2010

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

SAN ONOFRE NUCLEAR GENERATING STATION (SONGS) MITIGATION PROGRAM

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Submitted to the California Coastal Commission

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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 is based on its ability to meet 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

Monitoring results from the 2009 and 2010 surveys were encouraging in that the Wheeler North Reef showed great promise in its ability to support kelp forest biota. Giant kelp, understory algae, sessile invertebrates and reef fish all colonized the Wheeler North Reef during the first year following its construction (i.e., 2009) and 9 of the 14 performance standards established in the SONGS permit by the Commission for the Wheeler North Reef were met after just one year. The five performance standards that were not met in 2009 pertained to the area occupied by adult giant kelp, the abundance and diversity of the benthic community of algae and invertebrates, and the standing stock of kelp bed fish. Among the most notable findings revealed by the 2009 monitoring data were: (1) hard substrate at Wheeler North Reef, which is essential for supporting reef biota, was quite stable and there were no signs of it sinking or being exported to the beach, (2) an abundant and diverse fish assemblage at Wheeler North Reef, which exhibited reproduction and growth that was similar to or greater than that found on natural reefs, and (3) no evidence that the invasive sea fan *Muricea* spp. or other undesirable species were adversely affecting the important functions of the reef (although some colonization of sea fans was noted) .

The 2010 monitoring data showed that the kelp forest community at Wheeler North Reef is continuing to develop. Many of the juvenile giant kelp observed throughout the artificial reef in 2009 grew to adulthood by 2010 causing the area of adult kelp at Wheeler North Reef to increase dramatically from 19 acres in 2009 to 174 acres in 2010. This increase in the area of adult giant kelp allowed Wheeler North Reef to meet the 150 acre performance standard for adult giant kelp in 2010, which it failed to do in 2009. The three performance standards that pertain to the abundance and diversity of the benthic community of algae and invertebrates at Wheeler North Reef that were not met in 2009 were also not met in 2010. However, algal and invertebrate abundance on the artificial reef showed an increasing trend in 2010 suggesting that Wheeler North Reef is getting closer to meeting its goals with respect to the abundance of the benthic community. In contrast, the number of species of algae and invertebrates at Wheeler North Reef remained relatively unchanged between 2009 and 2010 and below that observed at the two reference reefs. Analyses are ongoing to determine the causes for the observed lower diversity of the benthic community at Wheeler North Reef and the likelihood that it will increase to levels observed on the natural reference reefs. The density, diversity, reproduction and growth of reef fish at Wheeler North Reef have consistently been equal to or greater than that of the two reference reefs. However, Wheeler North Reef fell short of the 28 ton target required by the performance standard pertaining to fish standing stock in both 2009 and 2010.

2.0 Introduction

2.1 Purpose of Report

This report focuses on Condition C of the San Onofre Nuclear Generating Stations (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 and 2010 and summarizes the status of the project's compliance with Condition C of the SONGS permit.

2.2 Background

SONGS Operations

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.

SONGS Impacts

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 on 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.

<u>Mitigation Requirements</u>

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 high density kelp bed and associated community resulting from the operation of SONGS Units 2 and 3. The artificial reef is to 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 found in April 1997 that there is continuing importance for the independent monitoring and technical oversight 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).

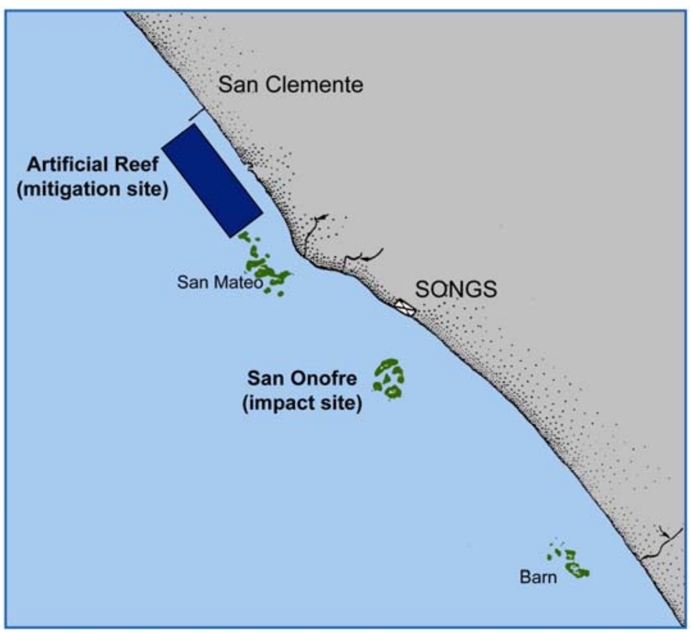

Figure 3.1.1. Location of the artificial reef mitigation site (shown as the blue rectangle) in relation to SONGS and the impacted San Onofre kelp forest. The green blotches depict the naturally occurring kelp forests at San Mateo and Barn.

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.

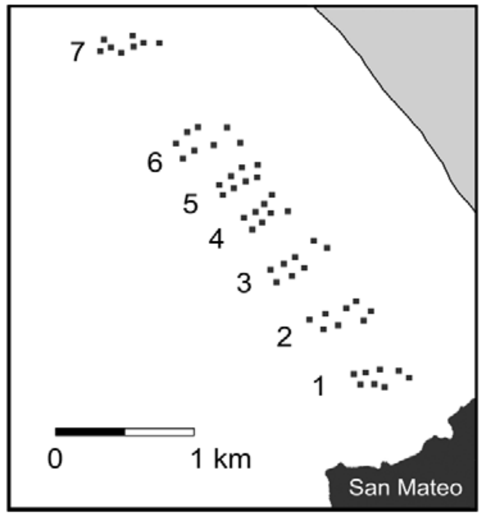

Figure 3.1.2. Design of the Phase 1 Experimental Reef. The black squares represent the 56 modules. Numbers indicate the 7 replicate sampling locations.

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 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 (Figure 3.2.1).

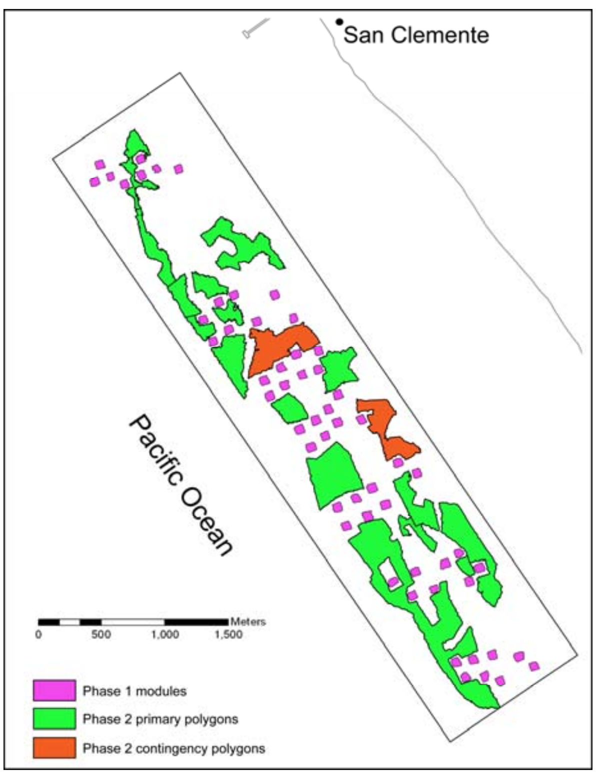

Figure 3.2.1. The 174 acre Wheeler North Artificial Reef, which includes the Phase 1 modules and the Phase 2 primary and contingency polygons.

When added to the 22.4 acre experimental reef a total of 174.4 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 22.4 acres of the Phase 1 reef to fulfill SCE's permit requirement that they construct a minimum of 150 acres of reef with an average of at least 42% cover. The 21.7 acres in the remaining two polygons (hereafter referred to as contingency polygons) 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 that the value of a resource be similar to that on 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 on a successful artificial reef should fluctuate in a manner similar to those on the natural reefs used for reference. One way to help ensure this is to select reference reefs that are located close to Wheeler North Reef and are physically similar to its design. 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 sites. 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 values for the relative performance variables at Wheeler North Reef be equal to or greater than the lower 80% confidence interval of the reference site with the lowest value. The rationale for this condition is that both reference sites are considered to provide acceptable measures of comparison for Wheeler North Reef. Given this assumption, if Wheeler North Reef is performing at least as well as one of the reference sites, it should be judged successful. The use of the 80% confidence limit 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 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 10m 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. The 82 transects on each reef are arranged in 41 pairs with the two transects in each pair spaced 25m apart. The 10 transects in the two contingency polygons at Wheeler North Reef are similarly arranged in 5 pairs. 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. Transect pairs 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

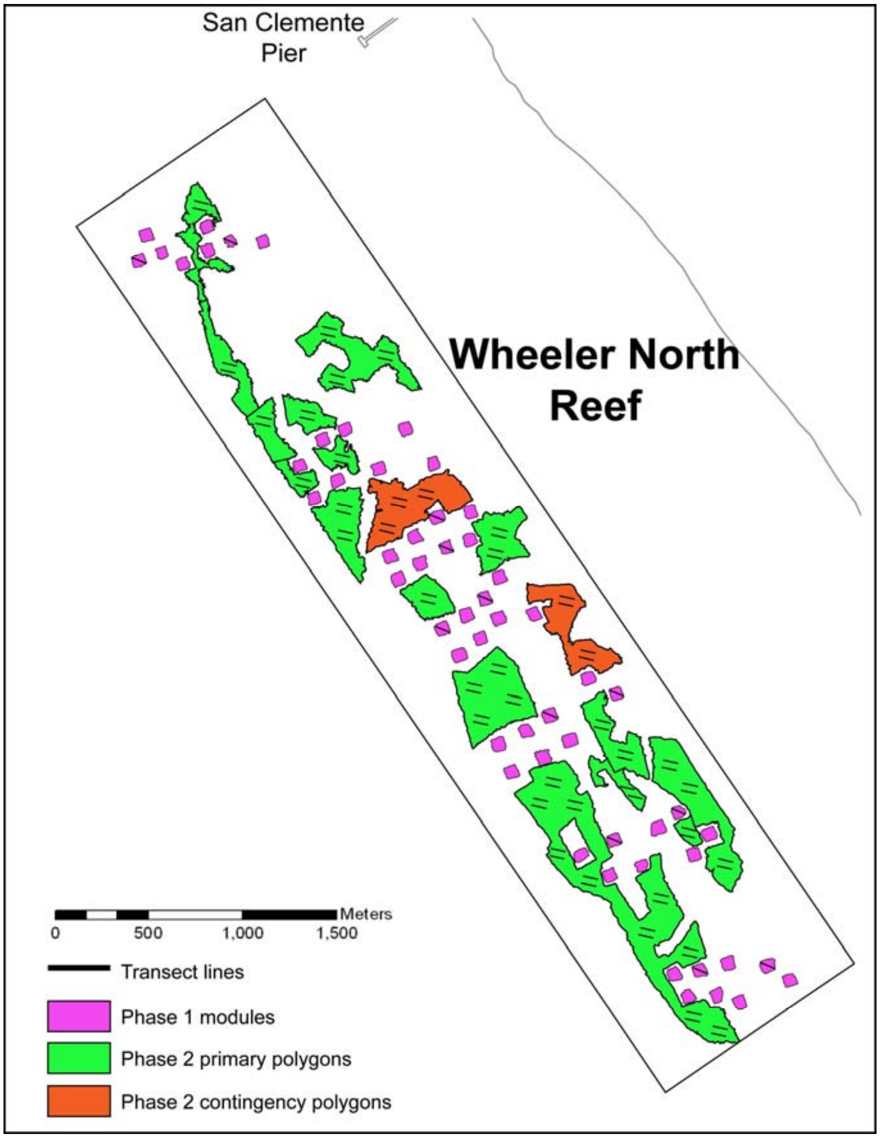

Figure 4.4.1. Schematic map of the Wheeler North Reef showing the location of the paired transects that are monitored to assess the performance standards.

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 10m 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).

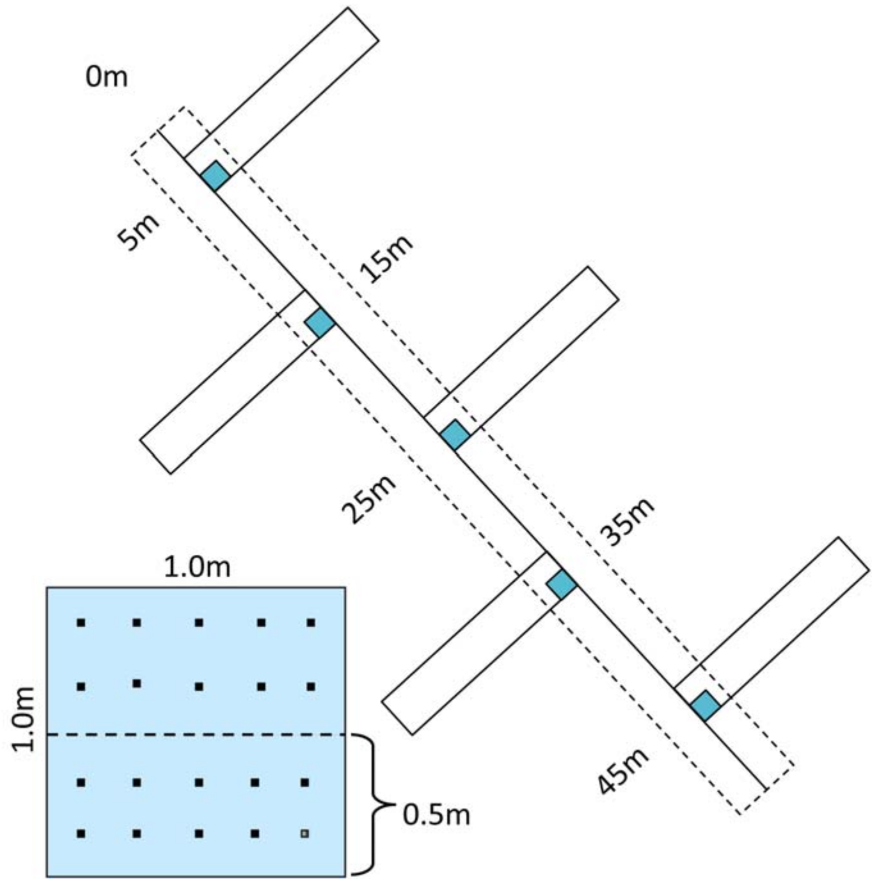

Figure 4.4.2. Schematic diagram of sampling station. Fish are sampled in 50m x 3m band transects that extend 1.5m off the bottom (outlined with a dotted line). Adult giant kelp > 1m tall, large understory algae, and large mobile invertebrates are counted in the five 10m x 2m rectangular quadrats positioned 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 2009-2010, which represents the 2-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 43%, 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. There was about a 10% increase in the cover of rock at San Mateo and Barn from 2009 to 2010, whereas the cover of rock at Wheeler North Reef remained relatively constant.

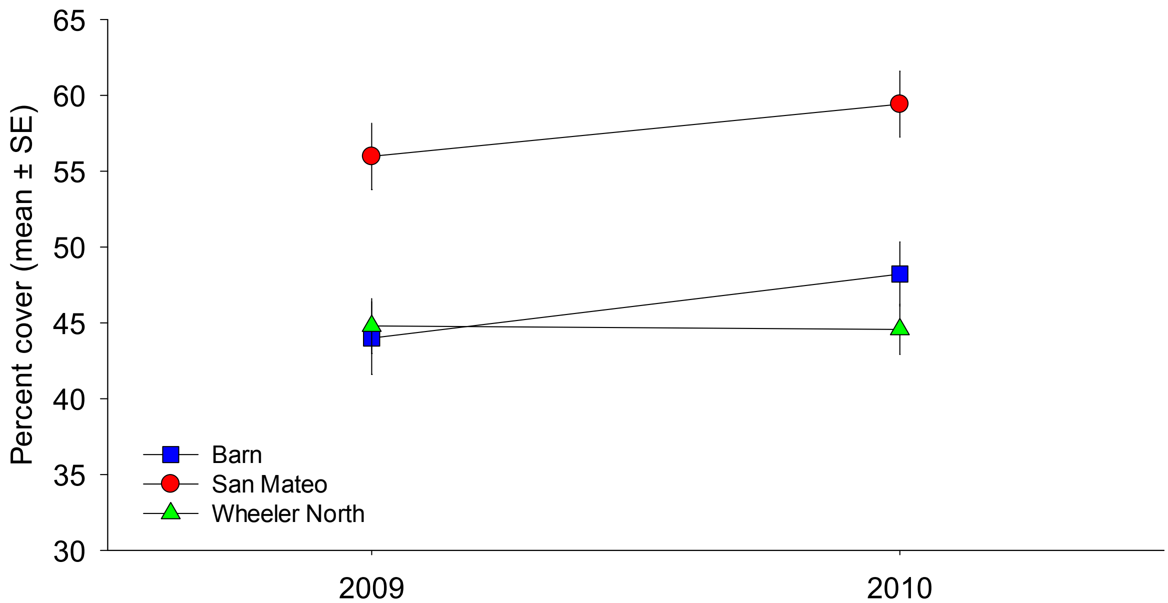

Figure 5.1.1 Mean percent cover (± 1 standard error) of exposed hard substrate at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

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.

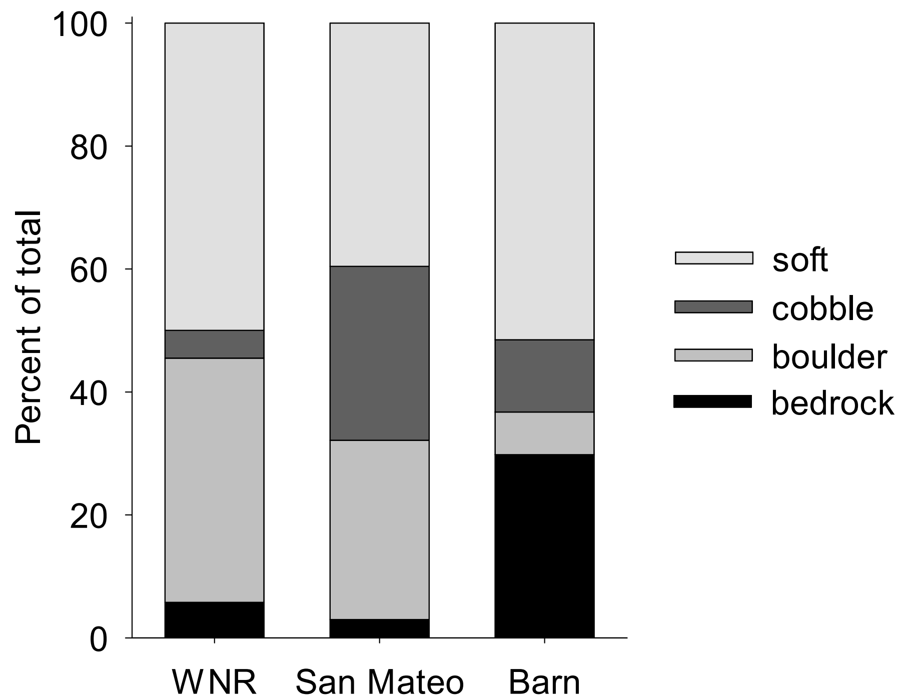

Figure 5.1.2. Distribution of substrate types at Wheeler North Reef (WNR), San Mateo and Barn.

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 we observed very high densities of giant kelp recruits 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 at Wheeler North Reef declined considerably in 2010 and was similar to levels observed at San Mateo and Barn. 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.

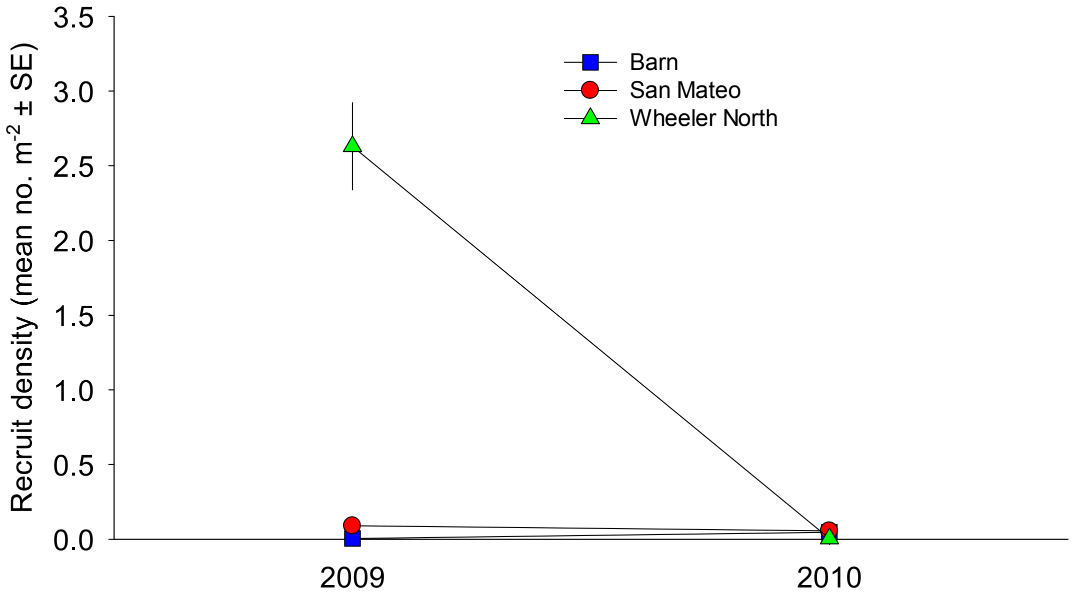

Figure 5.2.1. Mean density (± 1 standard error) of newly recruited giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef, San Mateo and Barn in 2009 and 2010

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 (Figure 5.2.3). The average density of older kelp at Wheeler North Reef in 2010 was about 3 times that observed at San Mateo and Barn, which in contrast to Wheeler North Reef showed a slight decline in the density of older kelp from 2009-2010. High densities of large kelp were observed on all of the Phase 2 polygons as well as on the Phase 1 modules (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 that at San Mateo and San Onofre, and was easily seen when viewed from space (Figure 5.2.5).

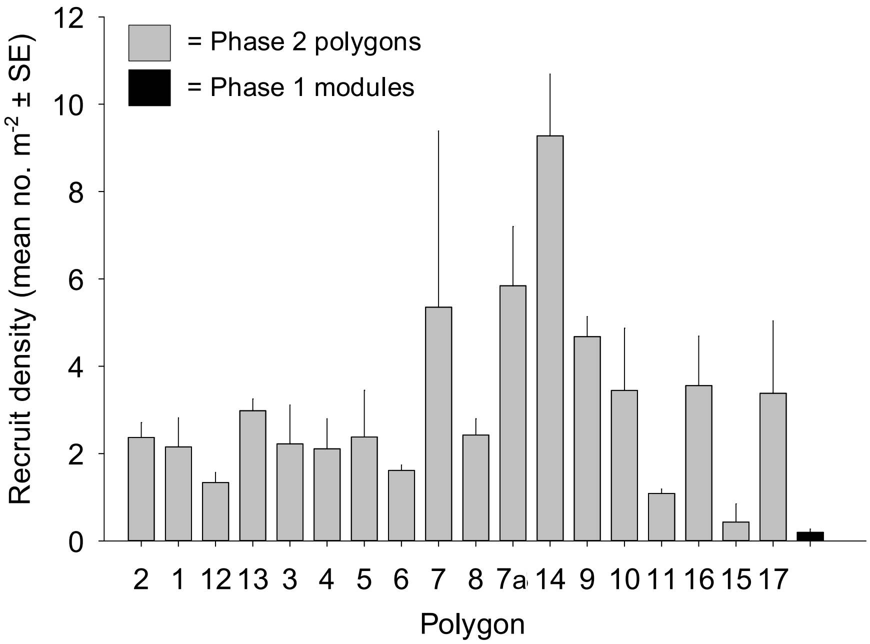

Figure 5.2.2. Mean density (± 1 standard error) of newly recruited giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef. Polygon numbers are ordered from south to north.

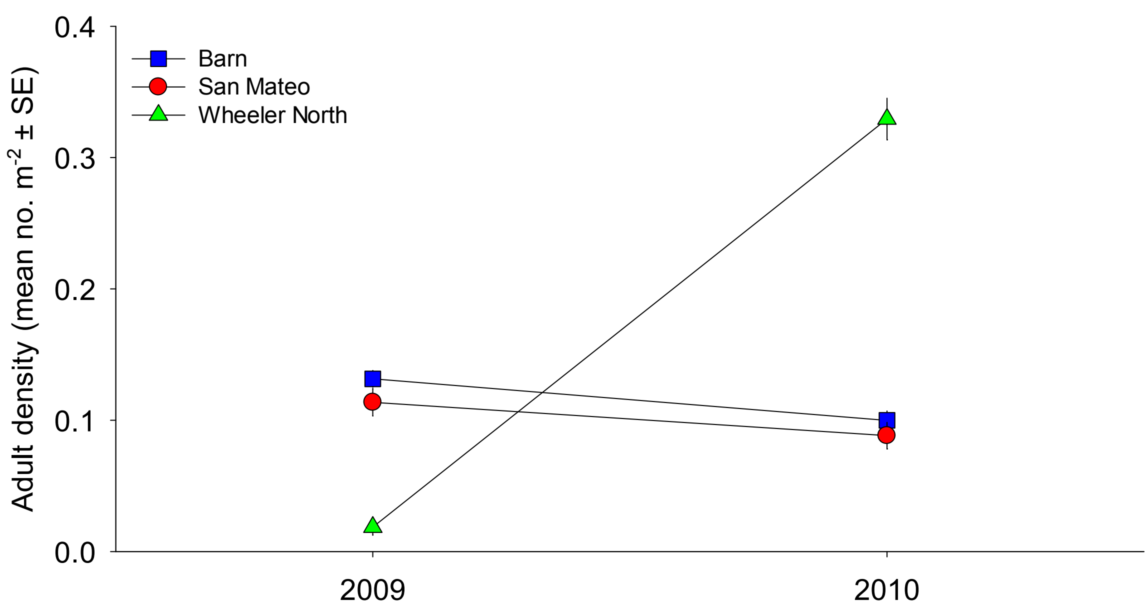

Figure 5.2.3. Mean density (± 1 standard error) of adult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

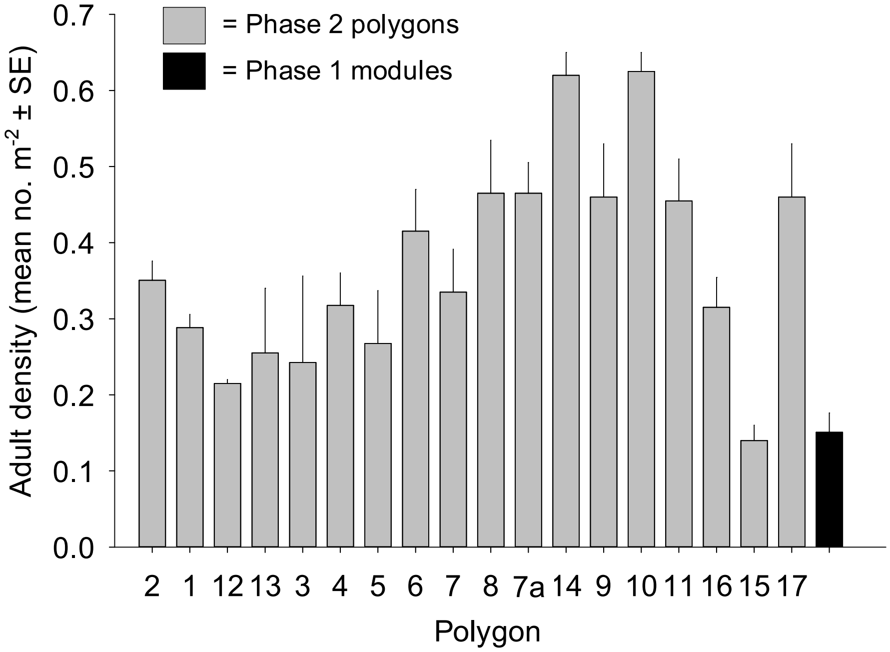

Figure 5.2.4. Mean density (± 1 standard error) of adult giant kelp plants (*Macrocystis pyrifera*) on the different polygons of Wheeler North Reef. Polygon numbers are ordered from south to north.

Figure 5.2.5. Wheeler North Reef, San Mateo and San Onofre kelp beds as seen from the Landsat 5 satellite in May of 2010. 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 and San Mateo Reefs. This is in contrast to the rather small canopy of kelp at San Onofre, which is the kelp bed impacted by SONGS' operations.

Giant kelp plants are made up of individual fronds, which 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 increased dramatically at Wheeler North Reef from 2009 to 2010 as small plants grew into adults (Figure 5.2.6). Nonetheless, kelp plants at Wheeler North Reef were still on average smaller than those at Barn and San Mateo, which were presumably older.

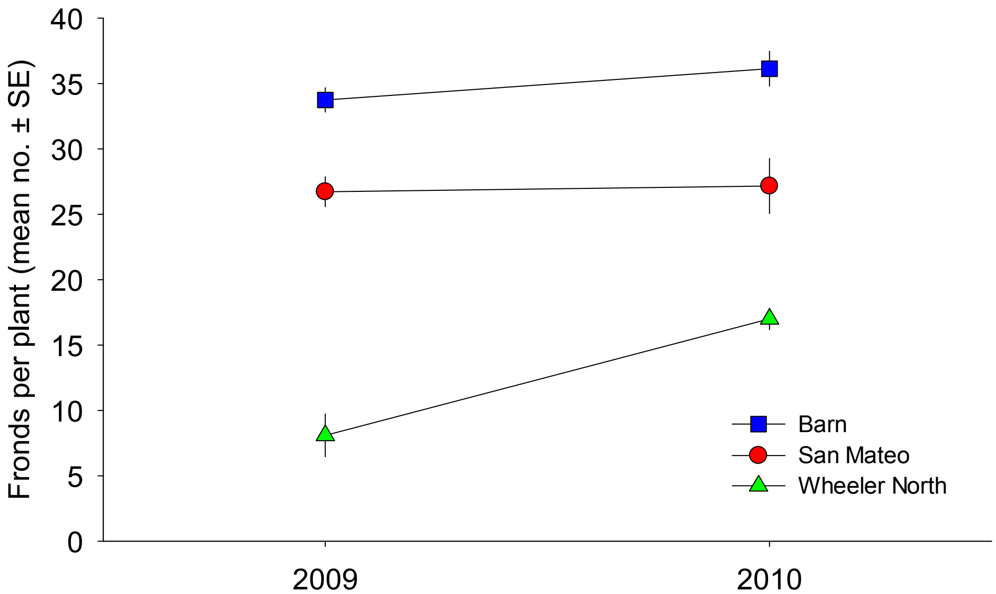

Figure 5.2.6. Mean number (± 1 standard error) of fronds per adult giant kelp plant at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

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 giant kelp biomass 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). On average the density of fronds at Wheeler North Reef in 2010 was about twice that at Barn and San Mateo.

<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.

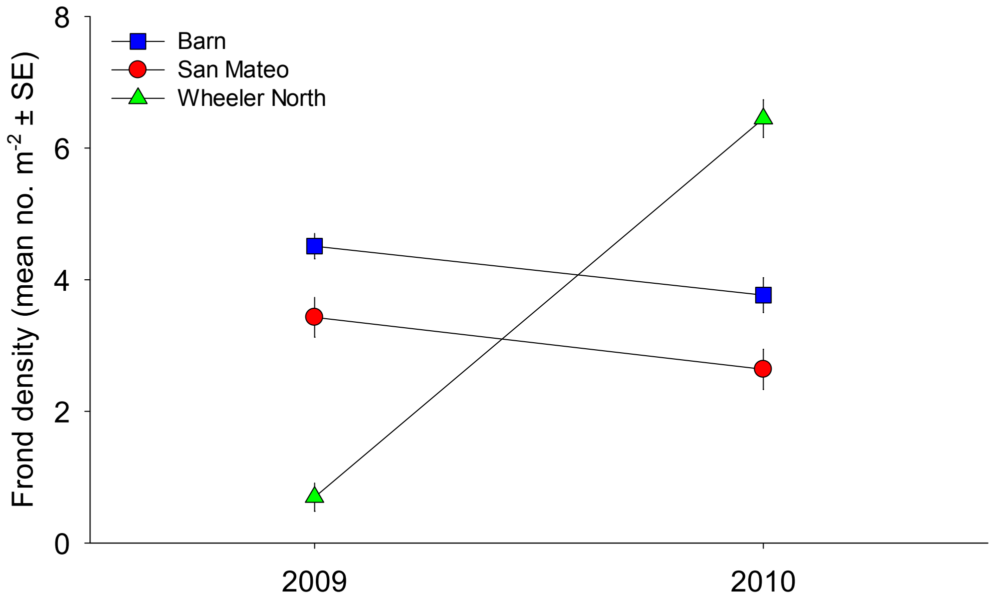

Figure 5.2.7. Mean density (± 1 standard error) of giant kelp fronds at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

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).

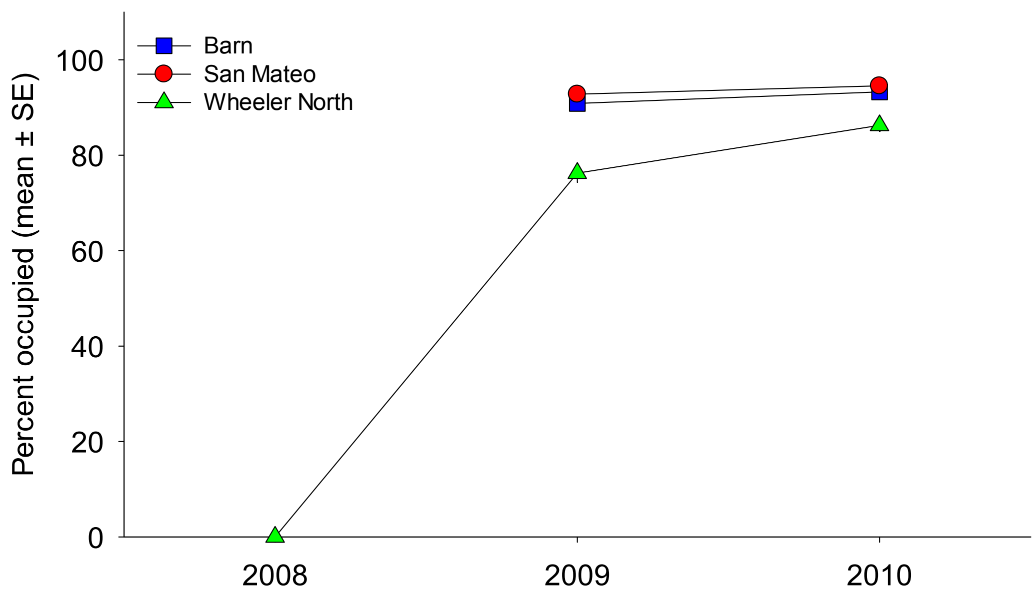

Figure 5.2.8. Mean percent (± 1 standard error) of hard substrate occupied by sessile reef biota (i.e., understory algae and sessile invertebrates) at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

The percent cover of algae and sessile invertebrates at Wheeler North Reef is rapidly approaching that observed at Barn and San Mateo, which unlike the Wheeler North Reef has remained relatively constant at about 90%.

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 from 2009 to 2010, whereas there was very little change in the percent cover of understory algae at San Mateo and Barn (Figure 5.2.9).

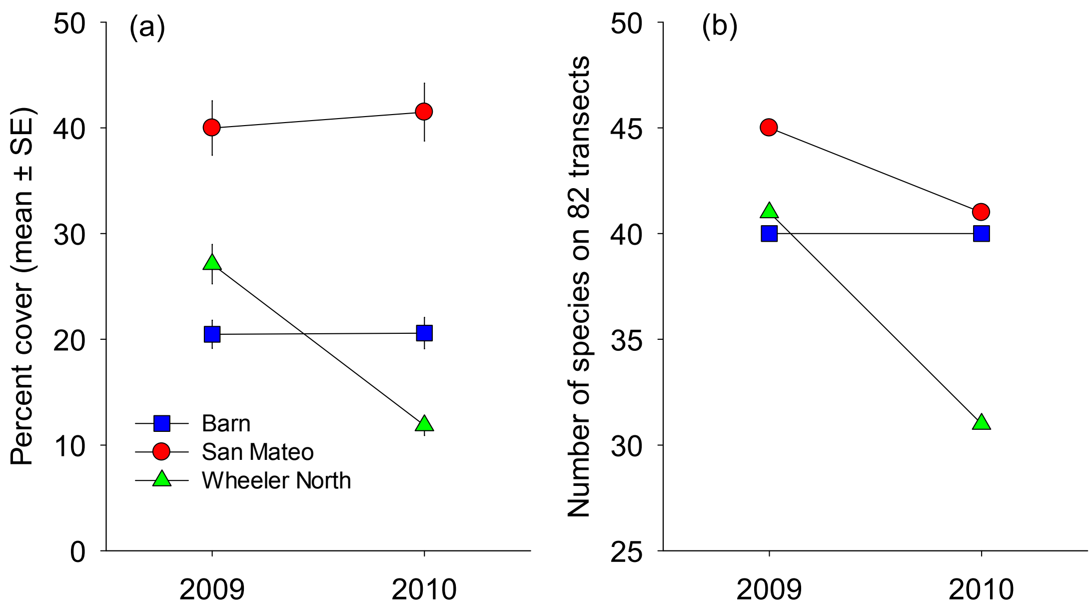

Figure 5.2.9. (a) Mean percent cover (± 1 standard error) and (b) total number of species of understory algae at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

This decline at Wheeler North Reef is to be expected given that dramatic increase in the abundance of adult giant kelp (and consequent shading) that occurred from 2009 to 2010. 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*.

The abundance of sessile invertebrates at Wheeler North Reef showed a pattern opposite to that of understory algae; their abundance nearly doubled from 2009 to 2010 reaching levels that were within the range observed at San Mateo and Barn (Figure 5.2.10a). Interestingly the total number of species of sessile invertebrates observed in the 82 transects at Wheeler North Reef did not change appreciably from 2009 and 2010, and was still substantially less than that observed at San Mateo and Barn (Figure 5.2.10b). The mix of species of sessile invertebrates at Wheeler North Reef remained relatively constant from 2009-2010, but their overall abundance increased. The sea squirt *Chelyosoma* and the sponge *Leucilla* were dominant species in both years and the abundance of both of these species increased in 2010, going from 5% to 7% and 2% to 4%, respectively.

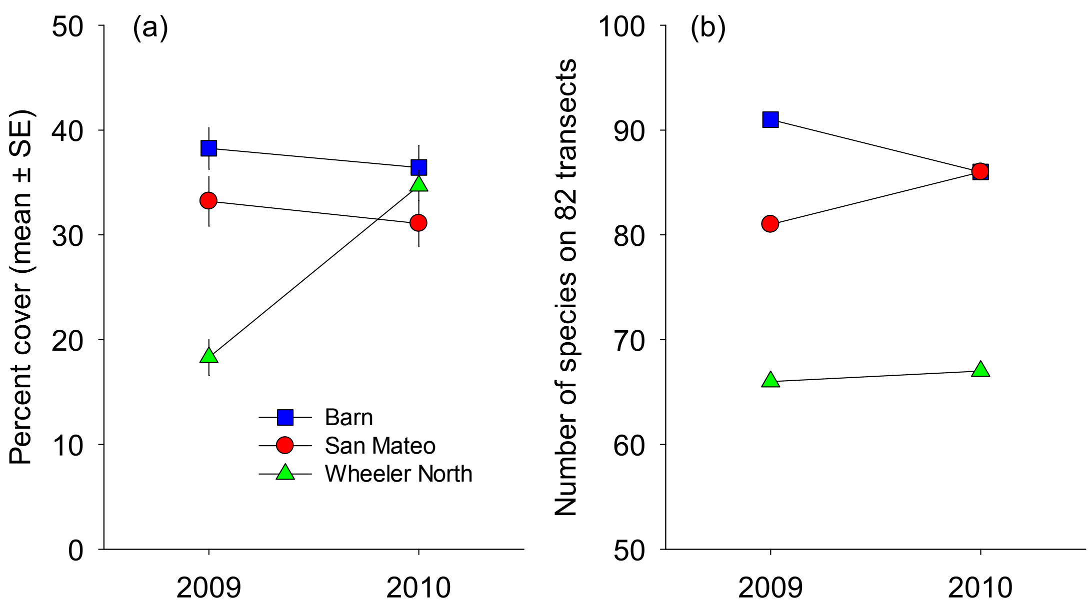

Figure 5.2.10. (a) Mean percent cover (± 1 standard error) and (b) total number of species of sessile invertebrates at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

A wide variety 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 (nearly 5 fold) from 2009 to 2010 reaching densities that were approaching those observed at San Mateo and Barn (Figure 5.2.11a). In contrast the total number of species of mobile invertebrates observed in the 82 transects at Wheeler North Reef showed only a slight increase from 2009 and 2010, and was still substantially less than that observed at San Mateo and Barn (Figure 5.2.11b). The five-fold increase in the density of mobile invertebrates resulted primarily from an increase in the density of the brittle star *Ophiothrix,* which went from an average density of 8 m^{-2} in 2009 to 42 m^{-2} in 2010. This brittle star is very common in the holdfasts of giant kelp and its increased abundance may have been due in part to an increase in the abundance of giant kelp.

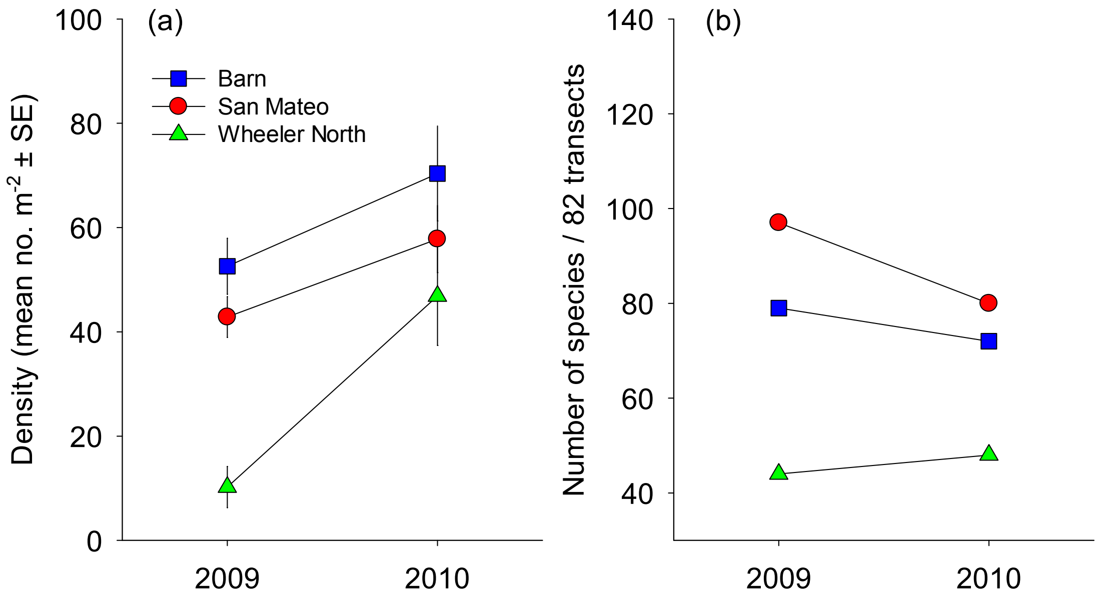

Figure 5.2.11. (a) Mean density (± 1 standard error) and (b) total number of species of mobile inveterbrates at Wheeler North, San Mateo and Barn in 2009 and 2010.

<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 5.2.12). 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. The number of species of reef fish declined on all three reefs from 2009 to 2010 at approximately the same rate. The number of species at Wheeler North Reef was intermediate between Barn and San Mateo in both years.

The high densities observed in 2009 were due to large numbers of the small blackeye goby, (*Rhinogobiops nicholsii)* which attained an average density of ~65 per $100m^{-2}$ (Figure 5.2.13). The next four most abundant species in 2009, blacksmith, barred sand bass, señorita, and scorpionfish averaged < 5 individuals 100 m^{-2}. Collectively, these five species accounted for 96% of all fish counted on transects at Wheeler North Reef in 2009. The large decrease in overall abundance of kelp bed fish in 2010 was due primarily to a 10 fold reduction in the density of blackeye gobies. Four of the five most abundant species in 2009 remained in the top 5 of the most abundant species in 2010. The only change was that señorita were replaced by pile perch. In contrast to 2009, the top five species in 2010 accounted for only 77 % of the all fish counted. This is because the abundance was more evenly distributed among species.

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 and did so at approximately the same rate (Figure 5.2.14). In contrast to numerical density, the biomass density of fish at Wheeler North Reef was similar to that at San Mateo, but considerably less than that at Barn.

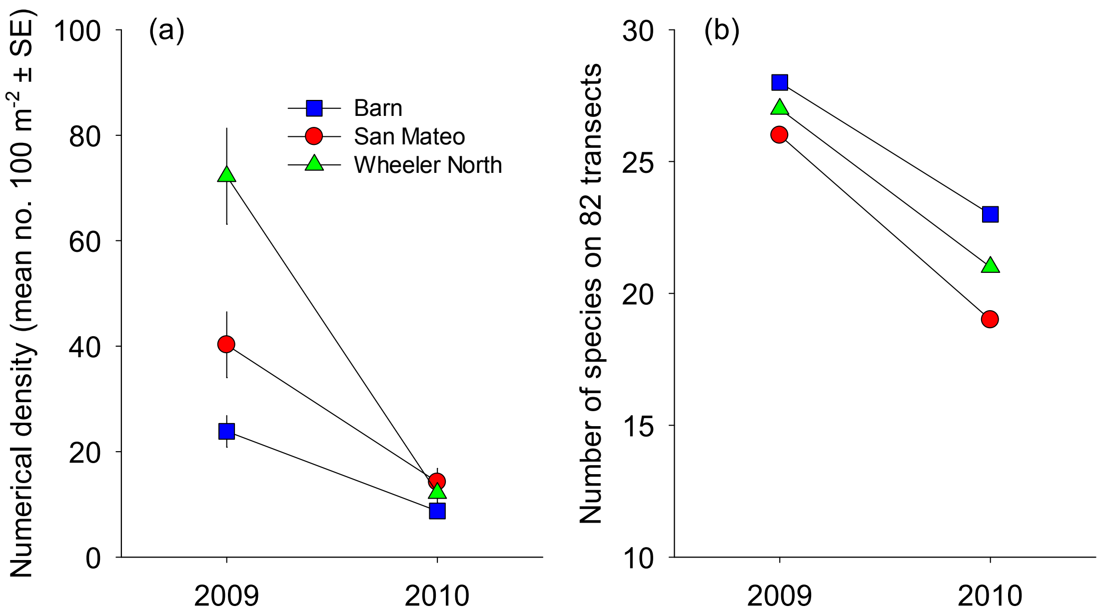

Figure 5.2.12. (a) Mean numerical density (± 1 standard error) and (b) total number of species of fish at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

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 and on average weigh only about 3 grams. Consequently, even though gobies were almost 50 times more abundant than barred sand bass, they accounted for only about half the biomass of barred sand bass (Figure 5.2.15). Four of the five most dominant species at Wheeler North Reef in 2009 in terms of biomass density declined in biomass in 2010. The lone exception was the sheephead wrasse, which nearly doubled in biomass density to become the most dominant species in 2010. This species is not very abundant at Wheeler North Reef, but because of its large size it accounted for a substantial amount of the fish biomass at Wheeler North Reef in 2010.

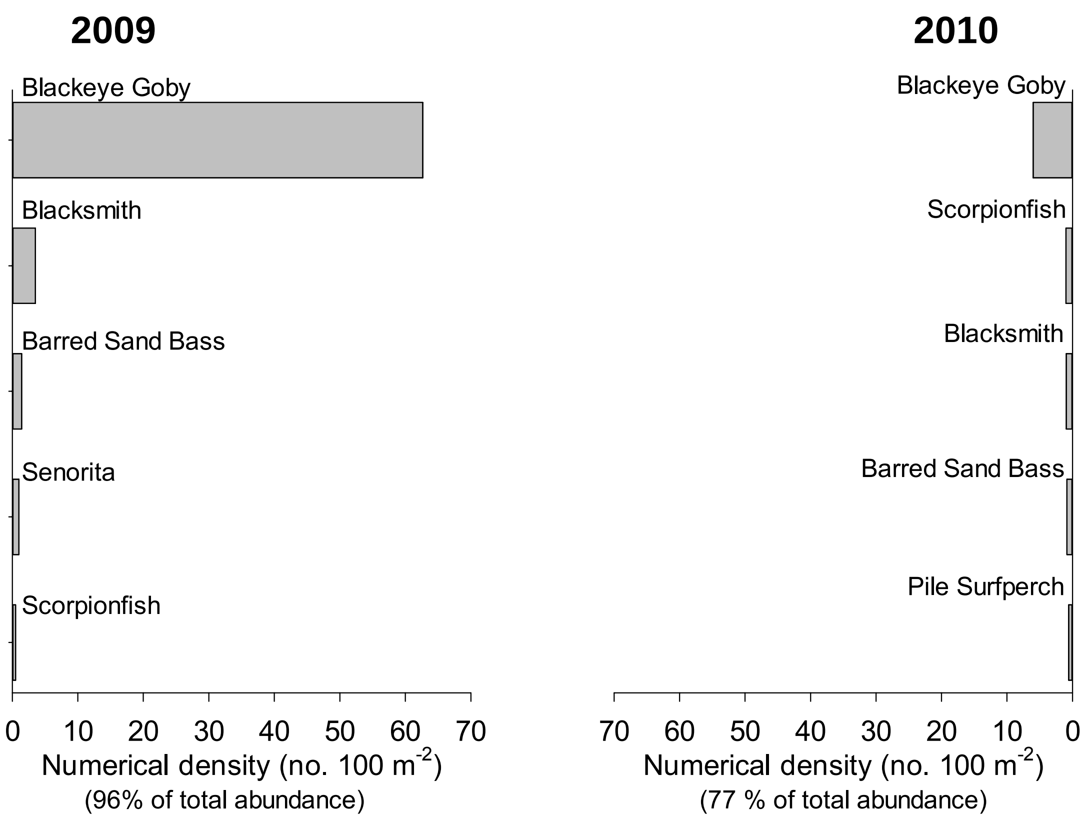

Figure 5.2.13. Numerical density of the five most abundant fish species at Wheeler North Reef in 2009 and 2010. The percentage of the total number of fish comprised by the most abundant 5 species is shown in parentheses.

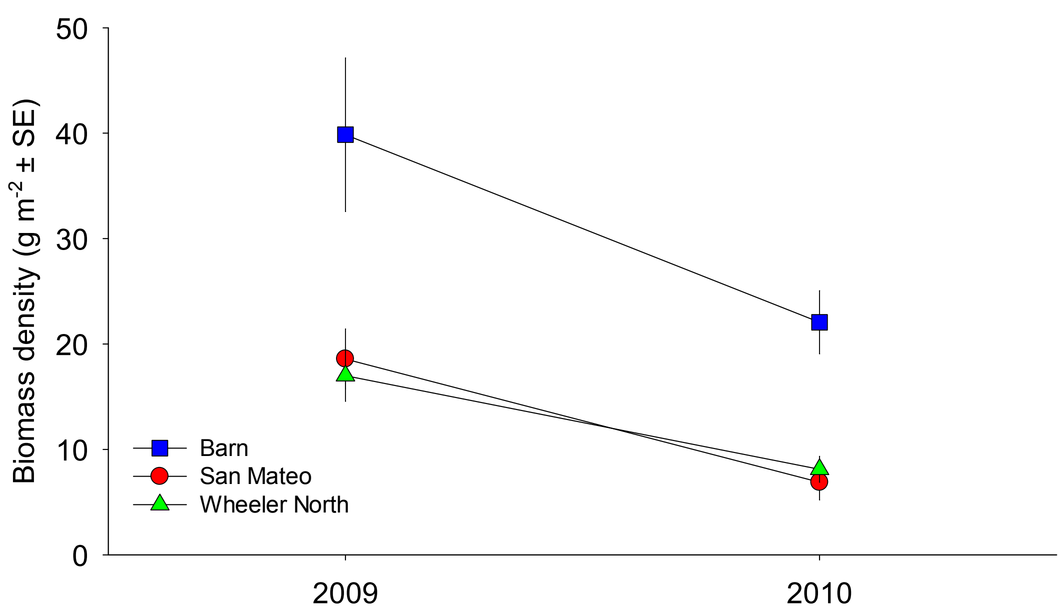

Figure 5.2.14. Mean biomass density (± 1 standard error) of fish at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

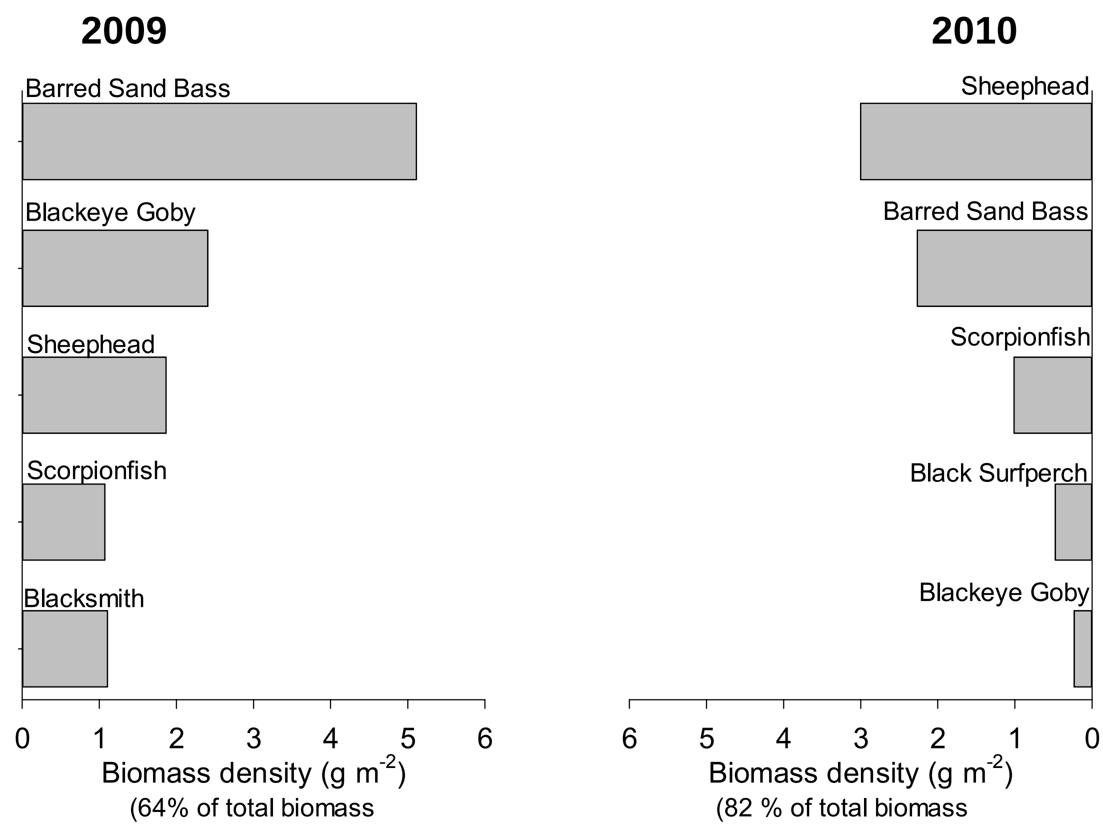

Figure 5.2.15. Biomass density of the five most abundant fish species at Wheeler North Reef in 2009 and 2010. The percentage of the total biomass of fish comprised by the most abundant 5 species is shown in parentheses.

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. 2010).

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.

Results: Both the footprint area of Wheeler North Reef and the proportion of it that is covered by hard substrate declined slightly during the period 2008 to 2010 (Figure 6.1a & b). These declines resulted in about a 3.5% decrease in the total area of hard substrate (Figure 6.1.1c). This change is well above the 90% value of the performance standard. Thus Wheeler North Reef met the hard substrate standard for both 2009 and 2010.

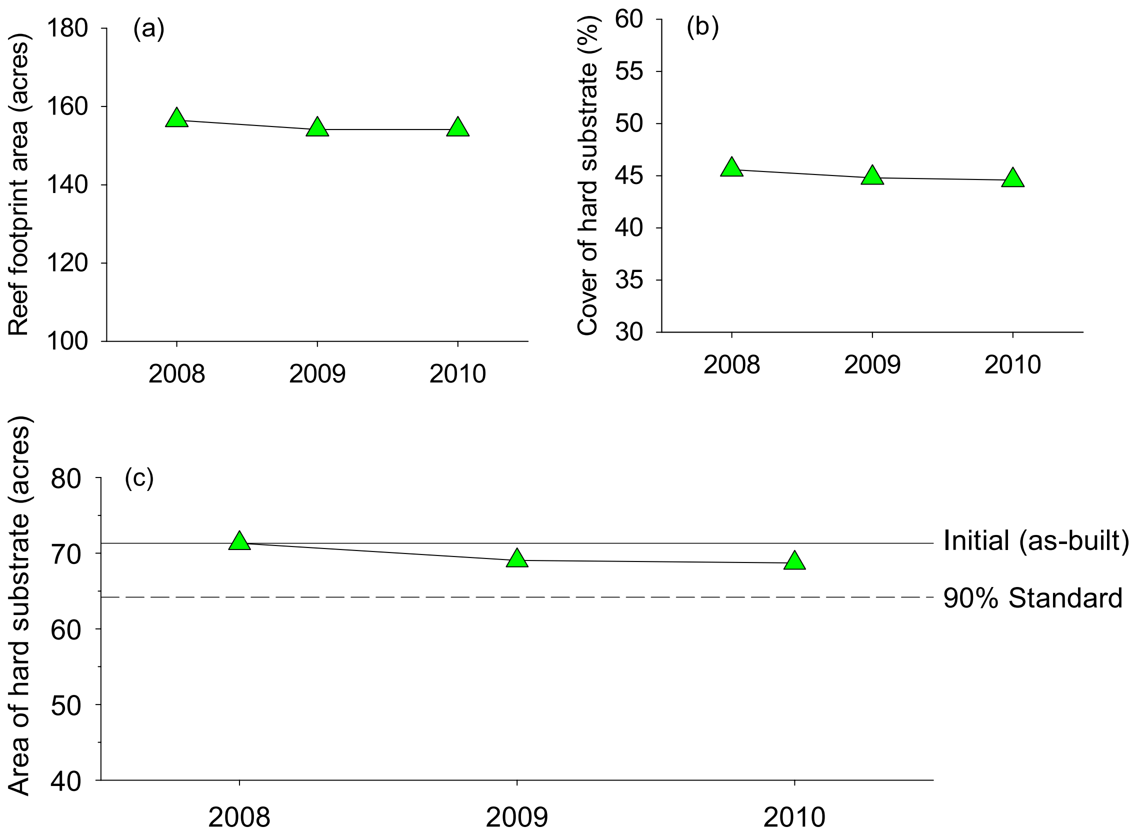

Figure 6.1. Variables used to calculate exposed hard substrate. (a) Reef footprint area, (b) Percent cover of hard substrate, and (c) Area of exposed hard substrate.

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 $100m^2$ 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 $100m^2$ (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, 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. 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: When the proportion of transects with ≥ 4 plants per $100m^2$ kelp is multiplied by 176 acres (which is the estimate of the area encompassed by Wheeler North Reef in the most recent sonar survey done in 2009) we find that Wheeler North Reef met the performance standard for giant kelp in 2010, but not in 2009 (Figure 6.2). The area of medium-to-high density adult kelp at Wheeler North Reef was only 19 acres in 2009, but increased dramatically to 174 acres in 2010. Most notably 91 of the 92 transects sampled in 2010 had at least 4 adult plants per $100m^2$.

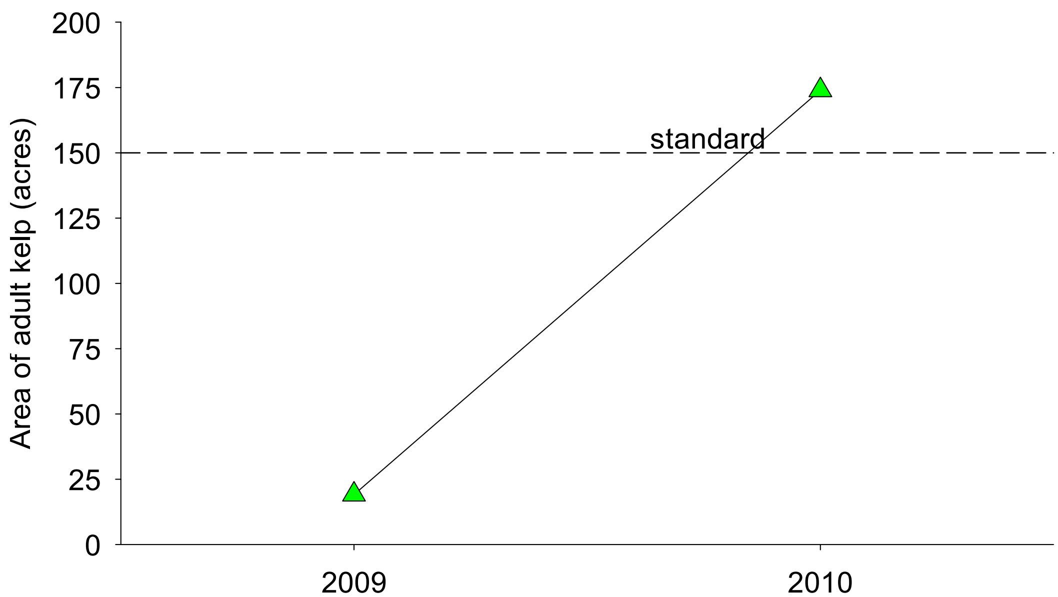

Figure 6.2. The number of acres of medium-to-high density giant kelp at Wheeler North Reef.

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 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 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). 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 standing stock of reef fish that live near the bottom at Wheeler North Reef declined by ~50% between 2009 to 2010 (Figure 6.3).

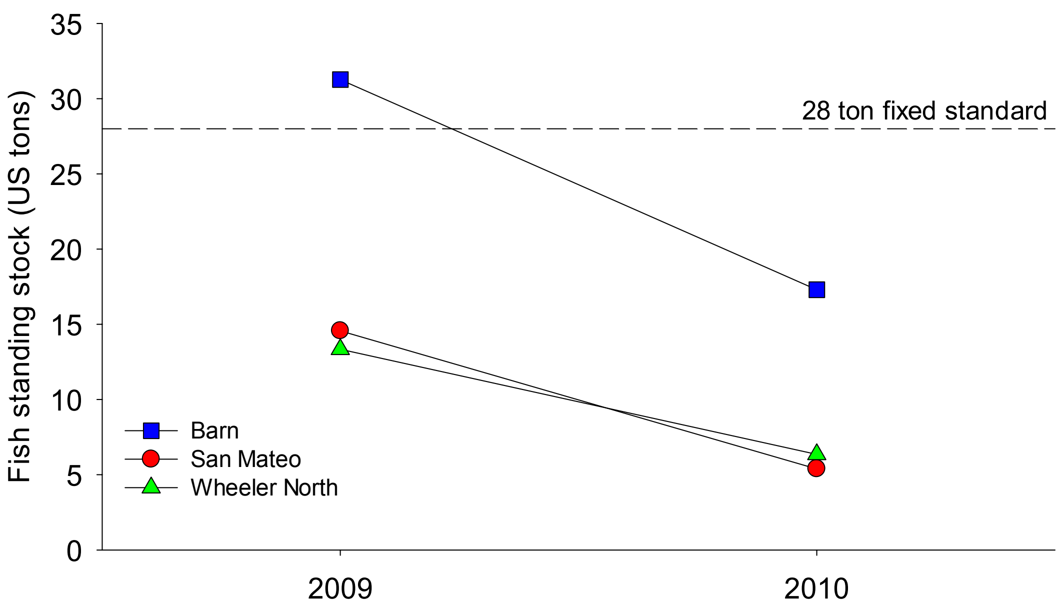

Figure 6.3. Estimated standing stock of fish at Wheeler North Reef, San Mateo and Barn in 2009 and 2010. Standing stock at San Mateo and Barn in each year are scaled to the area of Wheeler North Reef for that year.

Similar declines were observed at Barn and San Mateo. The standing stock of fish at Wheeler North Reef was estimated to be very close to that of a similar sized area at San Mateo, but only about half of that of a similar sized area at Barn. Importantly, Wheeler North Reef was far below the fixed performance standard of 28 tons in both 2009 and 2010.

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 2m x 2m transects.

Results: The density of resident fishes near the bottom at Wheeler North Reef was 2 to 3 times greater than that at San Mateo and Barn in 2009, 1 year after the Wheeler North Reef was built (Figure 6.4).

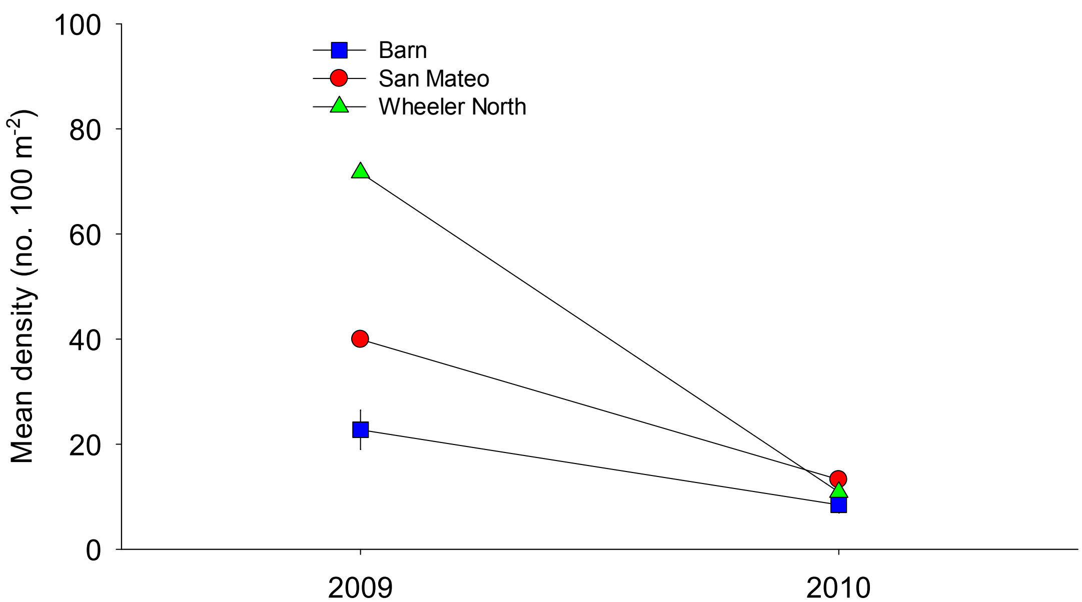

Figure 6.4. Mean density of resident kelp forest fishes at Wheeler North Reef, San Mateo and Barn in 2009 and 2010. 80% confidence intervals are shown for the reference reef with the lowest mean value.

The density of resident fishes declined markedly at all three reefs in 2010, largely due to a decrease in the density of the blackeye goby in the region. The decline in density was greater at Wheeler North Reef than at San Mateo and Barn because of the higher densities of blackeye gobies there. As a result the density of resident fishes at all three reefs was very similar in 2010, and the mean value for Wheeler

North Reef was intermediate between that of San Mateo and Barn. Thus Wheeler North Reef met the performance standard for the density of resident fishes in both 2009 and 2010.

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 generate 80% confidence intervals for the initial slope and the asymptote for purposes of determining similarity. Both the initial slope and the asymptote at Wheeler North Reef must be equal to or greater than the lower 80% confidence limit of these parameters at the reference reef with the lowest mean values for Wheeler North Reef to meet this performance standard.

Results: The slopes of the relationship between the number of transects sampled and the number of resident reef fish species observed remained relatively unchanged at Wheeler North and San Mateo from 2009 to 2010, but declined noticeably at Barn (Figure 6.5a). In contrast the total number of species of resident fish at each reef (as estimated by the asymptote of the species area curve) declined by about 20% at all three reefs (Figure 6.5b). Importantly, the values for both the slope and asymptote at Wheeler North Reef were intermediate between those at Barn and San Mateo in both 2009 and 2010. Therefore Wheeler North Reef met the performance standard pertaining to the number of species of resident reef fish in both 2009 and 2010.

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 annual per capita egg production of a select group of targeted reef fish species are collected at Wheeler North Reef, San Mateo, and Barn during 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 sheephead wrasse, black surfperch, señorita, and kelp bass. These species represent the major feeding and reproductive guilds of fishes on southern California reefs and are sufficiently abundant to facilitate collection.

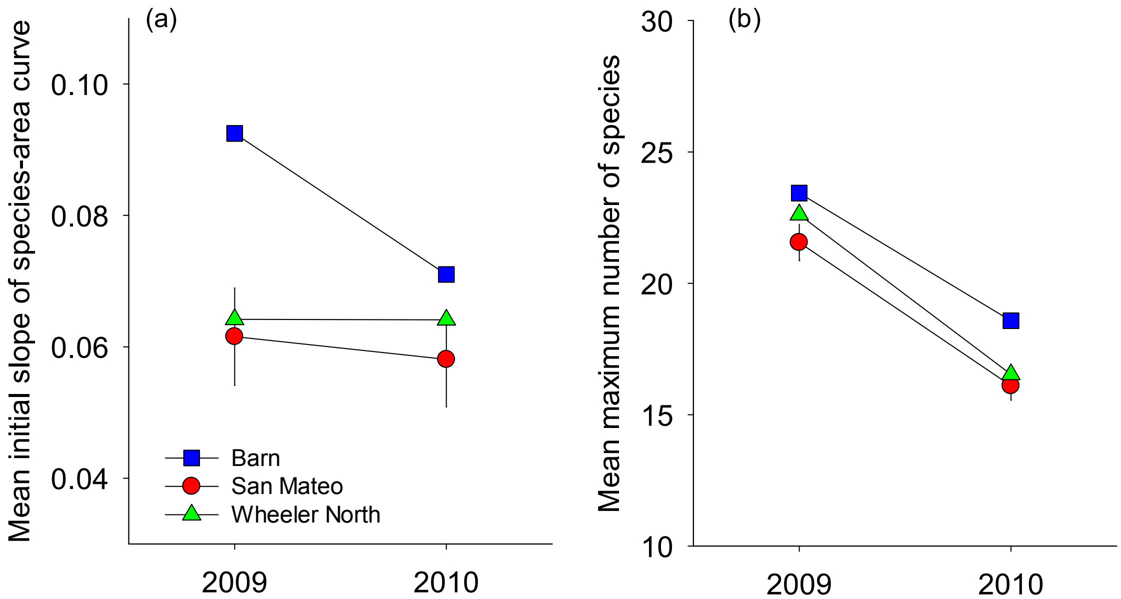

Figure 6.5. (a) Mean initial slope of species-area curve for adult resident fish species at Wheeler North Reef, San Mateo and Barn in 2009 and 2010. (b) Mean maximum number of species of resident fishes at the three reefs (asymptotic value of the species area curve). 80% confidence intervals are shown for the reference reef with the lowest mean value.

The relationship between the production of eggs (or embryos in the case of black surfperch) by a female vs. its body length for all four species combined is used to evaluate this performance standard. Egg production is scaled to body length to account for the fact that larger individuals tend to produce more eggs. The annual mass of eggs (or number of embryos in the case of black surfperch) produced per individual is calculated for each female specimen. Reproductive rates and fish lengths are standardized within species across reefs using a Z transformation (Z = (observed value – mean value$_{\text{species } i}$) / standard deviation$_{\text{species } i}$). Parameter estimates for standardized slopes and intercepts are averaged across species to produce standardized mean slopes and intercepts for each of the three reefs. Fish reproductive rates at Wheeler North Reef are considered similar to that at natural reference reefs if the standardized values of egg/embryo production at Wheeler North Reef are greater than or equal to the lower 80% confidence limit of the reference reef with the lowest standardized values of egg/embryo production for the entire size range of fish sampled.

<u>Results:</u> The production of eggs and embryos by target species at Wheeler North Reef was similar to or greater than that at Barn and San Mateo in both years of monitoring. In 2009, egg/embryo production tended to be higher in smaller fish at Wheeler North Reef compared to Barn and San Mateo and lower in larger fish at Wheeler North Reef compared to Barn, but similar to that at San Mateo (Figure

6.6a). Importantly, egg/embryo production was greater than the lower 80% confidence limit at San Mateo for all sizes of fish sampled. In 2010, egg and embryo production at Wheeler North Reef was consistently greater than that at Barn and San Mateo regardless of fish size (Figure 6.6b). Thus Wheeler North Reef met the performance standard for fish reproductive rates in both 2009 and 2010.

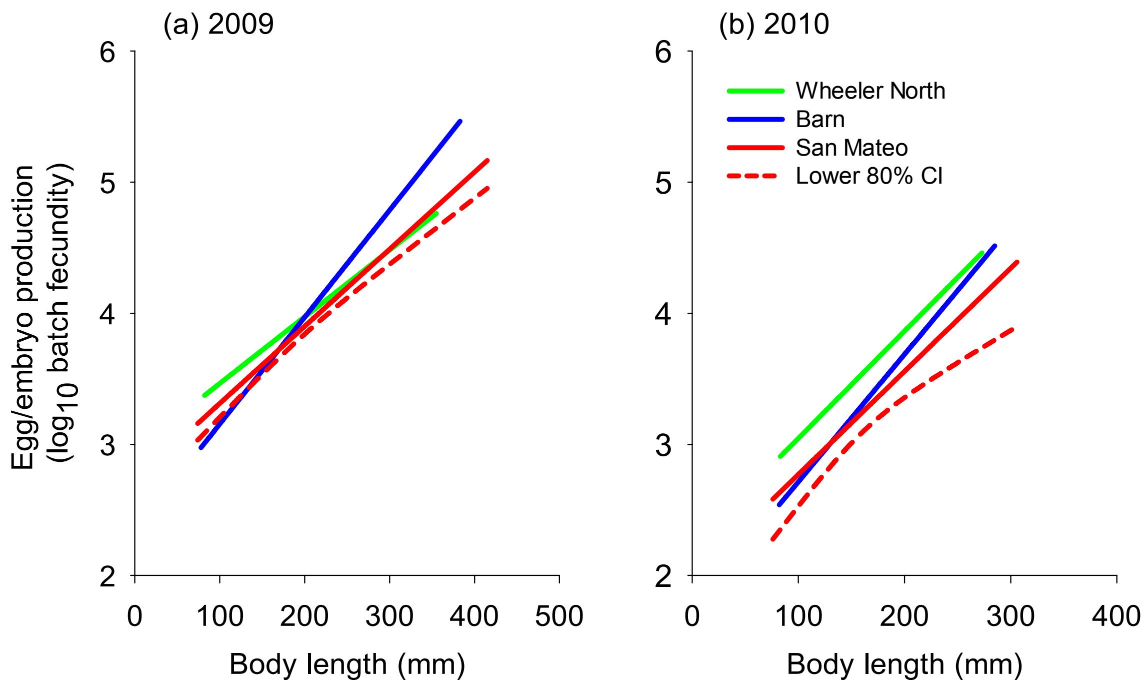

Figure 6.6. Relationship between egg production and body length for four species of kelp forest fish at Wheeler North Reef, Barn and San Mateo in (a) 2009 and (b) 2010.

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: Data on the density of young-of-year fishes 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 fishes increased at Wheeler North and San Mateo from 2009 to 2010 and decreased at Barn (Figure 6.7). The highest densities of young-of-year fishes in 2010 were observed at Wheeler North Reef. While these trends are significant the actual densities of young-of-year fishes were quite low on all three reefs, averaging about 1 individual per 100 m^2 transect. Nonetheless, these data show that Wheeler North Reef easily met this performance standard in 2009 and 2010.

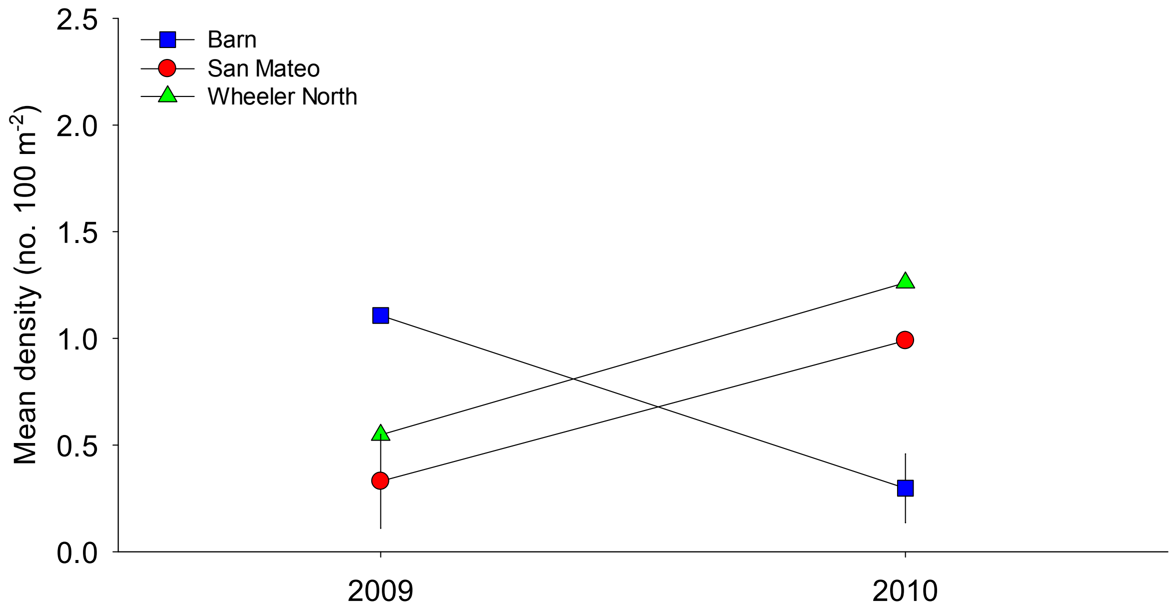

Figure 6.7. Mean density of young-of-year kelp forest fishes at Wheeler North Reef, San Mateo and Barn in 2009 and 2010. 80% confidence intervals are shown for the reference reef with the lowest mean value.

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: Relatively few species of young-of-year fishes (i.e. < 8) were observed at any of the reefs during 2009 and 2010. In 2009, both the slope (i.e. the rate of increase in new species counted) and the asymptote (i.e., the total number of species counted in all transects) of the species-area curve for young-of-year fishes at Wheeler North Reef were intermediate between Barn and San Mateo (Figure 6.8). In 2010, however, both of these components of species number had the highest values at Wheeler North Reef. Thus the Wheeler North Reef met this performance standard in both 2009 and 2010.

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 information collected for the purpose of estimating fish abundance and size structure for performance standards pertaining to fish density and standing stock, fish reproductive rates, combined with additional estimates of somatic growth rates obtained from otolith studies. Importantly, this method of estimating fish production assumes no net migration.

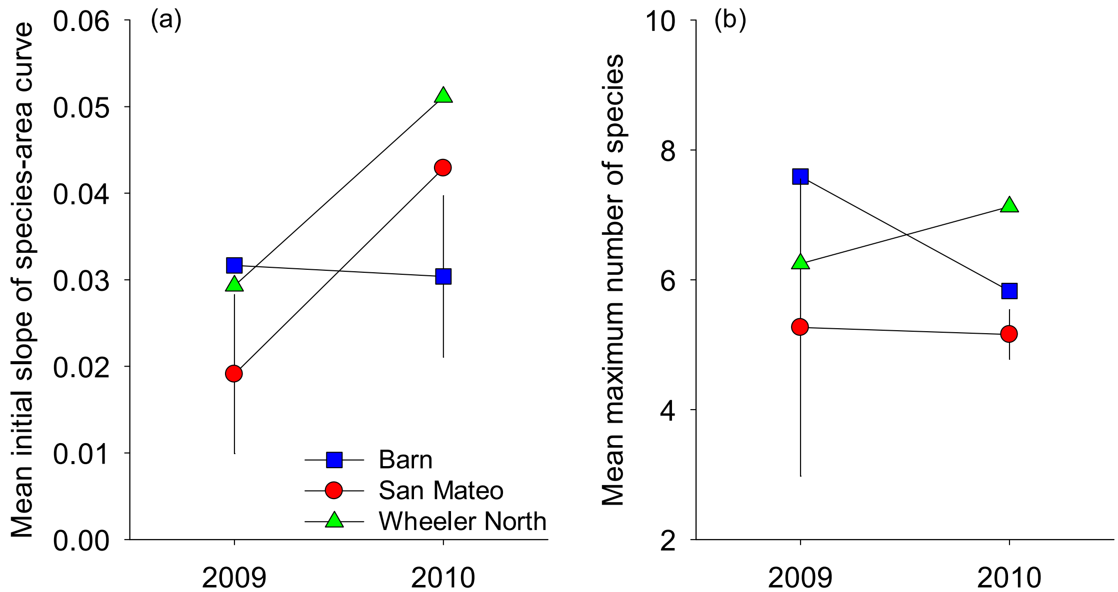

Figure 6.8. (a) Mean initial slope of species-area curve for young-of-year fishes at Wheeler North Reef, San Mateo and Barn in 2009 and 2010. (b) Mean maximum number of species of young-of-year fishes at the three reefs (asymptotic value of the species area curve). 80% confidence intervals are shown for the reference reef with the lowest mean value.

Fish production is estimated for five target species: blacksmith, black surfperch, señorita, sheephead and kelpbass. 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 senorita 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 a representative estimate of the annual fish production (± 80% confidence limits) for each of the three reefs. The value of fish production at Wheeler North Reef must be greater than or equal to the lower 80% confidence limit of the reference reef with the lowest mean value of fish production for Wheeler North Reef to meet this performance standard.

Results: Much like that observed for fish density and fish biomass, there was a dramatic 70-80% decline in fish production from 2009 to 2010 at all three reefs (Figure 6.9). The values observed at Wheeler North were intermediate between San Mateo and Barn in both 2009 and 2010 demonstrating that Wheeler North Reef met the performance standard for fish production in both 2009 and 2010.

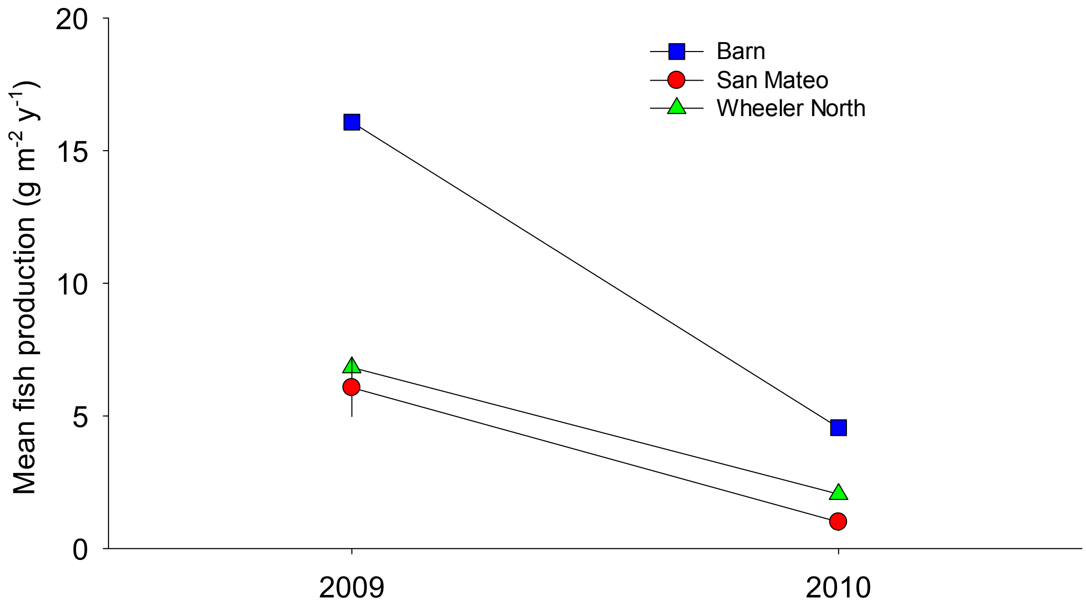

Figure 6.9. Mean fish production at Wheeler North Reef, San Mateo and Barn in 2009 and 2010. 80% confidence intervals are shown for the reference reef with the lowest mean value.

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

Approach: The benthic communities of algae and macroinvertebrates at Wheeler North Reef, San Mateo, and Barn are sampled annually in the summer. Many of the understory algae and sessile invertebrates are difficult to count as individuals and hence their abundance is estimated as percent cover. The percent cover of sessile invertebrates and understory algae 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%. For Wheeler North Reef to meet this performance standard its combined percent cover of algae and invertebrates must be greater than or equal to that of the lower 80% confidence limit of the reference reef with the lowest combined mean cover of algae and invertebrates.

Results: The percent cover of algae and invertebrates combined showed very little change between 2009 and 2010 on all three reefs (Figure 6.10).

As noted above (Figures 5.2.9 and 5.2.10), an increase in the percent cover of sessile invertebrates at Wheeler North Reef from 2009-2010 was countered by a corresponding decrease in the percent cover of understory algae. This resulted in only a very modest increase in the combined cover of algae + invertebrates at

Wheeler North Reef in 2010. Importantly, the combined cover of algae + invertebrates at Wheeler North Reef was noticeably lower than that at the two reference reefs in both 2009 and 2010. Consequently, Wheeler North Reef did not meet this performance standard in either 2009 or 2010.

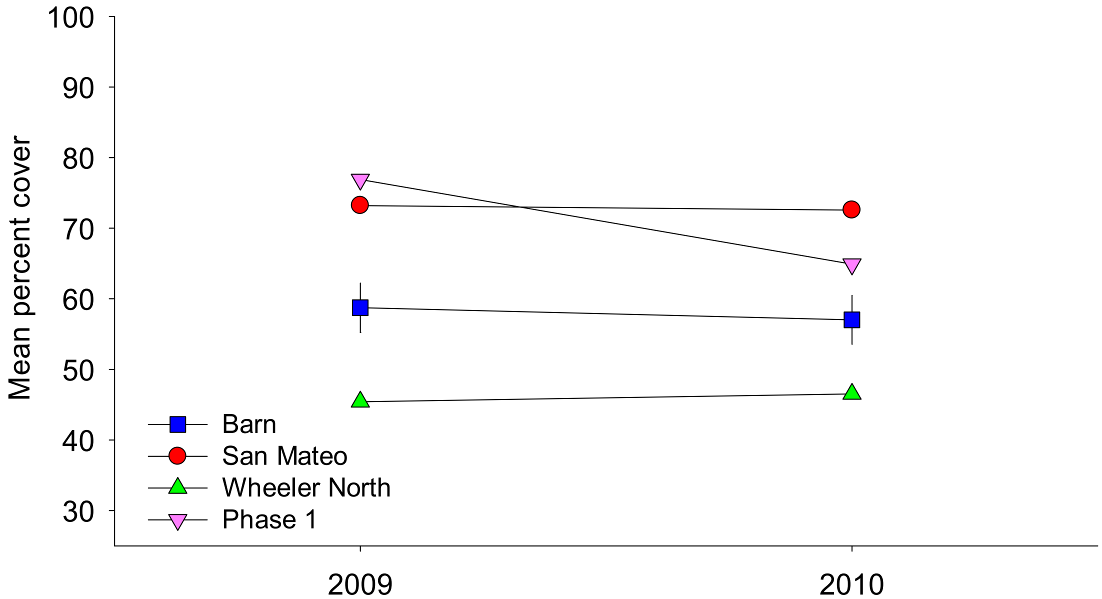

Figure 6.10. Mean percent cover of algae and sessile invertebrates combined at Wheeler North Reef, San Mateo, Barn and the Phase 1 Experimental Reef in 2009 and 2010. 80% confidence intervals are shown for the reference reef with the lowest mean value.

The mean combined cover of algae + invertebrates on modules of the older Phase 1 Experimental Reef was greater than that at San Mateo and Barn in 2009 and Barn in 2010. If the percent cover of the benthic biota on the Phase 2 polygons of Wheeler North Reef follows a trajectory similar to that observed for the Phase 1 modules, then we would expect the combined cover of algae + invertebrates at Wheeler North Reef to increase over time to a level that is similar to or greater than at San Mateo and Barn.

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., nudibranchs, shelled gastrapods, 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 unit area of reef. For Wheeler North Reef to meet this performance standard its combined density of mobile invertebrates must be greater than or equal to that of the lower 80% confidence limit of the reference reef with the lowest mean density of mobile invertebrates.

Results: The colonization of mobile invertebrates at Wheeler North Reef was initially sparse and their densities in 2009 were much lower than that at Barn and San Mateo (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 at Wheeler North Reef was slightly less than the lower 80% confidence interval at San Mateo, the reference reef with the lower density in 2010. Consequently, the performance standard for the density of mobile invertebrates was not met by Wheeler North Reef in either 2009 or 2010, although in 2010 it approached a value that was nearly similar to that of San Mateo (as determined by the lower 80% confidence limit).

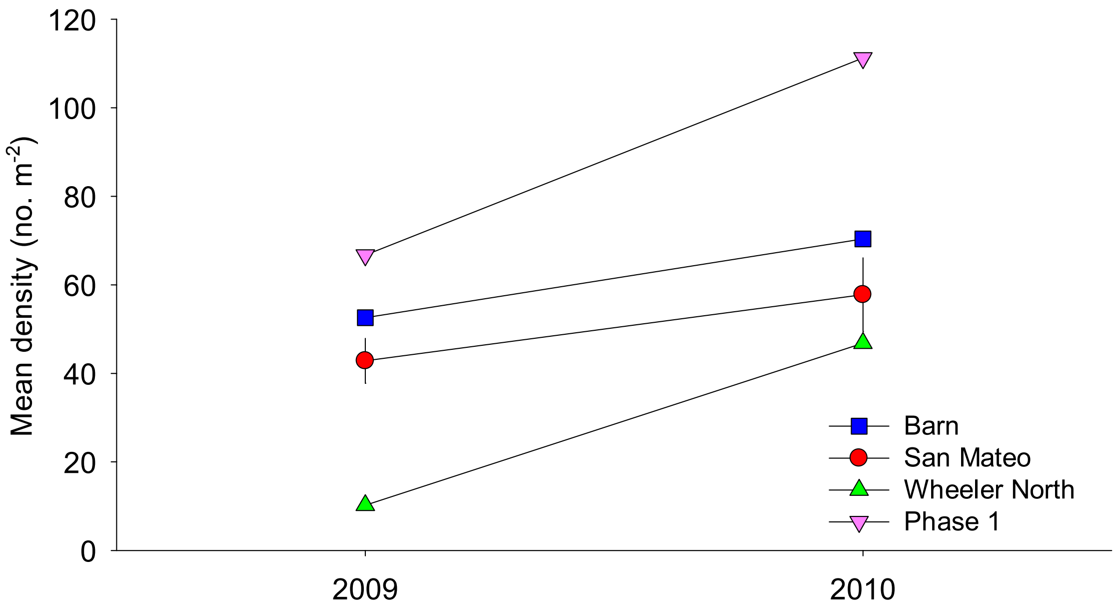

Figure 6.11. Mean density of mobile invertebrates at Wheeler North, San Mateo, Barn and the Phase 1 Experimental Reef in 2009 and 2010. 80% confidence intervals are shown for the reference reef with the lowest mean value.

The density of mobile invertebrates on the older Phase 1 experimental modules was more than twice that of the larger Wheeler North Reef in both 2009 and 2010. If the abundance of mobile invertebrates on the Phase 2 polygons of Wheeler North Reef follows a trajectory similar to that observed for the Phase 1 modules, then we would expect the density of mobile invertebrates at Wheeler North Reef to increase over time to a level that is similar to or greater than that at San Mateo and Barn.

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 count 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 for algae + invertebrates at Wheeler North Reef increased from 2009 to 2010 to reach a value that was nearly equal to that observed at San Mateo and was within the 80% confidence limit of the mean rate at San Mateo (Figure 6.12a). Thus this component of the performance standard pertaining to the number of species of algae and invertebrates was met in 2010, but not in 2009. In contrast, the total number of species (as estimated by the asymptote) declined on all three reefs in 2010 at approximately the same rate (Figure 6.12b). Most notably, the total number of species of algae and invertebrates at Wheeler North Reef was well below that at Barn and San Mateo in 2009 and 2010. Consequently, this component of the standard for species number of algae + invertebrates was not met by Wheeler North Reef in either 2009 or 2010. Because both the slope and asymptote of the species area curve at Wheeler North Reef must be similar to those at the reference reefs, Wheeler North Reef did not meet this performance standard in either 2009 or 2010.

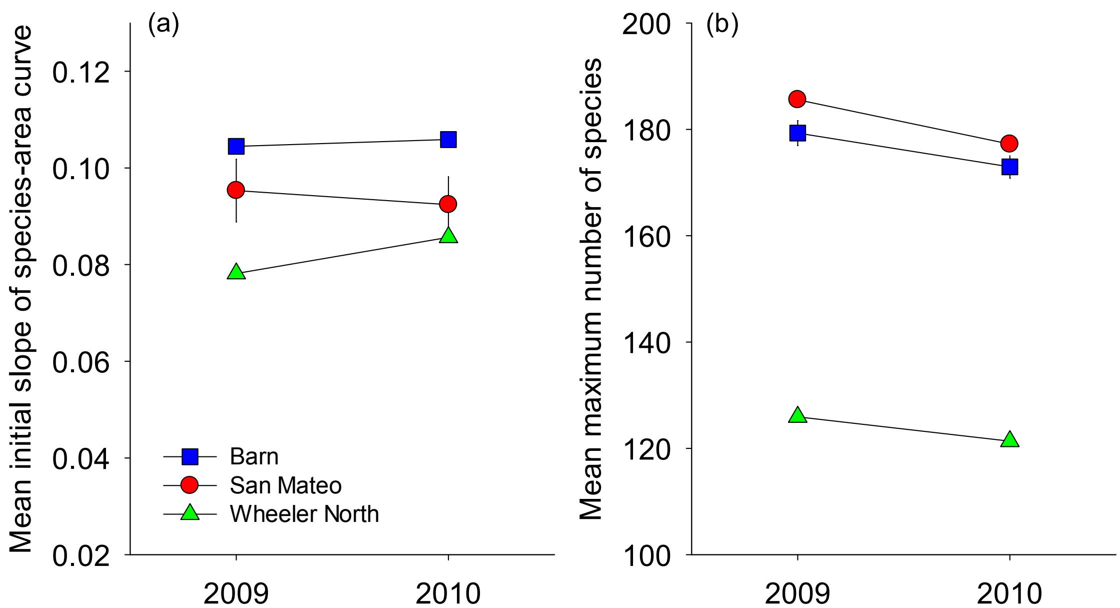

Figure 6.12. (a) Mean initial slope of species-area curve for the benthic community of algae and invertebrates at the Wheeler North Reef, San Mateo and Barn in 2009 and 2010. (b) Mean maximum number of species of algae and invertebrates at the three reefs (asymptotic value of the species area curve). 80% confidence intervals are shown for the reference reef with the lowest mean value.

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 data from both species; however, it does not allow FCS values to be compared among years. While this limitation does not affect our ability to evaluate the performance standard in any given year, it does preclude the examination of trends in the standardized FCS over time. For Wheeler North Reef to meet this performance standard its standardized FCS index must be greater than or equal to that of the lower 80% confidence limit of the reference reef with the lowest standardized FCS index.

Results: The FCS index for black surfperch was higher at Wheeler North Reef compared to San Mateo or Barn in 2009 and 2010 (Figure 6.13a), whereas the FCS index for sheephead at Wheeler North Reef was between the values observed at San Mateo and Barn in both 2009 and 2010 (Figure 6.13b). The standardized FCS, which combines data for both black surfperch and sheephead was highest at Wheeler North Reef in both 2009 (Figure 6.13c) and 2010 (Figure 6.13d).

These results suggest that whether viewed individually by species or collectively the amount of food supplied to black surfperch and sheephead by the benthic community at Wheeler North Reef was similar to or greater than that supplied by Barn and San Mateo. Thus Wheeler North Reef met the performance standard for food chain support in 2009 and 2010.

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 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 on 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.

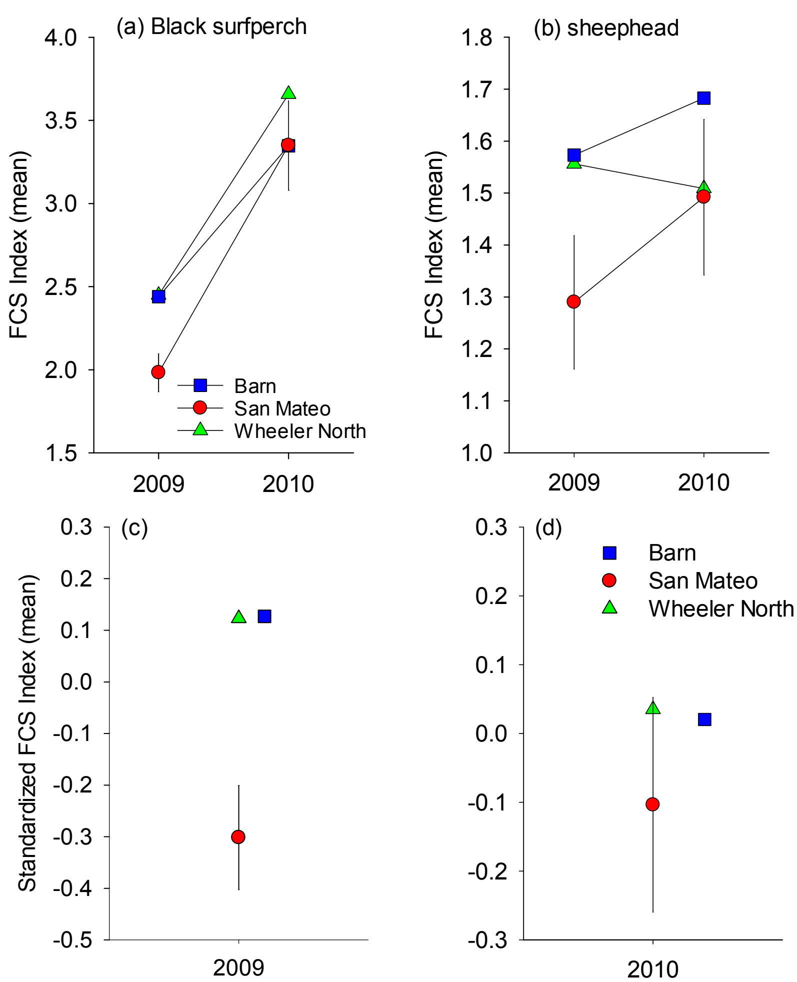

Figure 6.13. (a) Food chain support (FCS) index for black surfperch. (b) FCS for Sheephead. Standardized FCS for black surfperch and sheephead combined for Wheeler North Reef, San Mateo and Barn in (c) 2009 and (d) 2010. 80% confidence interval is shown for the reference reef with the lowest mean value.

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, Wheeler North Reef consistently met the performance standards pertaining to young-of-year fishes (Figure 6.7 and 6.8) and benthic food chain support (Figure 6.13) indicating that there was no impairment of these key ecological functions at Wheeler North Reef in 2009 and 2010. 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 that was present on the reef at this time (Figure 5.2.7). 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.

Monitoring data were used to evaluate trends in the abundance of potentially undesirable or 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.

The total density of sea fans increased at Wheeler North Reef, San Mateo and Barn between 2009 and 2010, but much more dramatically so at Wheeler North Reef (Figure 6.14). Despite this higher increase in the densities of sea fans at Wheeler North Reef, sea fans at Wheeler North Reef were still below the critical density of $10m^{-2}$ noted by Ambrose et al. (1987). 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, which was not sufficient to significantly affect the abundance of other organisms.

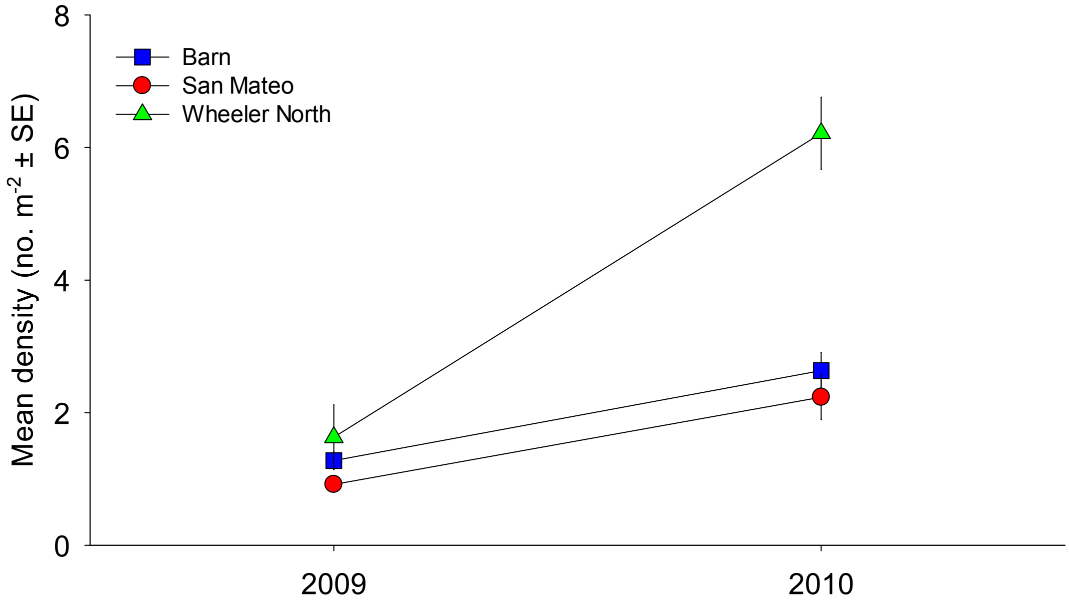

Figure 6.14. Mean density (± 1 standard error) of sea fans, *Muricea* spp. at Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

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 in areas where sea urchin densities exceeded 35 m^{-2}. Monitoring data from 2009 and 2010 show that sea urchin densities were far below this level at all three reefs in both years (Figure 6.15).

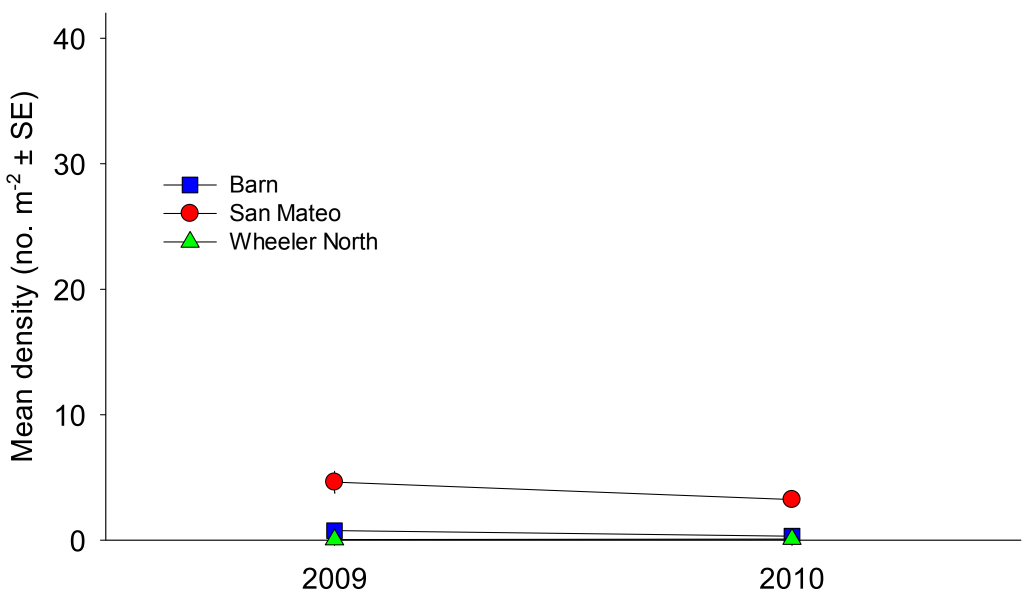

Figure 6.15. Mean density (± 1 standard error) of sea urchins, *Strongylocentrotus* spp. at the Wheeler North Reef, San Mateo and Barn in 2009 and 2010.

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 are reaching abundances that are high enough to impair important ecological functions of Wheeler North Reef.

7.0 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. Wheeler North Reef met 10 of the 14 performance standards in 2010 compared to 9 of the performance standards in 2009 (Table 7.1). There were no cases in which a standard was met in 2009, but not met in 2010 (i.e., no standard went from a YES to a NO in Table 7.1). The results obtained during the first two years of monitoring suggest that Wheeler North Reef is getting closer to meeting its goals, but is not yet in compliance with the mitigation requirements of the SONGS coastal development permit.

There are indications that Wheeler North Reef is continuing to improve as the percent cover of algae and sessile invertebrates and the density of mobile invertebrates is trending towards meeting these two performance standards. Additional time is needed before we can assess the likelihood that Wheeler North Reef will meet the performance standards pertaining to the number of species of algae and invertebrates and the standing stock of fish.

Table 7.1. Summary of the performance of Wheeler North Reef for each of the standards in 2009 and 2010. YES means that the standard was met for that year, NO means the standard was not met.

Performance Standard	2009	2010
1. Hard substrate	YES	YES
2. Giant kelp	NO	YES
3. Algal and invertebrate percent cover	NO	NO
4. Mobile invertebrate density	NO	NO
5. Algal and invertebrate species number	NO	NO
6. Resident fish density	YES	YES
7. Resident fish species number	YES	YES
8. YOY fish density	YES	YES
9. YOY fish species number	YES	YES
10. Fish standing stock	NO	NO
11. Fish reproductive rates	YES	YES
12. Fish production	YES	YES
13. Food chain support	YES	YES
14. Invasive species	YES	YES

8.0 References

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