Annual Report of the Status of Condition C: Kelp Reef Mitigation in 2016

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 is large enough to support 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 at least 150 acres of kelp forest habitat. Construction of the mitigation phase of the Wheeler North Reef was completed in 2008 and 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 year 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 (San Mateo and Barn) in the San Onofre region. 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 2016.

In 2016 the Wheeler North Reef met two of the four absolute standards used to judge its performance and nine of the 11 relative performance standards, which was one more than it met in 2015. The two relative standards not met in 2016 were the percent cover and the number of species of understory algae. The Wheeler North Reef has failed to meet these two standards in every year since 2010. Results of analyses from experiments and monitoring data indicate that the sparse cover and low diversity of understory algae at Wheeler North Reef is a natural phenomenon that 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 nine relative performance standards met by the Wheeler North Reef was equal to the nine relative standards met by Barn and exceeded the six relative standards met by San Mateo. Thus, the Wheeler North Reef was judged successful with respect to its ability to meet the relative performance standards because it was found to perform as well or better than a natural reef in the region. However, because the Wheeler North Reef met only two of the four absolute performance standards it did not earn any mitigation credit for 2016. So far the Wheeler North Reef has accumulated zero years of mitigation credit because it has never met all four absolute performance standards in a single year.

The absolute performance standards that the Wheeler North Reef did not meet in 2016 pertain to the acreage of giant kelp and the standing stock of fish. Anomalously warm water in the Pacific Ocean led to a regional decline in giant kelp in 2016 and resulted in the Wheeler North Reef's failure to meet the 150-acre kelp requirement for the first time since 2009. In contrast, the Wheeler North Reef has consistently failed to meet its requirement to support a fish standing stock of at least 28 tons. 28 tons is the average reduction in the standing stock of kelp bed fish caused by the operations of SONGS Units 2 and 3 determined by the impact assessment studies conducted by the Marine Review Committee. The standing stock of reef-dwelling fish on the Wheeler North Reef was below 15 tons for the first five years of monitoring (2009 - 2013). It increased sharply to 25.5 tons in 2014, but declined to 17.5 tons in 2015, and slightly increased to 19.1 tons in 2016. Thus after eight years the Wheeler North Reef has never met the 28-ton standard for fish standing stock. Results of analyses using longer-term data collected from the reference reefs and the Phase 1 experimental reef indicate that the reason the Wheeler North Reef has failed to meet the performance standard for fish standing stock is that its present configuration (low relief that covers 48% of the bottom) is not large enough to consistently support 28 tons of kelp bed fish. The conclusion drawn from these analyses is that remediation in the form of additional reef is needed for the Wheeler North Reef to consistently meet its current mitigation requirements over the long term.

Results of analyses using monitoring data collected from the Wheeler North Reef over a 16-year period show that the number of acres of additional reef needed for the Wheeler North Reef to meet the performance standard for fish standing stock with a 95% annual probability ranged from 30 to 200 depending on the configuration of rock coverage and vertical relief. Results also show that the tonnage of rock for a remediation reef consisting of a mixture of low and high relief decreases proportionally with the proportion of low relief reef, which leads to much greater material costs if high relief reefs are used for remediation.

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 hard substrate has been met every year and the absolute standard for adult giant kelp has been met in six of the eight years. In addition, the Wheeler North Reef has consistently met as many or more of the relative performance standards as the natural reefs. 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. and the non-native alga *Sargassum horneri* 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 – 2016 and summarizes the status of the project's compliance with Condition C of the SONGS permit for this period.

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. SCE's operating license has been modified to "possession only" and they are no longer authorized to operate the reactors. 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 to complete.

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. Since the shutdown, the flow in each unit has been reduced to about 42 million gallons a day or roughly 3% of the normal operating flow.

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 was approximately 19°F warmer than the intake water temperature. The diffusers were designed to cool the discharge water by increasing its mixing with ambient seawater at a rate of about ten times the discharge flow. The surrounding water was swept up along with sediments and organisms and transported offshore at various distances. Mixing caused by the diffuser system resulted in the formation of a turbid plume in the vicinity of the San Onofre kelp forest, which is located adjacent to and south of 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 fished caused by the mortality of fish impinged against the cooling water screens inside the power plant.
- A substantial reduction in the size of the giant kelp forest and its associated community adjacent to the SONGS diffusers.

Mitigation Requirements

As a result of the impact studies, in 1991 the CCC added new conditions to mitigate the adverse impacts of the power plant on the marine environment that require SCE and its partners to: (1) create or substantially restore at least 150 acres of southern California wetlands as out-of-kind mitigation for the losses of immature fish to entrainment in the power plant’s cooling water system (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 that supports 28 tons of reef fish (which could result in a reef larger than 150 acres) together with funding for a mariculture/marine fish hatchery as compensation for the estimated loss of 179 acres of a medium to high density kelp bed and associated community resulting from the discharge of cooling water from SONGS Units 2 and 3. Condition C requirements for the artificial reef consist of two phases, an initial small experimental reef (~24 acres) and a subsequent mitigation reef that is large enough to meet the 150-acre kelp and 28 ton fish standing stock requirements. 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 were 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 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 technical oversight team is aided by a crew of marine biologists hired under a contract with the University of California, Santa Barbara to collect and assemble the monitoring data. The technical oversight team is also assisted by independent consultants and contractors on an as need basis when expertise for specific tasks is required. 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).

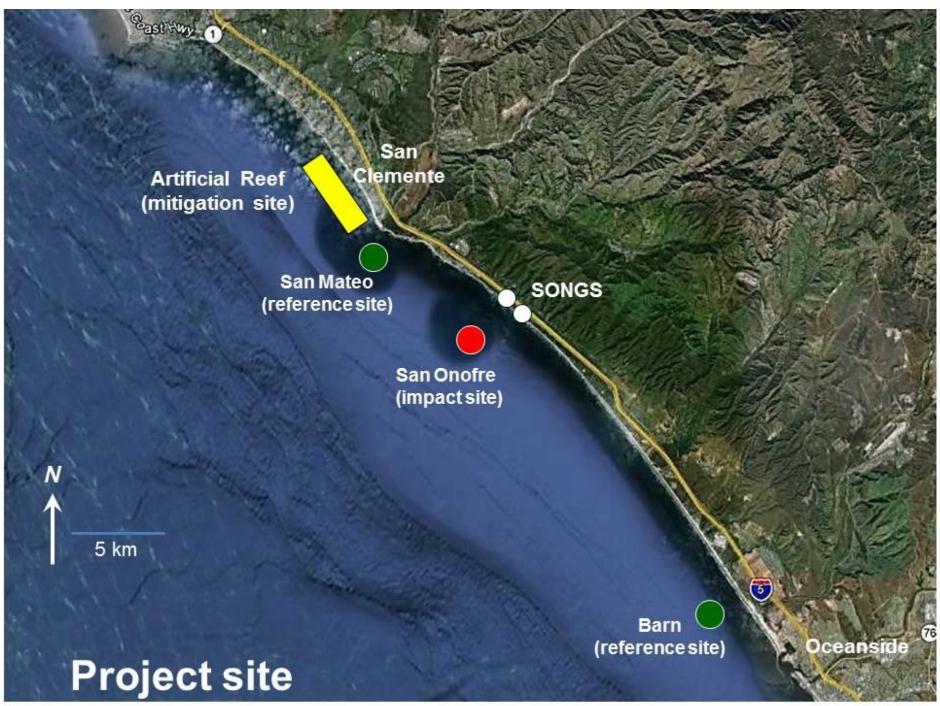


Figure 3.1.1. Location of the artificial reef mitigation site (shown as the yellow rectangle) in relation to SONGS and the impacted San Onofre kelp forest and the naturally occurring kelp forests at San Mateo and Barn.

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 measured roughly 40 m x 40 m and the 56 modules collectively covered about nine hectares (22.2 acres) of the sea floor when initially constructed.

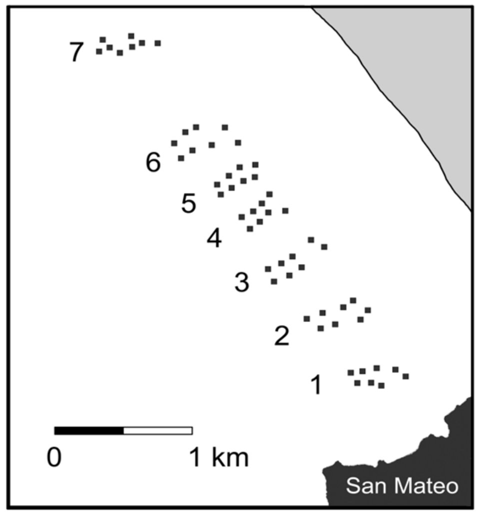


Figure 3.1.2. Design of the Phase 1 Experimental Reef. The black squares represent the 56 modules. Numbers indicate the seven locations.

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).

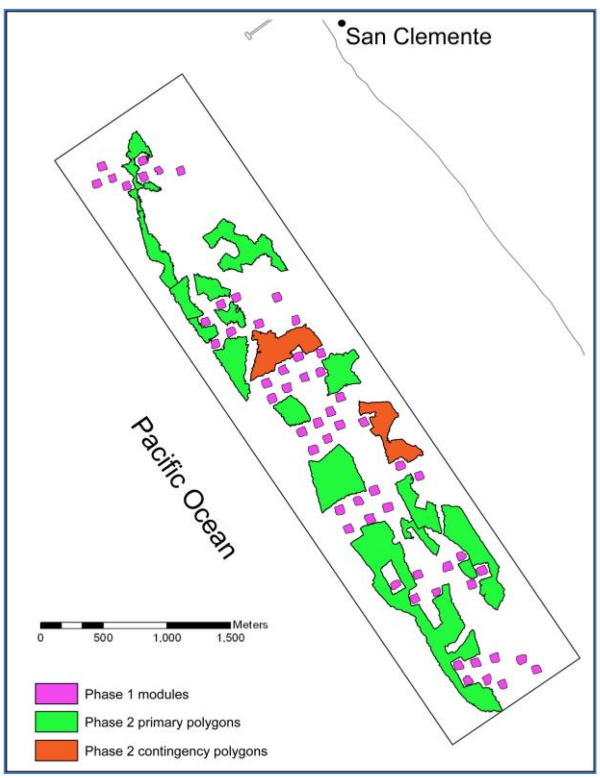


Figure 3.2.1. The 176-acre Wheeler North Artificial Reef, which includes the Phase 1 modules and the Phase 2 primary and contingency polygons.

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 acres (as estimated from multibeam sonar surveys in 2008 and 2009) of artificial 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 acres (hereafter referred to as primary polygons) were combined with the 24 acres of the Phase 1 reef (as determined in 2009, Elwany et al. 2009) to fulfill SCE's permit requirement that they construct a minimum of 150 acres of reef with an average of at least 42% cover. The 22 acres 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

This section briefly describes the general approach used to evaluate the success of the Wheeler North Reef in meeting its objective of compensating for the kelp forest resources lost due to SONGS' operations. A more detailed account of the approach and specific methods used can be found in the monitoring plan for the SONGS' reef mitigation project (Reed et al. 2017).

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 that is linked to the impacts measured at the San Onofre kelp forest, and relative standards, which require that the value of the variable of interest on Wheeler North Reef be similar to that measured at nearby 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 mitigation credit to be given 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 given year in order for that year to count towards compliance with Condition C.

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 and reference reefs for that year and the previous three years. An either /or criterion (i.e., using data from either a single year or a 4-year 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 those at 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 even the reference reefs will not consistently meet all the relative standards in a given year. 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) 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 similar 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 relatively close to it. The premise here is that nearby reefs with similar physical characteristics should support similar biota that are more likely to 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 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 of the San Mateo and Barn reference reefs requires that the mean (or in some cases the median) value for a given relative performance variable at Wheeler North Reef not be significantly lower than the mean (or median) value at the lower performing of the two reference reefs. We use a one-sample, one-tailed approach for all comparisons. Significance is determined using a method that utilizes both a formal probability value (i.e., p-value) and an effect size. This is generally done by means of a t-test except in the case of the performance standards pertaining to fish reproductive rates and food chain support for fish. For these two standards significance is determined by a resampling procedure in which the effect size is calculated as the proportional difference in the medians of the resampled distributions of the Wheeler North Reef and the lower performing reference reef, and the p-value is the percentile in the distribution of the lower performing reference reef that is equal to the median value of the Wheeler North Reef.

The 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 ≤ 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 Reed et al. 2017 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 reefs, 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 ensure 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.

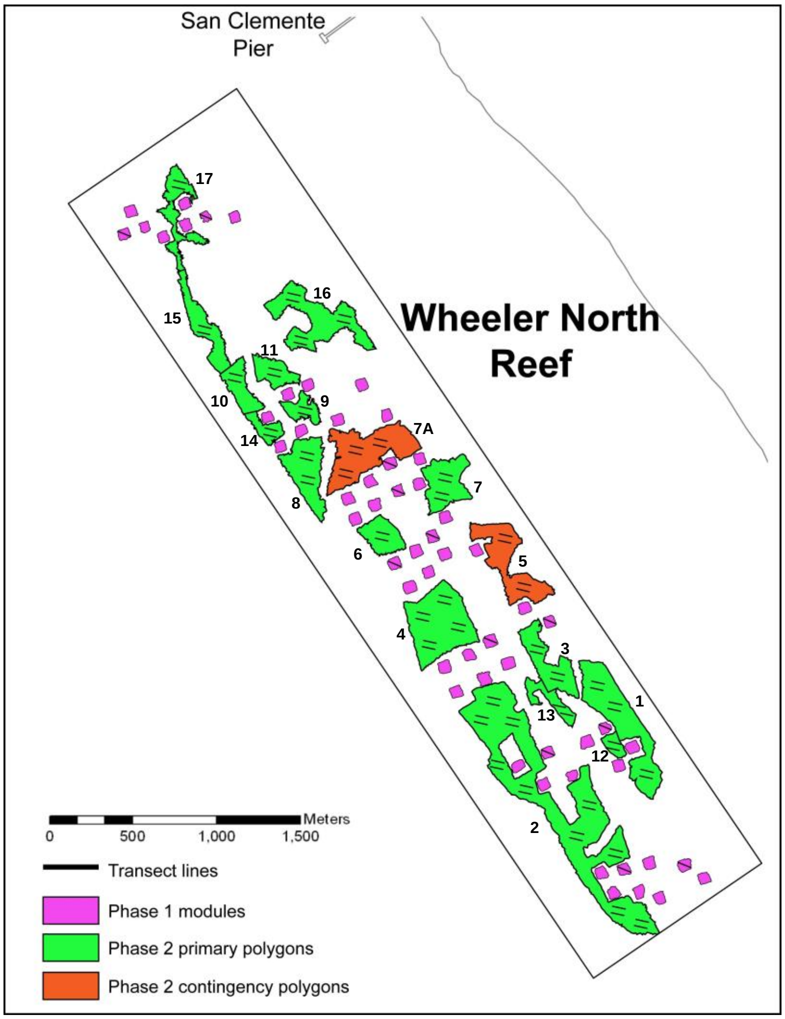


Figure 4.4.1. Schematic map of the Wheeler North Reef showing the location of the paired transects that are monitored to assess the performance standards. Numbers indicate polygon ID.

Data collected from these additional 10 transects are used with data from the 82 transects when evaluating the absolute 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 exceptions 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).

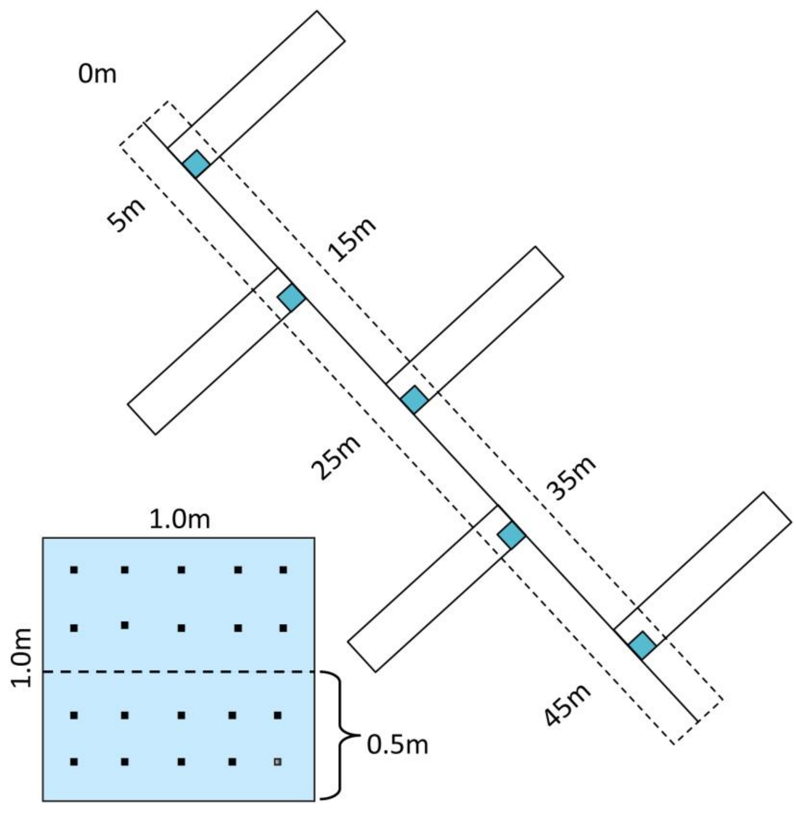


Figure 4.4.2. Schematic diagram of a sampling station. Fish are sampled in 50m x 3m band transects that extend 1.5m off the bottom (outlined with a dotted line). Adult giant kelp > 1m tall, large understory algae, and large mobile invertebrates are counted in the five 10m x 2m rectangular quadrats positioned 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 Physical and Biological Structure 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 – 2016, which represents the 8-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 because of sedimentation and burial, or increase due to scour caused by waves and currents. 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 82 transects located on the primary polygons and the Phase 1 modules at the Wheeler North Reef has been relatively constant over time ranging from a low of 42% in 2011 to a high of 46% in 2013, 2014 and 2016 (Figure 5.1.1).

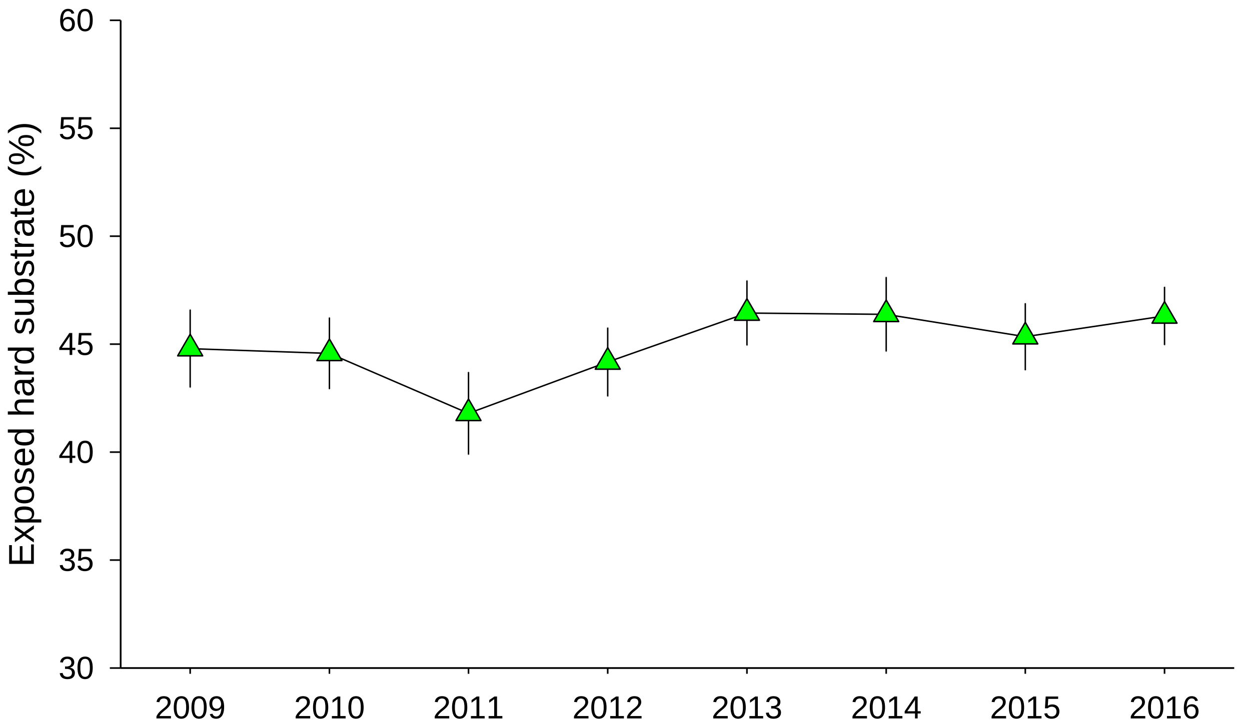


Figure 5.1.1 Mean percent cover (± 1 standard error) of exposed hard substrate at Wheeler North Reef from 2009 - 2016.

The percent cover of exposed rock at Wheeler North Reef is spatially heterogeneous and varies substantially among the polygons ranging from 31 to 58% cover in 2016 (Figure 5.1.2). Although the percent cover of rock averaged across the entire reef has varied little over time, rock cover of the individual polygons has fluctuated considerably. The largest fluctuations in the percent cover of exposed rock have been observed in polygons with relatively small footprint areas (e.g., # 6, 10, 11, 13 and 15, which had corresponding areas of 4.2, 3.9, 3.5, 2.9 and 5.5 acres) and are consequently sampled using fewer transects (n = 2). In contrast, the largest polygons (# 1, 2 and 16 with corresponding areas of 13.8, 38.9 and 11.2 acres) and the collective average of the 12 older Phase 1 modules are sampled with greater replication (n = 6 to 20 transects) and their mean percent cover of exposed rock has varied much less over the eight-year period.

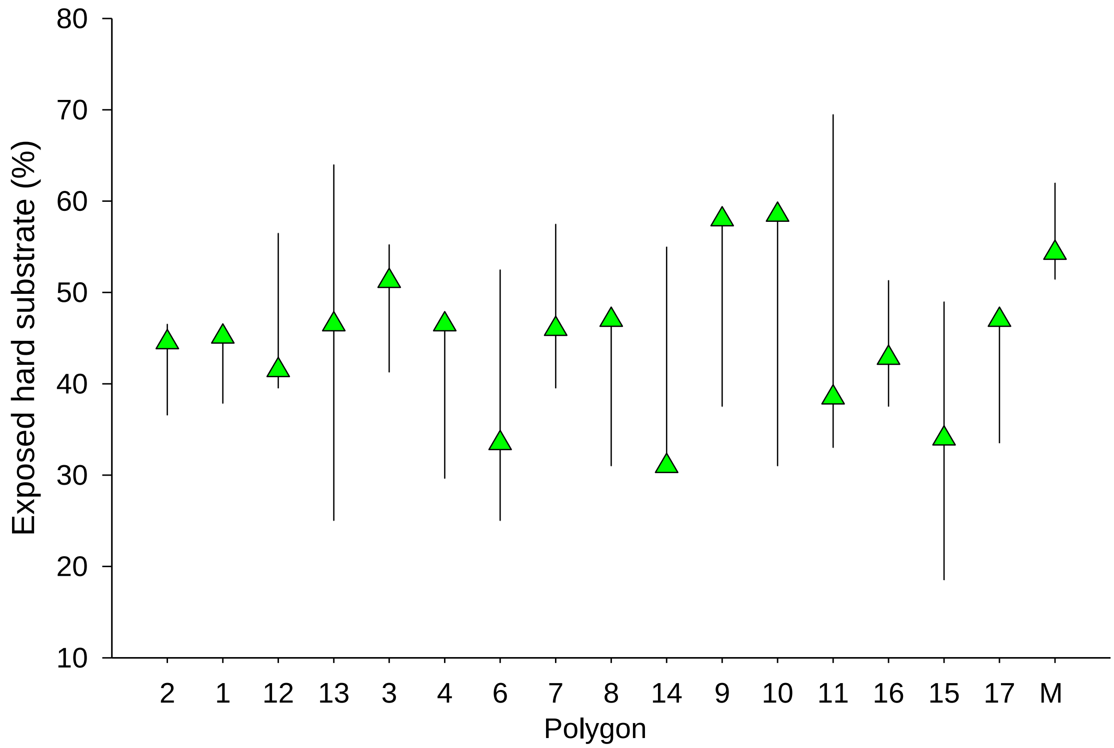


Figure 5.1.2. Mean percent cover of exposed hard substrate at Wheeler North Reef in 2016. Vertical lines represent the range of values observed from 2009 - 2016. Polygon numbers are ordered from south to north. M is the mean of the twelve Phase 1 modules.

Not surprisingly, the hard substrate at Wheeler North Reef consists mostly of boulders, 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 of which is a by-product of the quarry rock preparation) and natural bedrock also 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.

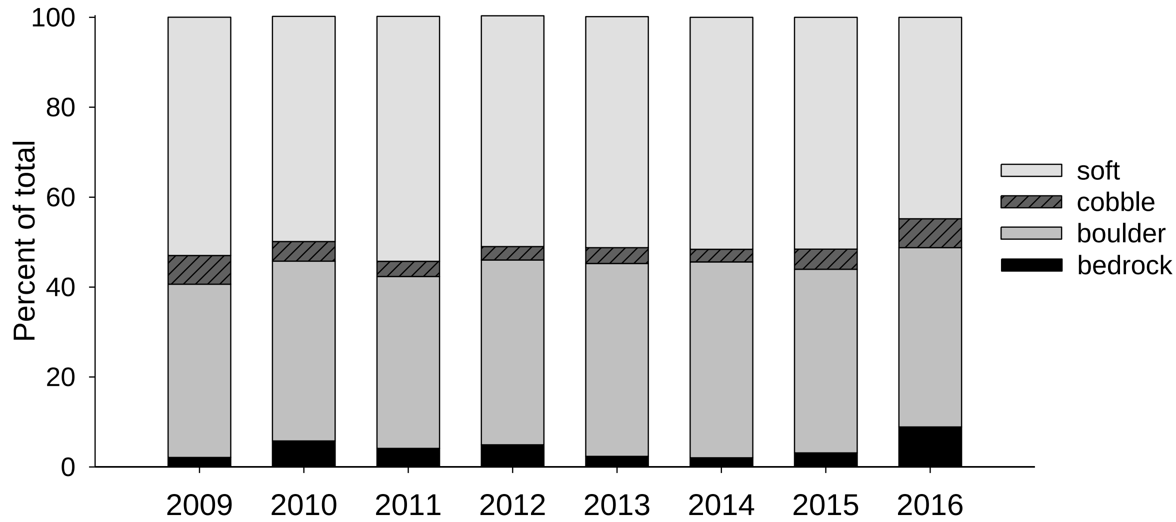


Figure 5.1.3. Distribution of substrate types on Wheeler North Reef from 2009 - 2016.

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 of any autotroph on Earth. Once established, small plants grow rapidly into large adult plants that extend through 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 structure 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 ensure 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). Densities of newly recruited giant kelp at Wheeler North Reef had been near zero since the initial colonization event of 2009 until 2014 when low densities (~0.2 m^{-2}) of kelp recruits were observed. A similar pattern of extremely low recruitment of giant kelp in years following initial high rates of colonization 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. 2015 marked a significant change as high numbers of kelp recruits were once again observed at Wheeler North Reef with mean densities averaging 50% higher than in 2009 (Figure 5.2.1). Densities of giant kelp recruits declined in 2016, but were nonetheless higher than that observed between 2010 – 2014.

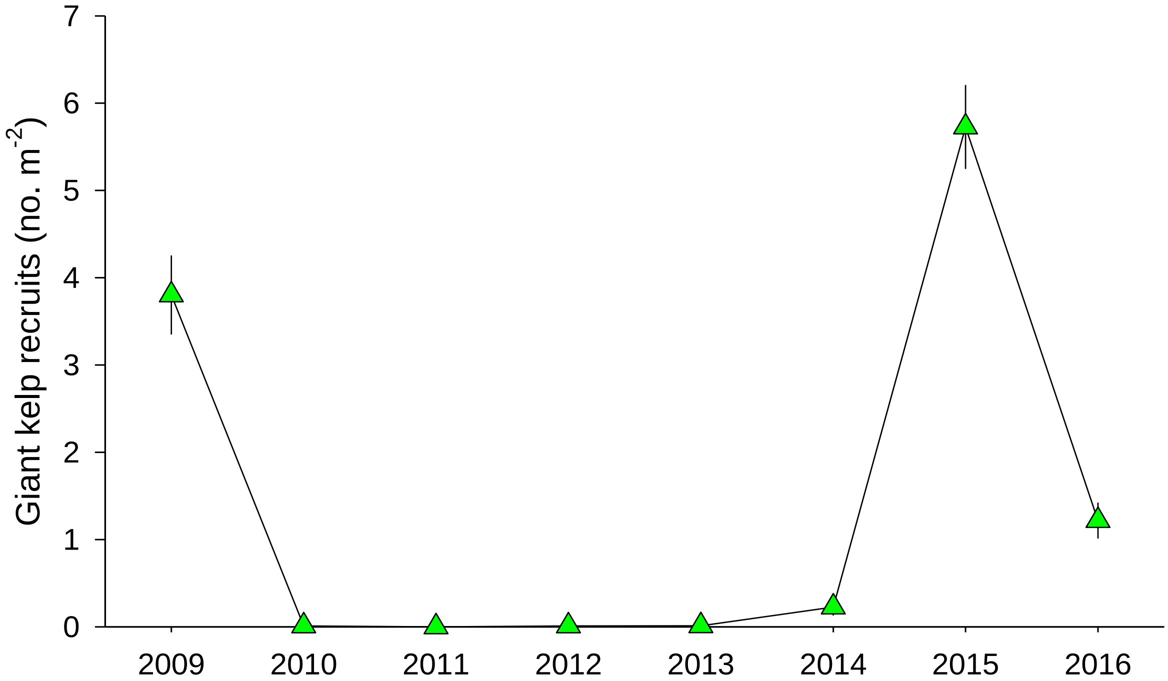


Figure 5.2.1. Mean density (± 1 standard error) of newly recruited giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef from 2009 - 2016.

Recruitment of giant kelp at Wheeler North Reef was noticeably patchy in 2016 as densities > 1 m^{-2} were observed at only 6 of the 18 polygons (Figure 5.2.2). This contrasts greatly with 2009 and 2015 when high densities were observed across the entire Wheeler North Reef.

The large kelp recruitment event at Wheeler North Reef in 2009 led to a large cohort of older large plants in 2010, which declined to approximately 2 individuals per 10 m^2 in 2012 – 2014 (Figure 5.2.3). Mean densities of giant kelp declined by 50% in 2015 to ~1 individual per 10 m^2 and by another 50% in 2016 to <0.5 individuals per 10 m^2. These declines in giant kelp abundance were observed region wide and have been attributed to prolonged anomalous conditions of warm, nutrient-poor water. Adult densities of giant kelp were uniformly low across all of Wheeler North Reef in 2016 (Figure 5.2.4). The lone exception to this was polygon 16 where adult densities exceeded 2 per 10 m^2.

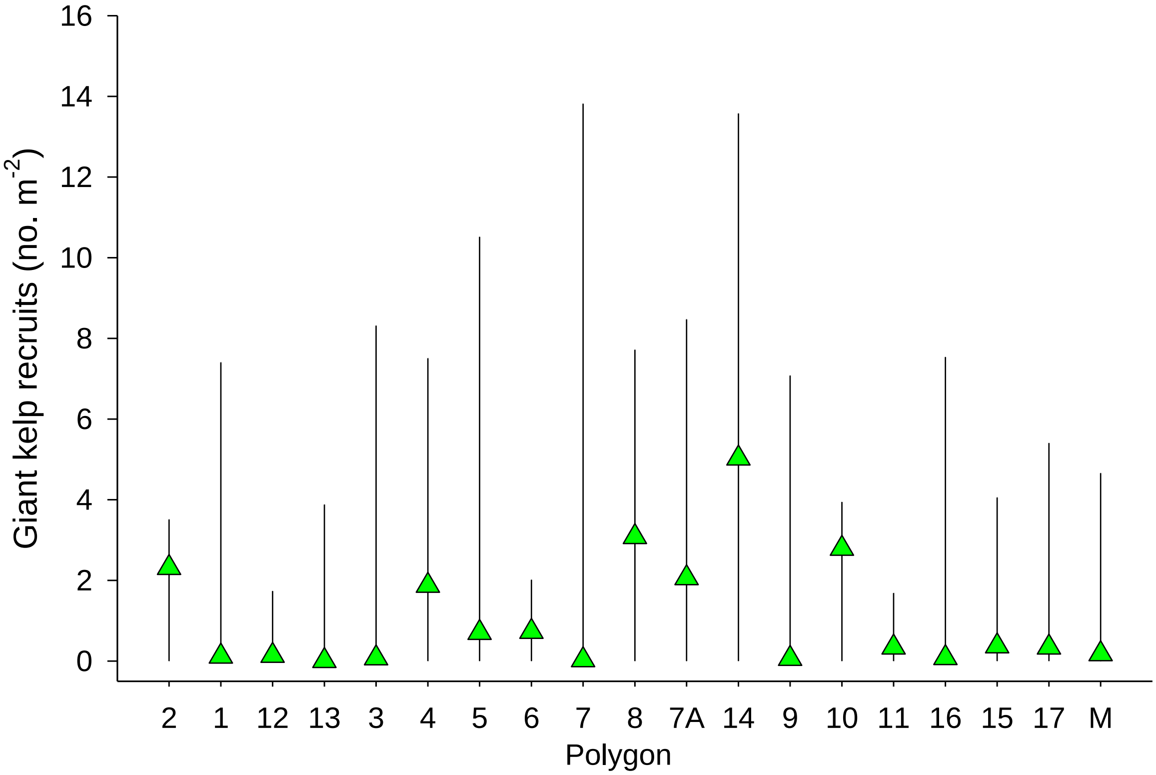


Figure 5.2.2. Mean density of newly recruited giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef in 2016. Vertical lines represent the range of values observed from 2009 - 2016, with the largest values occurring in 2015 in most polygons. Polygon numbers are ordered from south to north. M is the mean of the twelve Phase 1 modules.

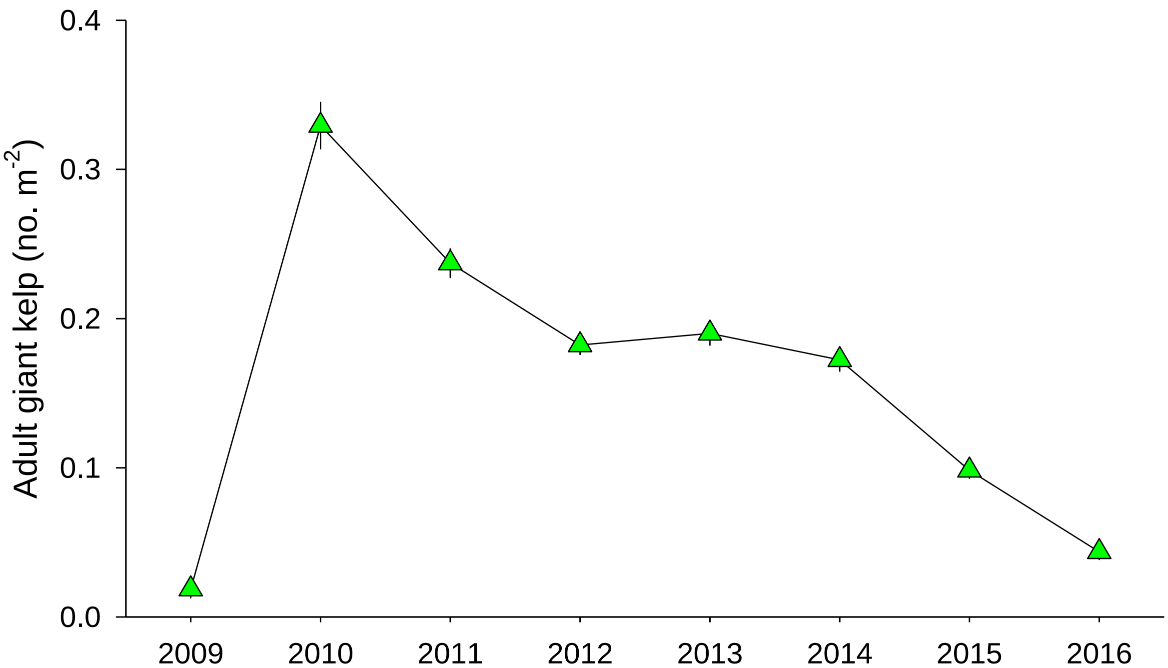


Figure 5.2.3. Mean density (± 1 standard error) of adult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef from 2009 - 2016.

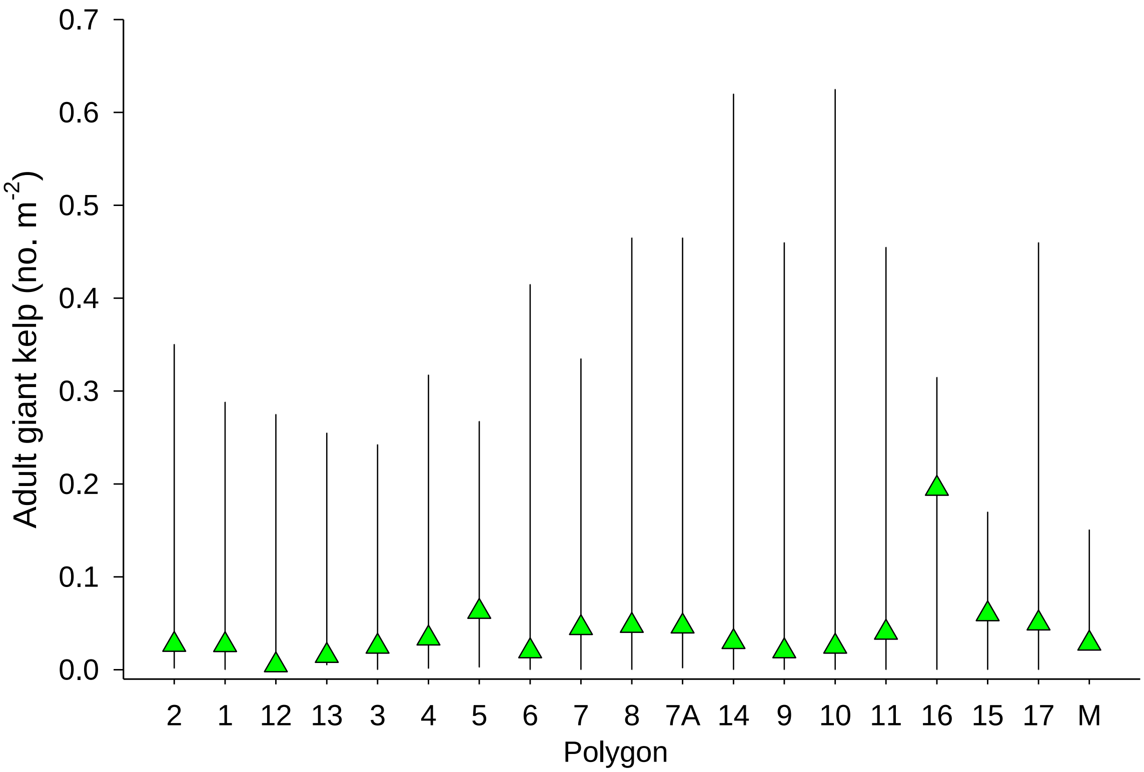


Figure 5.2.4. Mean density of adult giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef in 2016. Vertical lines represent the range of values observed from 2009 - 2016. Polygon numbers are ordered from south to north. M is the mean of the twelve Phase 1 modules.

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 increased dramatically at Wheeler North Reef between 2009 and 2010 as small plants grew into adults (Figure 5.2.5). By 2011, mean plant size at Wheeler North Reef was similar to that of nearby natural reefs at Barn and San Mateo and averaged about 21 fronds per plant. Plant size remained relatively steady at Wheeler North Reef through 2015 before declining precipitously to 8 fronds per plant in 2016 (Figure 5.2.5). Similar large declines in the number of fronds per plant were observed at San Mateo and Barn in 2015 and persisted through 2016. The relatively low numbers of fronds per plant observed in recent years is indicative of the poor growing conditions associated with unusually high ocean temperatures throughout the region.

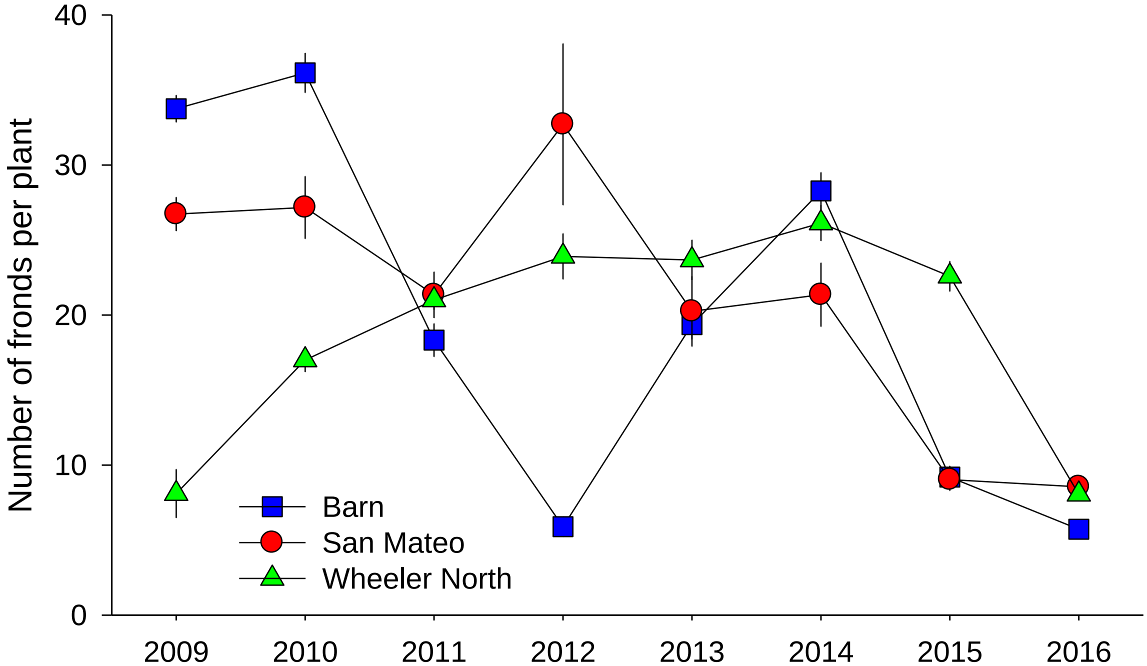


Figure 5.2.5. Mean number (± 1 standard error) of fronds per *Macrocystis* plant at Wheeler North Reef, Barn and San Mateo from 2009 - 2016.

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 its standing biomass 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 at ~ 6 fronds per m^2 through 2014. Frond density progressively declined to < 1 frond m^{-2} in 2016, which was similar to that observed at Barn and San Mateo (Figure 5.2.6). The decrease in mean frond density at Wheeler North Reef coupled with the decrease in adult density and adult size indicates that the decline in frond density resulted from both the mortality of adult plants and a decrease in the number of fronds per plant.

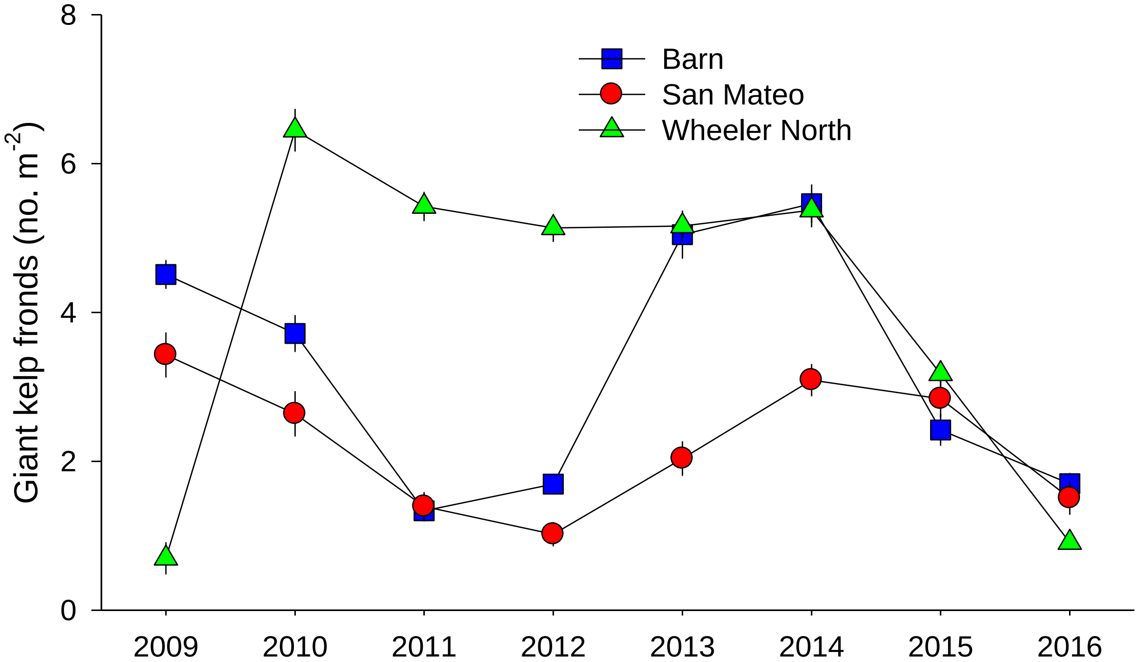


Figure 5.2.6. Mean density (± 1 standard error) of giant kelp fronds at Wheeler North Reef, Barn and San Mateo from 2009 - 2016.

<u>Benthos</u>

The benthic community on the shallow reefs off California typically include a diverse group of low-lying red, brown and green algae that occur on the bottom beneath the canopy of giant kelp (often referred to as understory algae) and a large number of sessile and mobile species of invertebrates. Like understory algae, sessile invertebrates attach themselves to the reef. 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 rock that becomes occupied by algae and sessile invertebrates increases over time during the normal succession of a kelp forest community.

Such has been the case at Wheeler North Reef, which has shown a dramatic increase in the percent cover of the benthic community since it was constructed in 2008 (Figure 5.2.7). Within one year of construction ~ 75% of the rock surface of Wheeler North Reef was covered by algae and sessile invertebrates. The coverage of benthic biota on the reef has increased gradually since then to ~ 95% in 2016.

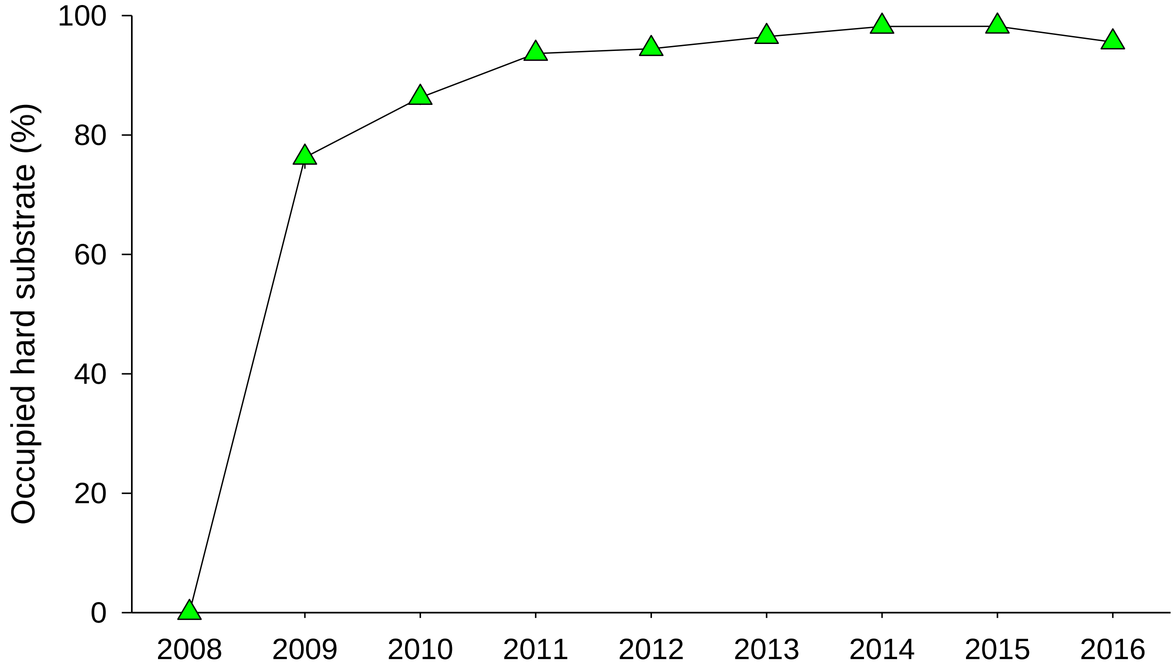


Figure 5.2.7 Mean percent cover of hard substrate occupied by sessile reef biota (i.e understory algae and sessile invertebrates) at Wheeler North Reef from 2009 - 2016.

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 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 sessile invertebrates are favored in the presence of giant kelp.

The percent cover of algae at Wheeler North Reef declined three to four-fold from 2009 to 2011, remained relatively low at ~ 10% through 2013, before steadily increasing to 48% in 2016, which is the highest cover of algae ever reported for Wheeler North Reef (Figure 5.2.8a). This high cover of algae occurred throughout the Wheeler North Reef as it was near or at the highest reported levels at 13 of the 16 primary polygons and the experimental modules (Figure 5.2.9). Temporal patterns in the number of species of algae followed those of percent cover with the highest number of algal species recorded in 2016 (Figure 5.2.8b). Not surprisingly, the high percent cover and species number of understory algae in 2016 coincided with a reef-wide reduction in giant kelp (Figures 5.2.3 – 5.2.6), which is known to inhibit understory algae via shading (Reed and Foster 1984, Arkema et al. 2009).

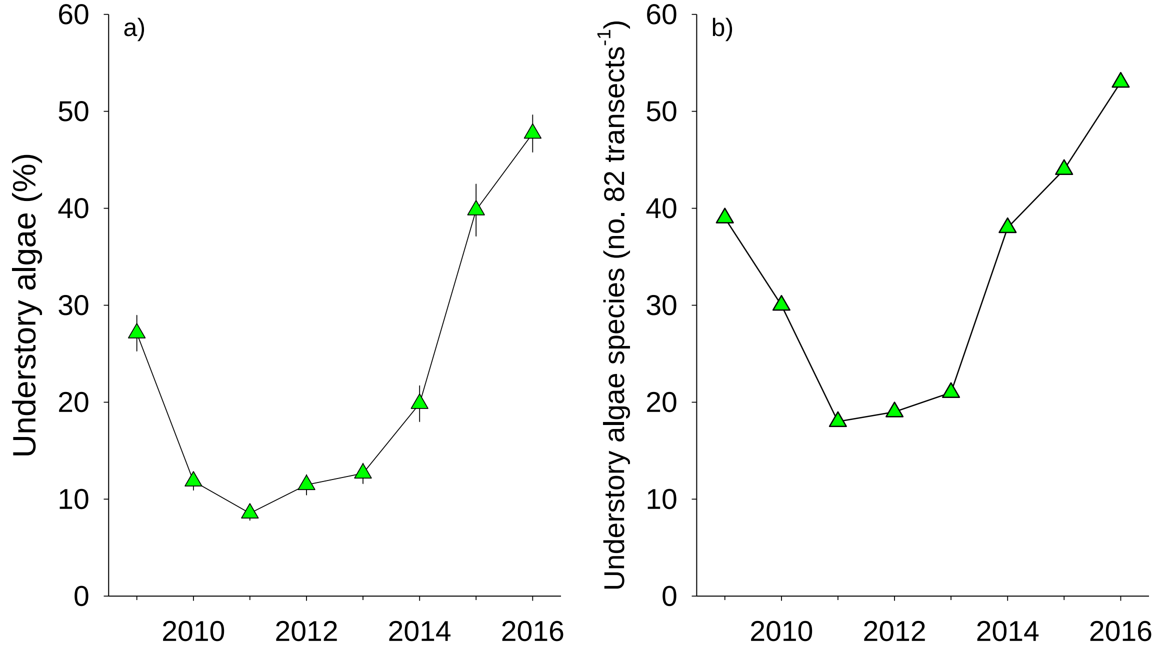


Figure 5.2.8. (a) Mean percent cover (± 1 standard error) and (b) total number of species of understory algae at Wheeler North Reef from 2009 - 2016.

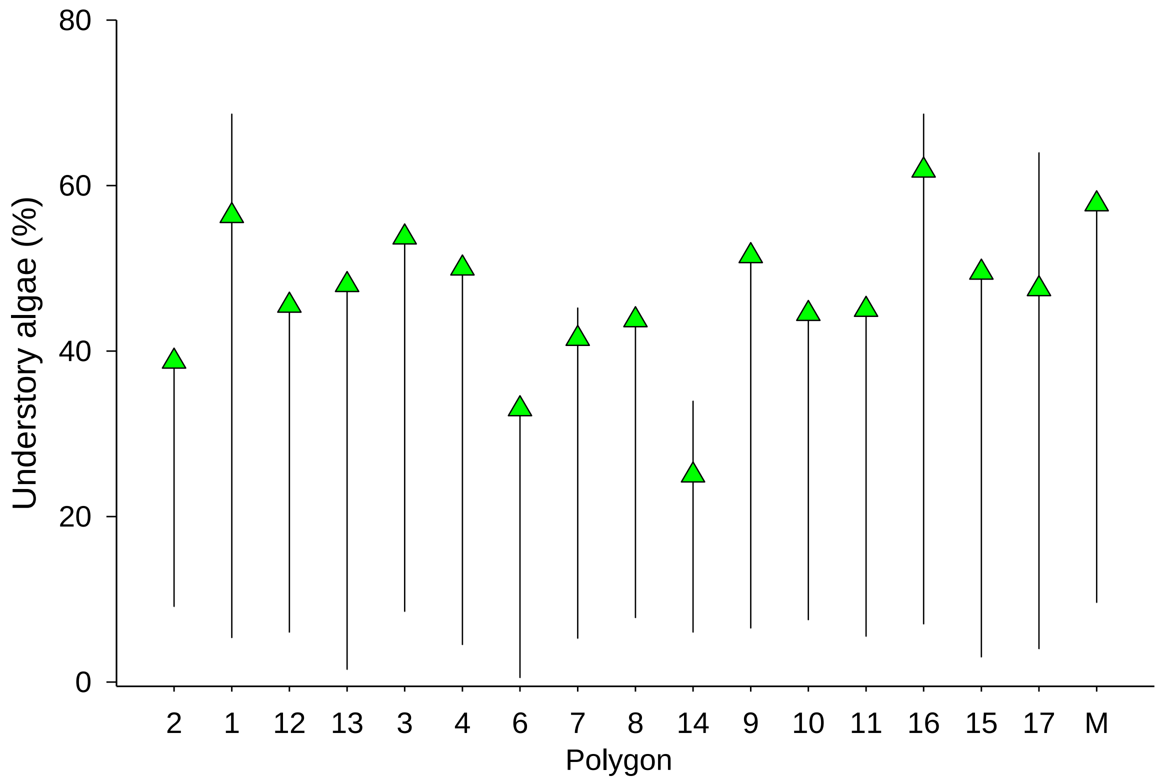


Figure 5.2.9. Mean percent cover of understory algae at Wheeler North Reef in 2015. Vertical lines represent the range of values observed from 2009 - 2016. Polygon numbers are ordered from south to north. M is the mean of the twelve Phase 1 modules.

The reduction in shading caused by the decline in giant kelp at Wheeler North Reef led to a proliferation in the abundance of fleshy red algae, most notably, *Acrosorium uncinatum,* which on average covered 36% of the bottom in 2016 (Figure 5.2.10). The high cover of this species is due in part to its ability to grow on a wide variety of substrates, including the ornate tube worm *Diopatra ornata,* which is abundant in the soft sediments at Wheeler North Reef. Other species of red algae that were common at Wheeler North Reef in 2016 included *Rhodymenia spp., Leptofaucha pacifica, and Botryocladia pseudodichotoma.* The holdfasts of giant kelp, which had previously accounted for nearly 50% of the total cover of algae, declined to about 7% of the total algal cover in 2016.

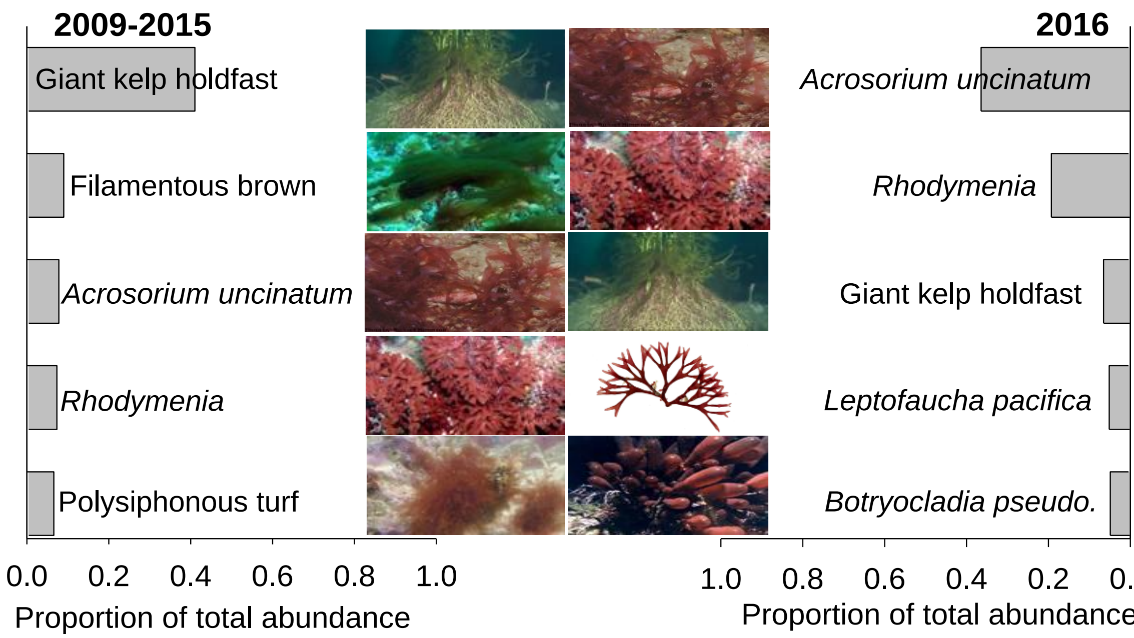


Figure 5.2.10. Proportion of the total percent cover of algae for the five most abundant algal species at Wheeler North Reef averaged for 2009 - 2015 and 2016.

The abundance of sessile invertebrates at Wheeler North Reef showed an opposite pattern to that of understory algae; their percent cover more than doubled to ~ 50% between 2009 – 2014 (Figure 5.2.11a). In 2015 the percent cover of sessile invertebrates began to decline and by 2016 was only 27%. This decline was coincident with the decrease in giant kelp and the increase in understory algae (Figure 5.2.12). In contrast the total number of species of invertebrates observed within the 82 transects at Wheeler North Reef increased by ~ 25% between 2009 and 2011 and has remained relatively constant at ~ 75 species since then (Figure 5.2.11b).

The mean percent cover of sessile invertebrates varied inconsistently across the 16 primary polygons in 2016 ranging from 19 – 37%, which was less variable than that observed in previous years (Figure 5.2.13). Interestingly, the percent cover of sessile invertebrates on the Phase 1 rock modules in 2016 was at its lowest level since 2009. All polygons have displayed relatively high inter-annual variation in the percent cover of sessile invertebrates since 2009 (as indicated by the vertical lines in Figure 5.2.13) and values for 2016 were in the lower third of the range for most polygons.

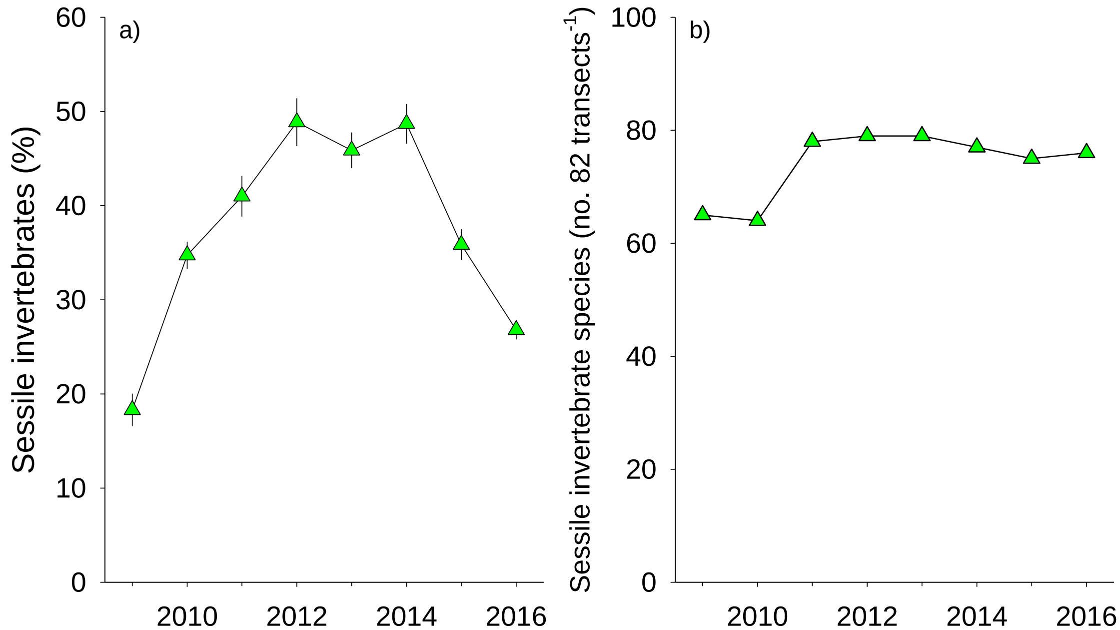


Figure 5.2.11. (a) Mean percent cover (± 1 standard error) and (b) total number of species of sessile invertebrates at Wheeler North Reef from 2009 - 2016.

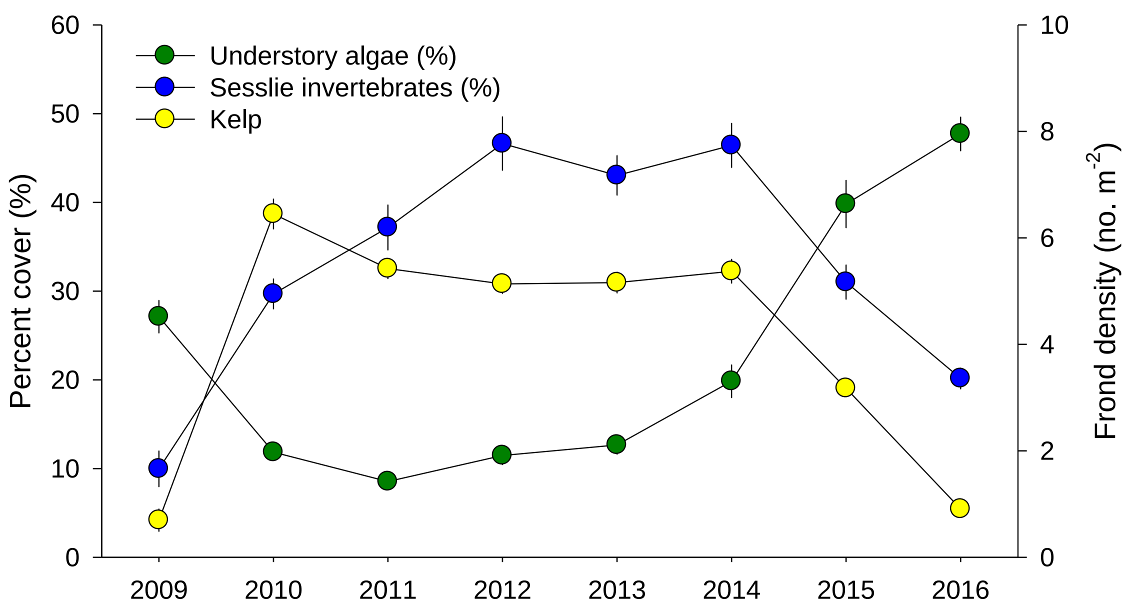


Figure 5.2.12 Comparison of mean percent cover (± 1 standard error) of understory alge (green) and sessile invertebrates (blue) on left axis and mean density (± 1 standard error) of adult giant kelp (yellow) on the right axis at Wheeler North Reef from 2009 - 2016.

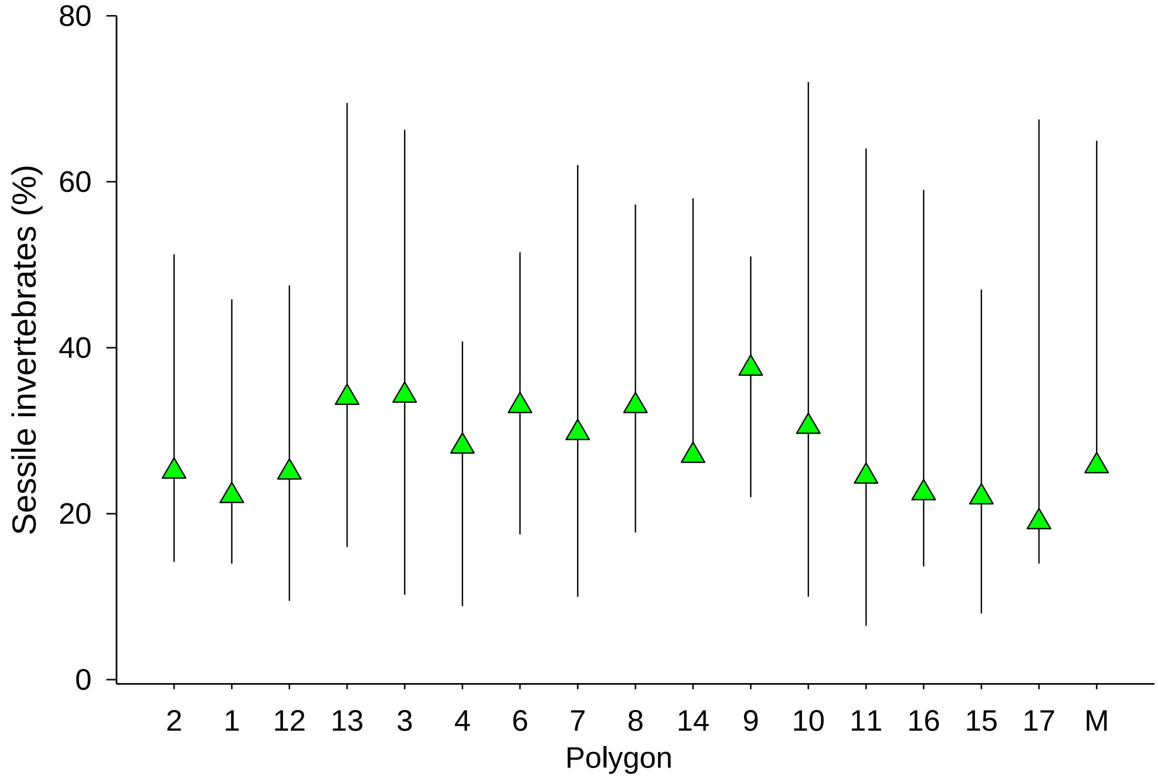


Figure 5.2.13. Mean percent cover of sessile invertebrates at Wheeler North Reef in 2016. Vertical lines represent the range of values observed from 2009 - 2016. Polygon numbers are ordered from south to north. M is the mean of the twelve Phase 1 modules.

The mix of common species of sessile invertebrates at Wheeler North Reef in 2016 differed somewhat from that observed in previous years when the overall percent cover of sessile invertebrates was higher (Figure 5.2.14). Previously, an assorted group of encrusting sponges and the colonial tunicate *Chelyosma productum* covered ~15% of the bottom at Wheeler North Reef and accounted for about one third of the total cover of all sessile invertebrates. In 2016 these two species covered only about 2% of the bottom and accounted for < 9% of the cover of all sessile invertebrates. They were largely replaced by encrusting bryozoans, a white encrusting foraminifera, the colonial polychaete *Salmacina tribranchiata*, and the golden sea fan *Muricea californica*, which collectively comprised 52% of the cover of all sessile invertebrates while covering only 14% of the bottom. With the exception of sea fans, the vast majority of sessile invertebrates occupying Wheeler North Reef are believed to be relatively short-lived, suggesting that their populations are maintained by replacement via the colonization of new individuals rather than by the survival of older long-lived individuals.

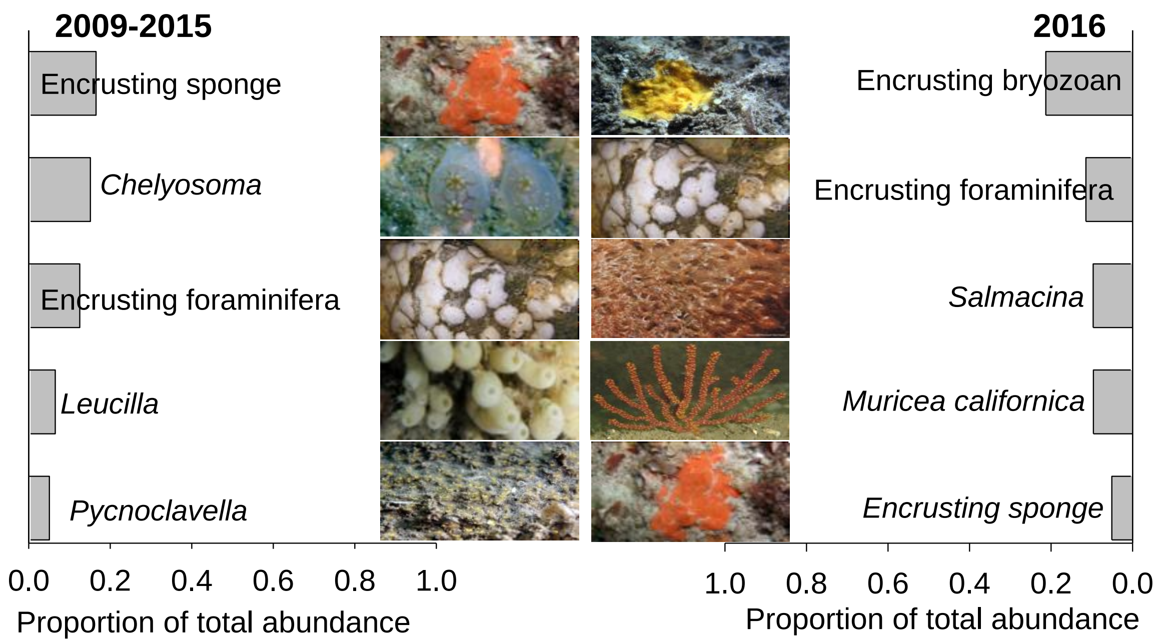


Figure 5.2.14. Proportion of the total percent cover of sessile invertebrates for the five most abundant sessile invertebrate species at Wheeler North Reef averaged for 2009 - 2015 and 2016.

A diverse array of mobile invertebrates is also common in southern California kelp forests including a variety of herbivorous and predatory snails, octopus, crabs, lobster, and many different kinds of echinoderms (e.g., brittle stars, sea stars, sea urchins, sea cucumbers). Like sessile invertebrates, the abundance of mobile invertebrates at Wheeler North Reef increased dramatically (~10 fold) during the first few years following its construction (Figure 5.2.15a). Mean densities of mobile invertebrates at Wheeler North Reef peaked at 109 per m^2 in 2012, before steadily declining to 18 per m^2 in 2016, which is the lowest level recorded since the first post-construction survey in 2009. Unlike abundance, the total number of species of mobile invertebrates observed in the 82 transects at Wheeler North Reef has steadily increased over time from 42 species in 2009 to 78 species in 2016 (Figure 5.2.15b).

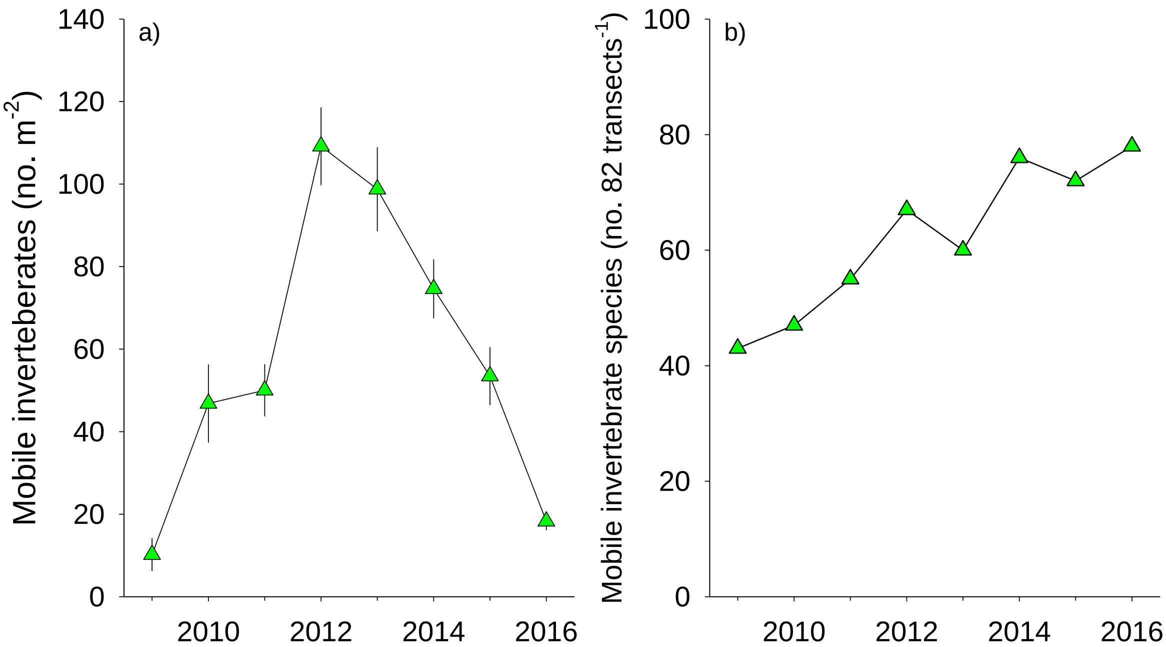


Figure 5.2.15. (a) Mean density (± 1 standard error) and (b) total number of species of mobile invertebrates at Wheeler North Reef from 2009 - 2016.

The large rapid increase in the density of mobile invertebrates early in the time series and the more recent decline resulted primarily from changes in the density of the brittle star *Ophiothrix spiculata,* which accounted for ~ 80% of all mobile invertebrates between 2009 – 2015, but only 45% in 2016 (Figure 5.2.16). Brittle stars commonly inhabit the holdfasts of giant kelp and the changes in the density of brittle stars at Wheeler North Reef has been associated with a corresponding change in the percent cover of kelp holdfasts. Hermit crabs consistently have been the second most abundant mobile invertebrate at Wheeler North Reef. Their densities have remained relatively constant over time, but their proportional abundance increased from 6% in 2015 to 23% in 2016 following the decrease in the density of brittle stars. Other mobile invertebrates that were abundant at Wheeler North Reef in 2016 included: the cone snail *Conus californicus*, the whelks *Pteropurpura festiva* and *Kelletia kelletia*, and the purple sea urchin *Strongylocentrus purpuratus,* which collectively accounted for 43% of all mobile invertebrates

Larger, economically important species of mobile invertebrates such as lobster, warty sea cucumbers, giant keyhole limpets and red sea urchins, while not as abundant as smaller species of mobile invertebrates, are commonly observed at Wheeler North Reef and often in greater abundance than at San Mateo and Barn (Figure 5.2.17). Of particular note is the California spiny lobster *Panulirus interruptus* a top predator in the kelp forest that is actively targeted by commercial and recreational fisherman. Lobster densities at Wheeler North Reef have increased nearly eight-fold since 2013 to about 5 individuals per 100 m^2 in 2016, which was 2 to 7 times higher than San Mateo and Barn, respectively.

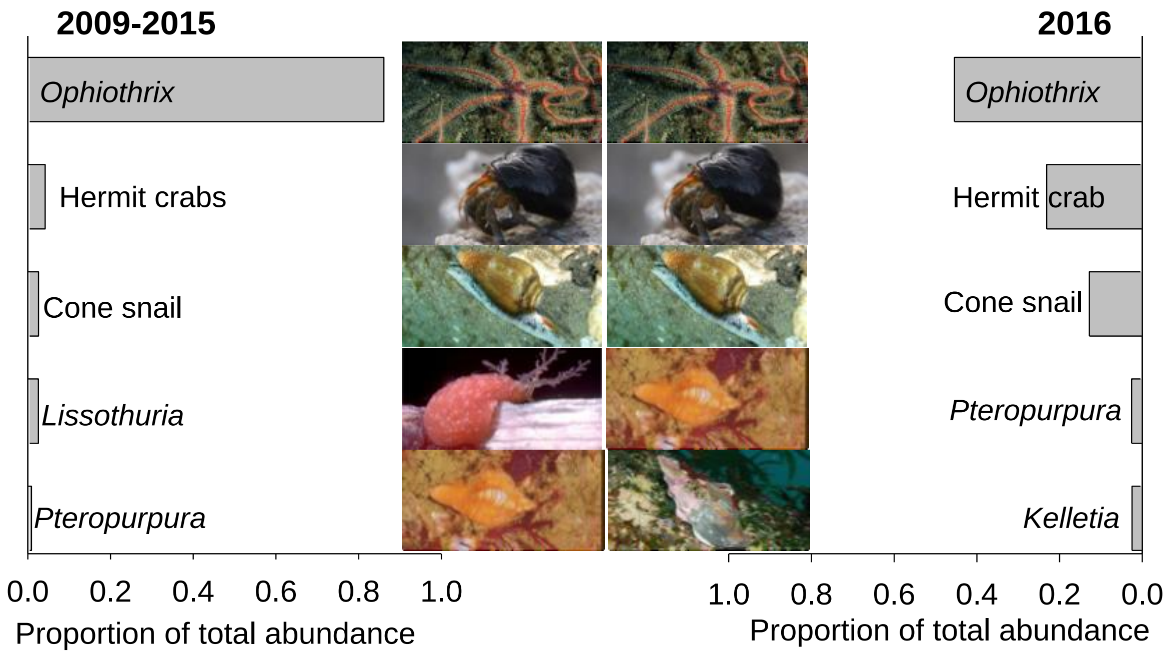


Figure 5.2.16. Proportion of total abundance of the five most abundant mobile invertebrate species at Wheeler North Reef averaged for 2009 - 2015 and 2016.

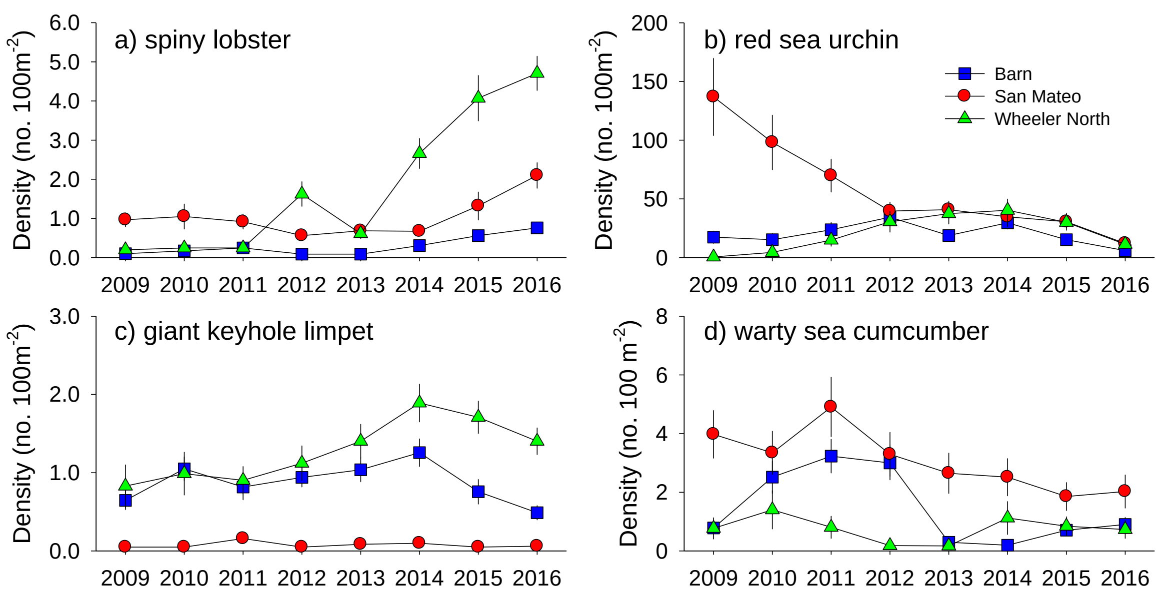


Figure 5.2.17. Mean density (± 1 standard error) of (a) spiny lobster, (b) red sea urchin, (c) giant keyhole limpet, and (d) warty sea cucumber at Wheeler North Reef, Barn and San Mateo from 2009 - 2016.

Fish

Abundances of fishes living near the bottom at Wheeler North Reef have fluctuated greatly during the eight years of monitoring. Fish rapidly colonized the Wheeler North Reef with densities reaching about 70 per 100 m^2 in the first year following construction, which is the highest level observed to date (Figure 5.2.18a). Fish densities declined precipitously in 2010 and have fluctuated between 10 – 50 m^{-2} since then, with densities in 2016 at their lowest level since 2010. Unlike fish density, fish diversity has increased over time at Wheeler North Reef. The total number of species of reef fish observed on the 82 transects combined nearly doubled between 2010 and 2012, remained relatively high at approximately 40 species between 2012 – 2014 and decreased since then to 29 species in 2016 (Figure 5.2.18b).

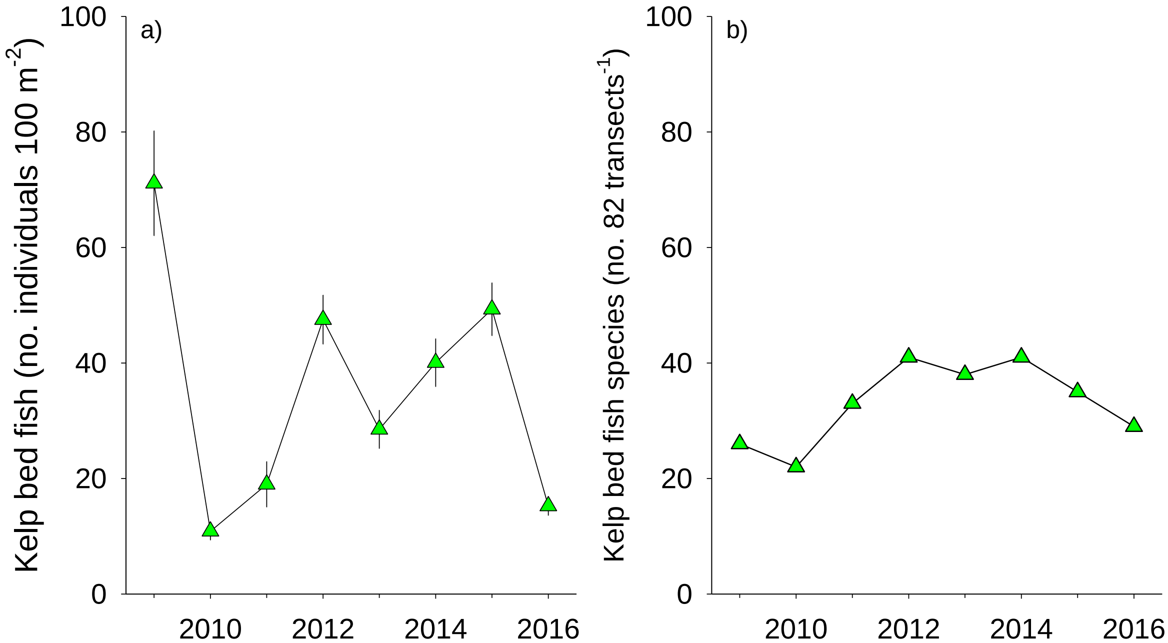


Figure 5.2.18. (a) Mean density (± 1 standard error) and (b) total number of species of kelp bed fish near the bottom at Wheeler North Reef from 2009 - 2016.

The mean density of kelp bed fish in 2016 was uniformly low throughout Wheeler North Reef with values near the lowest ever reported for all areas except polygon 13 (Figure 5.2.19). The exceptionally large range in densities observed among years at polygon 9 was due in large part to high interannual variation in the density of pile perch, which periodically form large schools that hover near the bottom. Fish densities at the older and smaller Phase 1 modules in 2016 were similar to those at the newer and larger Phase 2 polygons, suggesting that reef age and footprint area (or reef perimeter : edge ratio) did not profoundly influence the abundances of reef fish at Wheeler North Reef.

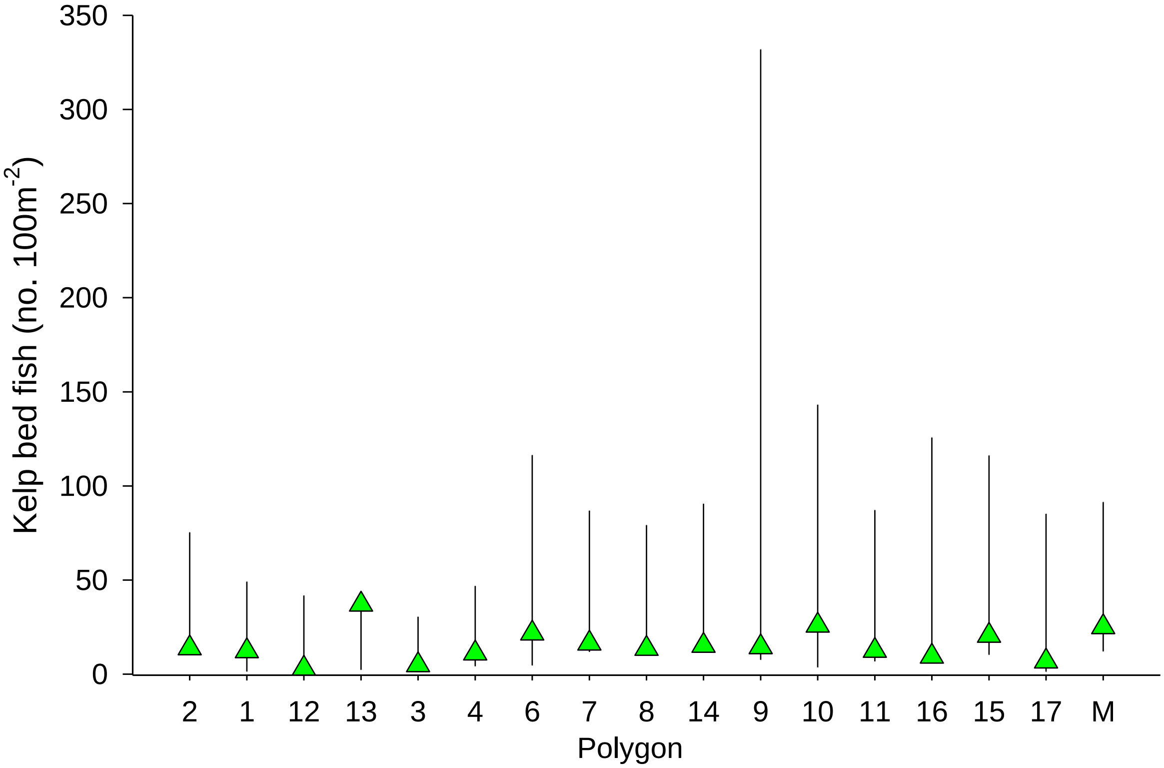


Figure 5.2.19. Mean density of kelp bed fish at Wheeler North Reef in 2016. Vertical lines represent the range of values observed from 2009 - 2016. Polygon numbers are ordered from south to north. M is the mean of the twelve Phase 1 modules.

The species composition of reef fish at Wheeler North Reef in 2016 was dominated by species with warm-water affinities. The Blacksmith, Señorita, California Sheephead, Barred Sand Bass and Kelp Bass accounted for nearly 70% of all fish on the reef (Figure 5.2.20). The Blackeye Goby, a small cool water species that lives on the bottom and feeds on small crustaceans, had consistently been the most numerically abundant species at Wheeler North Reef throughout the study period, accounting for ~67% of the fish on the reef from 2009 – 2015. However, its proportional abundance declined to ~6% in 2016.

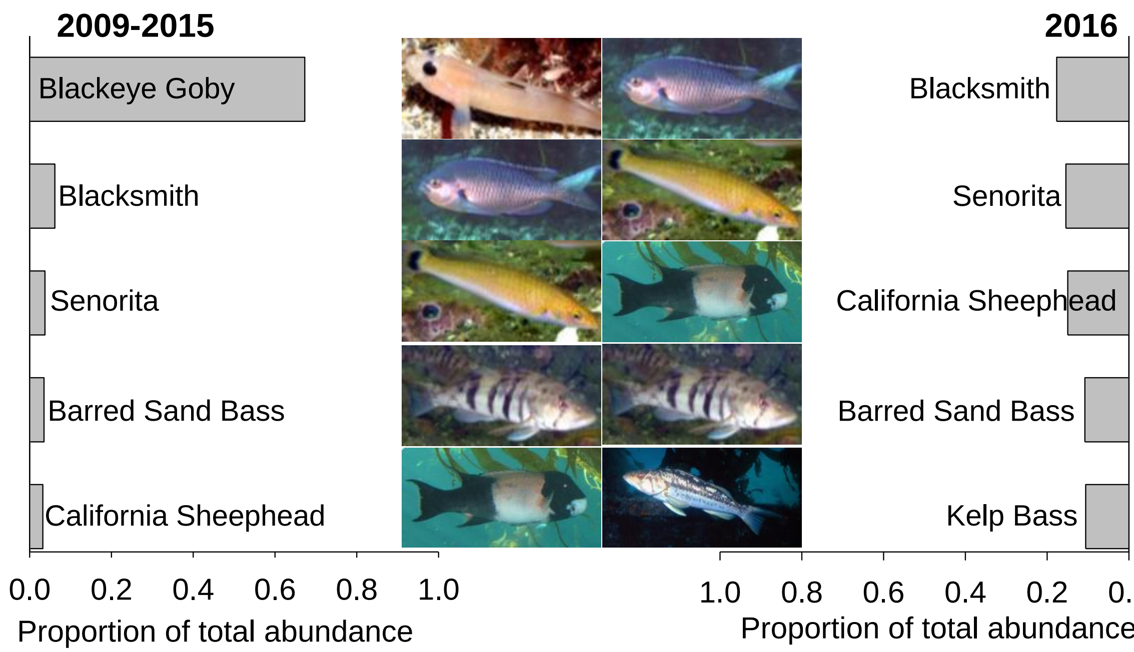


Figure 5.2.20. Proportion of total abundance of the five most numerically abundant species of kelp bed fish at Wheeler North Reef averaged for 2009 - 2015 and 2016.

Large predatory species of fish that are valued ecologically and/or economically such as the Kelp Bass, Giant Sea Bass and California Halibut were also observed during surveys at Wheeler North Reef, but because of their large size and high trophic status they were not as numerically abundant.

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 (Figure 5.2.21 vs. Figure 5.2.18a). Fish biomass density increased nearly continuously from 2010 – 2014 to a maximum of 33 gm^{-2} before declining to ~25 g m^{-2} in 2015 and 2016.

The relatively low biomass density of fish 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 in 2009, are relatively small (~ 3 grams in weight) and composed a small proportion of the biomass (~ 10 % in 2009). Since 2010, the most dominant species of reef fish at Wheeler North Reef in terms of biomass density have been the Barred Sand Bass and California Sheephead, which on average accounted for 55% of the reef fish biomass between 2009 – 2015 (Figure 5.2.22). By contrast, the Blackeye Goby, while still the most numerically abundant species at Wheeler North Reef during this period, accounted for only 4% of the reef fish biomass. The most dramatic change in 2016 was the emergence of Giant Sea Bass as the most important species in terms of its contribution to the biomass density of fish at Wheeler North Reef. This species is the largest fish that resides on rocky reefs and kelp forests in the southern California and Baja California, Mexico. Because it is a large apex predator, its densities are naturally far lower than that of the other species that compose the bulk of the fish standing stock at Wheeler North Reef. The rise of Giant Sea Bass as the biggest contributor to the biomass density of fish at Wheeler North Reef in 2016 resulted from two individuals in the 92 transects surveyed, which when scaled to the 174-acre Wheeler North Reef accounted for 26% of the fish biomass.

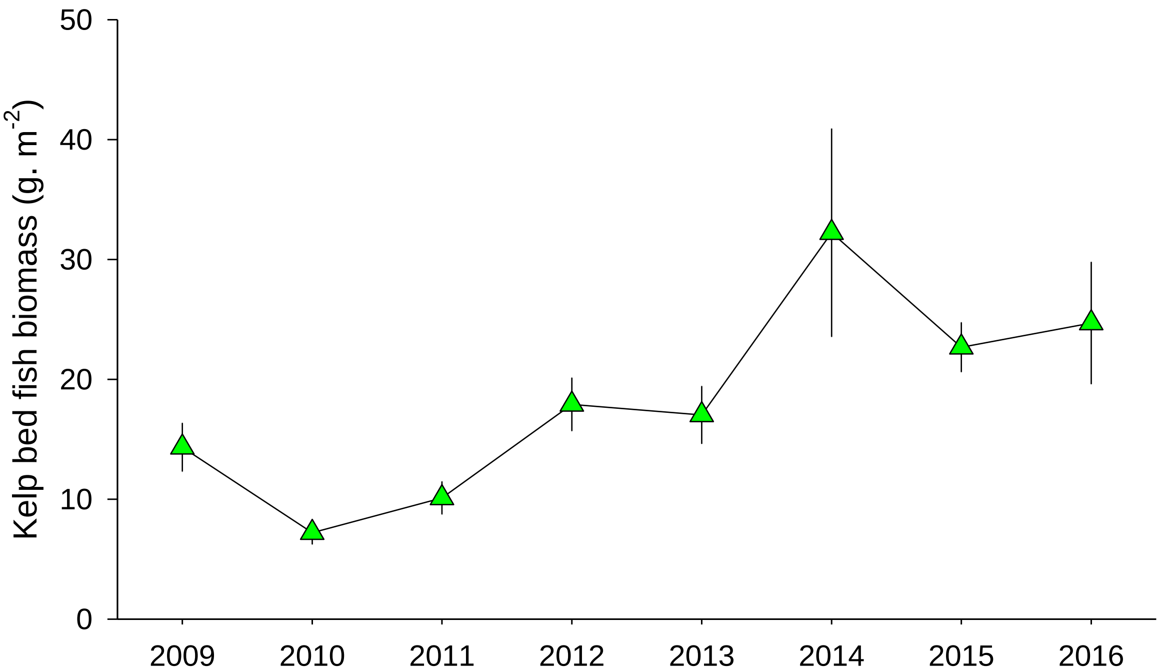


Figure 5.2.21. Mean biomass density (± 1 standard error) of kelp bed fish within 2 m of the bottom at Wheeler North Reef from 2009 - 2016.

The biomass density of kelp bed fish varied substantially across the Phase 2 polygons of Wheeler North Reef in 2016 from an average low of ~ 5 g per m^2 in polygons 7a, 12 and 14 to average highs of 54 g per m^2 on the Phase 1 modules and 160 g per m^2 in polygon 15 (Figure 5.2.23). The high values of fish biomass at these locations were due to the occurrence of a single Giant Sea Bass at each location; a 48 kg individual was recorded in one of the 12 transects sampled on the Phase 1 modules and a 38 kg individual was recorded in one of two transects sampled in polygon 15.

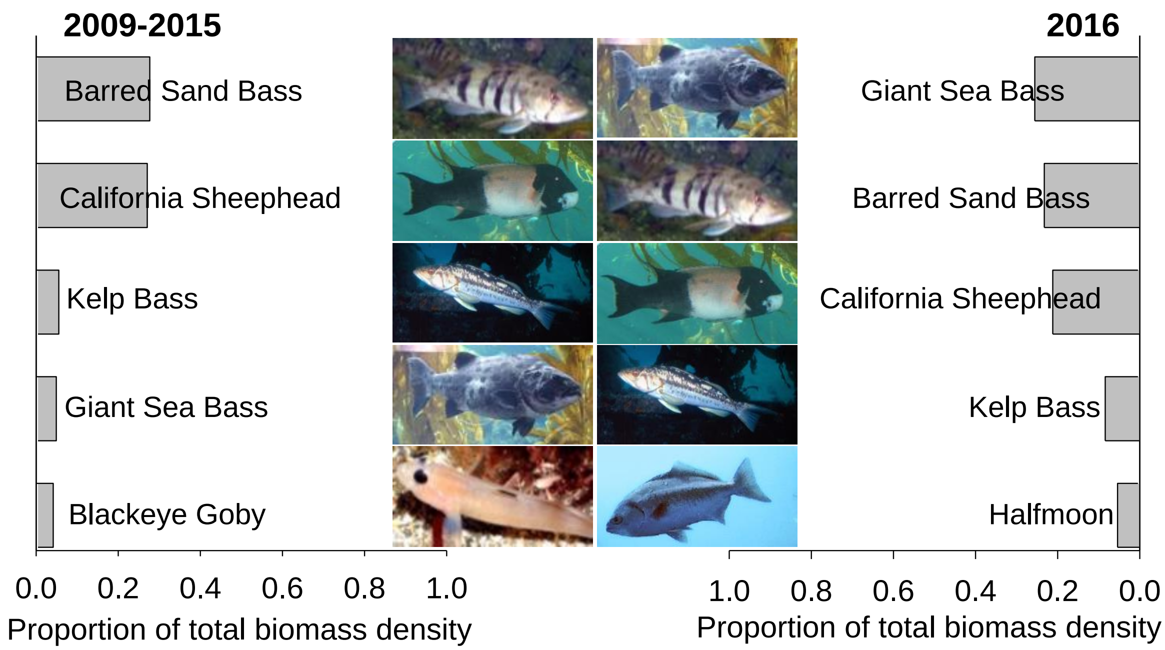


Figure 5.2.22. Proportion of total biomass density of the five most dominant species of kelp bed fish at Wheeler North Reef averaged for 2009 - 2015 and 2016.

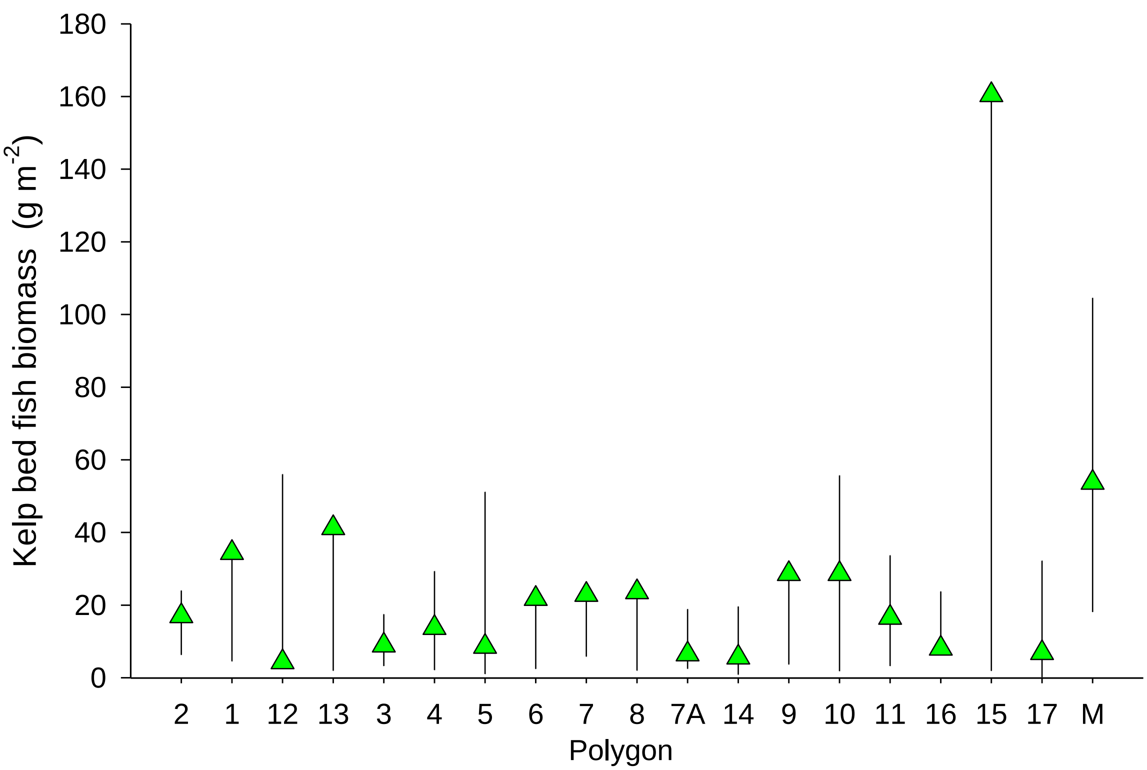


Figure 5.2.23 Mean biomass density of kelp bed fish within 2 m of the bottom at Wheeler North Reef in 2016. Vertical lines represent the range of values observed from 2009 - 2016. Polygon numbers are ordered from south to north. M is the mean of the twelve Phase 1 modules.

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. 2017).

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 1m^2 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,* and P_t is the proportion of the Wheeler North Reef covered by hard substrate in year *t*. A_t is determined from backscatter in the most recent multibeam sonar survey using a horizontal grid size of 0.25 meters with an isobath interval of 0.5 meters as described in Elwany et al. (2014). P_t is determined from data collected in diver surveys. The proportion of area covered by hard substrate in the as-built condition in 2008 immediately after construction ($S_0 = A_0 P_0$) that is remaining at time *t* can be expressed as S_t/S_0. The value of S_t/S_0 based on the current year or a four-year running average of the current year and the preceding three years (whichever is larger) must be ≥ 0.9 for the Wheeler North Reef to 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 acres (Elwany et al. 2009). Because the footprint area of the Phase 1 modules was not measured during the 2008 as-built survey, their footprint area measured in 2009 (25 acres) is used as their footprint area in 2008. Hence the initial footprint area of the Wheeler North Reef that is used to evaluate this performance standard (A_o) is 155 acres. The mean percent cover of rock of this initial footprint area in 2008 (P_0) was 45.6%.

Results: There was a slight decrease in the footprint area in 2009, the year following construction (Figure 6.1a), which is not unexpected as rocks settle into the soft sandy bottom. Because the footprint area of the reef is not expected to change much from year-to-year, multi-beam sonar surveys are done only once every five years. A sonar survey was done in 2009 and following this rule, the value for reef footprint area was assumed to be the same from 2009 through 2013. Reef footprint area was re-surveyed in 2014, and based on this survey the footprint area of the reef declined slightly from 2013 to 2014. Unlike footprint area, the percent of the bottom covered by rock is measured every year by divers. The percent cover of rock declined from 45% in 2008 to 42% in 2011, before gradually increasing to ~ 46% in 2016 (Figure 6.1b).

The initial amount of hard substrate at Wheeler North Reef used to judge this performance standard was 70.6 acres in 2008. The 2-acre decrease in footprint area in 2009 (Figure 6.1a) coupled with a continued decline in the percent cover of hard substrate through 2011 (Figure 6.1b) resulted in nearly a 10% decrease in the total area of hard substrate on Wheeler North Reef by 2011 (Figure 6.1c). An increase in the percent cover of rock accompanied by a very small decline in footprint area since then has resulted in the total area of hard substrate increasing to about 70.4 acres in 2016, which is nearly identical to that of the initially constructed acreage (Figure 6.1c). The four year running average in 2016 was also indistinguishable from the initial acreage (Figure 6.1d). Thus Wheeler North Reef met the performance standard for reef area in 2016 regardless of whether the evaluation was based on data from 2016 alone or the 4-year running average.

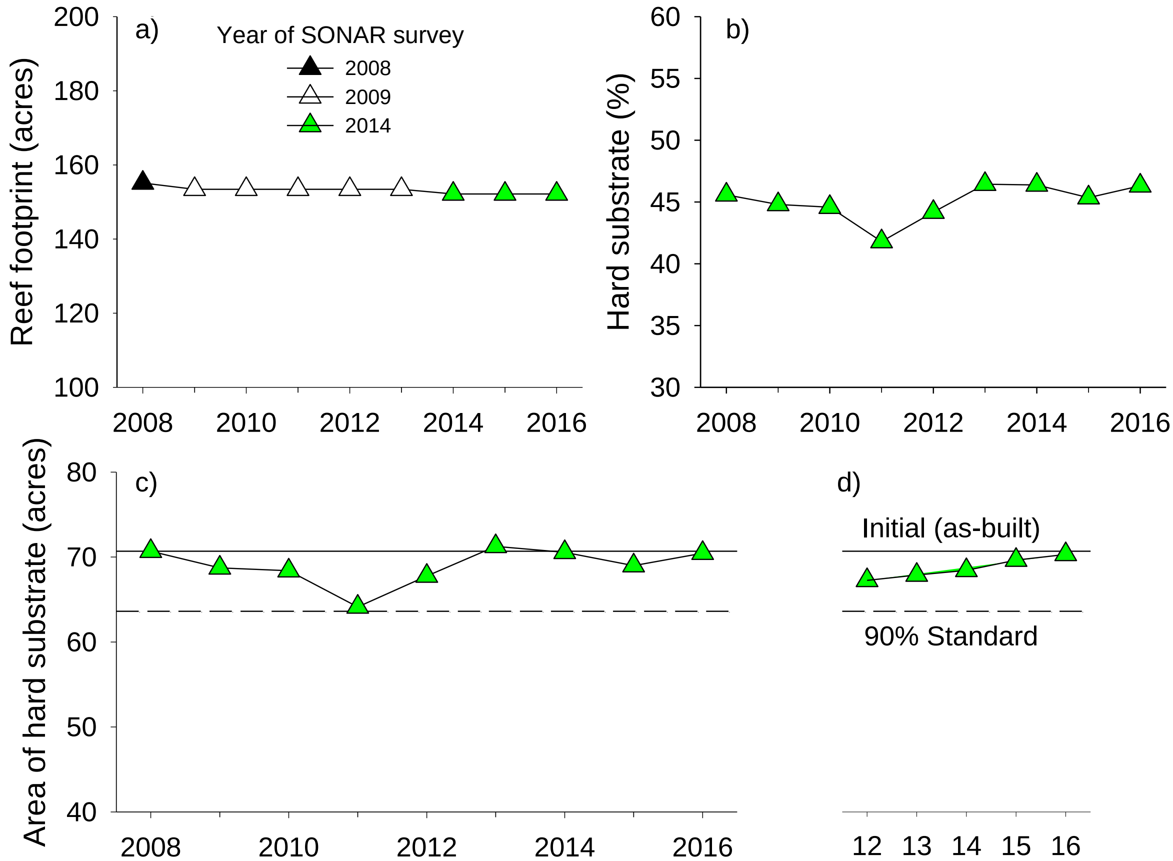


Figure 6.1. Variables used to calculate exposed hard substrate. (a) Reef footprint area, (b) Percent cover of hard substrate, (c) Area of exposed hard substrate and (d) 4-year running average of the area of exposed hard substrate.

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 ninety-two 50m transects at Wheeler North Reef (Figure 4.4.2). For the purpose of this performance standard, medium-to-high density giant kelp is defined as more than four adult plants per $100m^2$ of ocean bottom and adult giant kelp plants are defined as having eight or more fronds (these criteria are the same ones used to assess the impacts of SONGS on giant kelp). The summed total of adult plants in the five 10m x 2m quadrats provides an estimate of the number of adult plants per $100m^2$ at each transect. The proportion of transects with a density >4 adult plants per $100m^2$ is used as an estimate of the proportional area of the artificial reef occupied by medium to high density giant kelp. The total area A_k 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 2014 sonar survey, N_k = number of transects at Wheeler North Reef with >4 plants per $100m^2$, and N_r is the total number of transects sampled at Wheeler North Reef (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 the newly constructed reef in 2009. The large area of high density kelp observed in 2010 was sustained through 2014 when 89 of the 92 transects sampled had at least 4 adult plants per $100m^2$. Acreage of giant kelp began to decline in 2015 and by 2016 was reduced to 52.8 acres (Figure 6.2a), falling well below the 150 acre requirement. The large decline in kelp acreage in 2015 and 2016 caused the 2016 4-year running average to drop to 134.9 acres, which is the first time the four year running average did not meet the 150-acre performance standard (Figure 6.2b). Because neither the current year (2016) nor the 4-year running average met the 150 acre requirement, the Wheeler North Reef failed to meet the performance standard for giant kelp in 2016.

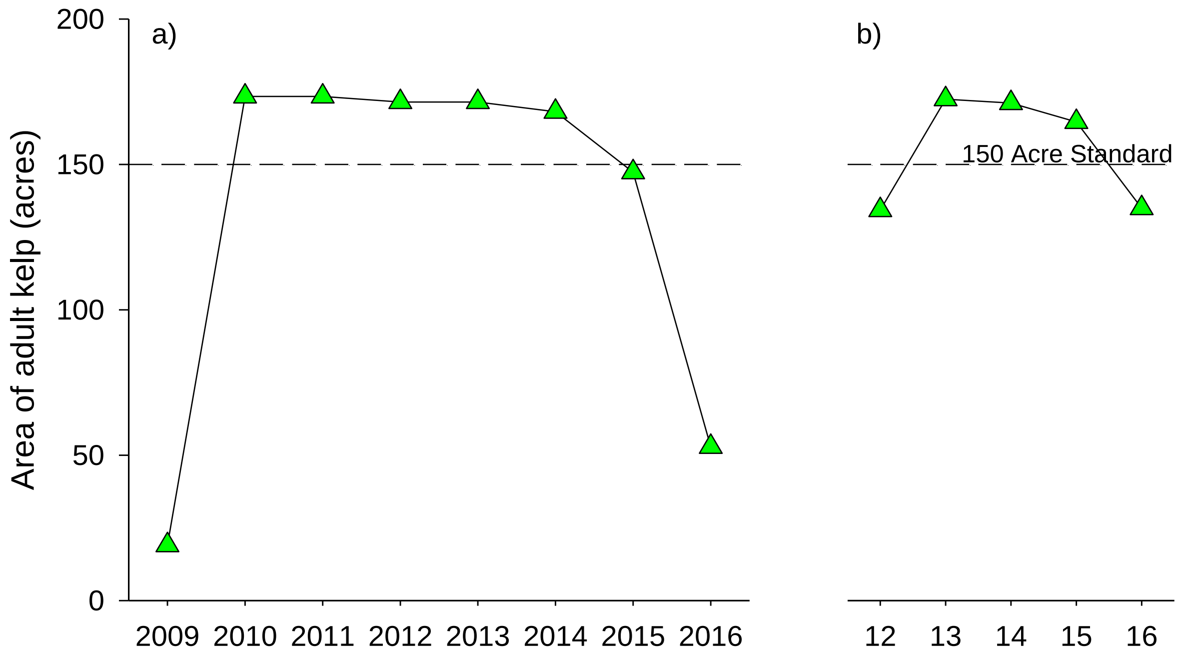


Figure 6.2. The number of acres of medium to high density adult kelp at Wheeler North Reef (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 the density of bottom-dwelling fish, 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 summer to early autumn of each year. Divers count, identify to species and estimate the total length (to the nearest cm) of each fish observed in a 3m wide x 1.5m high x 50m long volume centered above a measuring tape placed along the bottom 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. Smaller fish that shelter on or near the bottom are recorded in a 2m wide swath centered along the transect as divers return after completing the sampling of larger more visible fish. Small cryptic species (e.g. cottids, gobies, blennies) are recorded in the five 1m^2 quadrats used to sample invertebrates and algae. These data are augmented with data from additional surveys of fish lengths if more information is needed to accurately characterize population size structure.

Length data are used to assign each fish to one of three life stages (juvenile, subadult, and adult) using data from the literature (e.g. Love 2011) or best professional judgment by reef fish experts (e.g., Milton Love UCSB and Mark Steele CSUN). The biomass of each species within a transect is calculated by multiplying the number of fish in each life-stage by the average weight of the life stage and summing over all life stages. Fish weights are estimated from fish lengths using species-specific length-weight regressions obtained either from the literature (Gnose, 1967; Quast, 1968a, 1968b; Mahan, 1985; Wildermuth, 1983; Stepien, 1986; DeMartini et al., 1994, Love 2011) or from data collected as part of this project. The biomass densities of all species encountered on a transect are summed to produce an estimate of the total biomass of fish within each transect in units of g wet weight m^{-2}. This value is averaged across all transects, converted to US tons per acre, and multiplied by the total reef area (in acres) to obtain an estimate of the standing stock of bottom-dwelling fish at the Wheeler North Reef.

The sampling methods and calculations for determining fish standing stock described above are the same as those used by the Marine Review Committee (MRC, 1989) when they determined that SONGS operations caused a 28 ton reduction in the standing stock of bottom-dwelling kelp bed fish.

The Wheeler North Reef is considered to have met this performance standard if its standing stock of bottom-dwelling fish in a given year ≥28 tons, or its mean fish standing stock of bottom-dwelling fish averaged over that year plus the three preceding years ≥ 28 tons.

Results: In 2016, eight years after its construction, the Wheeler North Reef has yet to meet the performance standard for fish standing stock, regardless of whether it was evaluated using the current year or the most recent 4-year average. The standing stock of reef fish on the Wheeler North Reef was far below the absolute performance standard of 28 tons in the first five years of monitoring; however, in 2014 standing stock increased significantly from 13.3 to 25 tons, the highest value since monitoring began (Figure 6.3a). This increase was short-lived, however, and in 2015 and 2016 the standing stock declined to 17.6 and 19.1 tons, respectively. The 4-year running average has gradually increased over time to 18.8 tons in 2016, which is still well below the required 28 tons (Figure 6.3b). Thus after eight years the Wheeler North Reef has yet to meet the performance standard for fish standing stock, regardless of whether it’s evaluated using the current year or the 4-year average.

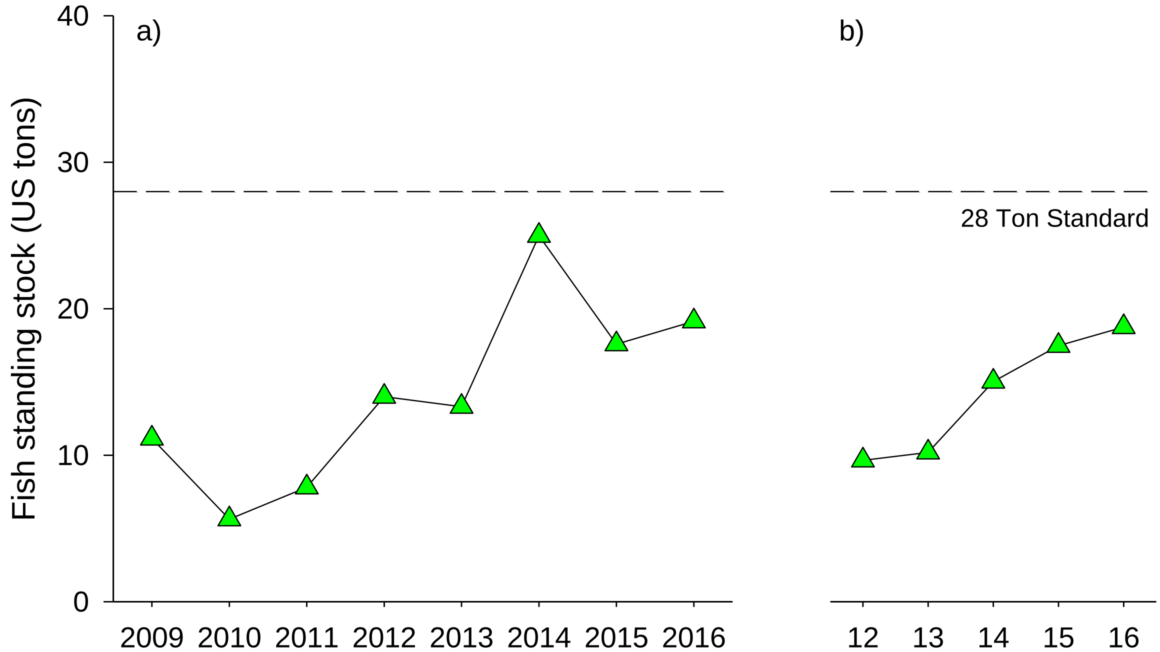


Figure 6.3. Estimated standing stock of fish at Wheeler North Reef (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 for fishes 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, Harrer et al. 2013) and is not required for evaluating the performance of Wheeler North Reef. However, net primary production by giant kelp (which constitutes the vast majority of macroalgal biomass on reefs in California; Graham et al. 2007) can be predicted from more easily obtained measurements of kelp frond density (Reed et al. 2009), which are made as part of the evaluation of the performance standard pertaining to giant kelp area.

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 potentially undesirable or invasive species are used to evaluate whether their abundances reach levels that have been shown to impair reef functions in previous studies.

<u>Results</u>: As noted in Section 5, the density of giant kelp fronds at Wheeler North Reef, declined dramatically since 2014 (Figure 5.2.6). Similar declines were observed throughout southern California including San Mateo and Barn indicating a regional reduction in giant kelp primary production rather than poor performance unique to Wheeler North Reef. Indeed, the decrease in this important ecological function has been attributed to extreme warming of the entire eastern north Pacific Ocean during 2014 – 2016.

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. 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 five of eight years including 2016 (Figure 6.16). While the specific reasons for the Wheeler North Reef’s failure to meet the food chain support standard in those three years is unknown, it does not appear to have been due to an increase in the abundance of undesirable or invasive species as indicated by their relatively low abundances during this period.

Invasive and potentially 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 $10m^{-2}$. We refer to a density of sea fans equal to 10 m^{-2} as the “Ambrose Line”. Densities above the Ambrose Line indicate a potential concern for a reef with respect to its ability to support giant kelp. Sea fan densities at Wheeler North Reef were consistently below the Ambrose Line until 2016 when a large recruitment event caused densities to increase to > 20 per m^2, which is twice that of the Ambrose Line (Figure 6.4 a, b). It is worth noting that sea fans observed by Ambrose et al. (1987) were mostly large ‘adult’ colonies that occupied a large amount of space on the reef. In 2016, the density of adult sea fans at Wheeler North

Reef was well below the Ambrose Line (< 5 individuals per m^2, Figure 6.4c). Moreover, the combined cover of all sea fans occupied <3% of the rock surface area, which was not sufficient to adversely affect the abundance of other species in the benthic community or the important ecological functions of the reef.

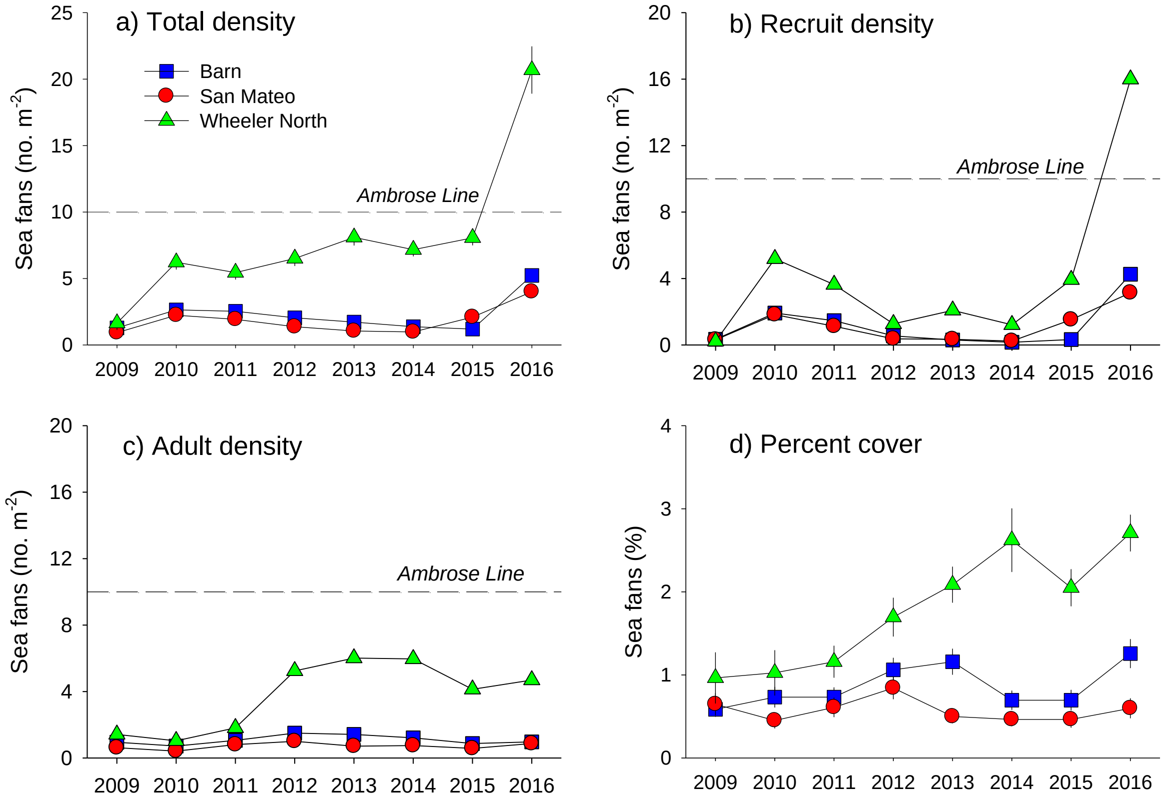


Figure 6.4. Mean density and percent cover (± 1 standard error) of sea fans at Wheeler North Reef, San Mateo and Barn for 2009 - 2016.

As with 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 – 2016 show that sea urchin densities have been consistently low at Wheeler North reef averaging ~ 1 individual m^{-2} (Figure 6.5). This density is far below that needed to significantly impact giant kelp and other components of the benthic community.

No invasive non-native species of invasive algae were observed from 2009 – 2013. A single non-reproductive individual of *Sargassum horneri*, a non-native brown alga, was observed on Wheeler North Reef in 2014 and a few more individuals were observed in 2015 and 2016. 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 2016.

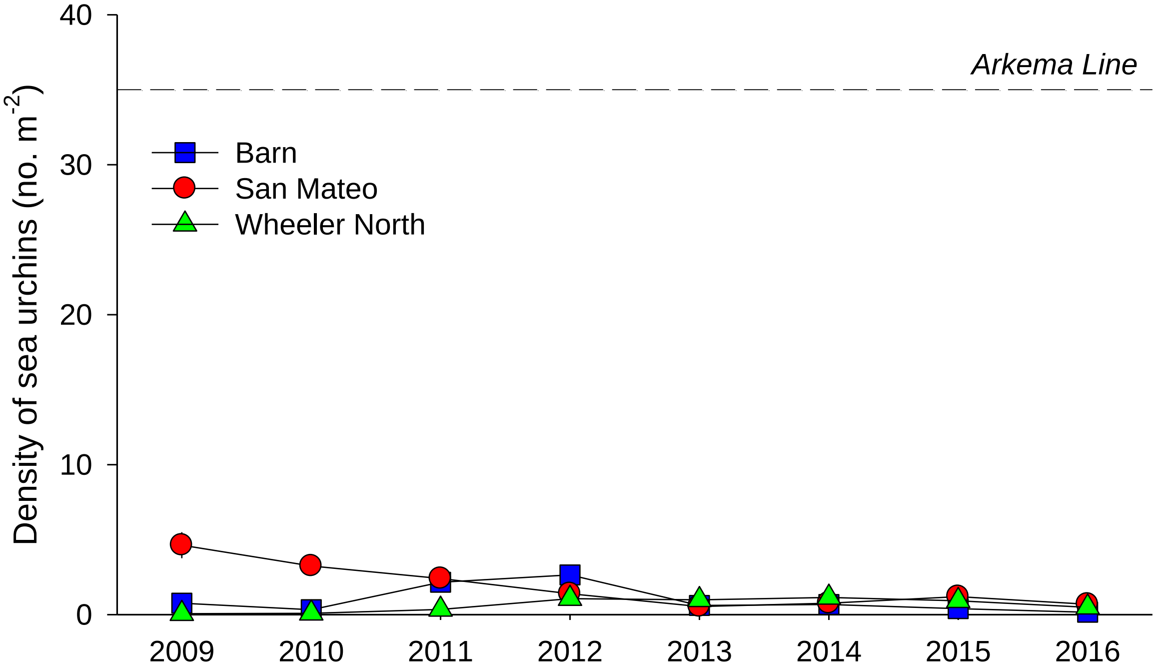


Figure 6.5. Mean density (± 1 standard error) of sea urchins, *Strongylocentrotus* spp. at Wheeler North Reef, San Mateo and Barn for 2009 - 2016.

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 1m^2 quadrats located at 10m intervals along each of the eighty-two 50m transects. At the Wheeler North Reef, these transects are 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 and decreased to about 10% in 2011 after the surface canopy of giant kelp became fully established (Figure 6.6a). It has increased since 2013, reaching nearly 48% in 2016 coincident with the decline in the abundance of giant kelp. The percent cover of macroalgae at the two reference sites has also increased since 2013 following declines in giant kelp (Figure 6.6a). The generally lower algal percent cover at the Wheeler North Reef compared to the reference reefs has resulted in a four-year running average of algal percent cover that has always been significantly lower than that of the two reference reefs (Figure 6.6b). Consequently, the Wheeler North Reef has never met this performance standard since the first four-year running average in 2012.

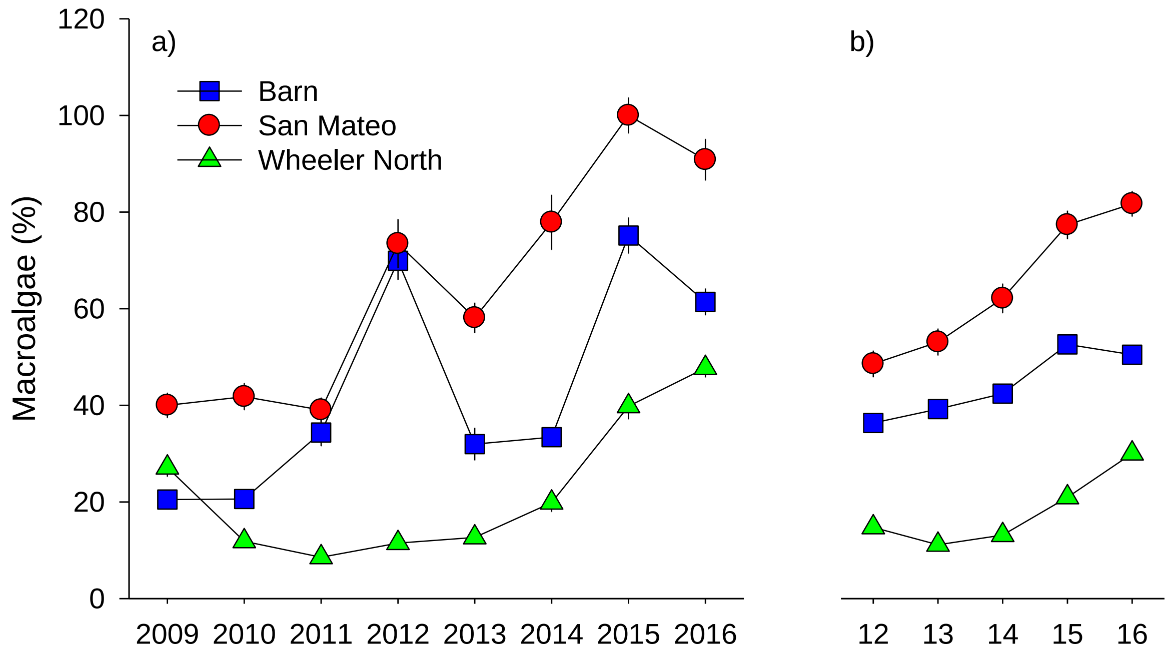


Figure 6.6. Mean percent cover (± 1 standard error) of macroalgae at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 reef. 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 the number of species of macroalgae per transect.

Results: The average number of macroalgal species per transect declined over time at the Wheeler North Reef from 2009 through 2013, and like macroalgal percent cover, has increased steadily since then through 2016. Both San Mateo and Barn showed similar increases, and species richness at the two reference reefs has been consistently and substantially higher than at Wheeler North Reef since 2010 (Figure 6.7a), as has the four-year running average since 2012 (Figure 6.7b). Consequently, the Wheeler North Reef did not meet the performance standard for algal diversity in 2016.

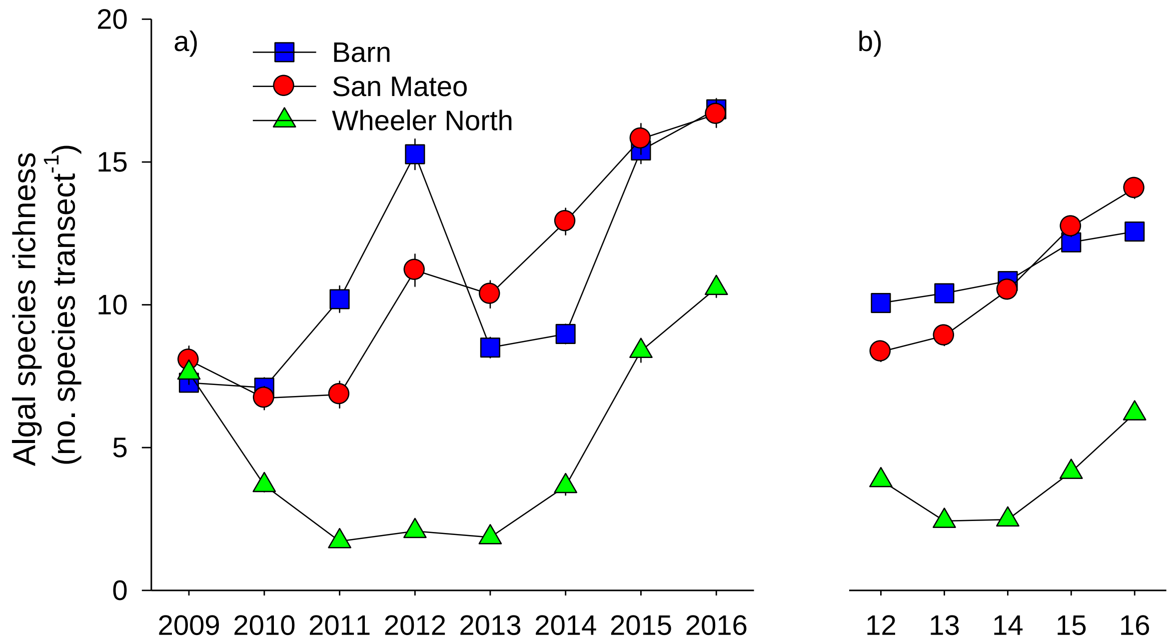


Figure 6.7. Mean species density (± 1 standard error) of understory algae at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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.

Results: As described in section 5.0, sessile invertebrates and algae compete for space on the bottom and as a result, increases in the percent cover of one group are typically accompanied by decreases in the percent cover of the other (Figure 5.2.12). This is exactly the pattern that we have seen at Wheeler North Reef, Barn and San Mateo. The percent cover of sessile invertebrates at Wheeler North Reef in

2009 was about half that at the reference reefs, but increased nearly three-fold by 2012 as the percent cover of algae declined (Figure 6.8a vs. Figure 6.6a). The percent cover of sessile invertebrates and algae remained relatively constant from 2012 – 2104, but changed dramatically in 2015 and 2016 as the percent cover of algae doubled while that of sessile invertebrates was halved. 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). The percent cover of sessile invertebrates at Barn has fluctuated between 25 and 39% since 2012 while that at San Mateo has remained relatively low during this period varying between 20 - 27% (Figure 6.8a). The four-year running average of percent cover of sessile invertebrates has been consistently higher at the Wheeler North Reef compared to San Mateo and Barn since 2012. As a result, the Wheeler North Reef has met this performance standard every year from 2012 through 2016 (Figure 6.8b).

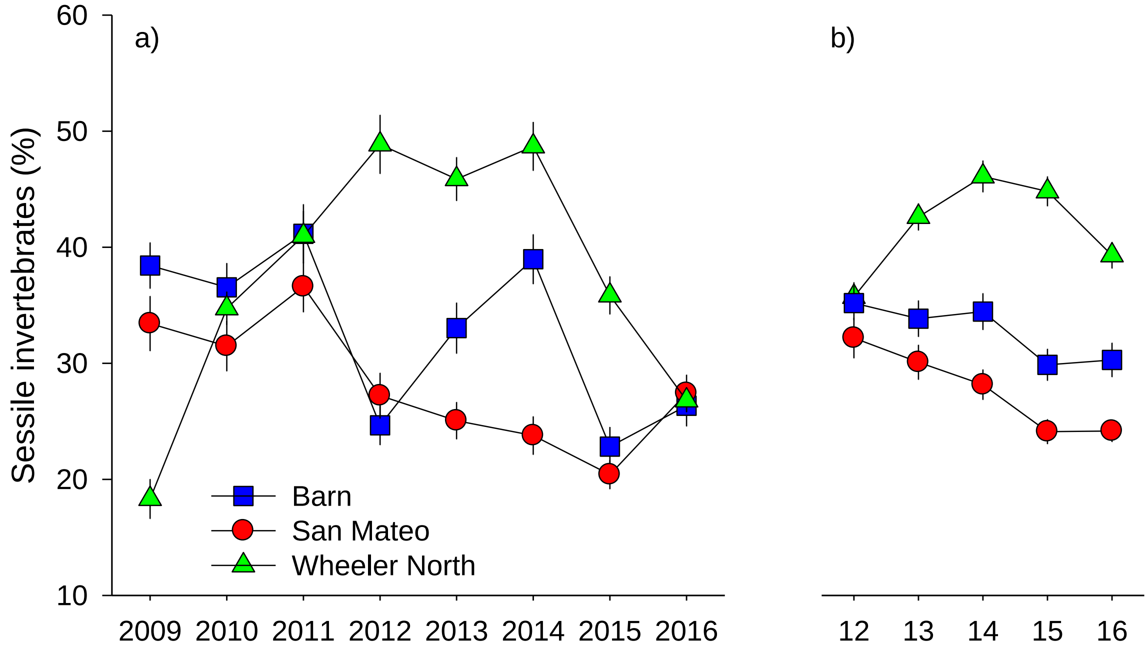


Figure 6.8. Mean percent cover (± 1 standard error) of sessile invertebrates at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 $1m^2$ or a $0.5m^2$ area created by dividing the $1m^2$ quadrats in half using an elastic cord stretched across the frame of the quadrat. Densities are expressed as number per m^2 of 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.

Results: Much like the percent cover of sessile invertebrates, the density of mobile invertebrates at Wheeler North Reef was initially low (< 10 m^{-2}) in 2009 and increased dramatically (> 100 individuals m^{-2}) by 2012 (Figure 6.9a). Mobile invertebrate abundance has steadily declined at Wheeler North Reef since 2012 to densities that were only slightly higher than those observed in 2009. Densities of mobile invertebrates have shown a general decline at San Mateo and Barn since 2010 and densities at both sites were very similar to that of Wheeler North Reef in 2016 (Figure 6.9a). The four-year running average of mobile invertebrate density at Wheeler North Reef was between those at the reference reefs in 2012 and was greater than that at the two reference reefs from 2013 through 2016 (Figure 6.9b). As a result, the Wheeler North Reef has consistently met this performance standard every year since 2012.

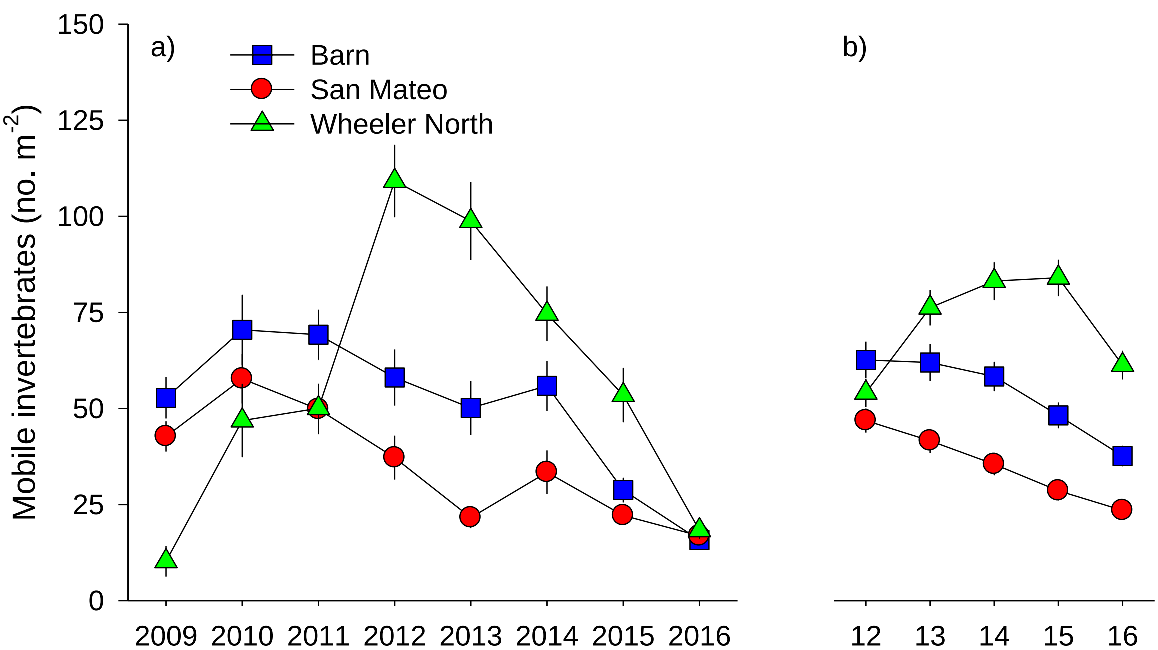


Figure 6.9. Mean density (± 1 standard error) of mobile invertebrates at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 per transect 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.

Results: The average number of species of benthic invertebrates per transect at the two reference reefs has declined slightly over the eight-year sampling period, whereas it has increased dramatically at Wheeler North Reef from a low value of 14 species per transect in 2009 to ~35 species per transect in 2012 (Figure 6.10a). It remained near this high level through 2015, which was within or above the range observed at San Mateo and Barn during this time. Invertebrate richness declined to 28 species per transect in 2016, which was slightly below that observed at the reference reefs. The increasing trajectory of the number of species of invertebrates at Wheeler North Reef resulted in a four-year running average within or slightly above the range of values observed at the two reference reefs since 2014 (Figure 6.10b). As a result, the Wheeler North Reef met the performance standard for the number of species of benthic invertebrate from 2014 through 2016.

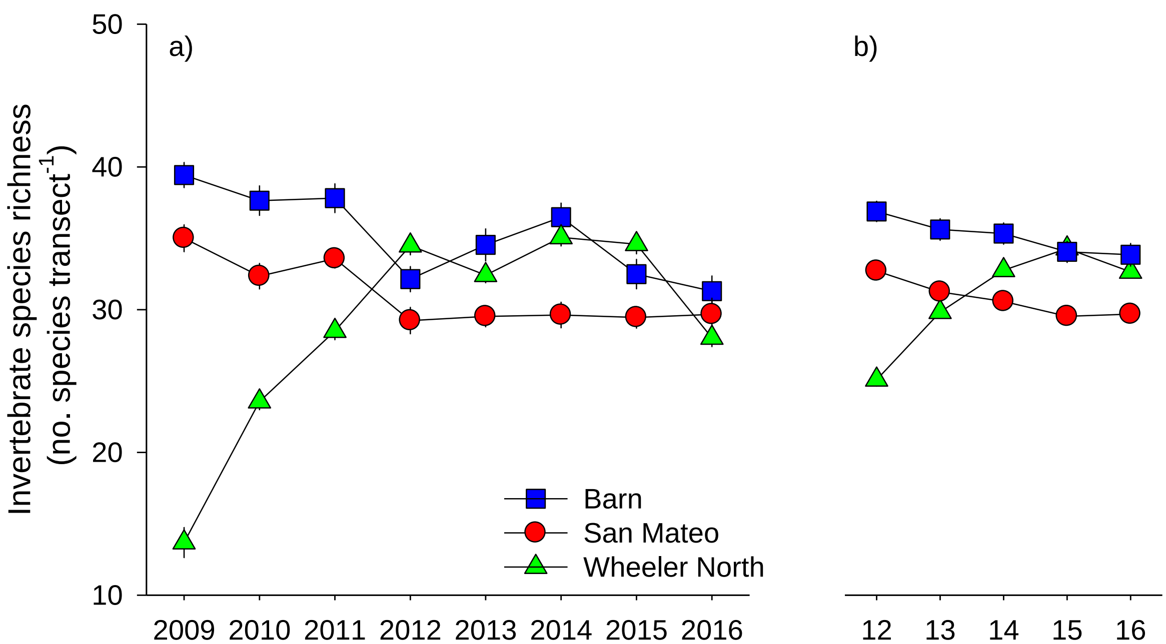


Figure 6.10. Mean species density (± 1 standard error) of invertebrates at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 (fish <1-year old are termed young-of-year). 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 at Wheeler North Reef, San Mateo, and Barn is calculated as the mean density of resident fishes near 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.

Results: In 2009, 1 year after its construction, the density of resident fish at the Wheeler North Reef was 50% - 300% greater than that at the reference reefs (Figure 6.11a). Since then, fish densities have been relatively similar among the three reefs. The lone exception to this was a spike in resident fish density at Barn in 2011 when schools of Señorita were observed on several transects. The four-year running average of resident fish at the Wheeler North Reef was between or slightly higher than that at San Mateo and Barn since 2012 (Figure 6.1b). Thus, Wheeler North Reef met the performance standard for resident fish density from 2012 through 2016.

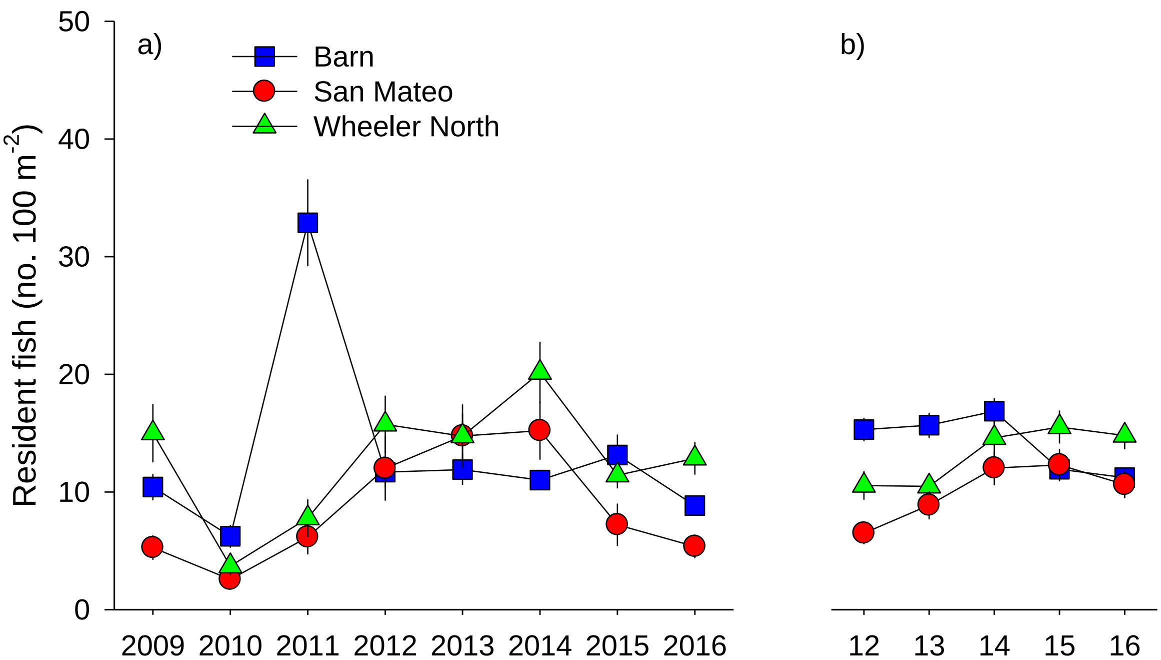


Figure 6.11. Mean density (± 1 standard error) of resident fish at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 at the Wheeler North Reef and the 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 fishes in 2009 were 1.7 – 5 times higher at Wheeler North compared to San Mateo and Barn (Figure 6.12a) due to a large recruitment of the Blackeye Goby, *Rhinogobius nicholsii*. Since then mean densities of YOY fish at Wheeler North Reef have fluctuated within the range set by San Mateo and Barn. The temporal pattern observed at Barn has been similar to that at San Mateo, but at substantially lower densities. YOY densities declined at all three reefs in 2016 reflecting the near absence of Blackeye Gobies. This cool-water species has a life span of about two years and its low abundance in 2016 was likely linked to anomalously warm water in 2014 – 2016. The four-year average for YOY density at Wheeler North Reef has been within or slightly above the range of values at San Mateo and Barn since 2012 (Figure 6.12b). Thus, the Wheeler North Reef has met the performance standard for YOY density every year from 2012 through 2016.

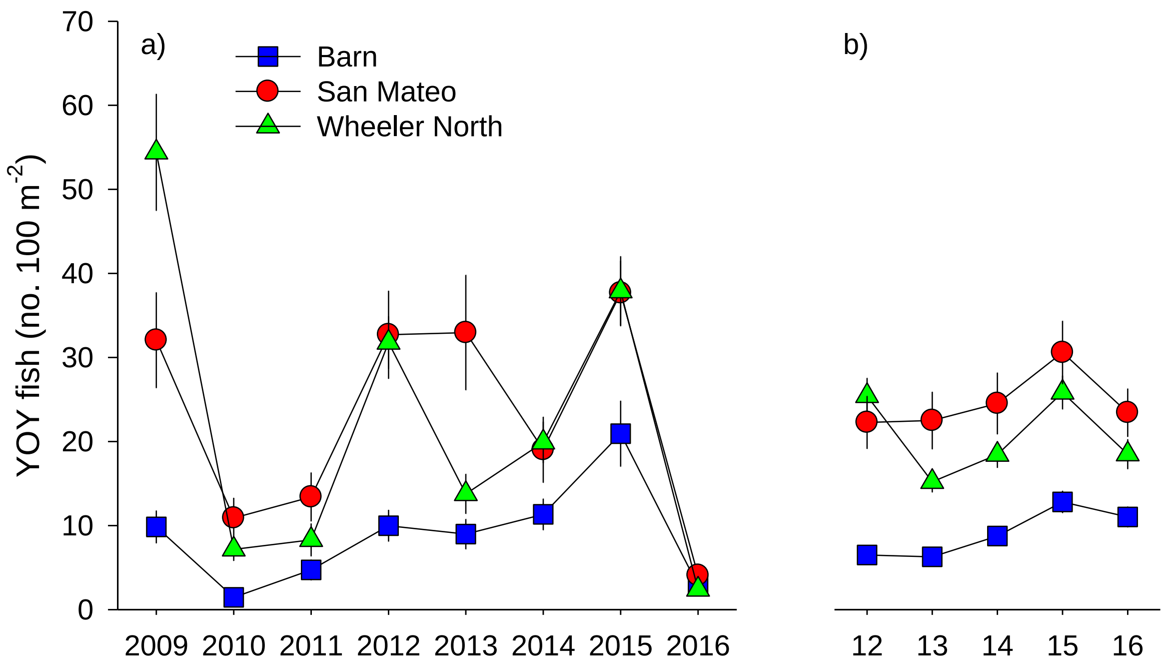


Figure 6.12. Mean density (± 1 standard error) of young-of-year fish at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 the number of species of kelp bed fish per transect.

Results: Fish diversity has generally increased at the three reefs since 2009, with Barn and Wheeler North Reef displaying the highest diversity and San Mateo consistently displaying the lowest diversity (Figure 6.13a). As a result, the 4-year average of the mean number of fish species per transect at Wheeler North Reef has been within or above that of the two reference reefs (Figure 6.13b). Thus the Wheeler North Reef met the performance standard for fish diversity from 2012 through 2016.

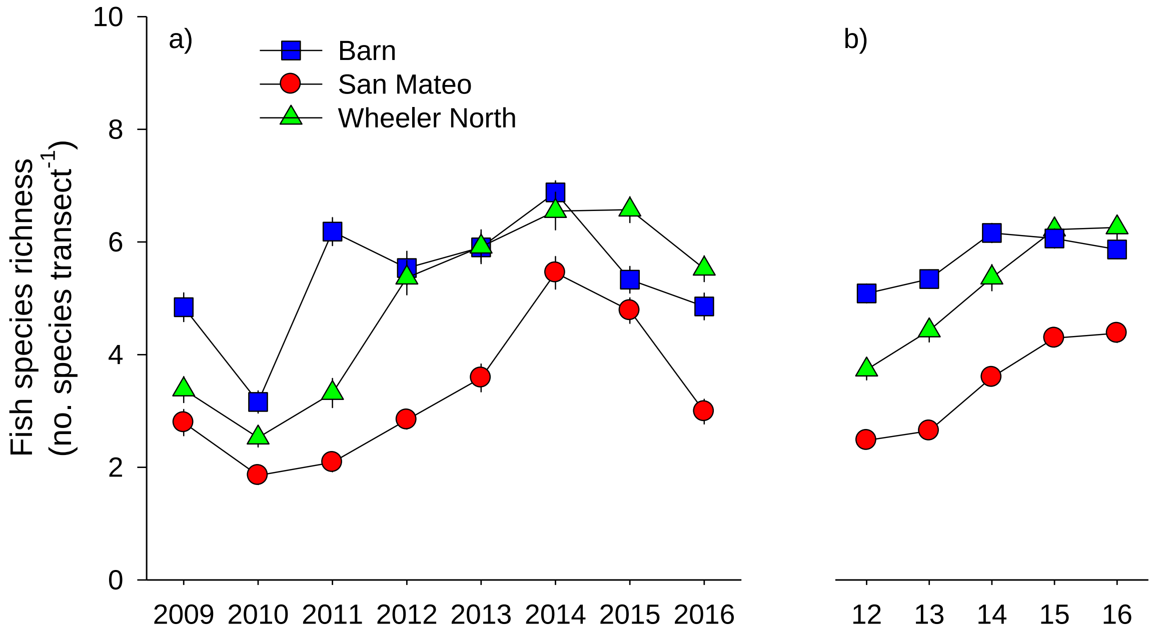


Figure 6.13. Mean species density (± 1 standard error) of fish at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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. 2017).

Fish production is estimated for five target species: Blacksmith, Black Perch, Señorita, California 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 Perch and Señorita feed on small invertebrates that live on or near the bottom, California 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.

Results: Temporal patterns of reef fish production at the Wheeler North Reef mirrored those at San Mateo, but with slightly higher values from 2009 through 2013 and significantly higher values from 2014 – 2016 (Figure 6.14a). Fish production at Barn has followed a similar trajectory but, with a notable spike in all five target species in 2011 (Figure 6.14a). The above described patterns resulted in the Wheeler North Reef having a four-year running average of fish production that was intermediate to that of the two reference reefs in every year since 2012 (Figure 6.14b). Consequently, the Wheeler North Reef consistently met the performance standard for fish production from 2012 through 2016.

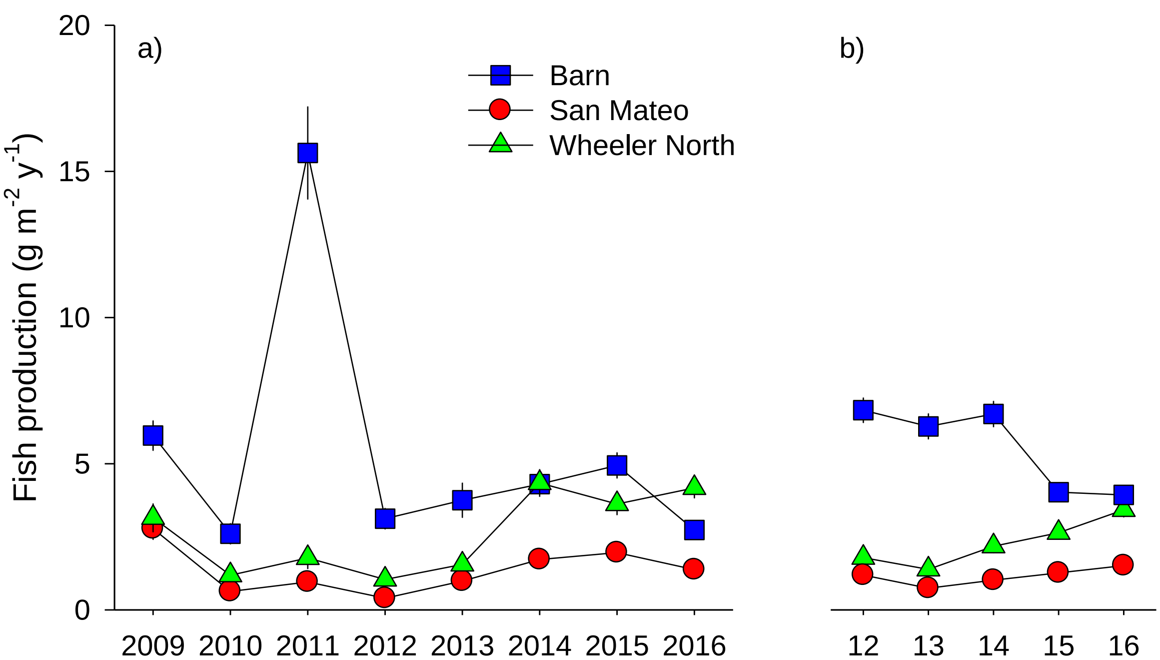


Figure 6.14. Mean fish production (± 1 standard error) at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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.

A resampling approach is used to statistically determine whether the Wheeler North Reef met this performance standard for a given year (see Appendix 2 in Reed et al. 2017 for details). This provides a method to estimate the variance and provides a basis for the calculation of a p-value. Because larger individuals tend to produce more eggs, the production of eggs is scaled to the body length and used to obtain a standardized measure of fecundity for each species at each reef.

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

Results: The value of the Median Fecundity Index varied inconsistently among the three reefs during the eight-years of monitoring (Figure 6.15a). This included a three-fold increase at Barn in 2016 that was not observed at San Mateo and Wheeler North Reef. Despite the erratic and asynchronous fluctuations in fish reproductive rates at the three sites, the median values of the 4-year running averages of their Fecundity Index have been relatively similar (Figure 6.15b). Consequently, the Wheeler North Reef has consistently met this performance standard each year from 2012 – 2016.

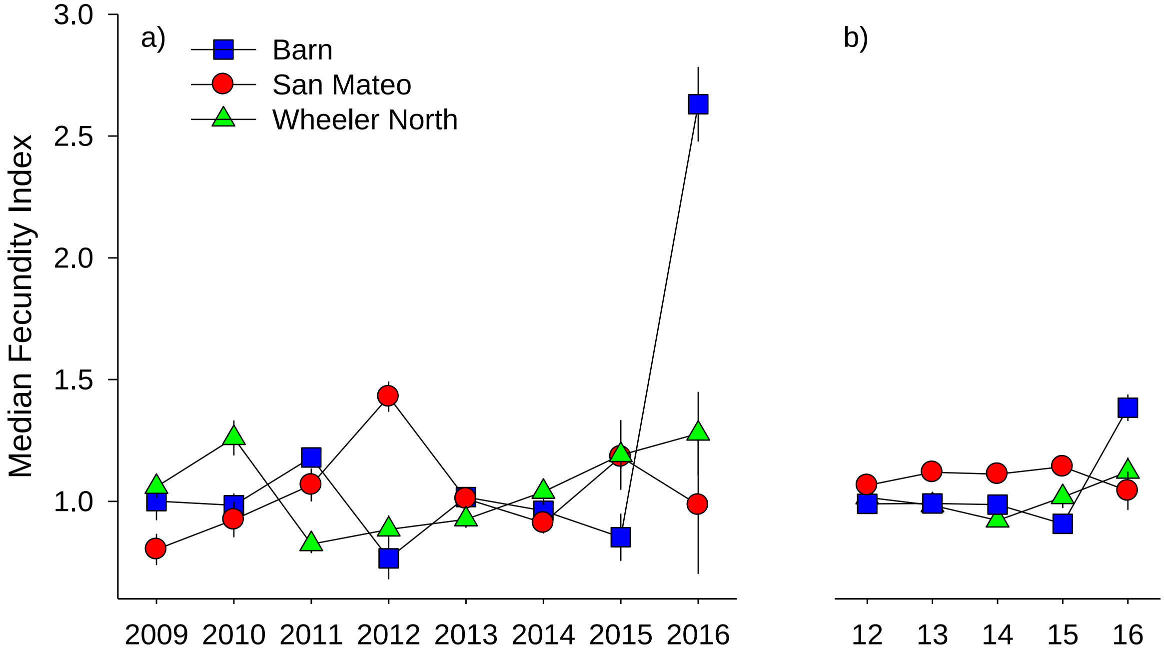


Figure 6.15. Median fecundity index (± 1 standard deviation) at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 California Sheephead specimens are placed on ice and transported to the laboratory where they are either immediately dissected and processed or frozen for processing at a later date. Sample processing for both species involves removing the entire tubular digestive tracts and weighing the contents, either before or after preservation by fixation in 10% formaldehyde and storage in 70% ethanol. These measurements are used to calculate an index of food chain support (FCS) that is based on the mass of the gut contents relative to the body mass of the fish

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

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

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

The four-year running average of the standardized FCS index for each reef is calculated using a four-year mean of each iteration based on the current year and the previous three years producing 1000 values of the four-year average of the standardized FCS index for each reef. The four-year mean and variance of the standardized FCS index for each reef is calculated from the resampled distribution of these 1000 values. The four-year running average of the standardized FCS index at Wheeler North Reef must be similar to that at the reference (as per the methods described in section 4.3) in order for the Wheeler North Reef to meet this performance standard for any given year.

<u>Results:</u> The three reefs have shown very different temporal patterns in the values of their standardized FCS index. The index steadily declined at Wheeler North Reef from 2009 to 2012, increased sharply in 2013 and decreased since then, most notably in 2016 (Figure 6.16a). In contrast the standardized FCS index at San Mateo increased from 2009 – 2011 and has remained high through 2016, while the FCS index at Barn remained relatively high from 2009 – 2012 before declining sharply in 2013 and then increasing steadily through 2016 (Figure 6.16a). The four-year running average of the FCS at Wheeler North Reef was significantly lower than both reference reefs in 2013 – 2015, but not in 2016 (Figure 6.16b). Thus, the Wheeler North Reef met the performance standard for food chain support in 2016.

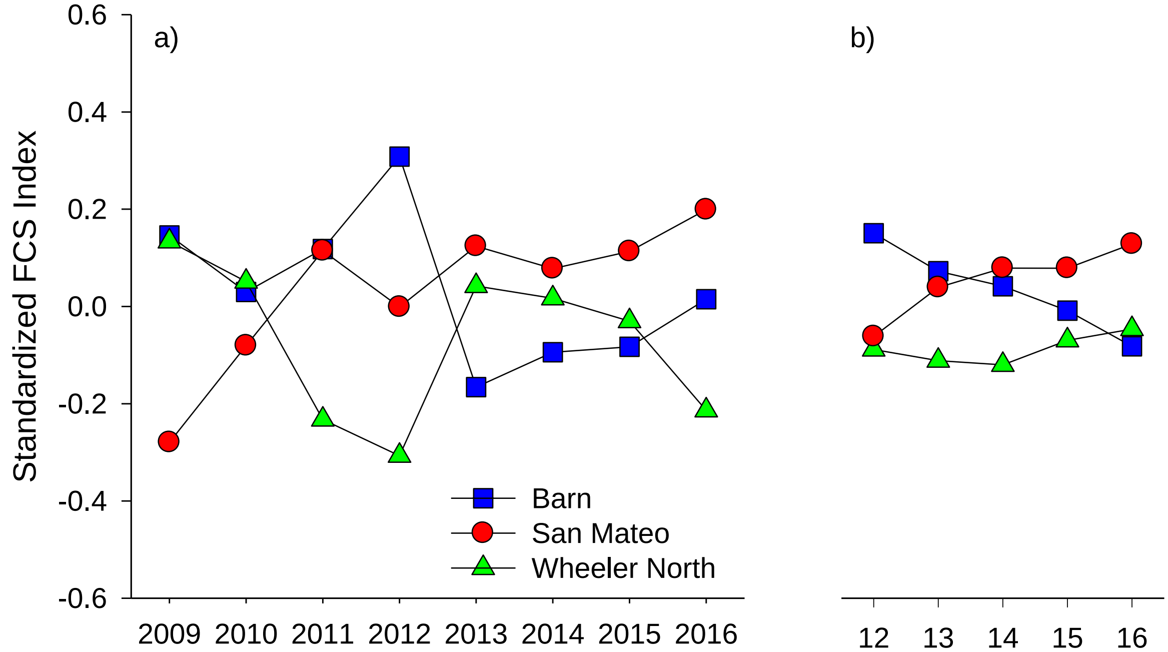


Figure 6.16. Food chain support (FCS) index (± 1 standard error) at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 - 2016 and (b) 4-year running average.

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 all four absolute performance standards, and at least as many relative standards as the reference reefs. The absolute performance standards are measured only at the Wheeler North Reef and they are assessed using values from either the current year (i.e., 2016) or the most recent four-year running average, whichever is higher. The relative performance standards are evaluated at Wheeler North Reef, San Mateo and Barn using only the most recent four-year running average (see Section 4.1).

A summary of the performance of the Wheeler North Reef in 2016 as measured by the four absolute performance standards and the 11 relative performance standards is shown in Table 7.1.1. In 2016 the Wheeler North Reef met two of the four absolute standards; failing to meet the standards for giant kelp and fish standing stock. Wheeler North Reef also met 9 of the 11 relative performance standards in 2016, which was the same number met at Barn, and three more than were met at San Mateo. Thus in 2016 the Wheeler North Reef met at least as many relative standards as San Mateo, the lower performing reference reef. However, because Wheeler North Reef did not meet the absolute standards for giant kelp and fish standing stock it received no mitigation credit for 2016.

		WNR		San Mateo	Barn
		2016	4-yr avg	4-yr avg	4-yr avg
	ABSOLUTE STANDARDS				
1.	Substrate	YES	YES		
2.	Giant Kelp	NO	NO*		
3.	Fish Standing Stock	NO	NO		
4.	Invasive species	YES	YES		
	Number of Absolute Standards met	**2**	**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		YES	NO	YES
6.	Resident fish density		YES	YES	YES
7.	YOY fish density		YES	YES	NO
8.	Fish species richness (all ages)		YES	NO	YES
9.	Fish reproductive rates		YES	YES	YES
10.	Fish production		YES	NO	YES
11.	Food chain support		YES*	YES	NO*
	Number of Relative Standards met		**9**	**6**	**9**

Table 7.1.1. Summary of the performance of Wheeler North Reef in 2016 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.* indicates a change from 2015.

Fulfillment of the SONGS reef mitigation requirement occurs when the number of years of mitigation credit accrued by the Wheeler North Reef equals the total years of operation of SONGS Units 2 & 3, including the decommissioning period to the extent that there is continuing discharge of cooling water. SONGS Unit 2 began operations in 1982 and Unit 3 in 1983. Both Units ceased operations in 2013, but continue to discharge approximately 3% of the volume of their full operational flow. Thus the Wheeler North Reef must obtain at least 30 years of mitigation credit to fulfill the requirements of Condition C of the SONGS coastal development permit. As of 2016 the Wheeler North Reef had not earned any years of mitigation credit (Table 7.1.2). The reason for this has been its failure to meet the absolute performance standards for giant kelp in 2009 and 2016 and for fish standing stock in all eight years.

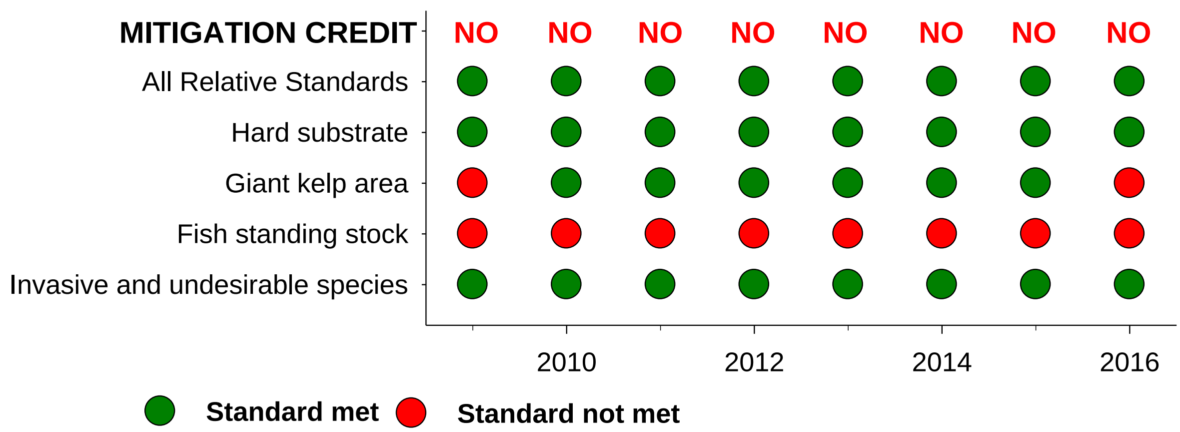


Table 7.1.2. Summary of the Wheeler North Reef's performance with respect to whether it met the four absolute performance standards and the collective group of relative performance standards for each year since 2009. To receive mitigation credit for a given year the Wheeler North Reef must meet all four absolute performance standards and the collective group of relative performance standards.

Despite its consistent failure to meet the performance standard pertaining 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 invasive species in all eight years of monitoring and the absolute standard for giant kelp in six of the eight years. Moreover, the overall performance of Wheeler North Reef with respect to the relative performance standards has consistently been within the range set by the two natural reference reefs (Table 7.1.3). Notably, the Wheeler North Reef has consistently met all the relative performance standards pertaining to fish density, species number, reproduction and growth (i.e., production). Moreover, it has steadily improved its relative performance with respect to the abundance and diversity of reef invertebrates and has met all three of these performance standards for the past three years. By contrast, the Wheeler North Reef continues to underperform with respect to understory algae, which is to be expected given its greater abundance of giant kelp, which inhibits understory algae via shading, thereby indirectly facilitating sessile invertebrates.

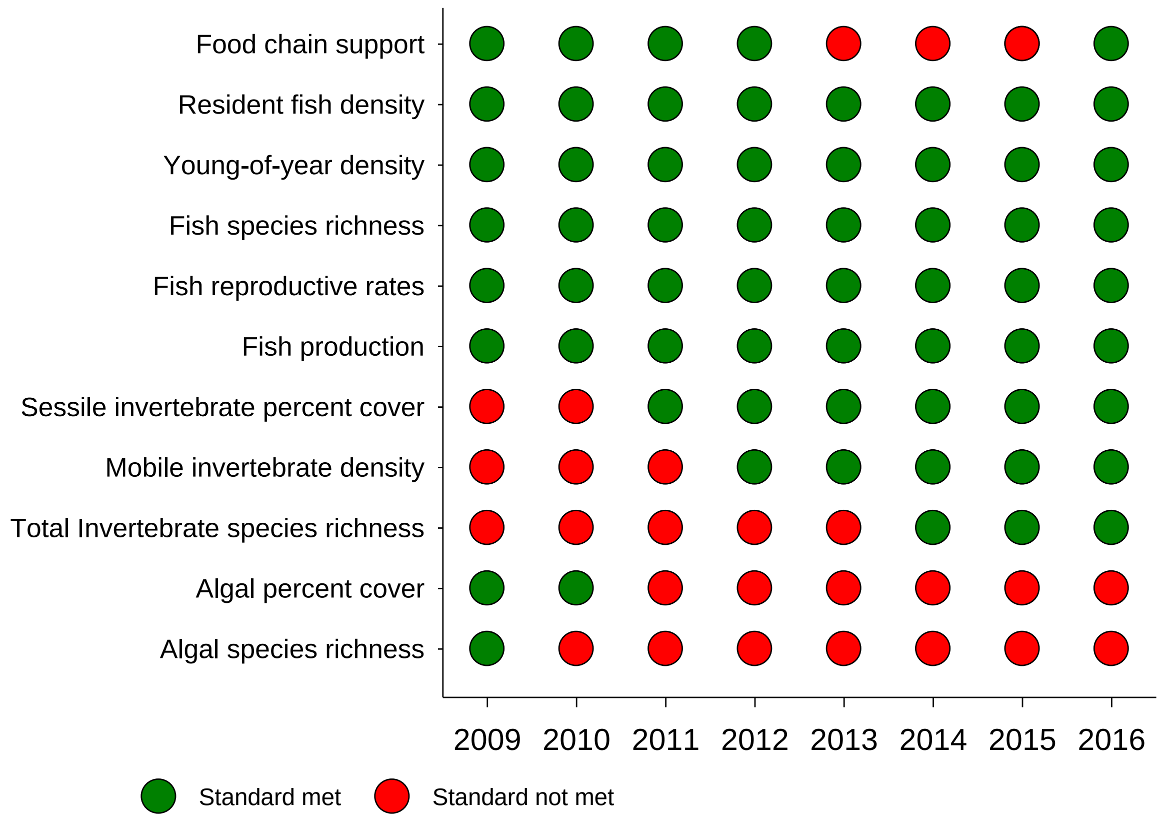


Table 7.1.3. Summary of the Wheeler North Reef's performance with respect to whether it met each of the 11 relative performance standards for each year since 2009.

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

The SONGS Coastal Development Permit requires that independent studies be done to determine the reasons why any performance standard has not been met. To fulfill this requirement, we analyzed the time series data collected at the artificial reef and nearby reference reefs during Phase 1 and Phase 2 of SONGS reef mitigation to determine the reasons for the Wheeler North Reef's failure to meet the performance standard for fish standing stock.

The standing stock of fish on a reef is influenced by a wide variety of factors including ocean climate, fishing pressure, and the physical attributes of the reef, such as its footprint area, rock coverage and topography. The most recent surveys show that the Wheeler North Reef has experienced a slight decrease in its footprint area and a slight increase in its percent cover of hard substrate relative to its as-built condition. Thus the best estimate of the present configuration of the Wheeler North Reef is ~174 acres of low relief rock that covers on average 48% of the bottom. The Wheeler North Reef was designed to be low relief to mimic natural reefs in the region, including the reef at San Onofre that was damaged by SONGS' operations. Low relief artificial reefs in southern California are also thought to be more likely to support giant kelp, which was a major objective of the mitigation project. A critical issue in assessing the long-term performance of the Wheeler North Reef is whether its present configuration is sufficient to sustain at least 28 tons of fish over the long term.

Results from our analyses show: (1) the standing stock of fish on a reef is positively related to the bottom coverage of rock and to reef topography, (2) the biomass density of fish at the Wheeler North Reef is within the range of the two reference reefs, (3) 174 acres of the reference reefs is not sufficient to consistently support a fish standing stock of 28 tons (Reed et al. 2016). Collectively, these results indicate that the present size (174 acres) and configuration (48% cover of low relief rock) of the Wheeler North Reef is not sufficient to consistently support 28 tons of reef fish. This finding is notable and indicates that remediation in the form of additional reef is needed for the Wheeler North Reef to consistently meet its current mitigation requirements over the long term.

7.3 Possible solutions for remediating of Wheeler North Reef to increase its fish standing stock

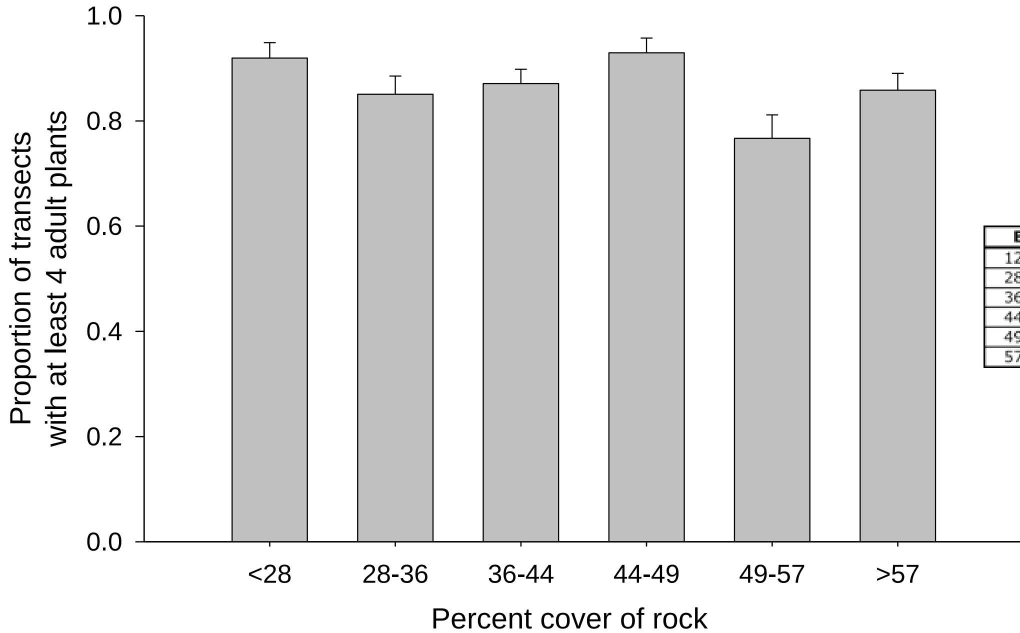
The SONGS Coastal Development Permit also requires independent studies be done to develop recommendations for appropriate remedial measures in the event that a performance standard is not being met. Determining the area and bottom coverage of new reef needed for remediation requires realistic estimates of the future performance of the existing 174-acre Wheeler North Reef with respect to fish standing stock, as well as the performance of the additional reef added as remediation. The time series data of fish biomass from the Phase 1 Experimental Reef are arguably the most useful data available for predicting the future capacity of an expanded Wheeler North Reef to sustain fish biomass because they: (1) include data for reefs with different rock coverages, (2) represent the longest time series of fish standing stock available, and (3) encompass a broad array of environmental conditions and a wide range of inter-annual variation in the standing stock of fish, which can be expected at Wheeler North Reef in the future.

The general approach used to determine the area of different configurations of new reef needed for remediation consisted of combining the expected future standing stock of the existing 174-acre Wheeler North Reef with the expected future standing stock of fish supported by new acreage of reef added as remediation (see Reed et al. 2016 for details). The estimated number of acres of various configurations of new reef that are needed for the Wheeler North Reef to meet the performance standard for fish standing stock with a 95% annual probability are provided in Table 7.3.1. These results show that remediation involving the addition of low relief, 41% rock cover reef will require nearly twice as many acres as remediation using low relief, 81% rock cover and nearly seven times more area than a high relief (2.5 m tall) reef with 100% rock cover.

Configuration of new reef to be added for remediation	Additional acres needed to support 28 tons of fish
Low relief (< 1 m), low rock cover (41%)	200
Low relief (< 1 m), medium rock cover (63%)	125
Low relief (< 1 m), high rock cover (81%)	105
High relief (2.5 m, 100% rock cover)	30

Table 7.3.1. The number of acres of new reef needed for the Wheeler North Reef to have a 95% probability of meeting the 28 ton performance standard for fish standing stock in a given year for different configurations of new reef using Phase 1 as the data source. Phase 1 data were collected from 2000 – 2016 on twenty one 40 m x 40 m low relief rock modules that consisted of low, medium and high rock cover.

Remediation involving larger areas with lower rock cover have the added advantage of providing more habitat for giant kelp, which increases the probability that the Wheeler North Reef will meet its requirement to sustain at least 150 acres of medium to high density giant kelp (defined as 4 or more adult plants per 100 m^2).. Monitoring results obtained to date show that the proportion of transects with 4 or more adult plants per 100 m^2 was independent of the percent cover of rock (Figure 7.3.1). Thus while 30 acres of high relief 100% cover rock is expected to support the same standing stock as 200 acres of low relief 41% rock coverage, it has the potential to produce 170 fewer acres of medium to high density kelp.



Bin	No. transects
12-28	87
28-36	107
36-44	155
44-49	85
49-57	90
57-84	120

Figure 7.3.1. Proportion of transects at Wheeler North Reef that supported medium to high density giant kelp (i.e. 4 or more adult plants per $100m^2$) for different percentages of hard substrate. Values are mean proportions (± SE) averaged over 7 years (n = 7 years; 2010-2016).

Importantly, the tonnage of rock needed to construct the four reef designs in Table 7.3.1 is inversely related to the area of reef (Figure 7.3.2). Thus, not only does a 30-acre high relief reef provide 170 fewer acres of kelp habitat than a 200-acre low relief low rock cover reef, but it costs much more to build as it requires about 6 times more rock. Nonetheless, there are other elements besides the amount of rock and kelp habitat that may need to be considered when remediating for Wheeler North Reef’s low fish standing stock. For example, there are physical limitations to the number of acres of new artificial reef that can be added to the existing lease site. The programmatic environmental impact report (PEIR) developed in 1999 for the construction of the SONGS mitigation reef identified a total of 356 acres within the designated lease site that were suitable for artificial reef construction. Thus the greatest area of new reef that can be added to the existing 174-acre Wheeler North Reef as per the PEIR is 182 acres. Moreover, the largest artificial reef evaluated in the PEIR was 277.6 acres. Thus under the existing regulations, remediation designs that involve adding more than 182 acres would require one or more additional lease sites to fulfill the requirement for artificial reef mitigation, while remediation that involves adding more than 103.6 acres (= 277.6 – 174) would require additional environmental impact studies. For these reasons remediation involving a mixture of high and low relief reef may have some advantages in terms of construction planning, permitting and impacts.

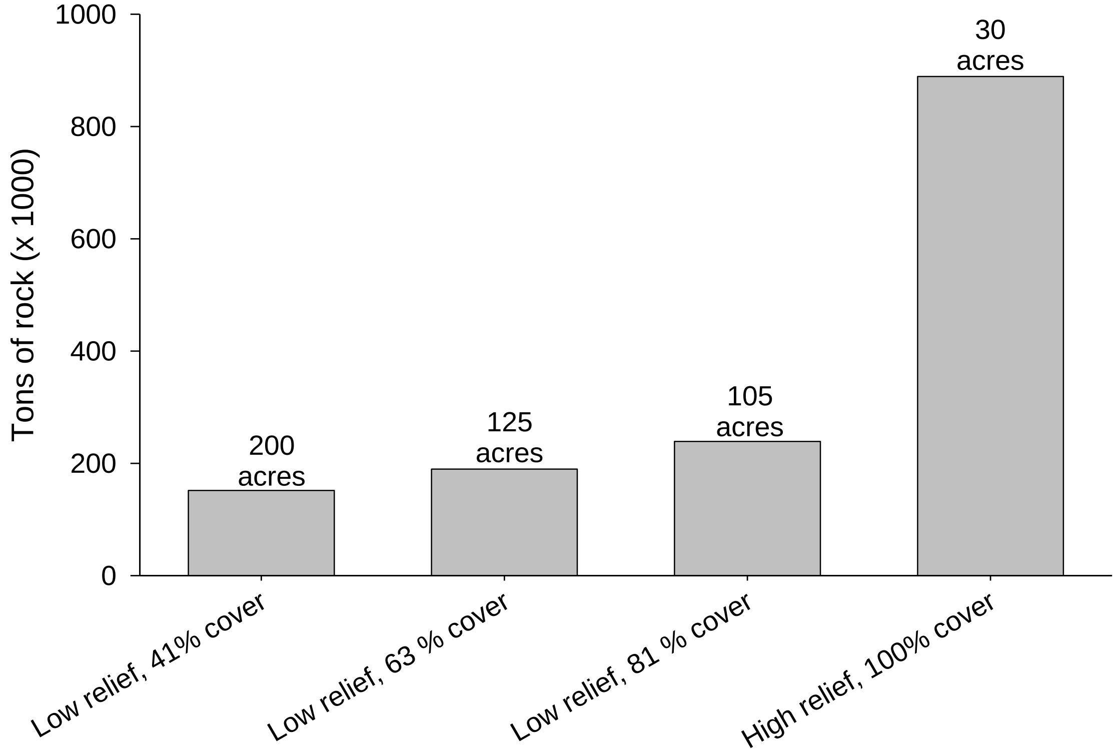


Figure 7.3.2. The tonnage of rock needed to construct the four different reef designs shown in Table 7.3.1., which when added to the existing Wheeler North Reef are expected to support a fish standing stock of 28 tons with 95% level confidence. Numbers above each bar are the number of acres of additional reef needed for each reef design as per Table 7.3.1.

Based on the results of the independent studies, the CCC Executive Director issued a directive to SCE on May 24, 2016 requiring them to remediate the Wheeler North Reef to enhance its ability to meet the 28 ton standard for fish standing stock. SCE responded by submitting a Draft Remediation Plan of Action to the CCC in July 2016 and has since been in discussions with the CCC staff regarding remediation designs and site constraints.

8.0 Future Monitoring and Remediation Plans

Monitoring of the Wheeler North Reef, San Mateo and Barn will continue in 2017 using the same level of effort and methods employed in 2016 as required by the SONGS coastal development permit. In addition to monitoring, additional analyses will be done with existing data as needed to aid the CCC staff in their discussions with SCE to finalize a remediation plan that enables the Wheeler North Reef to consistently meet its current mitigation requirements over the long term. A tentative timeline for remediation is as follows.

- March 2017 – SCE submitted lease amendment application to the State Lands Commission (SLC), begins underwater habitat surveys
- August 2017 (*est*.) - RFP for reef construction
- December 2017 (*est*.) - SLC reviews and acts on lease amendment application and appropriate California Environmental Quality Act (CEQA) action
- Spring 2018 (*est*.) - CCC, US Army Corps of Engineers, Regional Water Quality Board and other permits
- Summer 2018 (*est*.) - Begin reef construction

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