2011

Annual Report of the Status of Condition C: Kelp Reef Mitigation

San Onofre Nuclear Generating Station (SONGS) Mitigation Program

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Annual Report of the Status of Condition C: Kelp Reef Mitigation

SAN ONOFRE NUCLEAR GENERATING STATION (SONGS) MITIGATION PROGRAM

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By Daniel Reed, Stephen Schroeter and Mark Page
Marine Science Institute, University of California Santa Barbara

Contributors

General Data Collection and Analyses

David Huang, Denise Weisman, Andrés Deza,
Elizabeth Hellmers, Lindsey Hesla and Matthew Silbert,
Marine Science Institute, University of California Santa Barbara

Data Collection and Analyses of Fish Growth and Reproduction

Mark Steele and Mia Adreani,
Department of Biology, California State University Northridge

Science Advisory Panel

Richard Ambrose, University of California Los Angeles
Peter Raimondi, University of California Santa Cruz
Russell Schmitt, University of California Santa Barbara

Project Administration

Jody Loeffler

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1.0 Executive Summary

Condition C of the San Onofre Nuclear Generating Station's (SONGS) coastal development permit requires Southern California Edison (SCE) and its partners to construct an artificial reef that creates a minimum of 150 acres of functioning and sustainable kelp forest habitat as partial mitigation for the adverse impacts of SONGS operations to the San Onofre kelp forest. The artificial reef (named the Wheeler North Reef) was constructed in two phases: an initial small-scale experimental phase used to test different reef designs and a larger mitigation phase used to meet the mitigation requirement of creating 150 acres of kelp forest habitat. The success of the Wheeler North Reef in meeting the mitigation requirement for a given year is based on its ability to meet all 14 performance standards. Annual monitoring is done to determine whether the Wheeler North Reef has met these standards. The monitoring is overseen by the California Coastal Commission (CCC) and is done independently of SCE.

The Wheeler North Reef met 10 of the 14 performance standards in 2010 compared to 9 of the standards in 2009 and 2011. Of the five performance standards that were not met in 2011, two pertain to the kelp bed fishes, two pertain to the benthic community of algae and invertebrates, and one pertains to the interaction of kelp bed fishes with the benthic community. Of these five standards, those pertaining to fish standing stock, and the percent cover and number of species of algae and invertebrates have yet to be met. Furthermore, there is no indication from the monitoring results obtained to date that the Wheeler North Reef is on a trajectory to meet these three standards any time soon. The other two performance standards that were not met in 2011, fish reproductive rates and benthic food chain support for fishes, were met in 2009 and 2010, indicating that the performance of the Wheeler North Reef regressed with respect to these two performance criteria in 2011.

Results from analyses of monitoring data (including those that are continuing to be collected at the Phase 1 experimental reef) indicate the lower percent cover of rock at Wheeler North Reef relative to that at the two reference reefs and the dense surface canopy of giant kelp are contributing factors to Wheeler North Reef's inability to meet several of the performance standards. Additional monitoring data and analyses planned for 2012 will provide valuable information on the causes for the observed lower performance of the Wheeler North Reef with respect to specific performance standards.

Despite these deficiencies in performance, the Wheeler North Reef has shown considerable promise in meeting many of its objectives. For example, it has consistently met 7 of the 14 performance standards in each of three years of monitoring. Moreover, the performance standard for mobile invertebrate density, which had not been met in 2009 or 2010, was met in 2011. The steady increase in the density of mobile invertebrates on Wheeler North Reef over time suggests that it is on a successful trajectory with respect to this standard. Similarly, the performance standard pertaining to the area of adult giant kelp, which was met in 2010, but not 2009, continued to be met in 2011. Impressively, 174 of Wheeler North Reef's 176 acres were estimated to support medium to high densities of adult giant kelp in both 2010 and 2011. This indicates the Wheeler North Reef currently is meeting the objective of compensating for the loss of giant kelp caused by SONGS operations. Importantly, there was no evidence that the invasive sea fan *Muricea* spp. or other undesirable species were adversely affecting the important functions of Wheeler North Reef, which has been the case for other artificial reefs.

2.0 Introduction

2.1 Purpose of Report

This report focuses on Condition C of the San Onofre Nuclear Generating Station's (SONGS) coastal development permit (6-81-330-A), which pertains to mitigation for SONGS impacts to giant kelp and associated biota. Southern California Edison (SCE) and the California Coastal Commission (CCC) have clear and distinct roles in the implementation of Condition C. Under the condition, SCE is required to construct an artificial reef that creates a minimum of 150 acres of functioning and sustainable kelp forest habitat. The CCC is to provide scientific oversight and monitoring of the artificial reef mitigation that is independent of SCE. This report presents the results from the CCC's monitoring of the performance of the SONGS artificial reef (hereafter referred to as the Wheeler North Reef) during 2009 – 2011 and summarizes the status of the project's compliance with Condition C of the SONGS permit.

2.2 Background

<u>SONGS Operations</u>

In 1974, the California Coastal Zone Conservation Commission issued a permit (No. 6-81-330-A, formerly 183-73) to SCE for Units 2 and 3 of the San Onofre Nuclear Generating Station (SONGS). SONGS is located on the coast in north San Diego County. Construction of SONGS Units 2 and 3 was completed in 1981. Operation of Units 2 and 3 began in 1983 and 1984, respectively and each unit generates up to 1,100 MW of electric power. The SONGS Unit 2 and 3 reactors are cooled by a single pass seawater system and have separate intake lines, each 18 feet in diameter, that are located in about 30 feet of water offshore of the power plant. The volume of water taken in each day by these two intake lines when Units 2 and 3 are fully operational is about 4 billion gallons, equivalent to a square mile 12 feet deep.

The discharge pipe for Unit 2 terminates 8,500 feet offshore, while the discharge pipe for Unit 3 terminates 6,150 feet offshore. The last 2,500 feet of the discharge pipes for Units 2 and 3 consist of a multi-port diffuser that rapidly mixes the cooling water with the surrounding water. The diffusers for each Unit contain 63 discharge ports angled offshore that increase the velocity of the discharge. Under normal operations the discharge water is approximately 19°F warmer than the intake water temperature. To cool the discharge water, the diffusers draw in ambient seawater at a rate about ten times the discharge flow and mix it with the discharge water. The surrounding water is swept up along with sediments and organisms and transported offshore at various distances. Mixing caused by the diffuser system results in the formation of a turbid plume in the vicinity of the San Onofre kelp forest, which is located adjacent to the two diffuser lines.

<u>SONGS Impacts</u>

A condition of the SONGS permit required study of the impacts of the operation of Units 2 and 3 on the marine environment offshore from San Onofre and mitigation of any adverse impacts. The impact assessment studies found that the SONGS cooling water system for Units 2 and 3 had major adverse impacts to living marine resources, which included:

- Projected reductions in populations of adult fish throughout the Southern California Bight based on losses of fish eggs and immature fish entrained by the cooling water intakes and killed inside the power plant.
- Measured reductions in local populations of adult fished caused by the mortality of fish impinged against the cooling water screens inside the power plant.
- A substantial reduction in the size of the giant kelp forest and its associated community adjacent to the SONGS diffusers.

Mitigation Requirements

As a result of the impact studies, in 1991 the CCC added new conditions to mitigate the adverse impacts of the power plant on the marine environment that require SCE and its partners to: (1) create or substantially restore at least 150 acres of southern California wetlands as out-of-kind mitigation for the losses of immature fish (Condition A), (2) install fish barrier devices at the power plant to reduce the losses of adult fish killed in the plant (Condition B), and (3) construct a 300-acre kelp reef as in-kind mitigation for the loss of giant kelp forest habitat (Conditions C). The 1991 conditions also required SCE to provide the funds necessary for CCC to contract marine scientists to perform technical oversight and independent monitoring of the mitigation projects (Condition D). In 1993, the CCC added a requirement for SCE to partially fund construction of an experimental white sea bass hatchery. Due to the experimental nature of the hatchery, the CCC did not assign mitigation credit to its operation.

After extensive review of new kelp impact studies, in April 1997 the CCC approved amended conditions that revised the kelp mitigation requirements in Condition C. Specifically, the revised Condition C requires SCE to construct an artificial reef large enough to sustain 150 acres of medium to high density kelp bed community (which could result in a reef larger than 150 acres) together with funding for a mariculture/marine fish hatchery as compensation for the loss of 179 acres of a medium to high density kelp bed and associated community resulting from the operation of SONGS Units 2 and 3. Condition C requirements for the artificial reef consist of two phases, an initial small experimental reef (~22 acres) and a subsequent larger mitigation reef that meets the 150-acre requirement. The purpose of the Phase 1 Experimental Reef was to determine which combinations of substrate type and substrate coverage would most likely achieve the performance standards specified in the permit. The design of the Phase 2 Mitigation Reef was to be contingent on the results of the experimental reef.

The CCC also confirmed in April 1997 its previous finding that independent monitoring and technical oversight was required in Condition D to ensure full mitigation under the permit. Condition D requires SCE and its partners to fund scientific and support staff retained by the CCC to oversee the site assessments, project design and implementation, and monitoring activities for the mitigation projects. Scientific expertise is provided to the CCC by a small technical oversight team hired under contract. The technical oversight team members include three

Research Biologists from UC Santa Barbara: Steve Schroeter, Ph.D., marine ecologist, Mark Page, Ph.D., wetlands ecologist (half time), and Dan Reed, Ph.D., kelp forest ecologist (half-time). A half-time administrator completes the contract program staff. In addition, a science advisory panel advises the CCC on the design, implementation, monitoring, and remediation of the mitigation projects. Current science advisory panel members include Richard Ambrose, Ph.D., Professor, UCLA, Peter Raimondi, Ph.D., Professor, UC Santa Cruz, and Russell Schmitt, Ph.D., Professor, UC Santa Barbara. In addition to the science advisors, the contract program staff is aided by a team of field assistants hired under a contract with the University of California, Santa Barbara to collect and assemble the monitoring data. The contract program staff is also assisted on occasion by independent consultants and contractors when expertise for specific tasks is needed. The CCC's permanent staff also spends a portion of their time on this program, but their costs are paid by the CCC and are not included in the SONGS budget.

3.0 Project Description

Mitigation for SONGS impacts to the San Onofre kelp forest through the construction of an artificial reef is being done in two phases: a short-term, small-scale experimental phase for testing different reef designs, followed by a longer-term, larger-scale mitigation phase that is intended to compensate for the kelp forest resources lost due to SONGS operations. The information gained from the Phase 1 Experimental Reef was used to design the larger Phase 2 Mitigation Reef. The mitigation phase is to have a minimum duration equivalent to the operating life of SONGS Units 2 and 3.

The CCC decided that the goal of in-kind compensation for kelp forest resources lost due to SONGS operations will most likely be met if: (1) The artificial reef is built near SONGS, but outside its influence in order to ensure that the compensation for the lost resources will occur locally rather than at a distant location far from the impacts, and (2) The artificial reef is configured to mimic the natural reef at San Onofre, which is a low relief boulder field.

3.1 Experimental Phase

The Phase 1 Experimental Reef was constructed in August and September 1999 on a mostly sand bottom at 13 to 16 m depth approximately 1 km offshore of the city of San Clemente, CA, USA (Figure 3.1.1).

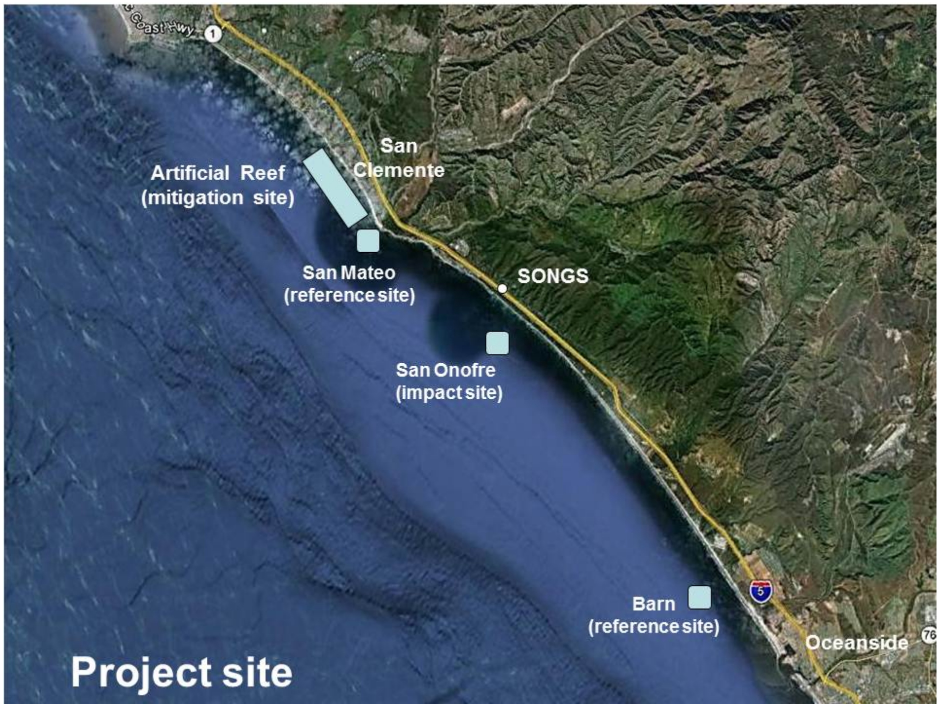

Figure 3.1.1. Location of the artificial reef mitigation site (shown as the blue rectangle) in relation to SONGS and the impacted San Onofre kelp forest and the naturally occurring kelp forests at San Mateo and Barn.

It consists of 56 modules clustered at seven locations (eight modules / location) spaced relatively evenly along 3.5 km of coastline encompassing an area of approximately 144 ha (Figure 3.1.2). Each artificial reef module was roughly 40m x 40m in area and the 56 modules collectively covered about nine hectares of the sea floor.

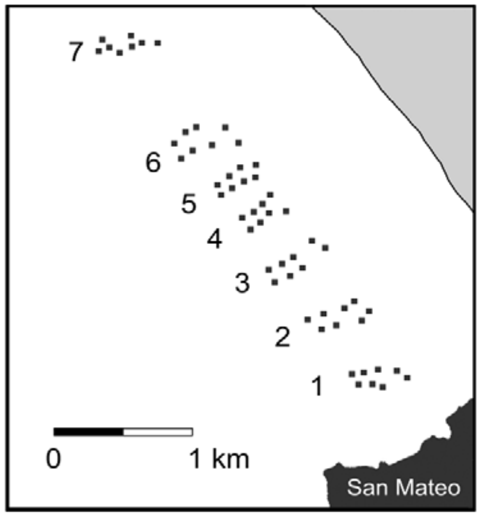

Figure 3.1.2. Design of the Phase 1 Experimental Reef. The black squares represent the 56 modules. Numbers indicate the 7 replicate sampling locations.

The modules at each location were built either from quarry rock or concrete rubble and were constructed to form low-lying reefs (i.e., < 1 m tall) that mimicked natural reefs in the region. These two types of materials were chosen because: (1) they are the two materials most preferred by the California Department of Fish and Game for building artificial reefs in California, and (2) little information existed on their relative effectiveness in supporting reef biota. Four modules at each location were built from quarry rock and four were built from concrete rubble. These two construction materials differed with respect to their size and shape; the quarry rock was boulder-like in appearance, while the concrete rubble consisted primarily of pieces of flat slabs that tended to be longer, wider, and slightly shorter than quarry rocks (Reed et al. 2004). The different sizes and shapes of the two materials caused rock and concrete modules to differ somewhat with respect to small-scale topography. The slabs used to build concrete modules resulted in modules that had a greater proportion of horizontal substrate and a surface that was slightly more regular than modules constructed from quarry rock (Reed et al. 2004). By design, the amount of quarry rock and concrete rubble used to build the modules was systematically varied to produce a wide range in the bottom coverage of hard substrate (~30 to 90%) on modules of the two reef types within each location. This was done to evaluate the extent to which the bottom coverage of reef substrate influenced the abundance and species richness of colonizing biota.

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

3.2 Mitigation Phase

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. Construction of Wheeler North Reef was completed in 94 days on September 11, 2008. Approximately 126,000 tons of boulder-sized quarry material was deposited in 18 polygons that collectively covered 152 acres of sea floor as determined from bathymetry using multibeam sonar (Figure 3.2.1).

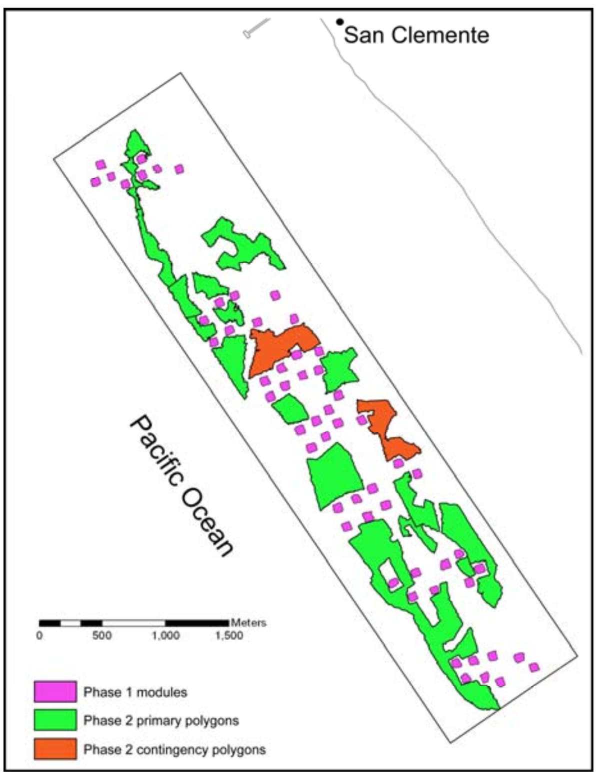

Figure 3.2.1. The 176 acre Wheeler North Artificial Reef, which includes the Phase 1 modules and the Phase 2 primary and contingency polygons.

Boulder length varied from 1 to 4 ft, with an average length of 2.3 ft; width varied from 0.5 to 3 ft, with an average width of 1.8 ft; and height varied from 0.5 to 2.5 ft, with an average of 1.4 ft. When added to the experimental reef a total of 176.81 acres of mitigation reef were constructed. The CCC 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 of the CCC 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) were combined with the 24.8 acres of the Phase 1 reef (as determined in 2009, Elwany et al. 2009) to fulfill SCE's permit requirement that they construct a minimum of 150 acres of reef with an average of at least 42% cover. The 21.7 acres in the remaining two polygons (hereafter referred to as contingency polygons) are included in evaluations assessing the biological performance standards that pertain to giant kelp and fish standing stock (see 6.0 Performance Assessment of the Wheeler North Reef).

4.0 Methods of Project Evaluation

4.1 Performance Standards

Performance standards for reef substrate, giant kelp, fish, and the benthic community of algae and invertebrates specified in Condition C are used to evaluate the success of the 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 is done in accordance with Condition D of the SONGS permit to: (1) determine whether the performance standards established for Condition C are met, (2) determine, if necessary, the reasons why any performance standard has not been met, and (3) develop recommendations for appropriate remedial measures. The performance standards fall into two categories: absolute standards, which require that the variable of interest attain or exceed a predetermined value, and relative standards, which require that the value of the variable of interest 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.

4.2 Reference Sites

Requiring resource values at Wheeler North Reef to be similar to those at natural reefs is based on the rationale that to be successful, Wheeler North 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 at a successful artificial reef should fluctuate in a manner similar to those at the natural reefs used for reference. One way to help ensure this is to select reference reefs that are physically similar to Wheeler North Reef and located close to it. 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 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 (Figure 3.1.1).

Temporal variability, especially of the sort associated with changes in oceanographic conditions, can be accounted for more easily by sampling Wheeler North Reef, San

Mateo and Barn concurrently. Concurrent monitoring of the mitigation and reference reefs helps to ensure that regional changes in oceanographic conditions affecting 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.

4.3 Determination of similarity

A requirement of the SONGS permit is that many of the response variables used to assess the relative performance standards of the Wheeler North Reef (hereafter referred to as "relative performance variables") be "similar" to those at nearby natural reference reefs. Evaluating whether the performance of Wheeler North Reef is similar to that at the San Mateo and Barn reference reefs requires that two conditions be met. The first condition requires that the mean (or median) value for a given relative performance variable at Wheeler North Reef not be significantly lower than the mean (or median) value at the lower of the two reference reefs. A one sample, one tailed approach is used to evaluate all such comparisons. Significance is determined using an approach that utilizes both a formal probability value and an effect size. Generally this is done by means of a t-test except in the case the performance standard pertaining to fish reproductive rates where significance is determined by a resampling procedure. The performance at Wheeler North Reef is considered to be worse than the lower of the two reference reefs if the p-value for the comparison ≤ the proportional effect size (i.e., the proportional difference between the Wheeler North Reef and the lowest performing reference reef). The only exception to this rule is when the p-value and the proportional effect size are both greater than 0.5 in which case assessment for the period is considered inconclusive and additional studies will be done. As an example, if the proportional effect size for a given variable was 0.25 (i.e., the mean value at Wheeler North Reef was 75% of the mean value at the lower of the two reference reefs), then a t-test yielding a p-value ≤ 0.25 would indicate the Wheeler North Reef did not meet the performance standard, whereas p-values > 0.25 would indicate that it did meet the performance standard. More details concerning the approach and rational for determining similarity are provided in the Monitoring Plan for the SONGS Reef Mitigation Project (Reed et al. 2012)

The rationale for using the mean value of the lower of the two reference reefs is that both reference reefs are considered to be acceptable measures of comparison for Wheeler North Reef. Hence if Wheeler North Reef is performing at least as well as one of the reference sites, then it should be judged successful. The scaling of the p-value (α) to the effect size recognizes sampling error when estimating mean values and balances the probability of falsely concluding that Wheeler North Reef is similar to the reference reefs when it is not with the probability of falsely concluding that the Wheeler North Reef is not similar to the reference reefs when it is.

The second condition pertaining to the determination of similarity requires that the Wheeler North Reef not have the lowest mean value for more performance variables than expected by chance alone. This condition ensures that to be successful the Wheeler North Reef must behave like the reference sites with respect to all the performance variables, eliminating the possibility of concluding that Wheeler North

Reef meets all the performance standards when it has the lowest mean value for a disproportionately large number of performance variables. A more detailed explanation of the definition of similarity used in the SONGS mitigation projects can be found in Appendix 1 of Reed et al. (2010).

4.4 General Sampling Design

Eighty two monitoring locations, each defined by a fixed 50m x 20m area, are sampled at Wheeler North Reef in the primary polygons, and at San Mateo and Barn in areas that are known to support persistent kelp (Figure 4.4.1). An additional 10 monitoring locations are sampled in the two contingency polygons at Wheeler North Reef.

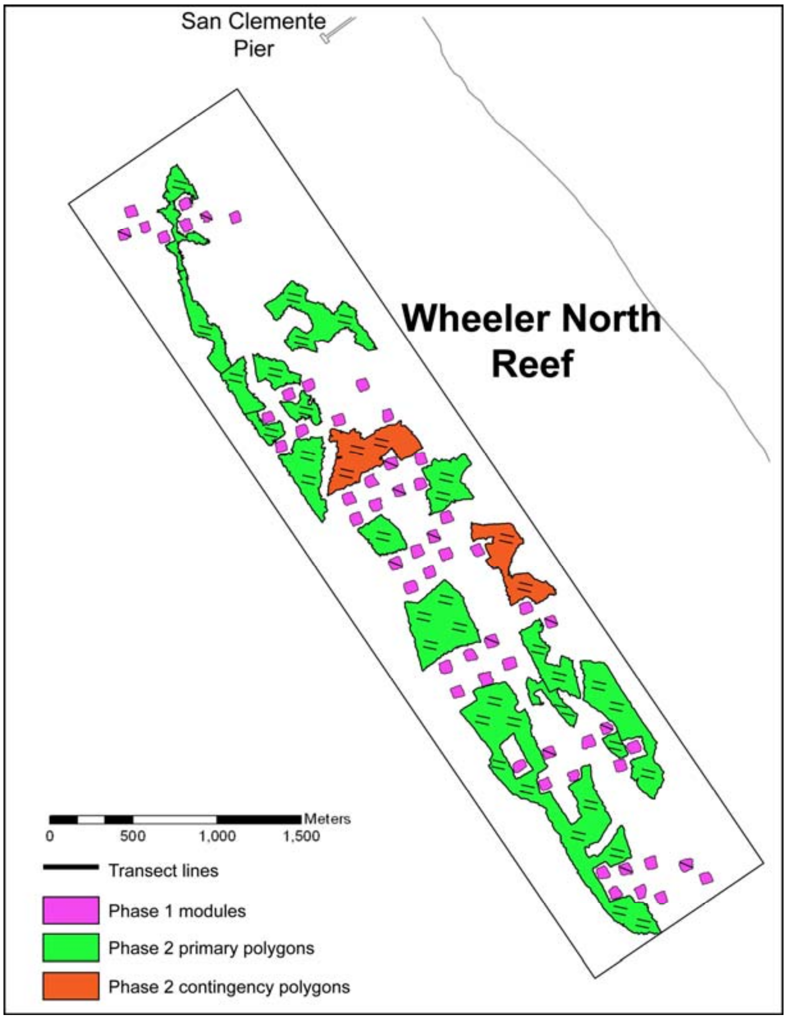

Figure 4.4.1. Schematic map of the Wheeler North Reef showing the location of the paired transects that are monitored to assess the performance standards.

Data collected from these additional 10 transects are used with data from the 82 transects when evaluating the performance standards pertaining to giant kelp and fish standing stock. Transects on each reef are arranged in pairs with the two transects in each pair spaced 25m apart. The lone exception to this are the single transects located on 12 of the Phase 1 modules of Wheeler North Reef. Pairing of transects is done to increase sampling efficiency. Maps of kelp persistence and hard substrate were used to strategically distribute the 41 transect pairs at San Mateo and Barn across areas of reef known to support giant kelp. Transects at Wheeler North Reef were allocated to the polygons and the existing experimental reef modules in proportion to their area.

Sampling of the Wheeler North Reef, San Mateo and Barn is done concurrently from late spring to early autumn on an annual basis. Each sampling area is identified by unique differential GPS coordinates that marks the "zero end" of a 50m transect and a compass heading along which divers lay out a 50m measuring tape. A 20m wide swath centered along the 50m transect defines the sample area at each sampling location. Different sized sampling units (e.g., 0.5m^2, 1m^2, 20m^2, and 100m^2) within this sampling area are used to evaluate different performance variables (Figure 4.4.2).

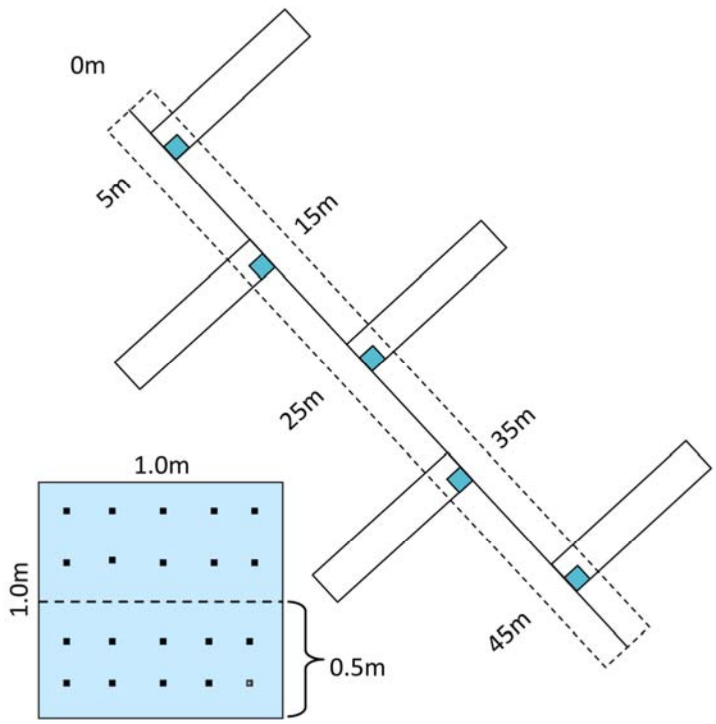

Figure 4.4.2. Schematic diagram of sampling station. Fish are sampled in 50m x 3m band transects that extend 1.5m off the bottom (outlined with a dotted line). Adult giant kelp > 1m tall, large understory algae, and large mobile invertebrates are counted in the five 10m x 2m rectangular quadrats positioned perpendicular to the main transect at 10 m intervals (outlined with solid lines). The percent cover of invertebrates, algae and substrate is estimated using a grid of 20 points in the five 1m x 1m quadrats (shown in blue). Smaller mobile invertebrates and small cryptic fish are counted either in 1m x 1m or 1m x 0.5m quadrats depending on their size and abundance.

5.0 Trends in the Development of the Wheeler North Reef

This section provides a brief summary on temporal patterns of change in the physical and biological attributes of the Wheeler North Reef and the two reference reefs, San Mateo and Barn for 2009 – 2011, which represents the 3-year period following the construction of the 152 acre Phase 2 Mitigation Reef.

5.1 Physical Characteristics

Exposed hard reef substrate is necessary for the establishment and persistence of giant kelp and other reef biota. Knowledge of its extent, type and persistence is essential to understanding how the Wheeler North Reef will function over the long term. In 2009, one year after construction, the percent of the sea floor covered by rock at Wheeler North Reef was about 45%, which was similar to that at Barn, but only about two thirds of that at San Mateo (Figure 5.1.1). The percent cover of rock on the bottom can decline as a result of sedimentation and burial, or increase due to scour caused by waves. The percent cover of rock increased by about 6 to 10% at San Mateo and Barn from 2009 to 2011, whereas it decreased by about 7% at Wheeler North Reef during this period.

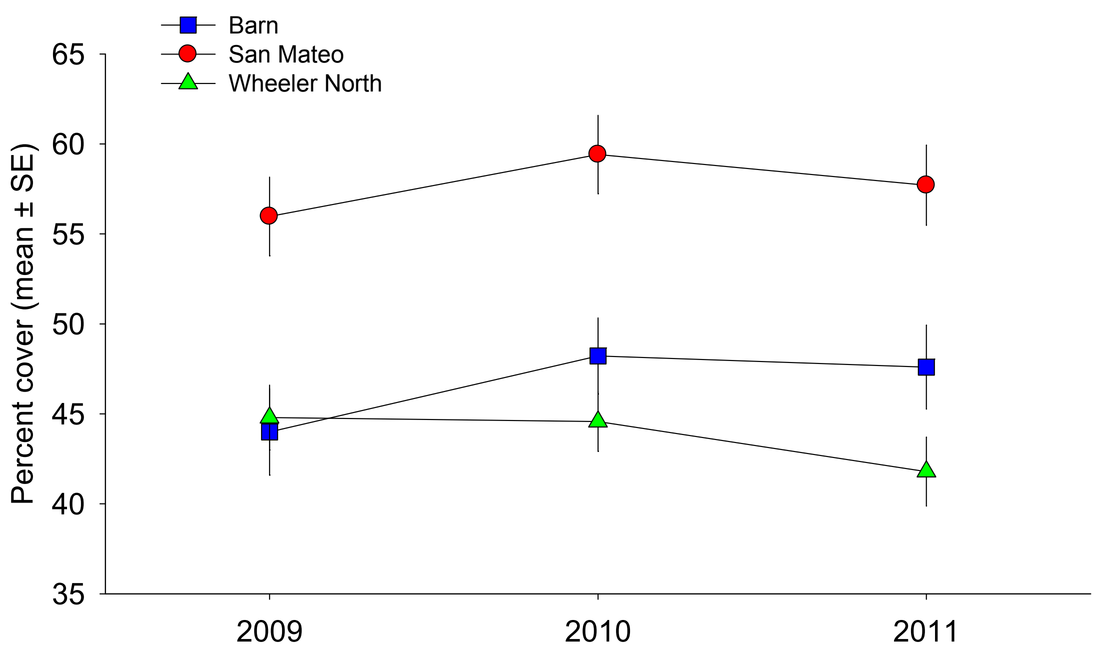

Figure 5.1.1. Mean percent cover (± 1 standard error) of exposed hard substrate at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

The three reefs also differed with respect to the relative amounts of the different types of substrates (Figure 5.1.2). Not surprisingly, the hard substrate at Wheeler North Reef is mostly boulder, which is what was intentionally produced at the quarries that supplied the rock for the construction of the reef. San Mateo is the most similar to Wheeler North Reef in that it has little bedrock and is mostly boulder and cobble, whereas most of the hard substrate at Barn is bedrock.

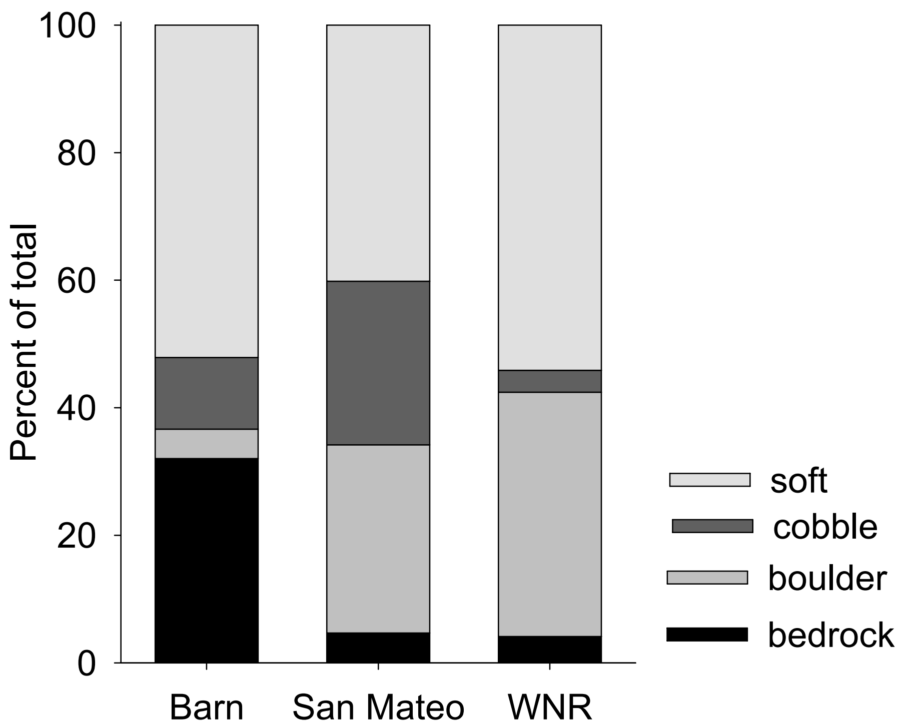

Figure 5.1.2. Distribution of substrate types on Wheeler North Reef (WNR), San Mateo and Barn for 2011.

5.2 Biological Characteristics

Giant kelp

The giant kelp, *Macrocystis pyrifera* is the world's largest alga and it displays some of the fastest elongation rates on Earth. Once established, small plants grow rapidly into large adult plants that extend throughout the water column to produce a floating canopy at the sea surface. It is considered the foundation species of the kelp forest because it provides food and shelter for a wide diversity of species. A primary goal in designing the Wheeler North Reef was to make it suitable for the establishment, growth, and persistence of giant kelp.

Results from the Phase 1 Experimental Reef indicated that giant kelp would readily colonize the newly constructed Phase 2 Mitigation Reef and that transplanting kelp would not be needed to insure it became established (Reed et al. 2006). This prediction proved to be true as very high densities of giant kelp recruits were observed at Wheeler North Reef in the summer of 2009, one year after construction (Figure 5.2.1). In contrast, there were very few kelp recruits on the natural reefs, which mostly likely reflected the presence of adult kelp inhibiting the establishment of young kelp due to shading by the adult canopy. The recruitment of giant kelp declined to near zero at Wheeler North Reef in 2010 and 2011. While kelp recruitment remained nil at San Mateo during 2009-2011, it showed an increase at Barn from near zero in 2009-2010 to 1.5 recruits / m^2 in 2011. A similar pattern of reduced recruitment in years following initial high rates of establishment by giant kelp was also observed during the development of the Phase 1 Experimental Reef (Reed et al. 2006). This pattern is a common occurrence in kelp forests generally as the canopy formed by large plants suppresses the development of small young plants by reducing the amount of light reaching the bottom.

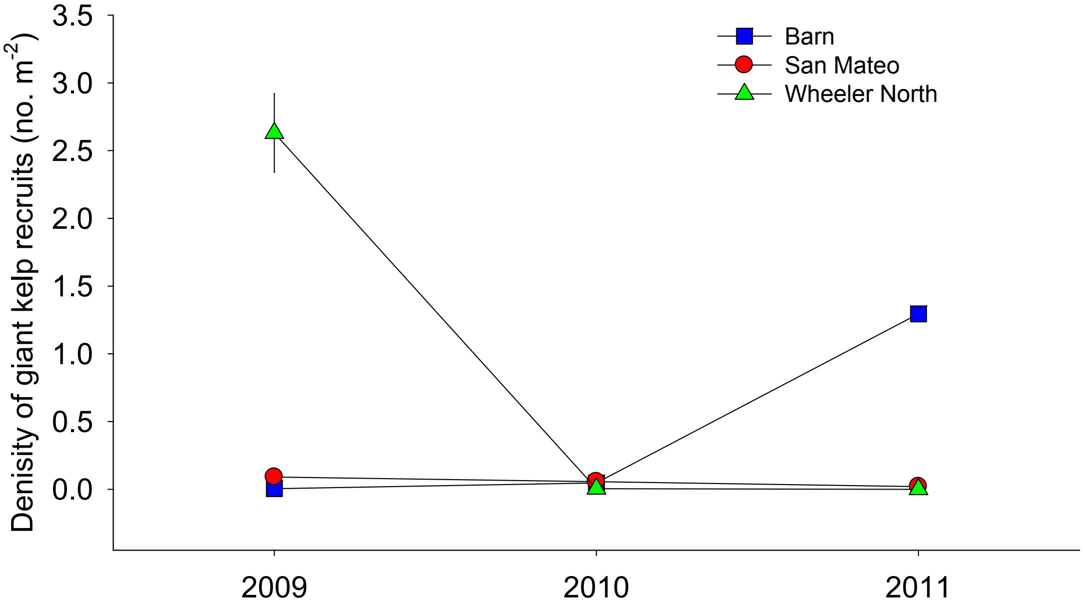

Figure 5.2.1. Mean density (± 1 standard error) of newly recruited giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

The dense recruitment of giant kelp observed in 2009 occurred across the entire Wheeler North Reef (Figure 5.2.2). All of the newly constructed polygons were colonized by giant kelp regardless of location. That kelp recruitment was lowest on the experimental modules where adult kelp was already established is further evidence of suppression of recruitment of young plants by an established surface canopy.

The large kelp recruitment event at Wheeler North Reef in 2009 led to a large cohort of older large plants in 2010, whose density was about 3 times that observed at San Mateo and Barn (Figure 5.2.3). Giant kelp densities declined on all three reefs in 2011, with proportionately greater declines at Barn (46%) compared to San Mateo (33%) and Wheeler North Reef (27%). Much like in 2010, high densities of large kelp (1.7 – 4 plants / 10 m^2) were present on all of the Phase 2 polygons as well as on the Phase 1 modules in 2011 (Figure 5.2.4). The canopy of giant kelp that developed at Wheeler North Reef during the summer of 2010 was extensive in comparison with the nearby kelp beds at San Mateo (reference reef) and San Onofre (the kelp bed impacted by SONGS), and was easily seen when viewed from space (Figure 5.2.5).

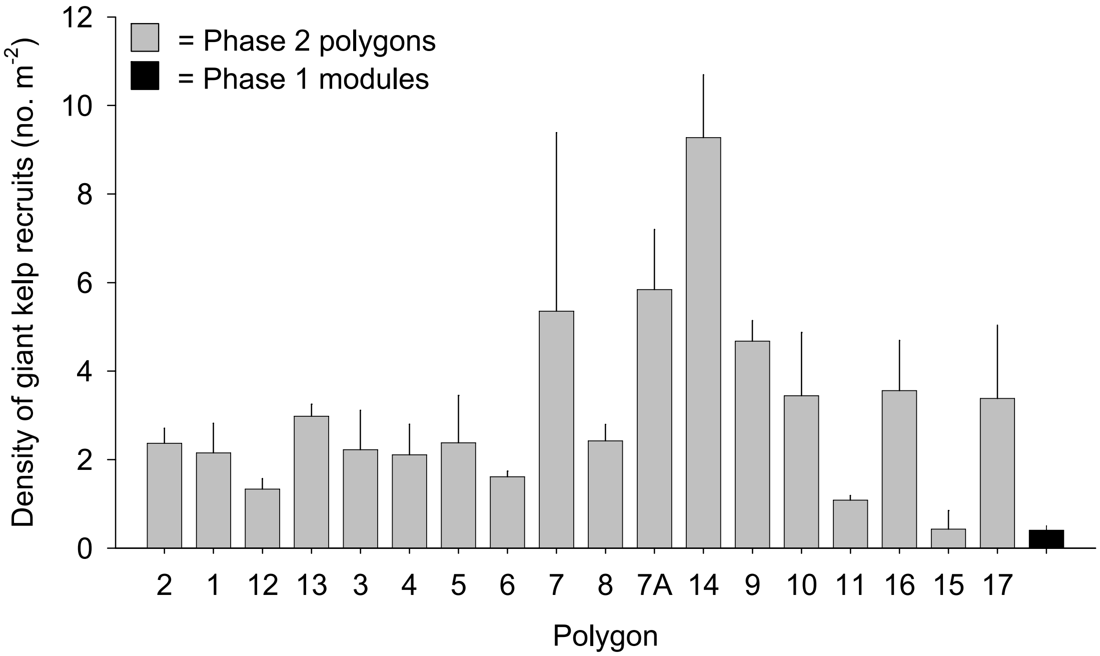

Figure 5.2.2. Mean density (± 1 standard error) of newly recruited giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef in 2009. Polygon numbers are ordered from south to north.

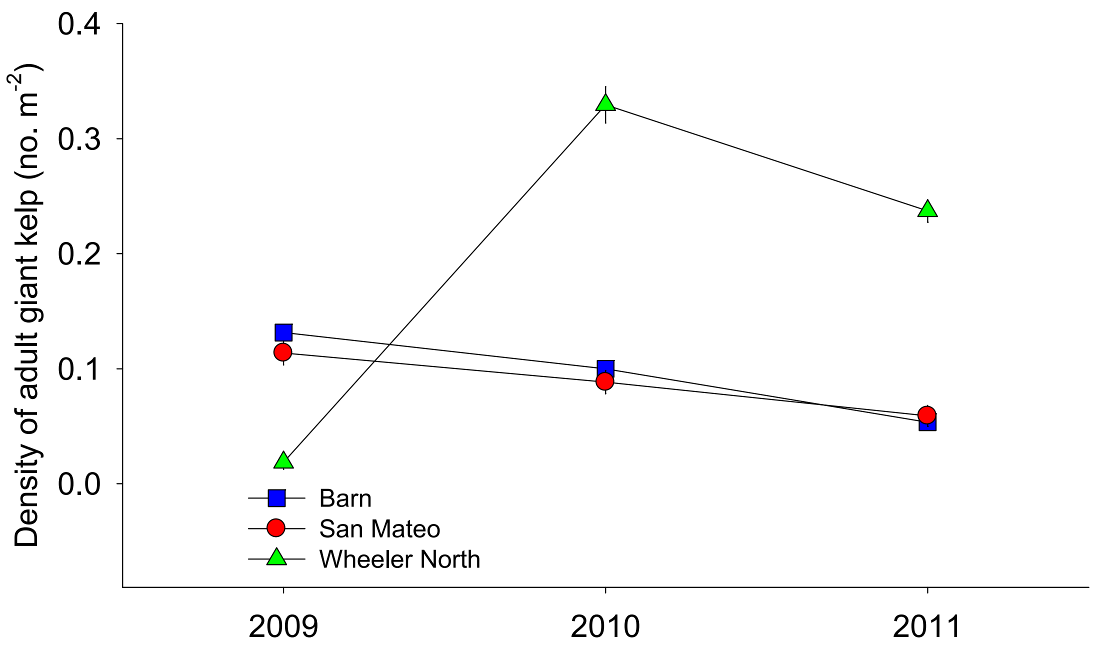

Figure 5.2.3. Mean density (± 1 standard error) of adult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

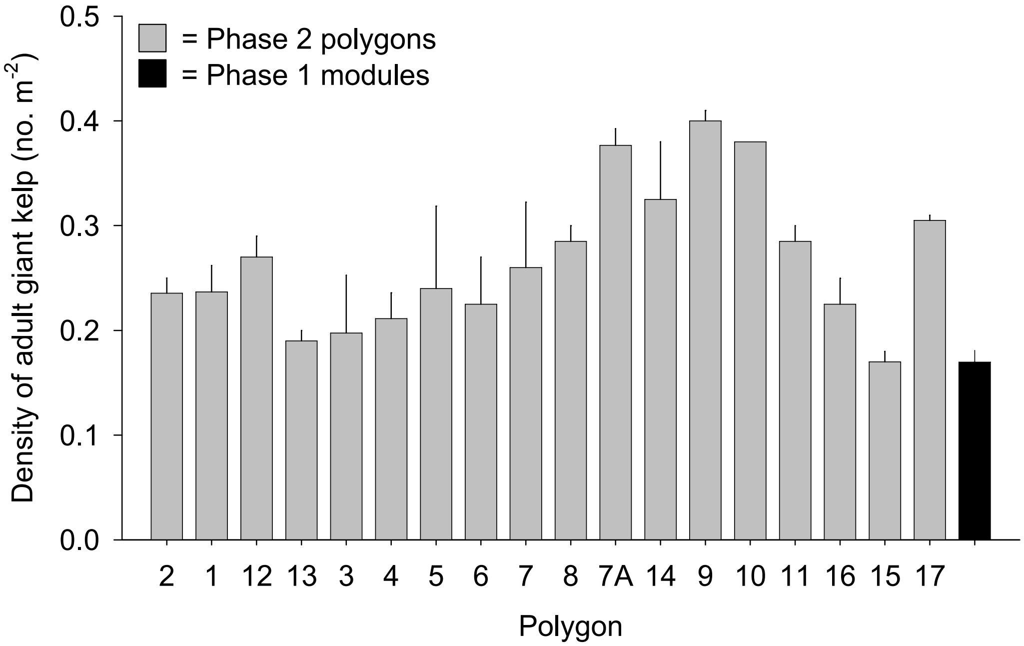

Figure 5.2.4. Mean density (± 1 standard error) of adult giant kelp plants (*Macrocystis pyrifera*) on the different polygons of Wheeler North Reef in 2011. Polygon numbers are ordered from south to north.

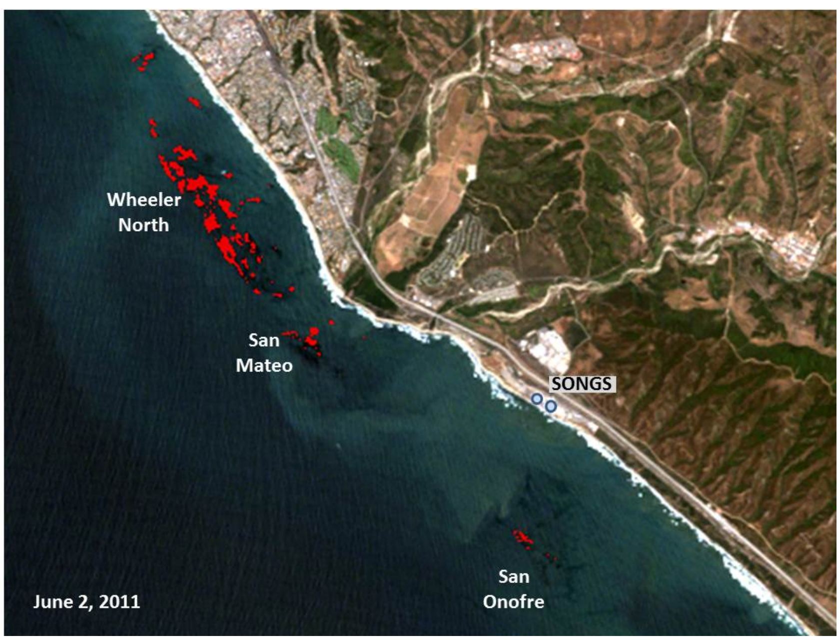

Figure 5.2.5. Wheeler North Reef, San Mateo and San Onofre kelp beds as seen from the Landsat 5 satellite in June 2011. The red in the image is a false color representation of the surface canopy of giant kelp. The image shows the large extent of giant kelp at Wheeler North Reef relative to San Mateo and San Onofre.

Giant kelp plants are made up of individual fronds that consist of a rope-like stipe to which blades are attached via a small gas-filled float. The number of fronds per plant is a good indication of a plant's size. As expected the average size of kelp plants has increased dramatically at Wheeler North Reef since 2009 as small plants grew into adults (Figure 5.2.6). By 2011, mean plant size at Wheeler North Reef was similar to that at San Mateo and Barn and averaged about 21 fronds per plant.

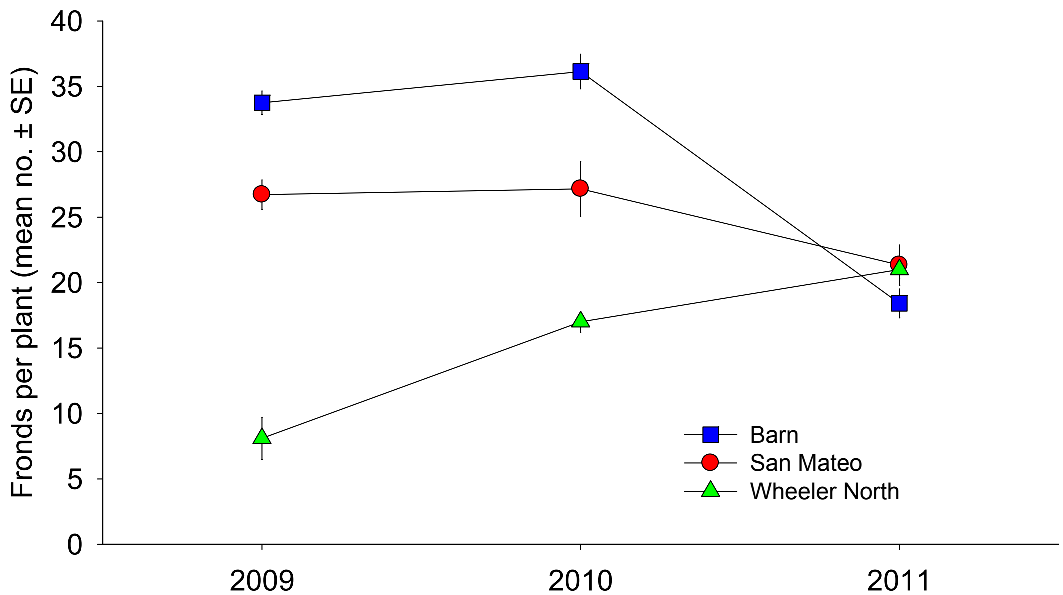

Figure 5.2.6. Mean number (± 1 standard error) of fronds per adult giant kelp plant at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

Because giant kelp plants can differ greatly in size from small recruits to large adults, the density of fronds tends to be a better predictor of the biomass density of giant kelp than the density of plants (Reed et al. 2009). The biomass of kelp as indicated by the density of fronds increased 6 fold at Wheeler North Reef from 2009 to 2010, whereas it showed about a 12% decline at San Mateo and Barn (Figure 5.2.7). Although kelp frond density declined at all three reefs in 2011, the declines were greater at San Mateo and Barn. In 2011, the average density of kelp fronds at Wheeler North Reef was more than four times higher than that at San Mateo and Barn.

<u>Benthos</u>

The benthic community on the shallow reefs off California typically include a diverse group of low-lying red, brown and green algae that occur on the bottom beneath the canopy of giant kelp (often referred to as understory algae) and a large number of sessile and mobile species of invertebrates. Like understory algae, sessile invertebrates attach themselves to the reef. Unlike algae that obtain their nutrition via photosynthesis, sessile invertebrates (which include organisms such as sponges, sea anemones, feather duster worms, bryozoans, rock scallops and sea squirts) feed by filtering plankton from the water column. The amount of the rock that becomes occupied by algae and sessile invertebrates increases over time during the normal development of a kelp forest community.

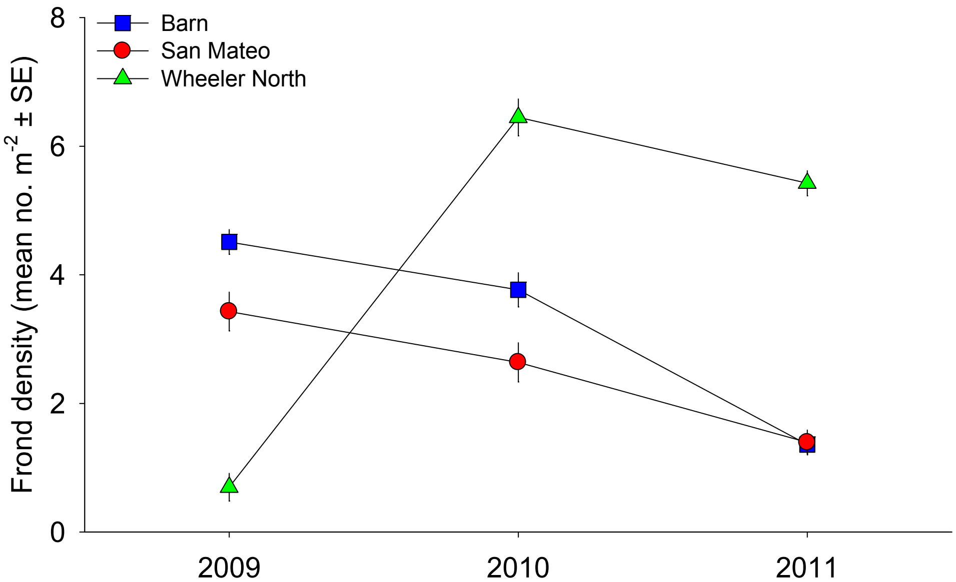

Figure 5.2.7. Mean density (± 1 standard error) of giant kelp fronds at Wheeler North Reef, San Mateo and Barn for 2009 - 2010.

Such has been the case at Wheeler North Reef which has shown a substantial increase in the percent cover of the benthic community since it was constructed in 2008 (Figure 5.2.8). By 2011, algae and sessile invertebrates covered on average 93% of the rock surface, which was very similar to that observed at San Mateo and

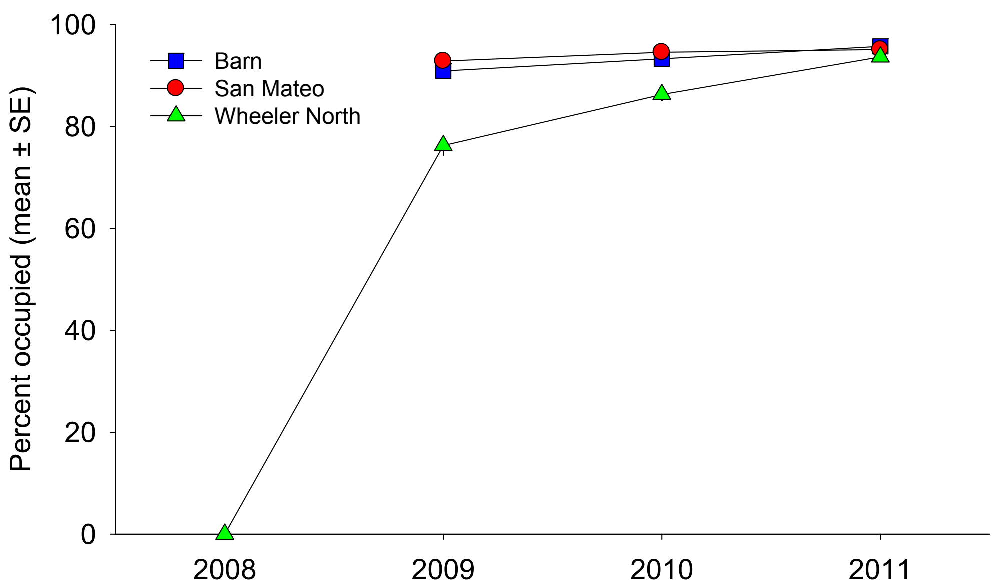

Figure 5.2.8. Mean percent (± 1 standard error) of hard substrate occupied by sessile reef biota (i.e. understory algae and sessile invertebrates) at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

Barn.

As occupiers of primary space, understory algae and sessile invertebrates compete for hard substrate on the bottom. Understory algae tend to be the stronger competitor except in low light environments where photosynthesis and growth are suppressed. Such is the case under a dense canopy of the giant kelp, which has a negative effect on understory algae by significantly reducing the amount of light reaching the bottom (Reed and Foster 1984). Experiments done at the Phase 1 Experimental Reef found that giant kelp had an indirect positive effect on sessile invertebrates due to its direct negative effect on understory algae (Arkema et al. 2009). These experiments demonstrated that the relative abundance of understory algae and sessile invertebrates on a reef is greatly affected by the presence of giant kelp. Understory algae are favored in the absence of giant kelp, while invertebrates are favored in the presence of giant kelp.

The percent cover of and number of species of algae at Wheeler North Reef declined 3-4 fold from 2009 to 2011. By contrast, algal percent cover and species number rose markedly at Barn during the same time period, and remained relatively unchanged at San Mateo (Figure 5.2.9).

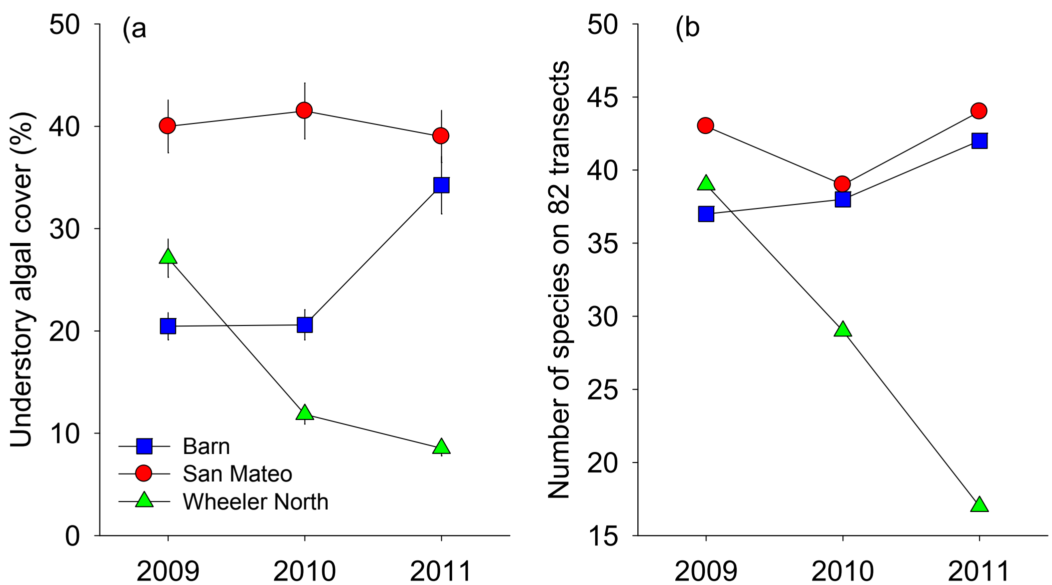

Figure 5.2.9. (a) Mean percent cover (± 1 standard error) and (b) total number of species of understory algae at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

This decline at Wheeler North Reef is to be expected given the dramatic increase in the abundance of adult giant kelp (and consequent shading) that has occurred since 2009. Additional analyses revealed that the decrease in understory algae at Wheeler North Reef resulted largely from a change in the species composition. Ephemeral filamentous brown and red algae are commonly some of the first species to colonize a reef and they were the most abundant algae at Wheeler North Reef in 2009. These short-lived species were replaced by perennial species in 2010. The holdfasts of giant kelp were the single most abundant species in terms of percent cover at Wheeler North Reef in 2010, followed by the small bladey red alga *Rhodymenia*. This pattern remained unchanged in 2011.

The abundance of sessile invertebrates at Wheeler North Reef showed a pattern opposite to that of understory algae; their percent cover more than doubled since 2009 reaching an average coverage in 2011 that was very similar to Barn and ~15% higher than San Mateo (Figure 5.2.10a). Interestingly the total number of species of sessile invertebrates observed in the 82 transects at Wheeler North Reef remained at 66 species from 2009 and 2010, before increasing sharply to 80 species in 2011, which was intermediate between that observed at Barn and San Mateo (Figure 5.2.10b). The mix of common species of sessile invertebrates at Wheeler North Reef has not changed dramatically since 2009, despite the sharp increase observed in their abundance. The sea squirt *Chelyosoma* has been the dominant sessile invertebrate species at Wheeler North Reef since 2009 accounting for 20-25% of the cover of all sessile invertebrate species. Other common taxa include the white sponge *Lucilla*, the red tube building worm *Salmacina* and the erect branching bryozoan *Crisia.*

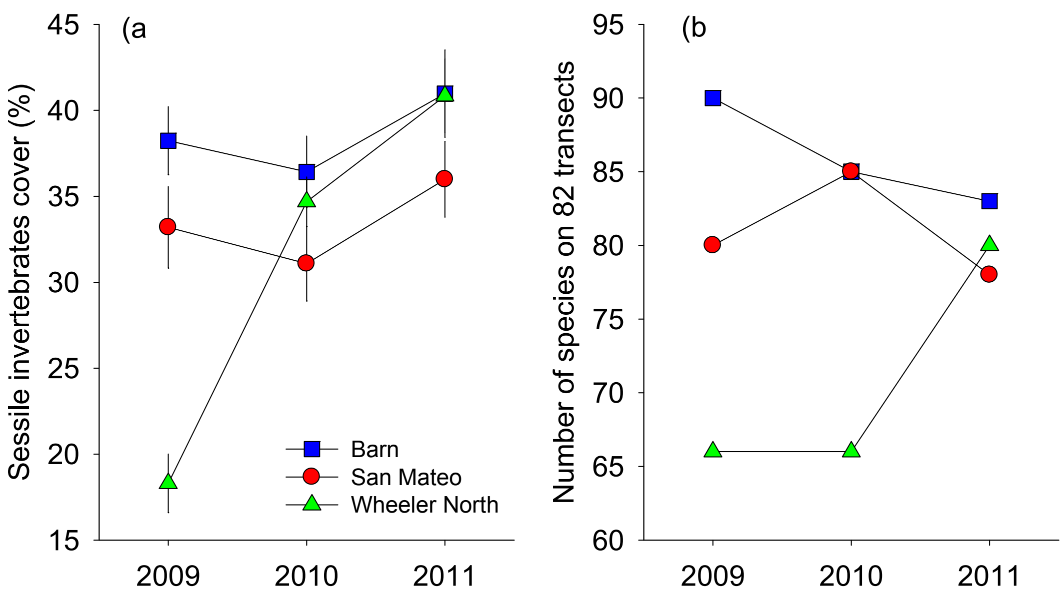

Figure 5.2.10. (a) Mean percent cover (± 1 standard error) and (b) total number of species of sessile invertebrates at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

A diverse array of mobile invertebrates are also common on kelp forest reefs including a variety of herbivorous and predatory snails, octopus, crabs, lobster, and many different kinds of brittle stars, sea stars and sea urchins. Like sessile invertebrates, the abundance of mobile invertebrates at Wheeler North Reef increased dramatically (~ 5 fold) since 2011 reaching densities in 2011 that were similar to those observed at San Mateo and Barn (Figure 5.2.11a). The total number of species of mobile invertebrates observed in the 82 transects at Wheeler North Reef has also steadily increased since 2009, however, it nonetheless remains 25-45% lower than that observed at Barn and San Mateo (Figure 5.2.11b). The five-fold increase in the density of mobile invertebrates at Wheeler North Reef resulted primarily from an increase in the density of the brittle star *Ophiothrix,* which has consistently accounted for ~ 85% of all mobile invertebrates since 2009. Larger, economically important species of mobile invertebrates such as lobster, warty sea cucumbers and sea urchins, while not as abundant as small brittle stars, are also commonly observed at Wheeler North Reef.

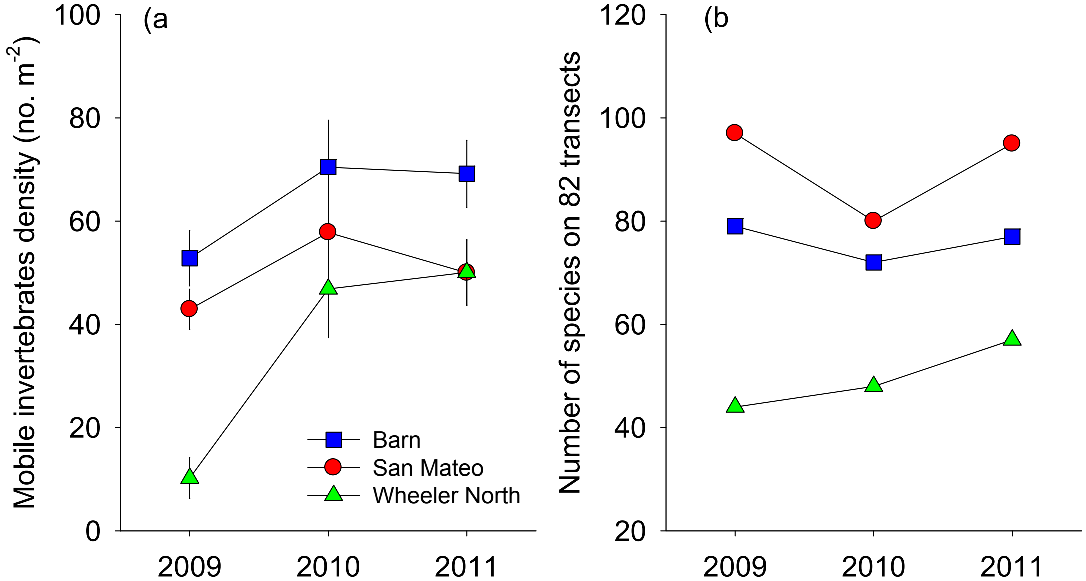

Figure 5.2.11. (a) Mean density (± 1 standard error) and (b) total number of species of mobile invertebrates at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

<u>Fish</u>

In the first year following construction, densities of reef fish near the bottom were 2-3 times higher at Wheeler North Reef than at San Mateo and Barn (Figure 5.2.12a). Large decreases in fish abundance were observed on all three reefs in 2010 with a proportionally larger decrease at Wheeler North Reef, resulting in similar densities of kelp bed fishes on all three reefs in 2010. Densities of fish increased in 2011, but much more so at Barn than at San Mateo and Wheeler North Reef. As a result fish density at Barn in 2011 was about twice that observed at San Mateo and Wheeler North Reef.

The species composition of reef fish at Wheeler North Reef has remained relatively constant despite the large fluctuations in density. The blackeye goby, a small fish that lives on the bottom and feeds on small crustaceans, has consistently been the most numerically abundant species at Wheeler North Reef since 2009 accounting for 60-80% of all fish observed. Other common taxa of reef fish observed include the blacksmith (a planktivore that feeds in the water column), barred sand bass and scorpionfish (predators that feed near the bottom on invertebrates and other fish), and señorita and black perch (pickers that feed on small invertebrates). Collectively these six species accounted for 85-96% of the fish observed at Wheeler North Reef. Large predatory species of fish that are valued both economically and ecologically were also commonly observed during surveys at Wheeler North Reef, but because of their large size and high trophic status were not numerically abundant. This includes the California halibut, California sheephead and kelp bass, which are important to commercial and recreational fisheries, and the giant sea bass, which is a protected species that can reach lengths of 5 feet and weigh over 500 pounds.

The large decline in fish density observed at all three reefs in 2010 was accompanied by a similarly large decline in the number of species of reef fish (Figure 5.2.12b). 2011 witnessed a return of species richness at Barn and Wheeler North Reef to levels that were similar to those observed in 2009, while fish species richness remained low at San Mateo. Thus even though the density of fish at Wheeler North Reef in 2011 was similar to that at San Mateo and half that at Barn, the number of species of reef fish observed at Wheeler North Reef was identical to that observed at Barn and 40% higher than that observed at San Mateo.

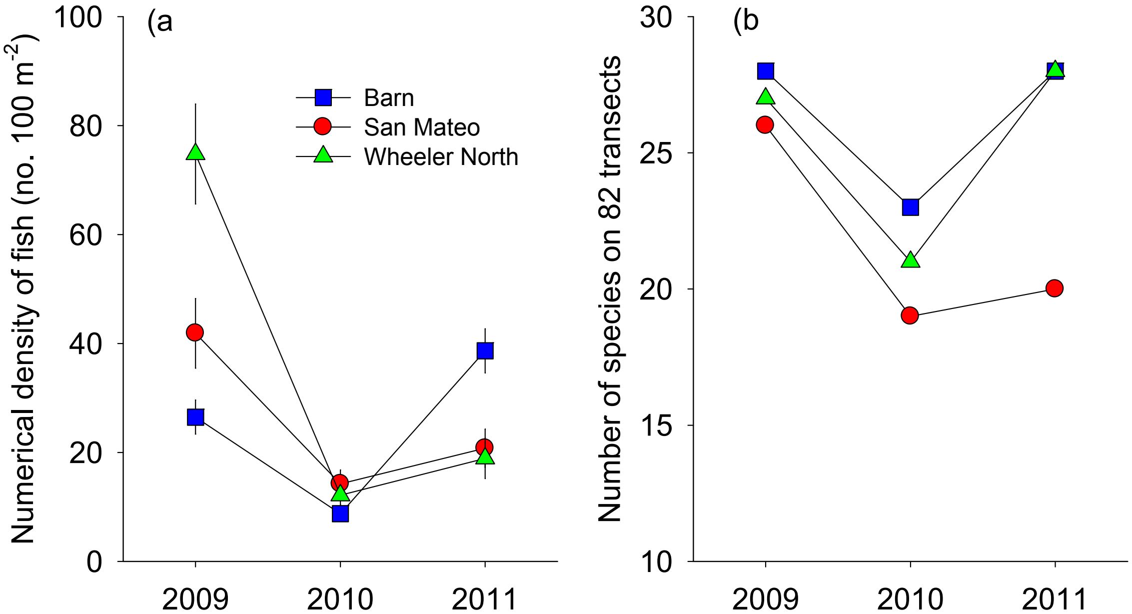

Figure 5.2.12. (a) Mean numerical density (± 1 standard error) and (b) total number of species of fish at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

Because different species of fish vary tremendously in size it is often desirable to have information on the amount of biomass of fish in a given area. This term is often referred to as biomass density to distinguish it from numerical density, which is the number per unit area. As observed for numerical density, the biomass density of fish declined at all three reefs in 2010, but did so at a lower rate than numerical density (55-60% for biomass density vs. 70-85% for numerical density; Figure 5.2.13). In contrast to numerical density, the biomass density of fish at Wheeler North Reef has been nearly identical to that at San Mateo, but considerably less than that at Barn for 2009-2011. The large increase in biomass density observed at Barn in 2011 compared to the relatively small increases observed at Wheeler North Reef and San Mateo matched the pattern seen for fish numerical density (Figure 5.2.12a)

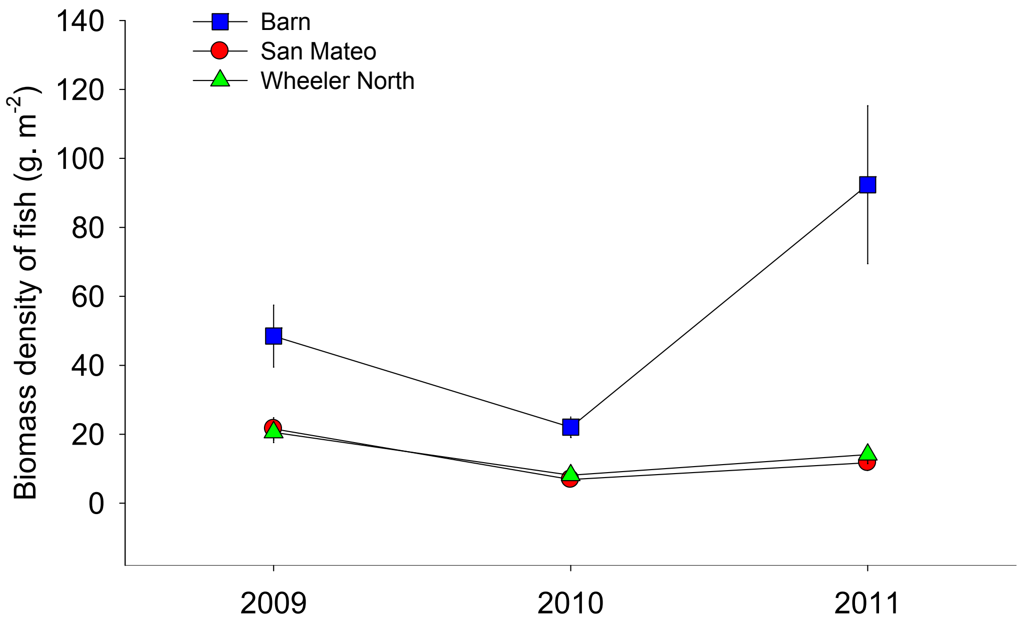

Figure 5.2.13. Mean biomass density (± 1 standard error) of fish at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

The relatively low biomass density at Wheeler North Reef in 2009 when the numerical density was extremely high can be explained by the fact that blackeye gobies, which were the most numerically abundant species, are relatively small (~ 3 grams in weight) and comprised a small proportion of the biomass (11 % in 2009). The most dominant reef fish species at Wheeler North Reef in 2011 in terms of biomass density were the scorpionfish, barred sand bass, California sheephead and kelp bass, which collective accounted for 80% of the reef fish biomass. The blackeye goby, while still the most numerically abundant species at Wheeler North Reef in 2011, accounted for only 3 % of the reef fish biomass.

6.0 Performance Assessment of Wheeler North Reef

Listed below are the 14 performance standards that are used to evaluate whether the Wheeler North Reef meets the goals and objectives of the reef mitigation set forth in Condition C of the SONGS coastal development permit. Below we describe the methodological approach used to evaluate each performance standard and the results from monitoring used to determine the performance of Wheeler North Reef relative to each standard. More detailed methods can be found in The Monitoring Plan for the SONGS Reef Mitigation Project (Reed et al. 2012).

1. AT LEAST 90 PERCENT OF THE EXPOSED HARD SUBSTRATE MUST REMAIN AVAILABLE FOR ATTACHMENT BY REEF BIOTA.

Approach: The percent cover of hard substrate is measured using a uniform grid of 20 points placed within the five $1m^2$ quadrats uniformly positioned along each of the 50m long transects in the primary polygons of Wheeler North Reef (Figure 4.4.2). Briefly, the observer sights an imaginary line through each of the points that is perpendicular to the bottom and records the substrate type intercepted by the line extending below the point. Substrates are 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. Only bedrock, boulders and cobbles are considered as exposed hard substrate when assessing this performance standard. Hard substrates covered with a thin layer of silt or sand are noted as being silted, but are nonetheless considered available for the attachment of reef biota for the purpose of evaluating this performance standard.

The total area of the exposed hard substrate (S) that is available for the attachment of reef biota during any given year t is determined as:

$S_t = A_t P_t,$

where A_t is the total area of the footprint of the Wheeler North Reef in year t (as determined by the most recent multibeam sonar survey) and P_t is the proportion of the Wheeler North Reef covered by hard substrate in year t. The proportion of area covered by hard substrate in the as-built condition in 2008 immediately after construction ($S_0 = A_0 P_0 =$) that is 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.

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

Results: There was a slight decrease in the footprint area in the year following construction (2009), which is not unexpected as rocks settle into the soft sandy bottom (Figure 6.1a). Because the footprint area of the reef is not expected to change much from year-to-year, multi-beam sonar surveys are only done once every five years. The last sonar survey was done in 2009. Thus the value for reef footprint area is assumed to be the same in 2010 and 2011 as it was in 2009. Unlike footprint area, the percent of the bottom covered by rock is measured every year by divers. There was a slight decrease in the percent cover of rock from 2008 to 2010, and a slightly larger decrease in 2011 (Figure 6.1b). The combined product of footprint area times percent cover of rock show that the Wheeler North Reef has met the standard for hard substrate in each of the three years since it was constructed (Figure 6.1c). Survey results show that the small declines in footprint area and percent cover of hard substrate that have occurred since the Wheeler North Reef was built have resulted in nearly a 10% decrease in the total area of hard substrate on Wheeler North Reef. Hence the 2011 estimate of reef substrate area is almost at the 90% value of the performance standard and will need to be monitored closely in future years.

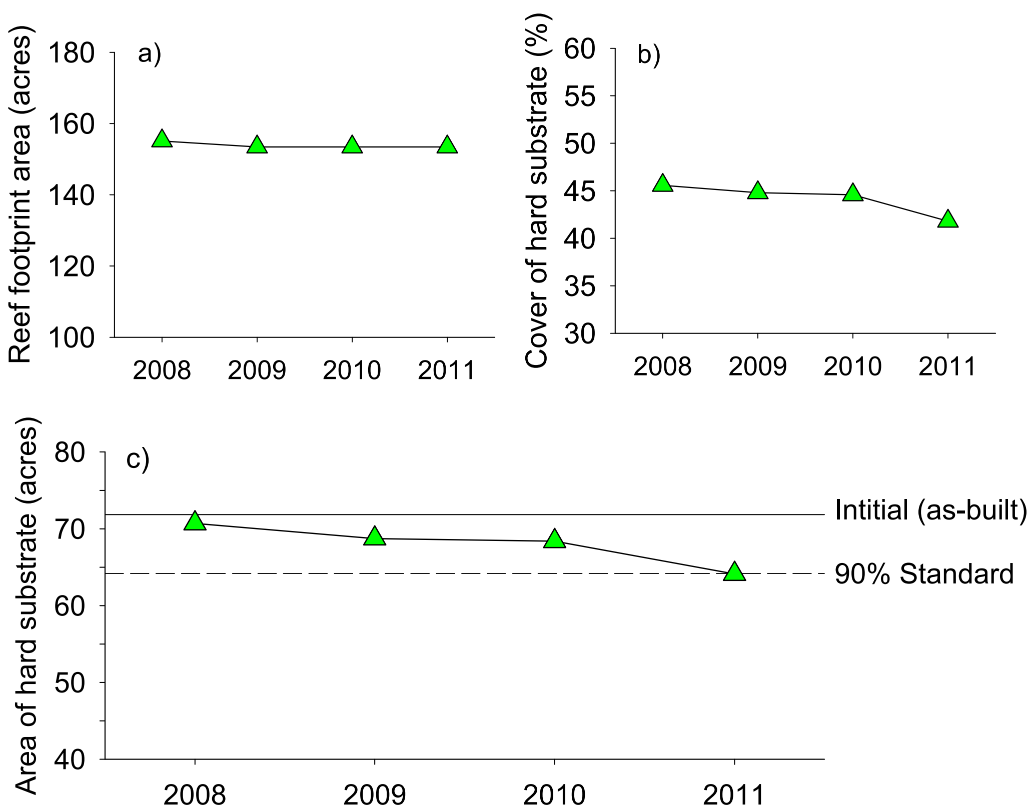

Figure 6.1. Variables used to calculate exposed hard substrate. (a) Reef footprint area, (b) Percent cover of hard substrate, and (c) Area of exposed hard substrate.

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

Approach: The abundance of giant kelp *Macrocystis pyrifera* is monitored by divers once per year in the summer in five replicate 10m x 2m plots arranged at 10m intervals along each of the replicate 50m transects at Wheeler North Reef (Figure 4.4.2). For the purpose of this performance standard, medium-to-high density giant kelp is defined as more than four adult plants per 100m2 of ocean bottom and adult giant kelp plants are defined as having eight or more fronds. The proportion of transects with a mean density ≥ 4 adult plants per 100m2 (based on the average of the five 10m x 2m plots in each transect) is used as an estimate of the proportional area of the artificial reef occupied by medium to high density giant kelp. The total area A_k of Wheeler North Reef occupied by medium to high density giant kelp in a given year is determined as:

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

Where A_r is the area of Wheeler North Reef based on the most recent sonar survey (in this case 2009), N_k = number of transects at Wheeler North Reef with ≥ 4 plants per 100m^2, and N_r is the total number of transects sampled at Wheeler North Reef (n=92). Unlike the standard for hard substrate, the data used to evaluate the performance standard for giant kelp are collected over the entire Wheeler North Reef (Phase 1 modules + Phase 2 primary polygons + Phase 2 contingency polygons). The reason for this is that the requirement for sustaining 150 acres of giant kelp is not tied to a specific coverage of hard substrate.

The value of A_k is calculated each year of the monitoring period and used to determine whether 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 have met 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 have met 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.

Results: The area of medium-to-high density adult kelp on Wheeler North Reef increased dramatically from 19 acres in 2009 to 173 acres in 2010 (Figure 6.2). This large increase represented the growth of the young kelp that colonized in 2009. The large area of high density kelp observed in 2010 was sustained in 2011. In both years 91 of the 92 transects sampled had at least 4 adult plants 100 per m^2. Thus the Wheeler North Reef met the performance standard for giant kelp in both 2010 and 2011, but not in 2009.

Figure 6.2. The number of acres of medium to high density adult giant kelp at Wheeler North Reef.

3. THE STANDING STOCK OF FISH AT THE MITIGATION REEF SHALL BE AT LEAST 28 TONS.

Approach: The standing stock of fish at Wheeler North Reef is estimated using data on total fish density, individual lengths, and relationships between fish length and fish mass. Data on fish density and length are recorded on the bottom along replicate fixed transects at Wheeler North Reef in late summer to autumn of each year. Divers count and estimate the total length (to the nearest cm) of each fish observed in a 3m wide x 1.5m high x 50m long volume centered above a measuring tape placed along the bottom of each replicate 50 m transect (Figure 4.4.2). For aggregating species such as the blacksmith (*Chromis punctipinnis*) and salema (*Xenistius californiensis*), the number and mean length of individuals in a group are estimated. Cryptic fishes such as the blackeye goby and the California scorpionfish (*Scorpaena guttata*) are recorded along the transect as divers return after completing the sampling of less cryptic fish. These data are augmented with data from additional surveys of fish lengths if more information is needed to accurately characterize the population size structure.

The concentration of bottom-dwelling fish estimated in replicate 50m x 3m x 1.5m transects at Wheeler North Reef is scaled up to the total area of the reef as determined by the most recent sonar survey. This scaled-up value is converted to biomass using data collected on individual length coupled with 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 biomass values are used to estimate the mean mass of all fish species per cubic meter near the bottom and multiplied by the total reef area (which in 2009 was 176 acres) to obtain an estimate of the mean standing stock of bottom-dwelling fish at Wheeler North Reef (this same approach was used by the impact assessment studies that determined that SONGS operations caused a 28 ton reduction in the standing stock of bottom-dwelling kelp bed fish). Much like the standard for giant kelp, the data used to evaluate the performance standard for fish biomass are collected over the entire Wheeler North Reef (Phase 1 modules + Phase 2 primary polygons + Phase 2 contingency polygons).

If for a given year the mean standing stock of bottom-dwelling fish at 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 Wheeler North Reef will be considered to have met this performance standard for that year.

Results: The Wheeler North Reef has been far below the fixed performance standard of 28 tons in all three years with the highest value reported for 2009 when standing stock was estimated at 13 tons (Figure 6.3). Thus the Wheeler North Reef has yet to meet the performance standard for fish standing stock.

Figure 6.3. Estimated standing stock of fish at Wheeler North Reef for 2009 - 2011.

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

Approach: Data on the density and lengths of resident fishes at San Mateo and Barn are collected using the same methods described above for estimating the standing stock of fish at Wheeler North Reef. Resident fish are defined as reef associated species > 1 year old (young-of-year fish are defined as reef associated species ≤ 1 year old). Data on fish length are used to classify each individual fish counted as a resident or young-of-year based on published size classes and/or expert knowledge. The total density of resident fishes at reef (Wheeler North Reef, San Mateo, and Barn) are calculated as the mean density of resident fishes on the bottom averaged over the 82 replicate 50m x 3m x 1.5m transects.

Results: Temporal trends in fish density resembled those observed for fish standing stock in that the highest values were observed in 2009, lowest in 2010 and intermediate values in 2011 (Figure 6.4). In 2009, 1 year after it was built, the density of fish on the Wheeler North Reef was 2 to 3 times greater than that of the reference reefs. The density of fish declined dramatically at all three reefs in 2010, such that densities were similar on all three reefs during this time. In 2011, the density of fish increased by 50-60% at Wheeler North Reef and San Mateo and by over 400% at Barn. While the mean density of fish at Wheeler North Reef fell below that of both reference reefs in 2011, it was not significantly lower than the value at the lowest performing reference reef San Mateo (p-value = 0.67 > proportional difference =0.12).

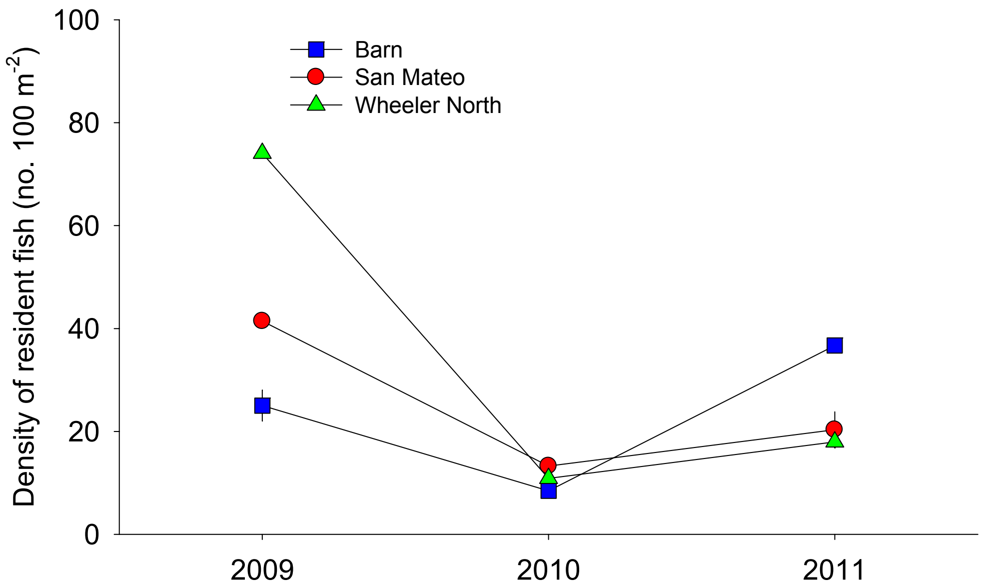

Figure 6.4. Mean density of resident kelp forest fishes within 1.5 m of the bottom at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value.

5. THE RESIDENT FISH ASSEMBLAGE SHALL HAVE A TOTAL NUMBER OF SPECIES SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Species richness (number of species) of resident fishes at Wheeler North Reef and reference reefs are assessed in the following manner. The species identification of each fish that is counted and sized in the 82 transects of each kelp bed fish is recorded. Sizes are used to distinguish between resident and young-of-year fishes. These data are used to fit a two parameter model relating the number of species encountered to the number of transects sampled (which is directly proportional to the area sampled). The first parameter of the model is the slope of the relationship, which represents the initial rate of increase in the number of new species counted with each new transect sampled. A larger value for the slope indicates a smaller area of reef is needed to accommodate all species; a higher average diversity of species per transect is typically associated with a larger slope. The second parameter of the model estimates the asymptote, which represents an estimate of the total number of species present on each reef (often referred to as the species pool). Resampling methods are used to estimate the variances in the initial slope and the asymptote required to perform t-tests of differences between values at the Wheeler North Reef and the reference reef with the lower value for each parameter. For the Wheeler North Reef to meet this performance standard, the mean values for the slope and asymptote parameters must not be significantly lower than the mean values for these parameters at the reference reef with the lower value (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

<u>Results:</u> Temporal patterns in the initial slopes in the species-area curves for resident fish varied among the three reefs (Figure 6.5a). The relatively high initial slopes observed at Barn varied greatly among years where the relatively low values of initial slope at San Mateo has shown a steady decline.

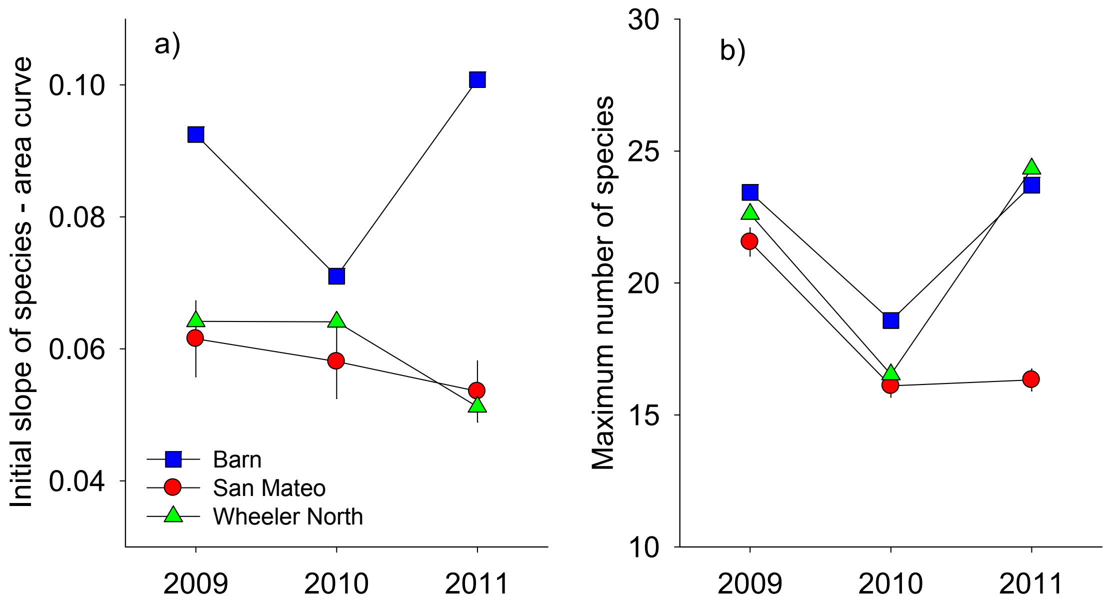

Figure 6.5. (a) Mean initial slope and (b) mean maximum number of species of the species-area curve for adult resident fishes at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value.

The initial slope at Wheeler North Reef has more closely followed that at San Mateo than that at Barn. The mean value of the initial slope of the species area curve at Wheeler North Reef was above that at San Mateo in 2009 and 2010. The mean value of the initial slope at Wheeler North Reef was lower than that of the two reference reefs in 2011, however, it was not significantly lower than that at San Mateo as judged by the t-test (p-value = 0.25 > proportional difference = 0.12). Thus the Wheeler North Reef has met this portion of the species number standard for resident fish in all three years. While the temporal pattern in the initial slope of the species area curve at Wheeler North Reef followed that at San Mateo, the temporal pattern in the maximum number of resident fish species has closely followed that at Barn, showing an ~20% decrease in 2010 and a 20% increase in 2011. The

Wheeler North Reef has been consistently within or above the range of the two reference reefs with respect to the maximum number of resident fish species. Thus the Wheeler North Reef has met the performance standard pertaining to the number of species of resident reef fish in all three years.

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

Approach: The rationale for the performance standard pertaining to fish reproductive rates is that for artificial reefs to be considered successful, fish must be able to successfully reproduce. Data on per capita egg production of a select group of targeted reef fish species collected throughout the spawning season (summer through fall) are used to determine whether fish reproductive rates at Wheeler North Reef are similar to those at San Mateo and Barn for similar sized individuals. The targeted species used to evaluate this performance standard are the California sheephead, señorita, and kelp bass. These species represent different feeding guilds of reef fishes in southern California and are sufficiently abundant to facilitate their collection with minimal impact to their local populations.

Data on per capita egg production (i.e., number of eggs in a clutch) and the proportion of individuals likely to have spawned within 24 hours (as determined by the hydrated status of the eggs) are collected monthly at Wheeler North Reef, San Mateo, and Barn during summer through fall and used to evaluate this standard. A resampling approach is used to statistically determine whether the Wheeler North Reef met this performance standard in a given year. This approach provides a method to estimate multivariate variance and a basis for the calculation of a p-value. Because larger individuals tend to produce more eggs, the production of eggs is scaled to body length and used to obtain a standardized measure of fecundity for each species at each reef. For each reef, a species-specific estimate of standardized fecundity is combined with a species- specific estimate of the proportion of individuals spawning to obtain a Fecundity Index that is averaged across all target species. In order for fish reproductive rates at Wheeler North Reef to considered similar to that at natural reference reefs the median value obtained from the resampled distribution of the Fecundity Index at Wheeler North Reef must not be significantly lower than that of the reference reef with the lowest Median Fecundity Index (i.e., the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: The value of the Median Fecundity Index was higher at Wheeler North Reef in 2009 and 2010 than at the two reference reefs and thus met the performance standard for fish reproductive rates in these years (Figure 6.6). This pattern changed markedly in 2011 when the Median Fecundity Index decreased by ~ 40% at Wheeler North Reef and increased by ~ 15% at San Mateo and Barn. As a result the Median Fecundity Index at Wheeler North Reef was significantly lower than that at Barn, the reference site with the lowest Median Fecundity Index (p-value < 0.001, which is less than the proportional difference between Wheeler North Reef and Barn = 0.384). Consequently, the Wheeler North Reef did not meet the performance standard for fish reproductive rates in 2011.

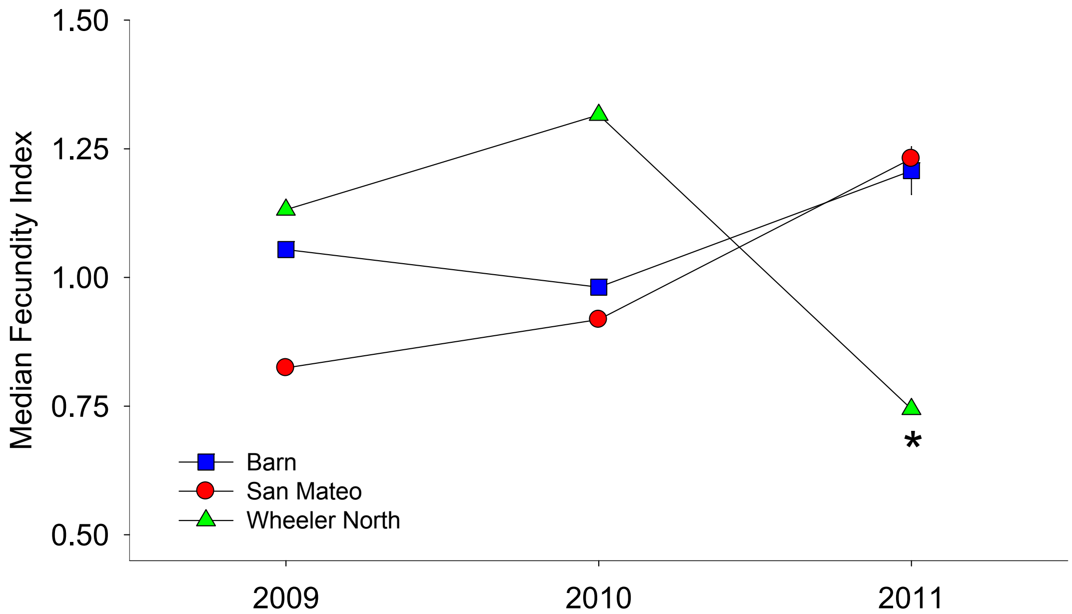

Figure 6.6. Median fecundity index averaged over three species of kelp forest fish at Wheeler North Reef, Barn and San Mateo for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest median value. * indicates median value of Wheeler North Reef is significantly lower than that of the reference reefs.

7. The total density of young-of-year fishes (individuals less than 1 year old) shall be similar to natural reefs within the region.

Approach: Giant kelp forests serve as nursery habitat for a variety of nearshore fishes and full compensation for the loss of kelp forest habitat caused by the operation of SONGS requires that the Wheeler North Reef provide this important ecological function at a level that is similar to that of natural reefs in the region. Data on the density of young-of-year fishes (defined as reef associated fish that were born in the year that they were sampled) at the Wheeler North Reef and reference reefs are collected using the same methods and at the same time as data for resident fishes. The approach used for determining whether the density of young-of-year fishes at Wheeler North Reef is similar to that on the reference reefs is the same as that used for resident fishes.

Results: Densities of young-of-year fish at Wheeler North Reef and San Mateo increased from 2009 to 2010 and decreased from 2010 to 2011, with Wheeler North Reef having higher densities of the two reefs in all three years (Figure 6.7). Temporal patterns in the density of young-of-year fish at Barn showed the exact opposite pattern of that observed at Wheeler North Reef and San Mateo; densities in 2010 were low compared to 2009 and 2011. While the temporal trends observed at Barn appear to be distinct from those observed at Wheeler North Reef and San Mateo, the actual densities of young-of-year fish observed were quite low on all three reefs, averaging about 1 individual per transect. Young-of-year fish can be relatively cryptic and often take shelter in the foliage of macroalgae including the midwater fronds and surface canopy of giant kelp. Logistical constraints and concerns for diver safety prevent thorough sampling throughout the water column and surface canopy. Thus the low densities of young-of-year fish reported at all three reefs reflect in part limitations of the sampling design. Because these limitations apply equally to the Wheeler North reef and the two reference reefs any differences observed among reefs are assumed to be real. Consequently, the data collected to date on young-of-year fish show that the Wheeler North Reef easily met this performance standard in all three years.

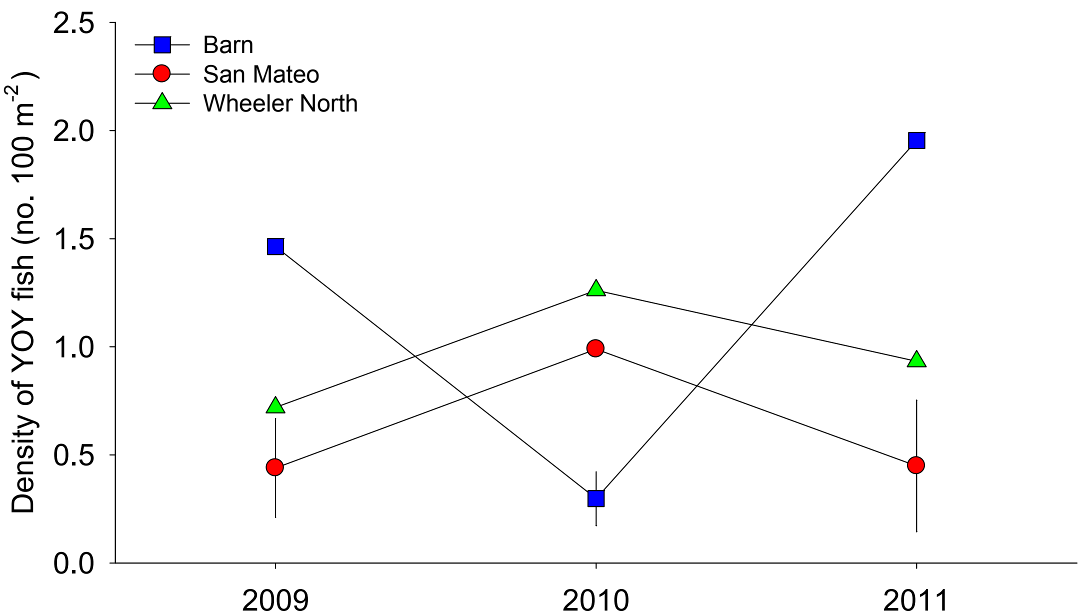

Figure 6.7. Mean density of young-of-year kelp forest fishes within 1.5 m of the bottom at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value.

8. THE TOTAL NUMBER OF SPECIES OF YOUNG-OF-YEAR FISHES (INDIVIDUALS LESS THAN 1 YEAR OLD) SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Data on the number of species of young-of-year fish at Wheeler North Reef and reference reefs are collected using the same methods and at the same time as data for resident fishes. The approach used for determining whether the number of species of young-of-year fish at Wheeler North Reef is similar to that on the reference reefs is the same as that used for resident fishes.

Results: In 2009 the initial slope of the species-area curve for young-of-year fish and the maximum number of young-of-year fish species counted on the Wheeler North Reef were intermediate between Barn and San Mateo (Figure 6.8). In 2010 and 2011, however, both of these components of species number had the highest values on the Wheeler North Reef. The initial slope of the species area curve at Wheeler North Reef in 2011 was considerably higher than that observed at San Mateo and Barn indicating that species of young-of-year fish were more evenly distributed across the Wheeler North Reef compared to the two reference reefs. In contrast, the maximum number of species of young-of-year fish encountered in 82 transects was quite similar for all three reefs (~ 7 species). These data show that the Wheeler North Reef has met both components of this performance standard each since 2009.

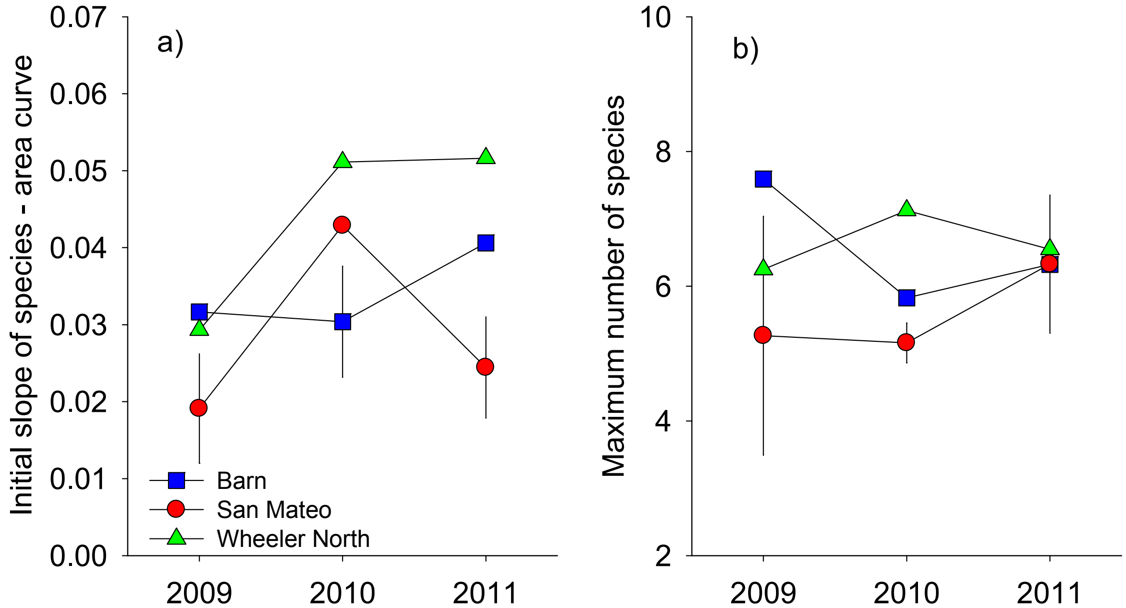

Figure 6.8. (a) Mean initial slope and (b) mean maximum number of species of the species-area curve for young-of-year fishes at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value.

9. 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 to assess this performance standard involves the use of data on biomass and gonadal growth collected for the purpose of the performance standards pertaining to fish density, fish standing stock, and fish reproductive rates, in combination with data of somatic growth rates obtained from otolith studies . Importantly, this method of estimating fish production assumes no net migration (i.e., the immigration of fish to a reef is assumed to be equal to the emigration of fish from a reef reefs).

Fish production is estimated for five target species: blacksmith, black surfperch, señorita, sheephead and kelp bass. These species represent the major feeding guilds of fishes in southern California kelp forests and are common to the study region. Blacksmith eat plankton during the day and seek shelter on the reef at night, black surfperch and señorita feed on small invertebrates that live on or near the bottom, sheephead feed on larger benthic invertebrates, and kelp bass feed on other species of fish. The annual production for each of these species is averaged to obtain an overall mean and standard error for each of the three reefs. In order for Wheeler North Reef to meet this performance standard its mean fish production must be not be significantly lower than that of the reference reef with the lower mean value of fish production (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: Much like that observed for fish density and fish standing stock, there was a dramatic 70-80% decline in fish production from 2009 to 2010 at all three reefs (Figure 6.9). Fish production remained low at Wheeler North and San Mateo in 2011, but increased dramatically at Barn, which also is similar to that observed for fish density and fish standing stock. The mean value of fish production at Wheeler North has been slightly greater that that at San Mateo in all three years indicating that it has consistently met this performance standard.

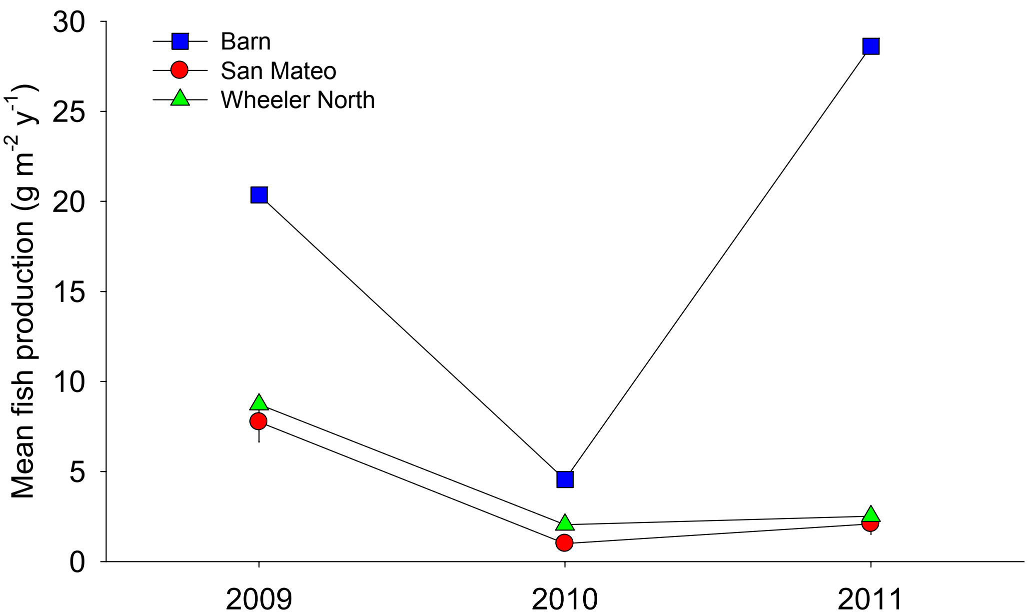

Figure 6.9. Mean fish production at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value.

10. THE BENTHIC COMMUNITY (BOTH ALGAE AND SESSILE INVERTEBRATES) SHALL HAVE COVERAGE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: The coverage of reef associated algae and sessile invertebrates provide a measure of the biomass associated with benthic community attached to the hard substrate of a reef. The benthic communities of algae and sessile invertebrates at Wheeler North Reef, San Mateo, and Barn are sampled annually in the summer.

Because many species of algae and sessile invertebrates are difficult to count as individuals their abundance is estimated as percent cover. The percent cover of algae and sessile invertebrates on the bottom is measured in five replicate $1m^2$ quadrats located at 10m intervals along each of the eighty-two 50m transects (Figure 4.4.2). Percent cover is estimated using a uniform point contact method that consists of noting the identity and relative vertical position of all organisms under 20 uniformly placed points within each quadrat, giving a total of 100 points per transect. Using this method the total percent cover of all species combined can exceed 100%, however, the maximum percent cover possible for any single species cannot exceed 100%. Because the benthic community of algae and invertebrates is expressed as percent cover of the bottom (rather than percent cover of the rock on the bottom) the ability of the Wheeler North Reef to meet this standard is not only influenced by biological processes that regulate species abundance (i.e., recruitment, growth, mortality), but also by the percent of the bottom covered by rock. For Wheeler North Reef to meet this performance standard its combined percent cover of algae and invertebrates must not be significantly less than that of the reference reef with the lower combined mean cover of algae and invertebrates (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

<u>Results:</u> The percent cover of algae and sessile invertebrates at Wheeler North Reef has increased slightly each year from an average value of 45% cover of the bottom in 2009 to 49% cover in 2011 (Figure 6.10).

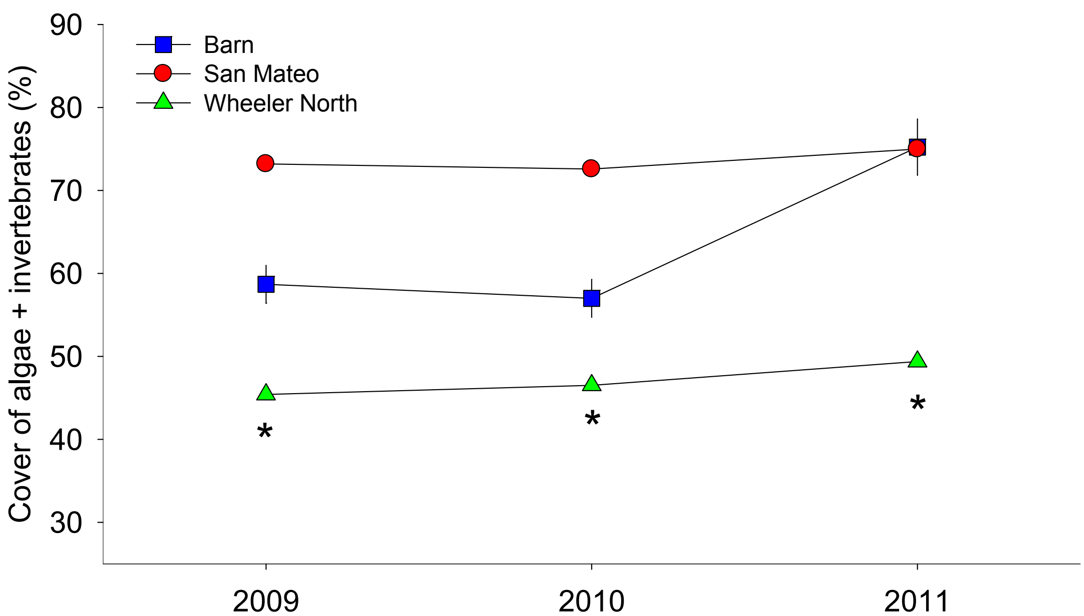

Figure 6.10. Mean percent cover of algae and sessile invertebrates combined at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value. * indicates mean value of Wheeler North Reef is significantly lower than that of the reference reefs.

Despite this steady increase, however, the percent cover of the benthic community at Wheeler North Reef has been considerably lower than that at San Mateo and Barn in all three years of sampling. It is worth noting that the difference in the percent cover of algae and sessile invertebrates between Wheeler North Reef and the two reference sites widen considerably in 2011 when the percent cover of the benthic community at Barn increased from 57% to 75% (compared to an increase of 46% to 49% at Wheeler North Reef). The percent cover of the benthic community at San Mateo has remained consistently high during the period 2009-2011 averaging > 70%. P-values for the t-tests comparing Wheeler North Reef to the lower of the two reference reefs were less than the proportional differences between Wheeler North Reef and the lower performing reference reef for all three years (p-value < 0.001 and the proportional difference was >0 .18 for all three years). Thus the Wheeler North Reef has yet to meet the performance standard for coverage of the benthic community of algae and invertebrates.

11. THE BENTHIC COMMUNITY OF MOBILE MACROINVERTEBRATES SHALL HAVE A DENSITY SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: The number of large solitary mobile invertebrates (e.g. sea stars, sea urchins, and lobsters) are counted in the five 10m x 2m plots centered along each 50m transect. Depending on their size and abundance, smaller solitary mobile invertebrates (e.g., brittle stars, nudibranchs, sea cucumbers) are counted in either a $1m^2$ or a $0.5m^2$ area created by dividing the $1m^2$ quadrats in half using an elastic cord stretched across the frame of the quadrat. Abundance values are expressed as density per m^2 bottom. For Wheeler North Reef to meet this performance standard its mean density of mobile invertebrates must not be significantly lower than that of the reference reef with the lowest mean density of mobile invertebrates (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: The colonization of mobile invertebrates at Wheeler North Reef was initially sparse and their densities in 2009 were much lower than that at San Mateo and Barn (Figure 6.11). Densities of mobile invertebrates increased at all three reefs from 2009 to 2010, but more dramatically so at Wheeler North Reef. Despite this disproportionately large increase, mobile invertebrates at Wheeler North Reef in 2010 were still less abundant than at the two reference reefs. The mean density of mobile invertebrates continued to increase in 2011 at Wheeler North Reef (albeit much less dramatically than in 2010), while decreasing at San Mateo, such that densities at these two reefs were nearly identical in 2011. Mobile invertebrate densities at Barn remained relatively unchanged in 2001. These data show that the Wheeler North Reef met the performance standard for the density of mobile invertebrates in 2011 when its mean density was slightly higher than that at San Mateo. This was not the case in either 2009 when the mean density of mobile invertebrates at Wheeler North Reef was significantly lower than that at the two reference reefs (p-value < 0.001 < proportional difference = 0.76) or 2010 (p-value = 0.047 < proportional difference = 0.19).

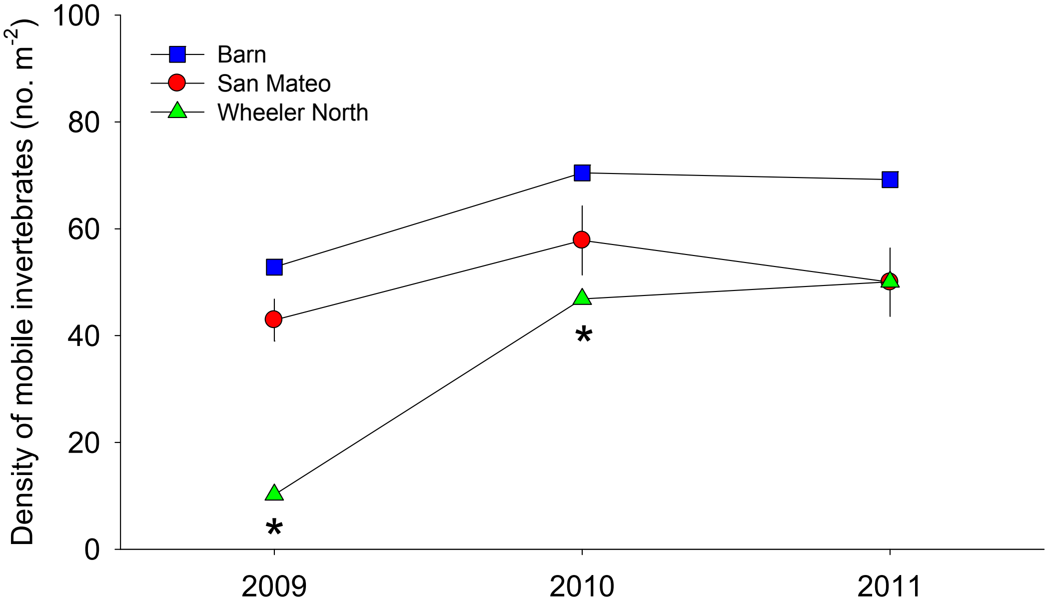

Figure 6.11. Mean density of mobile invertebrates at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value. * indicates mean value of Wheeler North Reef is significantly lower than that of the reference reefs.

12. THE NUMBER OF SPECIES IN THE BENTHIC COMMUNITY (BOTH ALGAE AND MACROINVERTEBRATES) SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Percent cover data of algae and sessile invertebrates are combined with density data of mobile invertebrates to determine the total number of species of understory algae and benthic invertebrates combined on each transect of each reef. The approach used for determining whether the number of species of algae + macroinvertebrates at Wheeler North Reef is similar to that at the reference reefs is the same as that used for resident fishes. Briefly, data are fit to a two parameter model relating the number of species encountered to the number of transects sampled and the slope and asymptote of this relationship are used as criteria for estimating this performance standard.

Results: The initial slope of the species area curve at Wheeler North Reef increased slightly from 2009 to 2010 with little change in 2011 (Figure 6.12a). Because the initial slope at Wheeler North has been significantly lower than that at the reference reefs in all three years (2009: p-value < 0.0010 and the proportional difference > 0.08 in all three years), this component of the performance standard has yet to be met, though it was close to being similar to San Mateo in both 2010 and 2011.

The maximum number of species of algae and invertebrates declined slightly on all three reefs in 2010 and increased slightly in 2011 (Figure 6.12b). While the three reefs have shown similar inter-annual trends in the number of benthic species they differ dramatically in the total number of species observed. Specifically, the number of species of algae and invertebrates observed at Wheeler North Reef has been approximately 2/3 that observed at San Mateo and Barn in all three years of sampling and p-values for t-tests between Wheeler North Reef and Barn (the lower performing reference reef) were < 0.001 in all three years. Consequently, this component of the standard for species number of algae and invertebrates has also not been met by Wheeler North Reef. Because the Wheeler North Reef has yet to meet both components of species number of algae and invertebrates it has failed to meet this performance standard for all three years.

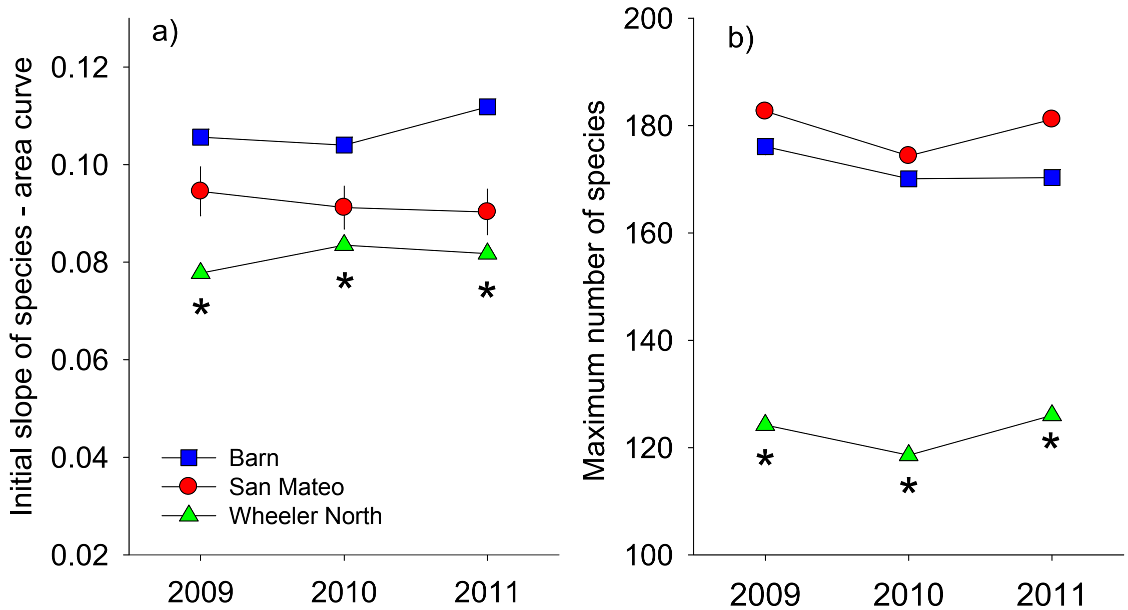

Figure 6.12. (a) Mean initial slope and (b) mean maximum number of species of the species-area curve for the benthic community of algae and invertebrates at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value. * indicates mean value of Wheeler North Reef is significantly lower than that of the reference reefs.

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

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

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

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

The values of the FCS index for each of the two species are transformed into a standardized FCS index using a Z transformation to control for species-specific differences in average feeding success. This standardization procedure allows the performance standard to be evaluated using a single metric that incorporates data from both species. For Wheeler North Reef to meet this performance standard, its standardized FCS index must not be significantly less than that at the reference reef with the lower standardized FCS index (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

<u>Results:</u> Year-to-year trends in the standardized FCS index at the three reefs have differed noticeably since 2009 (Figure 6.13). The standardized FCS index has increased steadily at Wheeler North Reef, and remained relatively unchanged at

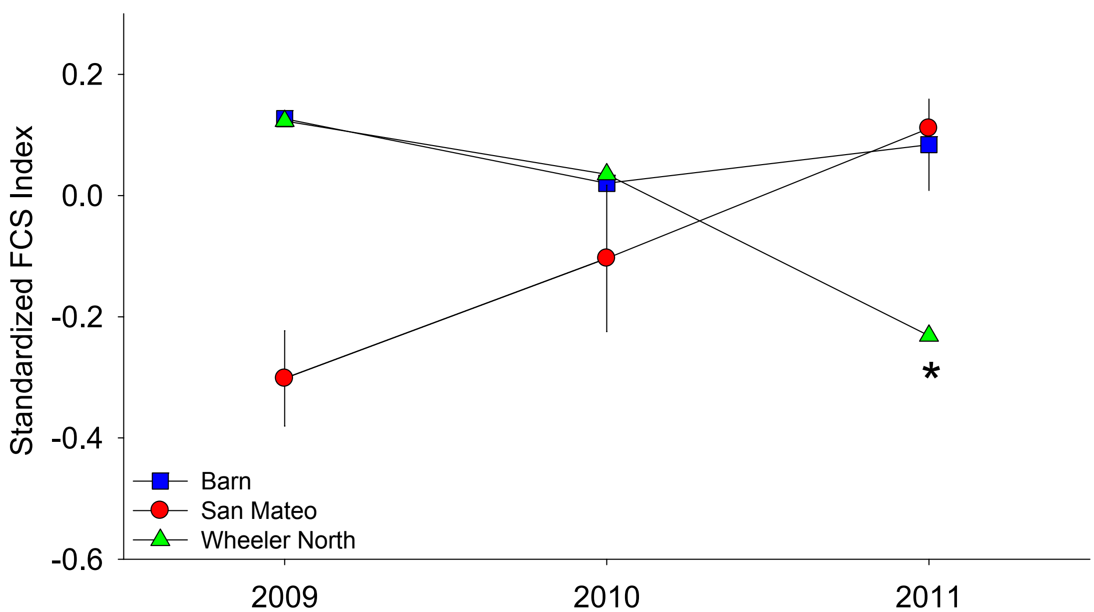

Figure 6.13. Food chain support (FCS) index at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value. * indicates mean value of Wheeler North Reef is significantly lower than that of the reference reefs.

Barn. The standardized FCS at Wheeler North Reef was within or above the range of the two references sites in 2009 and 2010, and thus met this performance standard in these years. In 2011 the mean FCS index at Wheeler North Reef dropped substantially to a level that was significantly below that of the reference reefs (p-value = 0.002 < proportional difference = 0.27). This suggests that the benthic community of Wheeler North Reef provided less food for the two indicator species than did the two natural reference reefs in 2011. Thus the Wheeler North Reef met the performance standard for food chain support in 2009 and 2010, but not in 2011.

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

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

Examples of key ecological functions provided by shallow reefs of southern California include the provision of nursery habitat for fishes, the production of invertebrate prey sufficient to support populations of predatory reef fish, and primary productivity by macroalgae. The first of these two functions are monitored for the purpose of evaluating the performance standards pertaining to the density and number of species of young-of-year fishes and benthic food chain support and thus incur no added cost to evaluate. By contrast, measuring primary productivity by reef macroalgae is very time consuming and is not required for evaluating the performance of Wheeler North Reef. However, more easily measured estimates of frond density can be used to accurately predict net primary productivity by giant kelp (Reed et al. 2009), which constitutes the vast majority of biomass on reefs in California (Graham et al. 2007). Data of kelp frond density are routinely measured for the purpose of evaluating the performance standard pertaining to giant kelp.

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

Results: As noted above, the density of giant kelp fronds was much lower at Wheeler North Reef in 2009 compared to San Mateo and Barn due to the young age of kelp (as indicated by plant size) that was present on the reef at this time (Figure 5.2.6). By summer of 2010, the density of kelp fronds at Wheeler North Reef was approximately double that at San Mateo and Barn indicating very high levels of kelp primary productivity at Wheeler North Reef and no evidence of impairment in this important function. Wheeler North Reef consistently met the performance standard pertaining to young-of-year fishes (Figure 6.7 and 6.8) indicating that there has been no impairment of this key ecological function at Wheeler North Reef since sampling began in 2009. In contrast, the function of the benthic community of Wheeler North Reef in providing food chain support for fishes was similar to or greater than that of the reference reefs in 2009 and 2010, but substantially less than that of the reference reefs in 2011 (Figure 6.13). While the specific reason for this decline in the food chain support at Wheeler North Reef is unknown, it does not appear to be caused by an increase in the abundance of undesirable or invasive species as indicated by monitoring data.

An invasive species of particular interest are native sea fans (*Muricea* spp.), which are known to attain high abundances on artificial reefs in California. In a broad survey of artificial and natural reefs in southern California Ambrose et al. (1987) found that giant kelp was rare or absent at reefs where sea fan abundance exceeded 10 per m^2. We refer to a density of sea fans greater than 10 m^{-2} as the "Ambrose line" which indicates a potential concern for a reef with respect to its ability to support giant kelp. 2010 was a good year for sea fan recruitment and the densities of sea fans at Wheeler North Reef increased 3-fold to 6 individuals / m^2 (Figure 6.14).

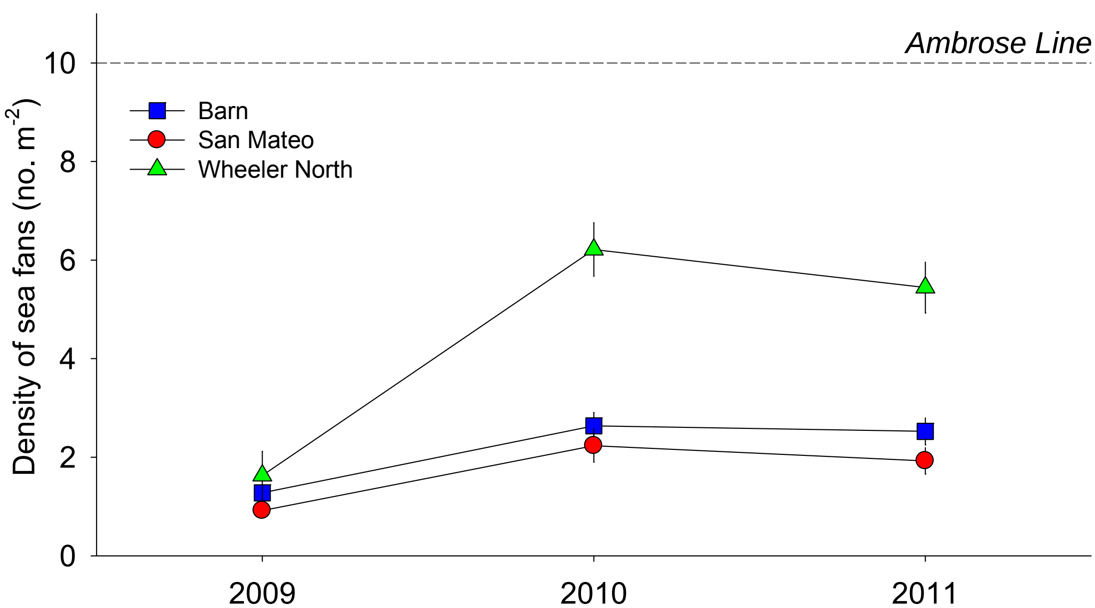

Figure 6.14. Mean density (± 1 standard error) of sea fans, *Muricea* spp. at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

Despite this large increase, sea fans at Wheeler North Reef were still below the critical density of 10m^{-2} noted by Ambrose et al. (1987). No increase in sea fan density was observed in 2011 suggesting little if any new sea fan recruitment at Wheeler North Reef. The small size of young sea fans at Wheeler North Reef and their low densities relative to the “Ambrose line” resulted in them covering a relatively small fraction of the hard substrate at Wheeler North Reef (< 2%), which was not sufficient to significantly affect the abundance of other species in the benthic community.

Much like sea fans, high densities of sea urchins can prevent the establishment of giant kelp and other organisms. For example, Arkema et al. (2009) found that giant kelp was absent on reefs where sea urchin densities exceeded 35 m^{-2}. Monitoring data from 2009 – 2011 show that sea urchin densities have changed little since 2009 at Wheeler North Reef, averaging < 1 individual per 2 m^2 (Figure 6.15). This density is far below that needed to significantly impact giant kelp and other components of the benthic community.

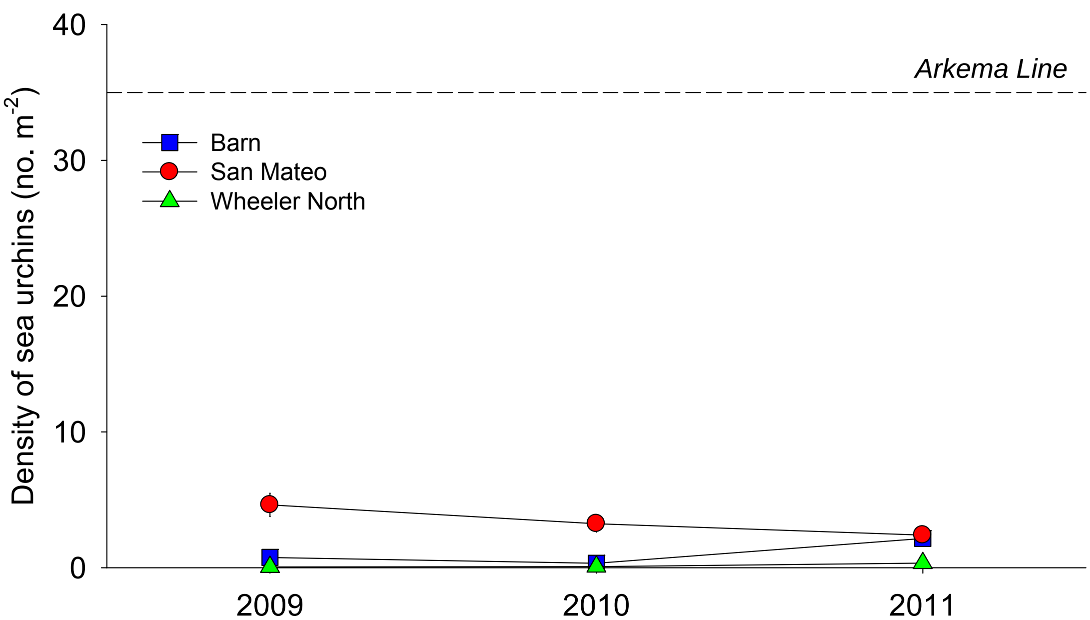

Figure 6.15. Mean density (± 1 standard error) of sea urchins, *Strongylocentrotus* spp. at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

No invasive non-native species were observed during any of the monitoring surveys done to date. Based on the above results we find no evidence that invasive or undesirable species reached abundances that were high enough to impair important ecological functions of Wheeler North Reef.

7.0 Permit Compliance

7.1 Multi-year summary of SONGS Permit compliance

All 14 performance standards must be met in a given year for Wheeler North Reef to be in compliance with the requirements of Condition C of the SONGS coastal development permit. The Wheeler North Reef met 10 of the 14 performance standards in 2010 compared to 9 of the standards in 2009 and 2011 (Table 7.1). Of the five performance standards that were not met in 2011, two pertain to kelp bed fishes (#3. Fish standing stock and #6. Fish reproductive rates), two pertain to the benthic community (#10. Algal and invertebrate percent cover and #12. Algal and invertebrate species number), and one pertains to the interaction of kelp bed fishes with the benthic community (#13. Benthic food chain support for fishes). Of these five standards, those pertaining to fish standing stock, algal and invertebrate percent cover, and algal and invertebrate species number have yet to be met in any year. Furthermore, there is no indication from the monitoring results obtained to date that the Wheeler North Reef is on a viable trajectory to meet these three standards any time soon. The other two performance standards that were not met in 2011 (fish reproductive rates and benthic food chain support for fishes) were met in 2009 and 2010, indicating that the performance of the Wheeler North Reef regressed with respect to these two performance standards.

Table 7.1. Multi-year summary of the performance of Wheeler North Reef with respect to the 14 standards that are used to judge whether it is meeting its intended goal of compensating for the kelp bed resources lost due to the operation of SONGS Units 2 and 3. YES means that the standard was met for that year, NO means the standard was not met.

Performance Summary

		2009	2010	2011
1.	Hard substrate	Yes	Yes	Yes
2.	Area of adult giant kelp	No	Yes	Yes
3.	Fish standing stock	No	No	No
4.	Resident fish density	Yes	Yes	Yes
5.	Resident fish species number	Yes	Yes	Yes
6.	Fish reproductive rates	Yes	Yes	No
7.	Young-of-year fish density	Yes	Yes	Yes
8.	Young-of-year fish species number	Yes	Yes	Yes
9.	Fish production	Yes	Yes	Yes
10.	Algal and invertebrate percent cover	No	No	No
11.	Mobile invertebrate density	No	No	Yes
12.	Algal and invertebrate species number	No	No	No
13.	Benthic food chain support for fishes	Yes	Yes	No
14.	Invasive and undesirable species	Yes	Yes	Yes
	Number of standards met (out of 14)	9	10	9

Despite the above noted deficiencies in the performance of the Wheeler North Reef it has shown promise in meeting many of its objectives. For example, it has consistently met 7 of the 14 performance standards in each of three years of monitoring. Moreover, the performance standard for mobile invertebrate density, which had not been met in 2009 or 2010, was met in 2011. This reflects the steady increase in the density of mobile invertebrates on Wheeler North Reef over time indicating that it is on a successful trajectory with respect to this standard. Similarly, the performance standard pertaining to the area of adult giant kelp, which was met in 2010, but not 2009, continued to be met in 2011. This indicates continued progress by the Wheeler North Reef in meeting the objective of compensating for the loss of giant kelp caused by SONGS operations.

7.2 Reasons for not meeting particular performance standards

Below we present the results of additional analyses aimed at determining why the Wheeler North Reef did not meet five of the 14 performance standards in 2011.

Fish standing stock

In their assessment of the impacts of SONGS the Marine Review Committee concluded that discharge of cooling waters from Units 2 and 3 reduced the standing stock of bottom dwelling reef fish in the San Onofre kelp bed by 28 tons (MRC 1989). Hence the Wheeler North Reef is required to sustain at least 28 tons of bottom dwelling reef fish to successfully mitigate this adverse effect. The Wheeler North Reef has failed to meet this requirement in each of the three years since its construction. Of considerable concern is the observation that the standing stock of fish at Wheeler North Reef peaked in the first year following reef construction and it has supported less than half the 28 ton requirement in each of the last two years (Figure 6.3). These results raise the question as to whether it is reasonable to expect a reef the size of the Wheeler North Reef (176 acres) to consistently support at least 28 tons of bottom dwelling reef fish.

One way to answer the above question is to evaluate whether 176 acres of the two natural reference reefs are capable of supporting 28 tons of fish. To do this we scaled the biomass density of fish measured at San Mateo and Barn in 2009-2011 to 176 acres. When this is done we see that 176 acres at Barn supported 28 tons of fish in 2 of the 3 years whereas 176 acres at San Mateo supported an equally low biomass of fish as that supported by Wheeler North Reef in all three years (Figure 7.1). It is worth noting that in the case of Barn, fish standing stock rose from 17 tons / 176 acres in 2010 to 72 tons / 176 acres in 2011, indicating that local fish populations may fluctuate greatly from year to year.

To examine the effects of rock cover on the probability of a 176 acre reef sustaining at least 28 tons of fish over the long term we scaled up the data obtained from the Phase 1 time series using 21 modules built with quarry rock only (7 modules of the low, medium and high coverage of rock). The results of this analysis show that fish standing stock has been consistently higher on the Phase 1 modules with medium and high rock cover (Figure 7.2). The projected standing stock of fish on the Phase 1 modules when scaled to 176 acres would have met the 28 ton standard in 8 of 9 years on the high coverage rock modules, 7 of 9 years on the medium coverage rock modules and only 4 of 9 years on the low coverage rock modules. The low rock Phase 1 modules have a mean coverage of rock similar to that of Wheeler North Reef (~ 42%).

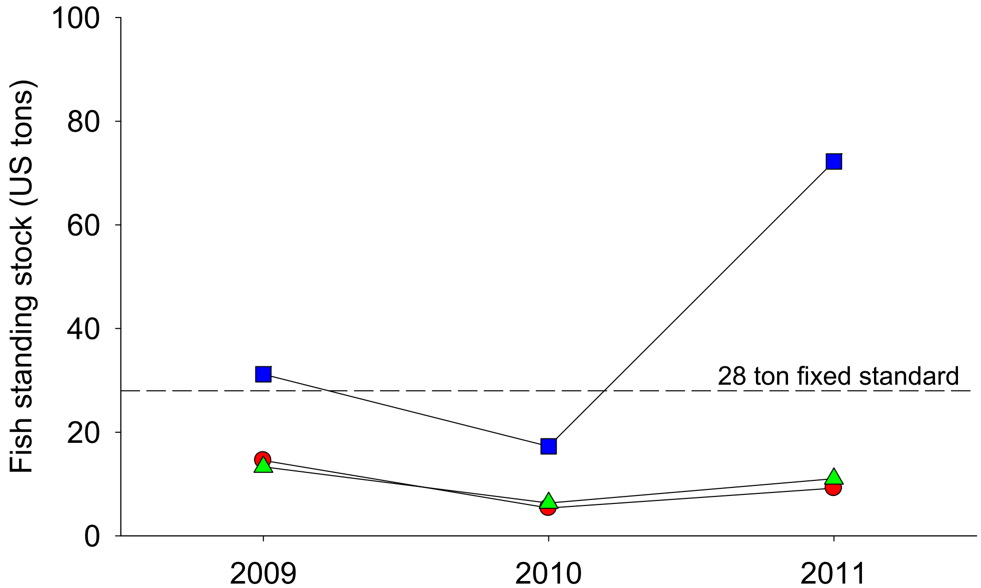

Figure 7.1. Estimated standing stock of fish per 176 acres at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

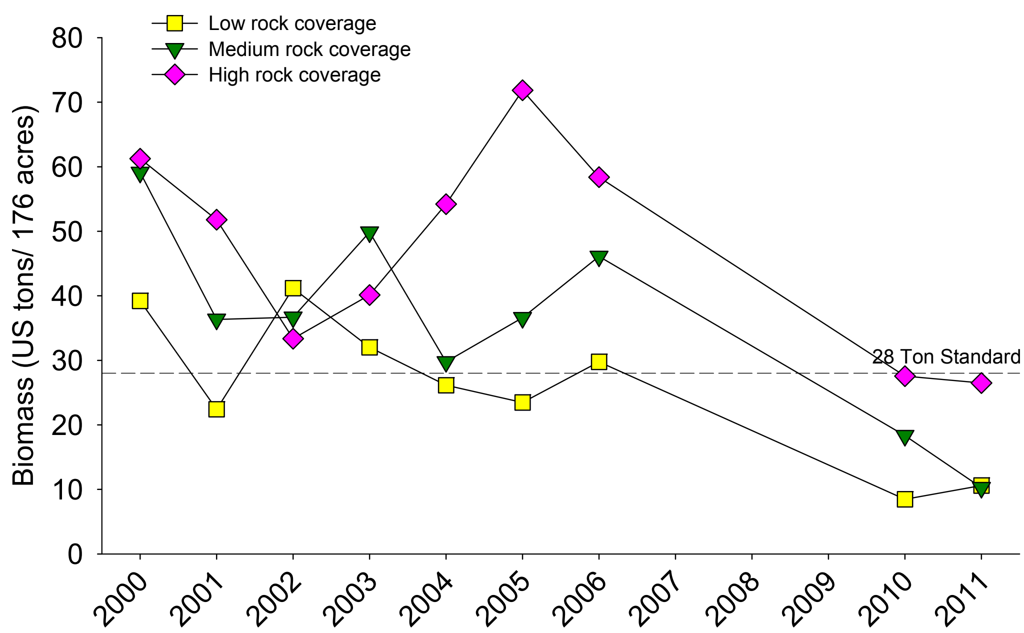

Figure 7.2. Estimated standing stock of fish per 176 acres for the three coverages of rock tested on the Phase 1 modules of Wheeler North Reef for 2000 - 2011.

The results of the above analyses of the reference reefs and at the Phase 1 modules suggest that a 176 acre reef has a reasonable probability of supporting 28 tons of fish if the coverage of rock is reasonably high (~60% or more). This finding is consistent with conclusions drawn from analyses in the final report on the Phase 1 experimental reef (Reed et al. 2005).

<u>Fish reproductive rates</u>

In 2011, fish reproductive rates averaged over three species declined at Wheeler North Reef while increasing at Barn and San Mateo (Figure 6.6). As a result the Wheeler North Reef failed to meet the performance standard for fish reproductive rates in 2011, despite having met it in 2009 and 2010. The Standardized Fecundity Index used to evaluate the fish reproductive rate standard normalizes egg production to body size for each species, then averages this standardized value across all three species in a given year to assess whether the performance standard is met. It incorporates two components of reproduction: (1) the standardized batch fecundity of each species, and (2) the proportion of individuals that were spawning. To better understand why Wheeler North Reef failed to meet the fish reproductive rates standard for 2011 we examined the three species separately to determine the extent to which low fish reproductive rates on the Wheeler North Reef in 2011 resulted from low batch fecundity vs. low proportion of individuals spawning for each of the three species.

Data on species specific reproductive rates show that standardized batch fecundity in 2011 was lower for all three species at Wheeler North Reef compared to the reference reefs (Figure 7.3). The magnitude of this difference in batch fecundity, however, differed among species with señorita and kelp bass displaying comparatively lower batch fecundity at Wheeler North Reef than sheephead.

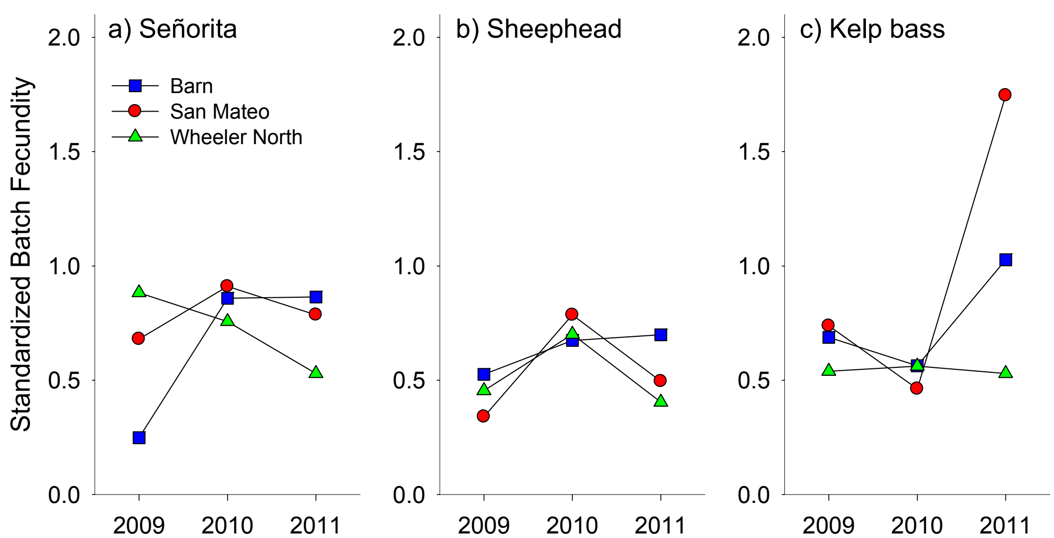

Figure 7.3. Standardized batch fecundity for (a) Señorita, (b) Sheephead and (c) Kelp bass at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

Species specific patterns observed for the fraction of individuals spawning on the three reefs in 2011 (Figure 7.4) were opposite of those observed for batch fecundity (Figure 7.3). A much higher fraction of señorita and kelp bass engaged in spawning at the Wheeler North Reef compared to the reference reefs, whereas the fraction of sheephead spawning at Wheeler North Reef was much lower than that observed at San Mateo and Barn.

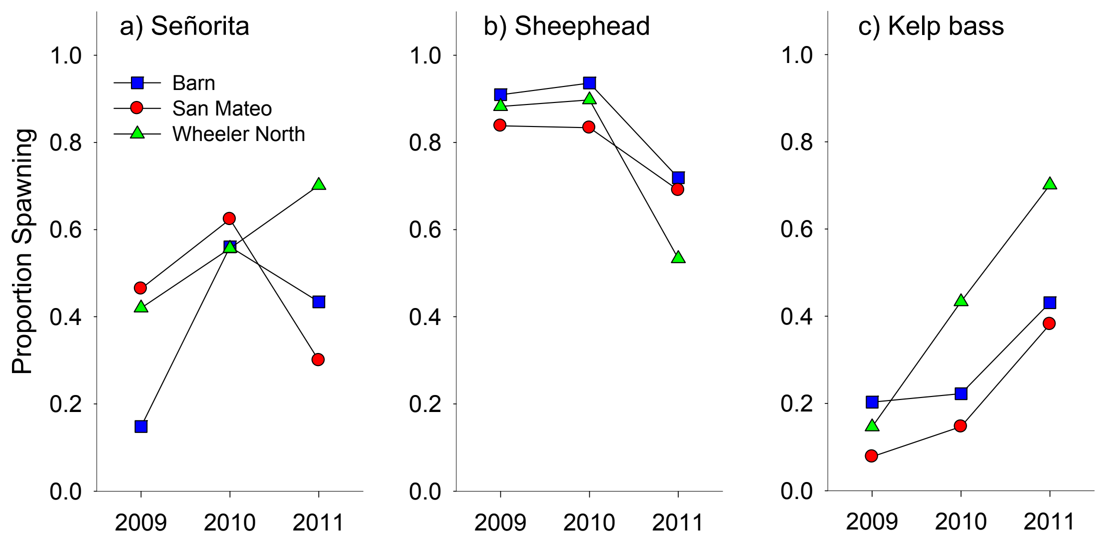

Figure 7.4. Proportion of female (a) Señorita, (b) Sheephead and (c) Kelp bass spawning at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

We compared the Fecundity Indices of each species (which integrate batch fecundity and proportion spawning) to evaluate whether all three species contributed equally to the failure of Wheeler North Reef to meet the performance standard for reproductive rates in 2011. Results of these analyses show that the Fecundity Indices for sheephead and kelp bass at Wheeler North Reef in 2011 were below those at the reference reefs, and markedly so for sheephead (Figure 7.5). In contrast the higher than average proportion of señorita spawning at Wheeler North Reef (Figure 7.4) offset the lower than average batch fecundity (Figure 7.3) to result in a Fecundity Index for señorita that was similar to Barn and higher than that at San Mateo (Figure 7.5).

Based on these results we conclude that the failure of the Wheeler North Reef to meet the fish reproductive rate standard in 2011 was largely due to a lower fecundity index for sheephead that resulted from a lower proportion of spawning individuals, and to a lesser extent a lower fecundity index for kelp bass that reflected lower levels of batch fecundity.

<u>Algal and invertebrate percent cover</u>
The gap between the percent cover of algae + sessile invertebrates at the Wheeler North Reef and the two reference sites widened considerably in 2011 (Figure 6.10). This was because of the slow increase in cover at Wheeler North Reef and a rapid

increase at Barn. To better understand the reasons for the lower coverage at Wheeler North Reef it is important to know whether it was due to changes in algae, invertebrates or both.

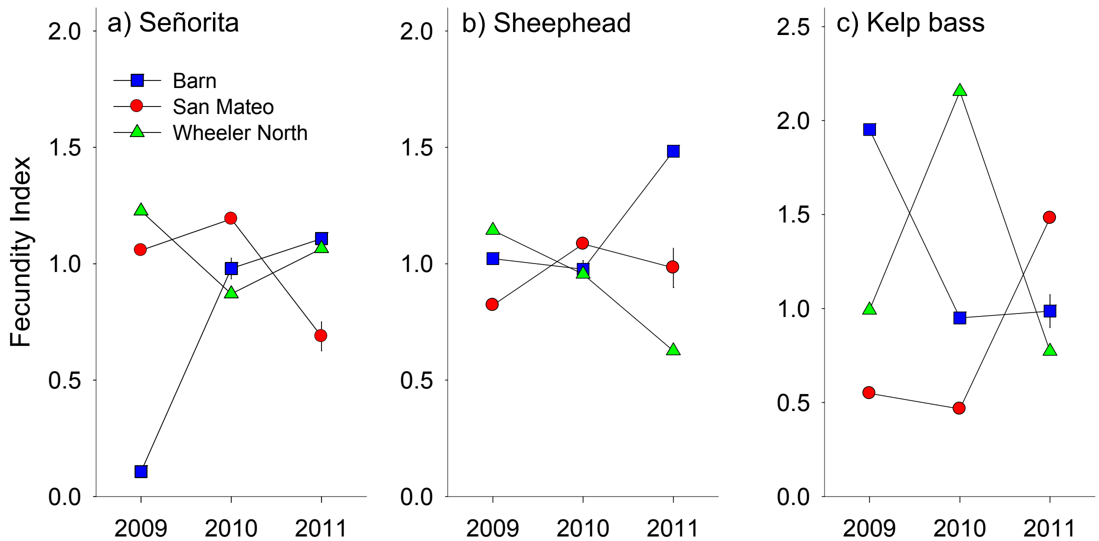

Figure 7.5. Fecundity index for (a) Señorita, (b) Sheephead and (c) Kelp bass at Wheeler North Reef, San Mateo and Barn for 2009 - 2011. ± 1 standard error is shown for the reference reef with the lowest mean value.

The results of annual monitoring show that the percent cover of algae has steadily declined at Wheeler North Reef over the last 3 years from 30% in 2009 to 8% in 2011 (Figure 5.2.9a). In contrast, algal percent cover remained relatively constant at San Mateo at ~ 49% while it increased at Barn from ~ 20% in 2009 and 2010 to 35% in 2011. Consequently, the percent cover of algae at Wheeler North Reef was about 20-25% of that at Barn and San Mateo in 2011. Trends observed in the percent cover of sessile invertebrates at Wheeler North Reef were opposite of those observed for algae in that it has risen steadily since 2009 and by 2011 it was as high or higher than at the two reference sites (Figure 5.2.10a). Thus the failure of Wheeler North Reef to meet the performance standard pertaining to the percent cover of algae + invertebrates was due in part to a continued decrease in the percent cover of understory algae, which did not occur at the reference sites.

Giant kelp is known to shade understory algae and the decline in understory algae at Wheeler North Reef has coincided with an increase in the biomass of giant kelp as measured by the density of kelp fronds (Figure 5.2.7). In 2011 kelp frond density at Wheeler North Reef was more than 3 times that at San Mateo and Barn. The lower percent cover of algae at Wheeler North most likely reflects the greater effects of shading from giant kelp.

Another factor that affects the percent cover of understory algae and sessile reef invertebrates is the availability of rock habitat, which is less at Wheeler North Reef compared to San Mateo and Barn (the percent of the bottom covered by rock at

Wheeler North Reef in 2011 was ~ 42% vs. 48% and 58% at Barn and San Mateo, respectively; Figure 5.1.1). The time series data that have been collected on the Phase 1 modules and reference reefs provide a useful means of evaluating the extent to which the differences in percent cover of the benthic community observed between the Wheeler North Reef and the two reference reefs are related to differences in the cover of rock. Figure 7.6 shows the percent cover of algae+ invertebrates for the low (42%), medium (60%) and high (86%) cover rock modules for the past 12 years.

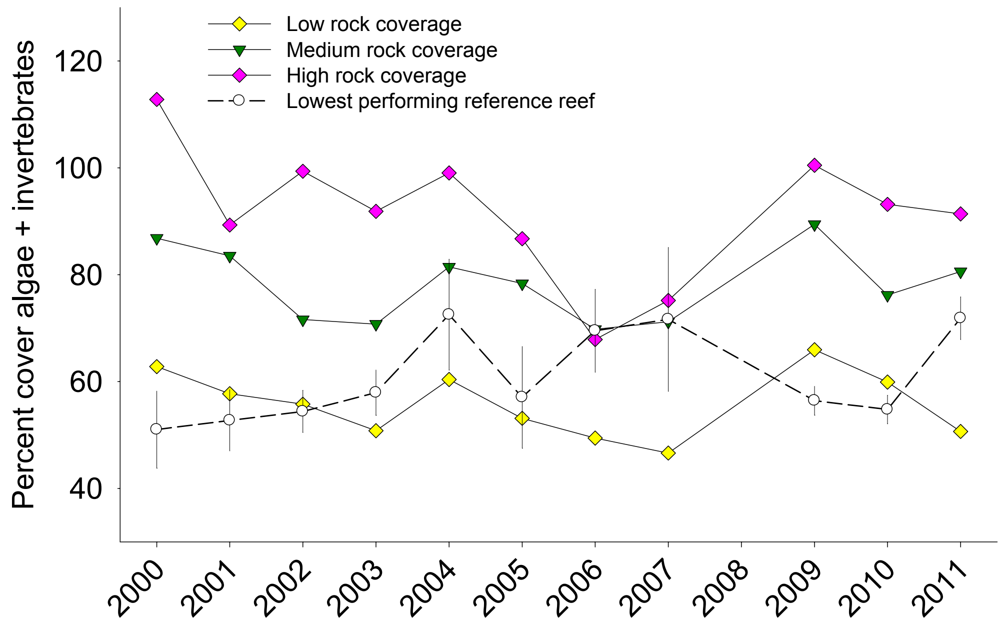

Figure 7.6. Mean percent cover of algae and sessile invertebrates combined for the three rock coverages of the Phase 1 modules at Wheeler North Reef and the lowest performing reference reef (± 1 standard error) for 2000 - 2011.

Values for the mean cover of algae + invertebrates for the reference reef (i.e., San Mateo or Barn) with the lowest cover of algae + invertebrates provide an indication of whether the different rock coverages would have met the performance standard for the percent cover of the benthic community. Not surprisingly, modules with higher rock coverage supported a higher coverage of algae + invertebrates. More important is the finding that the coverage of the benthic community on the medium and high cover rock modules was consistently at or above that of the lowest performing reference site for all 11 years in the time series. By contrast, the benthic cover on the low cover rock modules was only at or above that of the reference site with the lowest mean value in 5 of 11 years. These results indicate that with its present coverage of rock the Wheeler North Reef is at best likely to meet the percent cover standard for the benthic community only about half the time.

<u>Algal and invertebrate species number</u>

Not only has the percent cover of the benthic community been lower on Wheeler North Reef compared to the reference reefs, but it also has consistently supported many fewer species of algae and invertebrates (Figure 6.12). Closer examination of the data reveal that in 2011 there were 75 - 80 species of algae and invertebrates observed at Barn and San Mateo that were not observed at Wheeler North Reef (Figure 7.7). By contrast, relatively few species observed at Wheeler North Reef (20 - 28) were missing in surveys at San Mateo and Barn. While no two reefs are expected to share the same species assemblages, the asymmetry between Wheeler North Reef and the two references sites in terms of the numbers of shared and unshared species was considerably greater than the asymmetry in shared species observed between the San Mateo and Barn (Figure 7.7).

Algae, mollusks (primarily mobile grazers and predators) and echinoderms (sea urchins, sea cucumbers and sea stars) comprised the majority of species that were present at the reference reefs, but missing at Wheeler North Reef, whereas mollusks and crustaceans (small crabs and shrimp) comprised the majority of species that were present at Wheeler North Reef, but missing at the reference reefs (Figure 7.8). The species that were missing at Wheeler North Reef were primarily species that were uncommon at the reference reefs. (Figure 7.9), however there were some exceptions as several species missing at Wheeler North Reef were observed on as many as 37 of the 82 transects at the reference sites. By contrast, none of the species unique to Wheeler North Reef were found on more than 3 of the 82 transects.

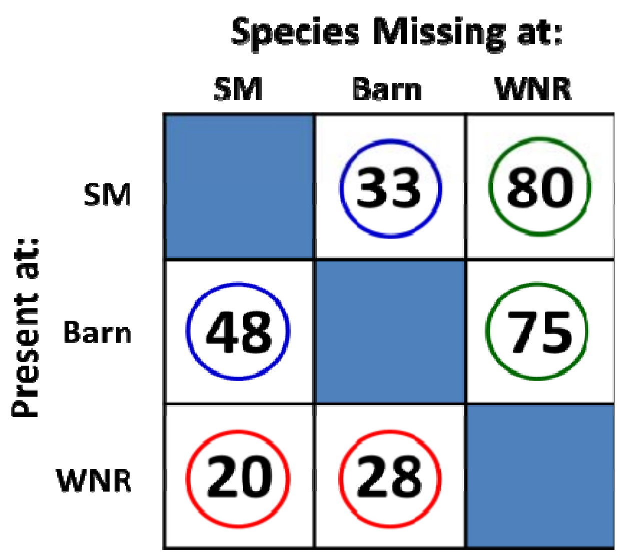

Figure 7.7. Matrix showing the numbers of unique species of algae and invertebrates present at reef, but missing from the other reefs. Data are from Wheeler North, San Mateo and Barn in 2011.

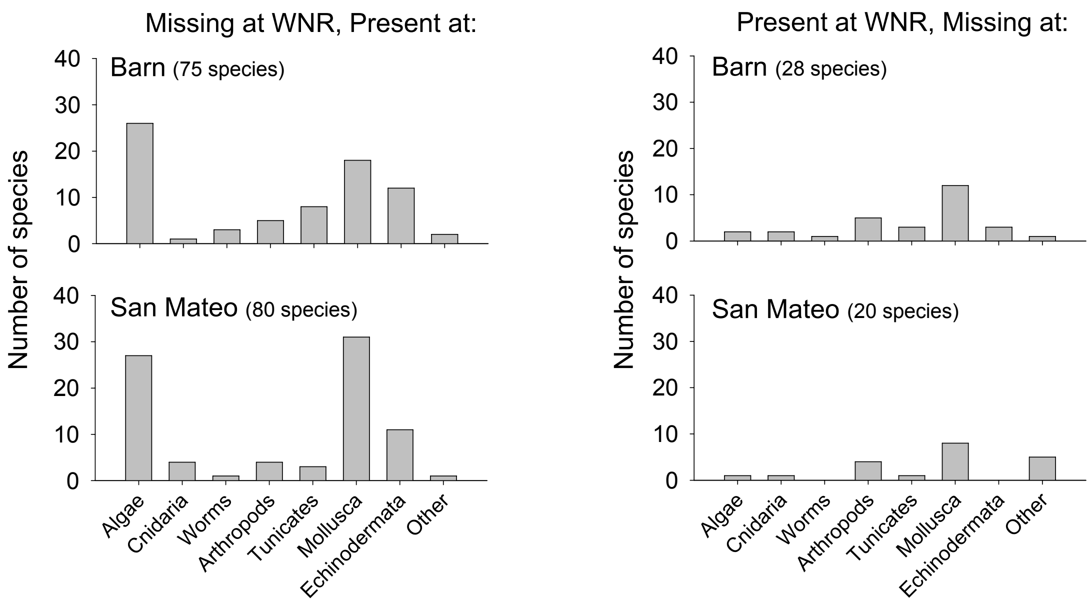

Figure 7.8. Number of sessile species missing at Wheeler North Reef and present at the two reference reefs or present at Wheeler North Reef and missing at the two reference reefs in 2011.

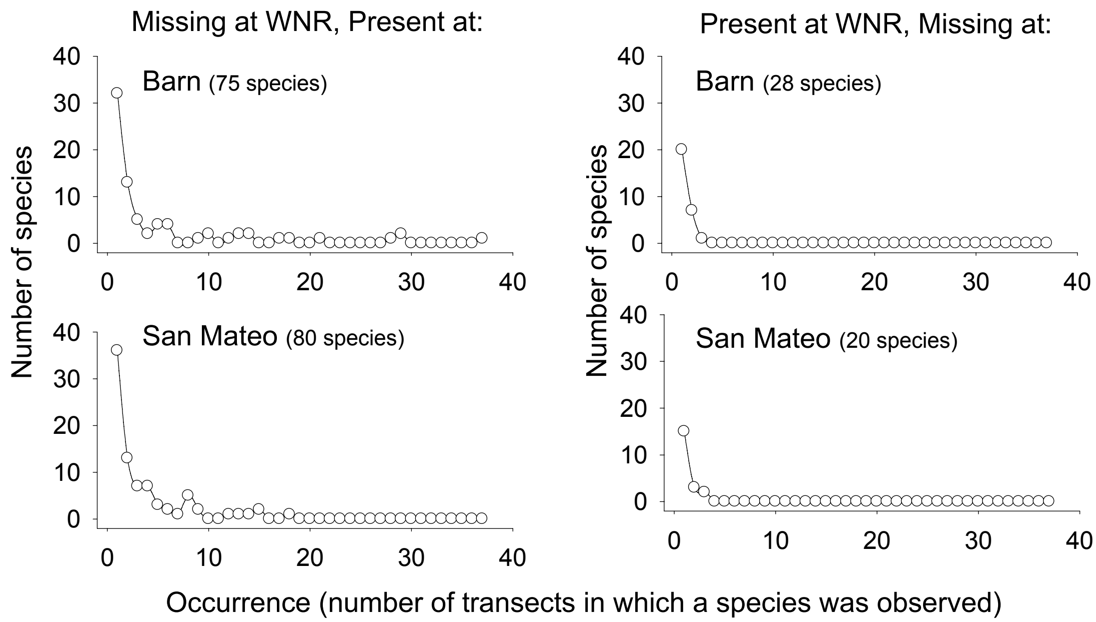

Figure 7.9. Frequency of occurrence of species missing at Wheeler North Reef and present at the two reference reefs or present at Wheeler North Reef and missing at the two reference reefs in 2011.

Benthic food chain support for fishes

Data from two species (black perch and sheephead) were used to evaluate the performance standard pertaining to benthic food chain support for fishes. This assessment entails calculating a separate Food Chain Support (FCS) Index for each species, which is then transformed into a single standardized FCS index that incorporates data from both species. Since 2009 the standardized FCS index has steadily declined at Wheeler North Reef, steadily increase at San Mateo and remained relatively constant at Barn (Figure 6.13). An examination of the non-standardized FCS indices of each species reveals that the temporal trend in the FCS Index of black perch at Wheeler North Reef has closely followed those observed at San Mateo and Barn; low in 2009, sharp increase in 2010 and steep decline in 2011 (Figure 7.10a). In contrast, the FCS index of sheephead has steadily declined at the Wheeler North Reef since 2009, while steadily increasing at both reference reefs (Figure 7.10b). These results show that the declining trend in the standardized FCS Index at Wheeler North Reef is due to reduced feeding by sheephead.

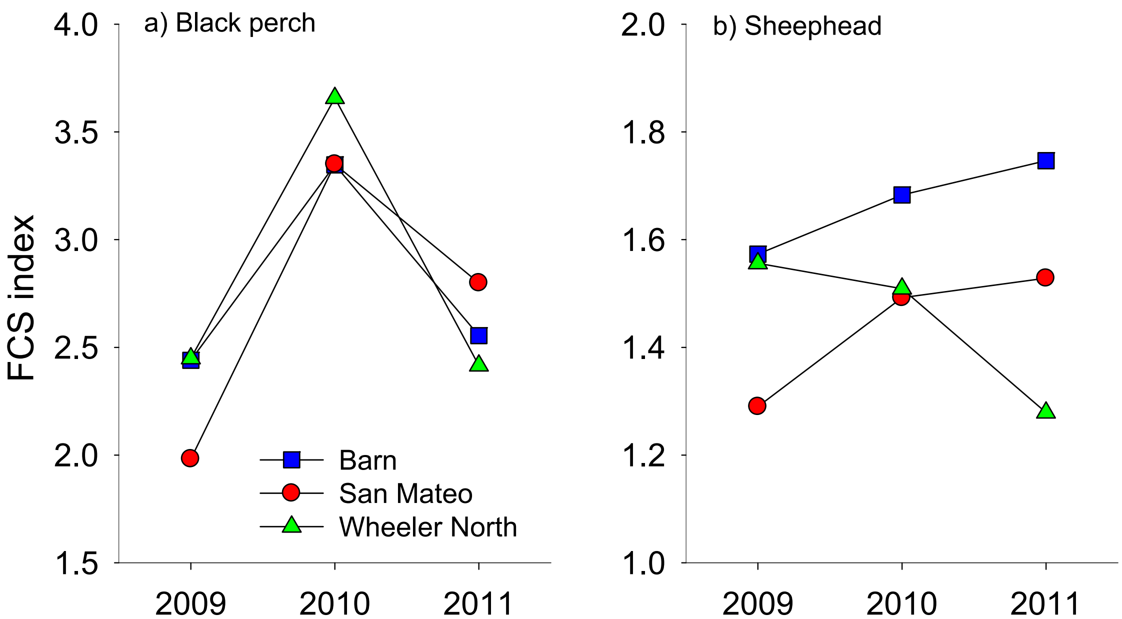

Figure 7.10. Food chain support (FCS) index for (a) Black perch (b) Sheephead at Wheeler North Reef, San Mateo and Barn for 2009 - 2011.

Sheephead are generalist predators that feed on benthic invertebrates. Hamilton et al. (2011) found that the diet of sheephead was broadly similar across nine kelp forests distributed throughout southern California. Small sea urchins, crabs, amphipods, shrimp, and gastropods comprised much of their diet in most areas and all of these taxa associate with understory algae. That Hamilton et al. (2011) found algae in the diet of sheephead at 7 of their 9 sites suggest that sheephead forage in understory algae for food. It is noteworthy that the declining trend in understory algae on Wheeler North Reef (Figure 5.2.9a) mirrors the declining trend in sheephead gut fullness (Figure 7.10b). Thus, it is possible that the low cover of algae at Wheeler North Reef has contributed to the low values of FCS for sheephead by reducing the food and habitat of its preferred prey.

8.0 Future Monitoring Plans

Monitoring of the Wheeler North Reef, San Mateo and Barn will continue in 2012 using the same level of effort and methods employed in 2009-2011. The lone exception to this is that we will modify our sampling of young-of-year fish to take into account their cryptic nature and thus obtain a more accurate measure of their abundance. Rather than estimating the density and species number of YOY at the same time as older resident fish (as done in previous years) we will survey YOY separately, taking additional time to search more cryptic habitats near the bottom (e.g., crevices, kelp fronds, understory algae) which is not done during the transect surveys for resident fish.

In addition to monitoring, additional analyses will be done with existing data to better understand why particular aspects of the Wheeler North Reef are not meeting their expected goals.

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