

Performance of the Wheeler North Reef

2023 Monitoring Results



April 8, 2024

SONGS Mitigation Monitoring Project
Marine Science Institute, University of California Santa Barbara

Performance Standards

The SONGS coastal development permit requires the use of different types of performance standards for evaluating the success of Wheeler North Reef in meeting its mitigation goals

Types of Performance Standards

1. Relative performance standards that require Wheeler North Reef to be similar to reference sites every year
2. Absolute performance standards measured at Wheeler North Reef only that must be met every year
3. Absolute performance standards measured at Wheeler North Reef only that accumulate mitigation credit over time until a required value is met

The goal of the Wheeler North Reef is to compensate for the loss of kelp forest habitat caused by the operations of SONGS.

- A variety of physical and biological performance standards are used to determine whether this goal is met

Three types of performance standards are used to judge the success of the Wheeler North Reef in meeting its goal

- 1) Relative performance standards, that require Wheeler North Reef to be similar to reference sites every year
- 2) Absolute performance standards measured at Wheeler North Reef only that must be met every year
- 3) Absolute performance standards measured at Wheeler North Reef only that accumulate mitigation credit over time until a required value is met.
 - The mitigation requirements for these “cumulative” absolute performance standards are based on estimated losses at the San Onofre kelp bed caused by SONGS operations

Relative Performance Standards

(requires comparison to natural reference reefs)

RATIONALE: To be successful, the Wheeler North Reef must sustain a kelp forest community that is *similar* to those of natural reefs in the region.

Criteria for reference reef selection:

- 1) History of sustaining giant kelp
- 2) Occur at a depth similar to that of the artificial reef
- 3) Primarily low relief, preferably consisting of cobbles & boulders
- 4) Located within the local region, but not affected by SONGS

The kelp forests at San Mateo and Barn best met these criteria



- Evaluating the relative performance standards requires comparing Wheeler North Reef to natural reference reefs in the region.
- Choosing the natural reefs that are used for reference was a critical element of the mitigation project because they form the basis for determining whether Wheeler North Reef is successful in meeting its goals
- The nearby kelp forests at San Mateo and Barn were selected as reference reefs because they:
 1. have a history of sustaining giant kelp
 2. occur at a depth similar to that of Wheeler North Reef
 3. are similar to the impacted reef at San Onofre in that they are primarily low relief, consisting of cobbles and boulders
 4. are located within the local region but outside the influence of the turbid plume caused by SONGS' operations

Relative Performance Standards

(must be similar to natural reference reefs)

Definition of similar:

The 4-year running average for a relative performance standard at Wheeler North Reef must *not be significantly less than* that at the reference reef with the lowest value for that performance standard

Rationale:

- For a given relative performance standard, the Wheeler North Reef should perform at least as well as the lowest performing reference reef
- The biological characteristics of a reef (natural or artificial) fluctuate over time, and a 4-year running average takes this variability into account when evaluating reef performance

- The SONGS Coastal Development Permit envisioned a quantitative definition of “similar” for comparing the performance of the artificial reef to natural reefs, and it specified that the measure of similarity be defined in the monitoring plan for the project
- After considerable discussion the definition for the measure of similarity that was adopted was “the 4-year running average for a relative performance standard at Wheeler North Reef must not be significantly less than that of the reference reef having the lowest value for that performance standard”
- This definition recognizes that no two natural reefs are identical, but that any reef chosen as a reference site should serve as an acceptable reference
- Because the biological characteristics of reefs often vary from year-to-year and there is a certain amount of error associated with any type of sampling, we use the 4-year running average of the performance standard to help account for this variability

Relative Performance Standards for Wheeler North Reef

1. Macroalgal percent cover
2. Macroalgal species richness
3. Sessile invertebrate percent cover
4. Mobile invertebrate density
5. Invertebrate species richness
6. Resident fish density
7. Young-of-Year fish density
8. Fish species richness
9. Fish reproductive rates
10. Fish production
11. Food chain support
12. Undesirable and invasive species



- Shown here are the 12 relative performance standards that are used to judge the performance of Wheeler North Reef
- Standards 1-5 pertain to the benthic community of macroalgae and invertebrates
- Standards 6-10 pertain to reef fishes
- Standard 11 integrates the benthic community of macroalgae and invertebrates with reef fishes by examining the extent to which the benthic community supplies food for reef fishes
- Standard 12 relates to impairment of important reef functions caused by an over abundance of native or non-native

Evaluation of Relative Performance Standards *(must perform as well natural reference reefs)*

Criteria

Wheeler North Reef (WNR) must meet as many relative performance standards as the lowest performing reference reef in a given year for that year to count towards mitigation credit

- *The lone exception is the performance standard for undesirable and invasive species, which must be met every year*

Rationale

Requiring WNR to meet at least as many relative performance standards as the reference reefs achieves the desired goal of WNR being similar to natural reefs without requiring it to consistently outperform them

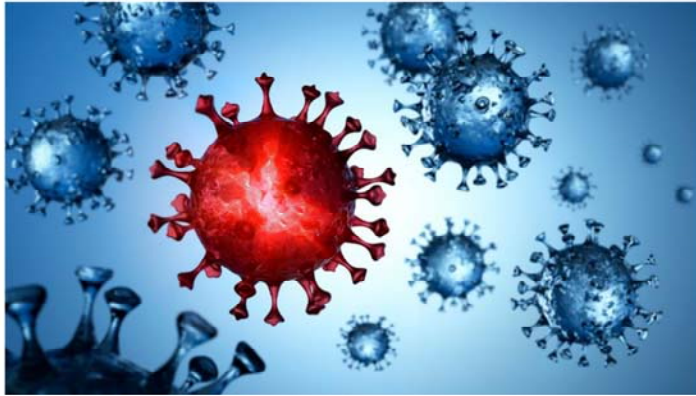
Method of Evaluation

1. Evaluate WNR and the reference reefs with respect to each other to determine whether they meet each relative performance standard
2. Tally the total number of relative performance standards met by each reef (*not counting the performance standard for undesirable and invasive species*) and compare the totals

- Because natural kelp forests vary greatly over time in their species composition and abundance, it is likely that they too would not consistently meet all the relative performance standards in a given year
- Therefore, to avoid requiring Wheeler North Reef to perform better than the reference reefs, Wheeler North Reef is required to meet only as many of the relative standards as the lowest performing reference reef in a given year for that year to count towards mitigation credit
- *The lone exception is the performance standard for undesirable and invasive species, which must be met every year*
- This approach achieves the desired goal of Wheeler North Reef being similar to natural reefs without requiring it to consistently outperform them
- The method involves evaluating the performance of the three reefs relative to each other to determine whether they meet each relative standard
- The total number of relative standards met by each reef (not counting the performance standard for undesirable and invasive species) is then tallied and compared

Performance Monitoring Impacts of COVID-19

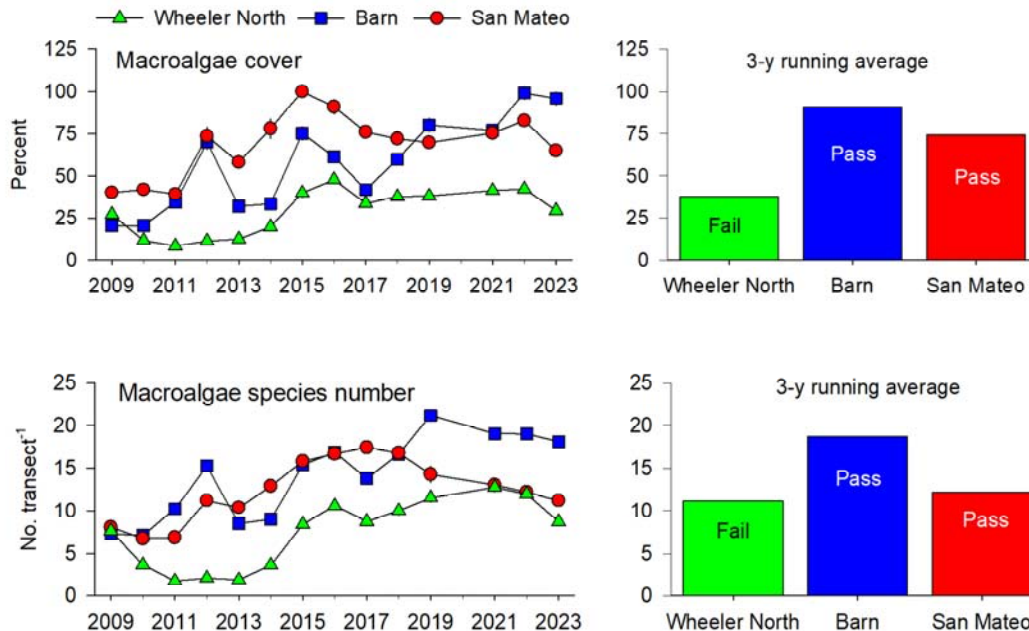
University sponsored research was shutdown from mid March to mid July 2020 causing a large reduction in sampling effort in 2020



- As a result, 2020 data were excluded from the 4-year running average used to evaluate many of the performance standards in 2023 (i.e., the running average for 2023 is based on data collected 2021, 2022 and 2023 only)

Performance Standards: Macroalgae

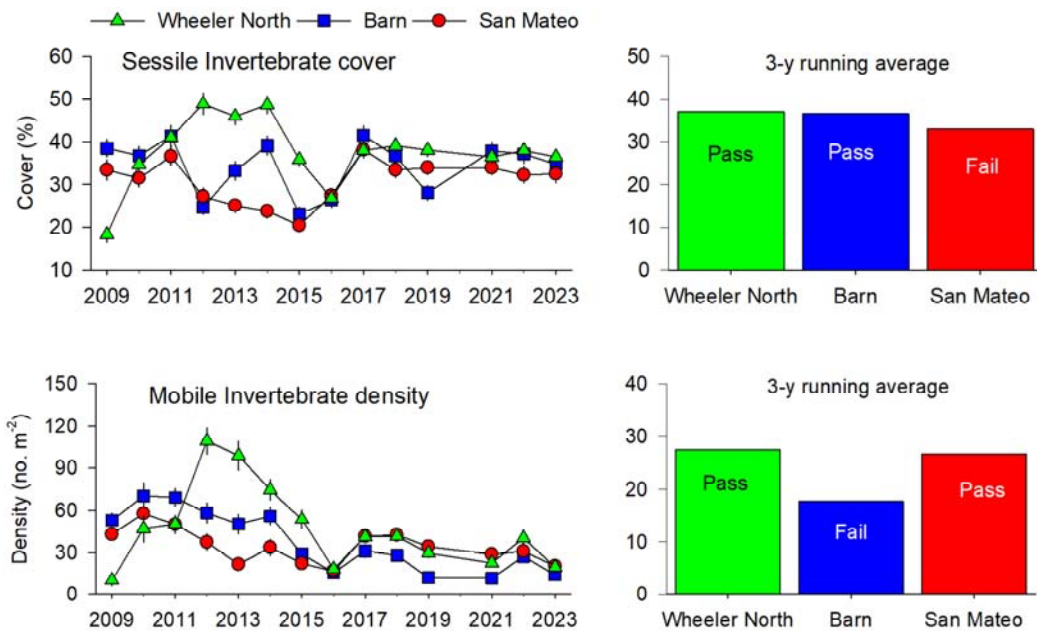
The percent cover and number of species of algae must be similar to natural reefs within the region



- In the slides that follow different colors are used for the different reefs
 - Green represents Wheeler North Reef and blue and red represent the reference reefs at Barn and San Mateo, respectively
- In each slide the annual time series since 2009 is plotted on the left and a bar graph showing the four-year average is plotted on the right
- The annual time series shows that percent cover and number of species of macroalgae at Wheeler North Reef has been generally lower than that of nearby natural reefs
- The exceptions to this were in 2009 the year after Phase 2 was constructed and in 2021 and 2022 when the number of algal species at Wheeler North Reef was similar to San Mateo
- Importantly, the 3-year averages (2021, 2022 and 2023) for macroalgal cover and species number at Wheeler North Reef in 2023 were significantly lower than that of either reference reef
- Consequently, Wheeler North Reef failed both of these performance standards in 2023, while Barn and San Mateo passed them

Performance Standards: Invertebrates

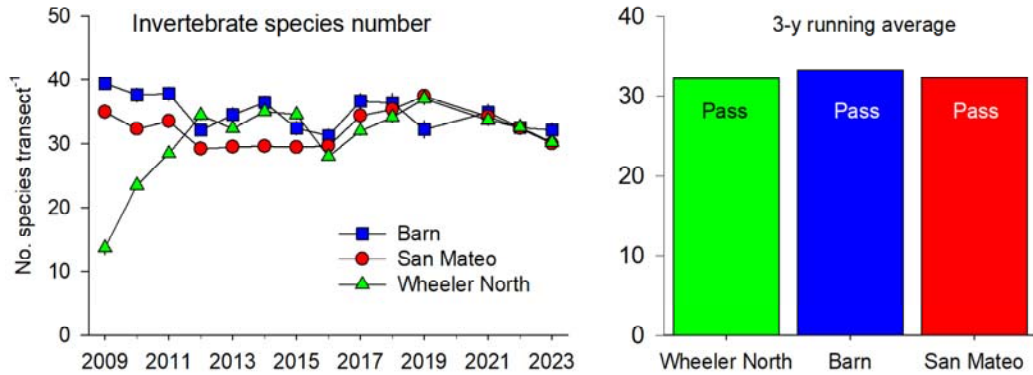
The percent cover of sessile invertebrates and the density of mobile invertebrates must be similar to natural reefs within the region



- Plotted here are data collected at Wheeler North, Barn and San Mateo reefs on the percent of the bottom covered by sessile invertebrates (top two graphs) and the density of mobile invertebrates (bottom two graphs)
- Sessile invertebrates compete for space on the reef with macroalgae, but instead of producing their own food via photosynthesis they feed by filtering plankton from the water column
- The percent cover of sessile invertebrates varied substantially at all three reefs from 2009 to 2017, but has been relatively constant since then.
- The average cover of sessile invertebrates at Wheeler North Reef and Barn have been nearly identical the last three years and slightly, but nonetheless significantly, higher than that at San Mateo
- As a result Wheeler North Reef and Barn passed this performance standard in 2023 while San Mateo failed it.
- In contrast to sessile invertebrates, mobile invertebrates consist of a wide range of grazers and predators that feed on reef associated macroalgae, detritus, sessile invertebrates and other mobile invertebrates
- With the exception of the first two years of the time series, their abundance at Wheeler North Reef has consistently been within or above the range of nearby natural reefs
- Based on the latest 3-y running averages Wheeler North Reef and San Mateo passed this performance standard in 2023 while Barn failed it

Performance Standards: Invertebrates

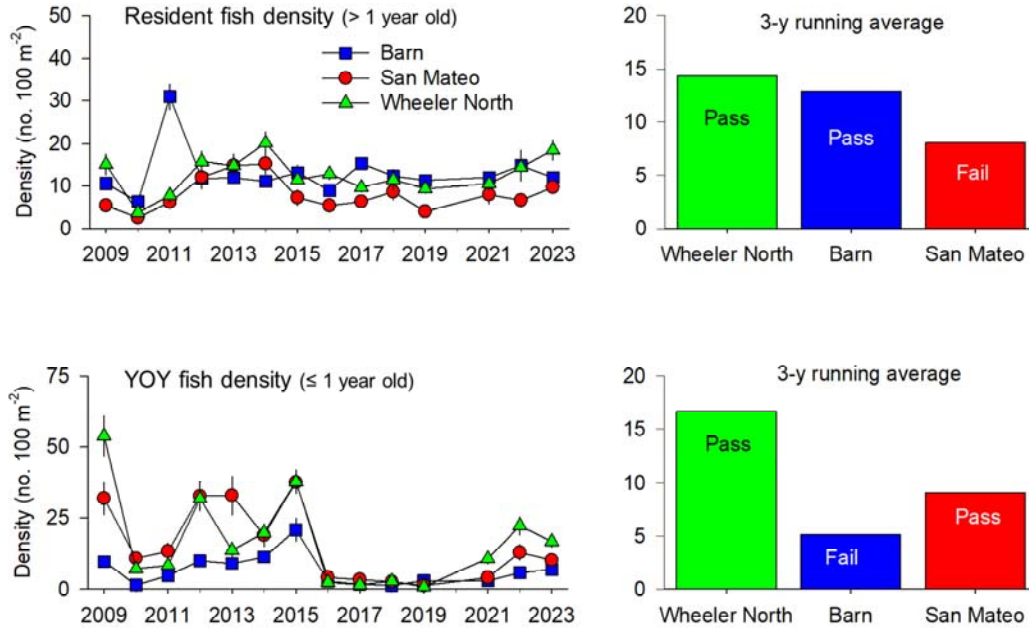
The number of species of invertebrates must be similar to natural reefs within the region



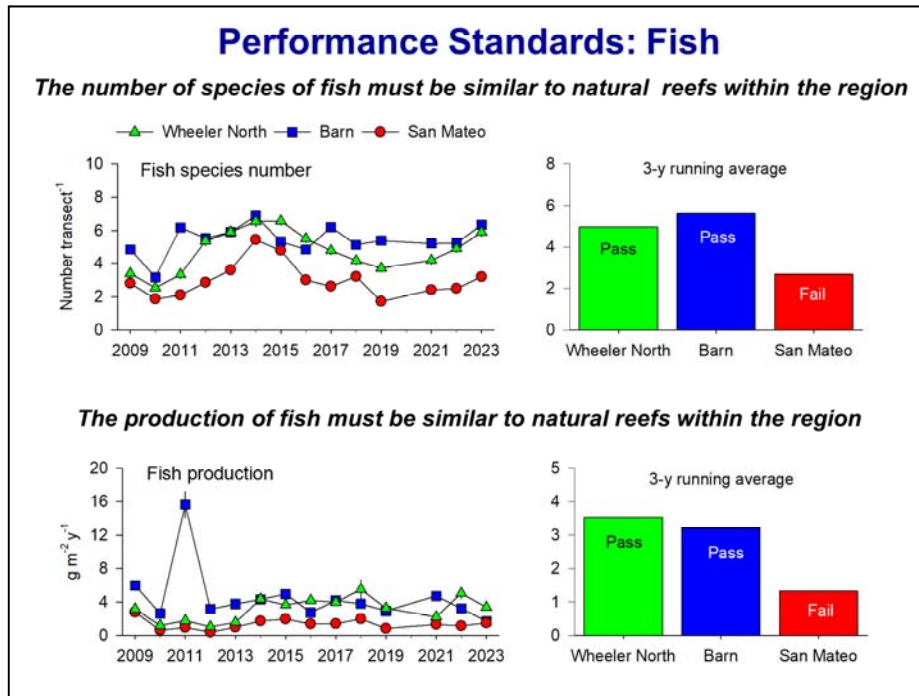
- This graph shows the mean number of species of all invertebrates (sessile + mobile) per transect at Wheeler North, Barn and San Mateo
- Comparatively, few species of invertebrates inhabited Wheeler North Reef during the first couple of years of its existence
- Since 2012 the number of species of reef invertebrates at Wheeler North Reef has been much more similar to that of nearby natural reefs
- The running average of the number of species of invertebrates the last three years was nearly identical at Wheeler North, Barn and San Mateo
- Consequently, all three reefs passed this standard in 2023

Performance Standards: Fish

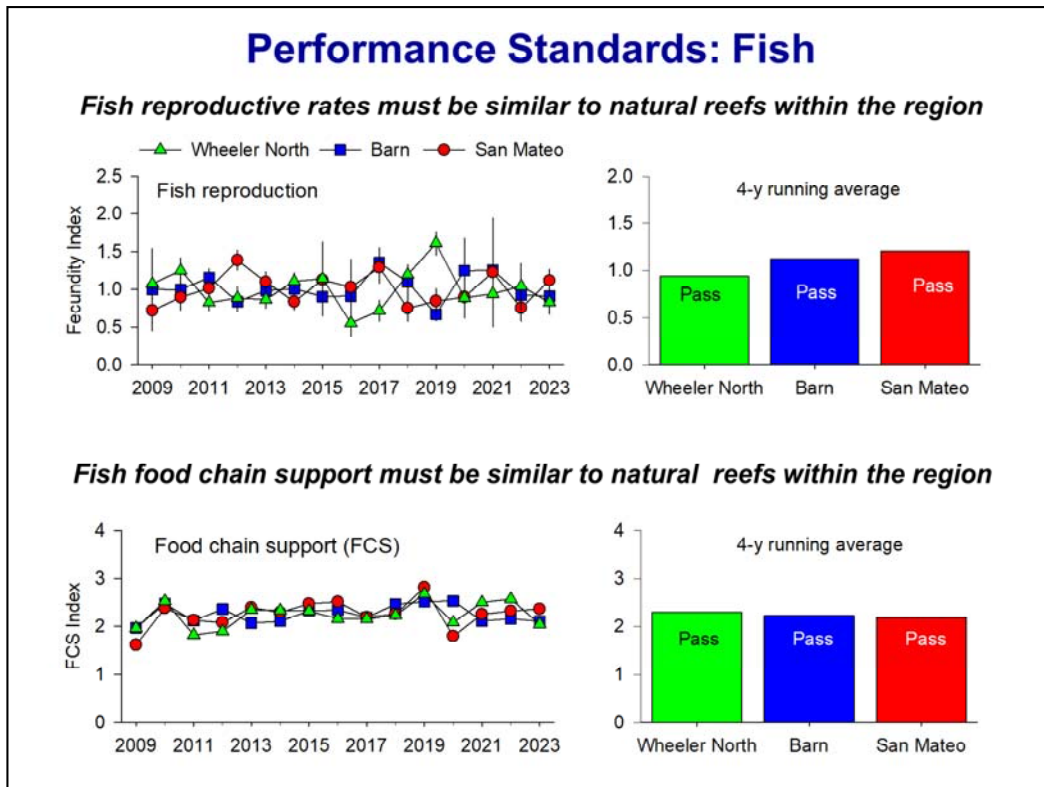
The abundances of resident and young-of-year fish (YOY) must be similar to natural reefs within the region



- Plotted here are data on the mean density of older resident fish (top 2 graphs) and newly recruited Young-of-Year reef fish (bottom 2 graphs)
- Resident fish are defined as fish > 1 year in age as determined by their size, while Young-of-Year fish are smaller fish that were born in the current year
- Densities of resident fish at all three reefs have remained relatively stable throughout the time series, especially since 2015 with the highest densities generally observed at Wheeler North and Barn and the lowest at San Mateo
- Thus based on the most recent running average, Wheeler North Reef and Barn passed this standard in 2023 while San Mateo failed it
- Densities of Young-of-Year fish fluctuated sporadically at all three reefs until 2016 when they declined dramatically at all three reefs
- YOY densities at Wheeler North Reef have consistently been within or above the range of nearby natural reefs throughout the time series
- Beginning in 2021 there has been an increasing trend in YOY abundance, especially at Wheeler North Reef and to a lesser extent San Mateo, which is reflected in the latest 3-year running averages
- Wheeler North Reef and San Mateo both passed this standard in 2023 while Barn failed it



- The top two graphs show the mean number of species of reef fish per transect at the Wheeler North, Barn and San Mateo reefs.
- The number of species of fish at Wheeler North Reef has consistently been within or above the range of nearby natural reefs with Barn typically having the highest fish diversity and San Mateo the lowest
- This resulted in a 4-year average at Wheeler North Reef in 2022 that was intermediate between the two reference reefs
- In 2023 the 3 year average at San Mateo was significantly lower than those at Wheeler North Reef and Barn, consequently Wheeler North and Barn passed this performance standard in 2023 and San Mateo failed it
- Fish production is the amount of fish biomass produced per unit area in a given year and it takes into account both somatic and gonadal growth
- Somatic growth is estimated from the width of annual rings in the ear bones of fish, while gonadal growth is measured as the production of tissue associated with reproduction, which can be quite large
- We measure growth in five indicator species: blacksmith, señorita, black perch, the California sheephead and kelp bass
- These species were chosen because they are among the most common species of fish in the kelp forest and they represent different feeding guilds that use the reef in different ways
- Blacksmith eat plankton during the day and seek shelter on the reef at night, señorita eat plankton and small invertebrates on the reef, black perch feed on small invertebrates that live on or near the bottom, sheephead feed on larger invertebrates on the bottom, and kelp bass primarily feed on other species of fish
- Fish production has been relatively constant over the time series ranging from ~ 1- 5 g per m² of bottom per year
- The exception was at Barn in 2011 when high production by all five species at this site caused production to spike to ~ 15 g per m² per year
- Throughout the time series fish production at Wheeler North Reef and Barn has consistently been higher than that at San Mateo
- In 2023 Wheeler North Reef and Barn met this performance standard and San Mateo failed it



- Plotted in the top two graphs are indices of female fecundity, which we use as a measure of fish reproductive rates
- The fecundity index represents a mean of the annual egg production scaled to female size averaged over three indicator species: kelp bass, California sheephead and seniorita
- The mean fecundity index has varied somewhat across all three reefs over the 15 years of monitoring, without any consistent trends among the reefs
- In 2023 the 3-y running average of the fecundity index was statistically similar at all three reefs and they all passed this performance standard
- There is also a performance standard that requires the benthic community of Wheeler North Reef to provide food for the fishes that feed on the reef at a level that is similar to that provided by natural reefs
- We evaluate this performance standard by measuring the weight of the food in the guts of two common species of fish that feed on the bottom: black perch and the California sheephead
- We use this information to calculate an index of food chain support that is scaled to the weight of the fish
- The food chain support (FCS) index has been relatively constant and similar at all three reefs throughout the 15-y time series, and the running average at Wheeler North Reef, Barn and San Mateo the last 4 years was nearly identical
- As a result all three reefs passed this performance standard in 2023

Performance Standard: Undesirable and invasive species (must be met every year)

The important functions of the reef shall not be impaired by undesirable or invasive benthic species



Undesirable species that are of potential concern include:

- High density sea fans
- High density sea urchins



Invasive species that are of potential concern include:

- Non-native algae and invertebrates

Primary production by giant kelp and secondary production of reef fishes are the important reef functions used to evaluate this standard

- The relative performance standard that must be met every year for Wheeler North Reef to receive mitigation credit requires that its important ecological functions not be impaired by undesirable or invasive benthic species
- Native species can become “undesirable” if they become so abundant that they impair important functions of the reef
- Two examples of this are dense aggregations of sea fans that can monopolize space and exclude other species including giant kelp, and high densities of sea urchins that can intensively graze the bottom and create large deforested areas commonly called “sea urchin barrens”
- Invasive species are non-native species that become abundant and displace native species or otherwise harm important reef attributes and functions.
- Two non-native species that are known to be invasive in southern CA are the brown alga *Sargassum horneri* and the bryozoan *Watersipora subatra*
- Primary production by macroalgae and secondary production by reef fishes are two important functions of reefs that we use to evaluate this performance standard
- We are using data on the density of giant kelp fronds to estimate the net primary production of giant kelp, and data on the growth, reproduction and biomass of 5 indicator species of reef fish to estimate the secondary production of reef fish

Method used to evaluate impairment of reef functions by undesirable and invasive species

1. Measure the abundance of undesirable and invasive species at Wheeler North Reef relative to the reference reefs to determine their potential to impair important reef functions
2. Compare the production of giant kelp and fish at Wheeler North Reef relative to the reference reefs to determine whether these functions at Wheeler North Reef are underperforming relative to the reference reefs
3. If the production of giant kelp or fish at Wheeler North Reef are underperforming, then complete additional analyses/studies to determine whether underperformance is caused by impairment from undesirable and invasive species

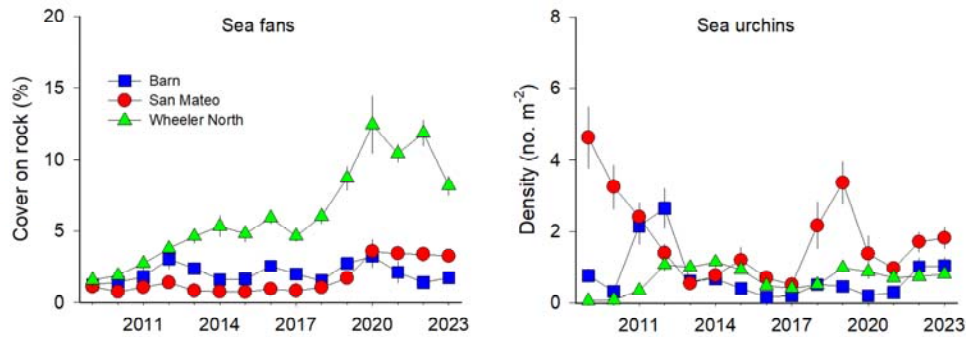


The method used to evaluate impairment of reef functions by undesirable and invasive species is a three-step process

1. Measure the abundances of undesirable and invasive species at Wheeler North Reef relative to the reference reefs to determine their potential to impair important reef functions
2. Compare the production of giant kelp and fish at Wheeler North Reef relative to the reference reefs to determine whether these functions at Wheeler North Reef are underperforming relative to the reference reefs
3. If the production of giant kelp or fish at Wheeler North Reef are underperforming, then complete additional analyses/studies to determine whether underperformance is caused by impairment from undesirable and invasive species

Thus we begin the evaluation of this performance standard by looking at the abundances of undesirable and invasive species at Wheeler North Reef and the reference reefs

Abundances of Undesirable & Invasive Species



- The percent cover of sea fans has been consistently higher at Wheeler North Reef compared to the reference reefs
 - *Potential concern for impairment of important reef functions by sea fans*
- The density of sea urchins at Wheeler North Reef has been consistently low
 - *Little concern at this time for the impairment of important reef functions by sea urchins*
- Invasive, non-native species have not been observed at Wheeler North Reef
 - *No concern at this time for the impairment of important reef functions by invasive non-native species*

- When examining this first step in the evaluation process we see that the percent cover of sea fans has been increasing more at Wheeler North Reef compared to the reference reefs, raising a potential concern that sea fans could impair important reef functions
- In contrast, the average density of sea urchins at Wheeler North Reef has remained relatively low ranging from near 0 to 1.1 per m².
- This low density is far below the threshold of 20-30 urchins per m² that is known to convert kelp forested reefs to barren areas
- Consequently, there is little concern that sea urchins are impairing the important functions of Wheeler North Reef at this time
- Lastly, no invasive non-native algae or invertebrates were observed at Wheeler North Reef in 2023 so there is no reason for concern that they are impairing important reef functions at this time

Method used to evaluate impairment of reef functions by undesirable and invasive species

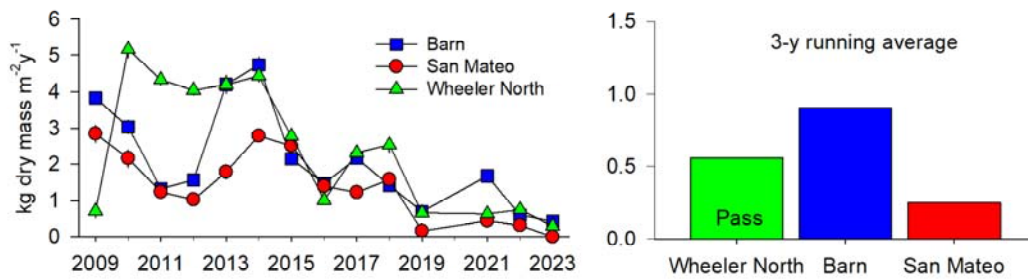
1. Measure the abundance of undesirable and invasive species at Wheeler North Reef relative to the reference reefs to determine whether they have a potential to impair important reef functions
2. Compare the production of giant kelp and fish at Wheeler North Reef relative to the reference reefs to determine whether these functions at Wheeler North Reef are underperforming relative to the reference reefs
3. If the production of giant kelp and fish at Wheeler North Reef are underperforming, then complete additional analyses/studies to determine whether underperformance is caused by impairment from undesirable and invasive species



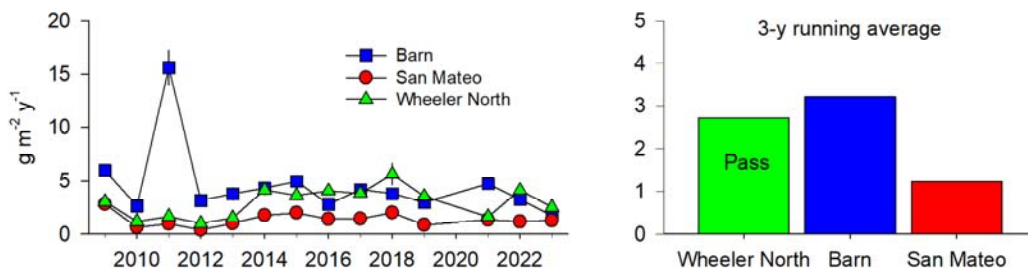
The second step in evaluating whether dense aggregations of sea fans impairs the functions of Wheeler North Reef involves comparing these functions at Wheeler North Reef to those measured at the reference reefs

Performance of important reef functions

Giant kelp primary production



Fish secondary production



The important functions of Wheeler North Reef are within the range of the reference reefs

- In the case of giant kelp primary production we find that the level of this important reef function at Wheeler North Reef has consistently been within the range or higher than that of the reference reefs in all but 2009, which was the first year after the construction of the Phase 2 reef
- Reef fish production at Wheeler North Reef has also consistently been within the range of the two reference reefs throughout the time series
- The value for Wheeler North Reef in 2023 whether using the current year or the 3-year running average was within the range of the reference reefs

Performance Standard: Undesirable and invasive species
(*must be met every year*)

The important functions of the reef shall not be impaired by undesirable or invasive benthic species

Wheeler North Reef: PASS

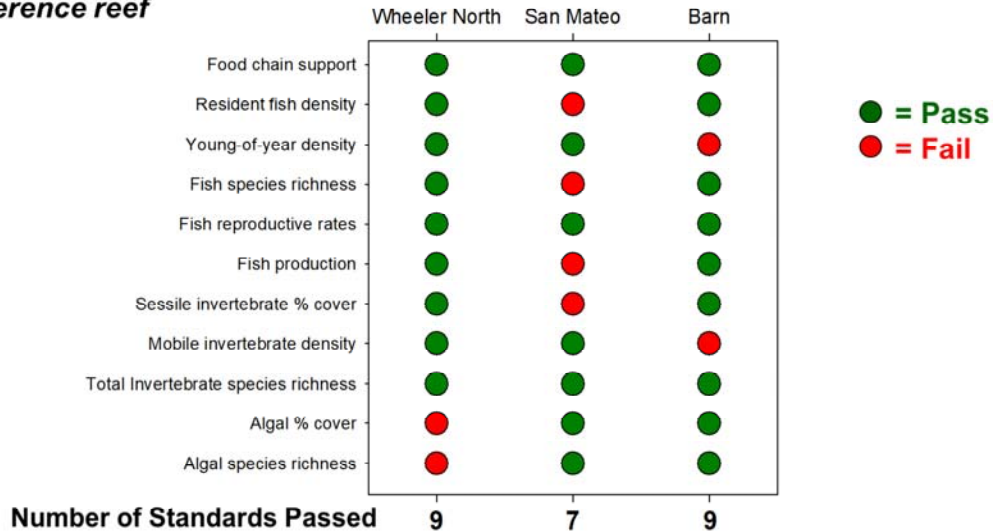
- No compelling evidence that *undesirable* native species or *invasive* non-native species impaired important functions of Wheeler North Reef in 2023
- We will continue to closely monitor the abundance of sea fans and their potential impact on the primary production of giant kelp and the secondary production of reef fish



- We conclude from these analyses that there is no compelling evidence that undesirable native species or invasive non-native species impaired important functions of Wheeler North Reef in 2023
- Therefore Wheeler North Reef met the performance standard for undesirable and invasive species
- Nonetheless, due to their relatively high abundance we will continue to closely monitor sea fans and their potential impact on the primary production of giant kelp and the secondary production of reef fish

2023 Summary of relative performance standards

✓ **Wheeler North Reef met more standards than the lowest performing reference reef**



✓ **Wheeler North Reef met the standard for undesirable and invasive species**

Wheeler North Reef met the mitigation requirement for the relative performance standards in 2023

- This slide summarizes the number of relative standards met by Wheeler North Reef and the two reference reefs (San Mateo and Barn) in 2023
- The monitoring results show that Wheeler North Reef met 9 of the 11 relative standards in 2023, which was one more than the number of standards met by Barn and 2 more than that met by San Mateo, the lower performing reference reef
- Based on these results we conclude that the ecological resources and functions provided by Wheeler North Reef in 2023 were *similar* to those provided by nearby natural reefs
- Therefore, Wheeler North Reef met the collective mitigation requirement for the relative performance standards in 2023

Absolute performance standard that must be met every year

(measured at Wheeler North Reef only)



At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota

Method of evaluation

The evaluation of each standard is based on the value measured for the current year, or the 4-year running average (calculated from the current year and the previous three years), *whichever is higher*.

There is one absolute performance standards that Wheeler North Reef must meet each year in order for it to receive mitigation credit:

- The performance standard for hard substrate requires at least 90% of the exposed rock initially present on the Phase 1 and 2 Wheeler North Reef remain available for the attachment by reef biota
- The evaluation of each of this standard is based on the value measured at the Phase 1 and 2 Wheeler North Reef for the current year, or the running average, which ever is higher.
 - The running average in 2023 is based on three years (2021, 2022, and 2023) due to restricted sampling in 2020 caused by COVID-19

Method used to measure the Area of Hard Substrate

1. Measure footprint area (A) of Wheeler North Reef (Phases I + 2) in sonar surveys
2. Measure percent cover of exposed rock (P)
3. Calculate area of exposed rock as $A \times P$
4. Compare area of exposed rock to that measured shortly after reef construction in 2009 to determine whether 90% or more is still available for reef biota



9 Substrate categories:

Bedrock
Large boulder (≥ 100 cm)
Medium boulder (≥ 50 cm & <100 cm)
Small boulder (≥ 26 cm and <50 cm)
Cobble (≥ 7 cm and ≤ 25 cm)
Pebble (≥ 2 mm and < 7 cm)
Sand (< 2 mm)
Shell hash
Mudstone

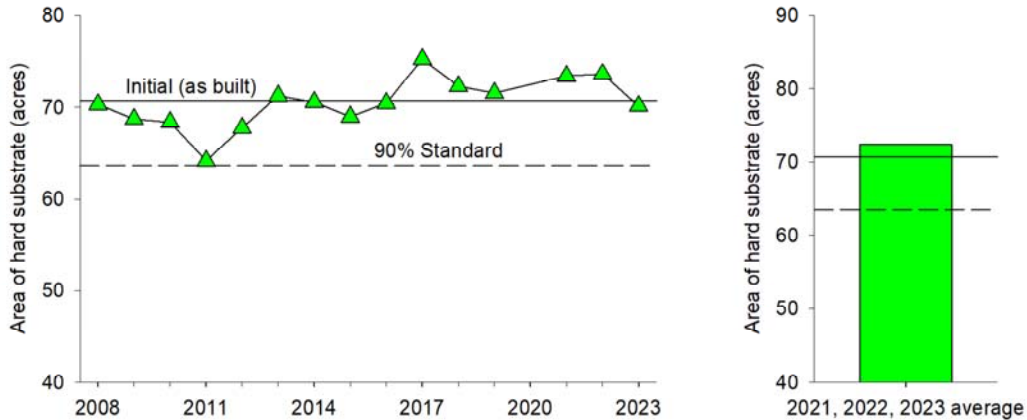
The performance standard for hard substrate is evaluated in the following way:

- Multi-beam sonar is used to measure the combined footprint area (A) of Phase 1 and 2 of Wheeler North Reef once every 5 years
- Divers estimate the percent cover of exposed rock (P) in five 1 m^2 quadrats on the 82 transects distributed across Phase 1 and 2 of Wheeler North Reef.
- The product $A \times P$ is the estimate of the area of exposed hard substrate
- We compare this estimate to that obtained immediately following construction of Phase 2 of Wheeler North Reef
- The SONGS coastal development permit requires that this amount not fall below 90% of what was available immediately after the reef was constructed
- Divers collect percent cover data for nine different types of bottom substrate
- The five categories of bottom substrates outlined in the green box are those that constitute hard substrate in our analyses

Performance Standard: Hard Substrate

At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota

PASS



- Plotted here is an annual time series of the total area of exposed hard substrate at Wheeler North Reef (left) and the 3-year average for 2023 (right)
- The annual time series shows that at least 90% of the initial area of exposed hard substrate on the Phase 1 and 2 Wheeler North Reef has remained available every year since the Phase 2 reef was constructed
- Annual values greater than the initial as-built in some years likely reflect scouring and/or redistribution of reef material that resulted in an increase in the total area of exposed hard substrate
- Wheeler North Reef met this performance standard in 2023 as both the annual value and the 3-year average were greater than the as-built condition and thus exceeded the 90% threshold

Absolute performance standards that accumulate partial mitigation credit on an annual basis



The artificial reef(s) shall sustain 150 acres of medium-to-high density giant kelp



The standing stock of fish at the mitigation reef shall be at least 28 tons

Method of evaluation

- The annual standing stock of fish and acreage of giant kelp at Wheeler North Reef are measured each year and summed over time until they reach a cumulative total equivalent to the annual target x the number of years of SONGS operations (= 32 years)
- Accumulation of kelp acreage and fish standing stock began in 2019

Unlike the absolute performance standards for hard substrate that must be met each year, the absolute standards pertaining to giant kelp area and fish standing stock are evaluated on a cumulative basis and Wheeler North Reef receives partial credit for these standards each year

1. The performance standard for giant kelp is based on the intent that Wheeler North Reef sustain 150 acres of medium-to-high density giant kelp for a period of time equivalent to the operating life of SONGS
 2. Similarly, the performance standard for fish standing stock is based on the intent that Wheeler North Reef sustain a fish standing stock of at least 28 tons for a period of time equivalent to the operating life of SONGS
- Mitigation credit for these two performance standards is summed over time until the accumulated credit for each performance standard reaches a total value equivalent to the annual target (which is 150 acres for kelp and 28 tons for fish) x the number of years of SONGS operations which was defined by the CCC to be 32 years
 - The CCC determined that the accumulation of kelp acreage and fish standing stock would begin in 2019

Methods used to estimate the area of medium-to-high density of adult giant kelp

Divers record the density of adult giant kelp in a fixed 100 m² area of each transect at Wheeler North Reef (n = 151 transects)

- medium-to-high density is defined as > 4 adults per 100 m²
- adults are defined as individuals with > 7 fronds



Acres of medium-to-high density adult kelp = $P \times 373$ acres

where:

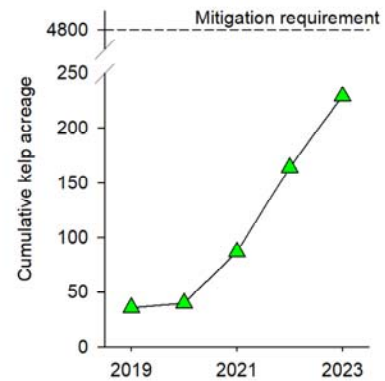
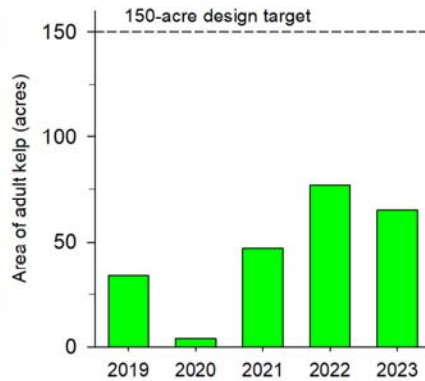
P = proportion of transects with > 4 adult plants, and

373 = footprint area of Wheeler North Reef in acres based on the most recent sonar survey

- The performance standard for giant kelp is evaluated by measuring the density of giant kelp in 151 fixed transects across all three phases of Wheeler North Reef
 - medium-to-high density is defined as > 4 adults per 100 m²
 - adults are defined as individuals with > 7 fronds
- Using these data we calculate the proportion of transects at Wheeler North Reef that have a density of adult kelp > 4 plants per 100 m²
- This proportion is multiplied by 373 acres (= the combined footprint area of Phases 1, 2 and 3 of Wheeler North Reef measured in the most recent sonar survey) to obtain the total acreage of adult kelp at Wheeler North Reef.

Performance Standard: Giant Kelp

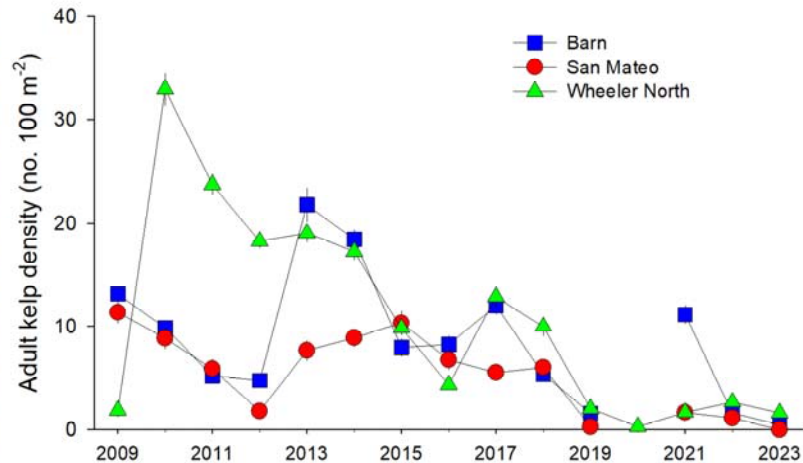
Reef design: Average 150 acres of medium-to-high density adult giant kelp for a minimum of 32 years



Wheeler North Reef earned mitigation credit for 65 acres of medium-to-high density adult giant kelp in 2023 resulting in a cumulative total of 229 acres

- This graph shows the area of medium-to-high density adult giant kelp supported by Wheeler North Reef since 2019, which is the first year that mitigation credit for the cumulative performance standards went into effect
- In 2023 Wheeler North Reef earned 65 acres of credit for supporting medium-to-high density giant kelp, which is more than it supported in the previous three years
- When added to the previous four years, Wheeler North Reef has accumulated a total of 229 acres of medium-to-high density adult giant kelp
- Notably, the area of medium to high density adult kelp at Wheeler North Reef has been well below the 150-acre design target since 2019, which could be reason for concern

Area of adult giant kelp at Wheeler North Reef compared to natural reference reefs



The density of adult kelp at Wheeler North Reef has typically been *within or above* the range of nearby reference reefs

- Comparison of temporal changes in the density of adult kelp at nearby natural reefs provides insight into whether the low kelp acreage is specific to Wheeler North Reef or more characteristic of the broader region
- The data plotted in this graph show that since 2010 the Wheeler North Reef has typically supported as much or more adult kelp per unit area as the two reference reefs
- The general decline in giant kelp observed at Wheeler North Reef since 2017 was also observed at Barn and San Mateo, with the exception that Barn showed a brief increase in 2021, before declining to near zero in 2022 and 2023.

Methods used to evaluate the standing stock of reef fish

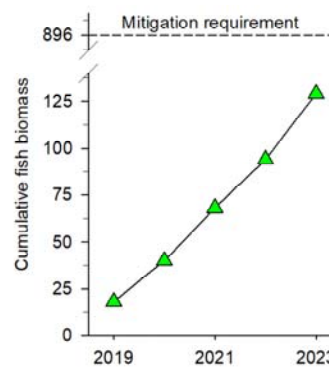
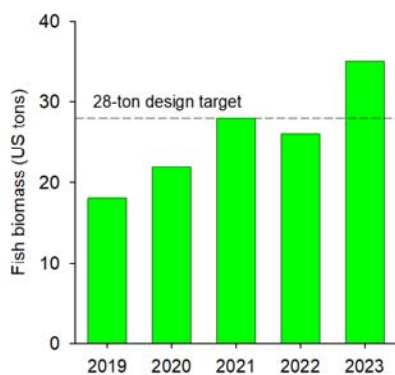


1. Apply species-specific length-weight relationships to fish density and size data collected by divers to calculate the average biomass density (g m^{-2} reef) of all fish near the bottom from all transects
2. Scale up estimates of fish biomass m^{-2} to the footprint area of Wheeler North Reef (= 373 acres) to obtain an estimate of the standing stock of fish near the bottom at Wheeler North Reef

- Data on fish density and length collected from the 151 transects distributed across the 3 phases of Wheeler North Reef are used to calculate the total standing stock of reef associated fish near the bottom
- The weights of the fish counted are estimated from known relationships between length and weight for each species
- The weights of all fish counted on a transect are summed to obtain an estimate of fish biomass density for each transect in units of grams per m^2 of reef
- The biomass density of fish is averaged over all transects in a polygon and multiplied by the area of the polygon to obtain an estimate of the biomass of fish in each polygon
- The biomass of fish in each polygon is summed to obtain an estimate of the standing stock of fish near the bottom on the 373-acre Wheeler North Reef

Performance Standard: Fish Standing Stock

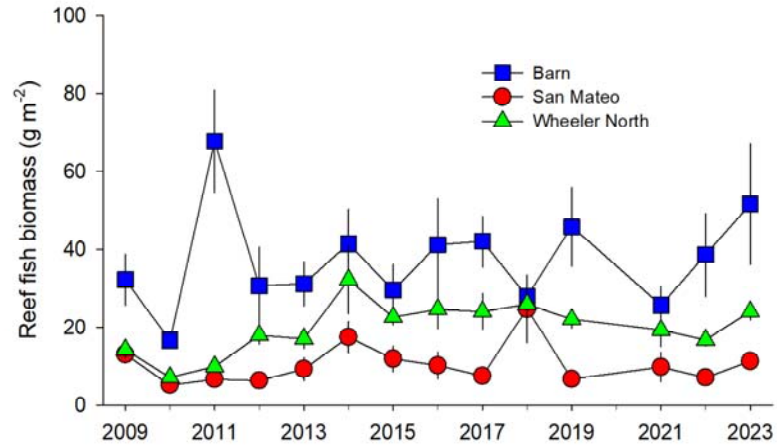
Reef design: support a standing stock of fish that averages at least 28 tons for 32 years



Wheeler North Reef earned mitigation credit for 35 tons of fish standing stock in 2023 resulting in a cumulative total of 129 tons of fish standing stock

- Shown here is annual standing stock of reef fish on Wheeler North Reef since 2019
- Wheeler North Reef earned 35 tons of credit for its fish standing stock in 2023, which is above the 28-ton design target
- Since 2019 Wheeler North Reef has accumulated mitigation credit for 129 of the 896 tons of fish standing stock required for this performance standard

Fish biomass at Wheeler North Reef compared to natural reference reefs



Fish biomass density at Wheeler North Reef has been consistently within the range of nearby natural reefs

- It's worth noting that the biomass density of fish at Wheeler North Reef has been consistently *within the range* of nearby natural reefs, lower than Barn but higher than San Mateo
- This suggests that the standing stock of fish at Wheeler North Reef is within the range of a natural reef of comparable size

SONGS Reef Mitigation Requirements

Assignment of mitigation credit

➤ ***Relative performance standards and the absolute performance standard that must be met every year***

- One year of mitigation credit is given for each year that Wheeler North Reef meets both of these types of performance standards
- Fulfillment of this mitigation requirement occurs when the number of years of mitigation credit accrued by the Wheeler North Reef equals the total years of operation of SONGS Units 2 & 3 (= 32 years)

➤ ***Absolute performance standards that accumulate partial mitigation credit over time (i.e., giant kelp area and fish standing stock)***

- Giant kelp and fish standing stock are separately evaluated and assigned mitigation credit
- Fulfillment of these mitigation requirements occurs when the total accrued mitigation credit for each standard equals the targeted annual value (= 150 acres of kelp or 28 tons of fish) x the total years of operation of SONGS Units 2 & 3 (= 32 years)

- The goal of the SONGS reef mitigation project is to replace the kelp forest resources that were lost due to the operations of SONGS Units 2 & 3, which lasted for 32 years
- One year of mitigation credit is given for each year that Wheeler North Reef meets the collective group of relative performance standards, the relative standard for undesirable and invasive species and the absolute standard pertaining to hard substrate Fulfillment of the mitigation requirement for these 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)
- Unlike the other performance standards the absolute performance standards for giant kelp area and fish standing stock accrue partial mitigation credit over time independently of the other performance standards
- Fulfillment of the mitigation requirements for these performance standards occurs when the total amount of credit accrued equals the targeted annual value (= 150 acres in the case of giant kelp and 28 tons in the case of fish standing stock) x the total years of operation of SONGS Units 2 & 3 (= 32 years)

2023 Summary of earned mitigation credit

(assignment of mitigation credit began in 2019)

Performance Standards that must be met every year

(Relative standards and absolute standard for hard substrate,)

| | |
|--|------------|
| Credit earned in 2023 | Yes |
| Years of credit earned since 2019 | 5 |
| Years of credit required | 32 |
| Years of credit still needed | 27 |

Performance Standards that accumulate credit over time

| | 2023 credit | Cumulative credit | Credit required | Credit needed |
|----------------------------|-----------------|----------------------|--------------------|-------------------|
| Giant kelp area | 65 acres | 229 acres | 4800 acres | 4571 acres |
| Fish standing stock | 35 tons | 129 tons | 896 tons | 767 tons |

- Shown here is a summary of project compliance for the SONGS reef mitigation project
- Wheeler North Reef earned 1 year of credit in 2023 for meeting the collective group of relative standards, the relative standard for undesirable and invasive species and the absolute standard for hard substrate
- It has earned a total of 5 years of mitigation credit for these performance standards and needs another 27 years of credit for this mitigation requirement to be met
- In 2023 Wheeler North Reef earned credit for 65 acres of giant kelp for a cumulative credit of 229 of the 4,800 acres of giant kelp required for the giant kelp performance standard
- An additional 4,571 kelp acres is needed before the mitigation requirement for the giant kelp performance standard is met
- In 2023 Wheeler North Reef earned credit for 35 tons of fish standing stock for a cumulative credit of 129 tons
- It needs to earn an additional 767 fish tons of mitigation credit before the mitigation requirement for the fish standing stock performance standard is met

Provisions in the SONGS' coastal development permit for reduced monitoring of Wheeler North Reef

Condition C. Kelp Reef Mitigation

Upon completion of **ten years of independent monitoring** that demonstrate the mitigation reef is in compliance of the performance standards, the permittee shall be fully responsible for funding independent **annual site inspections**, which will serve to identify any noncompliance with the performance standards.

Condition D. Administrative Structure

The mitigation projects will be successful when all performance standards have been **met each year for a three-year period**. If the Commission determines that the performance standards have been met and the project is successful, the monitoring program will be scaled down, as recommended by the Executive Director and approved by the Commission.

Wheeler North Reef has been monitored for > 10 years and has met all the performance standards for > 3 consecutive years

Annual site inspections will begin in 2024

- There are provisions in the SONGS' coastal development permit to reduce the level of monitoring to annual site inspections once the Wheeler North Reef has demonstrated that it has successfully met the performance standards.
- Specifically, Condition C of the permit pertaining to kelp reef mitigation states that after 10 years of monitoring that demonstrate the artificial reef is meeting the performance standards monitoring shall be reduced to annual site inspections that serve to identify whether the performance standards are being met
- Condition D states that monitoring will be scaled down after all the performance standards have been met each year for a three-year period
- Wheeler North Reef has been monitored for more than 10 years and has met all of the performance standards for more than three consecutive years. Therefore, annual site inspections will begin in 2024.

Assessment of similarity using full monitoring vs. annual site inspections

Full monitoring

Uses inferential statistics to compare performance variables to determine whether Wheeler North Reef is similar to the reference reefs

- sampling effort of the relative performance variables was designed to detect a 20% difference between reefs (effect size = 0.2) with 80% statistical power using a Type I error (α) = 0.2

Annual site inspections

Compares mean values of performance variables without inferential statistics to determine whether Wheeler North Reef is similar to the reference reefs

- based on historical performance, sampling effort of the relative performance variables was designed to “identify any noncompliance with the performance standards”, but with substantially reduced monitoring and associated costs

- The approach that will be used to assess whether the Wheeler North Reef is similar to the reference reefs with respect to the relative performance standards during annual site inspections differs fundamentally from that used during full monitoring
- The full monitoring approach uses inferential statistics to compare performance variables to determine whether Wheeler North Reef is similar to the reference reefs. The sampling effort of the relative performance variables was designed to detect a 20% difference between reefs (effect size = 0.2) with 80% statistical power using a Type I error (α) = 0.2.
- In contrast, the approach that will be used to assess similarity during annual site inspections compares mean values of the performance standards without inferential statistics to determine whether Wheeler North Reef is similar to the reference reefs.
- This approach is based on our knowledge of past performance since 2009 and the sampling effort of the relative performance standards was designed to “identify any noncompliance with the performance standards”, but with substantially reduced monitoring and associated cost.

Annual site inspections for relative performance standards

Comparison of sampling effort between full monitoring vs. reduced monitoring of annual site inspections

| Type of Performance Standard | Monitoring effort per reef | | Amount Reduced |
|---|----------------------------|-----------------------|----------------|
| | <i>Full</i> | <i>Reduced</i> | |
| Relative: transect data (WNR, SM, B) | | | |
| 9 standards | 82 | 15 | 82% |
| Undesirable & invasive species | 151 (WNR), 82 (SM, B) | 111 (WNR), 15 (SM, B) | 55% |
| Relative: fish collections (WNR, SM, B) | | | |
| Fish production | 100 of 5 species | 0 (measured by proxy) | 100% |
| Fish reproduction | 100 of 4 species | 50 of 2 species | 75% |
| Fish food chain support | 100 of 2 species | 50 of 2 species | 50% |

WNR = Wheeler North Reef, SM = San Mateo, B = Barn

- This table shows the comparison of sampling effort between full monitoring and the reduced sampling approach developed for annual site inspections for the relative performance standards.
- For nine of the relative standards currently collected on transects, sampling will be reduced from 82 to 15 transects, which is an 82% reduction.
- The undesirable and invasive species standard will be reduced from 151 to 111 transects on WNR and from 82 to 15 transects on the reference reefs, which is a 55% reduction.
- For the relative standards currently collected via fish collections, fish production will no longer incorporate fish collection under reduced sampling and will instead be measured by a proxy measured in transects (i.e., fish biomass density), which represents a 100% reduction.
- For fish reproduction and fish food chain support, we will reduce the number of individuals and species of fish collected, representing a 75% reduction for fish reproduction and a 50% reduction for fish food chain support.

Comparison of “Relative Performance” Full monitoring vs. reduced monitoring

Analyses based on 11 relative performance standards*

| Year | Wheeler North | | San Mateo | | Barn | |
|-------------------------------|-----------------|--------------------|-----------------|--------------------|-----------------|--------------------|
| | Full monitoring | Reduced monitoring | Full monitoring | Reduced monitoring | Full monitoring | Reduced monitoring |
| 2012 | 8 | 8 | 6 | 5 | 10 | 9 |
| 2013 | 7 | 8 | 6 | 5 | 10 | 9 |
| 2014 | 8 | 8 | 5 | 5 | 10 | 10 |
| 2015 | 9 | 7 | 6 | 5 | 9 | 10 |
| 2016 | 9 | 8 | 6 | 5 | 9 | 9 |
| 2017 | 9 | 7 | 5 | 5 | 10 | 10 |
| 2018 | 8 | 7 | 8 | 6 | 9 | 9 |
| 2019 | 8 | 6 | 8 | 7 | 10 | 9 |
| 2020 | 9 | 7 | 7 | 6 | 10 | 9 |
| 2021 | 9 | 9 | 7 | 4 | 10 | 9 |
| # years not the lowest | 10 | 9 | 2 | 1 | 10 | 10 |

Red = lowest performing reef

**the relative standard for undesirable and invasive species was not included in this analysis because it must be met each year for Wheeler North Reef to receive mitigation credit for that year*

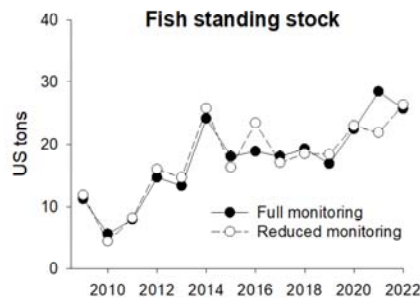
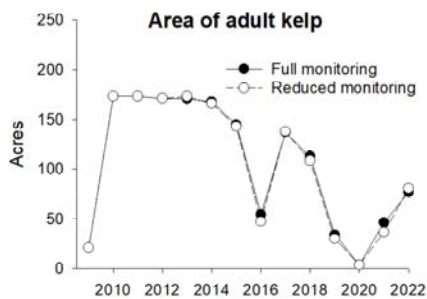
Estimates of similarity based on reduced monitoring are comparable with those based on full monitoring

- To verify that annual site inspections would maintain our ability to “identify any noncompliance with the relative performance standards” we applied the annual inspection approach to similarity using reduced sampling effort to historic data collected from 2009-2021 and compared reef-level outcomes for 11 of the relative performance standards to those obtained with the similarity approach used with full monitoring.
 - The relative standard for undesirable and invasive species was not included in this analysis because it must be met each year for Wheeler North Reef to receive mitigation credit for that year.
- Numbers in columns are the number of performance standards passed by a reef in that year for full monitoring (left) and reduced monitoring (right).
- Green numbers mean a reef met as many or more standards as the lower performing reef used for reference (i.e., it was “similar”)
- Red numbers mean a reef met fewer standards than the lower performing reef used for reference (i.e., it was “dissimilar”)
- The bottom row sums the number of years that a reef was deemed to be the lowest using full vs. reduced monitoring.
- Overall, estimates of similarity based on reduced monitoring (i.e. # of years not the lowest) are comparable with those based on full monitoring

Reduced monitoring for absolute performance standards

Eliminate one of the transects in each of the 40 pairs on Phase 2

| Type of Performance Standard | Monitoring effort per reef | | Amount Reduced |
|------------------------------------|----------------------------|---------|----------------|
| | Full | Reduced | |
| Absolute: transect data (WNR only) | | | |
| Hard substrate | 82 | 47 | 43% |
| Kelp area | 151 | 111 | 26% |
| Fish standing stock | 151 | 111 | 26% |



Estimates of adult kelp area and fish standing stock based on reduced monitoring are comparable with those based on full monitoring

- A change to annual site inspections for evaluating the relative performance standards and provides an opportunity to reduce the sampling effort for the absolute standards.
- This is most easily accomplished by eliminating one of the transects in each of the 40 pairs of transects used to sample Phase 2 of Wheeler North Reef
- This table shows the comparison of sampling effort between full monitoring and the reduced sampling approach developed for annual site inspections for the absolute performance standards, which are all collected on transects.
- For the hard substrate standard, sampling will be reduced from 82 to 47 transects, which is a 43% reduction.
- For the kelp area and fish standing stock standards, sampling will be reduced from 151 to 111 transects, which is a 26% reduction.
- The bottom two figures show that estimates of adult kelp area and fish standing stock based on reduced monitoring (open circles) are comparable with those based on full monitoring (black circles).

Plans for future monitoring of Wheeler North Reef

- Begin reduced monitoring for annual site inspections in **2024**
- Return to full monitoring if:
 1. Wheeler North Reef fails to meet as many relative performance standards as the lowest performing reference reef,
and
 2. the reason for Wheeler North Reef's failure is not associated with reduced monitoring



- Moving forward, reduced monitoring for annual site inspections will begin in **2024**
- The project will return to full monitoring if:
 - Wheeler North Reef fails to meet as many relative performance standards as the lowest performing reference reef, and
 - the reason for Wheeler North Reef's failure is not due to lower confidence associated with reduced monitoring, but rather actual underperformance relative to the reference reefs.

Annual Public Workshop
San Onofre Nuclear Generating Station Artificial Reef Mitigation Project
April 8, 2024

Questions?



Annual Public Workshop
San Onofre Nuclear Generating Station Artificial Reef Mitigation Project
Monday, April 8, 2024

Agenda

- 1:30 – 1:45** **Introduction to SONGS reef mitigation – *Dan Reed, UCSB***
- 1:45 – 2:30** **Results from the 2023 performance monitoring of the Wheeler North Reef – *Rachel Smith, UCSB***
- 2:30 - 2:45** **Questions and comments on performance monitoring results**
- 2:45 – 3:00** **Lessons learned from 25 years of monitoring Wheeler North Reef
*Kat Beheshti, UCSB***
- 3:00 - ??** **Questions, comments and general discussion**

