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

SAN ONOFRE NUCLEAR GENERATING STATION (SONGS) MITIGATION PROGRAM

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

SAN ONOFRE NUCLEAR GENERATING STATION (SONGS) MITIGATION PROGRAM

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2.0 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 28 tons of reef fish and 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 Wheeler North Reef) was constructed in phases: an initial small-scale experimental phase used to test different reef designs (Phase 1) and a larger mitigation phase used to meet the mitigation requirement of creating at least 150 acres of kelp forest habitat (Phase 2). Construction of the mitigation phase was completed in 2008 and monitoring of the physical and biological attributes of Wheeler North Reef and two nearby reference reefs (San Mateo and Barn kelp beds) has been completed each year beginning in 2009. Results of monitoring and additional studies showed that the combined 175-acre configuration of the Phase 1 and 2 reefs was too small for Wheeler North Reef to consistently meet the performance standards pertaining to fish standing stock and area of adult giant kelp. Consequently, the CCC required SCE to remediate this deficiency by expanding the existing Phase 1 and 2 Wheeler North Reef to include additional acreage. Construction of a 198-acre Phase 3 remediation reef occurred during the summers of 2019 and 2020.

Performance standards for reef substrate, giant kelp, fish, and the benthic community of algae and invertebrates are used to evaluate the success of Wheeler North Reef in meeting the intended goal of replacing the kelp forest resources damaged or lost by SONGS operations. Absolute performance standards are evaluated only at Wheeler North Reef, whereas relative performance standards are used to compare Wheeler North Reef with two natural reference reefs (San Mateo and Barn) in the region. Annual monitoring is done to determine whether Wheeler North Reef has met these standards. The monitoring is overseen by the California Coastal Commission (CCC) and conducted independently of SCE. This report summarizes the monitoring results and the amount of mitigation credit earned through 2021.

Mitigation credit for meeting the relative performance standards and the absolute performance standards pertaining to hard substrate and undesirable and invasive species is assigned on an annual basis. The fulfillment of these mitigation requirements is achieved when the number of years of mitigation credit equals the number of years of SONGS Units 2 and 3 operations (= 32 years). The accrual of mitigation credit for these performance standards began in 2019 upon construction of the Phase 3 remediation reef. In 2021 Wheeler North Reef met the absolute performance standards pertaining to hard substrate and invasive species and nine of the 11 relative performance standards, which was one less than the number of relative standards met by Barn and two more than met by San Mateo. Therefore, Wheeler North Reef was deemed to be performing similar to natural reefs because it met the absolute standards for hard substrate and invasive species and at least as many relative standards as the lower performing reference reef (i.e., San Mateo).

Consequently, Wheeler North Reef earned one year of mitigation credit in 2021 for meeting this collective group of performance standards for a cumulative total of three years of mitigation credit. It needs an additional 29 years of mitigation credit to fulfill its mitigation requirement for these performance standards.

Mitigation credit for the absolute performance standards pertaining to the area of adult giant kelp and the standing stock of reef fish is assigned on a cumulative basis in which the amount of kelp area and fish standing stock supported by Wheeler North Reef in any given year is added to the cumulative total of previous years. Fulfillment for each of these two performance standards will occur\s when the cumulative total for each equals the annual designed target of kelp acres or fish standing stock x the 32 years of SONGS Units 2 and 3 operations. The accumulation of mitigation credit for these two performance standards also began in 2019. In 2021 Wheeler North Reef earned credit for 47 acres of giant kelp for a cumulative total of 84 acres, and 28 tons of reef fish for a cumulative total of 68 tons. It needs an additional 4716 acres of kelp credit and 828 tons of fish standing stock credit to fulfill these two mitigation requirements.

In sum, the monitoring results to date show that Wheeler North Reef has demonstrated considerable promise in meeting many of its objectives. Importantly, it has shown no decline in the area of hard substrate available to reef biota or loss of important reef functions due to invasive or undesirable species, and it has been shown to perform similarly to natural reference reefs across a broad suite of criteria, including kelp area and reef fish standing stock. Moreover, monitoring data indicated that the recently constructed Phase 3 remediation reef has already begun to add substantial mitigation value as it accounted for 27% of the acreage of giant kelp and 25% of the fish standing stock of Wheeler North Reef in 2021.

Additional information on the rationale, objectives and results of SONGS marine mitigation monitoring, including relevant documents and data can be found at the UCSB SONGS Mitigation Monitoring Program website https://marinemitigation.msi.ucsb.edu/.

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 (California Coastal Commission 1997), 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 supports 28 tons of reef fish and 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 independent monitoring of the performance of the SONGS artificial reef (hereafter referred to as Wheeler North Reef) from 2009 – 2021 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 until completion.

The SONGS Unit 2 and 3 reactors are cooled by a single pass seawater system and have separate intake lines, each 18 feet in diameter, that are located in about 30 feet of water offshore of the power plant. The volume of water taken in each day by these two intake lines when Units 2 and 3 were fully operational was about 2.4 billion gallons, equivalent to a square mile 12 feet deep. Since the shutdown, the flow in each unit has been reduced to about 42 million gallons a day or roughly 2% 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 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 due 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 giant kelp forest (defined as > 4 kelp plants per 100 m^2 with 8 or more fronds) 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 forest and its 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 (~25 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 consists of Drs. Kathryn Beheshti, Mark Page, Dan Reed and Steve Schroeter who are research ecologists at the Marine Science Institute, University of California Santa Barbara (UCSB). 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 emeritus, 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 UCSB to collect and assemble the monitoring data. The technical oversight team is also assisted by independent consultants and contractors on an as needed basis when expertise for specific tasks is required. Of particular note in this regard are Drs. Mark Steele and Mia Adreani of California State University Northridge who have contributed to studies of fish growth and reproduction since 2009. 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 phases: a short-term, small-scale experimental phase for testing different reef designs (Phase 1), followed by a longer-term, larger-scale mitigation phase that is intended to compensate for the kelp forest resources lost due to SONGS' operations (Phase 2). An additional remediation phase (Phase 3) was constructed in 2019 and 2020 after it was determined that the combined area of the Phase 1 and 2 reefs was insufficient to fully compensate for the lost resources. The information gained from the Phase 1 experimental reef was used to design the larger Phase 2 mitigation reef. The design of the Phase 3 remediation reef mirrored that of the Phase 2 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. In March 2019 the CCC concluded that it is unlikely that the greatly reduced flow following the cessation of SONGS operations in 2013 would continue to cause significant adverse impacts to the kelp bed community off San Onofre and thus defined the operating life of SONGS as the beginning of 1982 to the end of 2013 (= 32 years).

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 to ensure that the compensation for the lost resources occurs locally rather than at a distant location far from the impacts, and (2) the artificial reef is configured to mimic the impacted 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 (42 to 52 feet) depth approximately 1 km (0.6 miles) offshore of the city of San Clemente, CA, USA (Figure 3.1.1). 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 (25 acres) of the sea floor when initially constructed.

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

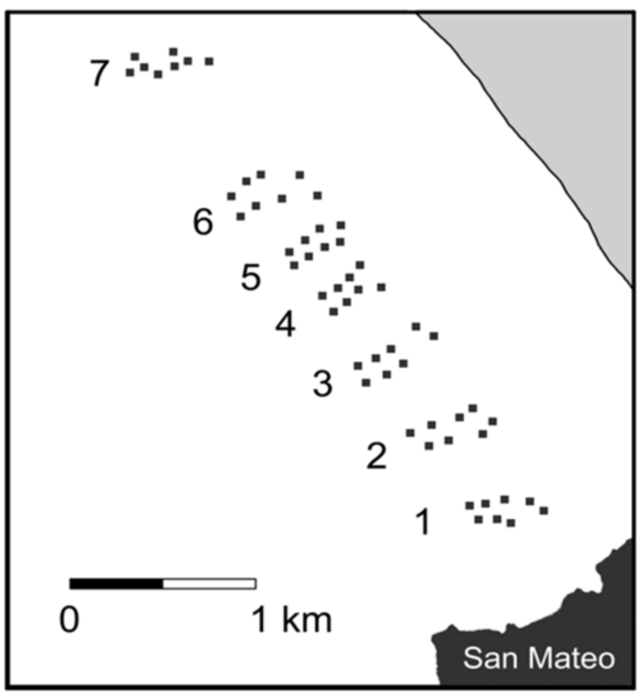


Figure 3.1.2. Design of the Phase 1 Experimental Reef. The black squares represent the 56 modules. Numbers indicate the seven locations.

The modules at each location were built from either 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, shape and specific gravity; the heavier quarry rock was boulder-like in appearance, while the less dense 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 of the experimental phase were completed in December 2004. Results from the monitoring were quite promising in that all of the 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 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 needed to 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, a renowned kelp forest ecologist. Construction of the Phase 2 reef was completed in 94 days on September 11, 2008 (Coastal Environments 2008). Approximately 126,000 tons of boulder-sized quarry material was deposited in 18 polygons that collectively covered 150 acres of sea floor as determined from a bathymetric survey using multibeam sonar (Figure 3.2.1).

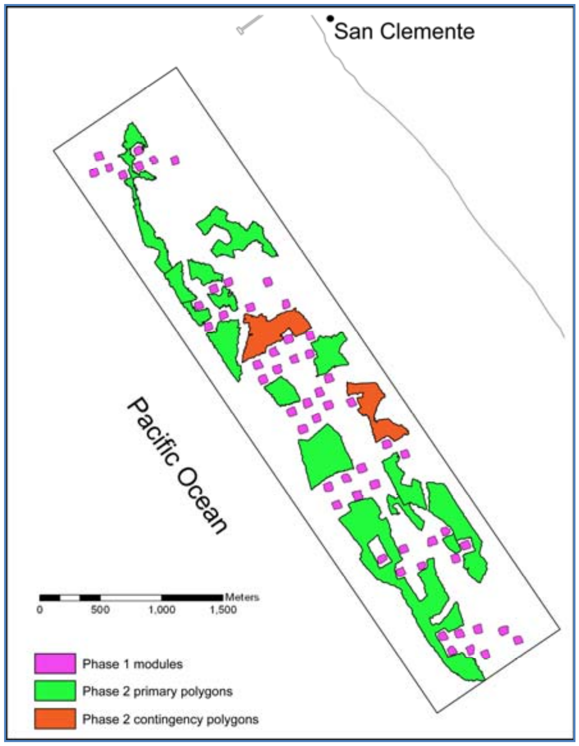


Figure 3.2.1. The 175-acre Wheeler North Artificial Reef, which includes the Phase 1 modules and the Phase 2 primary and contingency polygons.

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 175 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 (CDP 6-81-330-A). 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 25 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 remaining two polygons were classified as contingency polygons (Figure 3.2.1.; See Section 4.4).

3.3 Remediation Phase

The SONGS Coastal Development Permit requires that independent studies be conducted to develop recommendations for appropriate remedial measures in the event that Wheeler North Reef fails to meet its mitigation requirements. These studies determined that the 175-acre configuration of Wheeler North Reef (Phase 1 + Phase 2) was too small to meet the mitigation requirement for fish standing stock (Reed et al. 2015). Based on these results, the Executive Director of the CCC notified SCE in May 2016 that that remediation of Wheeler North Reef was necessary for it to meet the conditions of the SONGS permit. On March 7, 2019 following extensive consultation and environmental review, the CCC approved a coastal development permit for the expansion of Wheeler North Reef to bring it into compliance with the performance standards required by the SONGS permit (California Coastal Commission 2019). The approved remediation plan included the construction of up to 210 acres of low-relief, low coverage (~41%) reef in state waters offshore of the City of San Clemente (Coastal Environments 2017). Construction of a 198-acre remediation reef occurred during the summers of 2019 and 2020 and consisted of approximately 151,000 tons of quarried rock covering an average of 45% of the bottom in 20 irregular shaped polygons located at depths of 28 – 49 feet (8.5 -15 m) north and inshore of the existing Wheeler North Reef (Figure 3.3.1). Construction of the Phase 3 reef occurred during the summers of 2019 and 2020 and upon its completion increased the total footprint area of Wheeler North Reef to 373 acres.

Figure 3.3.1. Map showing the locations of the polygons of the three phases of Wheeler North Artificial Reef. Phase 1 was constructed in 1999, Phase 2 in 2008 and Phase 3 in 2019 and 2020.

4.0 Methods of Project Evaluation

This section briefly describes the general approach used to evaluate the success of 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. 2021).

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 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 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 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.

Absolute performance standards

Prior to the construction of the Phase 3 remediation reef the evaluation of each absolute performance standard in any given year was based on the greater value obtained from either: (1) data collected at Wheeler North Reef that year, or (2) a four-year running average calculated from data collected at 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 had to be met in a given year in order for that year to receive mitigation credit.

The manner in which mitigation credit is assigned for the absolute performance standards pertaining to fish standing stock and giant kelp area was changed by the CCC in March 2019 when it approved SCE's plans to construct the Phase 3 remediation reef (California Coastal Commission 2019). The size of the Phase 3 reef was based on calculations of the additional area of reef needed for the expanded Wheeler North Reef (Phases 1, 2, and 3) to eventually sustain a fish standing stock of 28 tons and 150 acres of medium-to-high density giant kelp with 95 % confidence. The expectation is that it would take some unknown period of time for the stock of fish and kelp to build up to the required levels during which SCE would receive no mitigation credit. To address the uncertainty in this timeline for receiving mitigation credit, the CCC changed the assignment of mitigation credit for the fish standing stock and kelp area performance standards from an all or nothing annual assessment to a cumulative approach that assigned mitigation credit for the biomass of fish and area of kelp supported by the expanded Wheeler North Reef in any given year. Using this approach fish biomass and kelp area would be measured each year and the annual total for that year would be added to the cumulative total of previous years. Fulfillment of the mitigation requirement for the fish standing stock will occur when the total accrued tons of fish equals the annual design target of 28 tons x the 32 years of operation of SONGS Units 2 & 3 (= 896 tons of reef fish). Similarly, the mitigation requirement for area of giant kelp will be fulfilled when the total area of accrued giant kelp equals the annual design target of 150 acres x the 32 years that SONGS Units 2 and 3 were operating (= 4800 acres of giant kelp). The CCC determined that the implementation of this cumulative approach to assigning mitigation credit was to begin in 2019 upon the installation of the expanded Phase 3 remediation reef. The manner in which mitigation credit is assigned for the other two absolute performance standards (i.e., hard substrate availability and invasive and undesirable species) was not changed and both of these standards must be met in a given year for that year to receive mitigation credit.

Relative performance standards

The evaluation of each relative performance standard is based solely on a four-year running average calculated from data collected at Wheeler North Reef and the two reference reefs for that year and the previous three years. Only data collected from the Phase 1 modules and the Phase 2 primary polygons are used to evaluate whether Wheeler North Reef meets the relative performance standards. This is because: (1) the combination of the Phase 1 modules and the Phase 2 primary polygons fulfills SCE's permit requirement to construct a minimum of 150 acres of reef with an average of at least 42% cover of rock, (2) this configuration is sufficient for determining whether Wheeler North Reef is performing similarly to natural reefs in the region, and (3) the sole regulatory requirement for constructing the Phase 3 reef was to increase the aggregate fish standing stock and giant kelp acreage of Wheeler North Reef.

An either / or criterion (i.e., using data from either a single year or a 4-year running average) was deemed inappropriate 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 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. Thus, to avoid requiring Wheeler North Reef to perform better than the reference reefs, 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 receive mitigation credit and thus 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 the 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 increase the odds of this occurring 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 are more likely to support similar biota that 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 adults at medium-to-high densities (i.e., > 4 plants per 100 m^{-2}). The criterion that the reference reefs have a history of supporting giant kelp is important because communities on reefs without giant kelp can differ dramatically from those with kelp. Based on these criteria, the San Mateo kelp bed (located adjacent to the southern end of Wheeler North Reef) and the Barn kelp bed (located approximately 12 km south of San Mateo kelp bed) were chosen as reference reefs for evaluating the performance of Wheeler North Reef (Figure 4.2.1).

Figure 4.2.1. Map showing the locations of Wheeler North Artificial Reef and the two natural reefs San Mateo and Barn that are used as reference sites.

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 similarly in the performance criteria at the reference reefs, 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 as many of the response variables used to assess the relative performance standards of Wheeler North Reef (hereafter referred to as "relative performance variables") be "similar" to those at nearby natural reference reefs. Evaluating whether the performance of Wheeler North Reef is similar to that at the San Mateo and Barn reference reefs requires that the mean (or in some cases the median) four-year running average for a given relative performance variable at Wheeler North Reef not be significantly lower than the mean (or median) four-year average of the lower performing of the two reference reefs. Thus, we use a one sample, one tailed approach for all comparisons. Statistical significance is determined using a method that utilizes both a formal probability value (i.e. p-value) and a proportional effect size of the four-year averages. 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, which are based on data collected from varying numbers and sizes of different species of fish rather than data collected from 82 replicate transects. For these two standards a resampling procedure is used to calculate the p-value for determining statistical significance.

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 Wheeler North Reef and the lowest performing reference reef (see Reed et al. 2021 for details). 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 Wheeler North Reef is similar to the reference reefs when it is not).

To ensure that 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 Wheeler North Reef and Barn (or San Mateo) as the two reference reefs. Wheeler North Reef is considered similar to the reference reefs if the number of relative standards met by 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 (1) recognizes that species of different groups of organisms naturally interact and that these interactions can affect whether a performance standard is met, and (2) 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

151 sampling locations, each defined by a fixed 50 m x 20 m area, were established at Wheeler North Reef; 12 transects are in Phase 1, 70 in the primary polygons of Phase 2, 10 in the contingency polygons of Phase 2, and 59 in Phase 3 (Figure 4.4.1). An additional 82 transects were established at both San Mateo and Barn in areas with a history of frequently supporting giant kelp.

Transects on each reef are arranged in pairs with the two transects in each pair spaced 25 m apart. The exceptions to this are transects located on Phase 1 and Phase 3 reefs, which are not paired. 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.

Figure 4.4.1. Schematic map of Wheeler North Reef showing the location of the transects (shown as black lines) that are monitored to assess the performance standards.

Sampling of 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 50 m transect and a compass heading along which divers lay out a 50 m measuring tape. A 20 m wide swath centered along the 50 m transect defines the sample area at each sampling location. Different sized sampling units (e.g., 0.5 m^2, 1 m^2, 20 m^2, and 150 m^2) within this sampling area are used to evaluate different performance variables (Figure 4.4.2).

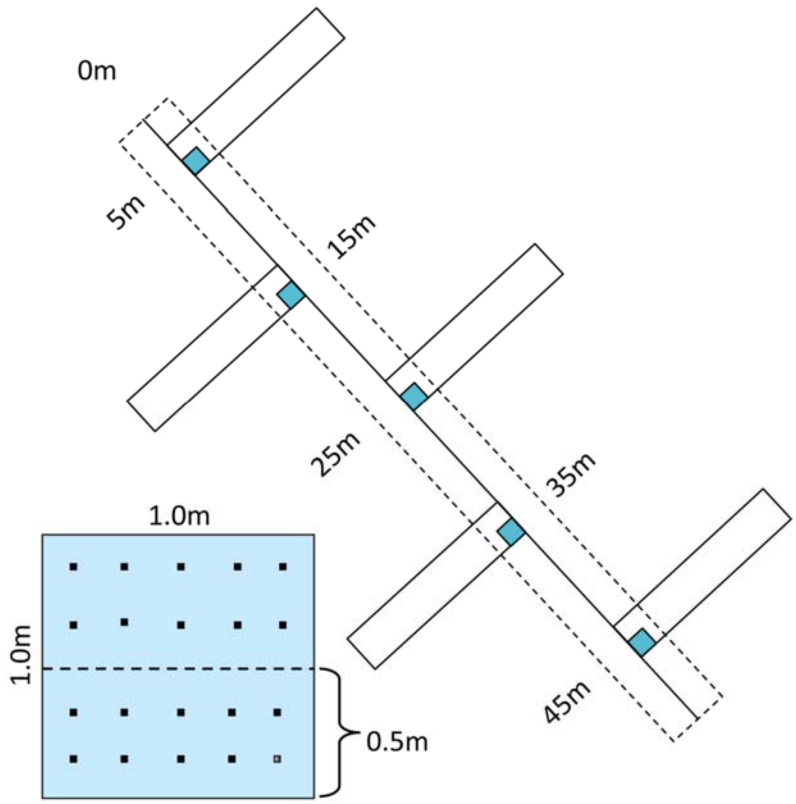


Figure 4.4.2. Schematic diagram of a sampling station. Fish are sampled in 50 m x 3 m band transects that extend 1.5m off the bottom (outlined with a dotted line). Adult giant kelp > 1 m tall, large solitary understory algae, and large mobile invertebrates are counted in the five 10 m x 2 m rectangular 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 1 m x 1m quadrats (shown in blue). Smaller mobile invertebrates and small cryptic fish are counted either in 1 m x 1 m or 1 m x 0.5 m quadrats depending on their size and abundance.

University sponsored research was shut down from mid-March to mid-July 2020 in response to the COVID-19 pandemic, which delayed the start of the 2020 performance monitoring by two months. New health and safety protocols were established by UCSB in July 2020 that allowed research to resume in a limited capacity, which effectively reduced the amount of sampling that could be completed in 2020. As a result, the number of sampling stations at Wheeler North Reef, San Mateo and Barn that were used to evaluate the relative performance standards and the absolute standards for hard substrate and undesirable and invasive species was reduced from 82 to 15 The exception to this were the relative performance standards pertaining to fish reproduction and food chain support which are evaluated using fish collections rather than transect sampling.

The reduction in sample size in 2020 required that the calculation of the 4-year running average in 2020 be based on n = 15 for all four years using only the 15 transects sampled in 2020. Doing so increased the level of uncertainty in assessing these performance standards in 2020. To limit this increased uncertainty in subsequent years the 2020 data were excluded from the calculation of a running average and instead the running average for 2021 was based on three years with n = 82 transects for each year. Similarly, the running average for 2022 and 2023 will exclude 2020 data.

5.0 Trends in the Physical and Biological Structure of Wheeler North Reef

This section provides a brief summary of temporal patterns of change in the physical and biological attributes of Wheeler North Reef from 2009 – 2021, which represents the 13-year period following the construction of the 150-acre Phase 2 mitigation reef and the 2-year period following the construction of the Phase 3 remediation 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 Wheeler North Reef will function over the long term. The mean percent cover of exposed rock on the Wheeler North Reef Phase 1 modules and Phase 2 polygons has been relatively constant since 2009 averaging 57% on the Phase 1 modules and 44% on the Phase 2 polygons (Figure 5.1.1a). As intended, the coverage of exposed rock in the Phase 3 polygons following their construction in 2019 and 2020 was similar to that of Phase 2 averaging 45% (rock coverage in Phase 3 was not surveyed in 2021 as it is not a component of the annual monitoring). The higher average rock coverage of Phase 1 was by design as it reflects the large range in rock coverage (~ 25 to 85%) among the experimental modules tested during this phase of the project (Figure 5.1.1b). The lower average rock coverage of the larger Phase 2 polygons was spatially variable due to adjustments in the amount of rock deployed during construction that were made to meet the targeted design of at least 42%. (Figure 5.1.1b).

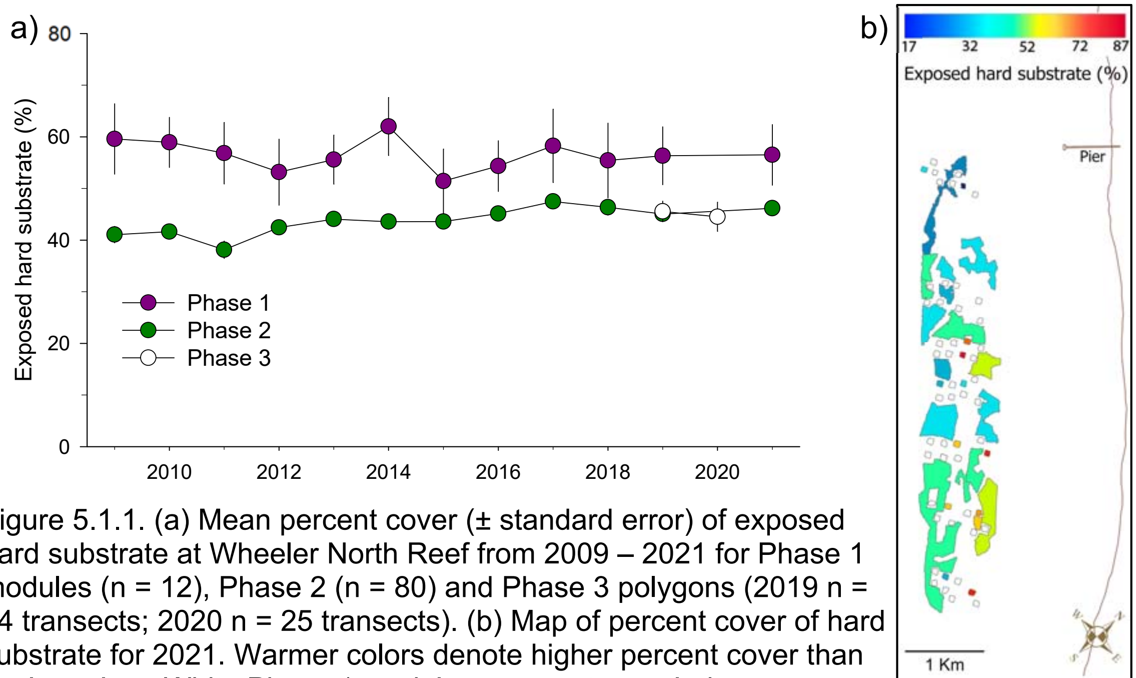


Figure 5.1.1. (a) Mean percent cover (± standard error) of exposed hard substrate at Wheeler North Reef from 2009 – 2021 for Phase 1 modules (n = 12), Phase 2 (n = 80) and Phase 3 polygons (2019 n = 34 transects; 2020 n = 25 transects). (b) Map of percent cover of hard substrate for 2021. Warmer colors denote higher percent cover than cooler colors. White Phase 1 modules were not sampled.

Not surprisingly, the hard substrate at Wheeler North Reef consists mostly of boulder, which is what was intentionally produced at the quarries that supplied the rock for the construction of the reef (Figure 5.1.2). 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 Wheeler North Reef. Soft substrates, consisting primarily of sand and a smaller amount of shell hash, cover approximately 40% of the bottom of the Phase 1 modules and 50% of the bottom of the Phase 2 polygons of Wheeler North Reef. The relative amounts of the different bottom substrates on the Phase 1 and 2 reefs have changed little since 2009.

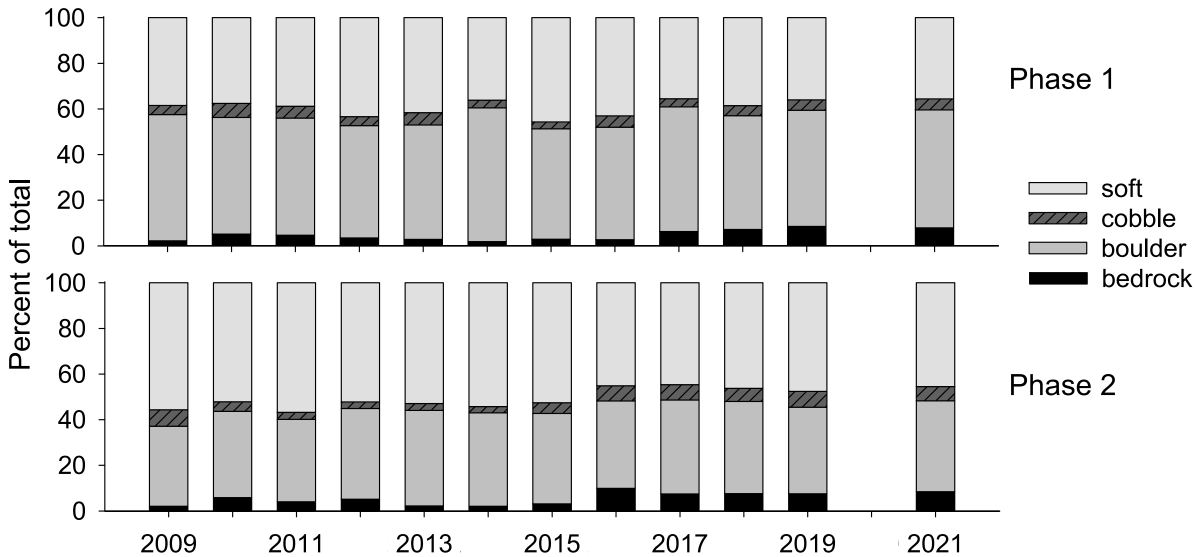


Figure 5.1.2. Distribution of substrate types on Wheeler North Reef Phase 1 modules (top) and Phase 2 polygons (bottom) from 2009 – 2021. 2020 data was excluded due to reduced sampling imposed by COVID-19 restrictions.

5.2 Biological Characteristics

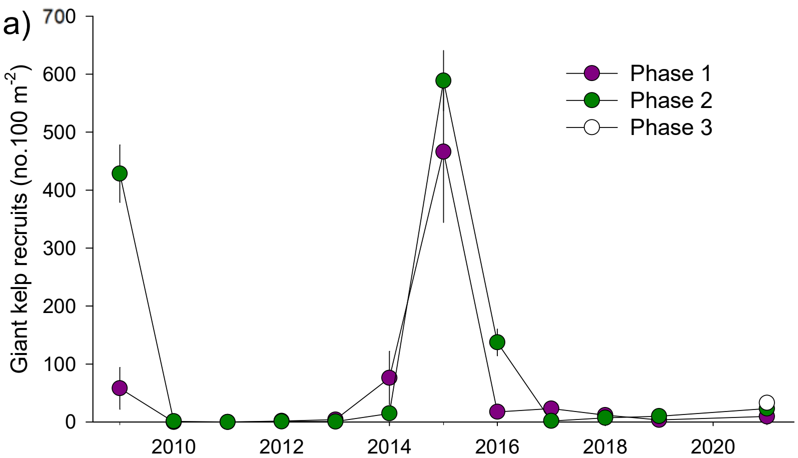
Giant kelp

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 its structural and functional attributes determine the abundance, diversity and stability of the kelp forest community, and modulate critical ecosystem processes (Miller et al. 2018, Castorani et al. 2018, 2021, Lamy et al. 2020). A primary goal in designing Wheeler North Reef was to make it suitable for the establishment, growth, and persistence of giant kelp.

Results from the Phase 1 reef indicated that giant kelp would readily colonize the newly constructed Phase 2 reef and that transplanting kelp would not be needed to ensure its establishment on Wheeler North Reef (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 (i.e. individuals < 1 m tall) at Wheeler North Reef had been near zero since the initial colonization event of 2009 until 2014 when low densities 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 early development of the Phase 1 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. High numbers of kelp recruits were once again observed at Wheeler North Reef in 2015, with mean densities in the Phase 2 polygons averaging 50% higher than in 2009 (Figure 5.2.1a). Densities of giant kelp recruits declined sharply in 2016 and were near zero from 2017 – 2019. The abundance of giant kelp recruits increased on Wheeler North Reef in 2021 to an average of 9, 23 and 33 individuals per 100 m^2 in the Phase 1, 2 and 3 reefs, respectively.

The density of giant kelp recruits varied widely across Wheeler North Reef in 2021 ranging from an average of zero per 100 m^2 in some modules and polygons to as many as 260 per 100 m^2 in others (Figure 5.2.1b). There was little spatial pattern to the distribution of giant kelp recruits in 2021 other than the southern and northern most polygons tended to have lower densities compared to more centrally located polygons.

a)



b)

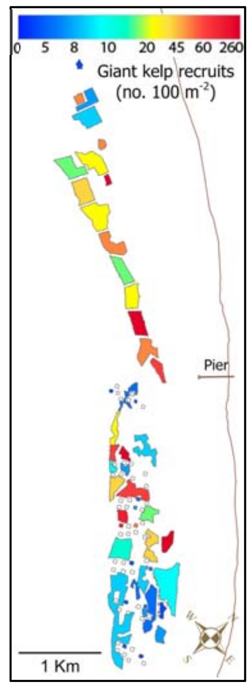
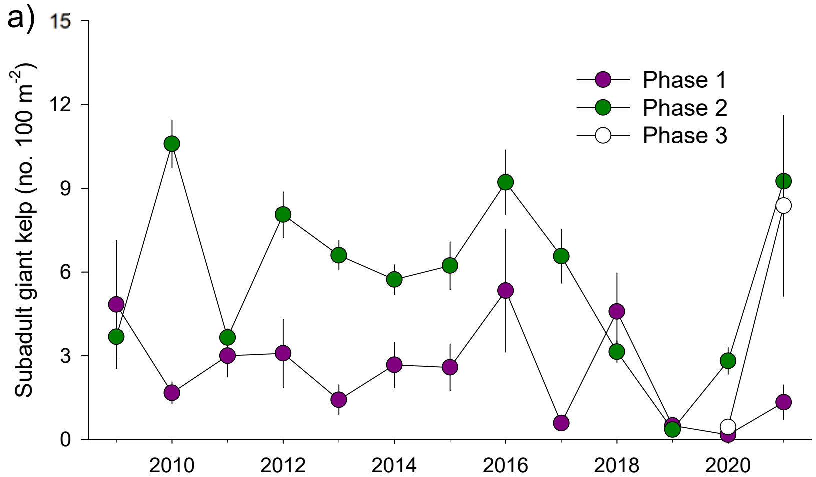


Figure 5.2.1. (a) Mean density (±1 standard error) of newly recruited giant kelp plants (*Macrocystis pyrifera*) at Wheeler North Reef Phase 1 modules, Phase 2 and Phase 3 polygons from 2009 – 2021. (b) Map of newly recruited giant kelp density (no. 100 m^{-2}) in 2021. Warmer colors denote higher abundance than cooler colors. White Phase 1 modules were not sampled. Sampling of recruits did not occur in 2020 due to reduced monitoring.

The density of subadult kelp (i.e., individuals with less than 8 fronds > 1 m tall) typically reflects the growth and survival of kelp recruits in the previous or current year. For example, the density of subadult kelp in the Phase 2 polygons increased substantially in 2010 and 2021 in response to pulses in recruitment (in 2009 and 2021), as did the density of subadults in the newly constructed Phase 3 polygons in 2021 (Figure 5.2.2). Increases in the abundance of subadults can also result from unfavorable conditions for growth of adult kelp that limits their ability to sustain 8 or more fronds (i.e., adults become subadults). Such was the case for the Phase 1 modules in 2018 when an increase in the density of subadult kelp coincided with a decrease in the density of adult kelp (Figures 5.2.2a vs. 5.2.3a) during a sustained period of minimal recruitment (Figure 5.2.1a). By contrast, subadult densities decreased dramatically in the Phase 2 polygons from 2016-2019 (Figure 5.2.2a) following a sustained decline in the density of both recruit and adult kelp suggesting poor conditions for the growth and survival of all life stages (Figures 5.2.1a and 5.2.3a). Much like the density of kelp recruits, the density of subadults varied sporadically among the modules and polygons of the Phase 1, 2 and 3 reefs in 2021 (Figure 5.2.2b).



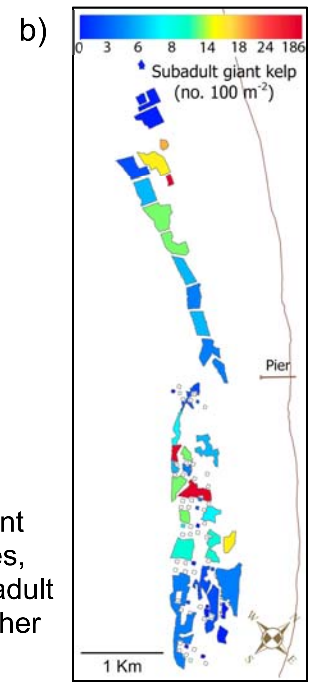
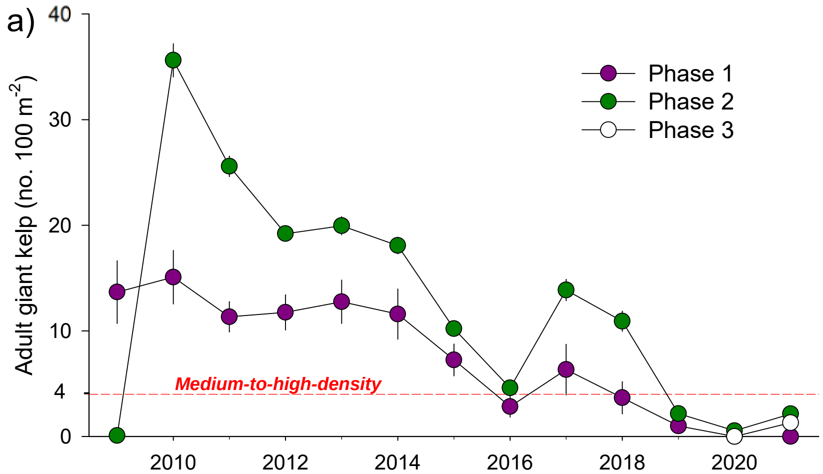


Figure 5.2.2. (a) Mean density (±1 standard error) of subadult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef Phase 1 modules, Phase 2 and Phase 3 polygons from 2009 – 2021. (b) Map of subadult giant kelp density (no. 100 m^{-2}) in 2021. Warmer colors denote higher abundance than cooler colors. White Phase 1 modules were not sampled.

The growth and survivorship of recruit and subadult kelp in turn influences the density and spatial distribution of adult kelp (i.e., individuals with 8 or more fronds > 1 m tall). For example, the large kelp recruitment event in the Phase 2 polygons in 2009 led to a large cohort of adult kelp in 2010 that averaged 36 plants per 100 m^2, which was nearly three-fold higher than the density of adults on the Phase 1 modules (Figure 5.2.3a). In the near absence of recruitment adult densities gradually declined over time and by 2016 had thinned to approximately 3 and 4 individuals per 100 m^2 on the Phase 1 and 2 reefs, respectively (Figure 5.2.3a). The large recruitment event in 2015 and corresponding increase in subadults in 2016 on the Phase 1 and 2 reefs caused adult densities in 2017 to increase to 6 and 14 individuals per 100 m^2, respectively. This moderate spike in the abundance of giant kelp adults, however, was short lived as adult densities in 2020 declined to their lowest levels since 2009 in the absence of appreciable recruitment. Modest increases in adult density were observed in the Phase 2 and 3 polygons in 2021 (Figure 5.2.3a), and could increase substantially in 2022 depending of the survival and growth of the 2021 cohorts of recruit and subadult kelp (Figures. 5.2.1a and 5.2.2a). Spatial patterns of adult kelp abundance closely resembled those of subadult kelp abundance as polygons with the high densities of subadults also had the highest densities of adults (Figures 5.2.2b vs. 5.2.3b).



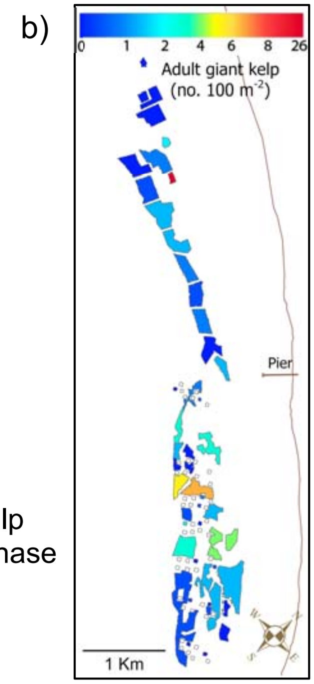
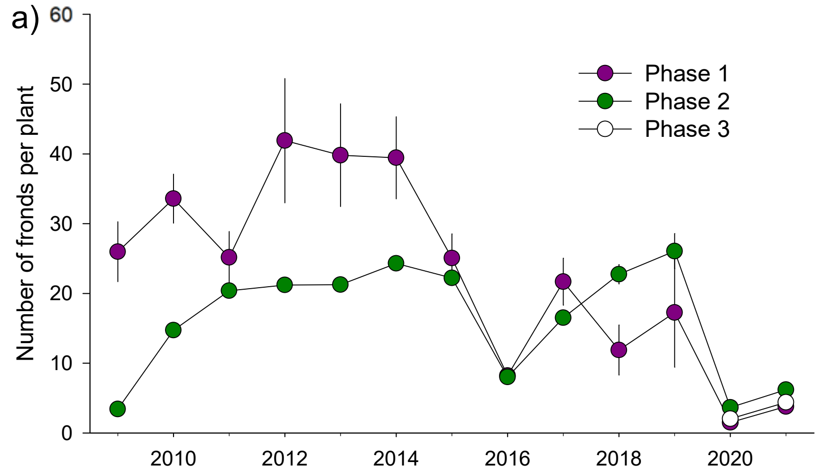


Figure 5.2.3. (a) Mean density (±1 standard error) of adult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef Phase 1 modules, Phase 2 and Phase 3 polygons from 2009 – 2021. (b) Map of adult kelp density (no. 100 m^{-2}) in 2021. Warmer colors denote higher abundance than cooler colors. White Phase 1 modules were not sampled.

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 on a plant that are > 1 m tall is a good predictor of plant size as measured in units of mass (Rassweiler et al. 2018). As expected, the average number of fronds per plant increased dramatically in the Phase 2 polygons between 2009 and 2010 as small recruits grew into subadult and adult kelp (Figure 5.2.4a). By 2012, giant kelp > 1 m tall (i.e. subadult + adult kelp combined) averaged 21 fronds per plant in the Phase 2 polygons compared to 41 fronds per plant on the older Phase 1 modules. Plant size remained relatively steady on the Phase 1 and 2 reefs before declining precipitously to 8 fronds per plant in 2016 (Figure 5.2.4a). The relatively low numbers of fronds per plant observed in 2016 was indicative of the poor growing conditions associated with unusually high ocean temperatures throughout the region (Cavanaugh et al. 2019). Cooler conditions prevailed in 2017, and by 2019 average plant size on the Phase 1 and 2 reefs increased to 18 and 26 fronds per plant, respectively. The average number of fronds per plant dropped precipitously in 2020 to < 4 across most of Wheeler North Reef, with a few notable exceptions where average plant size remained as high as 18 fronds per plant (Figure 5.2.4b). The low number of fronds per plant observed on Phases 1 and 2 at this time reflected the senescence of older large individuals rather than the emergence of small recruits as most plants had relatively large holdfasts.



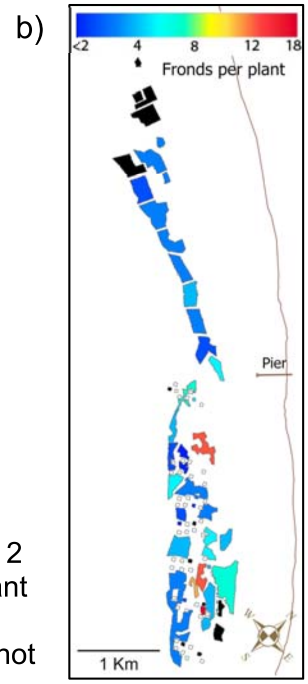


Figure 5.2.4. (a) Mean number (± 1 standard error) of fronds per *Macrocystis* plant at Wheeler North Reef Phase 1 modules, Phase 2 and Phase 3 polygons from 2009 – 2021. (b) Map of fronds per plant in 2021. Warmer colors denote higher densities than cooler colors. Black indicates no plants observed. White Phase 1 modules were not sampled.

Because giant kelp plants can differ greatly in size from small recruits to large adults, the density of fronds per unit area 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 dramatically on the Phase 2 reef to nearly 7 fronds per m^2 by 2010 (two years following construction), which was slightly higher than that on the older Phase 1 modules (Figure 5.2.5a). Frond density remained relatively high on both phases of Wheeler North Reef through 2014 before progressively declining to < 1 m^{-2} in 2016 following a two-year period of anomalous ocean warming (Cavanaugh et al. 2019). This low density of fronds reflected declines in both the density and size of subadult and adult plants (Figures 5.2.2, 5.2.3 and 5.2.4). The increase in the density and size of adult kelp observed in 2017 and 2018 (Figures 5.2.3 and 5.2.4) accounted for the corresponding increases in frond density on the Phase 1 and 2 reefs (Figure 5.2.5a), however, this increase was short lived and frond density in 2020 declined to < 0.1 m^{-2}, its lowest level observed since 2009. The modest increases in subadult densities on the Phase 2 and 3 reefs in 2021 (Figure 5.2.2a) produced a noticeable, albeit small, increase in frond density in 2021 (Figure 5.2.5).

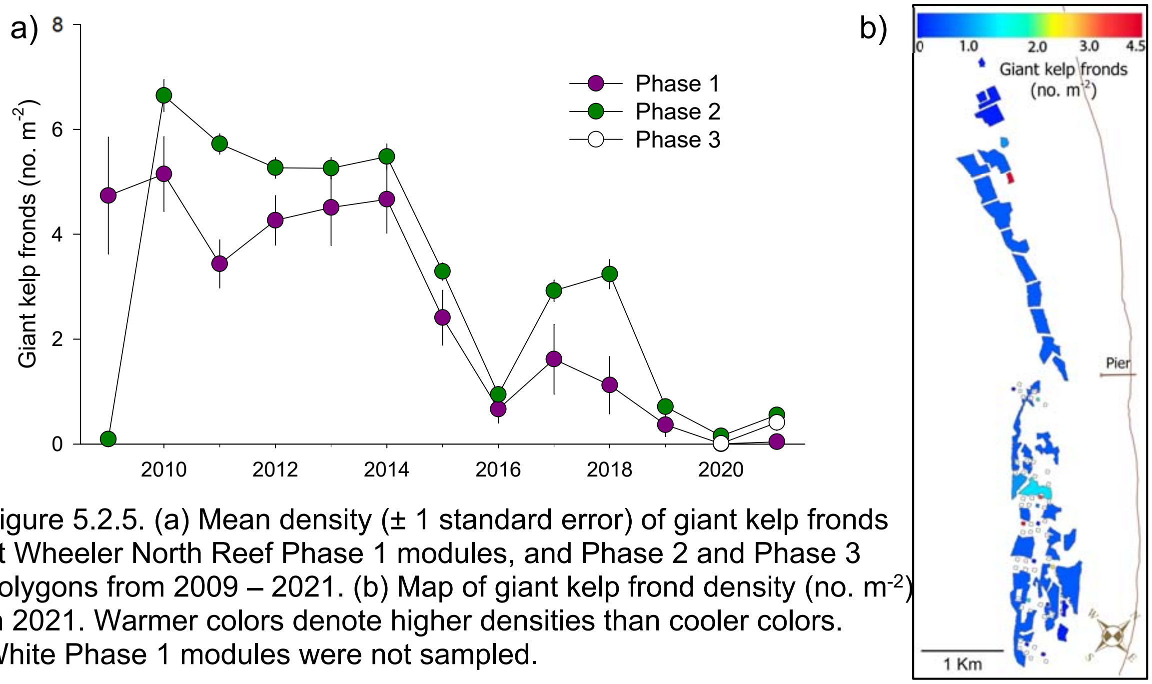


Figure 5.2.5. (a) Mean density (± 1 standard error) of giant kelp fronds at Wheeler North Reef Phase 1 modules, and Phase 2 and Phase 3 polygons from 2009 – 2021. (b) Map of giant kelp frond density (no. m^{-2}) in 2021. Warmer colors denote higher densities than cooler colors. White Phase 1 modules were not sampled.

Fish

Much like giant kelp, the abundance of fishes living near the bottom at Wheeler North Reef has fluctuated greatly during the 13 years of monitoring. Reef fish rapidly colonized the Phase 2 Wheeler North Reef with total densities of all species combined averaging about 70 individuals per 100 m^2 in the first year following construction (2009), which was slightly higher than that of the older Phase 1 modules (Figure 5.2.6a). Reef fish densities declined precipitously on both phases of Wheeler North Reef in 2010. Following this decline, fish densities increased steadily on the Phase 1 reef to an average of 91 individuals per 100 m^2 in 2015, which is the highest value recorded in the time series (Figure 5.2.6a). A more moderate increase during this time occurred on the Phase 2 reef where average fish densities peaked at 43 individuals per 100 m^2. Another abrupt decline in the abundance of fish on the Phase 1 and 2 reefs occurred in 2016 and densities on both reefs have remained relatively low (~ 10 -20 individuals per 100 m^2) since then (Figure 5.2.6a). Densities of fish on the newly constructed Phase 3 reef in 2020 and 2021 were slightly less than that of the older Phase 1 and 2 reefs. Fish density in 2021 tended to be highest in the offshore polygons of Phase 2 with the up-coast polygons generally showing higher densities than the down-coast polygons (Figure 5.2.7a).

The sharp decline in reef fish abundance at Wheeler North Reef in 2016 can be attributed to decreases in the abundance of the blackeye goby (Figure 5.2.6b), a small, short-lived (~ 2 years), cool-water species that lives on the bottom and feeds on small crustaceans. The density of this species, which had consistently been the most numerically abundant species at Wheeler North Reef through 2015, declined dramatically in 2016 and remained regionally uncommon until 2021 when a small cohort of recruits appeared in the central portion of Wheeler North Reef (Figure 5.2.7b).

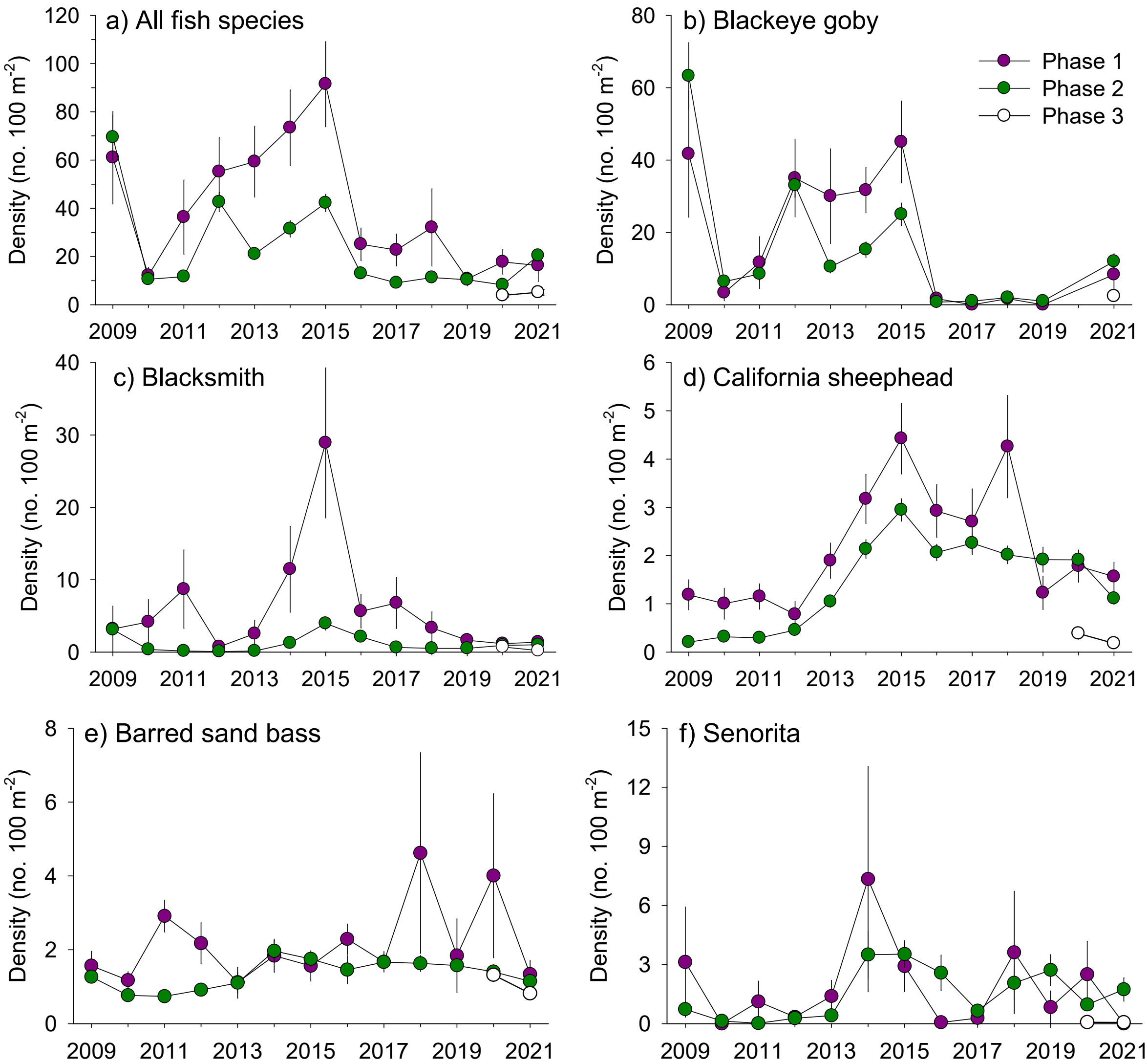


Figure 5.2.6. Mean densities (± 1 standard error) of (a) All species of reef fish, (b) Blackeye goby, (c) Blacksmith, (d) California sheephead (e) Barred sand bass and (f) Senorita at Wheeler North Reef Phase 1 modules, Phase 2 and Phase 3 polygons from 2009 – 2021.

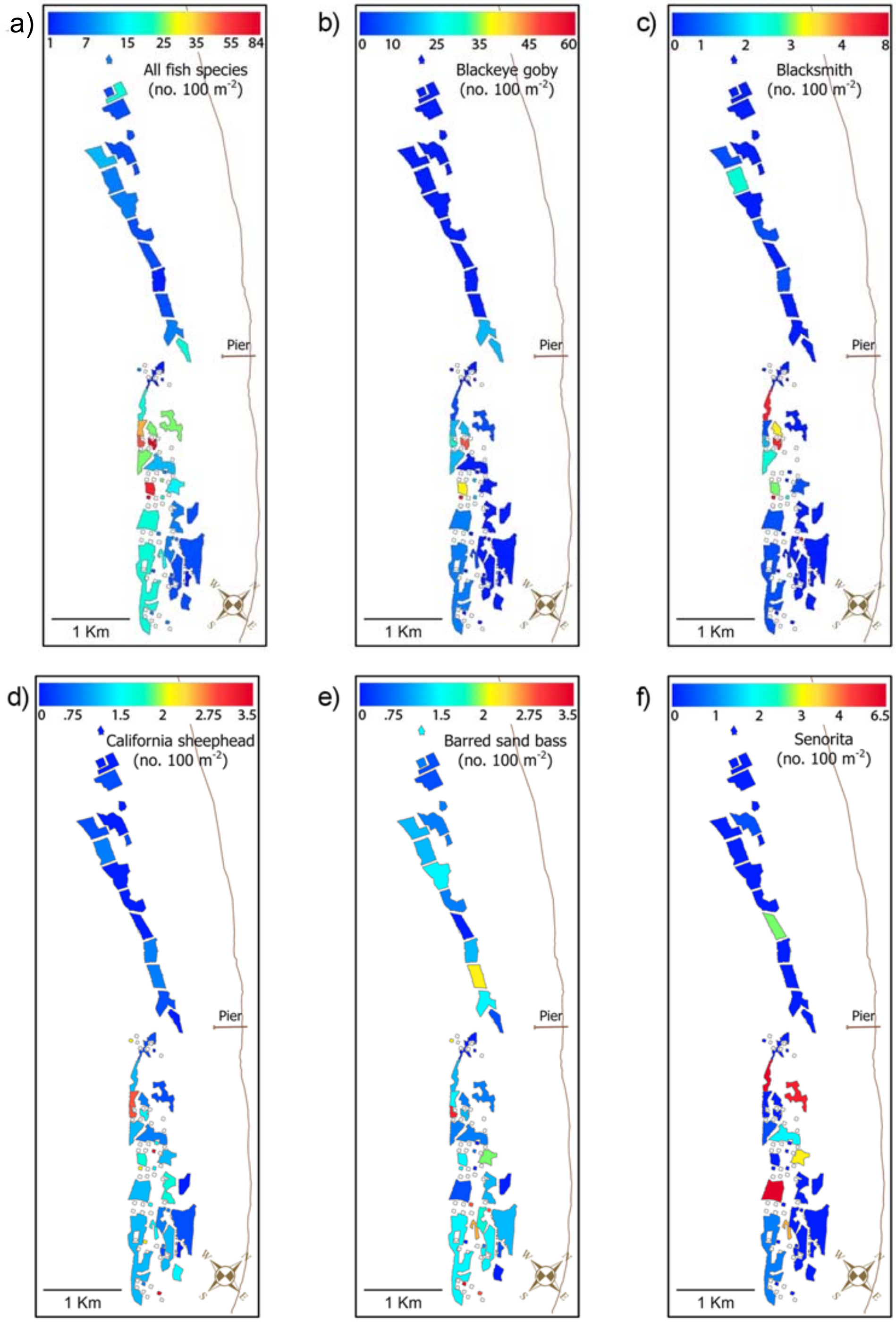


Figure 5.2.7. Maps of fish density in 2021 for Wheeler North Reef Phase 1 modules and Phase 2 and Phase 3 polygons. (a) All species of reef fish, (b) Blackeye goby, (c) Blacksmith, (d) California sheephead, (e) Barred sand bass, and (f) Senorita. Warmer colors denote higher densities than cooler colors. White Phase 1 modules were not sampled.

Other species of reef fish that have historically been relatively abundant at Wheeler North Reef are tropical derivatives that have affinities to warm water. These species include the blacksmith (a damsel fish), barred sand bass, and the wrasses California sheephead and señorita (Figure 5.2.6c-f and Figure 5.2.7c-f). With the exception of blacksmith and señorita on the Phase 1 modules, declines in the densities of these species in 2016 following the warm water event were much less pronounced than those observed for the blackeye goby. Collectively, these four species along with the blackeye goby have, on average, accounted for 73% of all fish observed on Wheeler North Reef since 2009. Large predatory species of fish that are valued ecologically and/or economically such as the giant sea bass (*Stereolepis gigas*) and California halibut (*Paralichthys californicus*) are also commonly observed at Wheeler North Reef, but because of their large size and high trophic status they are not numerically abundant.

Because different species of fish vary tremendously in size, it is often desirable to have information on the biomass of fish per unit area (i.e., biomass density) in addition to their numerical density. As observed for numerical density, the biomass density of reef fish on the Phase 1 reef has been consistently higher than that of Phase 2 in all years except 2021 when they converged to a similar value of ~ 30 g per m^2 (Figure 5.2.8a). This convergence reflects a gradual increase in fish biomass in the Phase 2 polygons coupled with a relatively recent decline in fish biomass on the Phase 1 modules.

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). Larger common species such as the California sheephead, barred sand bass, and kelp bass, along with smaller black perch which are numerically abundant, and the much larger but much less abundant giant sea bass have consistently been the most dominant species of reef fish at Wheeler North Reef in terms of biomass density (Figure 5.2.8b-f). In 2021 these five species collectively accounted for 86% of the total reef fish biomass at Wheeler North Reef.

Fish biomass density in the new Phase 3 polygons in 2020 and 2021 was approximately half that of the similarly designed Phase 2 polygons (Figure 5.2.8a). However, fish biomass density on the Phase 3 reef at this time was remarkably similar to that observed on the Phase 2 reef at a similar time in its development (i.e. 2009 and 2010).

Differences in biomass density among the three reef phases in 2021 are evident in the maps of fish biomass density (Figure 5.2.9). Unlike numerical density, fish biomass density was not concentrated in the offshore polygons of Phase 2 in 2021, but instead was more haphazardly distributed across the reef, with the highest biomass occurring in polygons where large giant sea bass were observed. This is to be expected as large species such as the giant sea bass and various species of sharks and rays contribute disproportionately to biomass density despite their relatively low abundance. Indeed, the large spike in biomass on the Phase 1 reef in

2014 (Figure 5.2.8a) resulted from the occurrence of three giant seabass in a single transect (Figure 5.2.8d).

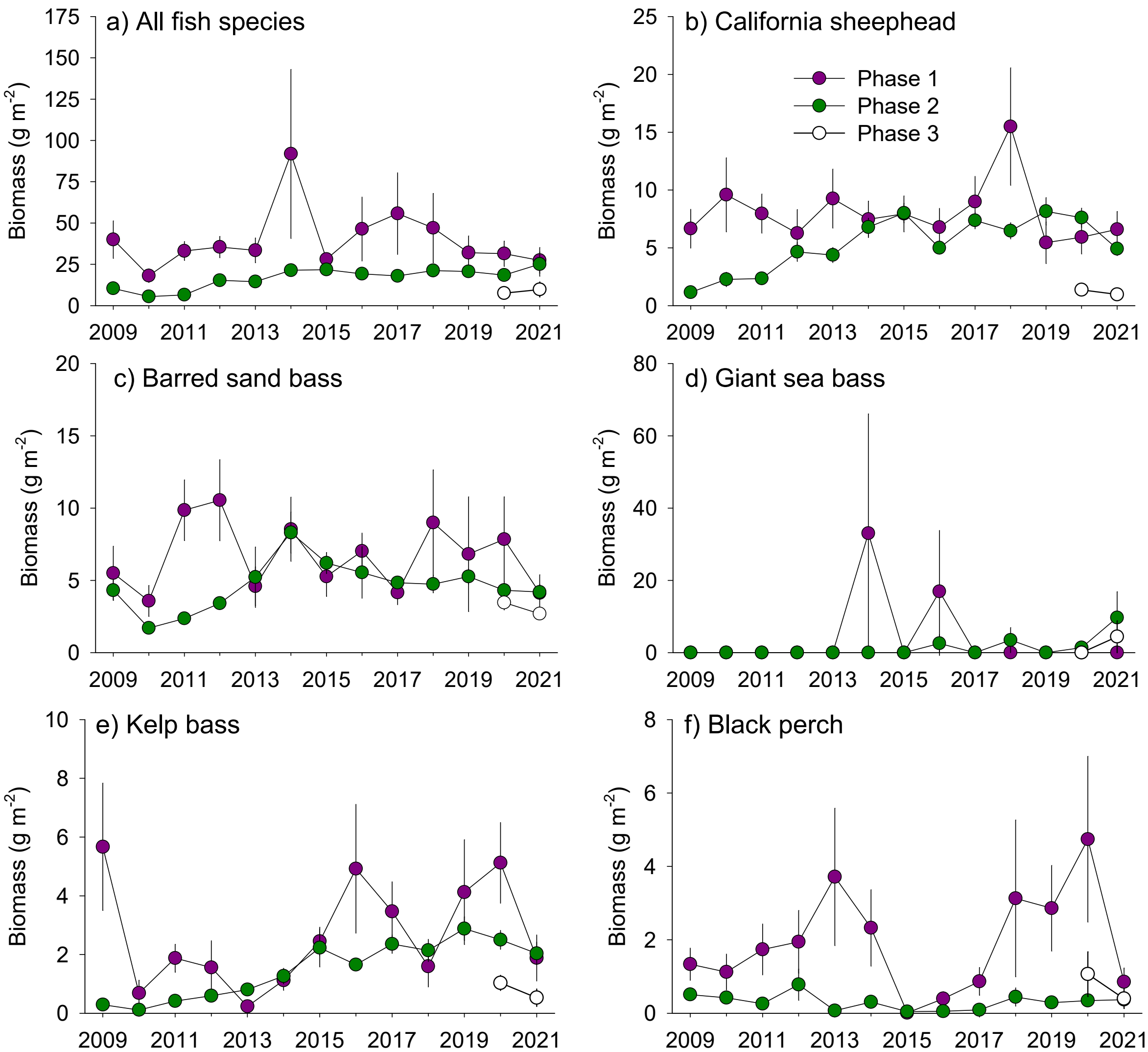


Figure 5.2.8. Mean biomass densities (± 1 standard error) of (a) All species of reef fish, (b) California sheephead, (c) Barred sand bass, (d) Giant sea bass (e) Kelp bass and (f) Black perch at Wheeler North Reef, Barn and San Mateo from 2009 – 2021. 2020 was excluded due to reduced monitoring.

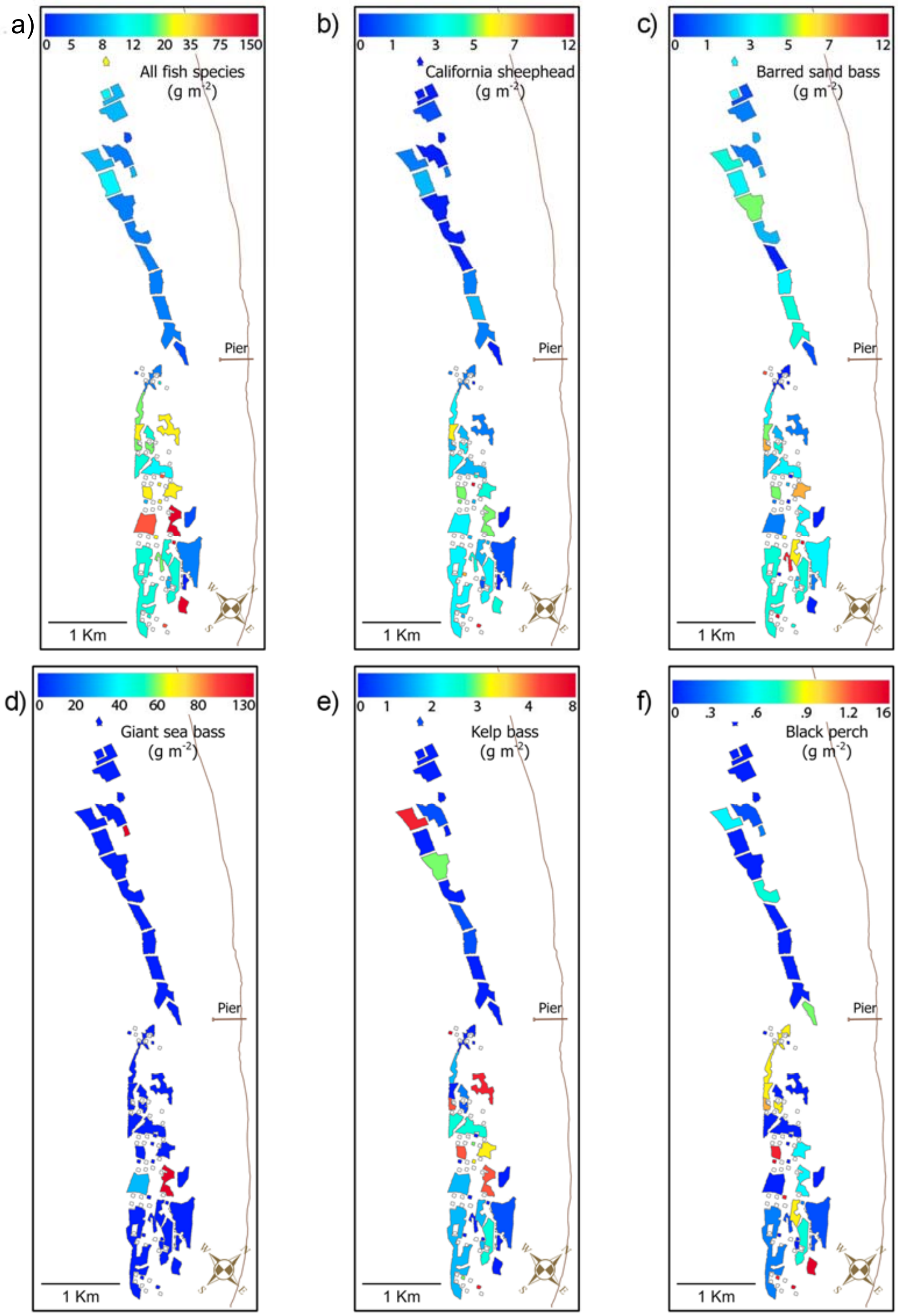


Figure 5.2.9. Maps of fish biomass in 2021 for Wheeler North Reef Phase 1 modules and Phase 2 and Phase 3 polygons. (a) All species of reef fish, (b) California sheephead, (c) Barred sand bass, (d) Giant sea bass, (e) Kelp bass, and (f) Black perch. Warmer colors denote higher biomass densities than cooler colors. White Phase 1 modules were not sampled.

Year-to-year variation in the number of fish species at Wheeler North Reef has fluctuated less compared to fish density. The total number of unique species of reef fish observed in the 92 transects sampled on the Phase 1 and 2 reefs doubled from 2010-2012 as the Phase 2 reef became colonized (Figure 5.2.10). Fish species number gradually declined from 2014-2019 to 22 species (the same as that observed in 2010 two years after Phase 2 was constructed), and then increased abruptly to 35 species in 2021. Interestingly, the addition of 59 transects sampled in the Phase 3 polygons in 2021 only added three unique species.

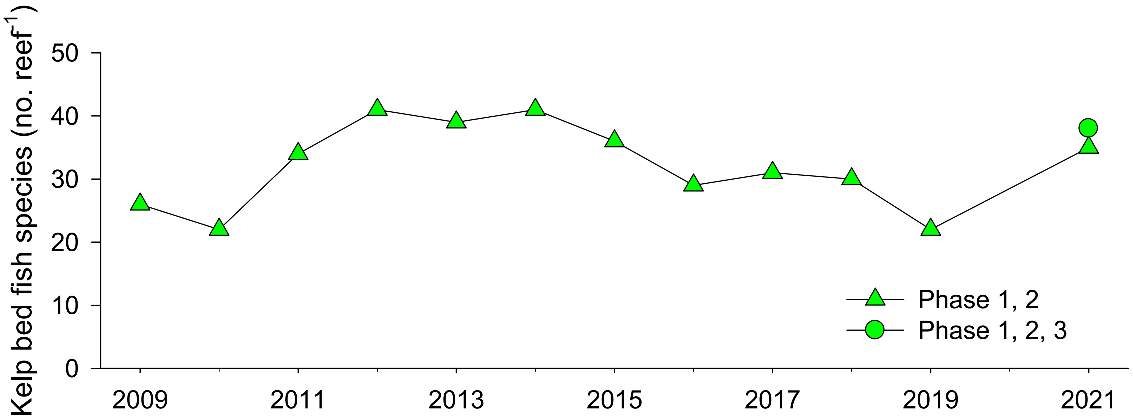


Figure 5.2.10. Total number of species of kelp bed fish near the bottom at Wheeler North Reef from 2009 – 2021. Values for 2009-2019 represent the number of unique species counted in 12 transects on Phase 1 and 80 transects on Phase 2 (i.e., n = 92). Values for 2021 include unique species counted in 59 transects on Phase 3 in addition to those counted in the 92 transects of Phases 1 and 2 (i.e., n = 151 transects). 2020 data are excluded as quadrat sampling for small cryptic species was not done due to reduced sampling imposed by COVID-19 restrictions.

<u>Benthos</u>

In addition to giant kelp, the benthic community on the shallow reefs off California typically includes 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 invertebrate species. 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, bivalves 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 for the Phase 2 reef, which showed a dramatic increase in the percent cover of the benthic community immediately following its construction (Figure 5.2.11a). Within three years of being built >90% of the rock surface of Phase 2 was covered by macroalgae and sessile invertebrates, which was similar to that observed on the older Phase 1 modules. The fraction of rock covered by reef biota has been relatively constant on the Phase 1 and 2 reefs since then and in 2021 it averaged 97%.

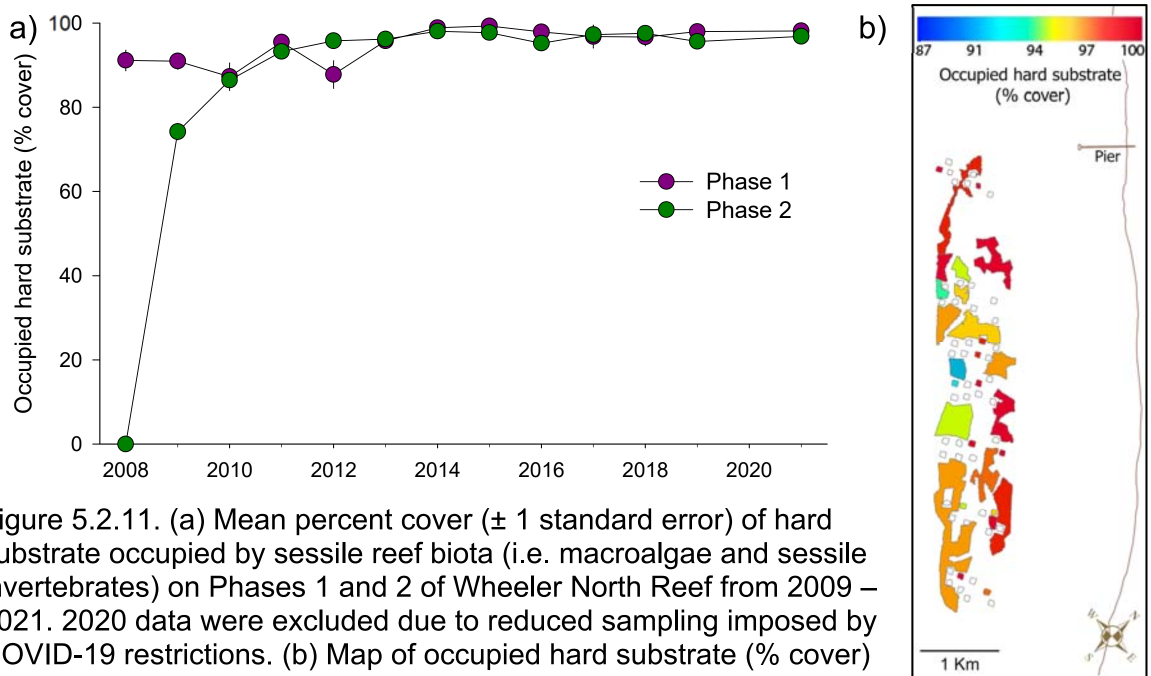
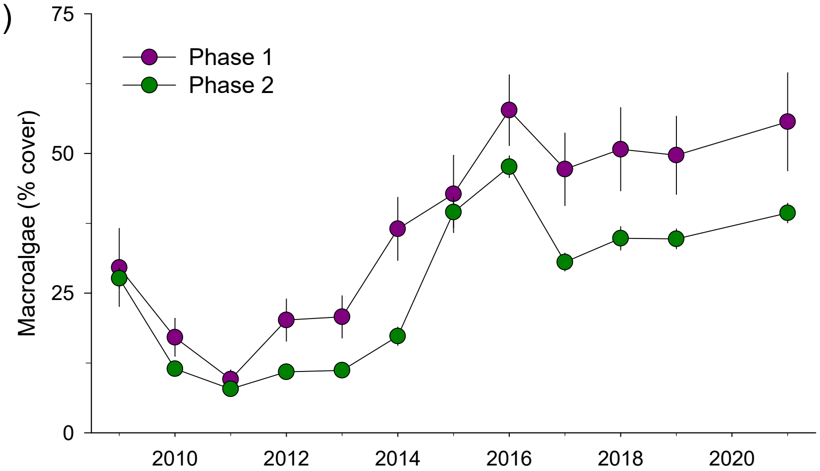


Figure 5.2.11. (a) Mean percent cover (± 1 standard error) of hard substrate occupied by sessile reef biota (i.e. macroalgae and sessile invertebrates) on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data were excluded due to reduced sampling imposed by COVID-19 restrictions. (b) Map of occupied hard substrate (% cover) on Phases 1 and 2 of Wheeler North Reef in 2021. Warmer colors denote higher densities than cooler colors. White Phase 1 modules were not sampled.

Macroalgae quickly colonized the newly constructed Phase 2 reef in 2009 attaining an average coverage of 28%, which was very similar to that of the older Phase 1 modules (Figure 5.2.12a). Macroalgal percent cover on both stages of Wheeler North Reef declined three-fold from 2009 to 2011, before gradually increasing over time to a peak of 58% and 48% in 2016 on the Phase 1 and 2 reefs, respectively. The cover of macroalgae on both reef phases declined slightly in 2017 and has gradually increased since then to near peak levels. Total algal cover in 2021 tended to be low in the deeper offshore portions of Wheeler North Reef compared to the shallower inshore portions (Figure 5.2.12b), which is not unexpected given that light needed for photosynthesis by macroalgae decreases with depth. The total number of species of macroalgae observed in the 92 transects sampled on the Phase 1 and 2 reefs increased from a low of 18 species in 2011 to a high of 56 species in 2019 (Figure 5.2.12). Macroalgal species richness remained high in 2021 with 55 species observed in the 92 transects.

a)



b)

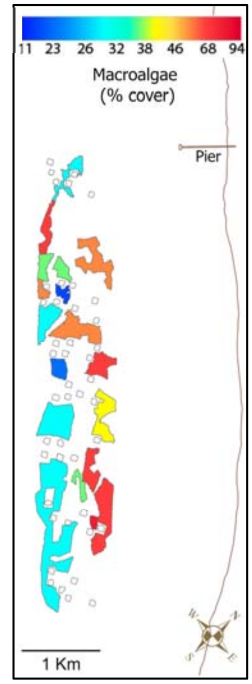


Figure 5.2.12. (a) Mean percent cover (± 1 standard error) of macroalgae on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data were excluded due to reduced sampling imposed by COVID-19 restrictions. (b) Map of macroalgal cover on Phases 1 and 2 of Wheeler North Reef in 2021. Warmer colors denote higher percent cover than cooler colors. White Phase 1 modules were not sampled.

Figure 5.2.13. Total number of species of macroalgae observed on Phases 1 and 2 of Wheeler North Reef from 2009 - 2021. 2020 data was excluded due to reduced sampling imposed by COVID-19 restrictions.

The species composition of the macroalgal community at Wheeler North Reef has changed over time since the construction of the Phase 2 reef in 2008. Initially, filamentous brown and red algae accounted for most of the cover of macroalgae at Wheeler North Reef (Figure. 5.2.14). This transitioned to giant kelp holdfasts, which dominated the cover of macroalgae from 2010 through 2014 accounting for up to 85% of the total algal cover. The percent cover of the red algae *Acrosorium unicatum* and *Rhodymenia* spp. increased substantially following the decline in giant kelp abundance in 2015 and 2016 (Figures 5.2.2 and 5.2.3), and their combined cover constituted 32%-57% of the total macroalgal cover from 2015-2019. The abundance of these two species declined substantially in 2021 when the cover of macroalgae was more evenly distributed among the most abundant species.

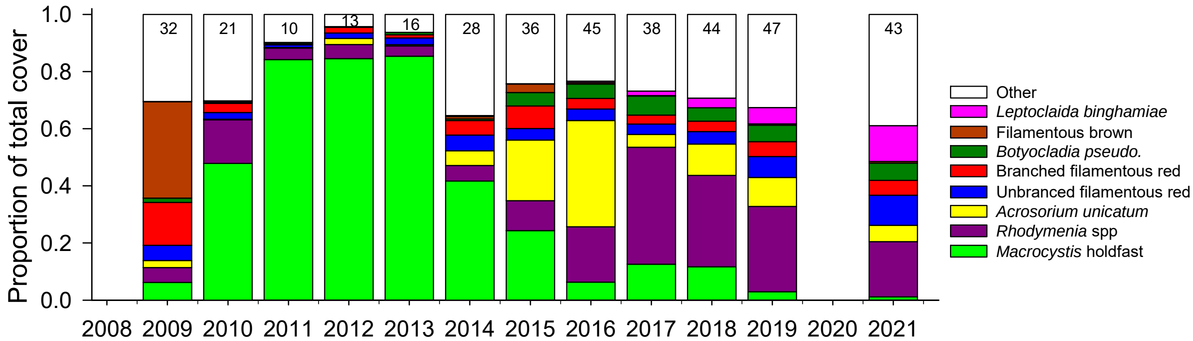


Figure 5.2.14. Proportions of the total percent cover contributed by the eight most abundant species of macroalgae and all remaining taxa of macroalgae combined (other) at Wheeler North Reef. Values were derived from data collected from 12 transects on the Phase 1 reef and 80 transects on the Phase 2 reef from 2009 – 2019 and 2021. 2020 was excluded from data due to reduced monitoring imposed by COVID-19 restrictions. Numbers in bars indicate the number of "other" species observed in that year.

Large solitary brown algae such as the kelps *Laminaria farlowii* and *Pterygophora californica* are known to be important components of the kelp forest understory and their abundance is best estimated by density rather than percent cover. *Laminaria* and *Pterygophora* initially colonized the Phase 2 reef at relatively high densities in 2009, the year after it was built (Figure 5.2.15a, b). The abundance of both these kelps rapidly declined and remained low in most areas of the reef until 2021 when *Laminaria* recruited in relatively high abundance throughout the Phase 2 reef (Figure 5.2.15c). By contrast, the recruitment of *Pterygophora* in 2021 was largely restricted to the offshore up coast portion of the Phase 2 reef (Figure 5.15d).

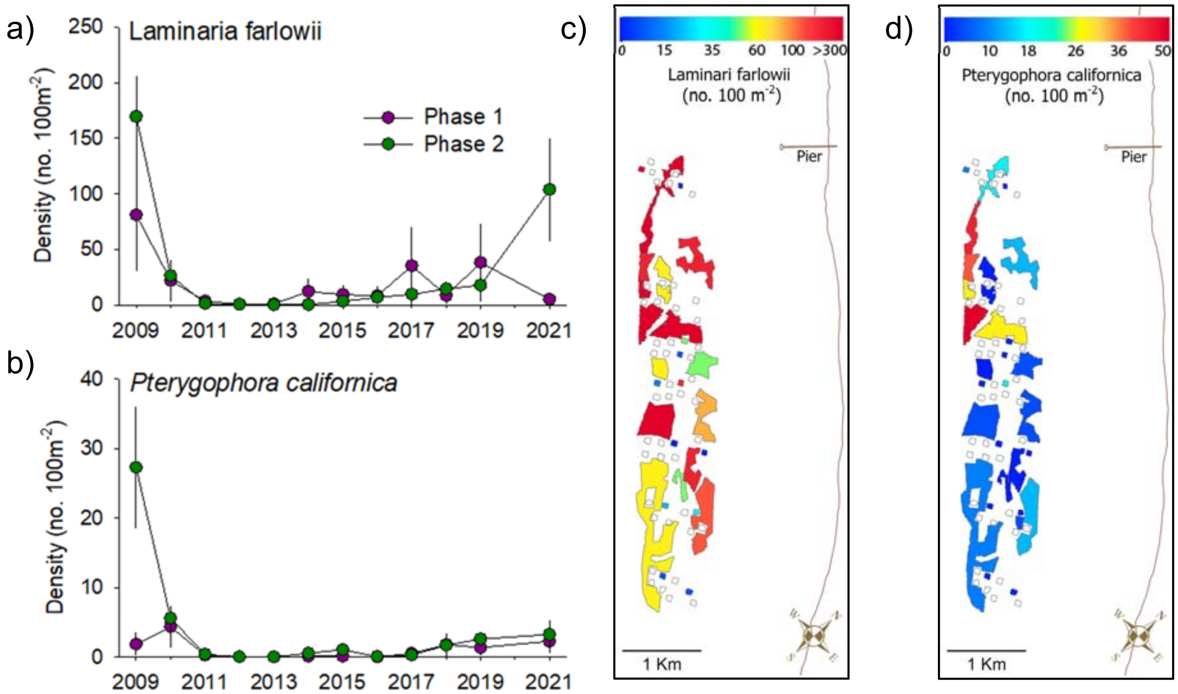
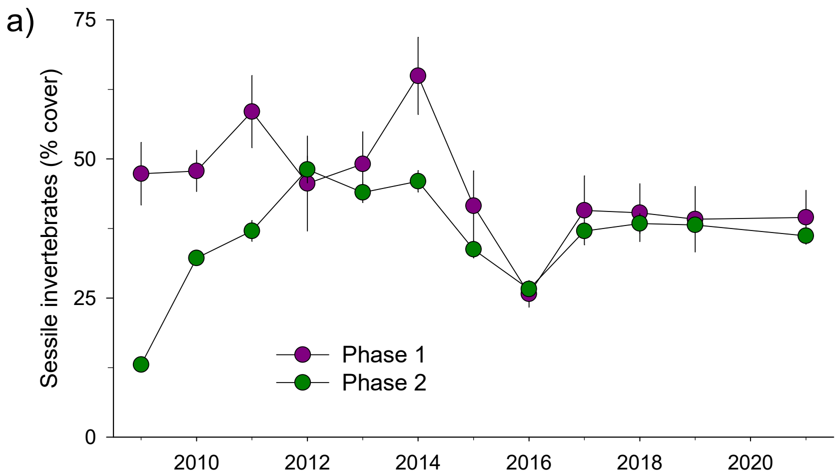


Figure 5.2.15. Mean densities (± 1 standard error) of (a) *Laminaria farlowii* and (b) *Pterygophora californica* on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 was excluded due to reduced monitoring imposed by COVID-19 restrictions. Map of the density of (c) *Laminaria farlowii* and (d) *Pterygophora californica* on Phases 1 and 2 of Wheeler North Reef in 2021. Warmer colors denote higher densities than cooler colors. White Phase 1 modules were not sampled.

As a group sessile invertebrates were slower to colonize the Phase 2 reef than macroalgae as sessile invertebrate cover in 2009 was less than half that of macroalgae (Figure 5.2.16a vs. 5.2.12a). Unlike macroalgae whose cover diminished rapidly after initiation colonization, the percent cover of sessile invertebrates increased steadily to 47% in 2012, which was comparable to that of the Phase 1 reef (Figure 5.2.16a). Sessile invertebrate cover on both the Phase 1 and 2 reefs fluctuated substantially between 2012-2016 but has remained largely constant at ~ 38% since 2017. In 2021, the cover of sessile invertebrates was relatively uniform across the Phase 2 polygons and somewhat more variable among the smaller, older Phase 1 modules (Figure 5.2.16b).

The trajectory of sessile invertebrate species richness was generally similar that of sessile invertebrate percent cover on the Phase 2 reef. The total number of species of sessile invertebrates observed within the 92 transects sampled on the Phase 1 and 2 reefs increased from a low of 65 species in 2009 and 2010 to 89 species in 2017 and has remained near this level since then (Figure 5.2.17).



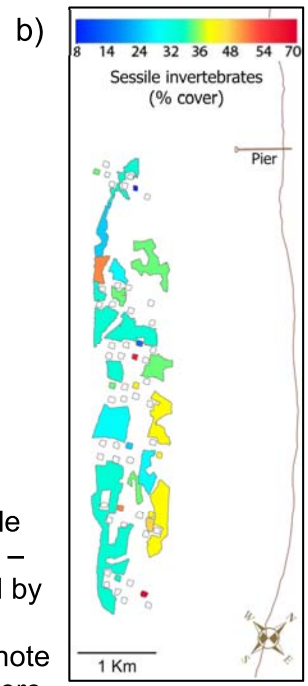


Figure 5.2.16. (a) Mean percent cover (± 1 standard error) of sessile invertebrates on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions. (b) Map of sessile invertebrate cover on Phases 1 and 2 of Wheeler North Reef in 2021. Warmer colors denote higher percent cover than cooler colors. White Phase 1 modules were not sampled.

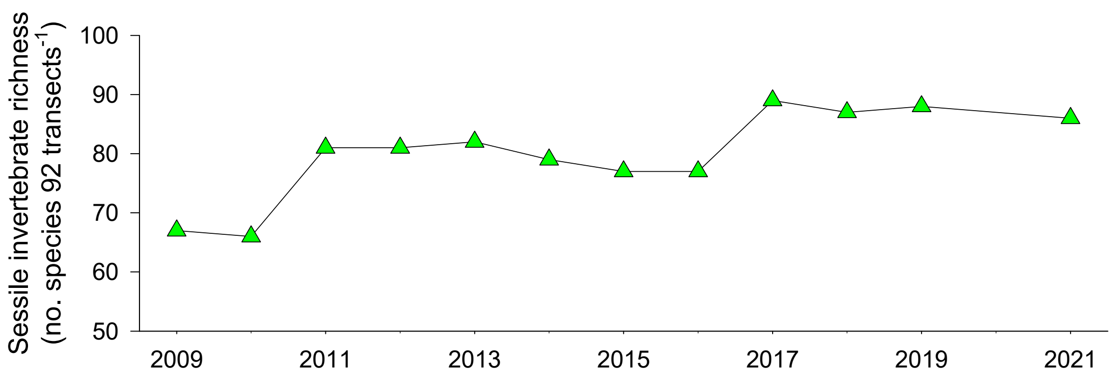


Figure 5.2.17. Total number of species of sessile invertebrates observed on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data was excluded due to reduced sampling imposed by COVID-19 restrictions

The mix of common species of sessile invertebrates at Wheeler North Reef in 2021 differed from previous years when the colonial tunicate Chelyosoma productum, and encrusting and colonial sponges (e.g., Lucilla nuttingi) and foraminifera accounted for 30-60% of the total cover of sessile invertebrates (Figure 5.2.18). Encrusting and erect bryozoans (e.g. Thalamoporella californica) and the sea fan Muricea spp. have become more abundant in recent years and have accounted for a greater proportion of the sessile invertebrate community. Collectively, the eight taxa shown in Figure 5.2.18 have accounted for 60-70% of the sessile invertebrate cover on Wheeler North Reef. Sea fans (Muricea spp.) are of particular interest as their density and percent cover have been gradually increasing over time on the Phase 2 reef, particularly in the deeper offshore polygons (Figure 5.2.19) and dense aggregations of sea fans have been associated with an absence of giant kelp on artificial reefs in

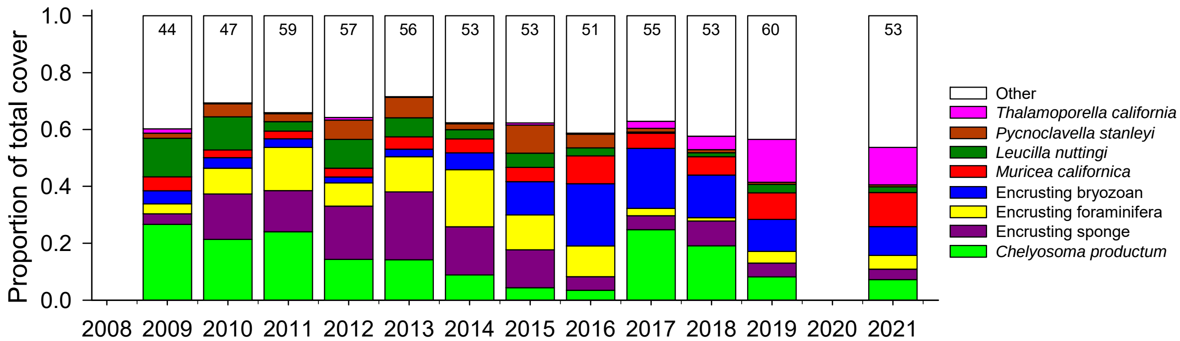


Figure 5.2.18. Proportions of the total percent cover contributed by the eight most abundant species of sessile invertebrate and all remaining sessile invertebrate taxa combined (other) at Wheeler North Reef. Values were derived from data collected from 12 transects on the Phase 1 reef and 80 transects on the Phase 2 reef from 2009 – 2019 and 2021. 2020 data was excluded due to reduced sampling imposed by COVID-19 restrictions. Numbers in bars indicate the number of “other” species observed in that year.

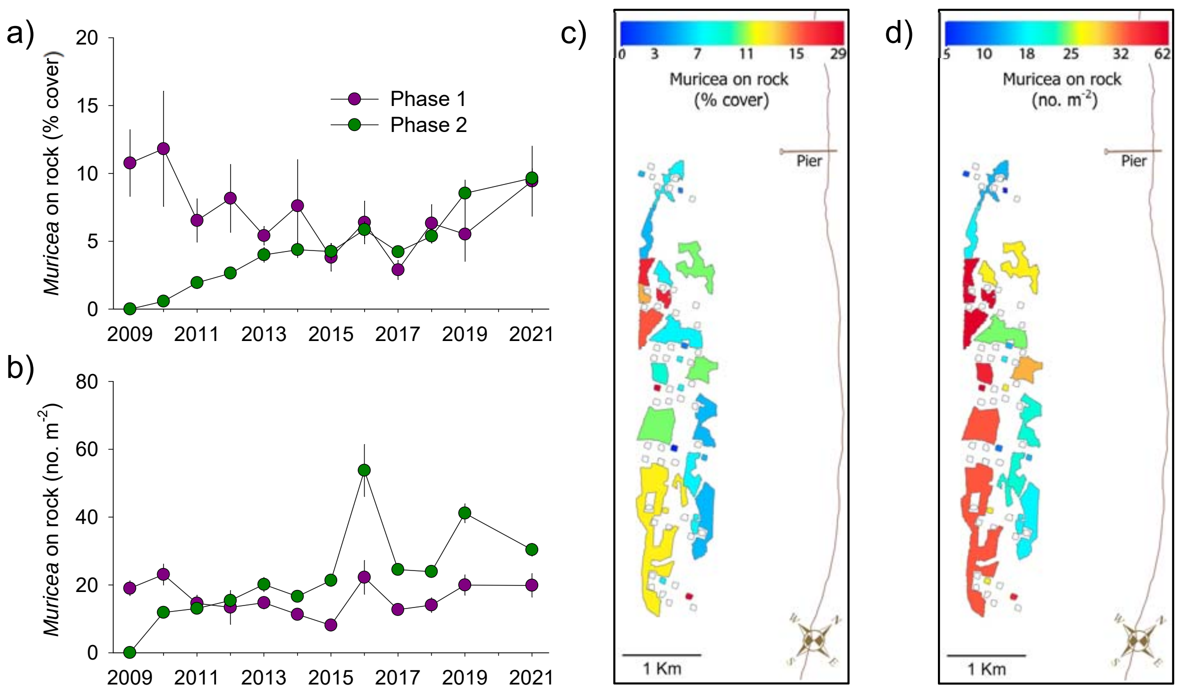


Figure 5.2.19. (a) Mean percent cover (± 1 standard error) and (b) mean density (± 1 standard error) of *Muricea* on rock on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data was excluded due to reduced sampling imposed by COVID-19 restrictions. Map of (c) percent cover and (d) density of *Muricea* on rock on Phases 1 and 2 of Wheeler North Reef in 2021. Warmer colors denote higher percent cover or densities than cooler colors. White Phase 1 modules were not sampled.

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 their photosynthesis and growth are suppressed. Such is the case under a dense canopy of the giant kelp, which has a negative effect on understory algae by significantly reducing the amount of light reaching the bottom (Reed and Foster 1984). Experiments done at the Phase 1 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 tend to be favored in the presence of giant kelp (Detmer et al. 2021).

Strong asynchrony in abundance between sessile invertebrates and understory algae, and between understory algae and giant kelp has been observed at Wheeler North Reef since 2009 (Figure 5.2.20). The negative covariance observed between the benthic cover of sessile invertebrates and understory algae (its primary competitor for space) and the positive covariance between the cover of sessile invertebrates and the density of giant kelp (which outcompetes understory algae for light) is indicative of the direct and indirect effects of competition among these three groups of primary space holders (Arkema et al. 2009).

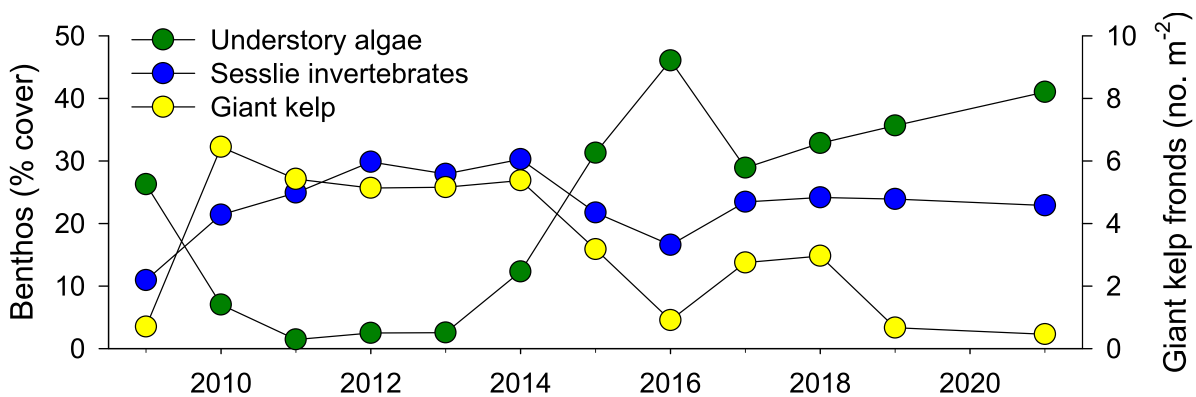


Figure 5.2.20. Comparison of mean percent cover of understory algae (green) and sessile invertebrates (blue) on left axis and mean frond density of adult giant kelp on the right axis on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data was excluded due to reduced sampling imposed by COVID-19 restrictions.

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 the coverage of sessile invertebrates, the density of mobile invertebrates in the Phase 2 polygons increased dramatically from < 1 individual per m^2 in 2009 to 117 per m^2 in 2012, which was ~ 50% higher than that observed on the Phase 1 modules at that time (Figure 5.2.21a). Mobile invertebrates steadily declined on Wheeler North Reef between 2012 and 2016 when densities on both the Phase 1 and 2 reefs plummeted to 15-18 individuals per m^2. Densities of mobile invertebrates have remained relatively low since then and in 2021 averaged ~`20 individuals per m^2 on both phases of Wheeler North Reef (Figures 5.2.21a and 5.2.21b).

Unlike abundance, the total number of species of mobile invertebrates observed in the 92 transects of the Phase 1 and 2 reefs increased steadily from 43 species in 2009 to 81 species in 2014 (Figure 5.2.22). Species richness of mobile invertebrates has remained relatively stable since 2014, with 83 species observed in the 92 transects in 2021.

Figure 5.2.21. (a) Mean density (± 1 standard error) of mobile invertebrates on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions. (b) Map of mobile invertebrate density on Phases 1 and 2 of Wheeler North Reef in 2021. Warmer colors denote higher densities than cooler colors. White Phase 1 modules were not sampled.

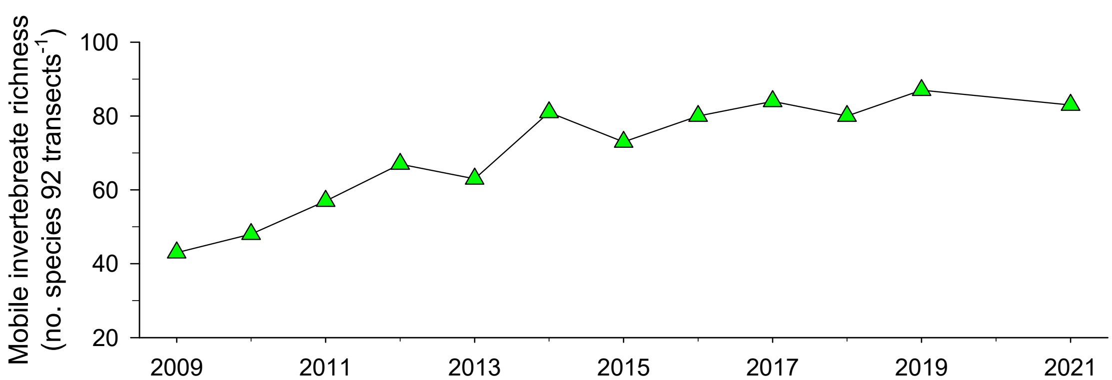


Figure 5.2.22. Total number of species of mobile invertebrates observed on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 data was excluded due to reduced sampling imposed by COVID-19 restrictions.

The brittle star *Ophiothrix spiculata,* has consistently been the most abundant species of mobile invertebrate at Wheeler North Reef accounting for 50-90% of all mobile invertebrates since 2009 (Figure 5.2.23). 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 decrease in the proportional cover of giant kelp holdfasts (Figure. 5.2.14). Aside from brittle stars, hermit crabs, the cone snail *Conus californicus,* and the whelk *Pteropurpura festiva* have consistently been among the most abundant mobile invertebrates at Wheeler North Reef. Their densities have remained relatively constant over time, but their proportional abundance has shifted with fluctuations in the densities of brittle stars. Collectively these four species accounted for 80% of all mobile invertebrates recorded in 2021 (n = 84 species), which is ~10% less than their average during the previous 11 years (2009 -2019).

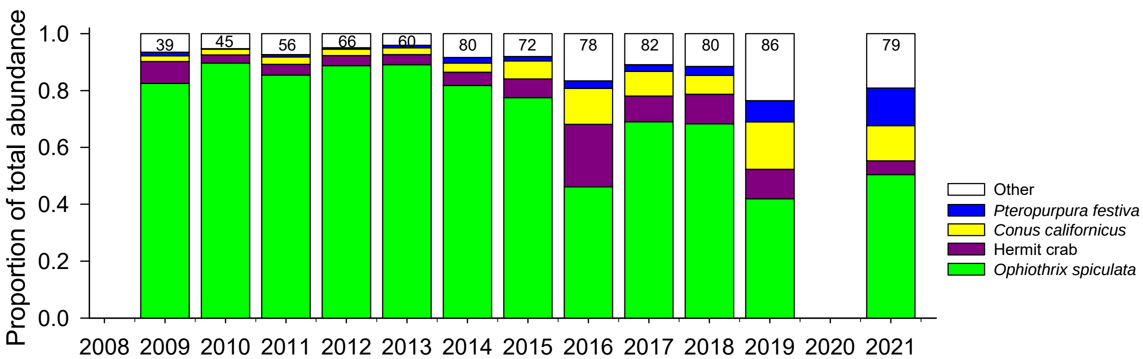


Figure 5.2.23. Proportions of the total abundance contributed by the four most common species of benthic mobile invertebrates and all remaining taxa of mobile invertebrates combined (other) at Wheeler North Reef. Values were derived from data collected from 12 transects on the Phase 1 reef and 80 transects on the Phase 2 reef from 2009 – 2019 and 2021. 2020 was excluded due to reduced monitoring imposed by COVID-19 restrictions. Numbers in bars indicate the number of "other" species observed in that year.

Larger species of common mobile invertebrates (e.g., spiny lobster, sea urchins, sea stars, and large gastropods), while not as abundant as smaller species of mobile invertebrates, are common at Wheeler North Reef and their foraging activities can play a disproportionate role in structuring the kelp forest community. 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 fishermen. Lobster densities on Phases 1 and 2 of Wheeler North Reef have increased nearly 20-fold since 2011 (Figures 5.2.24a, and 5.2.25a) to a level that is more than twice the densities observed at San Mateo and Barn. By contrast, densities of red and purple sea urchins, the herbivorous wavy turban snail *Megastrea undosum* and the Kellet's whelk *Kelletia kelletia* have fluctuated erratically in time and space. (Figures 5.2.24b-d, and 5.2.25b-d). Initially, the bat star (*Patiria miniata*) and spinned sea stars (*Pisaster* spp.) were common benthic invertebrate predators at Wheeler North Reef, however, they all but disappeared in 2015 due to an epidemic outbreak of a wasting disease that led to mass mortalities of at least 20 species of sea stars from Alaska to Mexico (Hewson et al. 2014). Sea star populations at Wheeler North Reef and elsewhere in California have yet to recover from this epidemic.

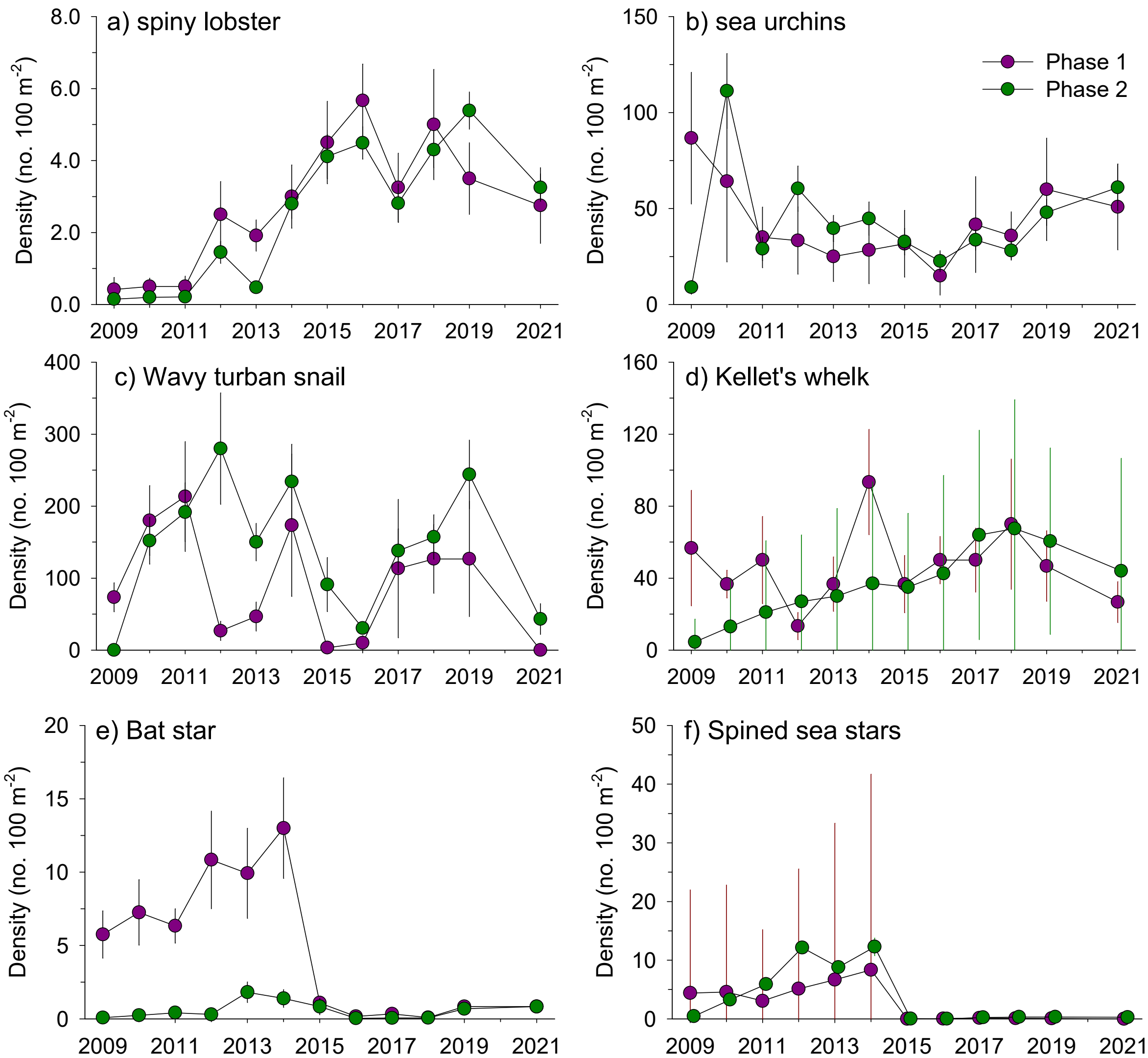


Figure 5.2.24. Mean densities (± 1 standard error) of: (a) spiny lobster, (b) red and purple sea urchins, (c) wavy turban snail, (d) Kellet's whelk, (e) bat star and (f) spined sea stars on Phases 1 and 2 of Wheeler North Reef from 2009 – 2021. 2020 was excluded due to reduced monitoring imposed by COVID-19 restrictions.

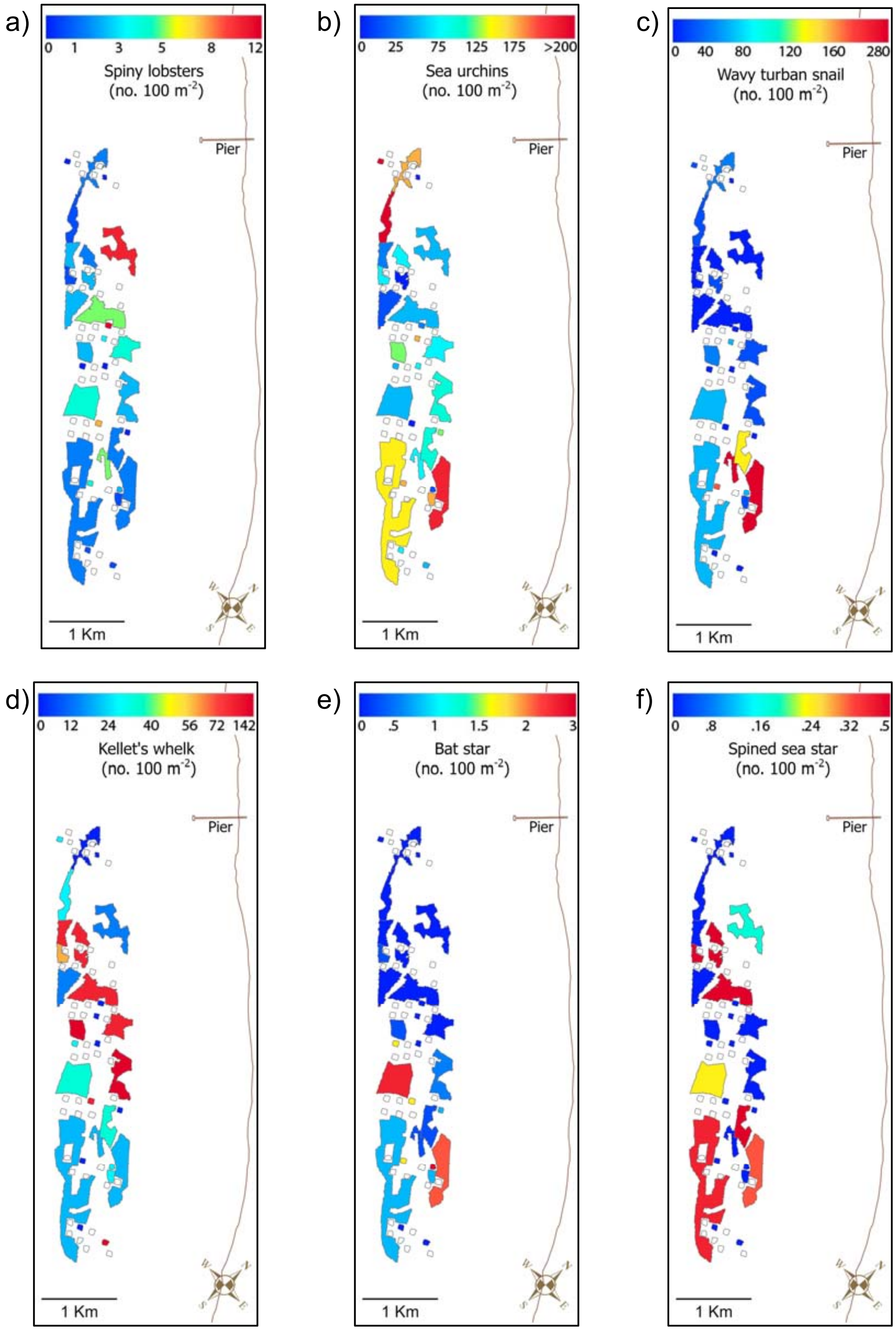


Figure 5.2.25. Maps of the densities of large benthic invertebrates. a) spiny lobster, (b) red and purple sea urchins, (c) wavy tuban snails, (d) Kellet's whelk, (e) bat star, and (f) spined sea stars on Phases 1 and 2 of Wheeler North Reef in 2021. Warmer colors denote higher densities than cooler colors. White Phase 1 modules were not sampled.

6.0 Performance Assessment of Wheeler North Reef

Listed below are the absolute and relative performance standards that are used to evaluate whether 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. 2021).

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 eighty-two 50 m long transects on Wheeler North Reef (12 transects on Phase 1 and 70 transects on the primary polygons of Phase 2; 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 footprint area of Wheeler North Reef in year *t,* and P_t is the proportion of 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 Wheeler North Reef to successfully meet this standard.

The reef footprint area used to evaluate this standard includes the Phase 1 modules and the 16 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 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%.

Because the footprint area of the artificial reef is not expected to change much from year-to-year, multi-beam sonar surveys are done only once every five years and the value for reef footprint area is assumed to remain constant between sonar surveys. Multibeam sonar surveys of Wheeler North Reef were completed in 2009, 2014 and 2020. Unlike footprint area, the percent of the bottom covered by rock is measured every year by divers.

Results: There was a slight decrease in the combined footprint area in 2009, the year following construction (Figure 6.1.1a), which is not unexpected as rocks settle into the soft sandy bottom. Since then, the footprint area of the Phase 1 modules and the Phase 2 primary polygons of Wheeler North Reef has remained relatively constant ranging from 152.1 to 153.8 acres. The percent cover of rock within the footprint areas of the Phase 1 modules and the Phase 2 primary polygons has also remained relatively constant ranging from a low of 42% in 2011 to a high of 49 % in 2017(Figure 6.1.1b).

The initial amount of hard substrate at Wheeler North Reef used to judge this performance standard was 70.6 acres in 2008 (Figure 6.1.1c). The 2-acre decrease in footprint area in 2009 coupled with a decline in the percent cover of hard substrate through 2011 (Figure 6.1.1b) resulted in nearly a 10% decrease in the total area of hard substrate on Wheeler North Reef by 2011 (Figure 6.1.1c). The total area of hard substrate returned to near as-built levels by 2013 following an increase in rock coverage and has remained near or slightly above this level through 2021 (Figure 6.1.1c). The running average of the area of hard substrate in 2021 based on data collected in 2018, 2019 and 2021 was 72.5 acres, which is 1.5 acres more than that initially constructed (Figure 6.1.1d). Thus, Wheeler North Reef met the performance standard for reef area in 2021 regardless of whether the evaluation was based on data from 2021 alone or the 4-year running average.

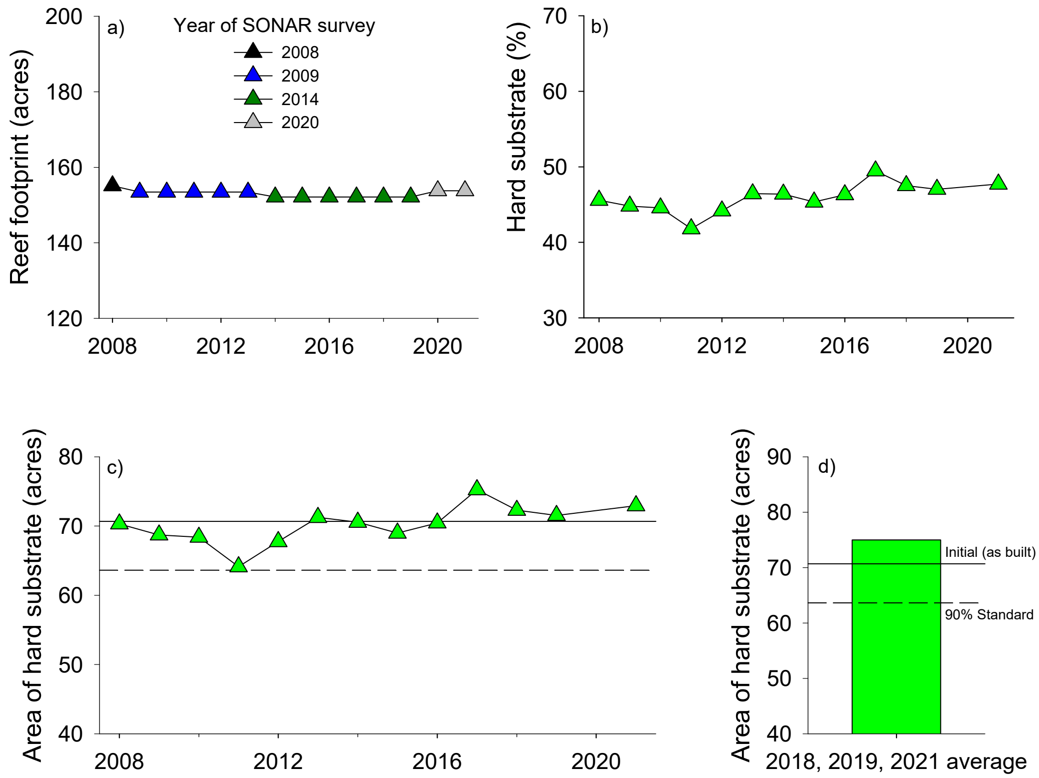


Figure 6.1.1. Variables used to calculate exposed hard substrate. (a) Reef footprint area, (b) Percent cover of hard substrate, (c) Area of exposed hard substrate and (d) 2018, 2019 and 2021 average of the area of exposed hard. 2020 was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 10 m x 2 m plots arranged at 10 m intervals along each of the 151 50m transects at Wheeler North Reef (12 transects on Phase 1 and 80 transects on Phase 2 and 59 transects on Phase 3; Figure 4.4.2). For the purpose of this performance standard, medium-to-high density giant kelp is defined as >4 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 as those used to assess the impacts of SONGS on giant kelp). The summed total of adult plants in the five 10 m x 2 m quadrats provides an estimate of the number of adult plants per 100 m^2 at each transect. The proportion of transects with a density >4 adult plants per 100 m^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:

$$A_k = \sum_{i=1}^{n} \left(\frac{N_{ki}}{N_{ri}}\right) * A_i$$

where n = total number of polygons at Wheeler North Reef (Phases 1+2+3), A_i is the area of a polygon based on the most recent sonar survey, N_{ki} = number of transects in that polygon with >4 plants per 100 m^2, and N_{ri} is the total number of transects sampled in that polygon. All 56 Phase 1 modules are considered to be a single polygon for the purpose of this calculation.

Unlike the absolute performance standard for hard substrate, the data used to evaluate the absolute performance standard for giant kelp and fish standing stock (see below) are collected over the entire Wheeler North Reef (Phases 1, 2, and 3). The reason for this is that the requirement for sustaining 150 acres of giant kelp and a fish standing stock of 28 tons is not tied to a specific coverage of hard substrate.

The value of A_k is calculated each year of the monitoring period and summed to that measured in previous years beginning in 2019. The mitigation requirement for giant kelp area will have been met when the total acres of giant kelp accrued by Wheeler North Reef equals the targeted annual value (i.e., 150 acres) x the total years of operation of SONGS Units 2 & 3 (= 32), which amounts to 4800 acres of medium-high density adult giant kelp.

Results: The area of medium-to-high density adult kelp on Wheeler North Reef in 2021 was estimated to be 47 acres (Figure 6.1.2a), substantially less than the design target of 150 acres established by the CCC. Phase 3 contributed 13 of the 47 acres (27%) of adult kelp in 2021 with Phase 2 contributing the remaining 34 (73%) acres (Figure 6.1.3). In 2021, Wheeler North Reef had accumulated a total of 84 of the 4800 acres of medium-to-high density giant kelp required for this performance standard (Figure 6.1.2b).

Monitoring data show that nearly every acre of the 175-acre Phase 1 and 2 Wheeler North Reef supported medium-to-high density adult giant kelp from 2010 – 2015 (Figure 6.1.4). However, beginning in 2016, the area of adult kelp on Wheeler North Reef has remained below 150 acres and fluctuated erratically, reaching its lowest level of 4 acres in 2020, the year that Phase 3 construction was completed.

Similar declines and erratic fluctuations in adult kelp area have been observed at San Mateo and Barn since 2016 (Figure 6.1.3). This observation suggests that the low kelp acreage observed at Wheeler North Reef since 2016 is due to unfavorable conditions for giant kelp growth and recruitment throughout the region rather than unsuitable conditions specific to Wheeler North Reef. The sharp increase in area of adult giant kelp observed at Barn in 2021, coupled with the increase in the density of recruits and subadults observed in the Phase 2 and 3 polygons of Wheeler North Reef in 2021 (Figures 5.2.1 – 5.2.4) suggest that the conditions for kelp growth and survival may be becoming more favorable throughout the region. If this trend continues, then we should expect to see a substantial increase in the area of adult kelp at Wheeler North Reef in 2022.

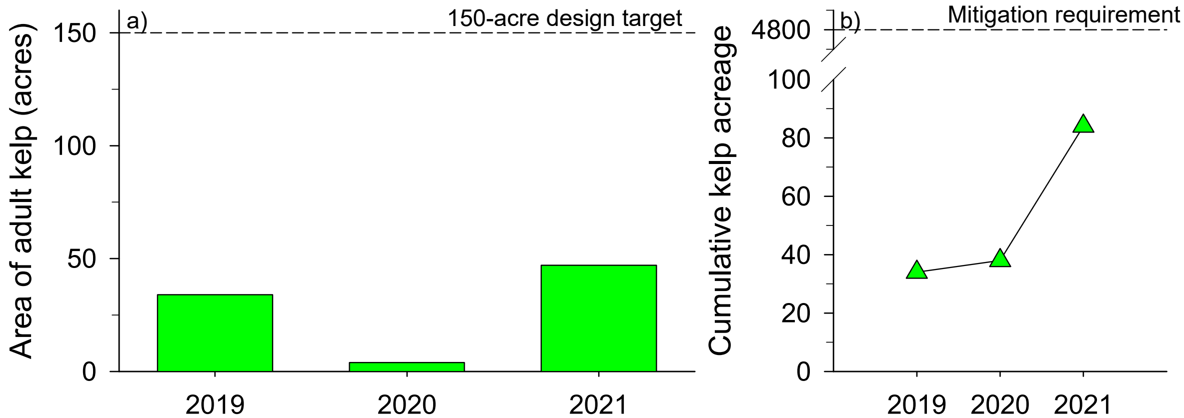


Figure 6.1.2. (a) The number of acres of medium to high density adult kelp at Wheeler North Reef in 2019 – 2021. (b) Cumulative acres of medium to high density adult kelp at Wheeler North Reef 2019 – 2021.

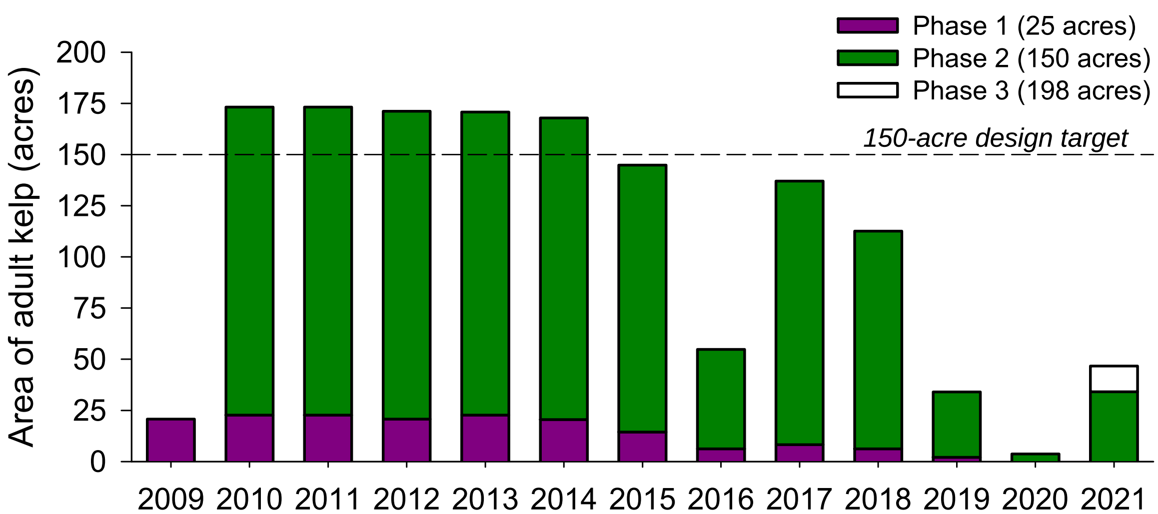


Figure 6.1.3. The number of acres of medium to high density adult kelp for Phase 1 modules, Phase 2 and Phase 3 polygons at Wheeler North Reef in 2019 – 2021.

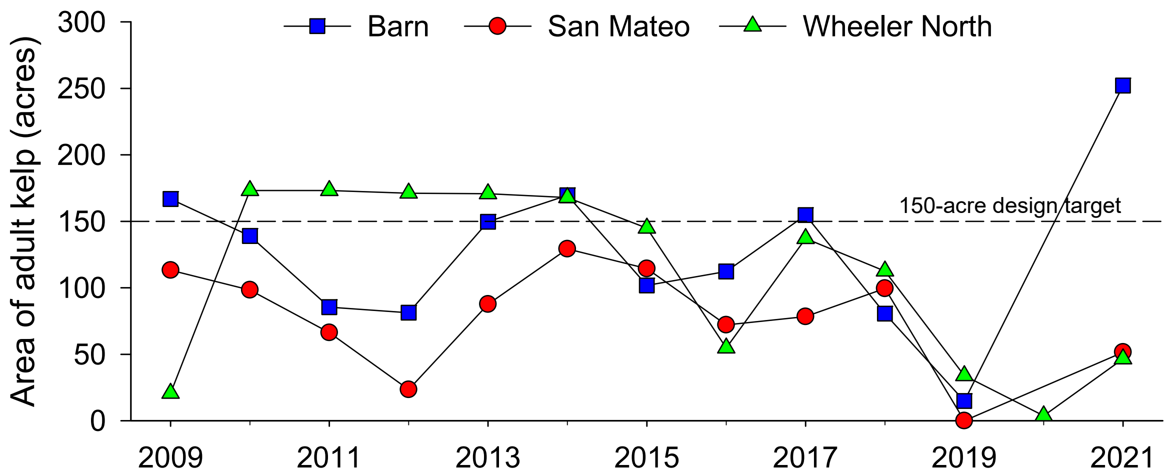


Figure 6.1.4. Mean (± 1 standard error) area of adult giant kelp (*Macrocystis pyrifera*) at Wheeler North Reef, San Mateo and Barn from 2009 – 2021. Values for San Mateo and Barn are scaled to the area of Wheeler North Reef, which changed from 175 acres during 2009 – 2019 to 373 acres beginning in 2020. 2020 data for San Mateo, Barn was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 body lengths, and the relationships between fish length and fish mass. The sampling methods and calculations for determining fish standing stock described below 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.

Data on fish density and length are recorded on the bottom along 151 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 3 m wide x 1.5 m high x 50 m long volume centered above a measuring tape placed along the bottom and extending the length of each 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 2 m 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 1 m^2 quadrats used to sample invertebrates and algae. These data are occasionally augmented with data from additional surveys of fish lengths when 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) based on 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} of ocean bottom. The biomass density of all transects in a polygon are then averaged, converted to US tons per acre, and multiplied by the total area of the polygon (in acres) to obtain the standing stock of fish in that polygon. The standing stock of fish in all polygons (Phases 1, 2 and 3) is summed to obtain an estimate of the total standing stock of fish at Wheeler North Reef. For the purpose of this calculation all 56 Phase 1 modules are considered to be a single polygon.

The standing stock of reef fish calculated for a given year is added to the cumulative total of previous years. The mitigation requirement for fish standing stock will have been met when the total tons of fish accrued by Wheeler North Reef equals the targeted annual value (i.e., 28 tons) x the total years of operation of SONGS Units 2 & 3 (= 32), which amounts to 896 tons of reef associated fish.

Results: The standing stock of reef fish on Wheeler North Reef in 2021 was estimated to be 28 tons, which was 10 more than that estimated for 2019 and 6 more than that for 2020 (Figure 6.1.5a). In 2021, Wheeler North Reef had accumulated a total of 68 of the 896 tons of reef fish required for this performance standard (Figure 6.1.5b).

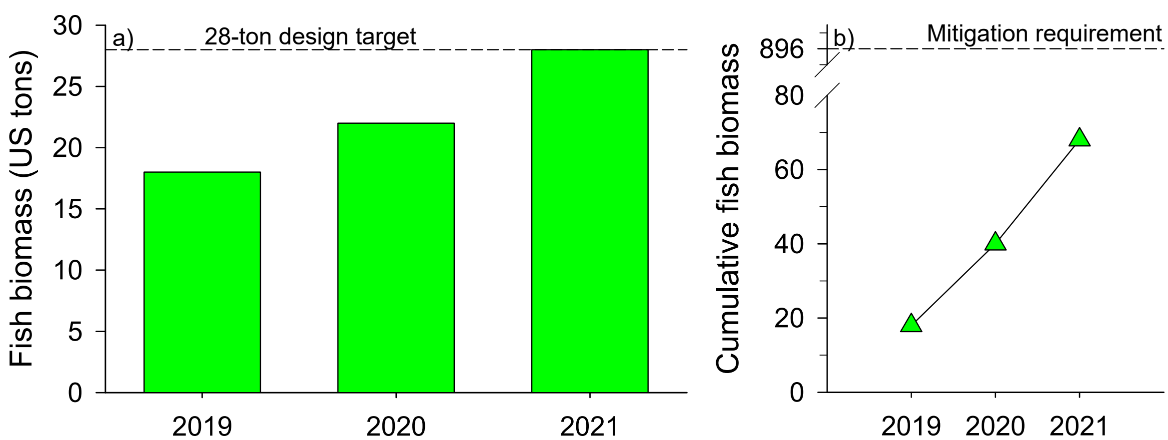


Figure 6.1.5. (a) Estimated standing stock of fish at Wheeler North in 2019 – 2021 and (b) cumulative fish biomass at Wheeler North Reef in 2019 – 2021.

2021 was the first year that Wheeler North Reef has ever met the 28-ton design target for reef fish standing stock (Figure 6.1.6), which is only 1 year after the completion of the 198-acre Phase 3 expansion. Phase 1 (25 acres) contributed 3 of the 28 tons, Phase 2 (150 acres) contributed 18 tons and Phase 3 (198 acres) contributed 7 tons. It is noteworthy that the standing stock of fish on the Phase 1 and 2 reefs did not decline with the addition of the Phase 3 reef in 2020. This indicates that the biomass of fish in the newly constructed Phase 3 expansion reef is additive and that there is no evidence that it is having an adverse effect on fish standing stocks of the Phase 1 and Phase 2 reefs.

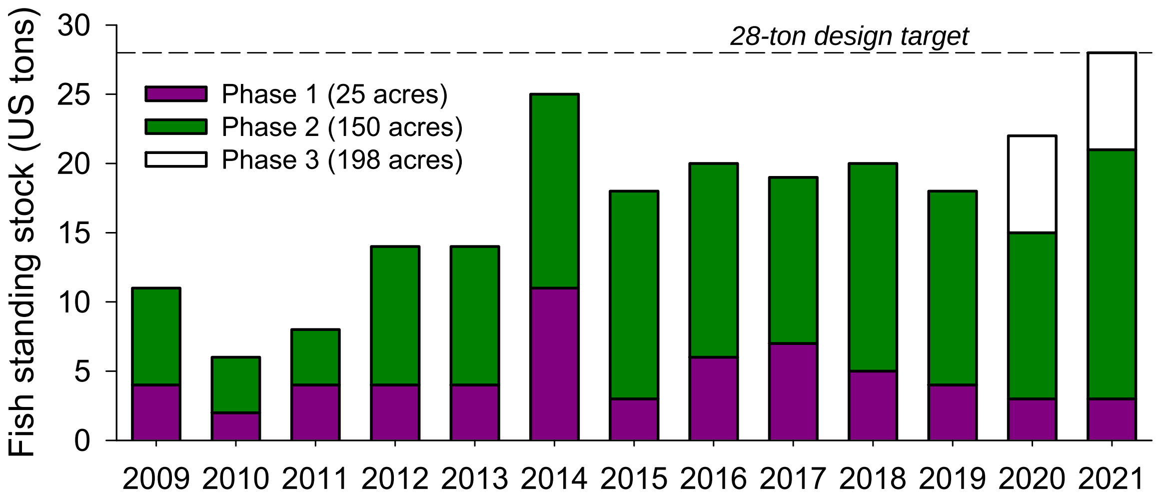


Figure 6.1.6. The number of acres of medium to high density adult kelp for Phase 1 modules, Phase 2 and Phase 3 polygons at Wheeler North Reef in 2019 – 2021.

The standing stock of fish at Wheeler North Reef has been consistently within the range estimated for the two reference reefs when scaled to the area of the Wheeler North Reef (Figure 6.1.7).

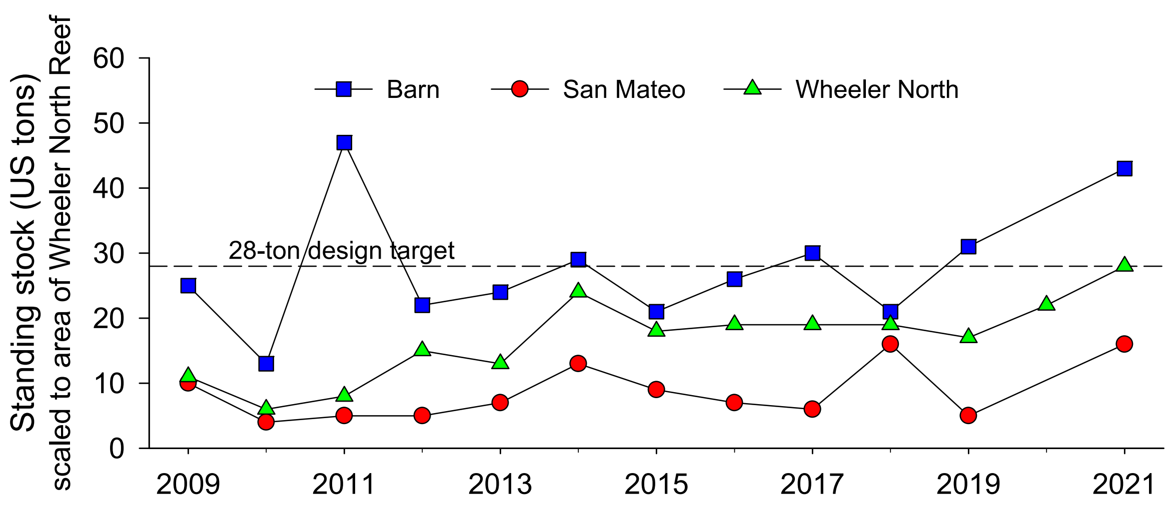


Figure 6.1.7. Mean (± 1 standard error) biomass density of kelp bed fish within 2 m of the bottom at Wheeler North Reef, San Mateo and Barn from 2009 – 2021. Values for San Mateo and Barn are scaled to the area of Wheeler North Reef, which changed from 175 acres during 2009 – 2019 to 373 acres beginning in 2020. 2020 data for San Mateo, Barn was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 outbreaks of some native species along with the introduction of invasive non-indigenous species have the potential to impair these functions and thus prevent Wheeler North Reef from attaining its mitigation goal of compensating for the loss of marine resources caused by SONGS' operations. Invasive reef species may include non-native taxa such as the green seaweeds *Caulerpa taxifolia* and *C. prolifera,* 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. Native species that may become undesirable when they attain very high abundances include dense aggregations of sessile invertebrates that can monopolize space and exclude other species including giant kelp, and starved sea urchins that overgraze the bottom and create large deforested areas commonly called sea urchin barrens (Graham et al. 2007, Schiel and Foster 2015). Data on the abundance of potentially undesirable and invasive species are collected as part of the monitoring done to evaluate the biological performance standards pertaining to the benthic community of reef algae, invertebrates and fish.

Important functions refer to the natural physical, chemical and biological processes or services that species play in the ecosystem in which they occur. Unlike discrete properties of species in an ecosystem (e.g., abundance, diversity), functional attributes emphasize rates of physiological/ecological processes (e.g., primary production, nutrient cycling) or ecological roles (e.g., the provision of structure, buffers to disturbance) that species play in defining an ecosystem. Such functions can be logistically difficult to measure and quantifying them often requires substantial effort and funding.

Reef fishes are highly valued for the ecological and socioeconomic importance and their production is a highly desirable function. This is especially true for artificial reefs whose role in attracting fish vs. producing fish has long been debated (Bohnsack 1989, Grossman et al. 1997, Pickering and Whitmarsh 1997). Fish production in the case of Wheeler North Reef is one of the relative performance standards by which it is judged and its use in evaluating this performance standard incurs no additional effort or cost. Net primary production (NPP) is one of the more important functions of an ecosystem as it provides the basis for sustaining life on Earth and NPP by giant kelp forests is among the highest of any ecosystem in the world (Reed and Brzezinski 2009). In contrast to the secondary production by reef fishes, measuring NPP by by giant kelp is not required for evaluating the performance of Wheeler North Reef. Although NPP by giant kelp is very time consuming to measure, it can be predicted from more easily obtained data of kelp frond density (Rassweiler et al. 2018), which are routinely collected as part of the evaluation of the performance standard pertaining to giant kelp area.

The secondary production by reef fishes and net primary production by giant kelp were selected as the “important functions” for evaluating this performance standard because of their important ecological roles, the minimal additional effort required to estimate them, and their overall relevance to the objectives of the reef mitigation requirement,

The evaluation of the performance standard pertaining to undesirable and invasive species involves a three-step approach. First, the performance of Wheeler North Reef with respect to reef fish production and giant kelp NPP is assessed relative to the two reference reefs to determine whether these important functions of Wheeler North Reef are impaired relative to the lowest performing reference reef. Second, data collected 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 and to assess whether key reef functions are negatively related to their abundance.

Results: We found little indication that important ecological functions of Wheeler North Reef were impaired in 2021 relative to the reference reefs at Barn and San Mateo. Results from monitoring showed that annual net primary production by giant kelp at Wheeler North Reef in 2021 was within the range of the two reference reefs (Figure 6.1.8a), and the average for 2018, 2019 and 2021 was slightly above the range (Figure 6.1.8b). While the secondary production by fishes at Wheeler North Reef declined in 2021, it was still within the range of the two reference reefs as was its average for 2018, 2019 and 2021 (Figure 6.1.8c and d).

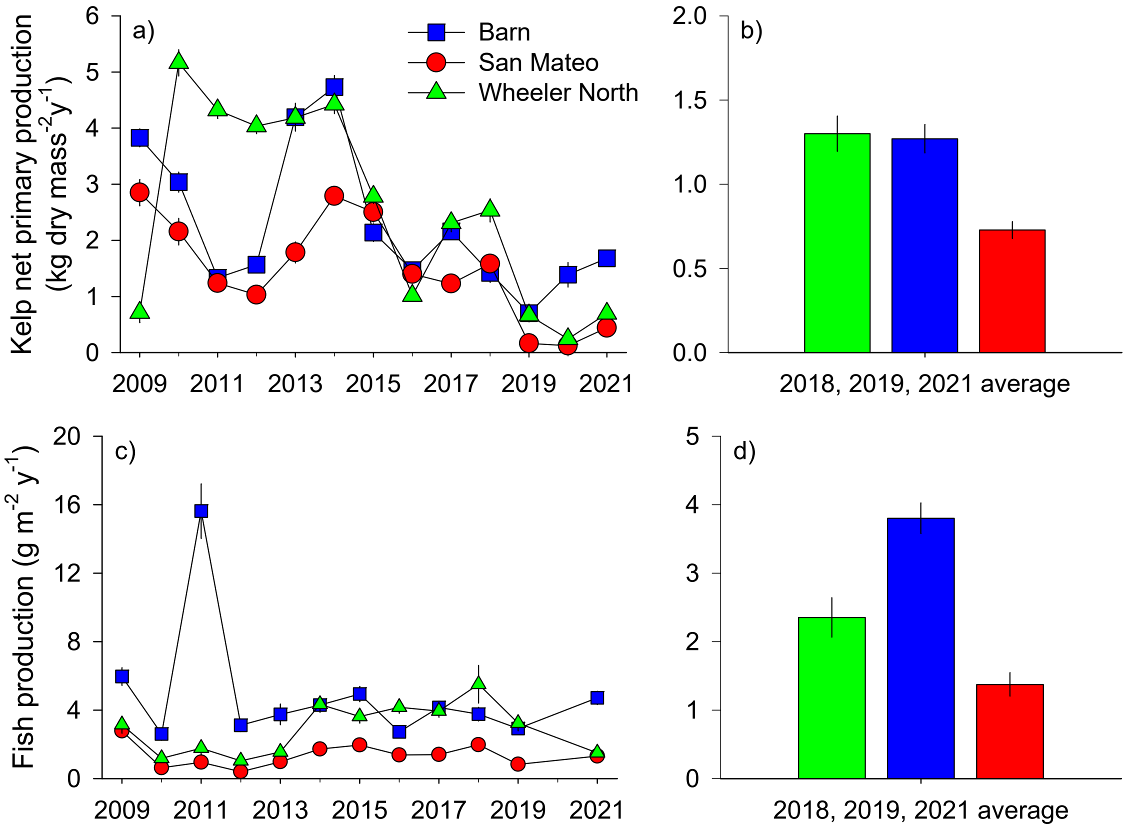


Figure 6.1.8. Mean (± 1 standard error) giant kelp net primary production at Wheeler North Reef, San Mateo and Barn for: (a) annual values for 2009 – 2021 and (b) average values for 2018, 2019 and 2021. Mean (± 1 standard error) fish primary production at Wheeler North Reef, San Mateo and Barn for: (c) annual values for 2009 – 2021 and (d) average values for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

Potentially undesirable native species of particular interest for this project are sea fans (*Muricea* spp.), which are known to attain high abundances on artificial reefs in California and exclude other species, including giant kelp (Patton et al. 1996). The percent cover of sea fans at Wheeler North Reef has steadily increased since the first year of monitoring in 2009 (Figure 6.1.9a). While the cover of sea fans is high at Wheeler North Reef relative to San Mateo and Barn it does not appear to be sufficient to substantially impact the abundances of other species in the benthic community. Importantly, we found no relationship between the percent cover of *Muricea* on a transect and the net primary production of giant kelp (Figure 6.1.10a and b) or the secondary production by reef fishes (Figure 6.1.10 c and d) using data for 2021 or for the average of 2018, 2019 and 2021. These results indicate that *Muricea* had no significant impact on these important ecological functions of Wheeler North Reef in 2021 or when averaged over the past several years

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}. Monitoring data from 2009 – 2020 show that sea urchin densities have been consistently low at Wheeler North Reef averaging about 1 individual m^{-2} (Figure 6.1.9b). This density is far below that needed to significantly impact giant kelp and other components of the benthic community. Not surprisingly, giant kelp NPP and reef fish production were unrelated to the density of sea urchins (Figure 6.1.10e-h) using data collected in 2021 or the average of 2018, 2019 and 2021. This provides further evidence that sea urchins did not impair the important ecological functions of Wheeler North Reef.

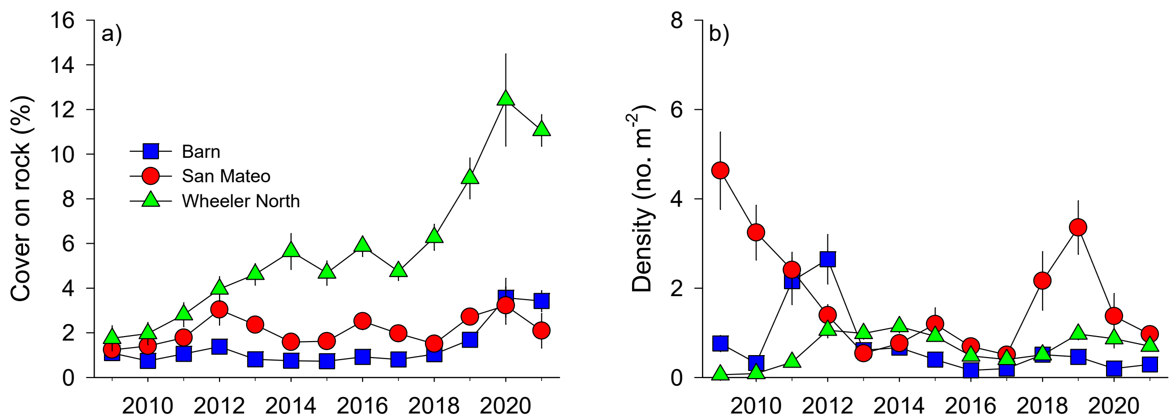


Figure 6.1.9. Mean (± 1 standard error) for (a) the percent cover of the sea fan *Muricea* spp. on hard substrate and (b) the density of sea urchins at Wheeler North Reef, San Mateo and Barn for 2009 – 2021.

No non-native species of invasive algae were recorded in the 92 transects sampled at Wheeler North Reef in 2021, which was also the case from 2009 – 2013. A single non-reproductive individual of *Sargassum horneri*, a non-native brown alga that has been expanding throughout southern California and Baja California (Marks et al. 2015), was observed in 2014 and a few more individuals of this species were observed in 2015 – 2018. Furthermore, very few non-native invertebrate species and no non-native fishes have been recorded at Wheeler North Reef since it was constructed.

Based on the above results we conclude that invasive or undesirable species did not impair important ecological functions of Wheeler North Reef. Thus Wheeler North Reef met this performance standard in 2021.

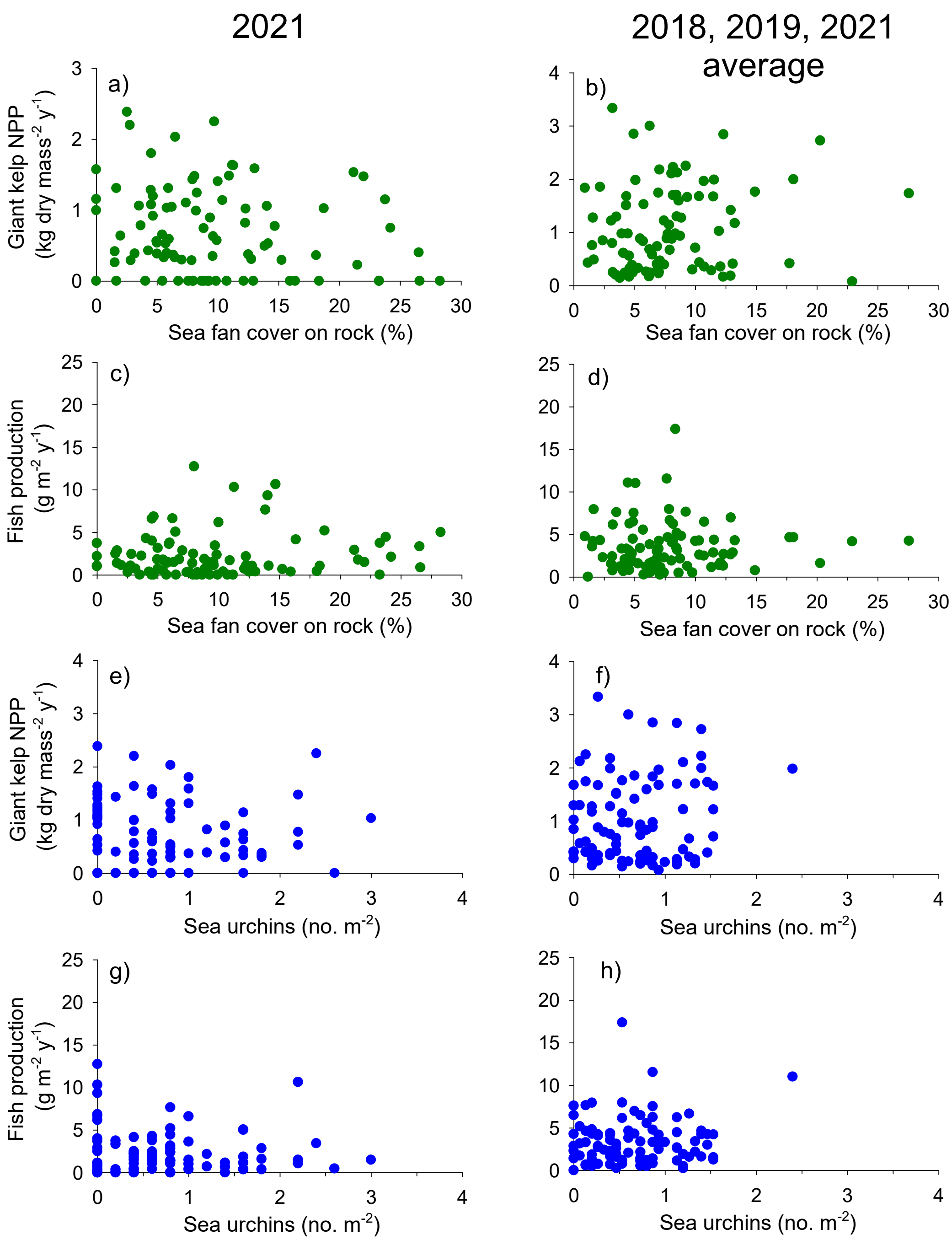


Figure.6.1.10. Mean percent cover of sea fans on rock (green circles) vs.: (a) giant kelp net primary production in 2021, (b) giant kelp net primary production averaged for 2018, 2019, and 2021, (c) reef fish production in 2021 and (d) reef fish production averaged for 2018, 2019, and 2021. Mean density of sea urchins (blue circles) vs.: (e) giant kelp net primary production in 2021, (f) giant kelp net primary production averaged for 2018, 2019, and 2021, (g) fish production in 2021, and (h) fish production averaged for 2018, 2019, and 2021. P > 0.05 for figures a through h.

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 macroalgae and sessile invertebrates provide a measure of the biomass of the benthic community attached to the hard substrate of a reef. Because many species of macroalgae 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 10 m intervals along each of the eighty-two 50 m transects. At Wheeler North Reef, 12 of these transects are located in the Phase 1 modules and 70 are in 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 intersecting 20 uniformly placed points within each quadrat. 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 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 9% in 2011 after the surface canopy of giant kelp became fully established (Figure 6.2.1a). It steadily increased to 48% in 2016 coincident with the decline in the abundance of giant kelp and has remained at about 40% since then. Importantly, the percent cover of macroalgae at Wheeler North Reef has been consistently lower than that at the two reference reefs since 2010, with the biggest discrepancy occurring from 2018 – 2021 when its cover was about half that of San Mateo and Barn. As a result, the average cover of macroalgae at Wheeler North Reef in 2018, 2019 and 2021 was significantly lower than that of both reference reefs (Figure 6.2.1b). Consequently, the Wheeler North Reef did not meet this performance standard in 2021.

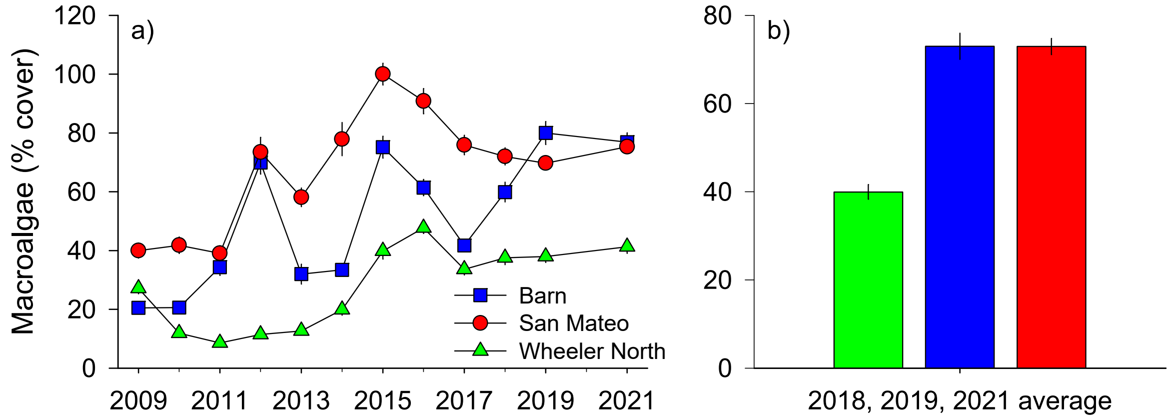


Figure 6.2.1. Mean percent cover (± 1 standard error) of macroalgae at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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

Approach: Data on the percent cover of macroalgae in the 1 m^2 quadrats are combined with data on the density of larger algal species sampled in the 20 m^2 quadrats to determine the total number of species of macroalgae per transect at Wheeler North Reef, San Mateo, and Barn. These values are averaged over the 82 transects on each reef to provide an estimate of average species density of macroalgae 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.

Results: Temporal fluctuations in the average number of macroalgal species per transect at Wheeler North Reef, Barn and San Mateo largely mirrored those of macroalgal percent cover in that species richness at Wheeler North Reef has been consistently (and usually substantially) lower than that at the two reference sites. (Figure 6.2.2a vs. Figure 6.2.1a). Macroalgal species richness has showed an increasing trend at all sites since 2013, with the exception that species richness has declined slightly at San Mateo since 2017. This decline at San Mateo coupled with the continuing increase at Wheeler North Reef resulted in near identical mean values of macroalgal richness for the two sites in 2021 (Figure 6.2.2a). However, Wheeler North Reef failed to meet this performance standard in 2021 because its mean number of macroalgal species per transect averaged over 2018, 2019 and 2021 was significantly lower than that of both reference reefs (Figure 7.2.2b).

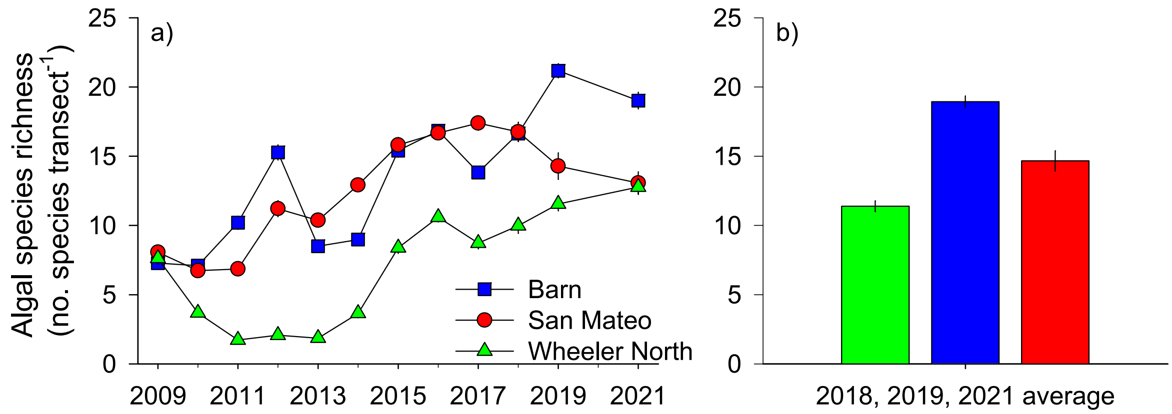


Figure 6.2.2. Mean (± 1 standard error) number of species of understory algae per 100 m^{-2} at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 5.2.39). This is 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 6.2.3a vs. Figure 6.2.2a). The percent cover of sessile invertebrates and algae remained relatively constant from 2012 – 2014 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 6.2.3a); the exact opposite pattern that was observed for the percent cover of macroalgae at these sites (Figure 6.2.2a). All three sites showed a sharp increase in the percent cover of sessile invertebrates in 2017 to ~ 40%. The cover of sessile invertebrates has remained near this level at Wheeler North Reef through 2021, declined slightly to ~ 35% at San Mateo, and fluctuated substantially at Barn (Figure 6.2.3a). The greater fluctuation in sessile invertebrate cover at Barn mirrors the greater fluctuations in the area of medium-to-high adult giant kelp observed at this site (Figure 6.1.3). In 2021 the average of the percent cover of sessile invertebrates for 2018, 2019 and 2021 was higher at Wheeler North Reef compared to San Mateo and Barn (Figure 6.2.3b). As a result, Wheeler North Reef met this performance standard in 2021.

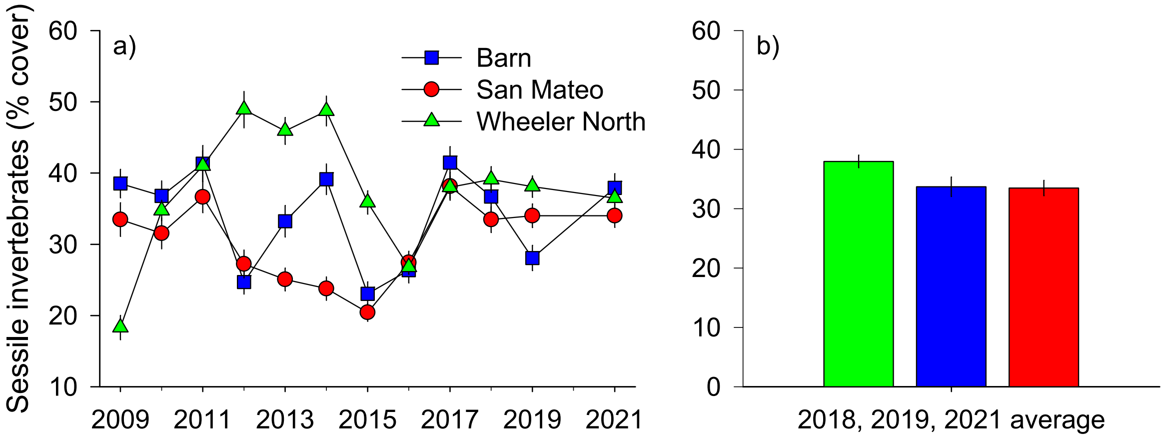


Figure 6.2.3. Mean percent cover (± 1 standard error) of sessile invertebrates at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 10 m x 2 m plots centered along each 50 m transect. Depending on their size and abundance, smaller solitary mobile invertebrates (e.g., brittle stars, nudibranchs, sea cucumbers) are counted in either a 1 m^2 or a 0.5 m^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 6.2.4a). Mobile invertebrate density steadily declined at Wheeler North Reef from 2012 – 2016, largely due to a decrease in the density of brittle stars, which associate with the holdfasts of giant kelp and are typically the most numerous mobile invertebrate on the reef. As kelp increased in 2017 so did the density of brittle stars and the overall density of mobile invertebrates reached 40 m^{-2} in 2017 and 2018 before declining to 23 m^{-2} in 2021. Since 2012, temporal trends in the density of mobile invertebrates at San Mateo and Barn have mirrored those at Wheeler North Reef (Figure 6.2.4a). The four-year running average of mobile invertebrate density at Wheeler North Reef in 2021 was statistically similar to that at San Mateo and significantly greater than that at Barn (Figure 6.2.4b). As a result, Wheeler North Reef met this performance standard in 2021.

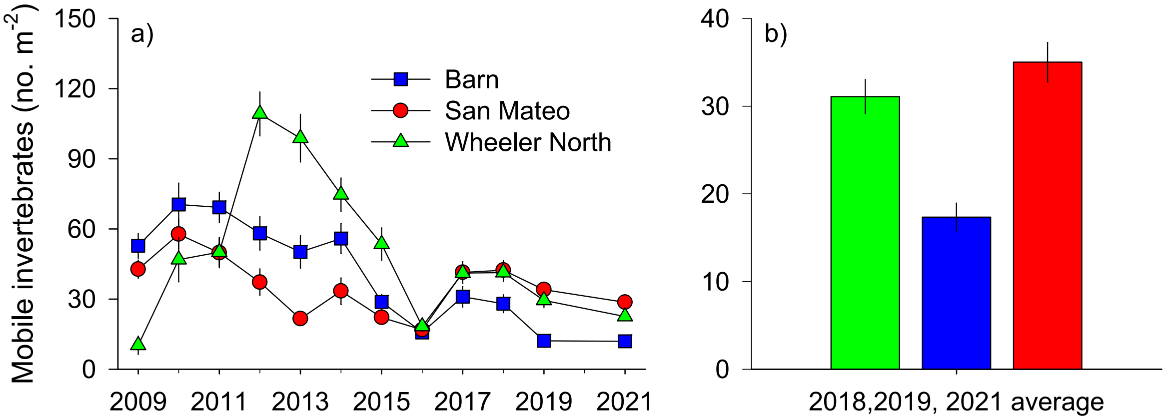


Figure 6.2.4. Mean density (± 1 standard error) of mobile invertebrates at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 (i.e., sessile + mobile combined) on each transect at Wheeler North Reef, San Mateo, and Barn. These values are averaged over the 82 transects on each reef to provide an estimate of average species density of benthic invertebrates per transect at each of the three reefs. 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.

Results: The average number of species of benthic invertebrates per transect at the two reference reefs declined slightly from 2009 to 2016, whereas it 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 6.2.5a). It has remained near this high level except in 2016 when invertebrate diversity declined on all three reefs. Mean invertebrate species richness for the three-year period of 2018, 2019 and 2021 was very similar at all three reefs averaging about 34 species per transect (Figure 6.2.5b). As a result, Wheeler North Reef met this performance standard in 2021.

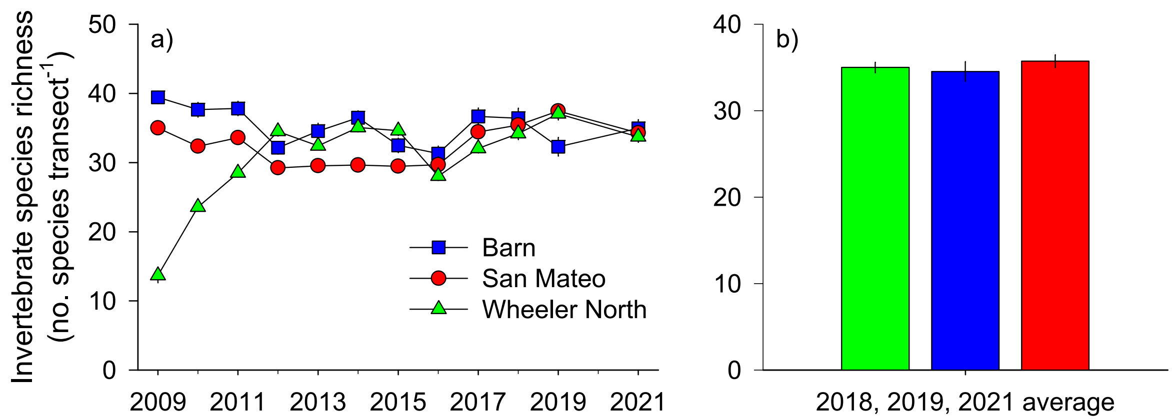


Figure 6.2.5. Mean species density (± 1 standard error) of invertebrates at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 50 m x 3 m x 1.5 m transects sampled on each reef. 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.

Results: In 2009, 1 year after its construction, the density of resident fish at Wheeler North Reef was 50% higher than Barn and 300% higher than San Mateo (Figure 6.2.6a). Since then, fluctuations in fish densities have been relatively similar among the three reefs with the highest densities typically observed at Barn and Wheeler North Reef and the lowest densities at San Mateo. The lone exception was a spike in resident fish density at Barn in 2011 when large schools of señorita were observed on several transects. The average resident fish density for 2018, 2019 and 2021 at Wheeler North Reef was ~13% lower than that at Barn but 50% higher than that recorded at San Mateo (Figure 6.2.6b). Thus, Wheeler North Reef met the performance standard for resident fish density in 2021.

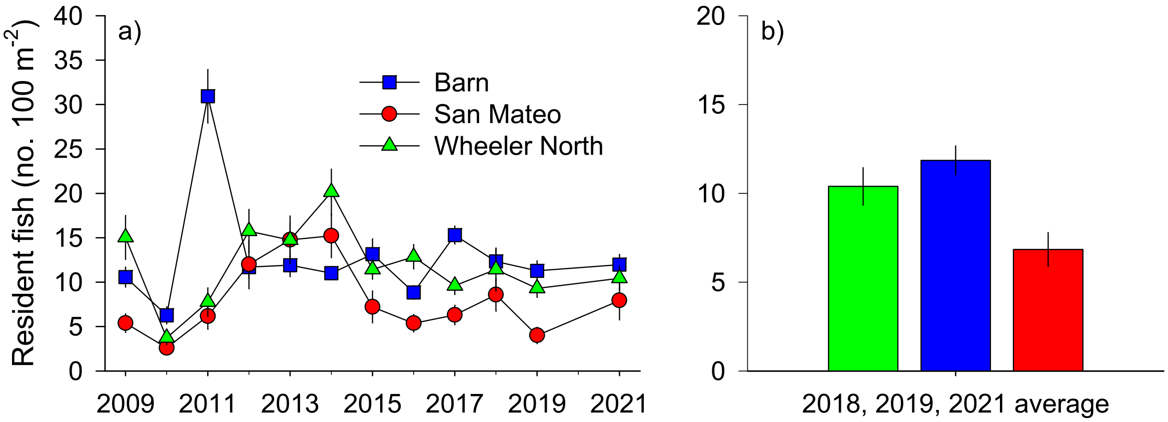


Figure 6.2.6. Mean density (± 1 standard error) of resident fish at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 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 Wheeler North Reef and the reference reefs are collected using the same methods and at the same time as data for resident fishes. The approach used for determining whether the density of 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 6.2.7a) 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 or above the range set by San Mateo and Barn. YOY densities declined precipitously at all three reefs in 2016 and have remained low reflecting the near absence of blackeye gobies. This cool-water species has a life span of about two years and its low regional abundance the past five years reflects low recruitment that may be linked to anomalously warm water during 2014 – 2016. Densities of this species increased substantially at Wheeler North Reef in 2021 but not appreciably so at Barn and San Mateo. As a result, the average for YOY density at Wheeler North Reef for 2018, 2019 and 2021 was twice that observed at San Mateo and Barn (Figure 6.2.7b). Thus, Wheeler North Reef met the performance standard for YOY density in 2021.

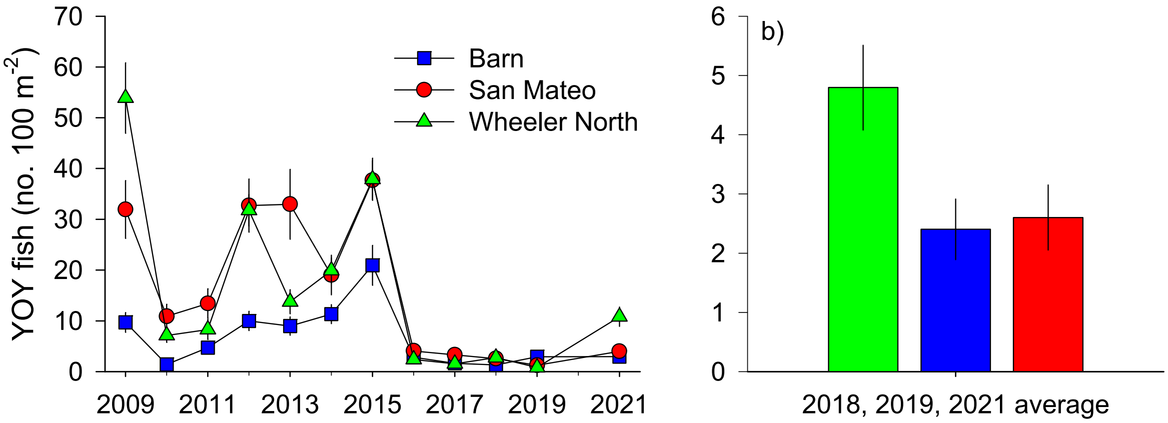


Figure 6.2.7. Mean density (± 1 standard error) of young-of year fish at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 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 the 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.

Results: The mean number of fish species per transect has largely fluctuated synchronously over time at the three reefs (Figure 6.2.8a). In general, Barn and Wheeler North Reef have displayed the highest diversity of fishes and San Mateo has consistently displayed the lowest diversity. The average number of fish species per transect at Wheeler North Reef for the three-year period of 2018, 2019 and 2021 was within the range set by the two reference reefs (Figure 6.2.8b). Thus, Wheeler North Reef met the performance standard for fish species richness in 2021.

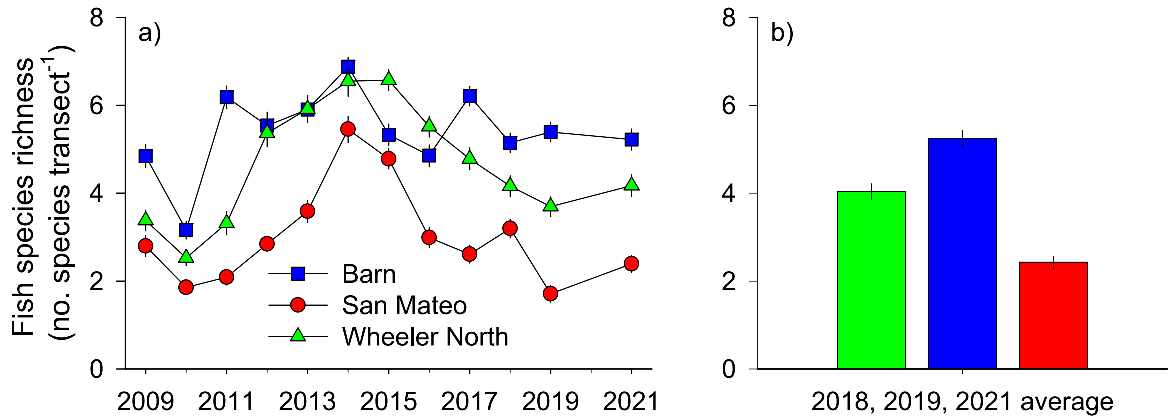


Figure 6.2.8. Mean species density (± 1 standard error) of fish at Wheeler North Reef, San Mateo and Barn. (a) annual values for 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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. 2021).

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 Wheeler North Reef mirrored those at San Mateo but with slightly higher values from 2009 through 2013 and significantly higher values from 2014 – 2019 (Figure 6.2.9a). Fish production at Barn has followed a similar trajectory but, with a notable spike in all five target species in 2011. In 2021, fish production at Wheeler North Reef declined to a value similar to that observed at San Mateo. Wheeler North Reef met the performance standard for fish production in 2021 as its average for 2018, 2019 and 2021 was intermediate between Barn and San Mateo (Figure 6.2.9b).

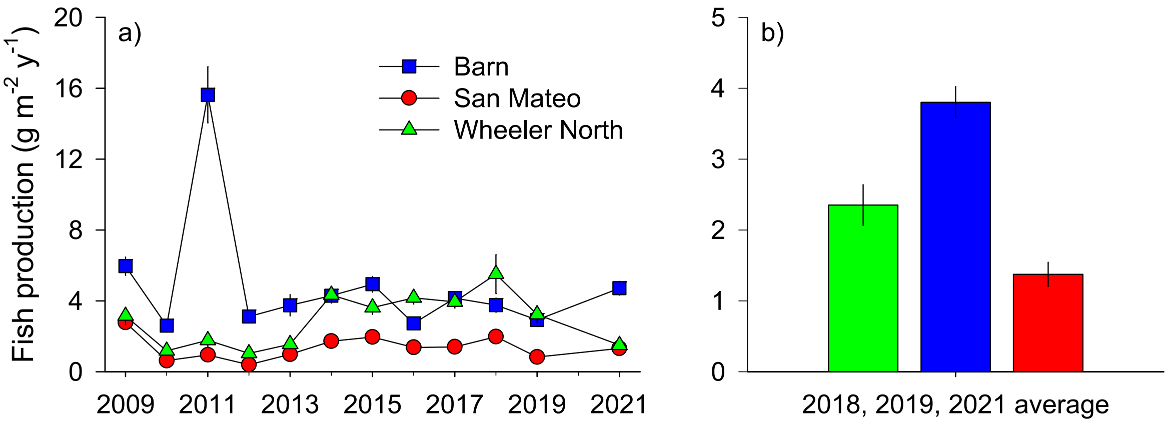


Figure 6.2.9. Mean fish production (± 1 standard error) at Wheeler North Reef, San Mateo and Barn. (a) annual values from 2009 – 2021 and (b) 3-year average for 2018, 2019 and 2021. 2020 data was excluded due to reduced monitoring imposed by COVID-19 restrictions.

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 at a level similar to that of natural reefs. 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 Wheeler North Reef met this performance standard for a given year (see Appendix 1 in Reed et al. 2021 for details). Resampling 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 13 years of monitoring (Figure 6.2.10a). 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 somewhat 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 constant over time and in 2021 did not differ significantly among the three reefs (Figure 6.2.10b). Consequently, Wheeler North Reef met this performance standard in 2021.

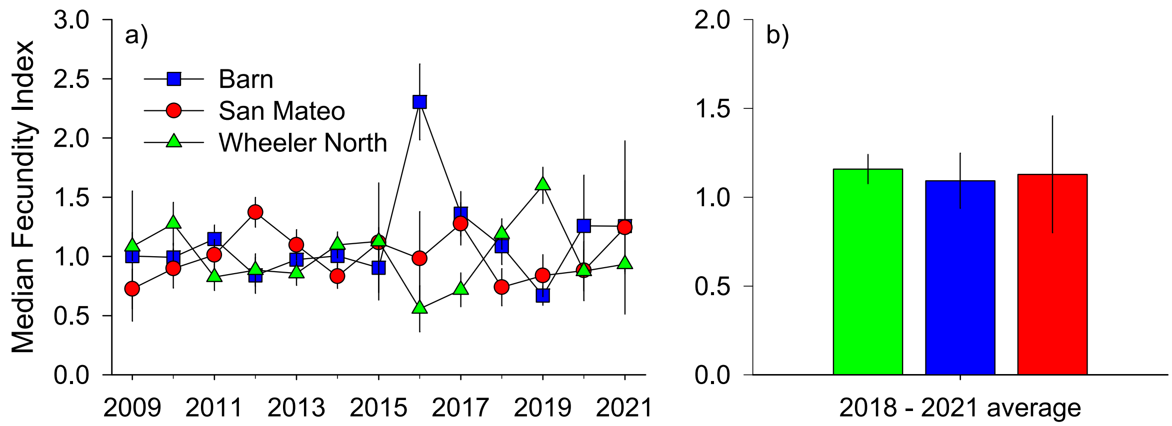


Figure 6.2.10. Median fecundity index (± 1 standard deviation) at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 – 2021 and (b) 4-year running average.

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 in supporting the nutritional needs of reef fishes, but the most direct and cost efficient of these approaches involves sampling gut contents in reef fishes that feed on the bottom and are collected for other purposes. Such is the case for the black surfperch and the California sheephead. Both species feed almost exclusively on benthic prey, and individuals of these species are collected for purposes of evaluating the performance standards pertaining to fish reproductive rates and fish production. Once collected, black surfperch and sheephead specimens are placed on ice and transported to the laboratory where they are either immediately dissected and processed or frozen whole 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) for each species that is based on the mass of the gut contents relative to the body mass of the fish

$$FCS = \frac{g}{b - (r + g)}$$

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

The overall FCS value for the reefs in a given year should represent both species and not be influenced by differences in the number of observations per species, which inevitably varies between species and among reefs. Hence, the average FCS values each species are averaged to produce a mean FCS Index for each reef and year. For Wheeler North Reef to meet this performance standard its four-year running average of the mean FCS Index must not be significantly less than that of the reference reef with the lower four-year running average. The proportional effect size is calculated using the four-year running FCS index values of Wheeler North Reef and the lower performing reference reef using the equation below, which for the purpose of illustration assumes Wheeler North Reef (WN) has a lower value than the lower performing reference reef (RR).

Proportional effect size = $(FCS_{RR} – FCS_{WN}) / FCS_{RR}$

Testing for significant differences in the mean FCS index between the reefs with the two lowest values in any given year involves calculating the proportional effect size between the four-year running averages of the two reefs (shown above) and the probability (i.e., p-value) that they are significantly different as described in Section 4.3. The calculation of a p-value involves a resampling procedure of standardized FCS values (i.e., z transformed data by each species, reef and year) to ensure each species and reef are weighted equally. Standardized FCS values for each species and reef in a given year are resampled with replacement and this process is iterated to ultimately produce a "null" distribution of the four-year averaged standardized FCS values from which the p-value is calculated.

Results: The Mean FCS Index at the three reefs has fluctuated erratically over time with large swings observed at all three reefs at some point in the 13-year time series (Figure 6.2.11a). This was especially true in 2011 when all three reefs showed dramatic increases in FCS and in 2020 when Wheeler North Reef and San Mateo (but not Barn) showed large declines.

The four-year running average of the mean FCS Index has gradually increased at all three reef since 2012. During this period the four-year average at Wheeler North Reef was within the range set by San Mateo and Barn in six of the ten years, including 2021 (Figure 6.2.11b). Consequently, Wheeler North Reef met this performance standard in 2021.

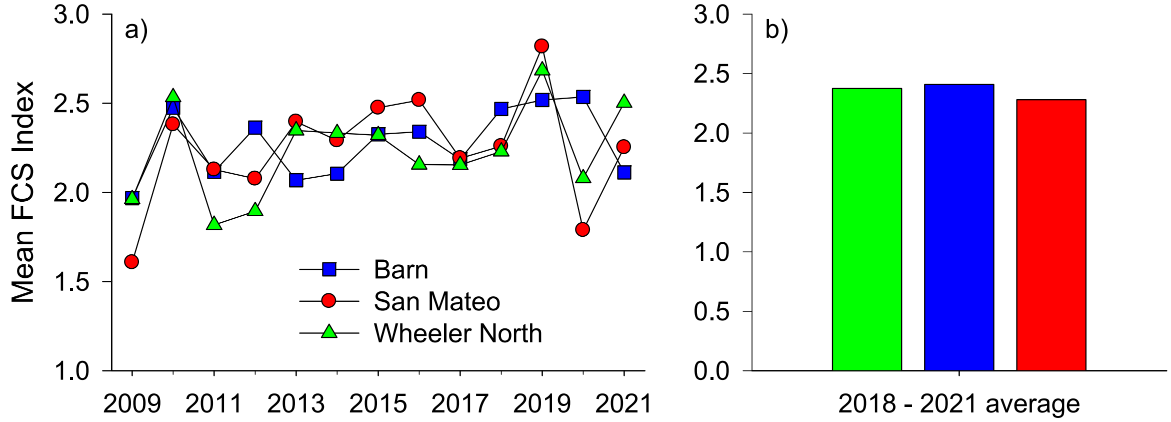


Figure 6.2.11. Mean food chain support (FCS) index at Wheeler North Reef, San Mateo and Barn (a) annual values for 2009 – 2021 and (b) 4-year running average.

7.0 Permit Compliance

7.1 Summary of the performance of Wheeler North Reef and earned mitigation credit

Annual mitigation credit

Mitigation credit for Wheeler North Reef is assigned on an annual basis for the absolute performance standards for hard substrate and undesirable/invasive species and the relative performance standards. To receive mitigation credit for a given year Wheeler North Reef must meet the absolute performance standards for hard substrate and undesirable and invasive species, and at least as many relative standards as the lower performing reference reef. The two absolute performance standards are measured only at Wheeler North Reef and they are assessed using values from either the current year (i.e., 2021) 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). Fulfillment of the mitigation requirement for this collective group of performance standards occurs when the number of years of mitigation credit accrued by Wheeler North Reef equals the total years of operation of SONGS Units 2 & 3 (= 32 years). The accrual of mitigation credit began in 2019 upon construction of the Phase 3 remediation reef.

A summary of the performance of Wheeler North Reef from 2012 - 2021 with respect to the two absolute performance standards for hard substrate and undesirable/invasive species and the 11 relative performance standards is shown in Table 7.1.1. In 2021, Wheeler North Reef met the two absolute standards and 9 of the 11 relative performance standards, which was one less than the number of relative standards met by Barn and two more than met by San Mateo. Wheeler North Reef underperformed relative to the reference reefs with respect to the percent cover and number of species of macroalgae (Figures 6.2.1 and 6.2.2), which it has consistently done since 2012.

Wheeler North Reef earned one year of mitigation credit in 2021 for meeting the absolute standards for hard substrate and undesirable/invasive species and at least as many relative standards as San Mateo, the lower performing reference reef (Table 7.1.2a). It also earned a year of credit for meeting these standards in 2019 and 2020 for a total of 3 years of mitigation credit. It needs another 29 years of credit in order to fulfill its mitigation requirement for this collective group of performance standards.

a) Wheeler North Reef										
Performance Standard	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1) Algal cover	No	No	No	No	No	No	No	No	No	No
2) Algal species richness	No	No	No	No	No	No	No	No	No	No
3) Sessile invertebrate cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4) Mobile invertebrate density	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5) Invertebrate species richness	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6) Resident fish density	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7) YOY fish density	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8) Fish species richness (all ages)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9) Fish production	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10) Fish reproductive rates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11) Food chain support	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes
Number of relative standards met	**8**	**7**	**8**	**9**	**9**	**9**	**8**	**8**	**9**	**9**

b) San Mateo										
Performance Standard	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1) Algal cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2) Algal species richness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3) Sessile invertebrate cover	No	No	No	No	No	No	Yes	Yes	No	Yes
4) Mobile invertebrate density	No	No	No	No	No	No	Yes	Yes	Yes	Yes
5) Invertebrate species richness	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
6) Resident fish density	No	No	No	Yes	Yes	No	No	No	No	No
7) YOY fish density	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8) Fish species richness (all ages)	No	No	No	No	No	No	No	No	No	No
9) Fish production	No	No	No	No	No	No	No	No	No	No
10) Fish reproductive rates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11) Food chain support	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Number of relative standards met	**6**	**6**	**5**	**6**	**6**	**5**	**8**	**8**	**7**	**7**

c) Barn										
Performance Standard	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1) Algal cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2) Algal species richness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3) Sessile invertebrate cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4) Mobile invertebrate density	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
5) Invertebrate species richness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6) Resident fish density	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7) YOY fish density	No	No	No	No	No	No	No	Yes	Yes	Yes
8) Fish species richness (all ages)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9) Fish production	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10) Fish reproductive rates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11) Food chain support	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Number of relative standards met	**10**	**10**	**10**	**9**	**9**	**10**	**9**	**10**	**10**	**10**

Table 7.1.1 Summary of the performance of Wheeler North Reef from 2012 - 2021 with respect to: (1) the absolute performance standards pertaining to hard substrate and undesirable/invasive species, and (2) the 11 relative performance standards that are used to judge whether it is performing similar to natural reefs in the region. YES means that the standard was met in a given year, NO means that the standard was not met in in a given year. The performance of the natural reefs at (b) San Mateo and (c) Barn with respect to the 11 relative standards are shown for comparison.

a) Annual Performance Standards	2019	2020	2021	Credit accrued	Credit required	Credit still needed
Relative standards	pass	pass	pass			
Hard substrate	pass	pass	pass			
Undesireable/Invasive species	pass	pass	pass			
Mitigation credit awarded	Yes	Yes	Yes	**3 years**	**32 years**	**29 years**
b) Cumulative Performance Standards						
Giant kelp area (acres)	36	4	47	**87**	**4800**	**4713**
Fish Standing stock (US tons)	18	22	28	**68**	**896**	**828**

Table 7.1.2. Summary of mitigation credit accrued by Wheeler North Reef for performance standards that are assigned mitigation credit on: (a) an annual basis and (b) a cumulative basis.

Cumulative mitigation credit

The absolute performance standards established for giant kelp area and fish standing stock are evaluated on a cumulative basis in which full compensation is based on mitigation for total losses rather than for annualized losses. In this case, the area of giant kelp and the standing stock of fish are measured each year and the annual total for each is added to the cumulative total of previous years. Each standard is evaluated independently, and their mitigation requirement is fulfilled when their cumulative total equals the target value (150 acres for kelp and 28 tons for fish standing stock) x the total years of operation of SONGS Units 2 and 3 (= 32). Using this approach, the mitigation requirement for giant kelp area will have been fulfilled when the cumulative kelp area provided by Wheeler North Reef equals 4800 acres (i.e., 150 acres x 32 years). Similarly, the mitigation requirement for reef fish standing stock will have been fulfilled when Wheeler North Reef's cumulative fish standing stock reaches 896 tons (i.e., 28 tons x 32 years).

In 2021, Wheeler North Reef earned credit for 47 acres of giant kelp for a cumulative total of 87 acres and 28 tons of reef fish for a cumulative total of 68 tons (Table 7.1.2b). It needs an additional 4713 acres of kelp credit and 828 tons of fish standing stock credit to fulfill these two mitigation requirements.

8.0 Future Monitoring Plans

Monitoring of the performance standards at Wheeler North Reef, San Mateo and Barn will continue in 2022 as required by the SONGS permit. Full monitoring consisting of 151 transects at Wheeler North Reef and 82 transects at each of the two reference reefs is planned for 2022.

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