

Performance Evaluation of Wheeler North Reef

2014 Monitoring Results



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

This presentation focuses on the results of the 2014 monitoring of the Wheeler North Reef and an evaluation of its performance with respect to the physical and biological standards on which it is being judged.

Types of Performance Standards

1. Absolute standards: Measured against a fixed value at Wheeler North Reef only.

(e.g., 150 acres of giant kelp, 28 tons of fish biomass)

2. Relative standards: Must be similar to natural reefs.

(e.g., the abundance and number of species of algae and macroinvertebrates must be similar to that of natural reefs)

Two types of physical and biological standards are used to judge the performance of the Wheeler North Reef.

- 1) Absolute standards are measured against fixed value at Wheeler North Reef only.
- 2) Relative standards are measured at Wheeler North Reef and the two reference reefs and are used to judge whether the Wheeler North Reef is performing similar to natural reefs.

Absolute Performance Standards

Requirement

Wheeler North Reef must meet each absolute performance standard in a given year for that year to count towards mitigation credit.

Method of Evaluation

The evaluation of each absolute performance standard is based on the value for the current year or the average value calculated from the current year and the previous three years, *which ever is higher*.

Rationale

- Absolute performance standards are based on average annual losses caused by SONGS and all of them need to be met to insure that the lost resources are replaced.
- Assessing the absolute performance standards using *either the current year's value or a four-year running average* recognizes that short-term fluctuations in the physical and biological attributes at Wheeler North Reef are to be expected even if it is providing adequate compensation on average.

Absolute Performance Standards for Wheeler North Reef



There are four absolute performance standards that the Wheeler North Reef must meet each year in order to receive mitigation credit:

1. The availability of hard substrate
2. The area of giant kelp
3. The size of the fish standing stock
4. Adverse effects of invasive and undesirable species

Performance Standard: Hard Substrate

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



Phase 1 Reef, March 2000

- The performance standard for hard substrate requires at least 90% of the exposed rock initially present at Wheeler North Reef to remain available for the attachment by reef biota.

Evaluating the Performance of Hard Substrate

1. Measure footprint area (A) of Wheeler North Reef
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 immediately after reef construction to determine whether 90% or more is still available for reef biota



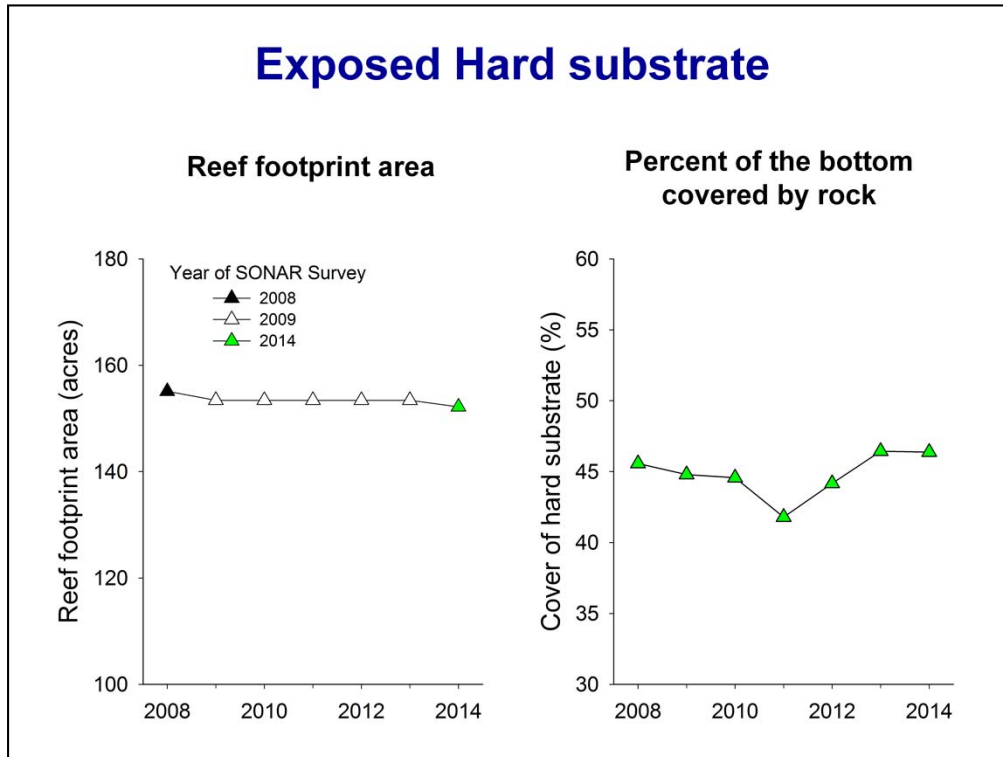
9 Substrate categories:

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:

- Measuring the footprint area (A) of Wheeler North Reef using multi-beam sonar.
- Estimating the percent cover of exposed rock (P) in the same 1 m² quadrats used to verify the construction 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 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 counted as hard substrate in our analyses.

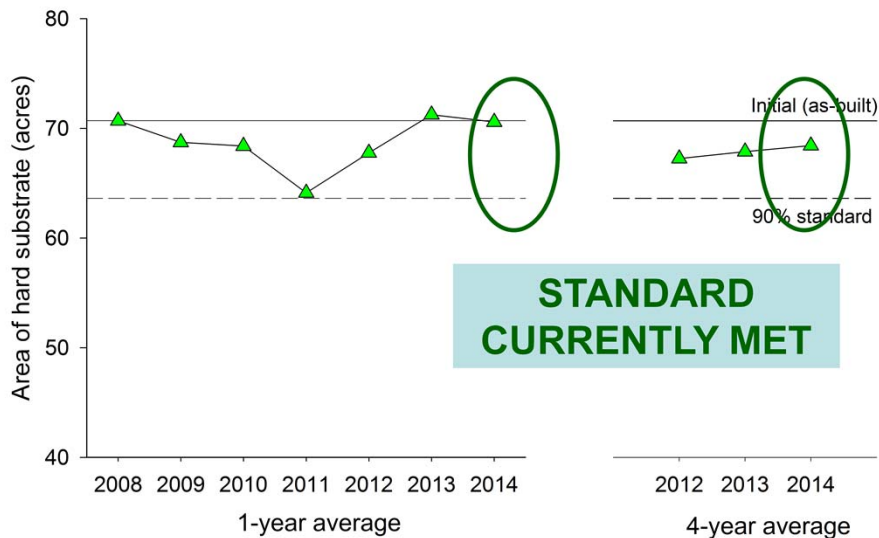
Exposed Hard substrate



- This slide shows the two variables used to estimate the amount of exposed hard substrate on the Wheeler North Reef.
- Both of these variables apply only to the 152 acre subset of the Wheeler North Reef, which was the portion of the reef that met the 150 acre standard of > 42% cover of rock following its construction in 2008.
- There was a small 2 acre decrease in the footprint area in the year following construction (2009), which was not unexpected as rocks settle into the soft sandy bottom.
- Because the footprint area of the reef is not expected to change much from year-to-year, beginning in 2009, multi-beam sonar surveys are only done once every five years.
- A second sonar survey was done in 2009 and the value for reef footprint area was assumed to be the same for the five-year period from 2009 to 2013.
- A third sonar survey was recently completed in 2014, 5 years after the 2009 survey and the footprint for this survey was used to estimate the area of hard substrate in 2014, which was slightly less than that measured in 2009.
- Unlike footprint area, the percent of the bottom covered by rock is measured every year by divers.
- The percent cover of rock declined from ~ 45.5% in 2008 to ~ 42% in 2011, before steadily increasing to ~ 46.5% in 2013 and 2014.

Performance Standard: Hard Substrate

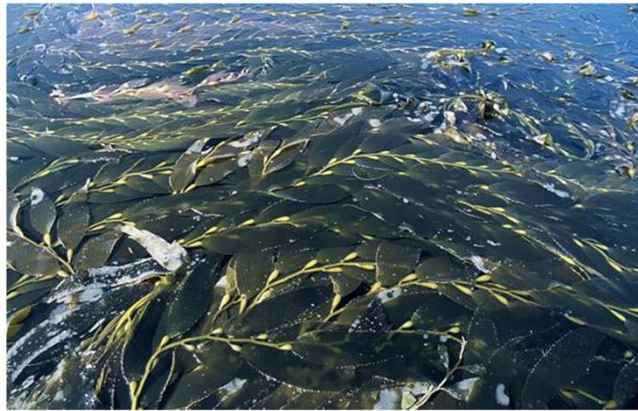
At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota



- The initial amount of hard substrate at Wheeler North Reef used to judge this performance standard was 70.6 acres in 2008.
- The 2 acre decrease in footprint area in 2009 coupled with a continued decline in the % cover of hard substrate through 2011 resulted in nearly a 10% decrease in the total area of hard substrate on Wheeler North Reef by 2011.
- An increase in the percent cover of rock since then has resulted in the total area of hard substrate increasing to about 71 acres in 2014 or roughly 1/2 acre larger than that initially constructed.
- Thus the performance standard for reef area was met in 2014 regardless of whether the evaluation was based on data from 2014 alone or the 4-year running average (2012-2014).

Performance Standard: Giant Kelp

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



- Medium-to-high density giant kelp is defined as at least 4 adult plants 100 m²
- Adult plants are defined as individuals having at least 8 fronds

- The performance standard for giant kelp requires the Wheeler North Reef to sustain 150 acres of medium-to-high density giant kelp.
- Medium-to-high density giant kelp is defined as at least 4 adult plants per 100 m².
- Adult plants are defined as individual plants with at least 8 fronds.
- These definitions for kelp are the same ones that were used to quantify the impacts to giant kelp caused by SONGS during the impact assessment phase of this project.

Evaluating the Performance of Giant Kelp



Measure the density of adult giant kelp in a fixed 100 m² area of each transect at Wheeler North Reef

Determine whether:

$$P \times 174 \text{ acres} \geq 150 \text{ acres}$$

where:

P = proportion of transects with at least 4 adult plants, and

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

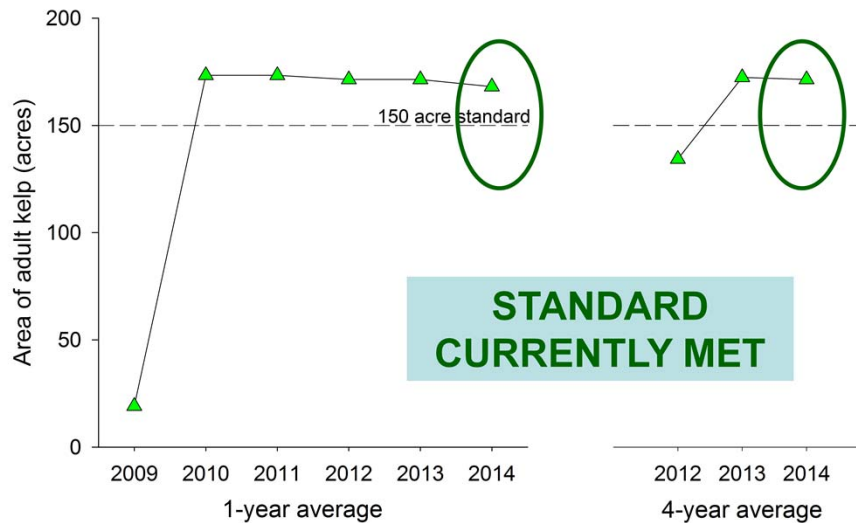
Method of Evaluation

The evaluation of whether the performance standard is met is based on the value for current year or the average value calculated from the current year and the previous three years, *which ever is higher*.

- The performance standard for giant kelp is evaluated by measuring the density of giant kelp in the fixed transects across the entire Wheeler North Reef.
- Using these data we calculate the proportion of transects on the Wheeler North Reef that have adult kelp densities greater than 4 plants per 100 m².
- This proportion is multiplied by 174 acres (= the total footprint area of Wheeler North Reef measured in the most recent sonar survey) to obtain the total acreage of adult kelp on the Wheeler North Reef.

Performance Standard: Giant Kelp

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



- The area of medium-to-high density adult kelp on Wheeler North Reef increased dramatically from 19 acres in 2009 to 174 acres in 2010.
- This represented the growth of the young kelp that colonized in 2009.
- 89 of the 92 transects sampled had at least 4 adult plants 100 per m² in 2014, resulting in ~ 168 acres of adult giant kelp.
- The acreage of giant kelp at the Wheeler North Reef exceeded the 150 acre threshold when evaluated using data from 2014 or the 4-year running average of 2011-2014.
- Thus the Wheeler North Reef met the performance standard for giant kelp in 2014.

Performance Standard: Fish Standing Stock

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



- The performance standard for fish biomass requires the Wheeler North Reef to support at least 28 US tons of fish, which is the estimated reduction in the biomass of kelp bed fish caused by SONGS operations.

Methods used to evaluate the standing stock of reef fish



1. Apply species-specific length-weight relationships to data on fish density and size to calculate the average biomass per m^2 of all fish near the bottom from all transects.
2. Scale up estimates of fish biomass m^2 to the area of Wheeler North Reef to obtain an estimate of the standing stock of fish near the bottom at Wheeler North Reef.

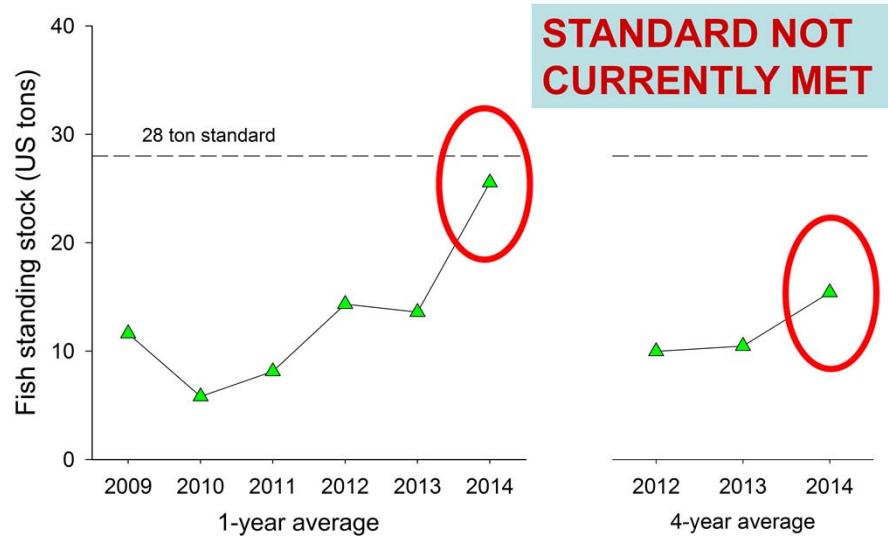
Method of Evaluation

The evaluation of whether the performance standard is met is based on the value for current year or the average value calculated from the current year and the previous three years, *which ever is higher*.

- Data on fish density and length collected from the 50 m transects are used to calculate the total standing stock of fish near the bottom on Wheeler North Reef to determine whether it supports 28 tons of reef fish.
- The weights of the fish counted are estimated from known relationships between length and weights 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 mean biomass density averaged over all transects is multiplied by 174 acres to obtain an estimate of the standing stock of fish near the bottom at Wheeler North Reef.

Performance Standard: Fish Standing Stock

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



- Plotted here are the estimates for standing stock of bottom reef fish at the Wheeler North Reef using the 1-year average on the left and the 4-year running average on the right.
- Fish standing stock on the Wheeler North Reef has fluctuated between a low value of 5.8 tons in 2010 to its highest value of 25.5 tons in 2014.
- Despite the high value in 2014, after six years the Wheeler North Reef has yet to meet the performance standard for fish standing stock, regardless of whether it was evaluated using 1-year or the 4-year average.

Performance Standard: Invasive Species

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

Important reef functions may include: food-chain support and nursery habitat for fishes, and primary production by giant kelp



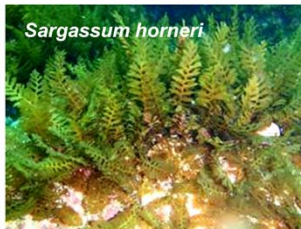
Sea fan aggregation



Caulerpa taxifolia



Sea urchin barrens



Sargassum horneri

Undesirable or invasive species that are of potential concern include:

- Sea urchins
- Sea fans
- Non-native algae (e.g., *Caulerpa*, and *Sargassum*)

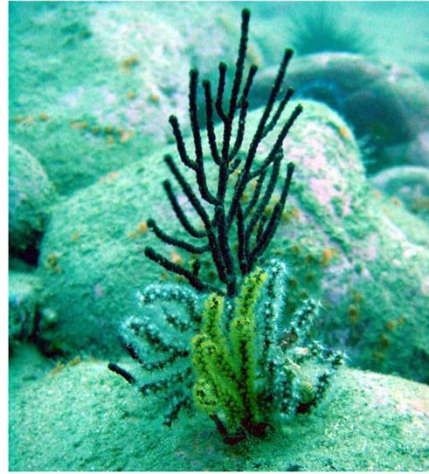
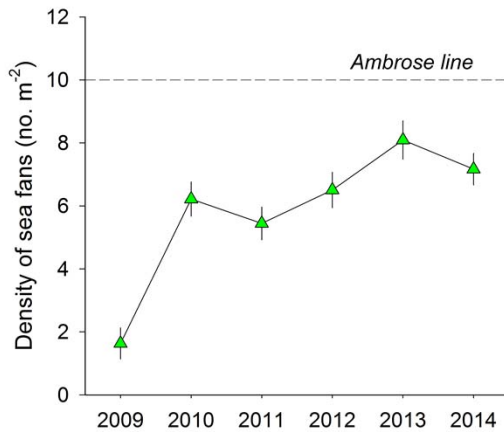
- Important functions of the reef can include, but are not limited to: food chain support for fishes, nursery habitat for fishes as estimated by the density of young-of-year fish and primary production by giant kelp, which can be estimated from the density of kelp fronds.
- Undesirable or invasive species can include native species that attain very high abundances, which can be the case for dense aggregations of sea fans that can monopolize space and exclude other species, or high densities of sea urchins that can over graze the bottom and create large deforested areas commonly called sea urchin barrens.
- Undesirable or invasive species can also include introduced or non-native species such as the green seaweed *Caulerpa* which has escaped from the aquarium trade and invaded many marine habitats worldwide including some in southern California, and the brown seaweed *Sargassum* which was accidentally introduced from Asia and has become increasingly abundant on some reefs off southern California.

High densities of sea fans may exclude giant kelp



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Invasive/Undesirable Species: Sea Fans

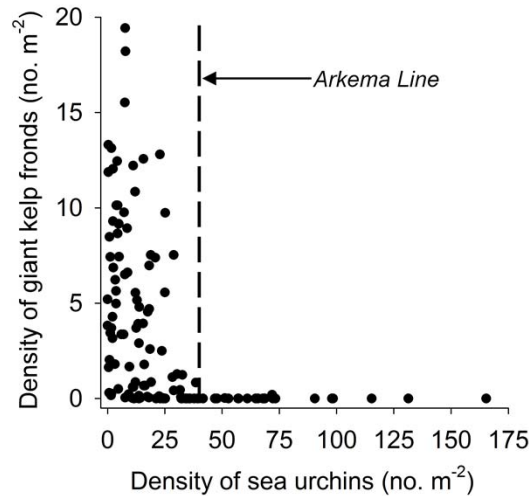


- Initial colonization of sea fans in 2010, with a steady increase through 2013 and a slight decline in 2014
- Sea fan density still below *Ambrose line*
- Sea fans cover < 3% of the rock surface at Wheeler North Reef

- Plotted here are the mean densities of sea fans at Wheeler North Reef for 2009 - 2014.
- The vertical lines through the symbols represent the standard error of the means.
- 2010 was a good year for sea fan recruitment and the densities of sea fans at Wheeler North Reef increased dramatically to about 6 m⁻².
- There was a slight decline in density in 2011 with a steady increase through 2013 to a density of ~ 8 individuals m⁻², followed by a slight decline in 2014, and thus no indication of a temporal trend toward the Ambrose line
- It is worth noting that sea fans observed in the earlier study by Ambrose were mostly very large individuals that occupied a large amount of space on the reef.
- In contrast, sea fans on Wheeler North Reef are much smaller and occupied only about 2.6% of the rock surface area in 2014.

Invasive/Undesirable Species: Sea Urchins

High densities of sea urchins may over graze giant kelp

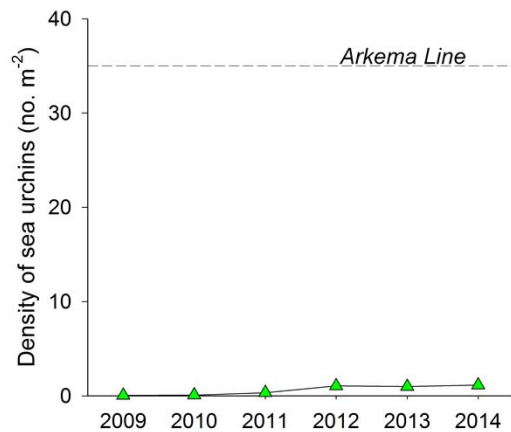


data from Arkema et al. 2009

- The destructive damage to kelp forests caused by the grazing activities of large aggregations of sea urchins has been observed in kelp forests throughout the world.
- Similar to the Ambrose study, Katie Arkema, a former graduate student of ours, found there was a critical density of sea urchins above which giant kelp was unable to persist.
- This density was about 35 urchins m⁻².
- For the sake of convention we refer to this density of sea urchins as the Arkema line.

Invasive/Undesirable Species: Sea Urchins

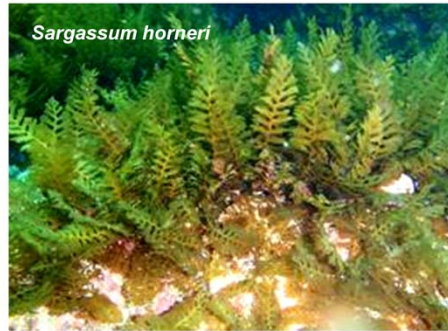
Sea urchin densities at Wheeler North Reef continue to be well below those known to eliminate giant kelp



- Plotted here are the mean densities of sea urchins on the Wheeler North Reef for 2009 to 2014.
- Sea urchin densities have consistently been very low and well below the Arkema line for the entire time series.

Performance Standard: Invasive Species

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



No non-native invasive species of algae have been observed in any abundance at Wheeler North Reef

Performance Standard: Invasive Species

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

Conclusion: No evidence that invasive or undesirable species have adversely affected the important functions of Wheeler North Reef

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- We conclude from these data that the important ecological functions of the Wheeler North Reef have not been impaired by invasive or undesirable species.
- Thus the Wheeler North Reef has consistently met this standard in all six years.

Relative Performance standards require 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 and boulders.
- 4) located within the local region.

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

- Choosing the natural reefs that are used as reference was a critical element of the mitigation project because the reference reefs are used to evaluate the success of the Wheeler North Reef.

What counts as similar when assessing the relative performance standards?

Definition of similar: The mean value for a performance standard at Wheeler North Reef must *not be significantly less than* that at the reference reef having 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 natural reef used as a reference.

- The SONGS Coastal Development Permit envisioned a quantitative definition of “similar” for evaluating the performance of the reef mitigation projects relative to reference sites, 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 chosen is that the mean value for a performance variable at Wheeler North Reef must not be significantly less than the reference reef having the lowest value for that performance variable.
- This definition recognizes that no two natural reefs are identical, but that any reef chosen as a reference site should serve as an acceptable standard. Because there is a certain amount of error associated with any type of sampling (especially when diving in less than favorable conditions) we determined that we needed to be at least 80% confident that the Wheeler North Reef performed as well as the lowest performing reference site.

Relative Performance Standards

Requirement

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

Method of Evaluation

- The evaluation of each relative standard in any given year is based on a four-year running average calculated from data collected at WNR and the reference reefs for that year and the previous three years.
- WNR and the reference reefs are evaluated with respect to whether or not they meet each relative standard and the total number of relative standards met by each reef is tallied and compared.

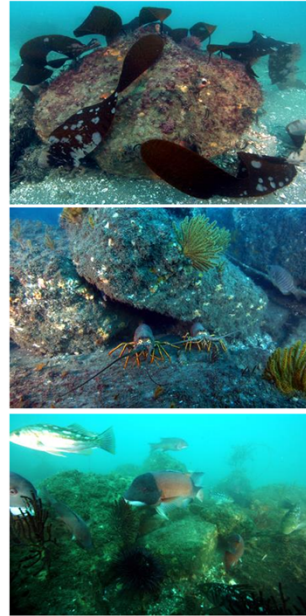
Rationale

- A running average rather than the value for the current year better accounts for natural fluctuations over time.
- Requiring WNR to meet at least as many relative standards as the reference reefs achieves the desired goal of WNR being similar to natural reefs without requiring it to consistently outperform them.

- The evaluation of each relative performance standard is based solely on a four-year running average calculated from data collected at the Wheeler North Reef and the two reference reefs for that year and the previous three years.
- A 4-year running average is long enough to account for natural variation in time, but not so long that it precludes evaluating the performance of WNR within a reasonable period of time.
- An either/or criterion (i.e., using data from either a single year or a running average) is not appropriate in this case because the purpose for the relative standards is not for WNR to achieve a specified value that is linked to the estimated losses at the San Onofre kelp forest, but rather for WNR to produce kelp bed resources similar to those at the reference reefs.
- Using an either/or criterion greatly reduces the ability to detect differences between the Wheeler North Reef and the reference reefs when such differences exist.
- Natural kelp forests vary greatly in their species composition and abundance and it is likely that the reference reefs will not consistently meet all the relative standards in a given year.
- To avoid requiring the Wheeler North Reef to perform better than the reference reefs the Wheeler North Reef is required to meet at least as many of the relative standards as the lowest performing reference reef in a given year for that year to count towards mitigation credit.

Relative Performance Standards for Wheeler North Reef

1. Algal percent cover
2. Algal 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



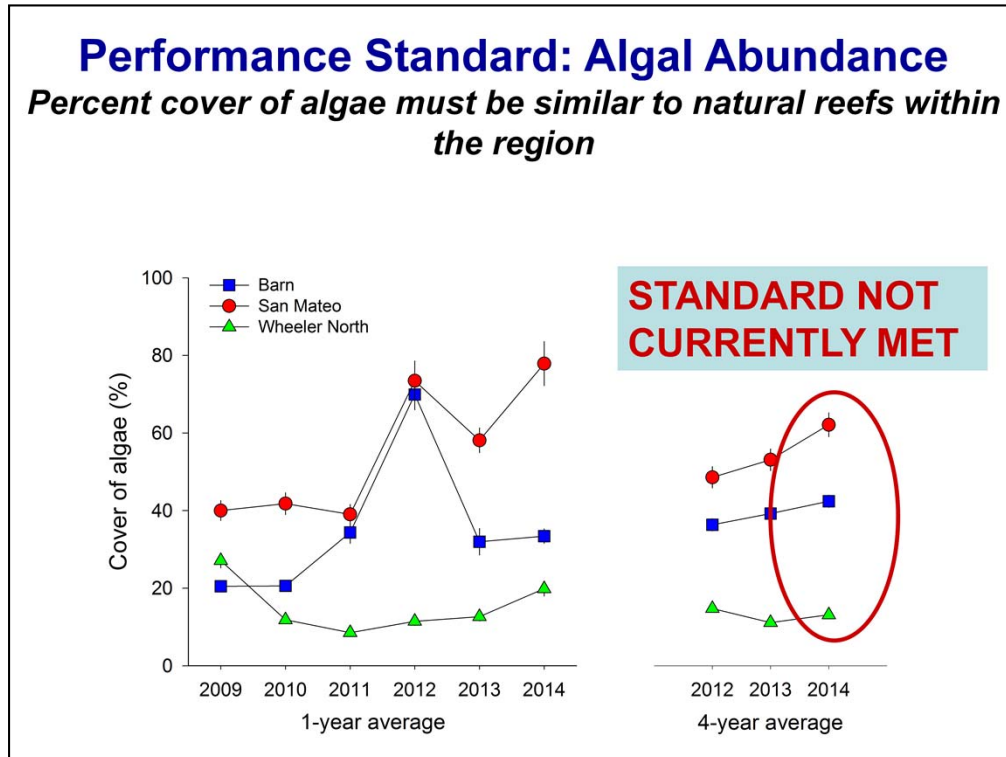
- Shown here are the 11 relative performance standards that are used to judge the Wheeler North Reef.
- Standards 1-5 pertain to the benthic community of algae and invertebrates.
- Standards 6-10 pertain to reef fishes.
- Standard 11 integrates the benthic community of algae and invertebrates with reef fishes by focusing on the extent to which the benthic community supplies food for reef fishes.
- What follows is an evaluation of how the Wheeler North Reef performed in 2014 with respect to these 11 standards.

Performance Standard: Algal Abundance

Percent cover of algae must be similar to natural reefs within the region



- The performance standard for algal abundance requires the percent cover of algae at the Wheeler North Reef to be similar to that on reference reefs within the region.



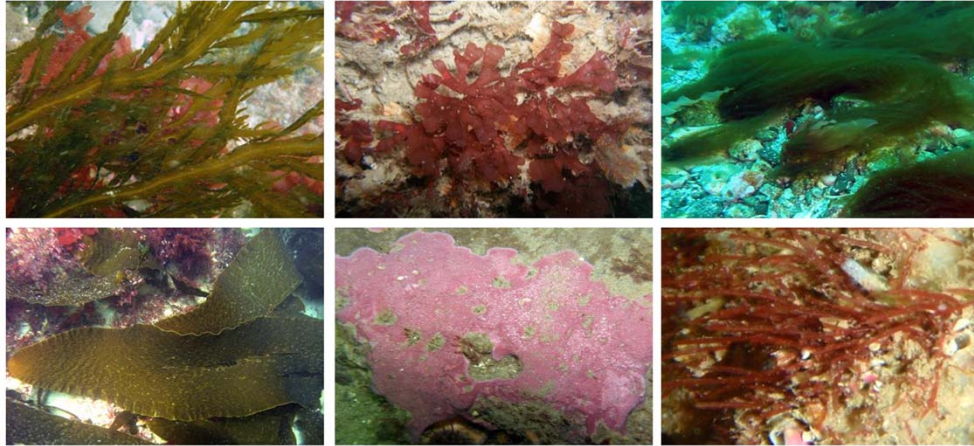
- This graph shows the percent cover of understory algae at Wheeler North Reef, Barn and San Mateo, both as a time series on the left and as the 4-year running average on the right.
- The colored symbols in this graph represent the mean value of each reef, and the vertical lines through the symbols represent ± 1 standard error.
- This same format with the time series on the left and the 4-year average on the right for Wheeler North Reef, San Mateo and Barn will be used for all the graphs in this presentation that pertain to the relative performance standards.
- The annual times series on the left shows that the percent cover of algae at Wheeler North Reef was initially within the range observed at San Mateo and Barn in 2009.
- The percent cover of algae at Wheeler North Reef decreased to about 8.5% in 2011 and has increased slightly to a value of about 20% in 2014, which was coincident with the slight decrease in giant kelp that year.
- It is well established that shading by giant kelp inhibits the recruitment and growth of understory algae.
- In contrast, the percent cover of algae at the two reference sites where giant kelp is less abundant increased during the six years of monitoring, most notably in 2012, before declining in 2013 following an increase in kelp at both sites.
- The percent cover of algae increased slightly at Barn and more substantially at

SMK between 2013 and 2014.

- As with all the relative standards the 4-year running average is used to evaluate whether Wheeler North Reef has met this performance standard.
- Despite the increase in the percent cover of algae in 2014, the 4-year running average remained substantially below values at the reference reefs.
- Consequently, the Wheeler North Reef did not meet this performance standard in 2014.

Performance Standard: Algal Diversity

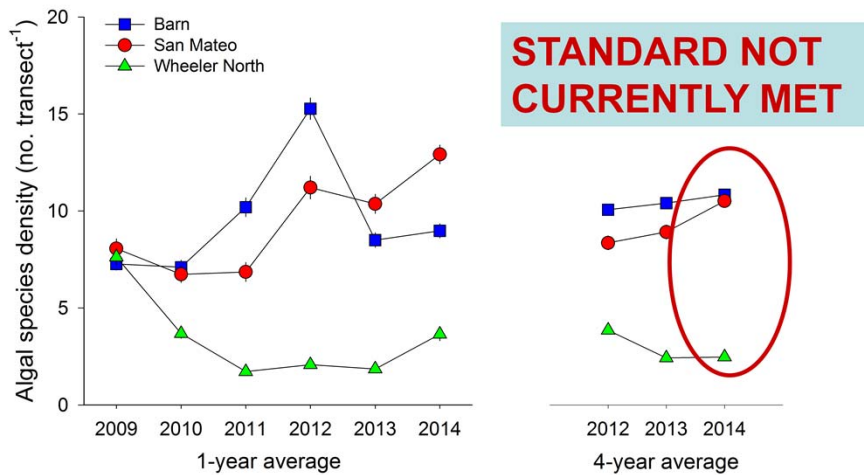
The number of species of algae must be similar to natural reefs within the region



- The performance standard for algal diversity requires the number of species of algae at the Wheeler North Reef to be similar to that on reference reefs within the region.
- There are many different types of brown red and green algae, including big blades, small blades and branches, fine filaments and crusts.
- The metric used to evaluate this performance standard is the mean number of algal species per transect.

Performance Standard: Algal Diversity

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



- These two graphs show the mean number of species of algae per transect at Wheeler North Reef, Barn and San Mateo as time series of 1-year averages on the left and as a 4-year running average on the right.
- The graph on the left shows that temporal trends in algal diversity were similar to those observed for algal percent cover.
- The average number of species per transect declined from 2009 through 2013 at Wheeler North Reef, while it increased at the two reference reefs.
- The average number of species per transect increased at all three reefs from 2013 to 2014.
- Despite the increase at the Wheeler North Reef in 2014, the 4-year running average of algal species density at Wheeler North Reef was much lower than that at Barn and San Mateo.
- Consequently, the Wheeler North Reef did not meet the performance standard for algal diversity in 2014.

Performance Standard: Invertebrate % Cover

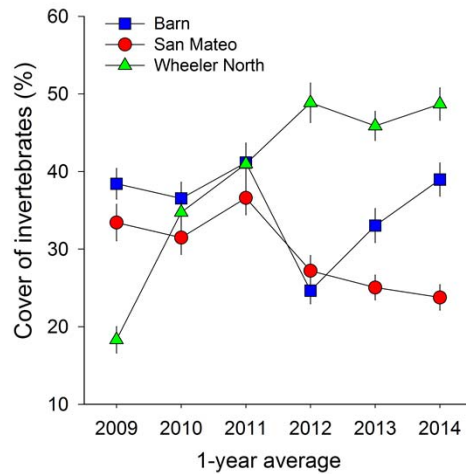
Percent cover of sessile invertebrates must be similar to natural reefs within the region



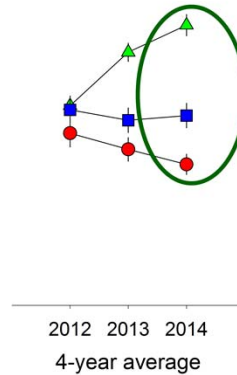
- The performance standard for invertebrate percent cover requires the percent cover of sessile invertebrates at the Wheeler North Reef to be similar to that at reference reefs within the region.
- Sessile invertebrates include a wide variety of taxa that feed by filtering particles out of the water column.
- Common sessile invertebrates monitored at Wheeler North Reef, San Mateo and Barn include sponges, bryozoans, sea anemones, sea fans, bivalves, and sea squirts.

Performance Standard: Invertebrate % Cover

Percent cover of sessile invertebrates must be similar to natural reefs within the region



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- Plotted in these graphs is the percent cover of sessile invertebrates at Wheeler North Reef, Barn and San Mateo.
- It turns out that sessile invertebrates and algae compete for space on the reef and increases in the percent cover of one of these groups is typically accompanied by a decrease in the percent cover of the other group.
- This is exactly that 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 quite low relative to the reference reefs, but increased over time as the cover of algae decreased.
- By contrast the percent cover of sessile invertebrates showed a sharp decrease at Barn and San Mateo in 2012, which is the exact opposite pattern observed for algae at these sites as shown in the previous slides.
- Invertebrate percent cover has continued to decline at San Mateo through 2014; has increased at Barn; and has remained high at the Wheeler North Reef.
- These patterns have resulted in a four-year running average of the percent cover of sessile invertebrates at the Wheeler North Reef that was greater than either Barn or San Mateo
- As a result the Wheeler North Reef met this performance standard in 2014.

Performance Standard: Invertebrate Density

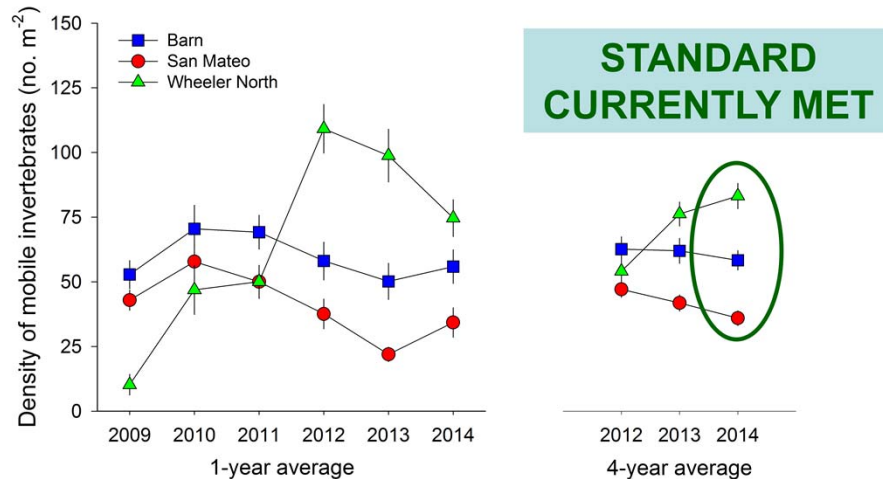
Density of mobile invertebrates must be similar to natural reefs within the region



- The performance standard for invertebrate density requires the density of mobile invertebrates at the Wheeler North Reef to be similar to that at reference reefs within the region.
- Mobile invertebrates are species of predators, grazers, detritivores and deposit feeders that move about the bottom in search of food.
- Common mobile invertebrates monitored at Wheeler North Reef, San Mateo and Barn include a wide range of snails, crustaceans, brittle stars, sea stars and sea urchins.

Performance Standard: Invertebrate Density

Density of mobile invertebrates must be similar to natural reefs within the region



- Much like the percent cover of sessile invertebrates, the density of mobile invertebrates at Wheeler North Reef was initially low ($< 10 \text{ m}^{-2}$) in 2009, and has increased over time to densities $\sim 110 \text{ individuals m}^{-2}$ in 2012.
- Brittle stars are the single most abundant group of mobile invertebrates.
- Since 2012, the density of mobile invertebrates at Wheeler North Reef has declined steadily from $\sim 110 \text{ individuals m}^{-2}$ to about 75 m^{-2} in 2014.
- In contrast the densities of mobile invertebrates at San Mateo and Barn have fluctuated much less over the six-year sampling period with densities ranging between 25 to 70 individuals m^{-2} .
- These patterns have resulted in a four-year running average of mobile invertebrate density at Wheeler North Reef in 2014 that was greater than that at the two reference reefs.
- Thus the Wheeler North Reef met this performance standard for 2014.

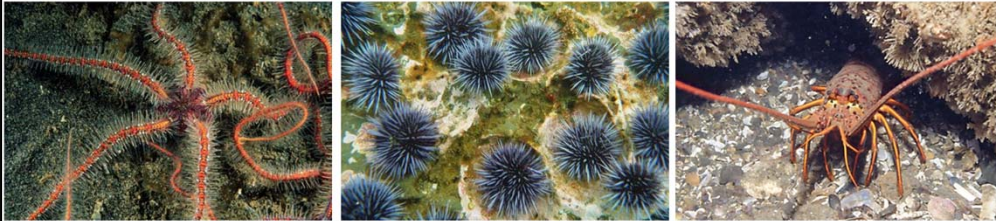
Performance Standard: Invertebrate Diversity

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

Sessile Invertebrates



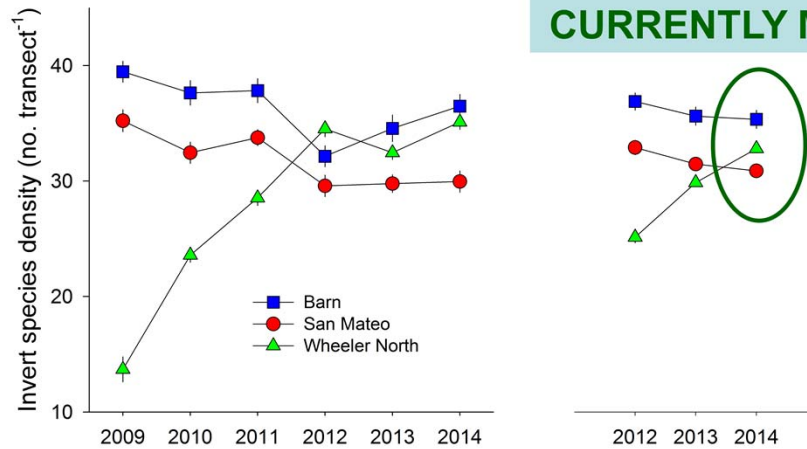
Mobile Invertebrates



- The performance standard for invertebrate diversity requires the combined number of species of sessile and mobile invertebrates at the Wheeler North Reef to be similar to that on reference reefs in the region.
- The metric used to evaluate this performance standard is the mean number of invertebrate species per transect.

Performance Standard: Invertebrate Diversity

The number of species of sessile and mobile invertebrates combined must be similar to natural reefs within the region



- Plotted here is the mean number of species of sessile and mobile invertebrates combined per transect at Wheeler North Reef, San Mateo and Barn from 2009 through 2014.
- The average number of invertebrate species per transect at the two reference reefs has declined slightly over the six-year sampling period, whereas it substantially increased at Wheeler North Reef from a low value of 12 species per transect in 2009 to ~ 35 in 2012 through 2014.
- The number of species of invertebrates at Wheeler North Reef has been similar to that of the reference reefs during the last three years.
- As a result its 4-year running average at the Wheeler North Reef is now similar to that of the two reference reefs in 2014.

Performance Standard: Resident Fish

The resident fish assemblage shall have a total density similar to natural reefs within the region

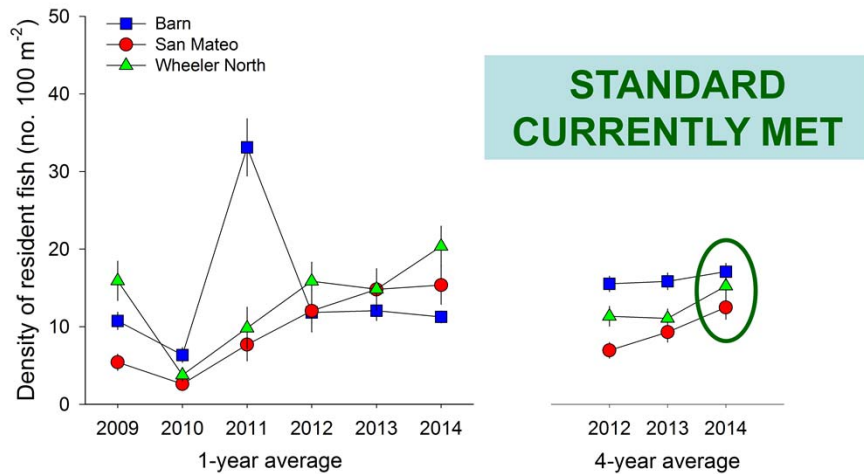


Resident Fish are defined as reef associated species 1 year of age or older

- The performance standard for resident fish requires the density of resident fishes at the Wheeler North Reef to be similar to that at reference reefs within the region.
- Resident fish are defined as reef associated species 1 year of age or older.

Performance Standard: Resident Fish

The resident fish assemblage shall have a total density similar to natural reefs within the region



- The densities of resident fish was relatively high at Wheeler North Reef during the first year of monitoring, reflecting immigration from the surrounding area.
- In 2009, 1 year after its construction, the density of fish at the Wheeler North Reef was 2 to 3 times greater than that at the reference reefs.
- Since then fish densities have been relatively similar among the three reefs and years.
- The lone exception to this was a spike in resident fish density at Barn in 2011.
- The four-year running average of resident fish at the Wheeler North Reef in 2014 is above that at San Mateo hovering around 20 fish 100 m⁻².
- Thus, Wheeler North Reef met the performance standard for resident fish density in 2014.

Performance Standard: Young-of-Year Fish

The total density of young-of-year fish shall be similar to natural reefs within the region

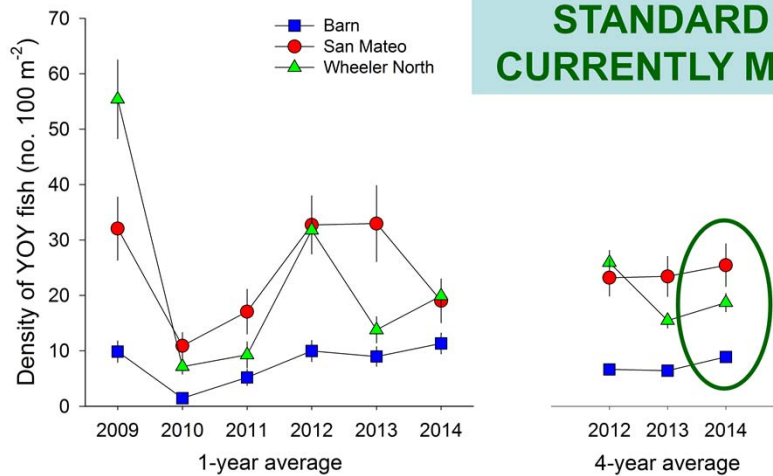


Young-of-Year Fish are defined as reef associated fish that are < 1 year old

- There is also a performance standard that requires the density of young-of-year fish at Wheeler North Reef be similar to natural reefs.
- Young-of-Year Fish are defined as reef associated fish that were born in the year that they were sampled.
- The rationale for this performance standard is that kelp forests serve as important nursery habitat for reef associated fish and that it is important for the Wheeler North Reef to provide this important ecological function.

Performance Standard: Young-of-Year Fish

The total density of young-of-year fish shall be similar to natural reefs within the region



- Plotted here are the average densities of young-of-year (YOY) fish for Wheeler North Reef, San Mateo and Barn from 2009-2014.
- YOY densities in 2009 were 2-5 times high at Wheeler North compared to San Mateo and Barn due to a large recruitment of the Blackeye Goby, *Rhinogobius nicholsii*.
- Since then the mean density of YOY fish at Wheeler North Reef have fluctuated within the range set by San Mateo and Barn.
- The 2014 value for YOY density at Wheeler North Reef was slightly higher than that at San Mateo and much higher than that at Barn.
- The four-year average of YOY density at Wheeler North Reef was intermediate between densities at San Mateo and Barn in 2014, resulting in Wheeler North Reef meeting this standard in 2014.

Performance Standard: Fish Diversity

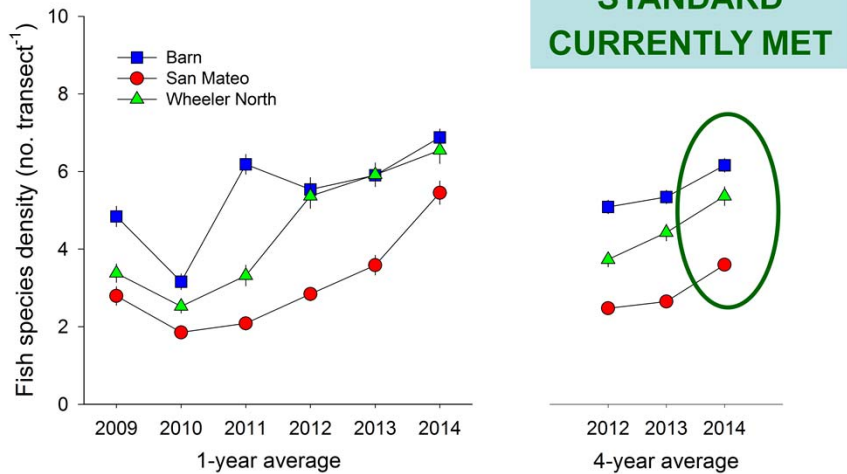
The number of species of resident and young-of-year fish shall be similar to natural reefs within the region



- The performance standard for fish diversity requires the density of resident and YOY fishes combined at the Wheeler North Reef to be similar to that at reference reefs within the region.
- The metric used to evaluate this performance standard is the mean number of fish species per transect.

Performance Standard: Fish Diversity

The number of species of fish shall be similar to natural reefs within the region



- Fish diversity has generally increased at the three reefs since 2009, with Barn typically displaying the highest diversity and San Mateo the lowest.
- The 4-year average of the mean number of fish species per transect for Wheeler North Reef in 2014 was intermediate between Barn and San Mateo.
- Thus the Wheeler North Reef met the performance standard for fish diversity in 2014.

Performance Standard: Fish Reproductive Rates

Fish reproductive rates shall be similar to natural reefs within the region

Goal :

Estimate annual egg production for three common “indicator” species

Method of Evaluation:

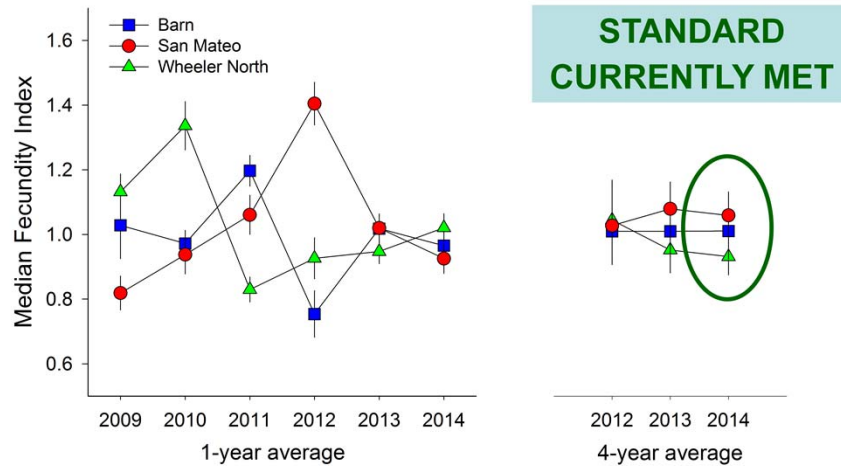
- Measure egg production and body length of individuals of each species collected from Wheeler North Reef and the two reference reefs.
- Standardize egg production and body length for each species across all reefs for each year.
- Use the standardized data to calculate a “Fecundity Index” for each reef in each year that represents an average fecundity index for the three species.



- The rationale for the performance standard pertaining to fish reproductive rates is that for artificial reefs to be considered successful, fish must be able to successfully reproduce.
- Our goal in evaluating this performance standard is to estimate the annual egg production (which we refer to as annual fecundity) for three common indicator species of reef fish.
- The species are the California Sheephead and Senorita, which are wrasses that feed on invertebrates, and Kelp Bass, which primarily feeds on other species of fish.
- To estimate annual fecundity we measure egg production and body length of individuals of each species collected from Wheeler North Reef and the two reference reefs.
- We then standardize the values of egg production and body length across all species and reefs for a given year.
- These standardized data are then used to calculate a “Fecundity Index” for each reef in each year that represents an average fecundity index of the three species.

Performance Standard: Fish Reproductive Rates

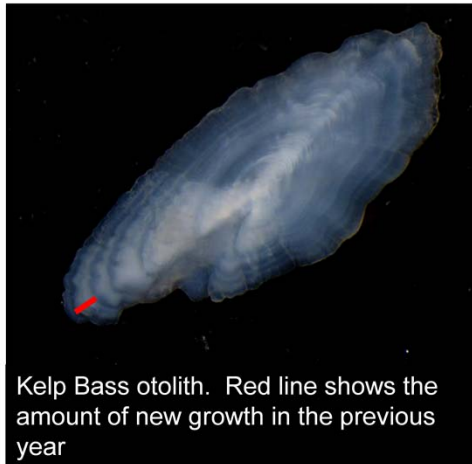
Fish reproductive rates shall be similar to natural reefs within the region



- Plotted here is the Median Fecundity Index averaged across the three species for Wheeler North Reef, San Mateo and Barn from 2009 through 2014.
- Fish reproductive rates has varied inconsistently among the three reefs during this period.
- Despite the erratic and asynchronous fluctuations in fish reproductive rates at the three sites, their 4-year running averages of the Median Fecundity Index have been very similar the past three years.
- The 4-year average for the Wheeler North Reef in 2014 was slightly less than that at the two references reefs, but not significantly so.
- Therefore the Wheeler North Reef met the performance standard for fish reproductive rates in 2014.

Performance Standard: Fish Production

Fish production shall be similar to natural reefs within the region



Kelp Bass otolith. Red line shows the amount of new growth in the previous year

Production: the rate at which biomass is produced per area of reef per year.

Method of Evaluation

Use information collected on fish density, size structure, and reproductive rates combined with estimates of somatic growth obtained from ear bones (otoliths) to calculate fish production in terms of the biomass of fish produced per unit area of reef per year

- There is also a standard for fish production. The rationale for this standard is that it is important that the Wheeler North Reef actually produce new fish and new biomass of older fish rather than simply attract older slow growing fish from other natural reefs.
- Production differs from standing stock in that production relates to the rate at which biomass is produced per unit time, whereas standing stock is simply a measure of the biomass that is on the reef at a particular point in time regardless of where and when it was produced.
- Like most organisms fish can allocate the production of new biomass to growing larger (referred to as somatic growth) or to reproduction (referred to as gonadal growth).
- Both of these components need to be measured to estimate the amount of fish biomass produced on a reef.
- We use information on fish density, size structure, and reproductive rates combined with estimates of somatic growth obtained from ear bones to calculate fish production in terms of the biomass of fish produced per area of reef per year.

Performance Standard: Fish Production

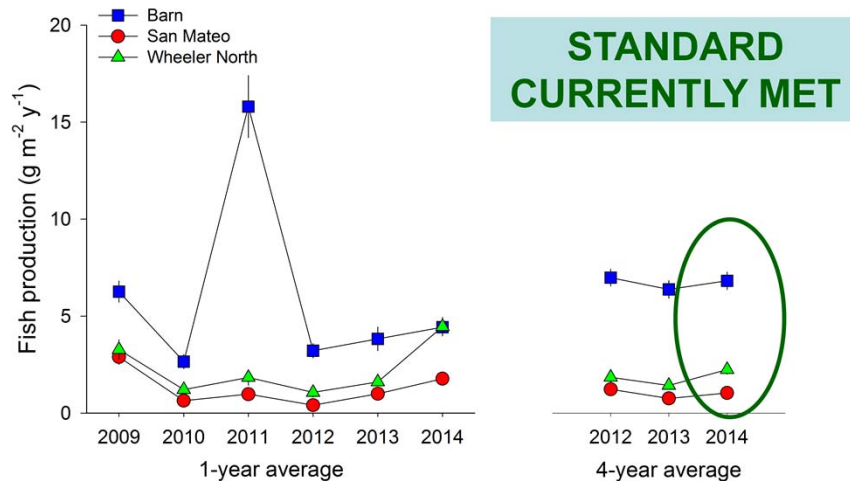
The fish production standard is evaluated using five common species that were chosen to represent the major feeding guilds of kelp forest fishes in the study region



- We use five indicator species to estimate fish production on Wheeler North, San Mateo and Barn.
- 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, California Sheephead feed on larger invertebrates on the bottom, and Kelp Bass primarily feed on other species of fish.

Performance Standard: Fish Production

Fish production shall be similar to natural reefs within the region



- Plotted in this graph is the average annual production of these five species combined for Wheeler North, San Mateo and Barn for 2009-2014.
- Temporal patterns of reef fish production at Wheeler North Reef mirrored those at San Mateo, but with slightly higher values.
- At both sites production was highest in 2009 at about $3 \text{ g m}^{-2} \text{y}^{-1}$ before declining to $< 2 \text{ g m}^{-2} \text{y}^{-1}$ in 2010, where it remained through 2013.
- Fish production at Barn has been higher than at the other two sites with very large peak in 2011, reflecting a spike in the biomass density of all five target species that year.
- Fish production increased at all three reefs from 2013 to 2014, but more strongly so at Wheeler North Reef.
- Because fish production at Wheeler North Reef has been intermediate between Barn and San Mateo from 2011 to 2014, the value of its 4-year running average was also intermediate between the two reference reefs.
- Thus, the Wheeler North Reef met the performance standard for fish production in 2014.

Performance Standard: Food Chain Support

The benthic community shall provide food-chain support for fish similar to natural reefs



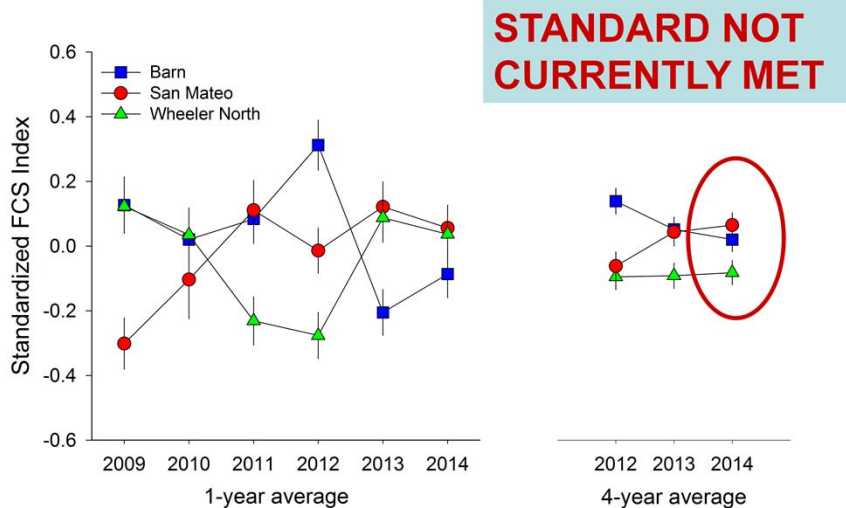
Method of Evaluation:

- Weigh gut contents in two common species of reef fish that feed directly on the bottom
- Scale mass of gut contents to body mass of fish to calculate an index of Food Chain Support (FCS) for two indicator species
- Transform the values of the FCS index for each species into a single standardized FCS index that incorporates data from both species

- There is also a performance standard that requires the benthic community of the Wheeler North reef to provide food for the fishes that feed on the reef in an amount that is similar to that provided by natural reefs.
- The way that we evaluate this performance standard is by weighing the content of the guts of two common species of fish that feed on the bottom.
- We then compare the mass of the gut contents relative to the mass of the fish, minus the mass of the gut contents and the reproductive organs (defined here as body mass) and use the ratio gut mass : body mass to calculate a index of food chain support that is scaled to the mass of a fish.
- To evaluate the Food Chain support performance standard we transform the values for the FCS index for each of the two species into a standardized FCS index and assess the performance standard using data from both species.

Performance Standard: Food Chain Support

The benthic community shall provide food-chain support for fish similar to natural reefs within the region



- The three reefs have shown very different temporal patterns in the values of their standardized food chain support index.
- The standardized FCS index at Wheeler North Reef declined steadily from 2009-2012 before showing a sharp increase in 2013.
- In contrast the FCS index at San Mateo increased from 2009 – 2011 and has remained high since then, while the FCS index at Barn remained relatively high from 2009-2012 before declining sharply in 2013, then increasing in 2014.
- FCS values followed the same trajectory at Wheeler North Reef and San Mateo between 2013 and 2014, declining slightly.
- In 2014 the four- year running average of the FCS at Wheeler North Reef was significantly lower than that of both reference reefs.
- Consequently, the Wheeler North Reef did not meet the performance standard for food chain support in 2014.

SONGS Reef Mitigation Requirement



To receive mitigation credit for a given year the Wheeler North Reef must:

- 1. Meet all four absolute performance standards**
- 2. Meet at least as many relative standards as the lowest performing reference reefs**

To receive mitigation credit for a given year the Wheeler North Reef must:

1. Meet all four absolute performance standards.
2. Meet at least as many relative standards as the reference reefs.

Wheeler North Reef Performance Summary for 2014

* indicates a change from 2013

	WNR		San Mateo	Barn
	2014	4-yr avg	4-yr avg	4-yr avg
ABSOLUTE STANDARDS				
1. Substrate	YES	YES		
2. Giant kelp	YES	YES		
3. Fish standing stock	NO	NO		
4. Invasive species	YES	YES		
<i>Number of Absolute Standards met</i>	3	3		
RELATIVE STANDARDS				
1. Algal cover		NO	YES	YES
2. Algal species richness		NO	YES	YES
3. Sessile invertebrate cover		YES	NO	YES
4. Mobile invertebrate density		YES	NO	YES
5. Invertebrate species richness		YES*	NO*	YES
6. Resident fish density		YES	NO*	YES
7. YOY fish density		YES	YES	NO
8. Fish species richness (all ages)		YES	NO	YES
9. Fish reproductive rates		YES	YES	YES
10. Fish production		YES	NO	YES
11. Food chain support		NO	YES	YES
<i>Number of Relative Standards met</i>		8	5	10

Because Wheeler North Reef did not meet the absolute standard for fish standing stock no mitigation credit was given for 2014

- Shown here is a summary of the performance of the Wheeler North Reef (WNR) for 2014 as measured by the 4 absolute performance standards and the 11 relative performance standards.
- The absolute performance standards are only measured at WNR using either values for 2014 or the 4-year running average.
- The relative performance standards are measured at WNR, San Mateo and Barn using only the 4-year running average from 2011-2014.
- A “YES” means that a performance standard was met while “NO” means that a performance standard was not met.
- An asterisk indicates a change from 2013 in whether a standard was or was not met
- WNR met 3 of the 4 absolute standards; it failed to meet the standard for fish standing stock.
- WNR met 8 of the 11 relative standards compared to San Mateo, which met 5 and Barn which met 10.
- Thus in 2014 WNR met as many or more relative standards than the lowest performing reference reef, which in this case was San Mateo.
- However, because WNR did not meet the absolute standard for fish biomass it received no mitigation credit for 2014.

Summary of mitigation credit for Wheeler North Reef

Year	Mitigation credit	Reason for no mitigation credit
2009	No	Kelp & fish standing stock too low
2010	No	Fish standing stock too low
2011	No	Fish standing stock too low
2012	No	Fish standing stock too low
2013	No	Fish standing stock too low
2014	No	Fish standing stock too low
TOTAL	0 years	
Mitigation Target	30 years (minimum)	

This table summarizes the mitigation credit earned by the Wheeler North Reef thus far.

- The Wheeler North Reef has received zero years of mitigation credit to date.
- The reason why it has not received any mitigation credit has been its failure to meet the performance standards for giant kelp in the first year and for fish standing stock in all six years.

Fulfillment of the SONGS reef mitigation requirement occurs when the number of years of mitigation credit accrued by the Wheeler North Reef equals the total years of operation of SONGS Units 2 & 3, including the decommissioning period to the extent that there is continuing discharge of cooling water.

- Unit 2 operated for approximately 30 years and Unit 3 for about 29 years.
- Thus the minimum number of years of mitigation credit needed is 30 years.

Agenda

Annual Public Workshop

San Onofre Nuclear Generating Station Artificial Reef Mitigation Project
Ocean Institute, Dana Point, CA
April 13, 2015

- | | |
|-------------|--|
| 1:30 – 1:45 | Introduction – <i>Dan Reed, UCSB</i> |
| 1:45 – 2:30 | Performance of the Wheeler North Reef: 2014 monitoring results – <i>Steve Schroeter, UCSB</i> |
| 2:30 – 3:00 | Patterns and future predictions of fish standing stock at Wheeler North Reef - <i>Dan Reed, UCSB</i> |
| 3:00 – 3:30 | General Discussion |

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