

2012

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

**SAN ONOFRE NUCLEAR GENERATING STATION (SONGS)
MITIGATION PROGRAM**



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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. Construction of the mitigation phase of the Wheeler North Reef was completed in 2008 and post construction monitoring of the physical and biological attributes of the Wheeler North Reef and two nearby reference reefs (San Mateo and Barn kelp beds) has been completed each of the four years since then.

Evaluation of the Wheeler North Reef is based on its performance with respect to four absolute standards and 11 relative standards. The absolute standards are evaluated only at the Wheeler North Reef, whereas the relative standards are evaluated in comparison with the two natural reference reefs. The success of the Wheeler North Reef in meeting the mitigation requirement for a given year is based on its ability to meet all four absolute performance standards and as many relative performance standards as the lower performing reference reef. 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. This report summarizes the monitoring results through 2012.

In 2012 the Wheeler North Reef met three of the four absolute standards used to judge its performance. The absolute standard that it failed to meet requires the Wheeler North Reef to support a fish standing stock of at least 28 tons. To date the Wheeler North Reef has produced at most half of this amount, and there is no indication from the monitoring results that the artificial reef is on a trajectory to meet the fish standing stock standard any time soon. Results of analyses using longer-term data collected from the reference reefs and the smaller modules constructed during the initial experimental phase indicate that the present size and configuration of the Wheeler North Reef is not sufficient to consistently support 28 tons of kelp bed fish. Additional analyses using these data are planned to better determine the configurations (i.e. rock coverage) and footprint area needed for the Wheeler North Reef to consistently meet all of the absolute performance standards.

The Wheeler North Reef met eight of the 11 relative performance standards in 2012. The three relative standards not met pertained to the number of species of benthic invertebrates and the percent cover and number of species of understory algae. Monitoring results show that the number of species of benthic invertebrates at Wheeler North Reef has rapidly increased during the first four years of its existence suggesting that the artificial reef is likely to meet this performance standard in the near future. Results of analyses from experiments and monitoring data indicate that the sparse cover and low diversity of understory algae at Wheeler North Reef can be

explained by the dense canopy of giant kelp that shades the bottom community, and to a lesser extent by the lower percent cover of rock at Wheeler North Reef relative to that at the two reference reefs.

The eight relative performance standards met by the Wheeler North Reef compared favorably to the seven relative standards met by San Mateo and the nine standards met by Barn. This finding indicates that the Wheeler North Reef is performing similarly to natural reefs in the region with respect to a diverse array of biological attributes. Thus the Wheeler North Reef was judged successful with respect to its ability to meet the relative performance standards. However, because the Wheeler North Reef only met three of the four absolute performance standards it did not earn any mitigation credit for 2012.

Despite the above noted deficiency in performance, the Wheeler North Reef has shown considerable promise in meeting many of its objectives. Importantly, the absolute performance standard pertaining to the area of adult giant kelp has been met continuously since 2010. Impressively, 174 of Wheeler North Reef's 176 acres were estimated to support medium to high densities of adult giant kelp since 2010. This indicates the Wheeler North Reef currently is meeting the objective of compensating for the loss of giant kelp caused by SONGS operations. As noted above, the Wheeler North Reef also met as many or more of the relative performance standards as the reference reefs. Moreover, the relative performance standard for mobile invertebrate density, which the Wheeler North Reef did not meet in 2009 or 2010, was met in 2011 and 2012 and the steady increase over time in the number of species of benthic invertebrates at the Wheeler North Reef suggests that it is on a successful trajectory with respect to this reef attribute. Finally, in contrast to other artificial reefs in the region, there is no evidence that invasive or undesirable species, including the sea fan *Muricea* spp. pose a threat to the important ecological functions of Wheeler North Reef.

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 -2012 and summarizes the status of the project's compliance with Condition C of the SONGS permit in 2012.

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 generated up to 1,100 MW of electric power. Both reactors were shut down in January 2012 due to excessive wear in the cooling tubes of the steam generators, and in June 2013 both units were permanently retired. Full retirement of the units prior to decommissioning is expected to take several years in accordance with customary practices; actual decommissioning will take many years until completion.

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 were fully operational was about 2.4 billion gallons, equivalent to a square mile 12 feet deep. The intake volume has been reduced by about 50% since the reactors were shut down in 2012.

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 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 fish 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 and its partners to provide the funds necessary for CCC to contract marine scientists to perform technical oversight and independent monitoring of the mitigation projects (Condition D). 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 Phase 1 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). 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 marine biologists 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 including the decommissioning period to the extent there are continuing discharges.

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.

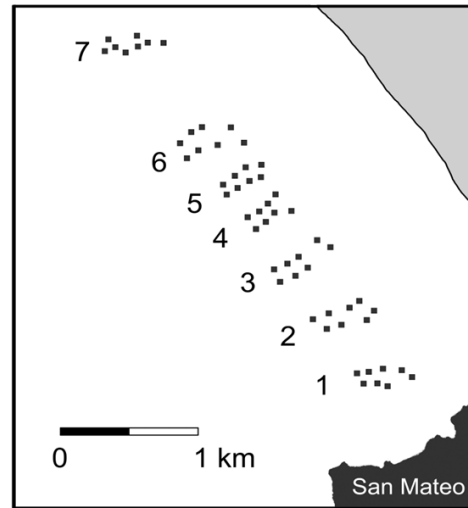


Figure 3.1.2. Design of the Phase 1 Experimental Reef. The black squares represent the 56 modules. Numbers indicate the seven sampling locations.

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 Wildlife 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

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).

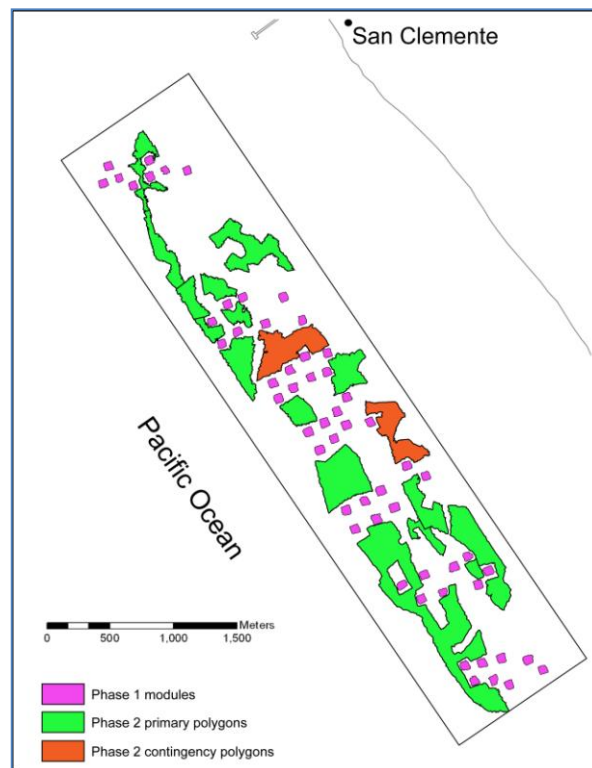


Figure 3.2.1. The 176 acre Wheeler North Artificial Reef, which includes the Phase 1 modules and the Phase 2 primary and contingency polygons.

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 24.79 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 are measured only at the Wheeler North Reef and require that the variable of interest attain or exceed a predetermined value, and relative standards, which require that the value of the variable of interest 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.

The evaluation of each absolute performance standard in any given year is based on the greater value obtained from either: (1) data collected at the Wheeler North Reef that year, or (2) a four-year running average calculated from data collected at the Wheeler North Reef for that year and the previous three years. A running average recognizes that short-term fluctuations in kelp forest biota are the norm, and it is used to allow credit for excess reef biota in good years to compensate for occasional years when values for the biota are slightly below those required by the absolute standards. All absolute standards must be met in a year in order for that year to count towards compliance with Condition C, regardless of whether a single-year or a running average is used to evaluate the standards.

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

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 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 performing of the two reference reefs. We use a one sample, one tailed approach for all comparisons. Significance is determined using an approach that utilizes both a formal probability value and an effect size. This is generally done by means of a t-test except in the case of the performance standard pertaining to fish reproductive rates where significance is determined by a resampling procedure. The performance at Wheeler

North Reef with respect to a given relative performance standard is considered to be worse than the lower of the two reference reefs if the p-value for the comparison is \leq to 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 both the p-value and the proportional effect size are greater than 0.5 in which case assessment for the period is considered inconclusive and additional studies will be done (see **3.2 Methods for assessing the performance standards** for details). 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. The rationale for using the lower of the two reference reefs is that both reference reefs are considered to be acceptable measures of comparison for Wheeler North Reef. Hence, if Wheeler North Reef is performing at least as well as one of the reference 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 a Type I error (falsely concluding that Wheeler North Reef is not similar to the reference reefs when it is) with the probability of a Type II error (falsely concluding that the Wheeler North Reef is similar to the reference reefs when it is not).

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

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

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.

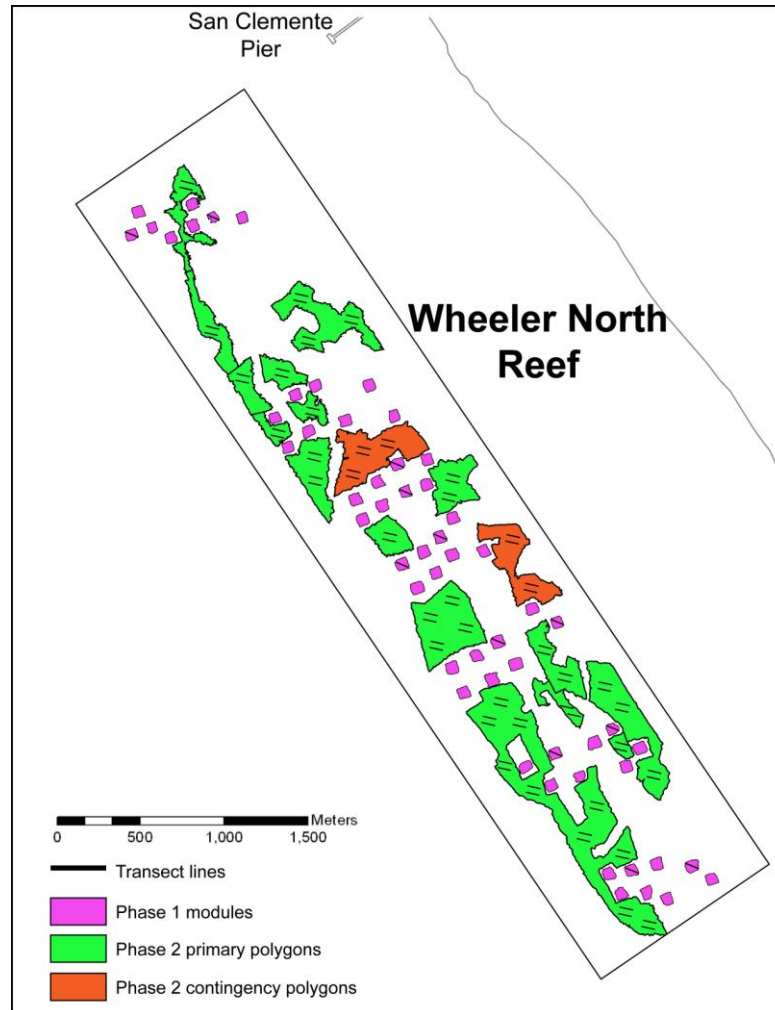


Figure 4.4.1. Schematic map of the Wheeler North Reef showing the location of the paired transects that are monitored to assess the performance standards.

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).

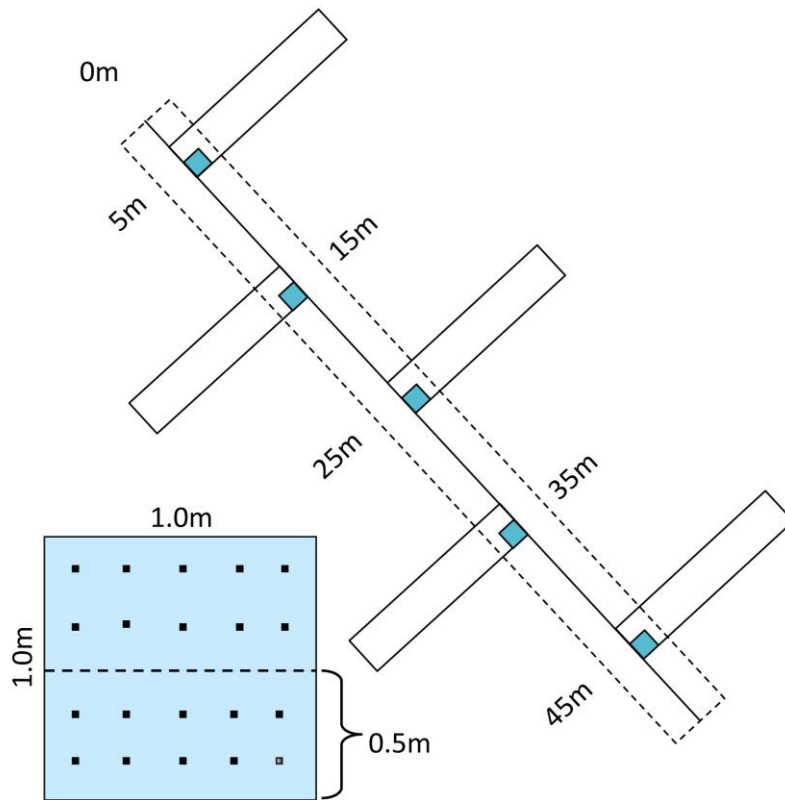


Figure 4.4.2. Schematic diagram of a sampling station. Fish are sampled in 50m x 3m band transects that extend 1.5m off the bottom (outlined with a dotted line). Adult giant kelp > 1m tall, large understory algae, and large mobile invertebrates are counted in the five 10m x 2m rectangular quadrats positioned perpendicular to the main transect at 10 m intervals (outlined with solid lines). The percent cover of invertebrates, algae and bottom 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 of 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 – 2012, which represents the 4-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. The percent cover of exposed rock on the bottom can decline as a result of sedimentation and burial, or increase due to scour caused by waves. Knowledge of the extent, type and persistence of exposed rock is essential to understanding how the Wheeler North Reef will function over the long term. Overall the mean percent cover of exposed rock averaged over all the primary polygons at the Wheeler North Reef has been relatively constant over time averaging about 44% in three of the four years since 2009; it declined to ~ 41 % in 2011 (Figure 5.1.1).

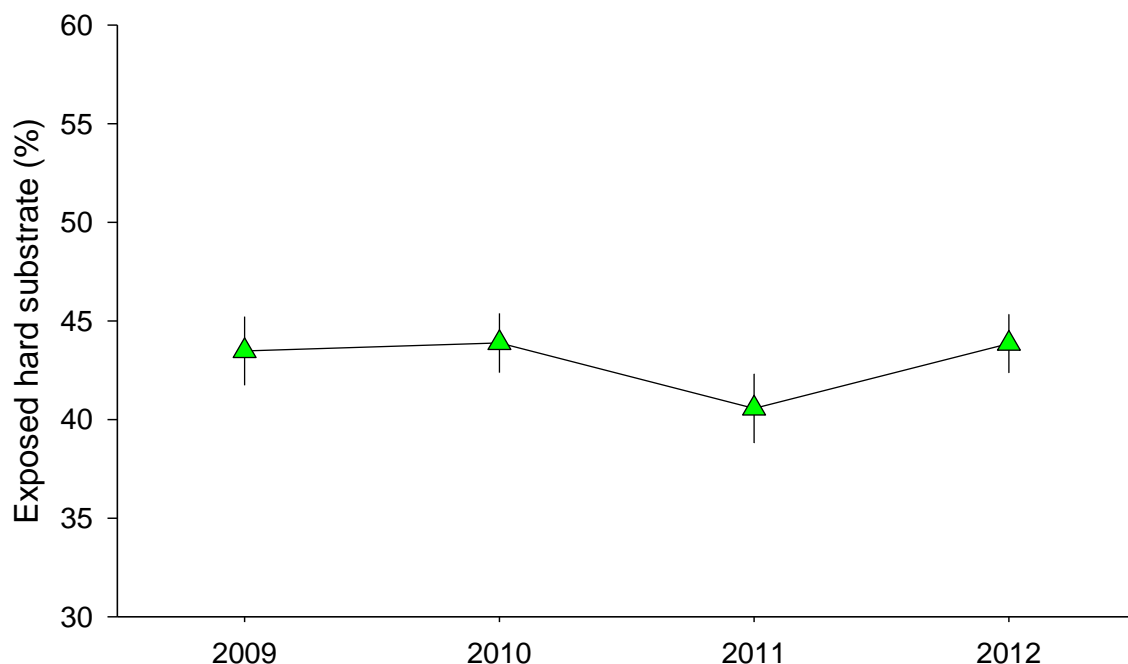


Figure 5.1.1 Mean percent cover (± 1 standard error) of exposed hard substrate at Wheeler North Reef for 2009 - 2012.

The percent cover of exposed rock varied substantially more among the 16 primary polygons than the overall average for the Wheeler North Reef over the period of 2009-2012 as the four-year average ranged from a low of 33% cover of exposed rock in polygon 4 to over 48% cover in polygons 3 and 12 (Figure 5.1.2). The overall four-year average cover of rock on the Phase 1 modules was substantially higher than the overall average for the Wheeler North Reef (i.e. 58% vs. 43%).

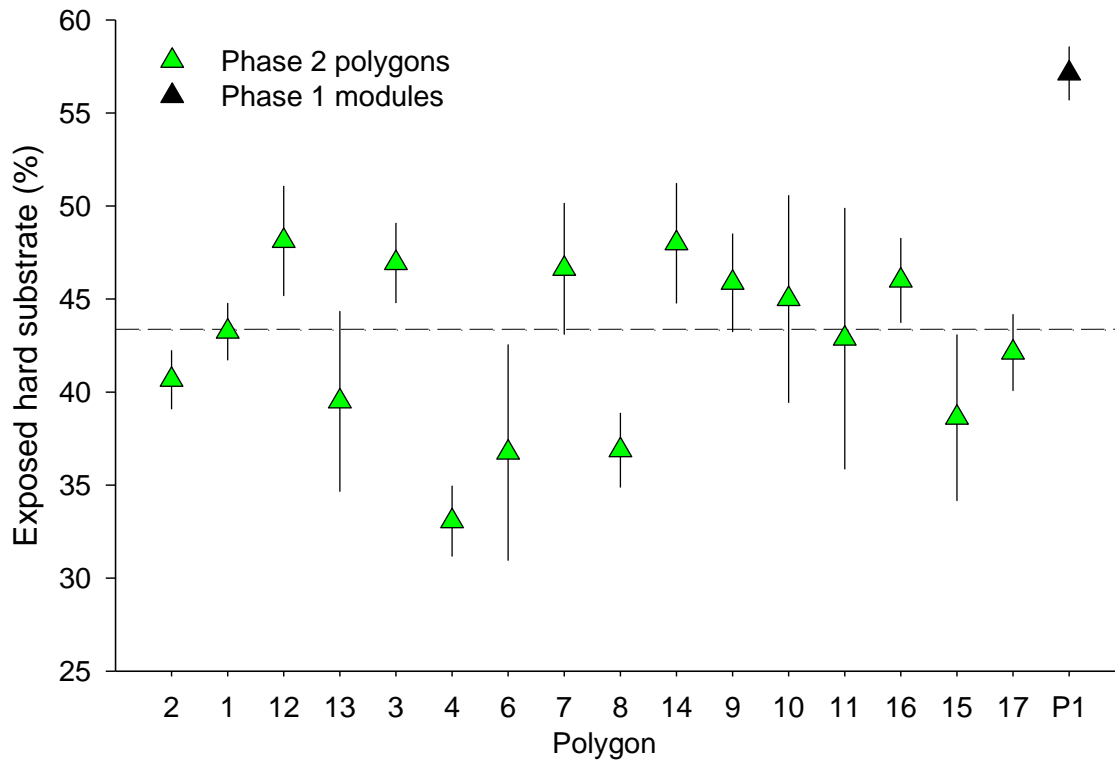


Figure 5.1.2. Four-year (2009-2012) running average of percent cover (\pm standard error) of exposed hard substrate at Wheeler North Reef. Polygon numbers are ordered from south to north. Dashed line represents the mean for the entire reef.

Not surprisingly, the hard substrate at Wheeler North Reef consists of mostly boulder, which is what was intentionally produced at the quarries that supplied the rock for the construction of the reef (Figure 5.1.3). A small amount of cobble (much

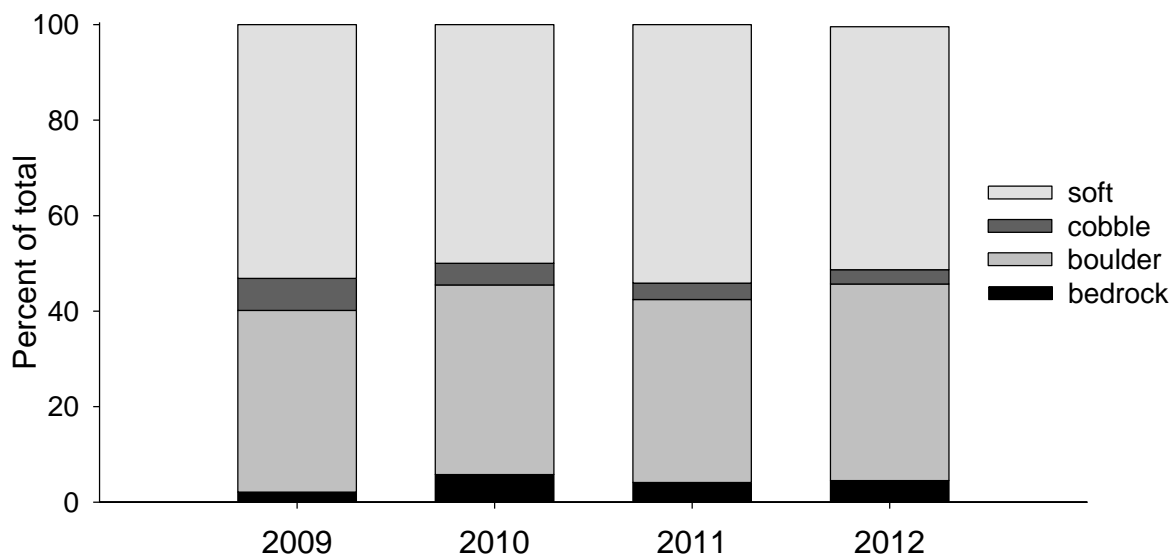


Figure 5.1.3. Distribution of substrate types on Wheeler North Reef for 2009 - 2012.

of which is a by-product of the quarry rock preparation) and natural bedrock contributes to the hard substrate on the reef. Soft substrates consisting primarily of sand with some shell hash cover approximately half the bottom within the footprint area of the Wheeler North Reef. The relative amounts of the different bottom substrates have changed little since 2009.

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). The recruitment of giant kelp declined to near zero at Wheeler North Reef in the three subsequent years. A similar pattern of reduced recruitment in years

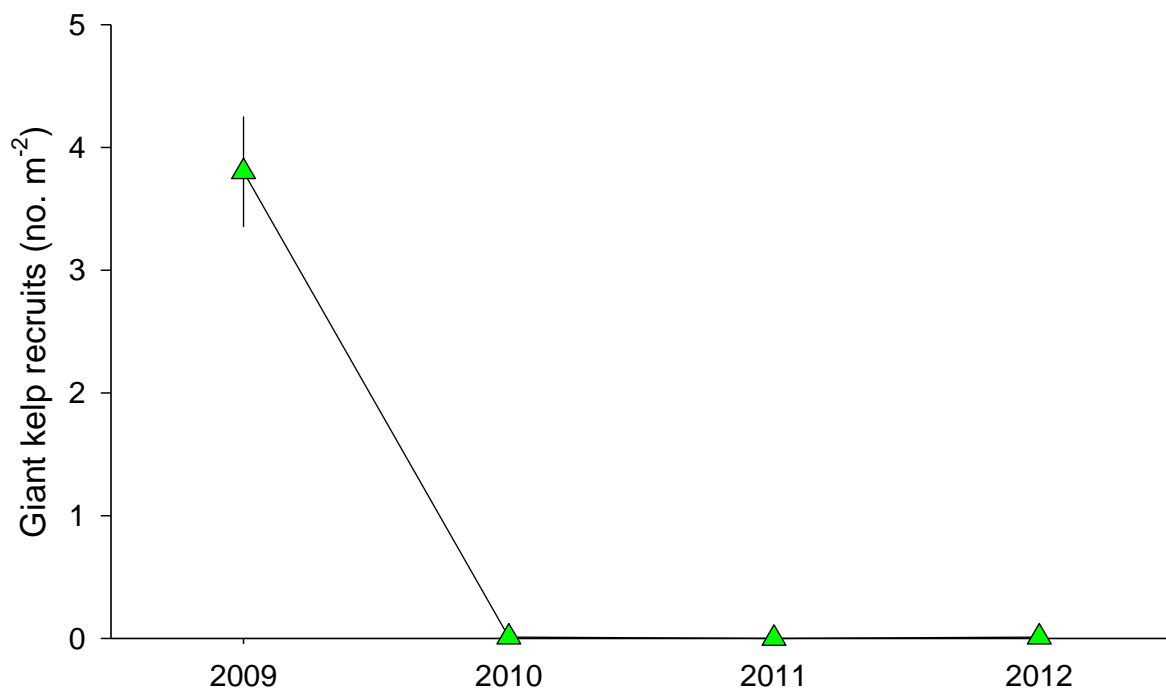


Figure 5.2.1. Mean density (± 1 standard error) of newly recruited giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef, San Mateo and Barn for 2009 - 2012.

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.

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 Phase 1 modules where adult kelp was already established is further evidence of suppression of recruitment of young plants by an established surface canopy.

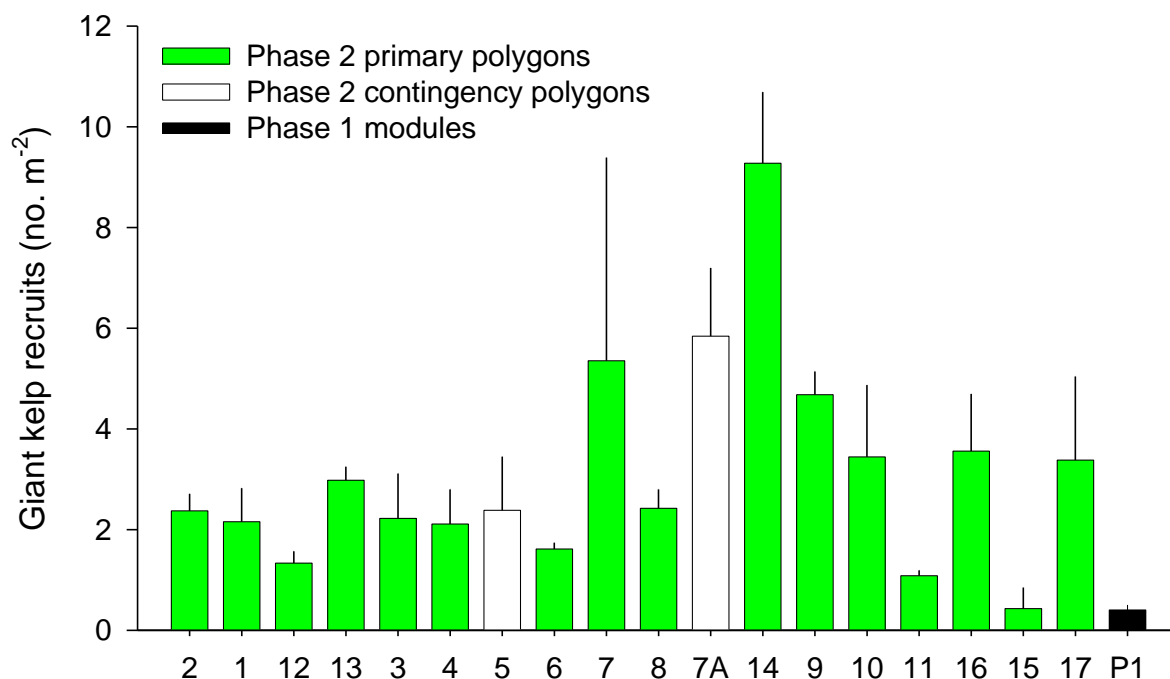


Figure 5.2.2. Mean density (± 1 standard error) of newly recruited giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef in 2009. Polygon numbers are ordered from south to north.

The large kelp recruitment event at Wheeler North Reef in 2009 led to a large cohort of older large plants in 2010, which gradually declined to approximately 2 individuals per 10 m² in 2012 (Figure 5.2.3). Much like small recruits, adult kelp was distributed across all primary and contingency polygons on Wheeler North Reef as well as being present 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 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).

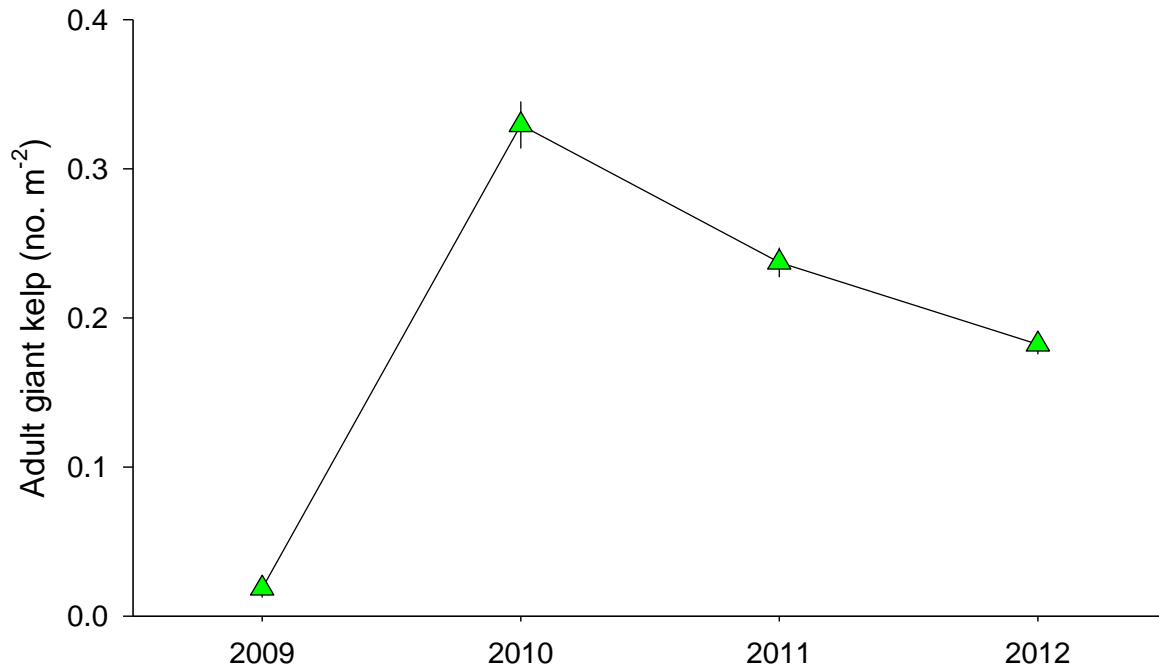


Figure 5.2.3. Mean density (± 1 standard error) of adult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef, San Mateo and Barn for 2009 - 2012.

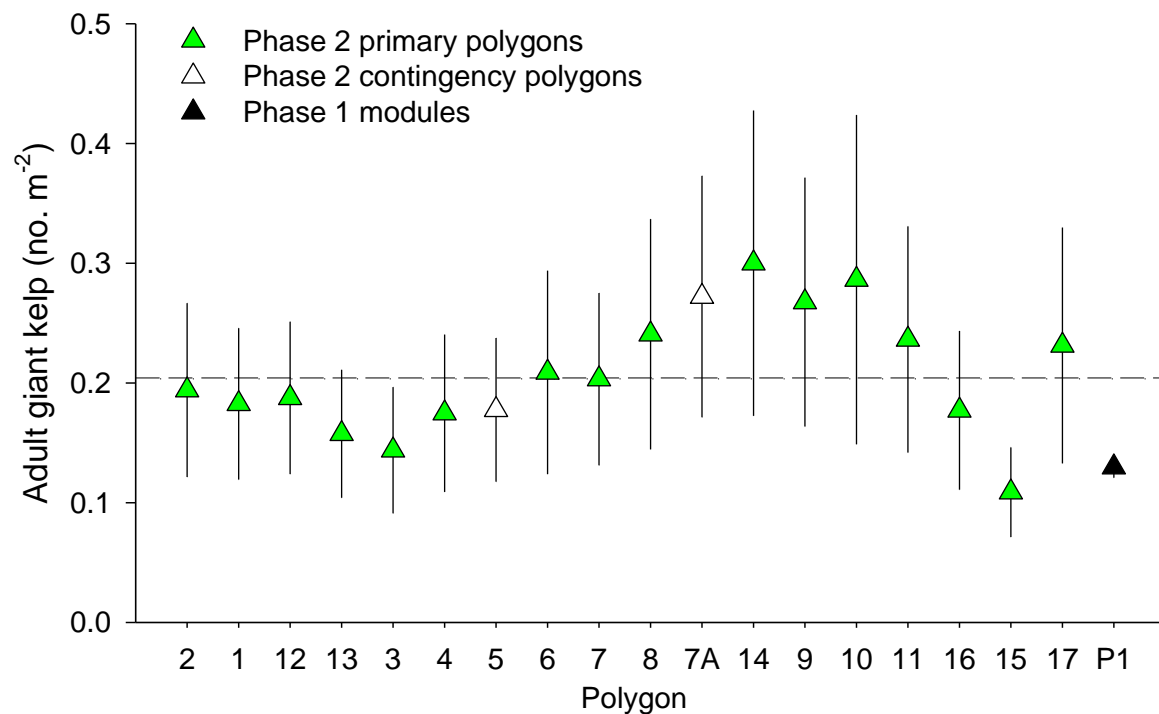


Figure 5.2.4 Four-year (2009 - 2012) running average density (\pm standard error) of adult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef. Polygon numbers are ordered from south to north. Dashed line represents the mean for the entire reef.



Figure 5.2.5. Wheeler North Reef, San Mateo and San Onofre kelp beds as seen from the Landsat 5 satellite in May 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 Reef relative to San Mateo and San Onofre.

Giant kelp plants are made up of individual fronds that consist of a vine-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

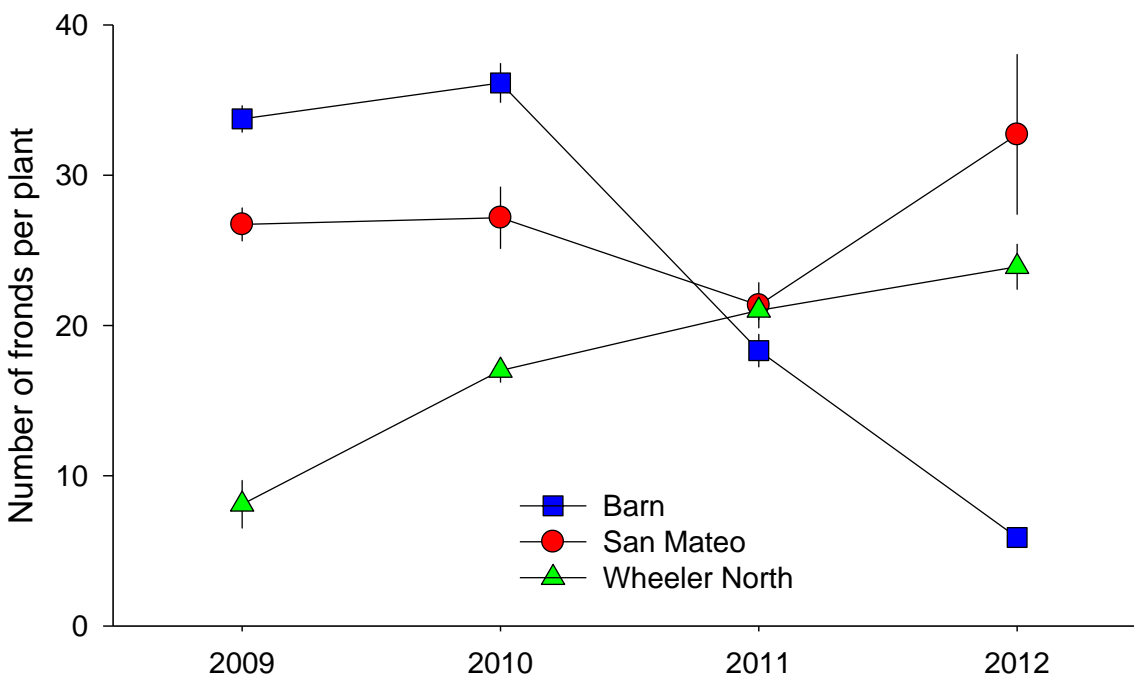


Figure 5.2.6 Mean number (± 1 standard error) of fronds per *Macrocystis* plant at Wheeler North Reef, Barn and San Mateo from 2009 - 2012.

that of nearby natural reefs and averaged about 21 fronds per plant. In 2012 the number of fronds per plant at Wheeler North Reef averaged about 24, which was intermediated between San Mateo (~32) and Barn (~7).

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 standing biomass of giant kelp than the density of plants (Reed et al. 2009). The biomass of kelp as indicated by the density of fronds increased six fold at Wheeler North Reef from 2009 to 2010, and remained relatively high through 2012 (Figure 5.2.7).

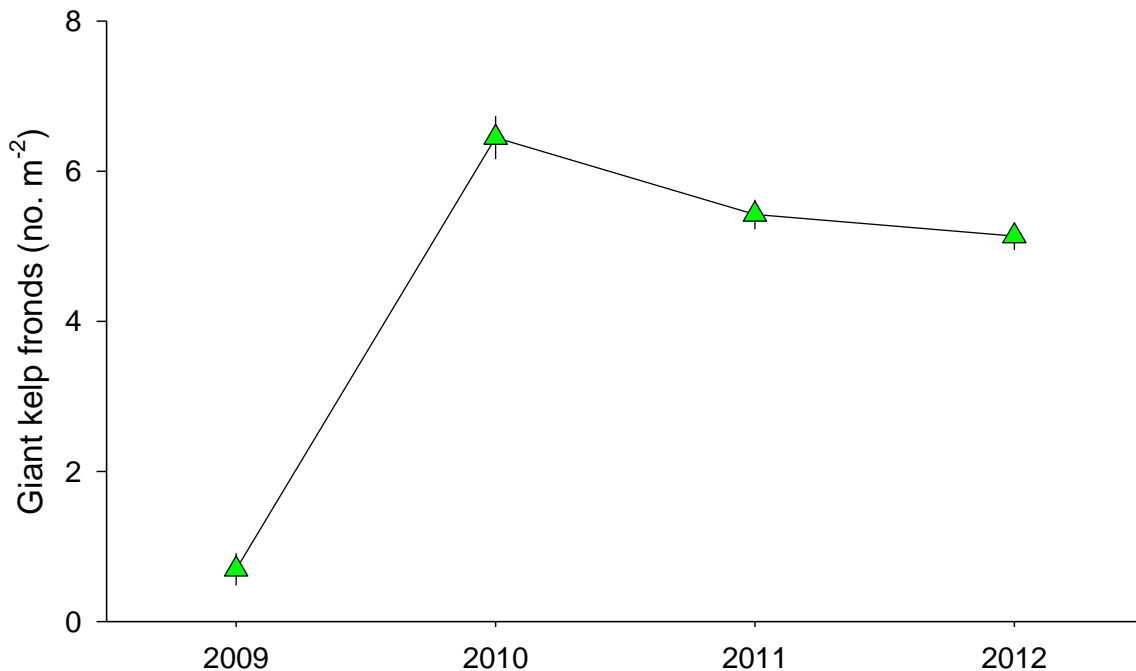


Figure 5.2.7. Mean density (± 1 standard error) of giant kelp fronds at Wheeler North Reef from 2009 - 2012.

Benthos

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. However, 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.

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 2012, the cover of algae and sessile invertebrates had plateaued at about 94% of the rock surface.

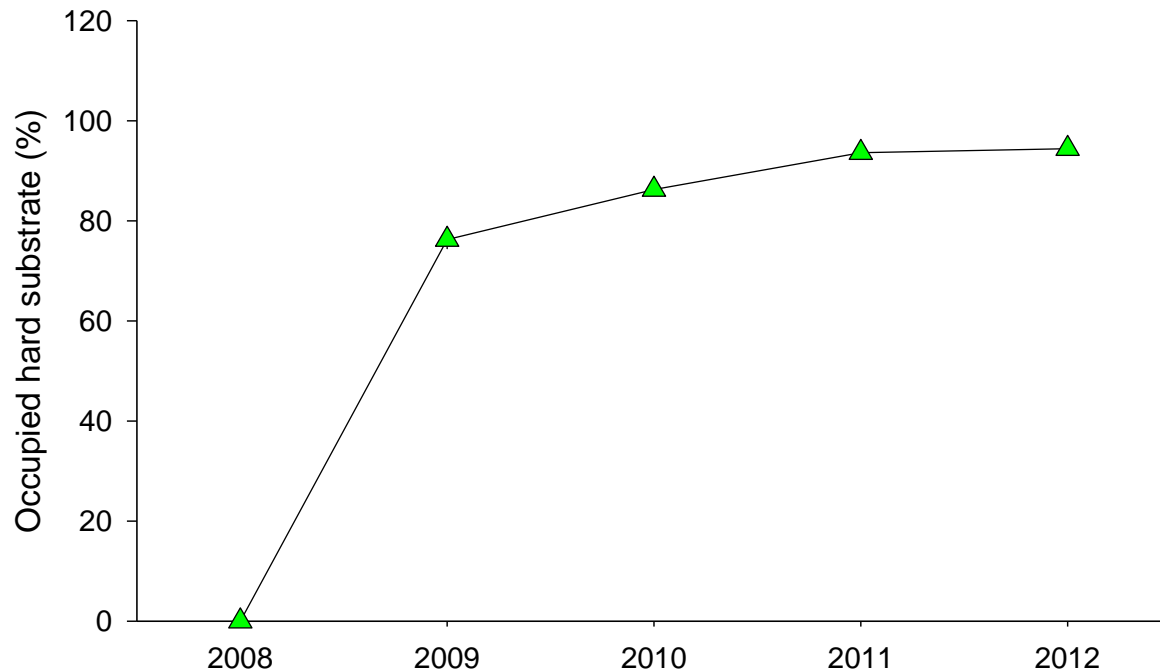


Figure 5.2.8 Mean percent cover of hard substrate occupied by sessile reef biota (i.e. understory algae and sessile invertebrates) at Wheeler North Reef for 2009 - 2012.

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 (Figure 5.2.9). A slight increase in algal percent cover was observed in 2012 with little change in the number of algal species. The percent cover of algae in 2012 was low across all of Wheeler North Reef with the average cover on the primary polygons and Phase 1 modules ranging from 8 to 20% (Figure 5.2.10).

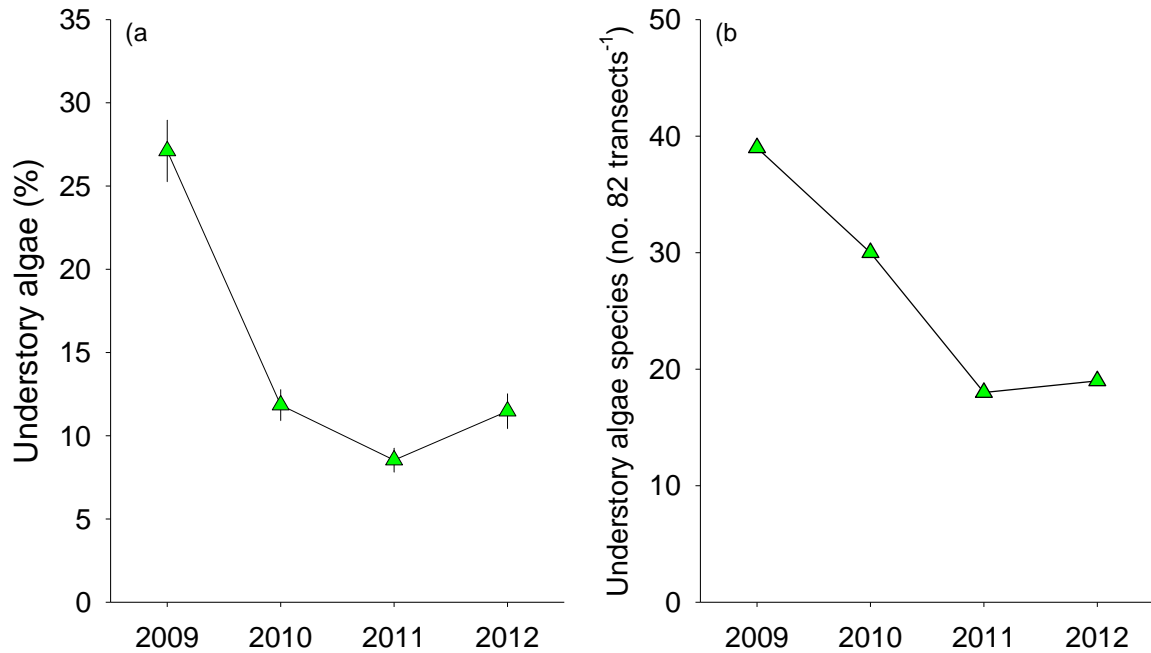


Figure 5.2.9. (a) Mean percent cover (± 1 standard error) and (b) total number of species of understory algae at Wheeler North Reef for 2009 - 2012.

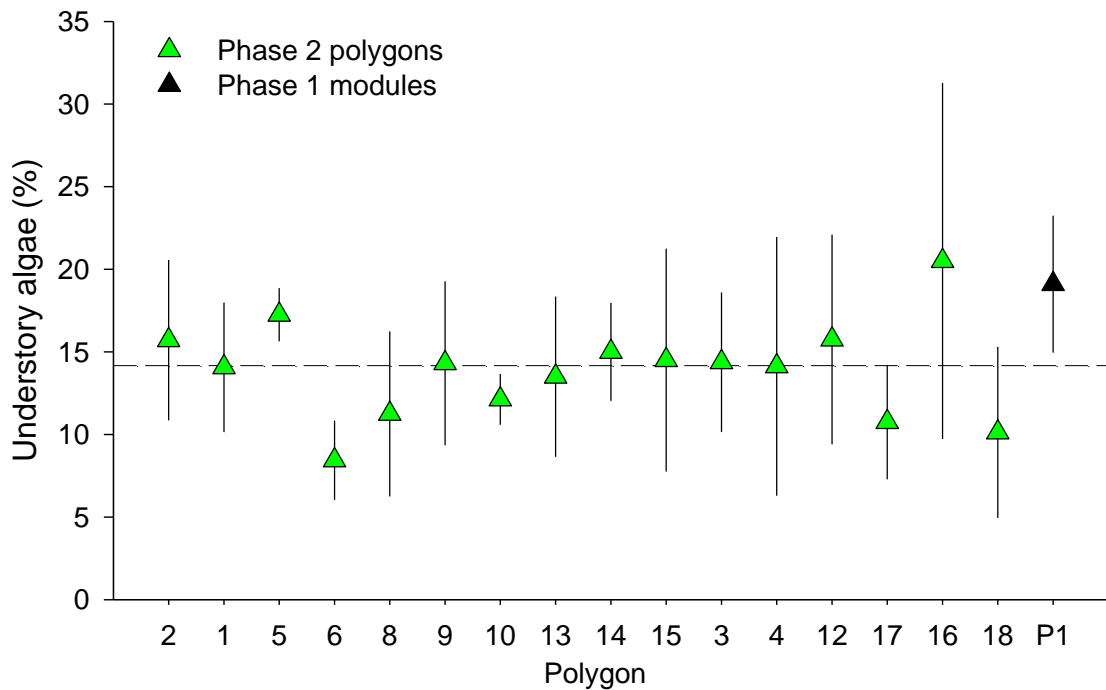


Figure 5.2.10. Four-year (2009 - 2012) running average of percent cover (\pm standard error) of understory algae at Wheeler North Reef. Polygon numbers are ordered from south to north. Dashed line represents mean for the entire reef.

The decline in understory algae at Wheeler North Reef since 2009 is to be expected given the dramatic increase in the abundance (and consequent shading) of adult

giant kelp 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 (Figure 5.2.11). 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 through 2012.

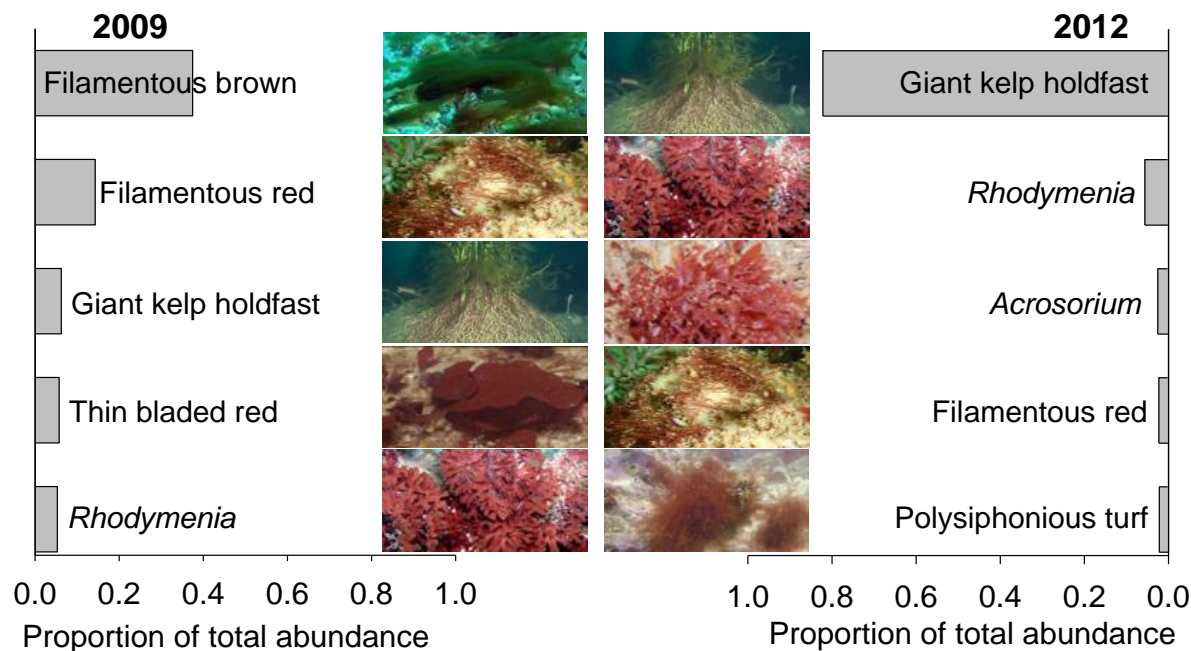


Figure 5.2.11. Proportion of total abundance of the five most abundant algal species at Wheeler North Reef from 2009 and 2012.

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 (Figure 5.2.12a). Interestingly the total number of species of sessile invertebrates observed in the 82 transects at Wheeler North Reef remained at 50 species from 2009 and 2010, before increasing to 60 species in 2011 and 2012 (Figure 5.2.12b).

The percent cover of sessile invertebrates on the Phase 2 polygons averaged about 35% over the four-year period, which was about 15% less than the average on the older Phase 1 modules in 2012 (Figure 5.2.13).

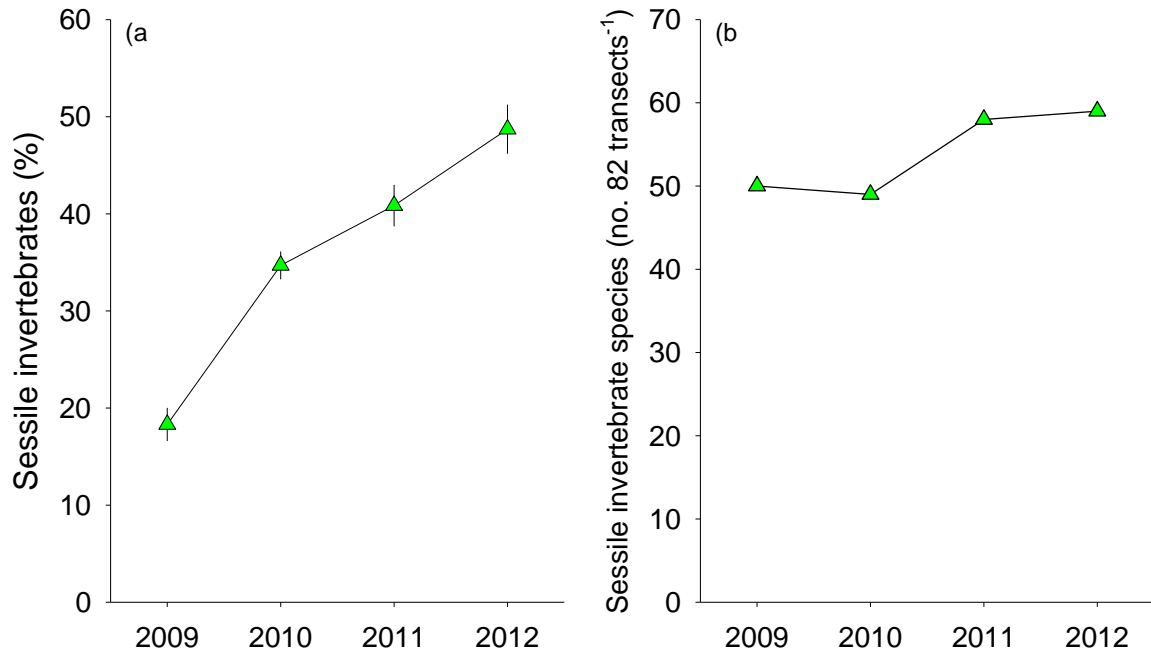


Figure 5.2.12. (a) Mean percent cover (± 1 standard error) and (b) total number of species of sessile invertebrates at Wheeler North Reef from 2009 - 2012.

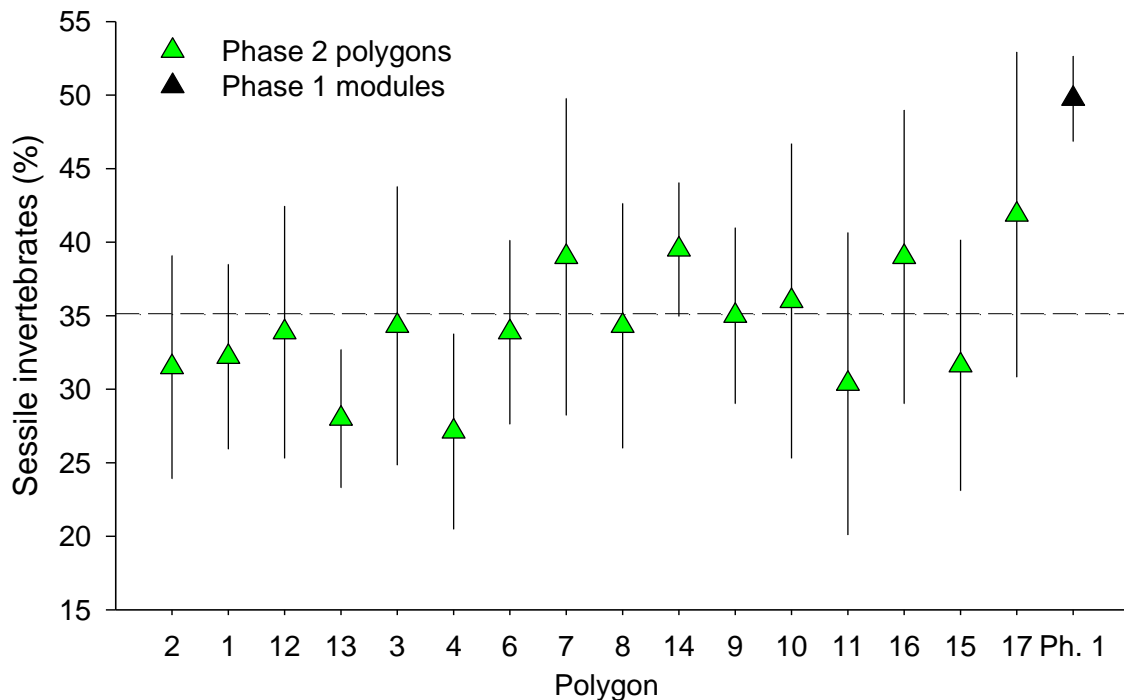


Figure 5.2.13 Four-year (2009 - 2012) running average of percent cover (± 1 standard error) of sessile invertebrates at Wheeler North Reef. Polygon numbers are ordered from south to north. Dashed line represents the mean for the entire reef.

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 during this period (Figure 5.2.14). The sea squirt *Chelyosoma* and the white sponge *Leucilla* have been dominant sessile invertebrate species at Wheeler North Reef since 2009 accounting for 30-40% of the cover of all sessile invertebrate species. Other common taxa include encrusting sponges, the red tube building worm *Salmacina* and the bryozoans *Filicrisia* and *Cryptoarachnidium*. All of the species shown in Figure 5.2.14 with the exception of the sea fan *Muricea* and possibly the orange encrusting sponge are believed to be relatively short-lived. This suggests that the high percent cover of sessile invertebrates at the Wheeler North Reef is maintained by replacement via the colonization of new individuals rather than by the survival of older long-lived individuals.

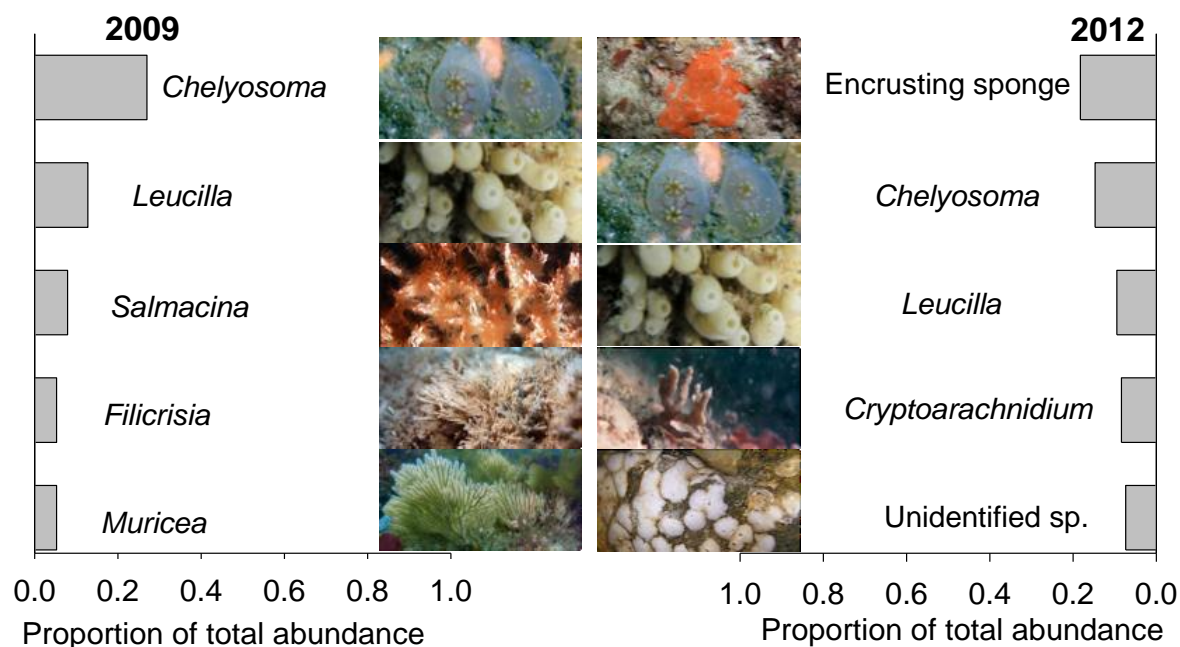


Figure 5.2.14. Proportion of total abundance of the five most abundant sessile invertebrate species at Wheeler North Reef in 2009 and 2012.

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 (~ 10 fold) since 2009 (Figure 5.2.15a). The total number of species of mobile invertebrates observed in the 82 transects at Wheeler North Reef has also steadily increased from a total of 42 in 2009 to 67 in 2012 (Figure 5.2.15b). 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 (Figure 5.2.16). Brittle stars commonly inhabit the holdfasts of giant kelp and the increase in the percent cover of kelp holdfasts on Wheeler North Reef has led to a large

increase in the density of brittle stars. Other abundant species that consistently round out the top five include hermit crabs, cone snails, and Kellet's whelks.

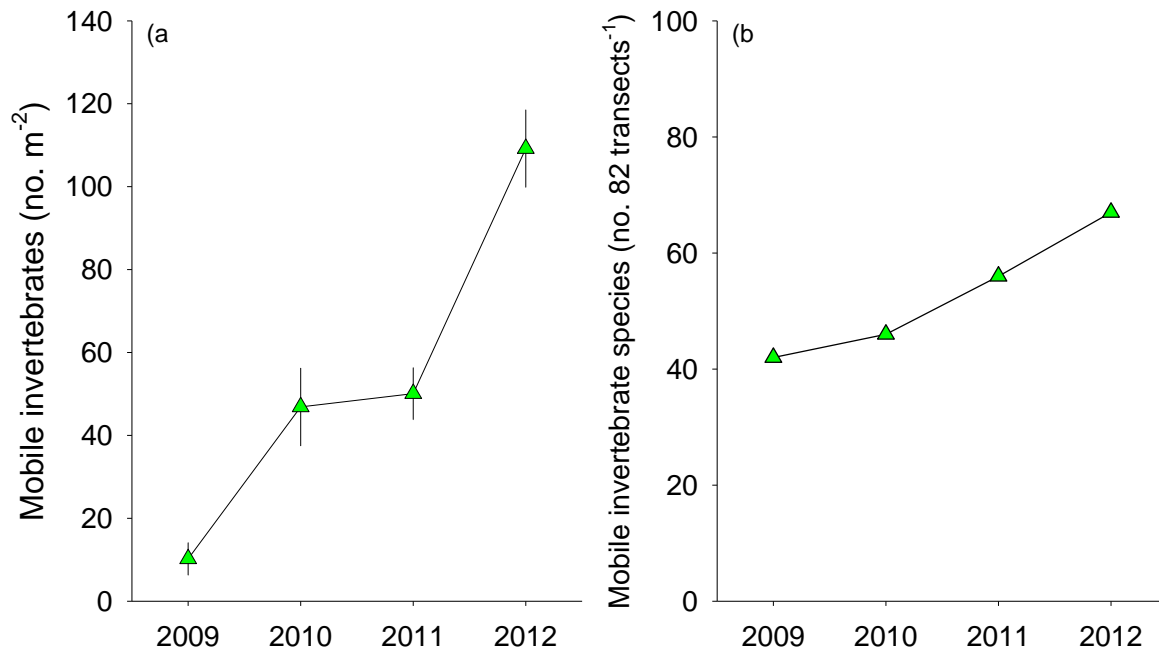


Figure 5.2.15. (a) Mean density (± 1 standard error) and (b) total number of species of mobile invertebrates at Wheeler North Reef from 2009 - 2012.

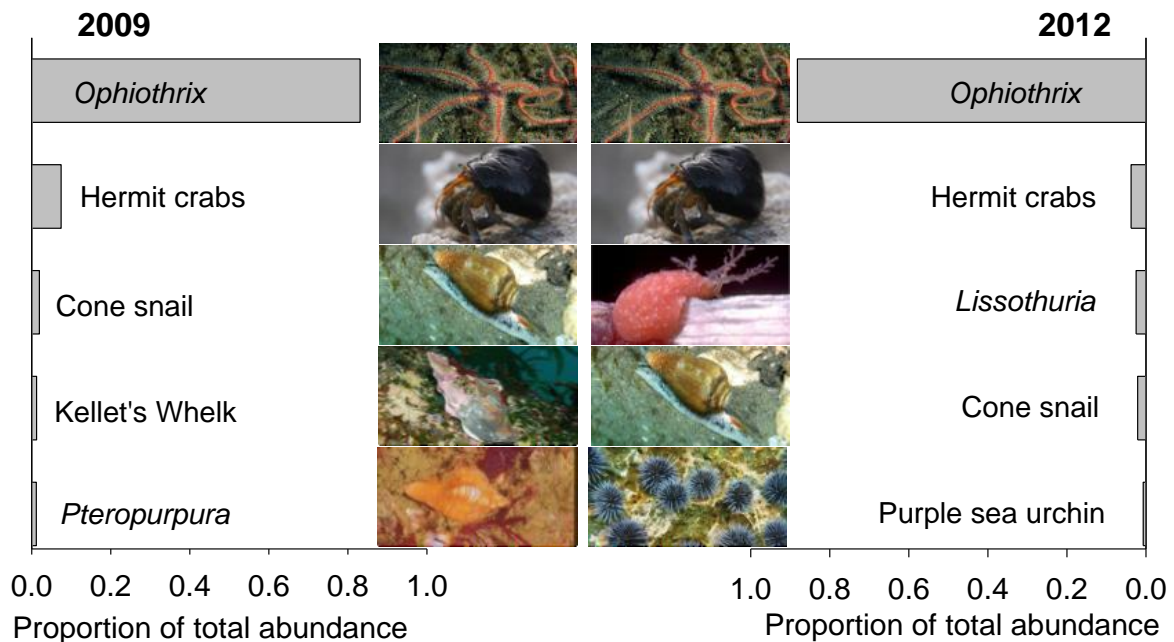


Figure 5.2.16. Proportion of total abundance of the five most abundant mobile invertebrate species at Wheeler North Reef in 2009 and 2012.

Purple sea urchins have been increasing in abundance at Wheeler North Reef and in 2012 they were the 5th most abundant species of mobile invertebrate. Larger, economically important species of mobile invertebrates such as lobster, warty sea cucumbers and red sea urchins, while not as abundant as small brittle stars, are also commonly observed at Wheeler North Reef.

Fish

Abundances of kelp bed fishes living near the bottom at Wheeler North Reef have fluctuated greatly during the first four years of monitoring. Kelp bed fish colonized the Wheeler North Reef rapidly, with densities of reef fish reaching about 70 m⁻² in the first year following construction (Figure 5.2.17a). Fish densities declined precipitously in 2010 and have gradually increased since then to a level in 2012 that was about two-thirds that observed in 2009. The number of species of kelp bed fish observed on the 82 transects has also steadily increased since 2010, but unlike fish density, fish species number was about 50% higher than that observed in the first year following construction (Figure 5.2.17b).

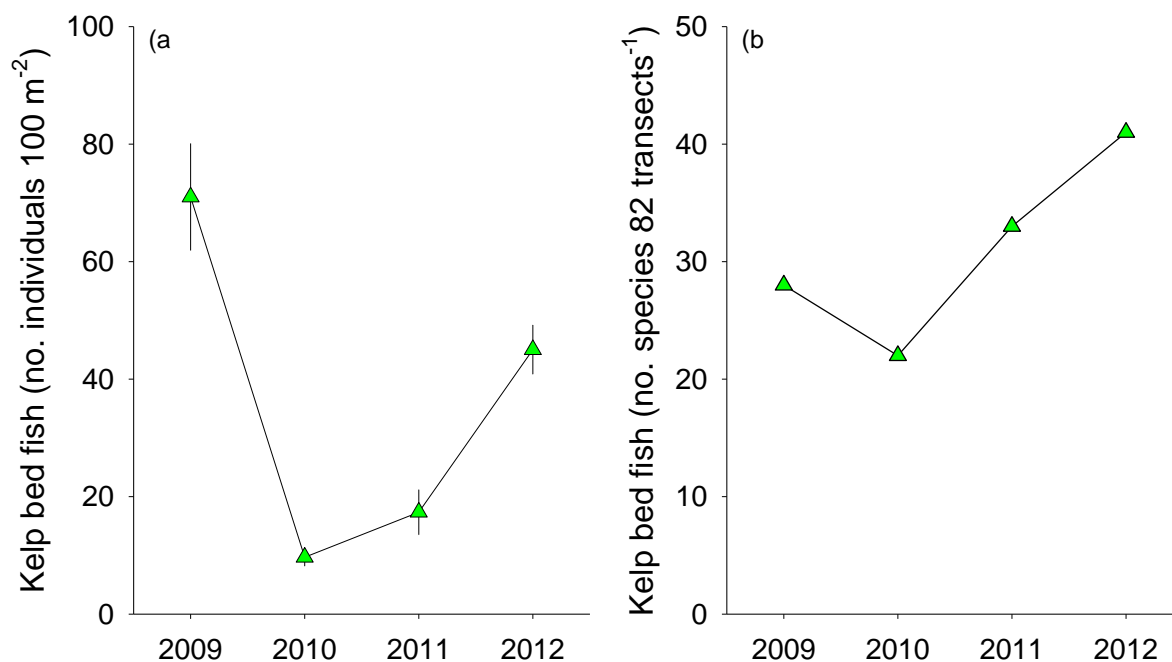


Figure 5.2.17. (a) Mean density (± 1 standard error) and (b) total number of species of kelp bed fish near the bottom at Wheeler North Reef for 2009 - 2012.

No obvious spatial pattern has been observed in the density of kelp bed fish, which has varied unpredictably among the polygons (Figure 5.2.18). Densities at the Phase 1 modules during the last four years has been very similar to the overall mean suggesting that fish densities at the older but smaller Phase 1 modules are representative of the newer larger polygons.

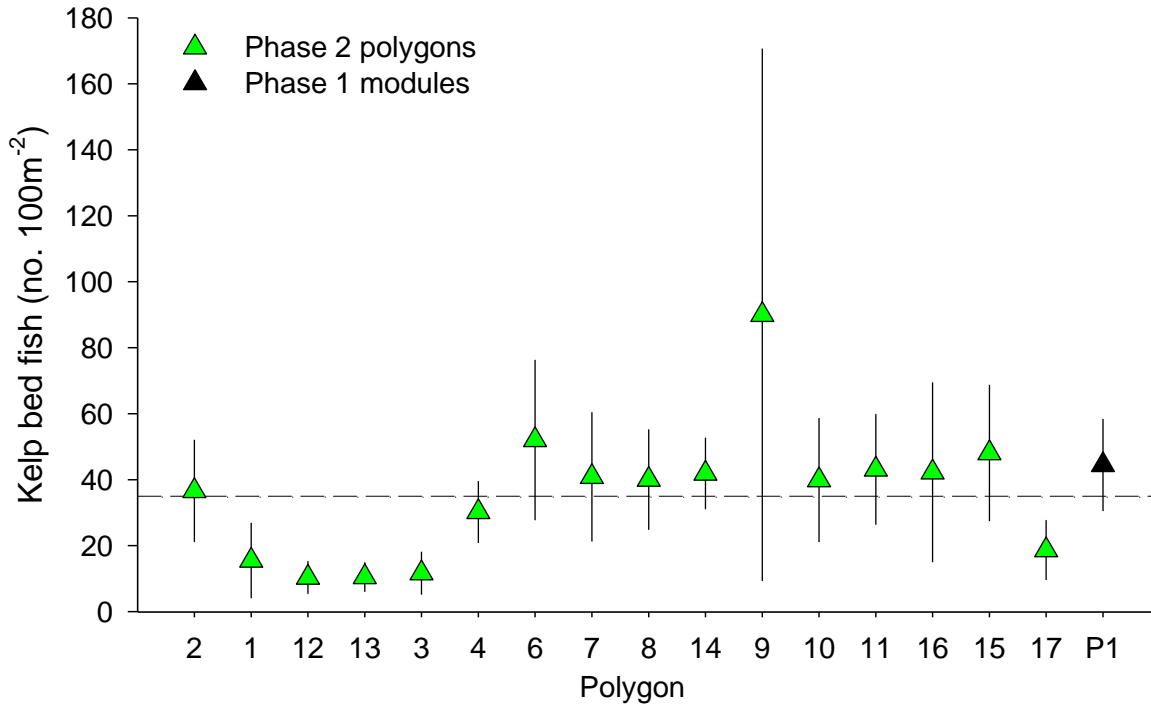


Figure 5.2.18. Four-year (2009 - 2012) running average of density (\pm standard error) of kelp bed fish at Wheeler North Reef. Polygon numbers are ordered from south to north. Dashed line represents the mean of the entire reef.

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 (Figure 5.2.19). Other common taxa of reef fish observed near the bottom include the blacksmith (a planktivore that feeds in the water column), barred sand bass (a predator that feeds near the bottom on invertebrates and other fish), señorita, surf perches, and the painted greenling (pickers that feed on small invertebrates). Collectively these species accounted for 85-96% of the fish observed near the bottom 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 they were not numerically abundant. This includes the kelp bass, California sheephead and California halibut, 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.

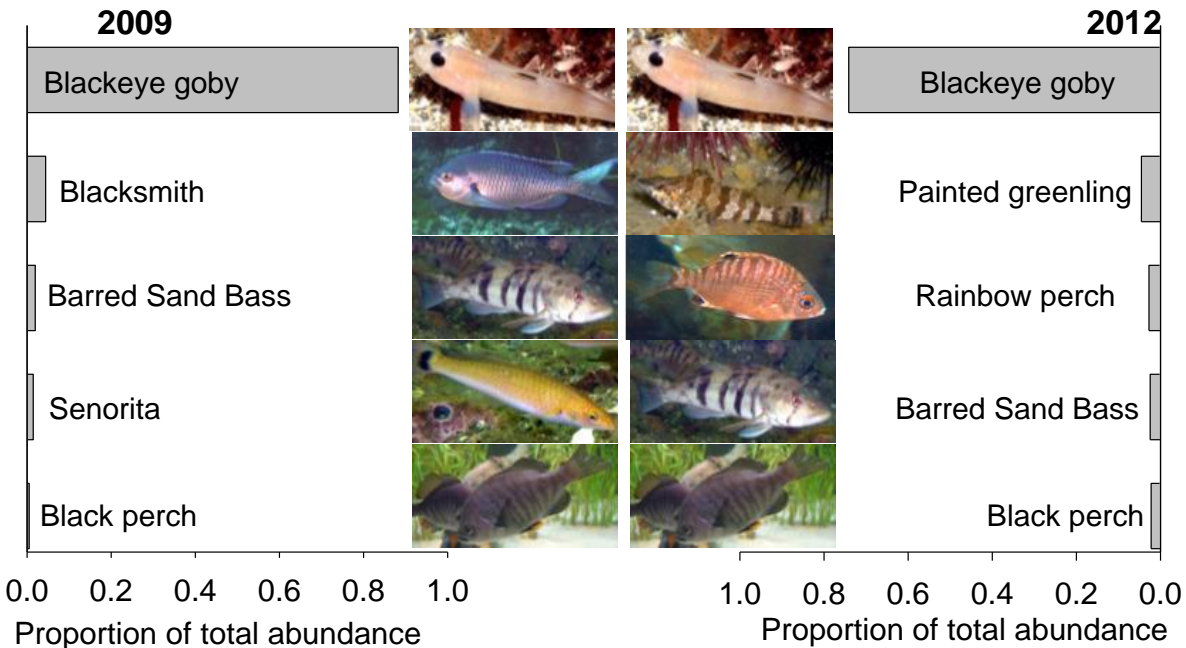


Figure 5.2.19. Proportion of total abundance of the five most kelp bed fish species at Wheeler North Reef in 2009 and 2012.

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 Wheeler North Reef in 2010, but did so at a lower rate than numerical density (a 44% decline for biomass density vs. a 86% decline for numerical density; Figure 5.2.20 vs. Figure 5.2.17a). Fish biomass density has steadily increased since 2010 and by 2012 it was 35% higher than that in 2009.

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 composed a small proportion of the biomass (~ 10 % in 2009). The most dominant reef fish species at Wheeler North Reef in 2012 in terms of biomass density were California sheephead and barred sand bass, which accounted for ~50% of the reef fish biomass. The blackeye goby, while still the most numerically abundant species at Wheeler North Reef in 2012, accounted for only 6% of the reef fish biomass.

The biomass density of kelp bed fish was not uniformly distributed across Wheeler North Reef (Figure 5.2.21). Of particular note was the high biomass density of fish on the older and smaller Phase 1 modules relative to the Phase 2 polygons. Although the numerical density of kelp bed fish on the Phase 1 modules was close to the average numerical density for the entire reef (Figure 5.2.18), its biomass density was three times higher than average for all of Wheeler North Reef. This

indicates that the average size of fish on the older Phase 1 modules is larger than that on the newer Phase 2 polygons.

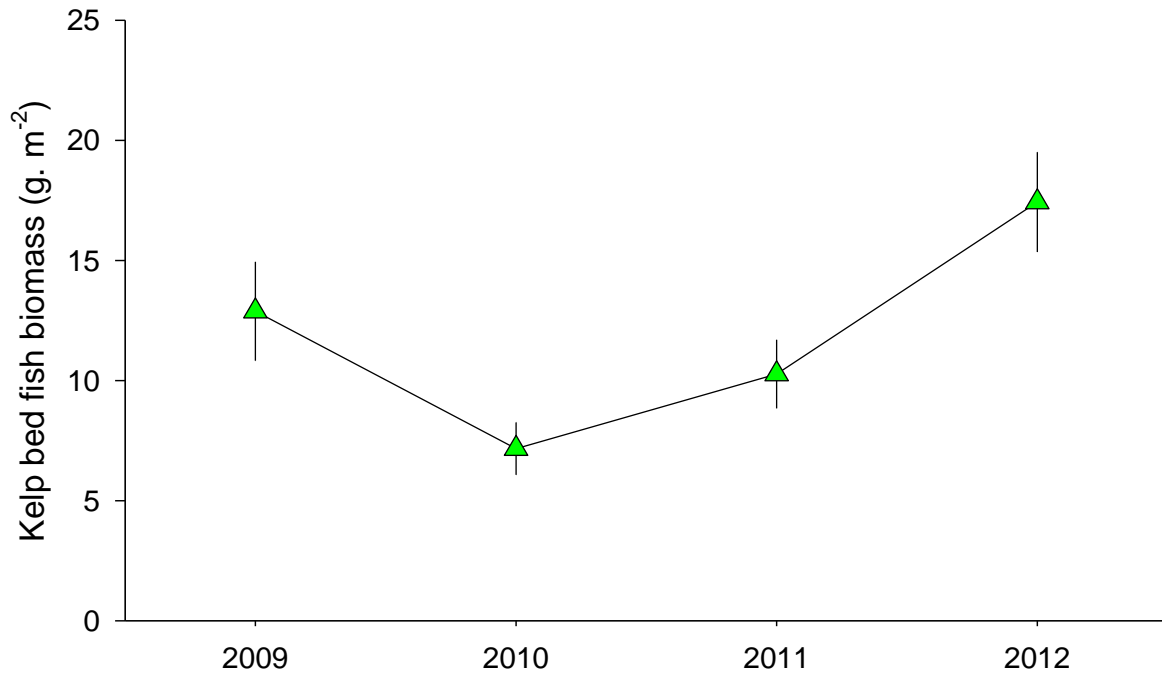


Figure 5.2.20. Mean biomass density (± 1 standard error) of kelp bed fish within 2 m of the bottom at Wheeler North Reef from 2009 - 2012.

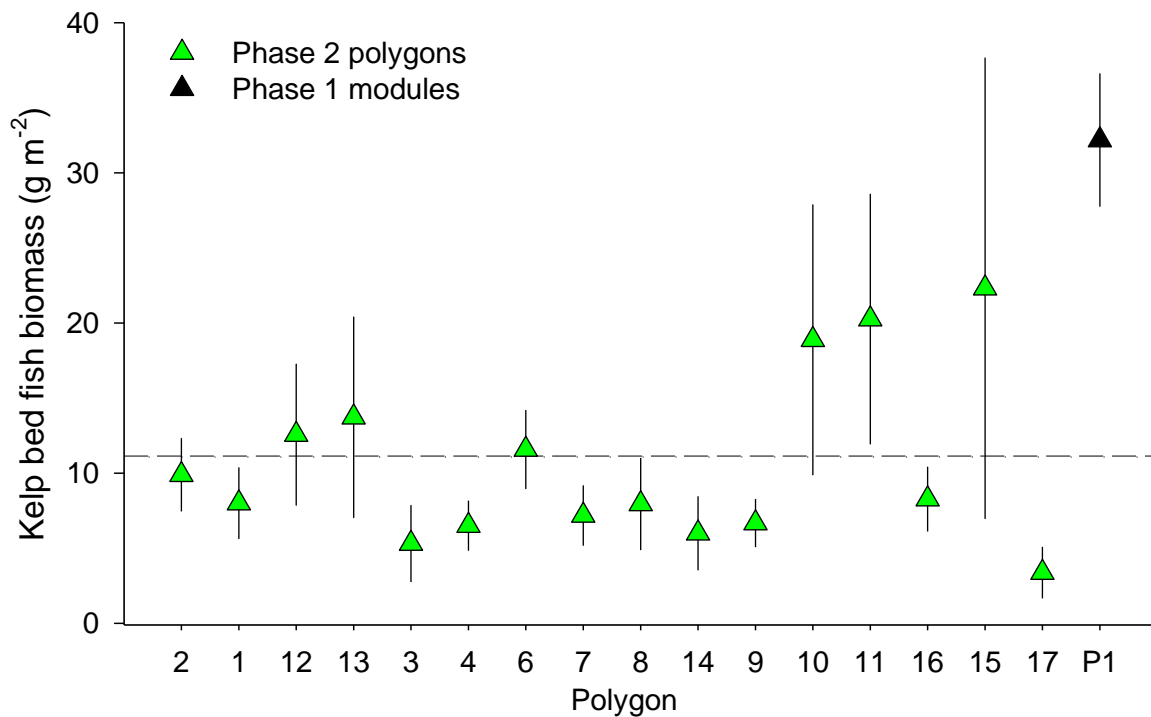


Figure 5.2.21. Four-year (2009 - 2012) running average of biomass density (\pm standard error) of kelp bed fish within 2 m of the bottom at Wheeler North Reef. Polygon numbers are ordered from south to north. Dashed line represents the mean for the entire reef.

6.0 Performance Assessment of Wheeler North Reef

Listed below are the absolute and relative 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. We describe the methodological approach used to monitor and evaluate each performance standard and present a determination of the performance of Wheeler North Reef for each standard based on the results obtained from these sampling methods. More detailed methods can be found in the monitoring plan for the SONGS reef mitigation project (Reed et al. 2012).

6.1 Absolute Performance Standards

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 1m² quadrats uniformly positioned along each of the 50m long transects in the primary polygons of Wheeler North Reef (Figure 4.4.2). The observer sights along 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 multi-beam sonar survey) and P_t is the proportion of the Wheeler North Reef covered by hard substrate in year t . The area covered by hard substrate remaining in year t , expressed as a proportion of the as-built area (determined in 2008 immediately after construction) is S_t/S_0 (where $(S_0 = A_0 P_0)$). The value of S_t/S_0 must be ≥ 0.9 for the Wheeler North Reef to successfully meet 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_0) is 155.1 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 from 2010 through 2012 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) at which time the area of hard substrate had decreased nearly 10% from the as-built condition. This was followed by an increase in percent cover of rock from 2011 to 2012, at which time the area of hard substrate was about 96% of the as-built area (Figure 6.1c), and the four-year running average was about 95% of the as-built area (Figure 6.1d). Thus, the Wheeler North Reef met this performance standard in 2012 using data from either 2012 only or the four-year running average.

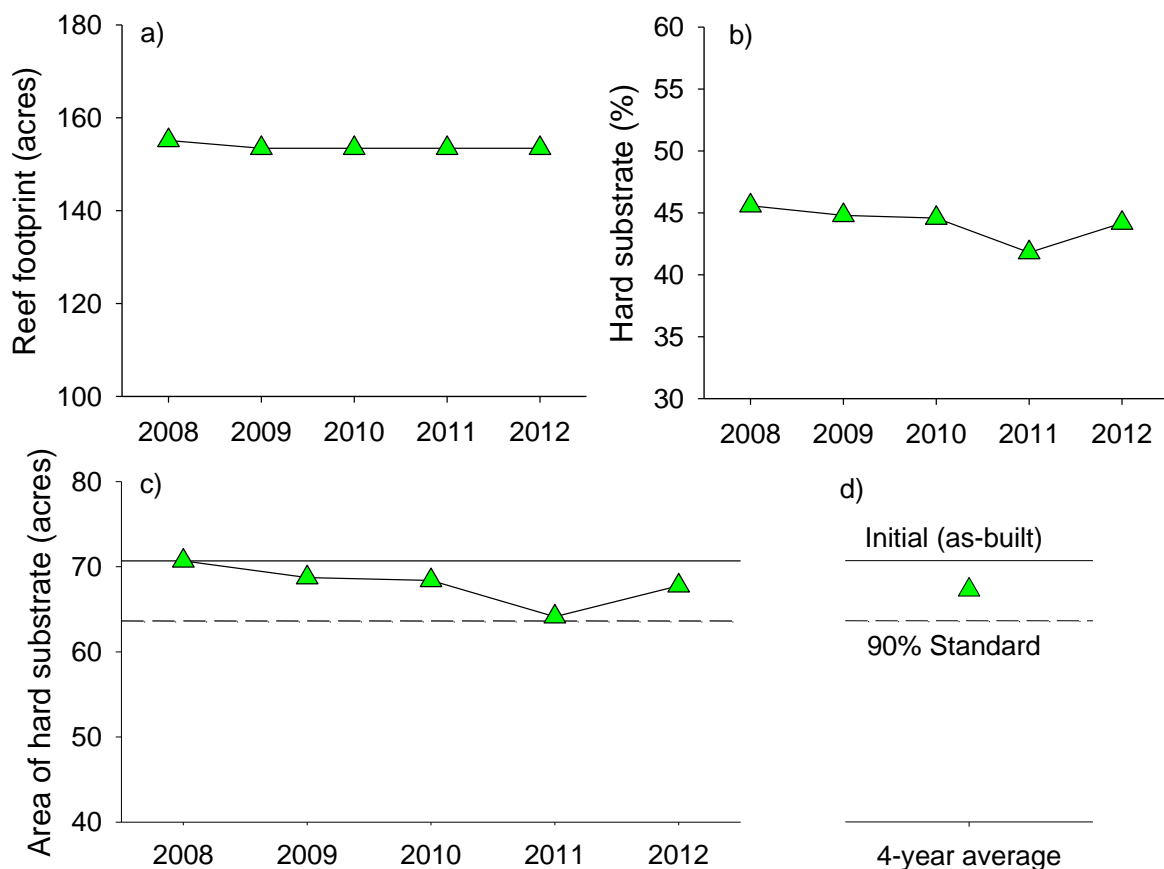


Figure 6.1. Variables used to calculate exposed hard substrate. (a) Reef footprint area, (b) Percent cover of hard substrate, and (c) Area of exposed hard substrate. (d) 4-year running average of the area of exposed hard substrate.

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 92 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 (these criteria are the same ones used to assess the impacts of SONGS on giant kelp). The proportion of transects with a mean density ≥ 4 adult plants per 100m² (based on the sum 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 100m², 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 has successfully met this performance standard. If for a given year the value of A_k is ≥ 150 acres, then the Wheeler North Reef is 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 and the three 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 6.2a). 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 through 2012 when 90 of the 92 transects sampled had at least 4 adult plants per 100m² (Figure 6.2a). Because of the low value in 2009, the four-year running average of medium-to-high density kelp was 134 acres, which is below the 150-acre standard (Figure 6.2b). However, since the performance standard for giant kelp is an absolute one, it is evaluated with either the value for 2012 or the four-year running average, and since the 2012 value exceeded 150 acres, the Wheeler North Reef met the performance standard for giant kelp in 2012.

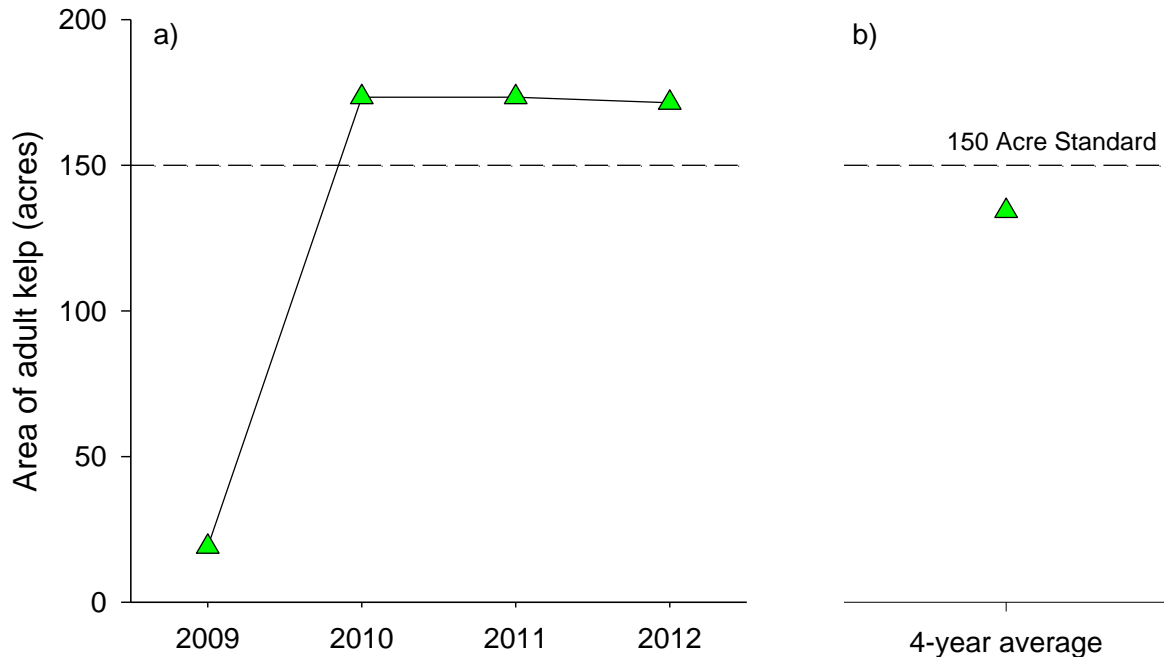


Figure 6.2. The number of acres of medium to high density adult kelp at Wheeler North Reef (a) annual values for 2009 - 2012 and (b) 4-year running average.

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 the 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 and extending the length 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 each 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 92 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 lengths 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). As is the case for 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 the mean standing stock of bottom-dwelling fish at Wheeler North Reef for the current year or for the four-year running average of the current year and the three preceding years is ≥ 28 tons, then Wheeler North Reef will be considered to have met this performance standard for that year.

Results: The standing stock of bottom-dwelling fish on the Wheeler North Reef has been far below the fixed performance standard of 28 tons in all four years of sampling. The highest value was in 2012 when standing stock was estimated at 13.6 tons, less than half of that required by the performance standard (Figure 6.3a). The four-year running average was 9.4 tons, about one-third of the required 28 ton standard (Figure 6.3b). Thus the Wheeler North Reef did not meet the performance standard for fish standing stock in 2012 or in any of the preceding three years.

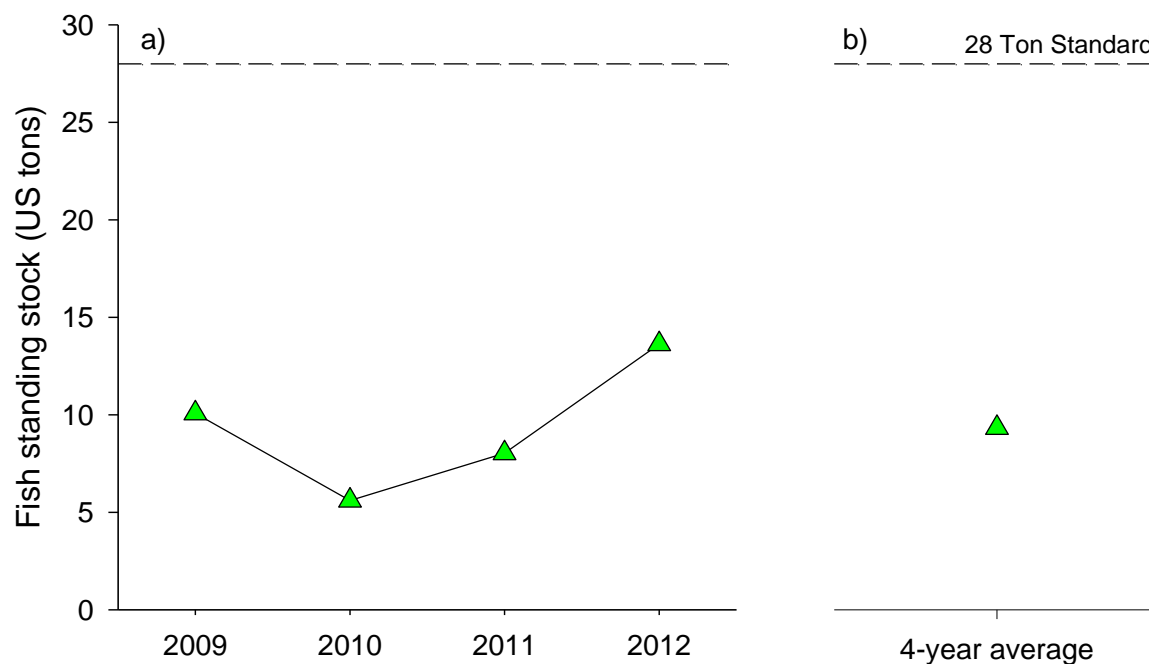


Figure 6.3. Estimated standing stock of fish at Wheeler North Reef (a) annual values for 2009 - 2012 and (b) 4-year running average.

4. 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 that 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 overgraze 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 the 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 (e.g., see Rassweiler et al. 2008) and is not required for evaluating the performance of Wheeler North Reef. However, more easily measured estimates of frond density (which are made as part of the evaluation of the performance standard pertaining to giant kelp area) 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).

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 these important functions of Wheeler North Reef are impaired. Second, data on the abundance of sea urchins, sea fans or other undesirable or invasive species are used to evaluate whether any impairment in these reef functions results 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 6.12a, b) 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 and 2012 (Figure 6.16a, b). 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 the relatively low numbers of such species in the monitoring data.

Invasive/undesirable 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 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 6.4). Despite this large increase, sea fans at Wheeler North Reef were still below the critical density of 10 m^{-2} noted by Ambrose et al. (1987). Sea fan density decreased slightly in 2011 and increased slightly in 2012 to levels that were similar to those in 2010, suggesting little if any net sea fan recruitment at Wheeler North Reef from 2010 to 2012.

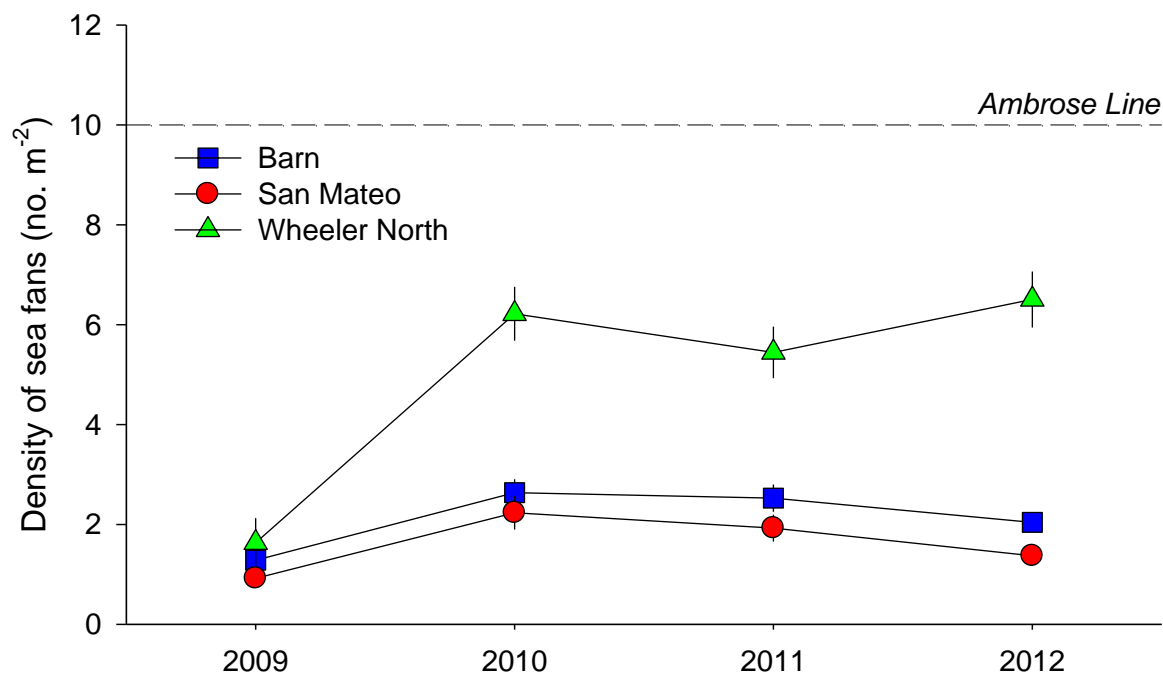


Figure 6.4. Mean density (± 1 standard error) of sea fans, *Muricea* spp. at Wheeler North Reef, San Mateo and Barn for 2009 - 2012.

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 small fraction of the hard substrate ($< 2\%$), 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} (labeled the *Arkema Line* in Figure 6.5). Monitoring data from 2009 -2012 show that sea urchin densities have changed little since 2009 at Wheeler North Reef, averaging ~ 1 individual m^{-2} in 2012 (Figure 6.5). This density is far below that needed to significantly impact giant kelp and other components of the benthic community (i.e., the *Arkema Line*).

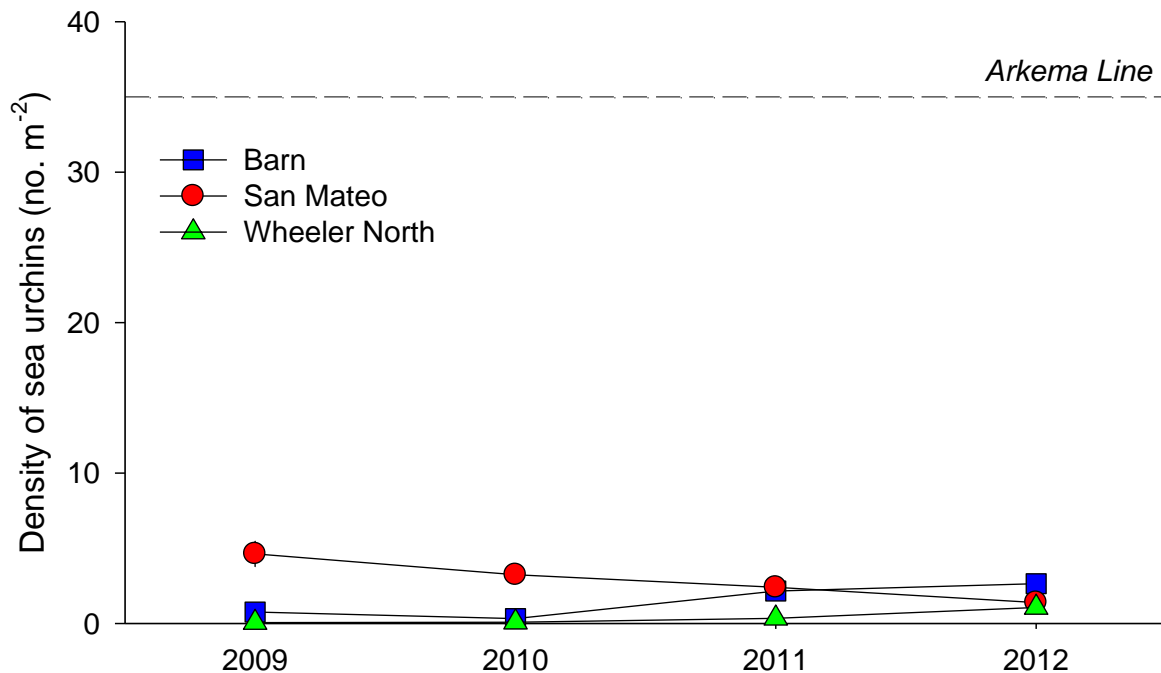


Figure 6.5. Mean density (± 1 standard error) of sea urchins, *Strongylocentrotus* spp. at Wheeler North Reef, San Mateo and Barn for 2009 - 2012.

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. Thus the Wheeler North Reef met the performance standard for invasive species in 2012.

6.2 Relative Performance Standards

1. THE BENTHIC COMMUNITY OF MACROALGAE SHALL HAVE A COVERAGE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: The coverages of reef associated algae and sessile invertebrates provide a measure of the biomass associated with the benthic community attached to the hard substrate of a reef. Because many species of algae are difficult to count as individuals their abundance is estimated as percent cover. The percent cover of benthic macroalgae at Wheeler North Reef, San Mateo, and Barn is measured annually in the summer in five replicate 1 m^2 quadrats located at 10m intervals along

each of the eighty-two 50m transects located in the Phase 1 modules and the Phase 2 primary polygons (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 of five quadrats located along each 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 abundance of macroalgae 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 the four-year running average of the percent cover of macroalgae calculated from the current year and the three preceding years must not be significantly less than that of the reference reef with the lower four-year running average of macroalgal cover (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: The percent cover of macroalgae at Wheeler North Reef was about 27% in 2009; decreased to about 10% in 2010 when the surface canopy of giant kelp became fully established, and has remained near this low level through 2012 (Figure 6.6a). In contrast, the percent cover of macroalgae at the two reference sites increased substantially during the four years of monitoring, most notably in 2012, reaching levels around 75% (Figure 6.6a). The different trajectories of algal percent cover at the Wheeler North Reef and the reference reefs resulted in a four-year running average of algal percent cover at the Wheeler North Reef that was substantially lower than that at the two reference reefs (Figure 6.6b). Consequently, the Wheeler North Reef did not meet this performance standard in 2012.

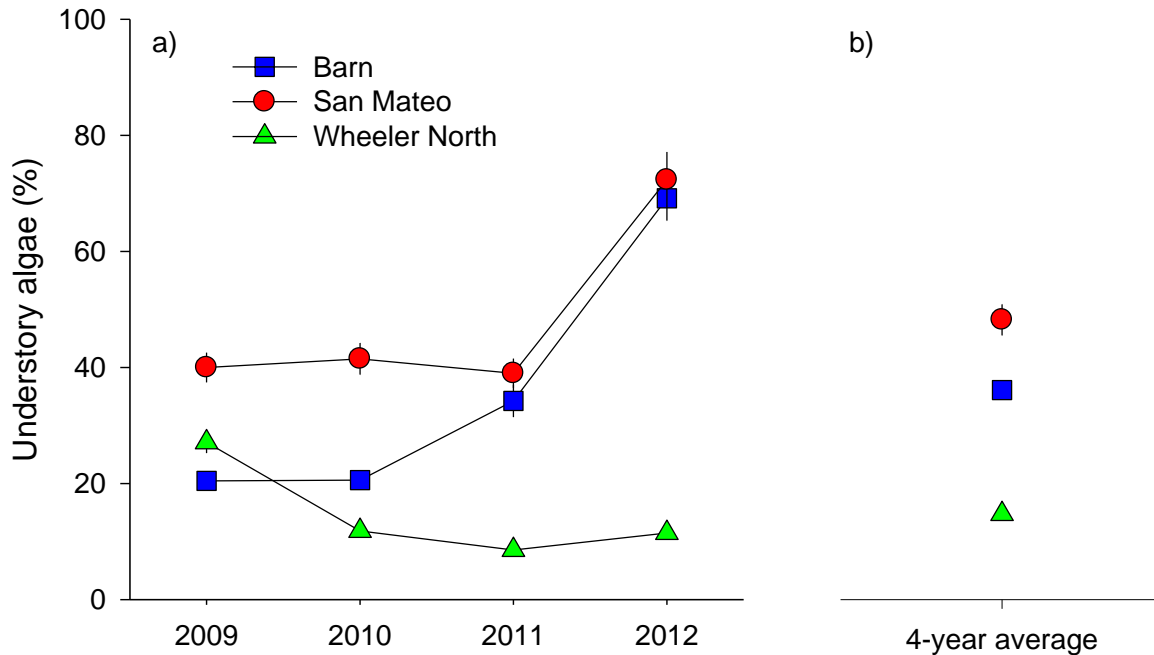


Figure 6.6. Mean percent cover (± 1 standard error) of understory algae at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

2. THE NUMBER OF SPECIES OF BENTHIC MACROALGAE SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: The percent cover data of macroalgae are used to determine the total number of species per transect on the Wheeler North Reef, San Mateo, and Barn. These values are averaged over the 82 transects on each reef to provide an estimate of average species density per kelp bed. For Wheeler North Reef to meet this performance standard its four-year running average of number of species of macroalgae per transect must not be significantly less than that of the reference reef with the lower four-year running average of number of species of macroalgae per transect (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: The average number of macroalgal species per transect declined over time at the Wheeler North Reef, while it increased at the two reference reefs (Figure 6.7a). As a result, the four-year running average of algal species density at the Wheeler North Reef was much lower than that at Barn and San Mateo (Figure 6.7b). Consequently, the Wheeler North Reef did not meet the performance standard for algal diversity in 2012.

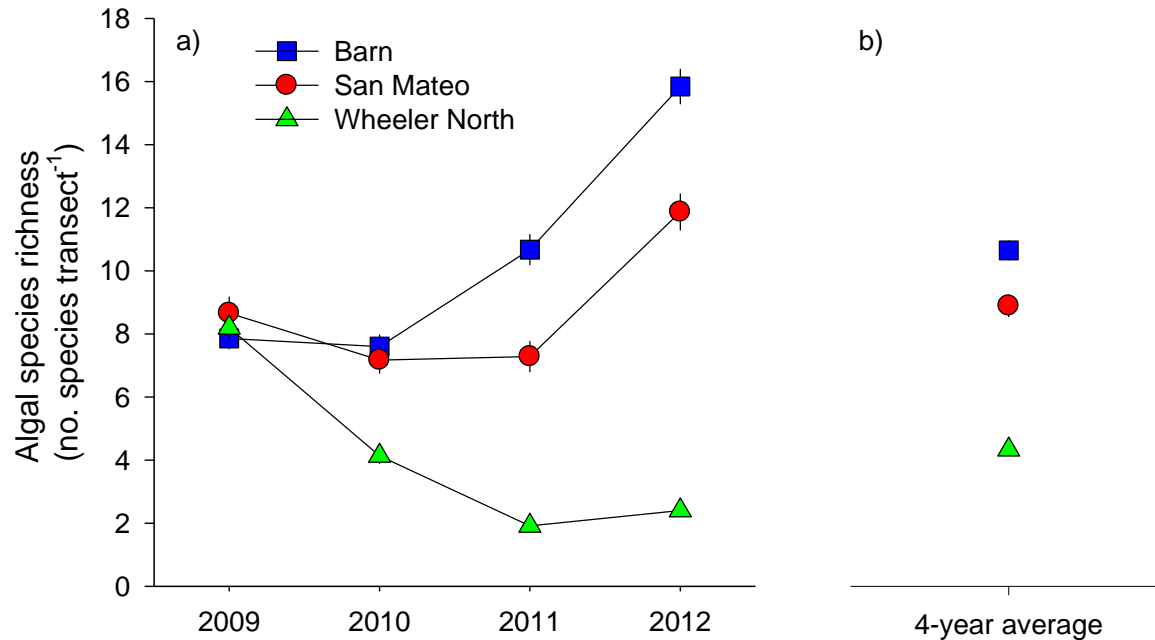


Figure 6.7. Mean species density (± 1 standard error) of understory algae at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

3. THE BENTHIC COMMUNITY OF SESSILE INVERTEBRATES SHALL HAVE A COVERAGE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: The percent cover of sessile invertebrates is measured at the same time and in the same way as the percent cover of benthic macroalgae. For Wheeler North Reef to meet this performance standard the four-year running average of the percent cover of sessile invertebrates calculated from the current year and the three preceding years must not be significantly less than that of the reference reef with the lower four-year running average of sessile invertebrate cover (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: As described in section 5.0, sessile invertebrates and algae compete for space and as a result, increases in the percent cover of one group are typically accompanied by decreases in the percent cover of the other. This is exactly the pattern that we have seen at the Wheeler North Reef, Barn and San Mateo. The percent cover of sessile invertebrates at the Wheeler North Reef in 2009 was about half of that at the reference reefs, but increased nearly three-fold over time as the cover of algae decreased (Figure 6.8a vs. Figure 6.6a). By contrast the percent cover of sessile invertebrates remained relatively constant at Barn and San Mateo from 2009 to 2011 before decreasing sharply in 2012 (Figure 6.8a); the exact opposite pattern that was observed for the percent cover of macroalgae at these sites (Figure 6.6a). Because the four-year running average of percent cover of sessile invertebrates at the Wheeler North Reef was nearly identical to that at Barn and slightly higher than that at San Mateo, the Wheeler North Reef met this performance standard in 2012 (Figure 6.8b).

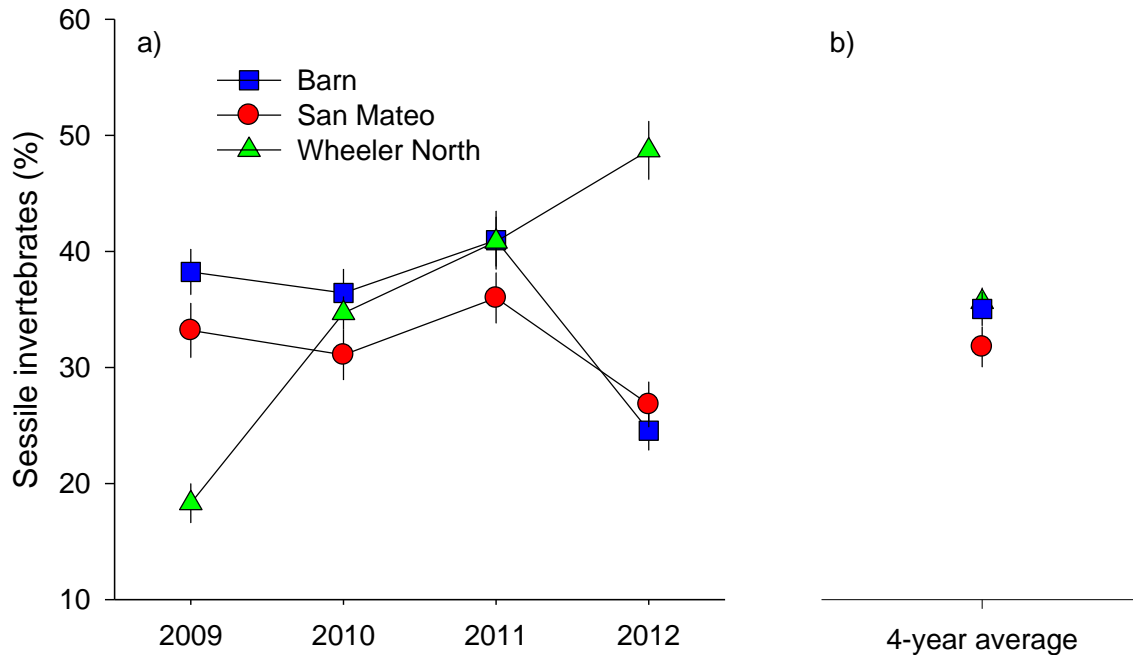


Figure 6.8. Mean percent cover (± 1 standard error) of sessile invertebrates at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

4. 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 1m² or a 0.5m² area created by dividing the 1m² quadrats in half using an elastic cord stretched across the frame of the quadrat. Densities are expressed as number per m² bottom. For Wheeler North Reef to meet this performance standard the four-year running average of the density of benthic mobile invertebrates calculated from the current year and the three preceding years must not be significantly less than that of the reference reef with the lower four-year running average of mobile invertebrate density (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: Much like the percent cover of sessile invertebrates, the density of mobile invertebrates at Wheeler North Reef was initially low ($< 10 \text{ m}^{-2}$) in 2009 and has increased over time to densities $> 100 \text{ individuals } 10 \text{ m}^{-2}$ (Figure 6.9a). In contrast the densities of mobile invertebrates at San Mateo and Barn have fluctuated much less over the four-year sampling period with densities ranging between 40 to 70 individuals per m² (Figure 6.9a). The four-year running average of mobile invertebrate density at Wheeler North Reef was intermediate between the two reference reefs (Figure 6.9b), thus the Wheeler North Reef met this performance standard for 2012.

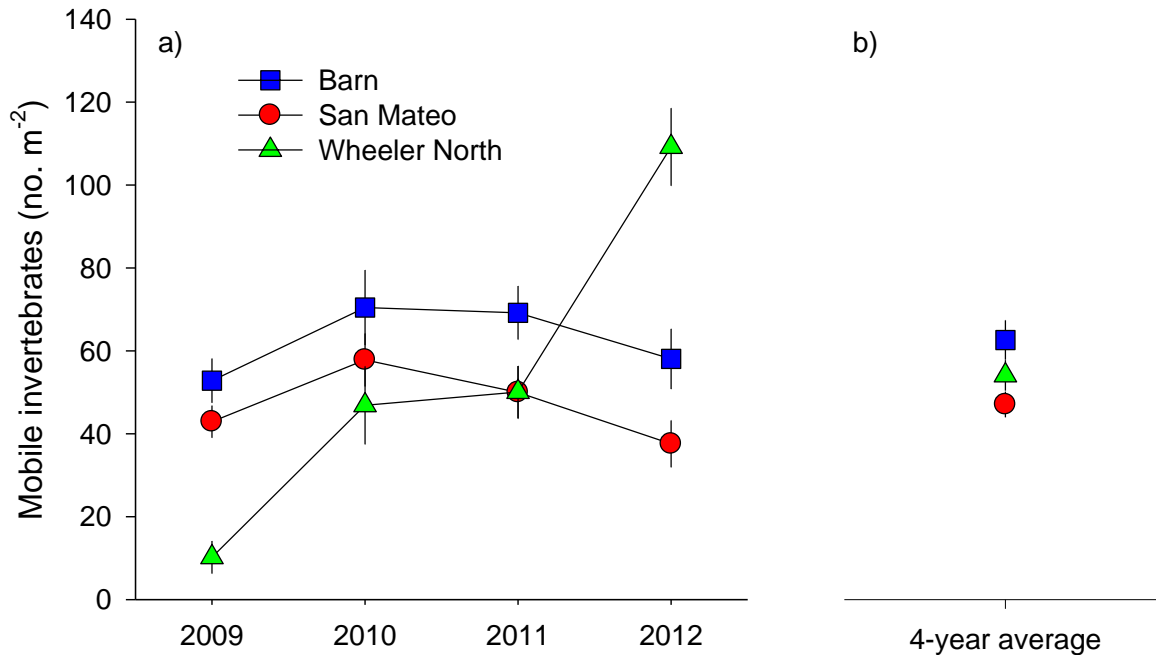


Figure 6.9. Mean density (± 1 standard error) of mobile invertebrates at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

5. THE COMBINED NUMBER OF SPECIES OF BENTHIC SESSILE AND MOBILE INVERTEBRATES SHALL BE SIMILAR TO NATURAL REEFS WITHIN THE REGION.

Approach: Data on the percent cover of sessile invertebrates are combined with data on the density of mobile invertebrates to determine the total number of species of benthic invertebrates on each transect at the Wheeler North Reef, San Mateo, and Barn. These values are averaged over the 82 transects on each reef to provide an estimate of average species density of benthic invertebrates per reef. For Wheeler North Reef to meet this performance standard its four-year running average of number of species of benthic invertebrates per transect must not be significantly less than that of the reference reef with the lower four-year running average of number of species of benthic invertebrates per transect (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: The average number of benthic invertebrate species per transect at the two reference reefs has declined slightly over the four-year sampling period, whereas it has steadily increased at Wheeler North Reef from a low value near 10 species per transect in 2009 to about 25 species per transect in 2012; slightly higher than the values observed at San Mateo and Barn (Figure 6.10a). While the number of species of invertebrates at Wheeler North Reef is on a promising trajectory, its four-year running average is still substantially below that of the two reference reefs due to the low numbers of species observed during the first couple years following its construction (Figure 6.10b). As a result, the Wheeler North Reef did not meet the performance standard for the number of species of benthic invertebrate in 2012.

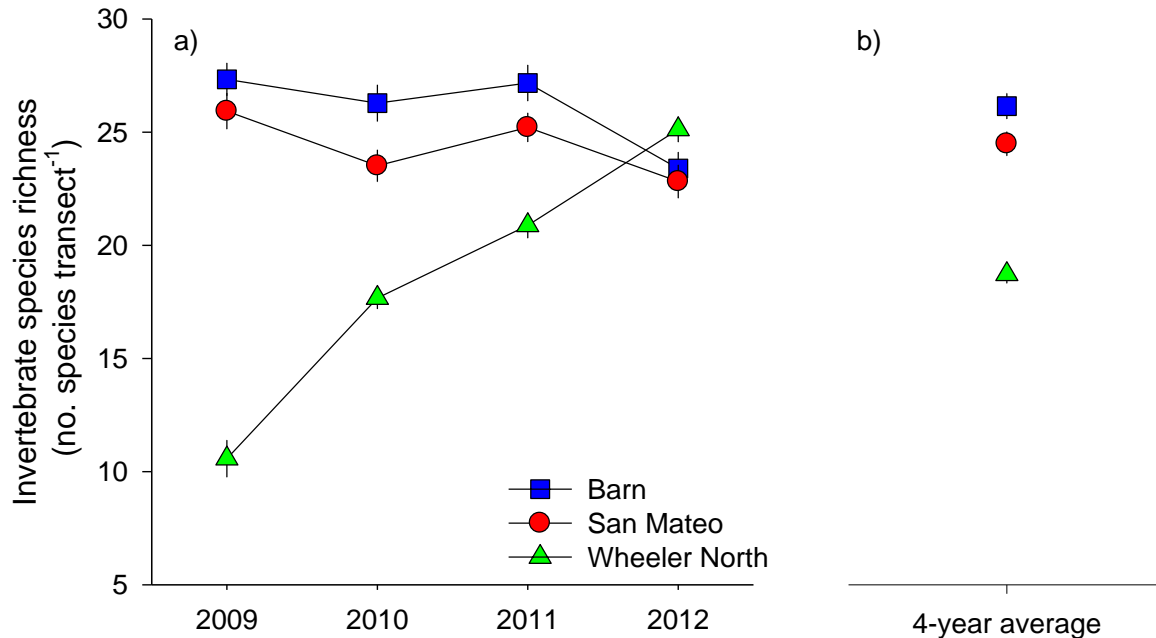


Figure 6.10. Mean species density (± 1 standard error) of invertebrates at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

6. 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 lengths 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 on a 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. For Wheeler North Reef to meet this performance standard the four-year running average of the density of resident fish calculated from the current year and the three preceding years must not be significantly less than that of the reference reef with the lower four-year running average of resident fish density (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: The densities of resident fish have fluctuated greatly during the four years of monitoring. In 2009, one year after reef construction, the density of resident fish at the Wheeler North Reef was 2 to 3 times greater than that at the reference reefs (Figure 6.11a). Fish densities declined dramatically to low values that were similar at all three reefs in 2010. In the two years following this decline densities steadily increased at the Wheeler North Reef and San Mateo, while at Barn they increased in 2011 and decreased in 2012 (Figure 6.11a). The four-year running average density of resident fish at the Wheeler North Reef during this variable period was slightly

higher than that at San Mateo and Barn (Figure 6.11b). Thus, Wheeler North Reef met the performance standard for resident fish density in 2012.

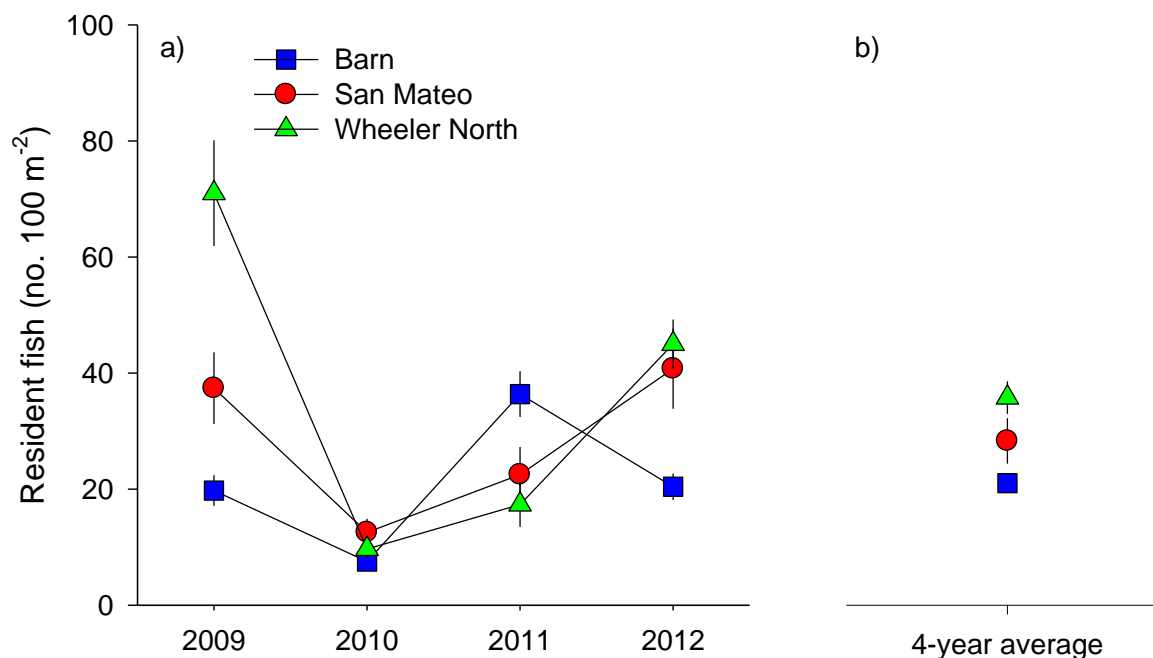


Figure 6.11. Mean density (± 1 standard error) of resident fish at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

7. THE 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 the Wheeler North Reef to 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 (YOY) 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 are data for resident fishes. The approach used for determining whether the density of YOY 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 YOY fish have been consistently low at all three reefs, averaging only a few individuals per transect. Temporal trends in YOY densities at the Wheeler North and San Mateo have been similar in that both sites showed a decrease from 2009 to 2010 followed by a steady increase in 2011 and 2012 (Figure 6.12a). In contrast YOY density at Barn has shown alternating increases and decreases during this time (Figure 6.12a), much like the pattern seen for resident fish at this site (Figure 6.11a). The four-year running average at the Wheeler North Reef was greater than that observed at both San Mateo and Barn (Figure 6.12b). Thus, the Wheeler North Reef met the performance standard for YOY density in 2012.

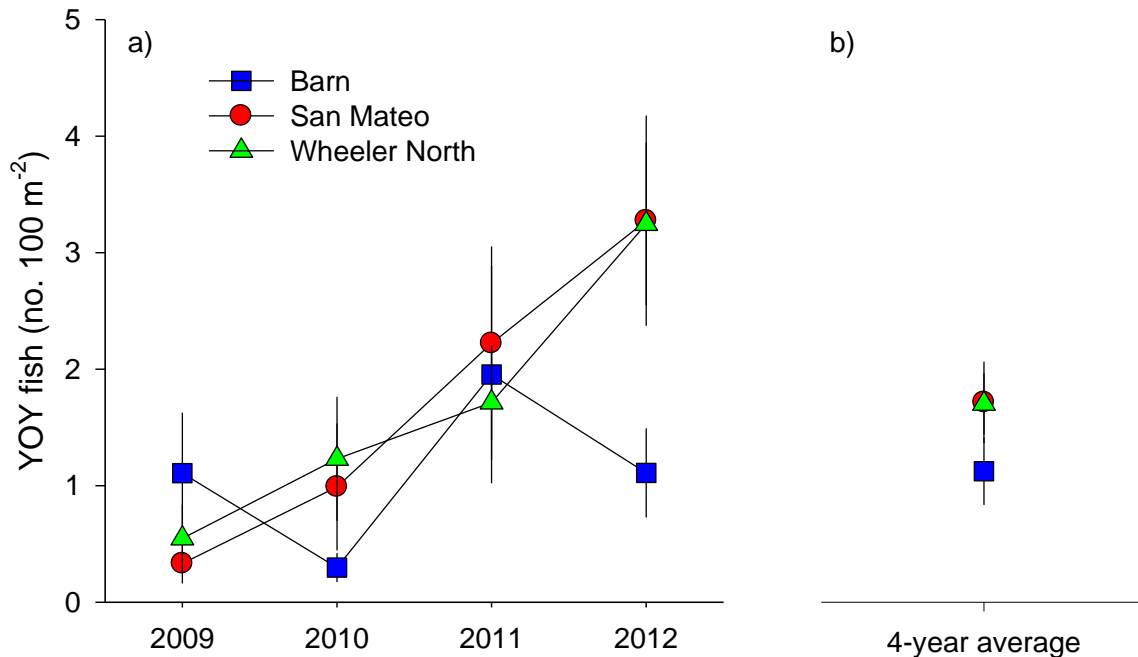


Figure 6.12. Mean density (± 1 standard error) of young-of-year fish at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

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

Approach: All fish counted to assess the abundance of resident and young-of-year fish are identified to species. These data are used to calculate the number of species of resident and young-of-year fish combined per transect on each reef. These values are then averaged over the 82 transects on the Wheeler North Reef, San Mateo, and Barn to provide an estimate of average species density of kelp bed fishes per reef. For Wheeler North Reef to meet this performance standard its four-year running average of number of species of kelp bed fish per transect must not be significantly less than that of the reference reef with the lower four-year running average of number of species of kelp bed fish per transect (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: During the four-year sampling period the diversity of kelp bed fish at the Wheeler North Reef and San Mateo followed a similar trajectory (decreasing from 2009 to 2010 and increasing from 2010 to 2012) with the number of species of fish per transect at the Wheeler North higher than that at San Mateo (Figure 6.13a). Fish diversity has been consistently higher at Barn during the four years of monitoring, although the diversity of fish at Wheeler North Reef was nearly equal to that at Barn in 2012 (Figure 6.13a). The four-year running average of fish diversity at the Wheeler North Reef was intermediate between Barn and San Mateo, consequently the Wheeler North Reef met the performance standard for numbers of species of fish in 2012.

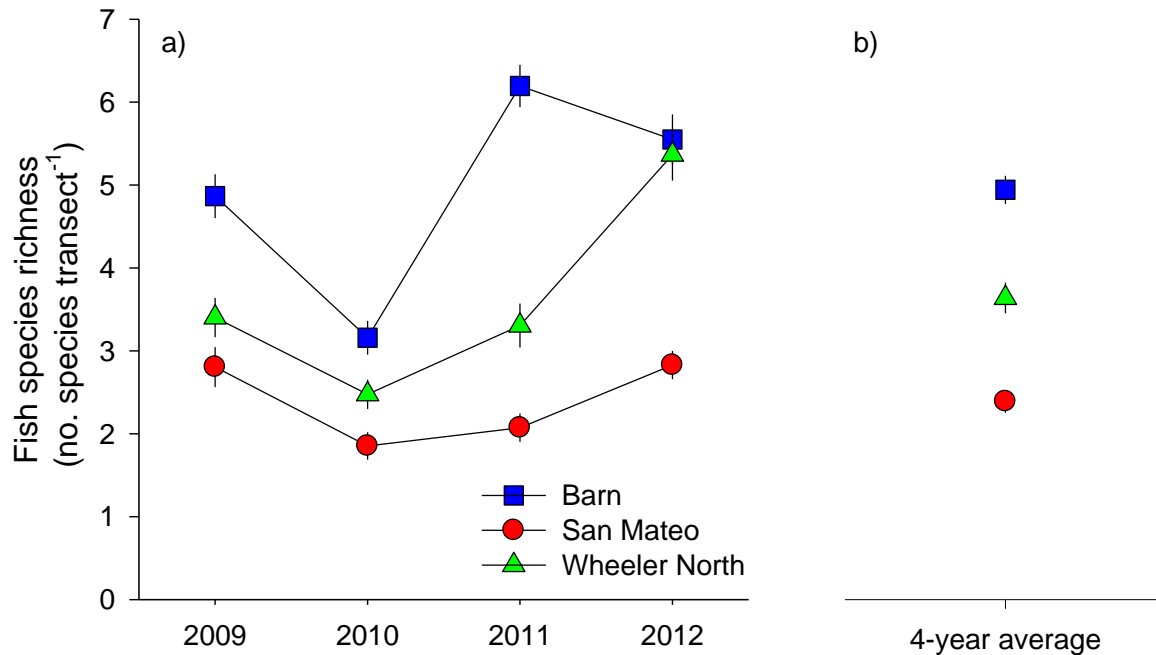


Figure 6.13. Mean species density (± 1 standard error) of fish at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

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). Details of the method used to estimate fish production are provided in the monitoring plan for the SONGS' reef mitigation project (Reed et al. 2012).

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 of fish production for each of the three reefs. For Wheeler North Reef to meet this performance standard the four-year

running average of fish production calculated from the current year and the three preceding years must not be significantly less than that of the reference reef with the lower four-year running average of fish production (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: Temporal patterns of reef fish production at the Wheeler North Reef mirrored those at San Mateo, but with slightly higher values. At both sites production was highest in 2009 (about $3 \text{ g m}^{-2} \text{ y}^{-1}$) before declining to $< 2 \text{ g m}^{-2} \text{ y}^{-1}$ in 2010. Fish production has remained near this low value for the past three years at both sites (Figure 6.14a). In contrast, fish production at Barn has fluctuated greatly over time, but nonetheless has been consistently higher than that observed at the Wheeler North Reef and San Mateo in each of the last four years (Figure 6.14a). Because fish production at the Wheeler North Reef has been intermediate between Barn and San Mateo in all four years the value of its four-year running average was also intermediate between the two reference reefs (Figure 6.14b). Thus, the Wheeler North Reef met the performance standard for fish production in 2012.

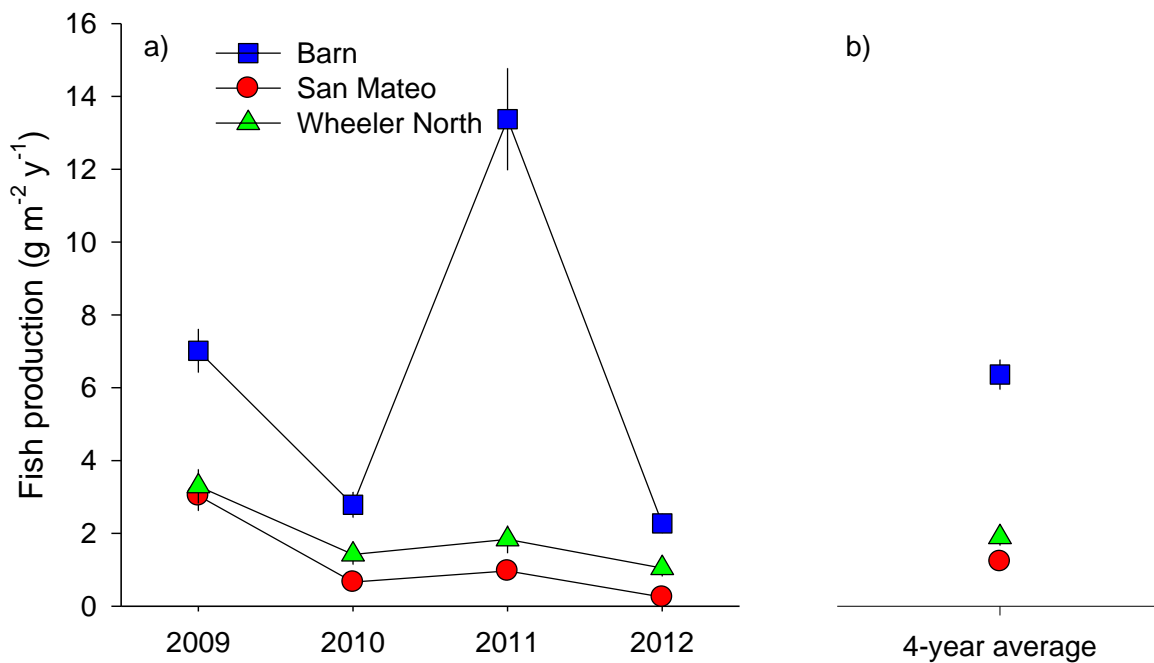


Figure 6.14. Mean fish production (± 1 standard error) at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

10. 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 effectively reproduce. Data on per capita egg production of a select group of targeted reef fish species collected throughout the spawning season (summer through autumn) 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 and autumn 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 the variance and thus 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 is 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 the Wheeler North Reef to be considered similar to that at natural reference reefs the four-year running average of the median value obtained from the resampled distribution of the Fecundity Index at the Wheeler North Reef must not be significantly lower than that of the reference reef with the lowest four-year average 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 varied inconsistently among the three reefs during the four-year period. It was highest at Wheeler North Reef in 2009 and 2010; lowest at the Wheeler North Reef in 2011; and intermediate at the Wheeler North Reef in 2012 (Figure 6.15a). Barn showed similar erratic fluctuations in the Median Fecundity Index over time that varied asynchronously with the Wheeler North Reef, while the Fecundity Index at San Mateo showed a consistent increasing trend (Figure 6.15a). Despite these erratic and asynchronous fluctuations in fish reproductive rates at the three sites, their four-year running averages were nearly identical (6.15b). Thus the Wheeler North Reef met the performance standard for fish reproductive rates in 2012.

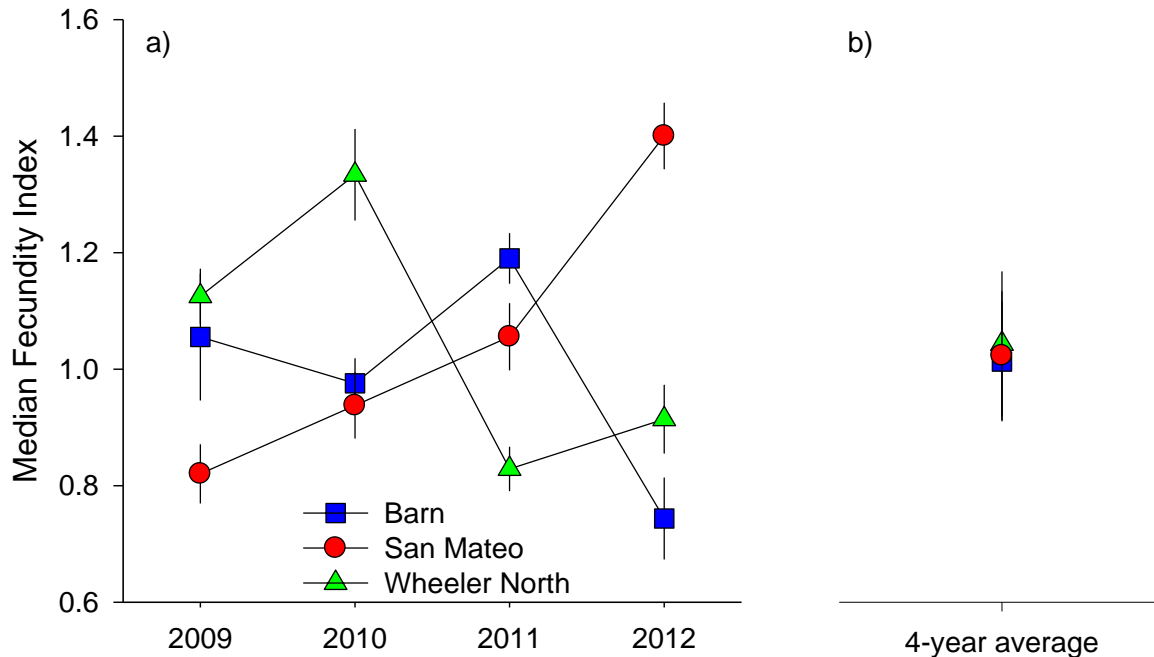


Figure 6.15. Median fecundity index (± 1 standard deviation) at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

11. 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 four-year running average of the FCS index must not be significantly less than that of the reference reef with the lower four-year running average of the FCS index (i.e. the p-value for the t-test must be less than the proportional difference between the two reefs).

Results: The three reefs have shown very different temporal patterns with respect to providing benthic food chain support. The standardized FCS index at the Wheeler North Reef has consistently declined in each of the last four years (Figure 6.16a). In contrast, the FCS index at San Mateo increased from 2009 to 2011, then declined slightly in 2012, while the FCS index at Barn remained relatively constant from 2009-2011 and increased in 2012 (Figure 6.16a). The four-year running average of the FCS at Wheeler North Reef was lower than at both reference reefs, but not statistically lower than that at San Mateo (Figure 6.16b). Consequently, the Wheeler North Reef met the performance standard for food chain support in 2012.

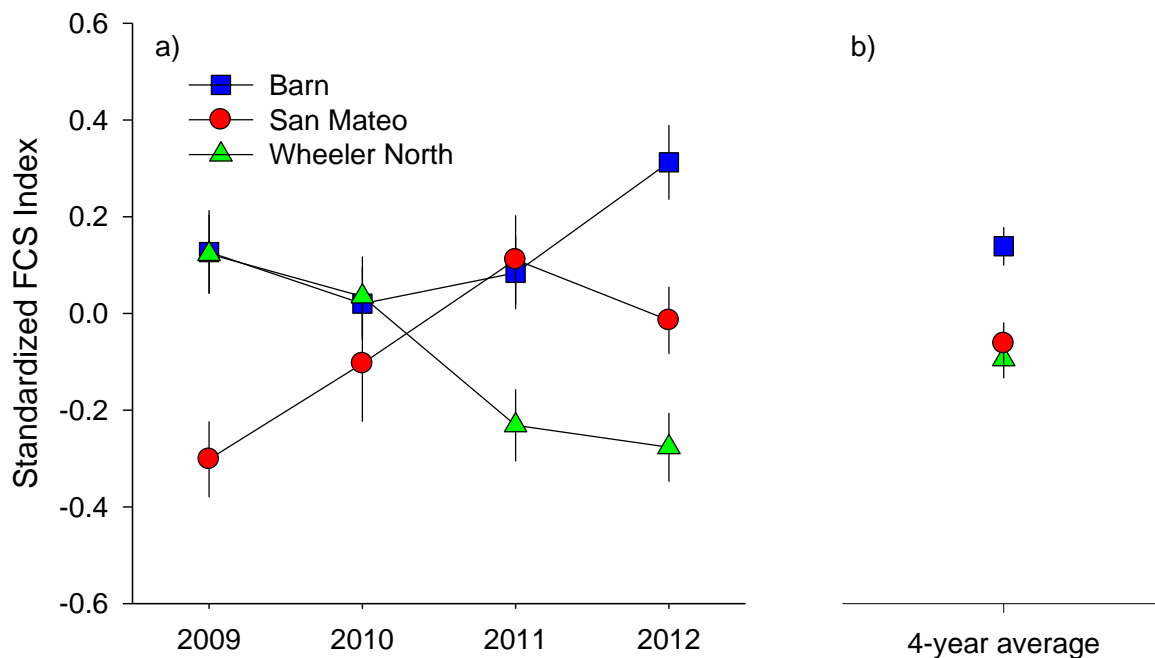


Figure 6.16. Food chain support (FCS) index (± 1 standard error) at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

7.0 Permit Compliance

7.1 Summary of SONGS Permit compliance

To receive mitigation credit for a given year the Wheeler North Reef must meet: (1) all four absolute performance standards, and (2) at least as many relative standards as the reference reefs. The absolute performance standards are only measured at the Wheeler North Reef and they are assessed using values from either the current year (i.e., 2012) or the four-year running average, whichever is higher. The relative performance standards are measured at Wheeler North Reef, San Mateo and Barn using only the four-year running average (see Section 4.1).

A summary of the performance of the Wheeler North Reef as measured by the four absolute performance standards and the 11 relative performance standards is shown in Table 7.1. In 2012 the Wheeler North Reef met three of the four absolute standards; it failed to meet the standard for fish standing stock. Wheeler North Reef met eight of the 11 relative performance standards compared to San Mateo which met seven and Barn which met nine. Thus Wheeler North Reef met more relative standards than San Mateo, the lowest performing reference reef. However, because Wheeler North Reef did not meet the absolute standard for fish standing stock it received no mitigation credit for 2012.

Table 7.1. Summary of the performance of Wheeler North Reef in 2012 with respect to the absolute and relative performance 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.

	WNR		San Mateo		Barn	
	2012	4-yr avg	2012	4-yr avg	2012	4-yr avg
ABSOLUTE STANDARDS						
1.Substrate	YES	YES				
2.Giant kelp	YES	NO				
3.Fish standing stock	NO	NO				
4.Invasive species	YES	YES				
Number of Absolute Standards met	3	2				
RELATIVE STANDARDS						
1.Algal cover		NO		YES		YES
2.Algal species richness		NO		YES		YES
3.Sessile invertebrate cover		YES		NO		YES
4.Mobile invertebrate density		YES		NO		YES
5.Invertebrate species richness		NO		YES		YES
6.Resident fish density		YES		YES		NO
7.YOY fish density		YES		YES		NO
8.Fish species richness (all ages)		YES		NO		YES
9.Fish production		YES		NO		YES
10.Fish reproductive rates		YES		YES		YES
11.Food chain support		YES		YES		YES
Number of Relative Standards met		8		7		9

Despite the above noted deficiency in the performance with respect to fish standing stock the Wheeler North Reef has shown promise in meeting many of its objectives. For example, it has consistently met the absolute performance standards pertaining to hard substrate and lack of invasive species in all four years of monitoring and the absolute standard for giant kelp in each of the last three years. Moreover, in 2012 the Wheeler North Reef performed at a level similar to that as the reference reefs with respect to the relative performance standards. The Wheeler North Reef continues to under-perform with respect to understory algae, which is to be expected given the intense shading by the dense canopy of giant kelp that has been present since 2010. The failure of the Wheeler North Reef to meet the performance standard for invertebrate species richness in 2012 might also be expected because colonization by many species of invertebrates does not occur every year. Thus it may take several years for many species of invertebrates to accumulate on a newly constructed artificial reef. The steady increase in the species richness of invertebrates at Wheeler North Reef since it was constructed supports this notion. That the mean value for invertebrate species richness at Wheeler North Reef in 2012 was higher than that at either Barn or San Mateo is quite promising. If this increasing trend in invertebrate species richness continues or if it stabilizes at current levels, then the four-year running average of this performance standard at the Wheeler North Reef should be similar to that of the reference reefs within a few years. On the other hand if the unmatched decreasing trend observed in benthic food chain support at the Wheeler North Reef continues or stabilizes at the current low level, then the four-year running average for this standard at the Wheeler North Reef will likely drop below that of both reference reefs.

7.2 Reasons for failing to meet the performance standard for fish standing stock

The standing stock of kelp bed fish at the Wheeler North Reef was compared to that of a comparable area at San Mateo and Barn to determine whether the physical characteristics or location of Wheeler North Reef were responsible for its failure to support 28 tons of fish biomass. This was done by scaling the mean biomass density of kelp bed fish at San Mateo and Barn up to 176 acres for the four-year mitigation period (2009-2012) as well as for the seven-year period in which data were collected during Phase 1 (2000-2006). Results of this analysis show that during the four-year mitigation period the standing stock of kelp bed fish at Wheeler North Reef was slightly higher than that at San Mateo, but considerably less than that at Barn. The standing stock of fish at Barn reached or exceeded 28 tons in only one of the four years, but the value in that year (2011) was high enough to cause the 4-year running average of Barn in 2012 to exceed 28 tons. Thus Barn met the 28 ton performance standard in 2012, but San Mateo did not. This pattern contrasts sharply with longer seven-year time series of Phase 1 during which the standing stock of fish at Barn was considerably below the 28 ton standard in every year (Figure 7.2.1a), while San Mateo exceeded 28 tons in three of the seven years using the current year value (Figure 7.2.1a) and in all four years that a four-year running average could be calculated (Figure 7.2.1b). These results suggest that 176 acres at either Barn or San Mateo is not sufficient to consistently support 28 tons of kelp bed fish over the long term.

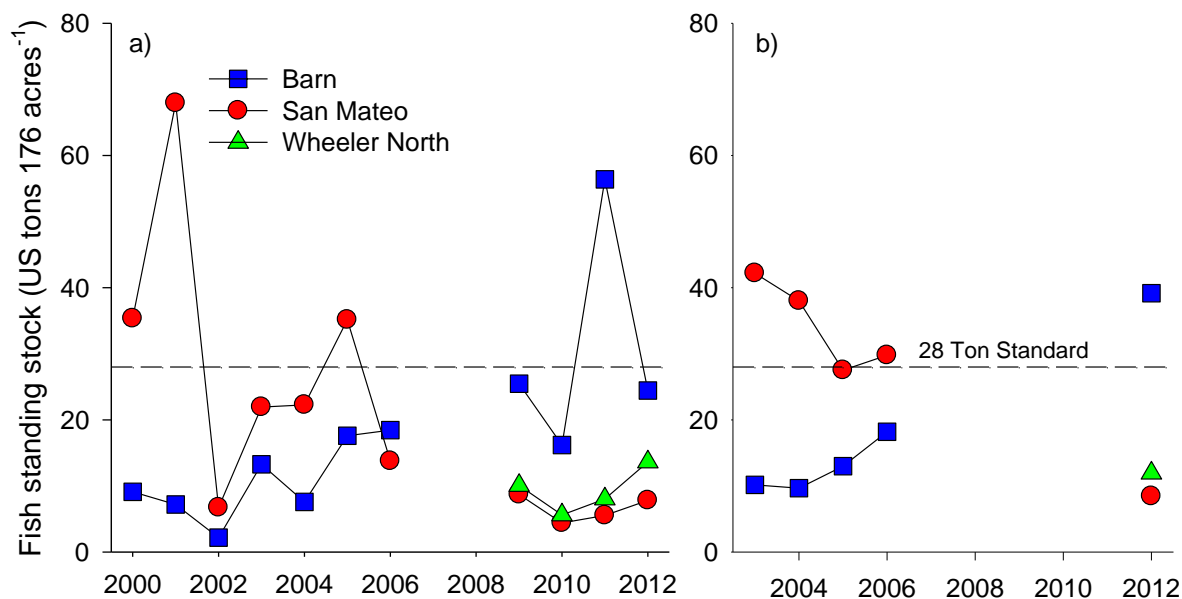


Figure 7.2.1 Estimated standing stock of fish at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2012 and (b) 4-year running average.

Data on fish biomass from the Phase 1 quarry rock modules collected during 2000 – 2006 and 2009-2012 were scaled to 176 acres and used to evaluate the extent to which the percent cover of rock on the bottom affects the standing stock of kelp bed fish. Results of these analyses show that higher rock coverage generally supports higher fish standing stocks. Modules with high rock coverage (i.e., ~ 80%) were projected to have met the 28 ton standard in all but two of the 11 years analyzed, whereas modules with low rock coverage (~ 42%) would not have supported 28 tons in any year, though it was within a half of a ton in 2006 (Figure 7.2.2a). A similar pattern was seen using the four-year running average; modules with high rock cover were projected to have exceeded 28 tons in all five years that could be evaluated while modules with low rock coverage would not have met the standard in any of the five years (Figure 7.2.2b). It is worth noting that the average rock coverage of the Wheeler North Reef is nearly identical that of the low cover rock modules (~ 40 %), while that at Barn is similar to the medium cover rock modules (~ 60%) and that at San Mateo is intermediate between the low and medium coverage (i.e., ~ 50%).

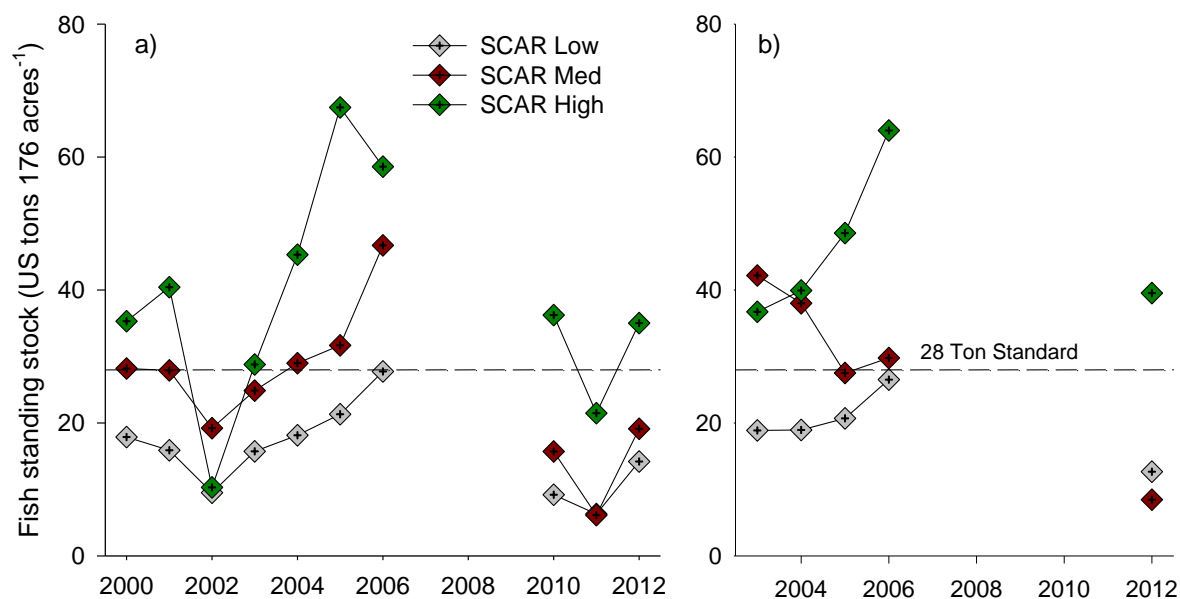


Figure 7.2.2. Estimated standing stock of kelp bed fish per 176 acres for the three coverages of rock tested on the Phase 1 modules of Wheeler North Reef. (a) annual values for 2009 - 2012 and (b) 4-year running average.

Collectively, the results of analyses using longer-term data from the reference sites and the Phase 1 modules strongly suggest that the present size and configuration of the Wheeler North Reef is not sufficient to consistently support 28 tons of kelp bed fish. This is a notable finding because the performance standard for fish standing stock, like all absolute performance standards, must be met in a given year by the Wheeler North Reef for that year to count towards mitigation credit.

8.0 Future Monitoring Plans

Monitoring of the Wheeler North Reef, San Mateo and Barn will continue in 2013 using the same level of effort and methods employed in 2012. In addition to monitoring, additional analyses will be done with existing data to better determine the configurations and footprint area needed for the Wheeler North Reef to consistently meet the performance standards.

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