concluding that the mitigation site is not similar to the reference site) tends to increase the Type II error (i.e., incorrectly concluding that the mitigation and reference sites are similar) and vice versa. Committing a Type I error when assessing similarity would be unfair to SCE because they would not be given credit for a successful mitigation project. On the other hand committing a Type II error would be a disservice to the public because lost resources would not be adequately compensated for. Increasing sample size (**n**) will reduce both types of errors, but comes with added monetary costs. Thus, in the interest of fairness to the public and the utility company it is desirable to strike a reasonable balance in setting α, β, and effect size when implementing the SCI to evaluate the success of the SONGS mitigation projects.

The conventional value used for α in the ecological literature is typically 0.05. However, given the variability inherent in natural wetland and reef ecosystems, it will likely be difficult to achieve an α = 0.05 without excessive sampling effort and/or reduced statistical power. A reasonable approach to balancing the risks of Type I and Type II errors in evaluating the SONGS performance standards is to set $\alpha = \beta$ (as recommended by Peterman 1990). Allowing $\boldsymbol{\beta}$ > 0.20 (i.e. power < 0.80) is unconventional (Cohen 1988), and would result in an unacceptably high probability of failing to detect a difference between the mitigation and reference site. Hence, we recommend setting both α and β equal to 0.20.

Although the SONGS permit does not specify an effect size for the purpose of determining similarity, its intent clearly is to fully replace coastal resources lost due to the operation of the power plant. Ideally, the mitigation project should have the same value as the reference site. In practice, there will be uncertainty about the true value at the mitigation and reference sites due to sampling error, and requiring the mitigation site to be identical to the value at the reference site would be unreasonable. In designing the monitoring program, we propose using the "effect size" to accommodate this uncertainty. Given this uncertainty, it seems reasonable to assume that a SONGS mitigation project estimated to yield less than 80% of the resource value of natural reference sites will not result in full compensation. Hence monitoring programs used to evaluate the performance standards should be designed to have the capability to detect a difference between the mitigation and reference sites of at least 20%. As per the recommendation of Mapstone (1995), effect size will be used as a criterion for developing the sampling designs used to evaluate the permit standards, not as an explicit criterion for determining permit compliance.

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Glossary

Confidence interval: The interval between the upper and lower confidence limits of the mean and specified by a percentage ranging from 0 to 100, which indicates the probability that the true mean lies within the confidence interval. A 95% confidence interval is often used.

Composite Confidence Interval (CCI): In the context of monitoring the performance of a mitigation project, the confidence interval centered on the mean calculated from data averaged across all reference sites.

Effect size: The difference between the values of two means. In the context of monitoring the performance of a mitigation site, the difference between the mean values of a performance variable at a reference and a mitigation site, often expressed as a percentage.

Hybrid Approach: A method for assessing similarity between the mitigation and reference sites that requires the mitigation site be within the range of the Separate Confidence Interval of the reference sites for all performance variables ***and*** that it not have the lowest value for the performance variables more often than expected by chance alone .

Performance Standards: Specific requirements in a permit that specify how a mitigation site should perform. Two different types of performance standards are included in the SONGS permit. *Fixed performance standards* require that performance be judged against a predetermined fixed value (e.g., "The total aerial extent of the mitigation reef (including the experimental reef and all larger artificial reefs) shall be no less than 150 acres."). *Relative performance standards* require that performance be judged relative to reference sites (e.g., "The resident fish assemblage shall have a total density and number of species similar to natural reefs within the region"). Compliance with relative performance standards is based on similarity to the reference sites.

Performance variable: The variable of interest used to assess a performance standard (e.g., the density of resident fish).

Power (1-β): The probability of correctly rejecting the alternative hypothesis. In the context of monitoring the performance of a mitigation project, the probability of correctly concluding that the value of a performance variable at the mitigation site differs from (i.e., is less than) the value at the reference site with the lowest value.

Separate Confidence Interval (SCI): In the context of monitoring the performance of a mitigation project, the confidence interval set by the upper confidence limit of the reference site with the highest mean value for a given performance variable and the lower confidence limit of the reference site with the lowest mean value for that performance variable

Type I error (α): Probability of incorrectly rejecting the null hypothesis. In the context of monitoring the performance of a mitigation project, the probability of incorrectly concluding that the value of a performance variable at the mitigation site is less than that of the reference site with the lowest value.

Type II error (β): Probability of incorrectly rejecting the alternative hypothesis. In the context of monitoring the performance of a mitigation project, the probability of incorrectly concluding that the value of a performance variable at the mitigation site does not differ from (i.e., is not less than) that of the reference site with the lowest value

APPENDIX 2

METHODS FOR ESTIMATING FISH REPRODUCTIVE RATES

General Methods

Fecundity of several species will be measured during their reproductive period. Six target species are currently being considered because they are among the most abundant fishes on the study reefs and they represent a range of feeding a reproductive modes (Table 2, Monitoring plan for SONGS Mitigation Reef), but other abundant species may also be used. Females of egg-laying species will be collected during their spawning season and females of live-bearing species will be collected just before parturition. Collections of the five egg-laying species currently under consideration would be made during summer (June to September); and the live bearer (black perch) would be collected during April. Specimens will be collected via hook and line, small-mesh gill nets, other nets and traps, and spear.

All common egg-laying species at the study sites 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 hours of spawning and are recognized by their relatively large size and translucent appearance.

A reasonable estimate of annual fecundity (F) for an individual female batch spawner is:

$$F = bs$$

Where b is the number of hydrated eggs in the ovaries on any given day during the spawning season, and s is the spawning frequency (i.e., the number of times that a female spawns during a given year).

Because spawning frequency is difficult to measure directly for any individual, we will estimate s as:

$$s = pt$$

where p is the average proportion of females with hydrated eggs on a given day, and t is the number of days in the spawning season.

Substituting *pt for s,* we will estimate the annual fecundity for an individual female batch spawner (F) as the product of three measured variables:

$$F = bpt$$

Live bearing fishes in California kelp forests reproduce no more than once a year. Their annual fecundity is simply the number of embryos produced per female per year. This number can be easily determined from females collected shortly before parturition. The proportion of females that reproduce each year is simply the proportion of pregnant females in the population of mature females.

Collection and Processing of Fish

I. Egg-Laying Species

Fish will be collected throughout the spawning season at several representative locations at each site. We will aim to capture at least 50 females with hydrated eggs in their ovaries from each site for each year sampled. In the field, the body cavity of each specimen will be opened and the sex and stage of development of the ovaries of females will be noted. Ovaries will be classified based on macroscopic examination as immature/inactive (no obvious oocytes); mature (obvious oocytes but none hydrated); and ripe (hydrated oocytes present). Specimens will be kept on ice until they can be processed in the laboratory (no more than 24 h).

In the laboratory, each fish will be weighed to the nearest 0.1 gram, and measured for total length, standard length, and body depth and girth (i.e., circumference) at the third dorsal spine. A digital photo of each fish will be taken side-on, with the fish on a gridded background, allowing additional morphometric measurements to be made later if deemed necessary. The morphological measurements will be used to investigate the feasibility of obtaining measurements that can be used as non-destructive predictors of fecundity. Sagittal otoliths will also be removed from each specimen for age and growth analysis needed for evaluating the performance standard 10 (Fish production). Ovaries from female fish will removed, blotted dry, weighed to the nearest 0.1 g. Ovary-free body weight will be determined by subtracting the ovary weight from the body weight. Ovaries will be preserved in 10% formalin for fecundity analysis in the laboratory.

Batch fecundity and spawning frequency will be estimated using hydrated eggs. It is usually impractical to count all of the hydrated ova within the ovaries of a female, so batch fecundity will be estimated as the product of the mean number of hydrated ova per gram of ovary and the total ovary weight. The preserved ovaries will be blotted dry and weighed to 0.01 g and then three subsamples will be removed and each weighed to 0.001 g. The number of hydrated ova in each subsample will be counted under a dissecting scope and the mean number of hydrated ova per gram of ovarian tissue will be determined from these three samples.

II. Live-Bearing Species

Livebearers will be collected from several representative locations at each reef just before parturition (e.g., mid to late April for black perch). Fish will either be processed in the laboratory within 24 h or frozen for later processing. In the laboratory, each fish will be weighed to the nearest 0.1 gram (g), and measured for body depth and girth at the third dorsal spine. A digital photo of each fish will be taken side-on, with the fish on a gridded background, allowing additional morphometric measurements to be made later if deemed necessary. Embryos will be removed from pregnant females, measured to the nearest mm standard length, blotted dry, and weighed to the nearest 0.01 g. Young-free body weight will be determined by subtracting the total weight for the young fish from the body weight. Sagittal otoliths will also be removed from each specimen for age and growth analysis for evaluating the performance standard 10 (Fish production).

APPENDIX 3

METHODS FOR ESTIMATING FISH PRODUCTION

This document describes the approach that will be 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 will be 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.

<u>Parameter estimation</u>

The equations above include several parameters that must be estimated. These will all be estimated with data collected from the three field sites.

N_{it} — The density of individuals in a size class during time t will be 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 will be 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 will be 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 will be 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 will be estimated as the product of the batch fecundity and the number reproductive bouts per year.

w_e — Egg weight will be estimated from the largest 20% of yolked (but not hydrated) eggs in a large, random selection of ovaries of each species. Egg weight will be 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 will be calculated for each size class from samples collected for the reproduction standard. Only mature, reproductively active fish will be used in estimating this ratio; and only females with mature but non-hydrated eggs will be used.