# Performance Evaluation of Wheeler North Reef

## 2012 Monitoring Results

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

This presentation focuses on:

1. The results of the first four years of compliance monitoring of the Wheeler North Reef,
2. An evaluation of the Wheeler North Reef in 2012 with respect to the performance standards on which it is being judged.

## Performance Standards

**Physical performance standards**

**Pertain to the percent cover and footprint area of hard substrate that must remain available to reef biota.**

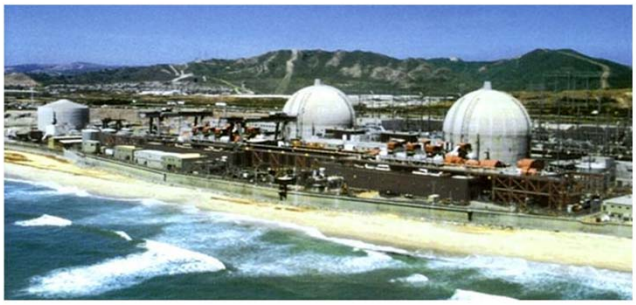
**Biological performance standards**


**Pertain to the abundance, diversity and ecological function of giant kelp, understory algae, invertebrates, and fish.**

- Physical and biological performance standards were established by the CCC to evaluate the success of the Wheeler North Reef in compensating for the kelp bed resources lost due to SONGS operations.

## SONGS Reef Mitigation

**Goal:** ***Replace kelp forest resources lost due to SONGS operations***



- **Performance standards used as a measuring stick to evaluate whether the lost resources are replaced.**
- **One year of mitigation credit is given for each year that Wheeler North Reef meets the performance standards.**
- **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.**

- The goal of the SONGS reef mitigation project is to replace the kelp forest resources that have been and continue to be lost due to the ongoing operations of SONGS Units 2 & 3.
- Performance standards are used as a measuring stick to evaluate whether the Wheeler North Reef is replacing those resources.
- One year of mitigation credit is given for each year that Wheeler North Reef meets the performance standards.
- Because damage to the San Onofre kelp forest is on going it is important that WNR provide kelp forest resources for a period of time equal to the lifetime operation of Units 2 & 3.
- Thus, 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.

## 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 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 WNR are to be expected even if it is providing adequate compensation on average.**

## Relative 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:*** **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.**

- "Similar" as defined in the dictionary means related in appearance, or alike though not identical.
- The SONGS Coastal Development Permit envisioned a more 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 plans for these projects.
- 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 no 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 of 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 court towards mitigation credit.

## Performance Standards for Wheeler North Reef

1. Hard substrate*
2. Giant kelp*
3. Algal percent cover
4. Algal species richness
5. Sessile invertebrate percent cover
6. Mobile invertebrate density
7. Invertebrate species richness
8. Resident fish density
9. Young-of-Year fish density
10. Fish species richness
11. Fish standing stock*
12. Fish reproductive rates
13. Fish production
14. Food chain support
15. Invasive species*

** Absolute standards*


- Shown here are the performance standards by which the success of the Wheeler North Reef is being judged.
- Absolute standards are shown in green and relative standards are shown in black.
- What follows is a summary of the monitoring results as they pertain to each of these standards.

## Performance Standard: Hard Substrate

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


- The performance standard for hard substrate is a fixed standard that 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

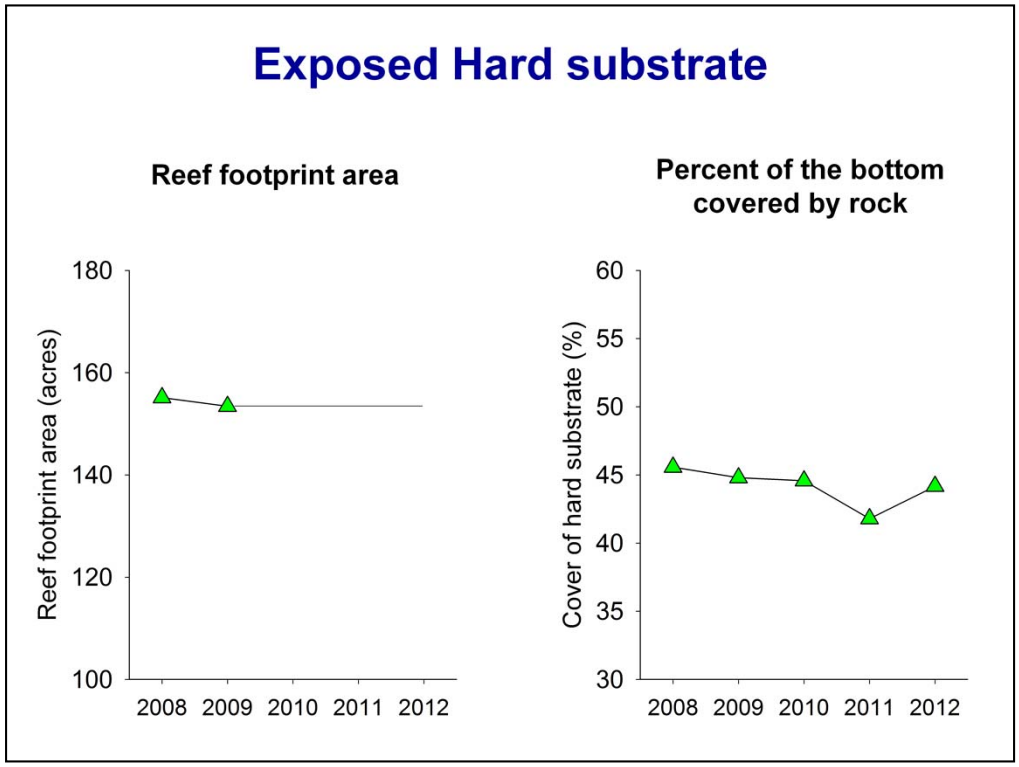
1. **Measure footprint area (A) of Wheeler North Reef**
2. **Measure percent cover of exposed rock (P)**
3. **Calculate area of exposed rock as A x P**
4. **Compare area of exposed rock to that measured immediately after reef construction to determine whether 90% or more is still available for reef biota**


**9 Substrate categories:**

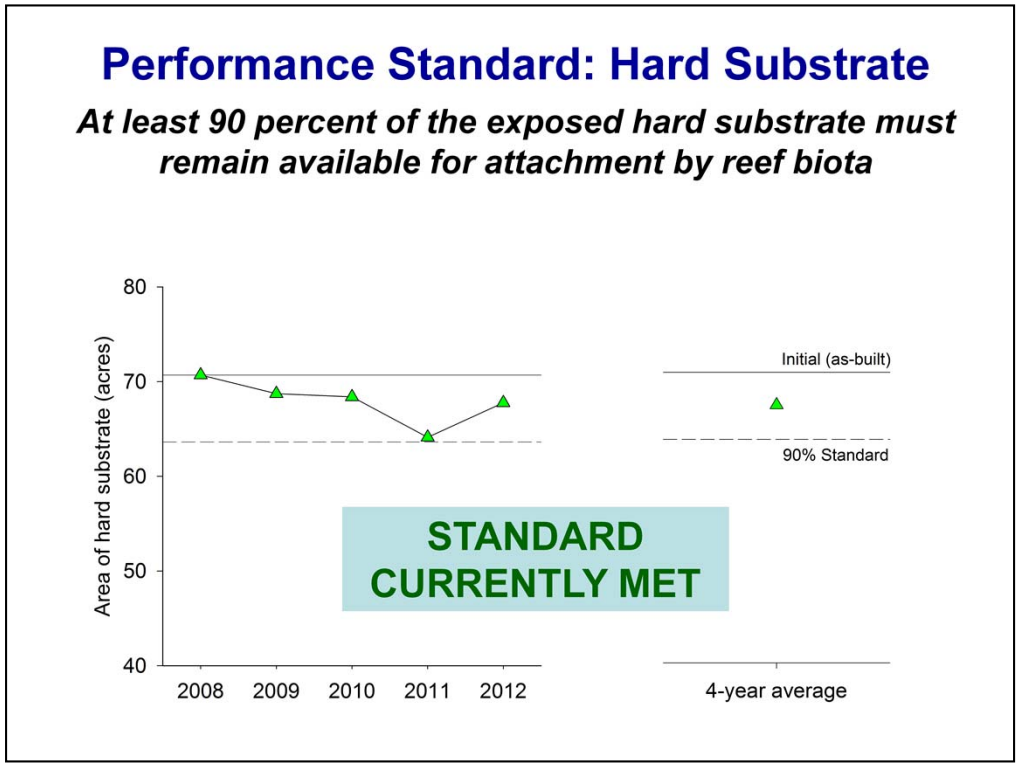
**Bedrock**
**Large boulder** (≥ 100 cm)
**Medium boulder** (≥ 50cm & <100cm)
**Small boulder** (≥ 26cm and <50cm)
**Cobble** (≥ 7cm and ≤ 25cm)
**Pebble** (≥ 2mm and < 7cm)
**Sand** (< 2mm)
**Shell hash**
**Mudstone**

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 $m^2$ quadrats used to verify the construction of Wheeler North Reef.
- The product A x 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.




- This slide shows the two variables required to estimate the amount of exposed hard substrate on the Wheeler North Reef.
- Both of these variables apply only to the 154 acre subset of the Wheeler North Reef, which was the portion of the 176 acre reef that met the 150 acre standard of > 42% cover of rock.
- There was a slight 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 multi-beam sonar surveys are only done once every five years.
- The last sonar survey was done in 2009. Thus the value for reef footprint area is assumed to be the same in 2010 ,2011, and 2012 as it was 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 ~ 46% in 2008 to ~ 42% in 2011, before increasing in 2012 to ~ 44%.




- The initial amount of hard substrate at WNR used to judge this performance standard was 70.6 acres in 2008.
- The small declines in footprint area and % cover of hard substrate that have occurred since then resulted in nearly a 10% decrease in the total area of hard substrate on Wheeler North Reef by 2011.
- An increase in the % cover of rock in 2012 resulted in the total area of hard substrate to increase from 64 acres in 2011 to 67.7 acres in 2012 (or roughly 96% of the initial amount of rock area).
- Thus the performance standard for reef area was met in 2012 regardless of whether the evaluation was based on data from 2012 alone or the 4-year running average (2009-2012).

## 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 $m^{-2}$**
**• Adult plants are defined as individuals having at least 8 fronds**

- The performance standard for giant kelp is a fixed standard that 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 $m^2$.
- 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 fixed 100 $m^2$ transects on Wheeler North Reef**

**Determine whether:**

***P*** **x 176 acres ≥ 150 acres**

***where:***

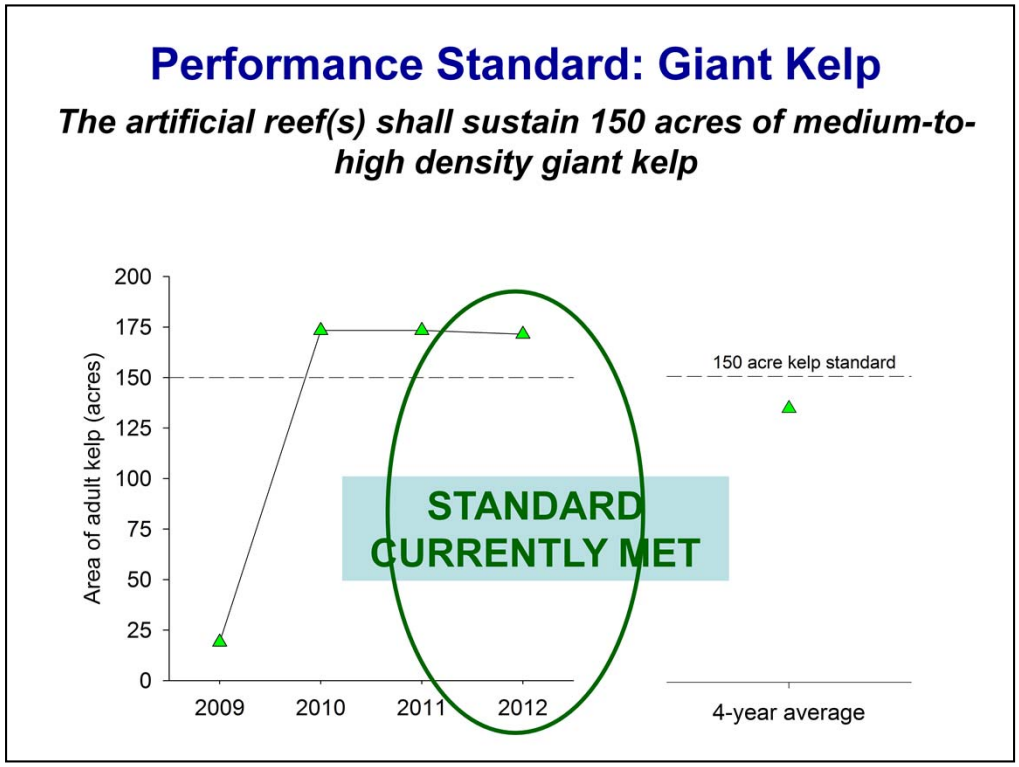
***P*** **= the proportion of transects with at least 4 adult plants , and**

**176 = Footprint area of Wheeler North Reef in acres**

**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*.**

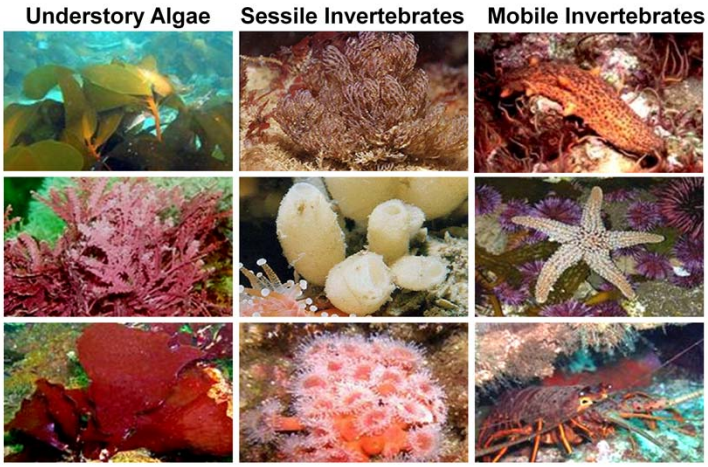
- The performance standard for giant kelp is evaluated by measuring the density of giant kelp in the fixed transects across the entire Wheeler North Reef.
- Using these data we calculate the proportion of transects on the Wheeler North Reef that have adult kelp densities greater than or equal to 4 plants per 100 $m^2$.
- This proportion is multiplied by 176 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.




- 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.
- 91 of the 92 transects sampled had at least 4 adult plants 100 per $m^2$ in 2010 through 2012.
- The acreage of giant kelp at the Wheeler North Reef exceeded the 150 acre threshold when evaluated using data from 2012 , but not when using the 4-year running average (due to the small number of kelp acres in 2009 one year after construction).
- Because the performance standard for giant kelp is an absolute standard either the value for 2012 or the 4-year running average can be used.
- Thus the Wheeler North Reef met the performance standard for giant kelp in 2012.

## Performance Standard: Benthic Community

***The benthic community (algae & macroinvertebrates) shall have coverage or density and number of species similar to natural reefs within the region***




- The performance standard for the benthic community is a relative standard that requires the abundance and number of species of algae and invertebrates on the Wheeler North Reef to be similar to that on reference reefs in the region.

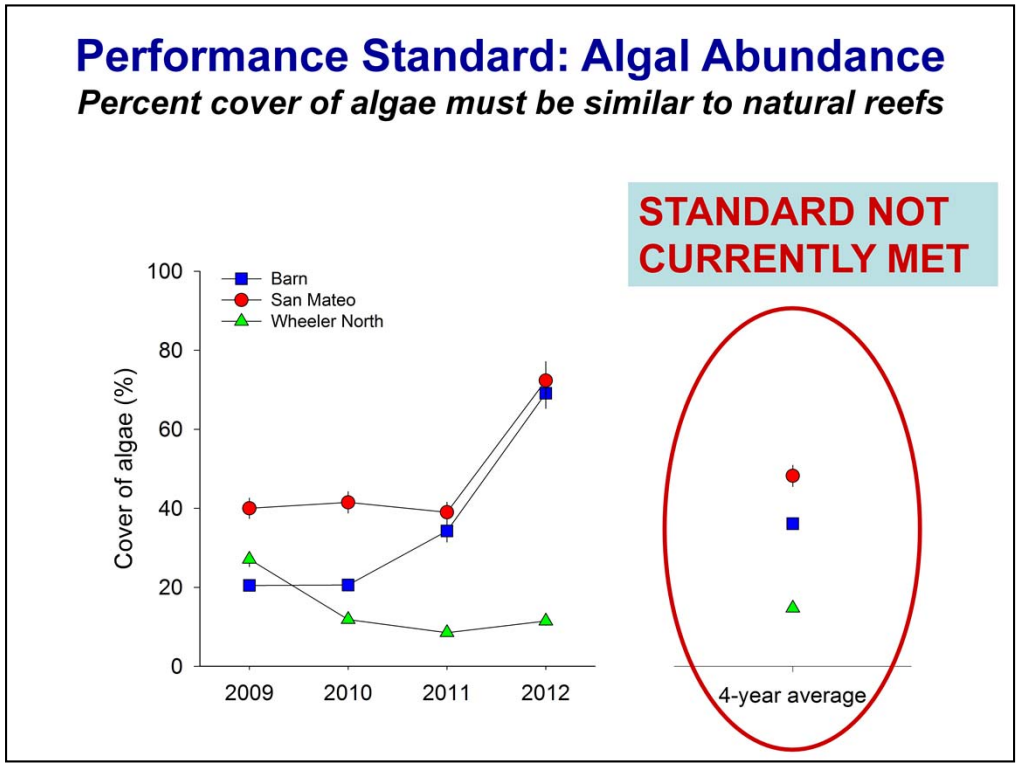
## Evaluating the Benthic Community


**Five components of the Benthic Community standard are evaluated separately**

1. **Percent cover of algae**
2. **Number of species of algae**
3. **Percent cover of sessile invertebrates**
4. **Density of mobile invertebrates**
5. **Number of species all invertebrates combined**

Because it is not possible to evaluate the benthic community standard using a single metric we consider 5 separate components of the benthic community when evaluating this performance standard.

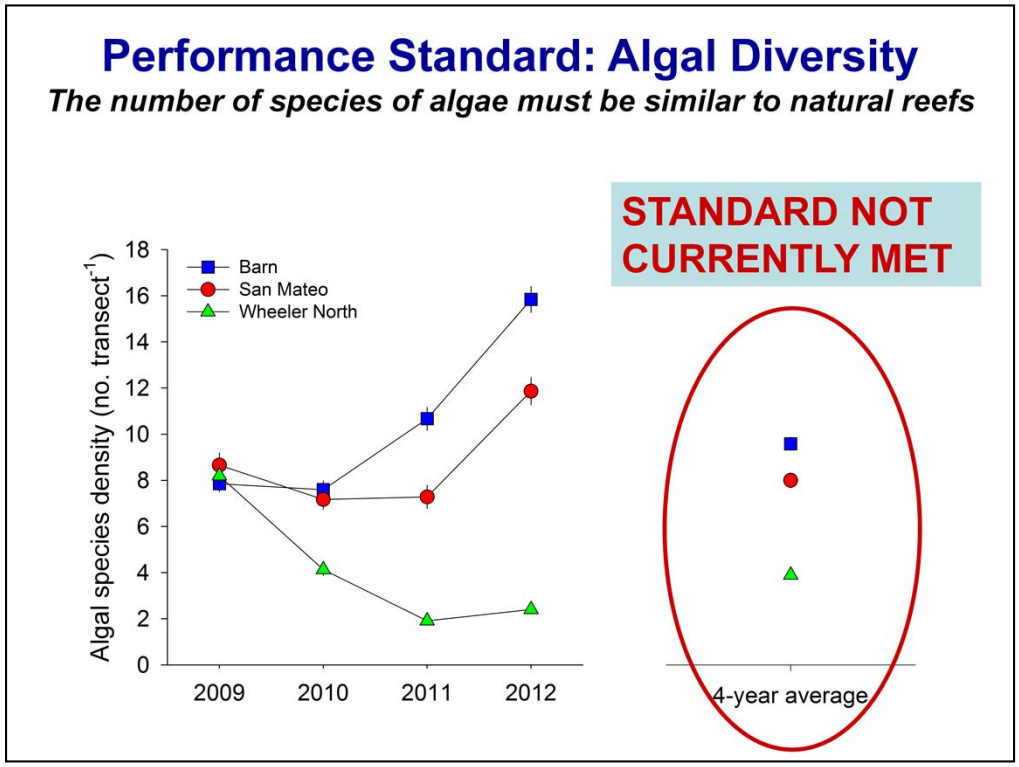
1. The mean percent cover of algae per transect
2. The mean number of species of algae per transect
3. The mean percent cover of sessile invertebrates per transect
4. The mean density of mobile invertebrates per transect
5. The mean number of species of sessile and mobile invertebrates per transect.



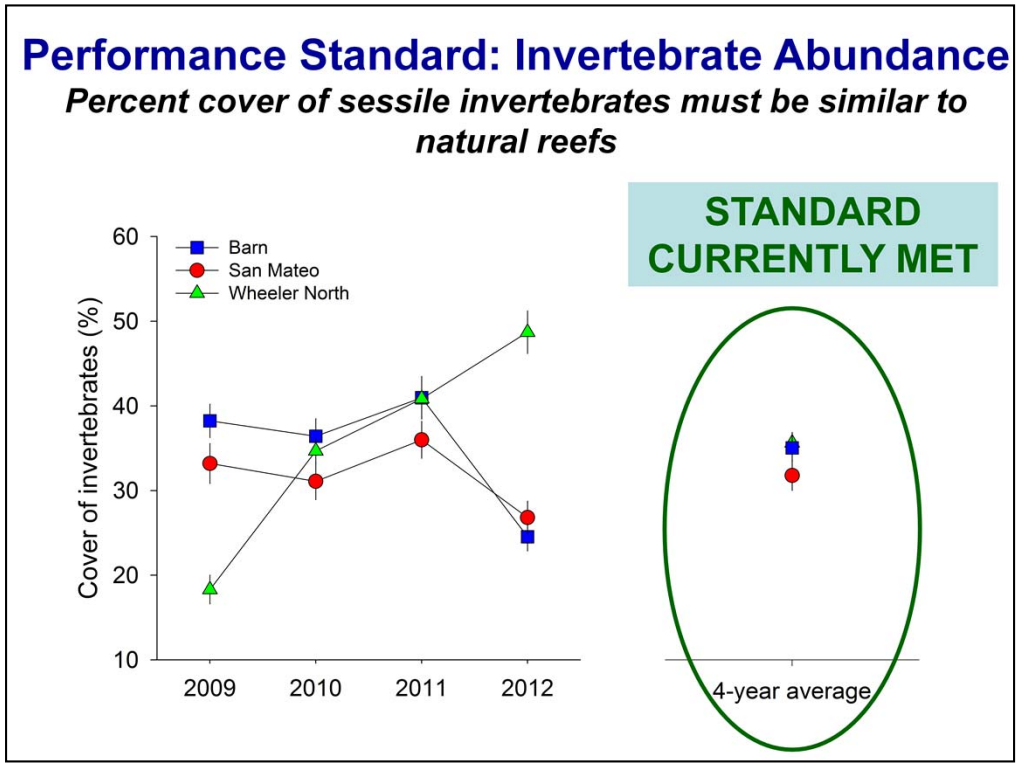

- This graph shows the percent cover of understory algae at Wheeler North Reef, Barn and San Mateo, both as a time series on the left and as the 4-year running average on the right.
- The colored symbols in this graph represent the mean value of each reef, and the vertical lines through the symbols represent +/- 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 4-year 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 10% in 2010 when the surface canopy of giant kelp became fully established, and it remained at this low level in 2011 and 2012.
- In contrast, the percent cover of algae at the two reference sites increased substantially during the four years of monitoring, most notably in 2012.
- As with all the relative standards the 4-year running average is used to evaluate whether Wheeler North Reef has met this performance standard.
- The different trajectories of algae at Wheeler North Reef and the reference reefs leads to a 4-year running average of algal percent cover at Wheeler North Reef

that is substantially lower than that at the two reference reefs.

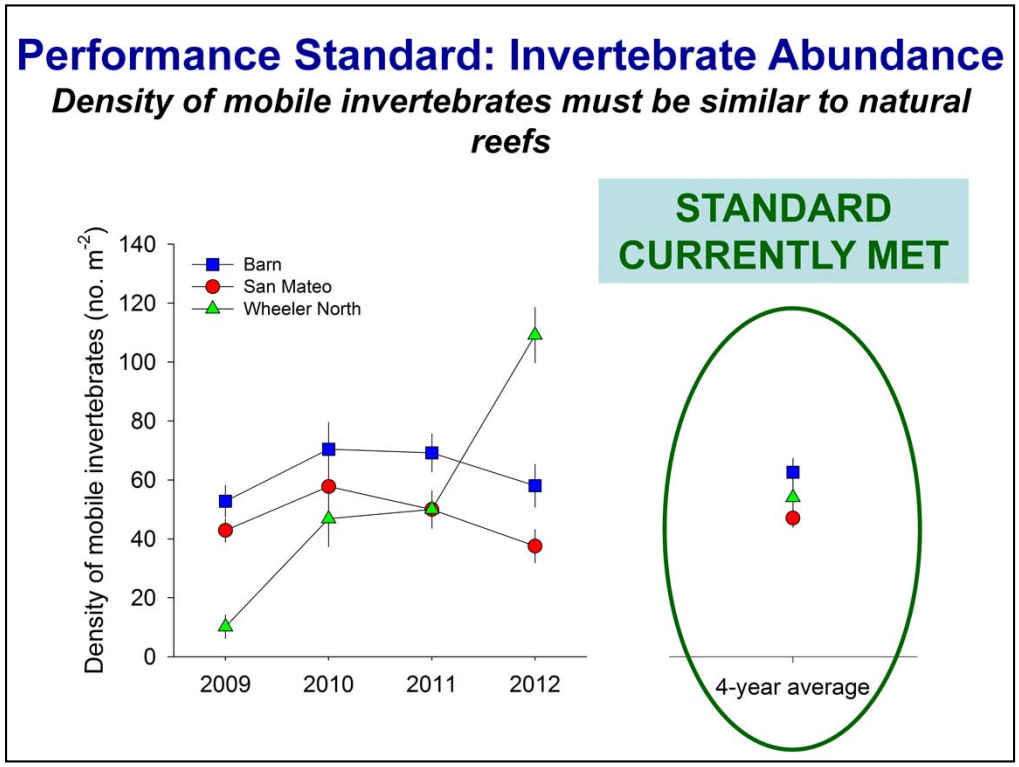
- Consequently, the Wheeler North Reef did not meet this performance standard in 2012.



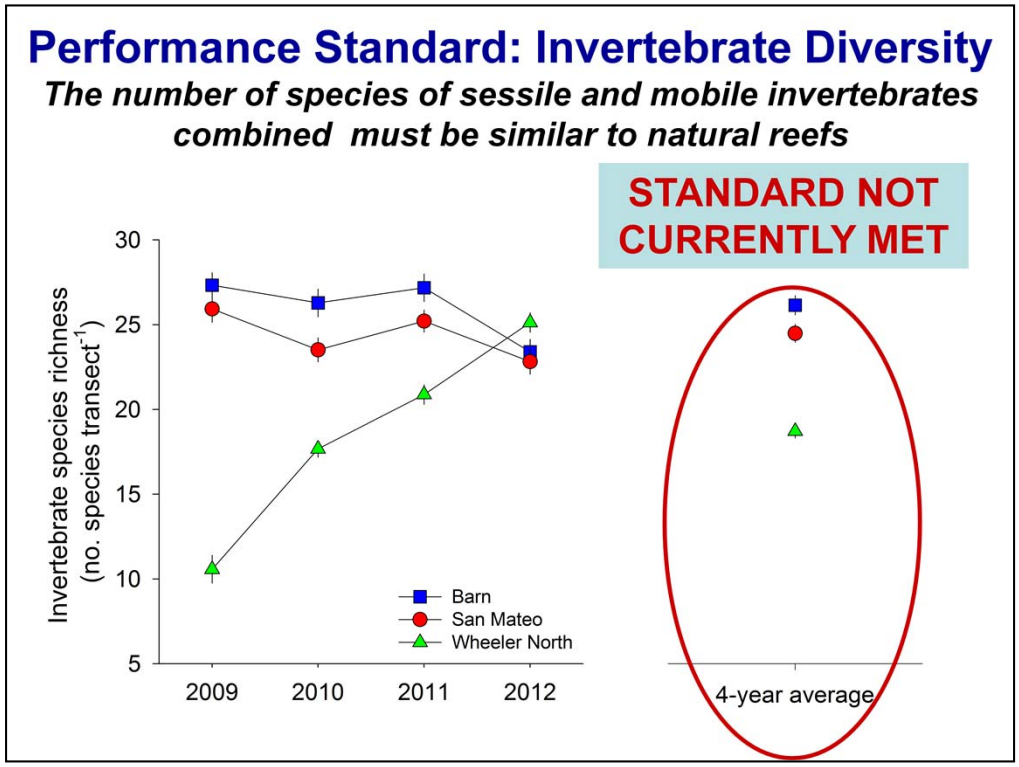

- These two graphs shows the mean number of species of algae per transect at Wheeler North Reef, Barn and San Mateo as a time series on the left and as the 4-year running average on the right
- The graph on the left shows that temporal trends in algal diversity were similar to those observed for algal percent cover.
- The average number of species per transect declined over time at Wheeler North Reef, while it increased at the two reference reefs.
- As a result, 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 2012.




- Plotted in these graphs is the percent cover of sessile invertebrates at Wheeler North Reef, Barn and San Mateo.
- As described in the previous presentation sessile invertebrates and algae compete for space 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, which is the exact opposite pattern observed for algae at this sites as shown in the previous slides.
- Because the four-year running average of percent cover of sessile invertebrates at Wheeler North Reef was nearly identical to that at Barn and slightly higher than that at San Mateo, the Wheeler North Reef met this performance standard in 2012.




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




- Plotted here is the mean number of species of sessile and mobile invertebrates combined per transect at Wheeler North Reef, San Mateo and Barn.
- The average number of invertebrate species per transect at the two reference reefs has declined slightly over the four-year sampling period, whereas it has steadily increased at Wheeler North Reef from a low value near 10 species per transect in 2009 to about 25 in 2012, which was slightly higher than that observed at San Mateo and Barn
- While the number of species of invertebrates at Wheeler North Reef is on a promising trajectory, its 4-year running average is still substantially below that of the two reference reefs due to the low numbers of species during the first couple years of its existence.
- Thus the Wheeler North Reef did not meet the performance standard for invertebrate diversity in 2012.

## Performance Standard: Resident Fish

***The resident fish assemblage shall have a total density similar to natural reefs***

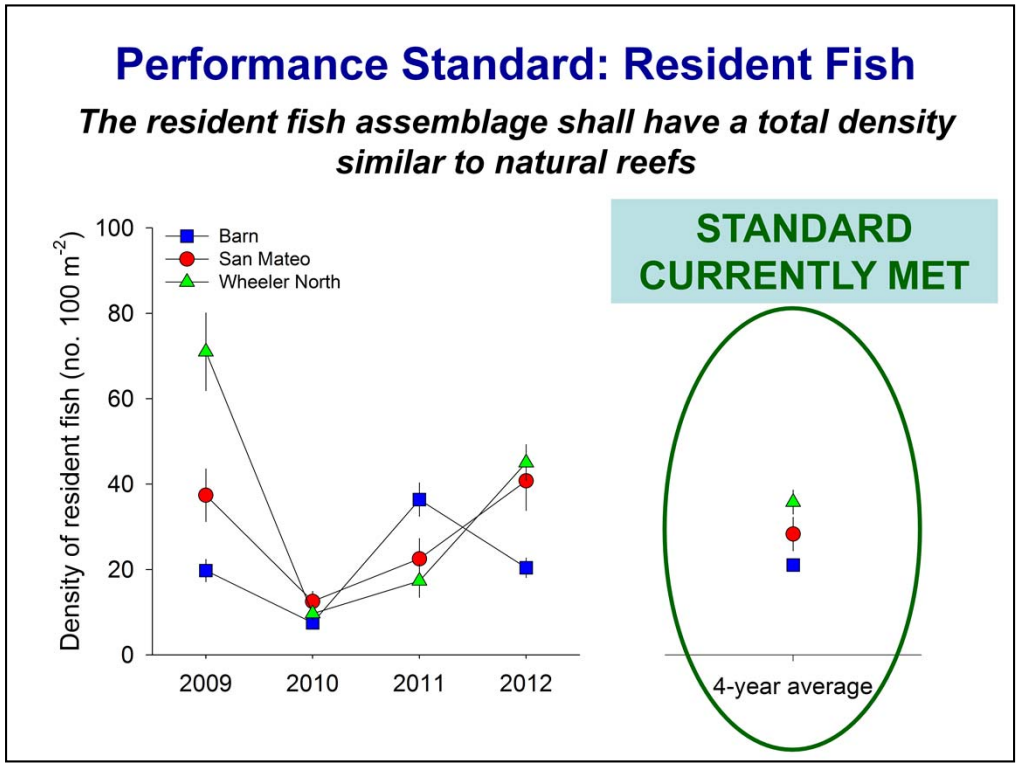
**Resident Fish are defined as reef associated species 1 year of age or older**

- The next several performance standards pertain to the abundance and number of species of reef fish.
- The first of these standard is that “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.
- Resident fish include species such as small gobies that are only a could inches long as well as large predatory species such as kelp bass and black sea bass.

## Measuring the density, size and number of species of reef associated fishes


- **Count the number of reef fish within 1.5 m of the bottom in a 3 m wide swath along each 50 m transect.**
- **Record the size (to the nearest cm) and species identity of each fish observed on each transect**
- **Size data are used to determine if an individual is > 1 year old**

- Reef fish are visually counted and sized by divers within 1.5 m of the bottom in a 3 m wide swath centered along each 50 m transect.
- Size data are used to determine if fish are > 1 year of age.
- Fish size data are also used to evaluate several of the other performance standards pertaining to kelp bed fishes.



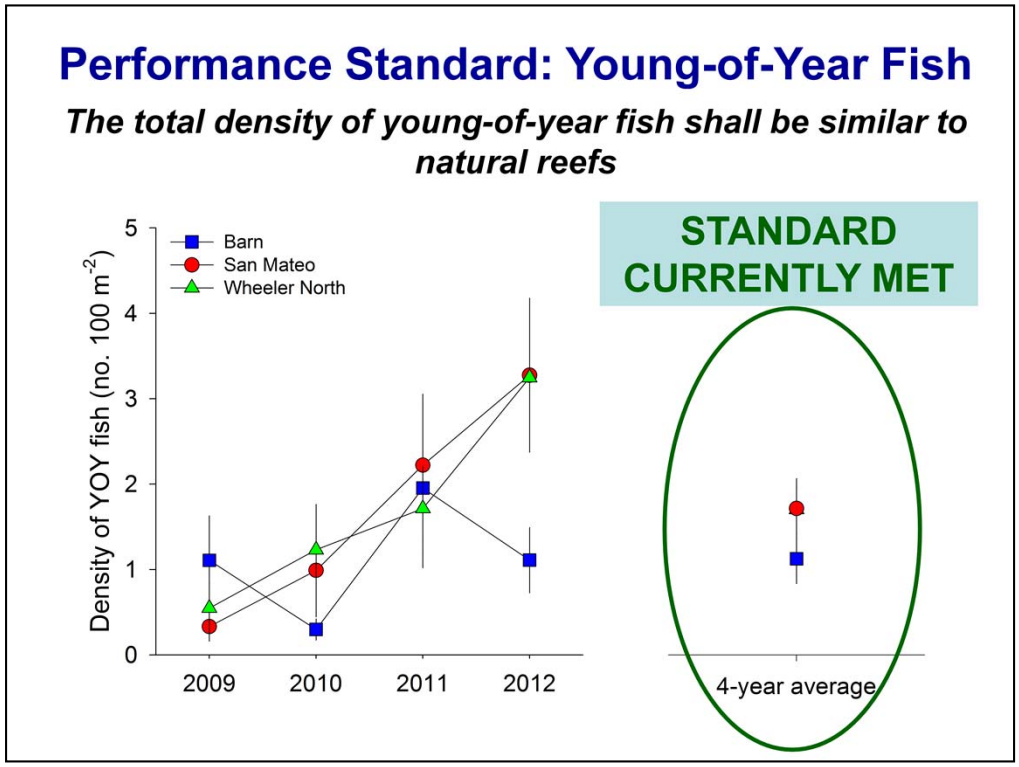

- The densities of resident fish have fluctuated greatly during the four years of monitoring.
- In 2009, 1 year after its construction, the density of fish at the Wheeler North Reef was 2 to 3 times greater than that at the reference reefs.
- Fish densities declined dramatically at all three reefs in 2010 and were universally low at all reefs.
- In the two years following this decline densities steadily increased at Wheeler North Reef and San Mateo, while at Barn they increased in 2011 and decreased in 2012.
- The four-year running average density of fish at Wheeler North Reef during this variable period four-year was slightly higher than that at San Mateo and Barn.
- Thus, Wheeler North Reef met the performance standard for resident fish density in 2012.

## Performance Standard: Young-of-Year Fish

***The total density of young-of-year fish shall 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**

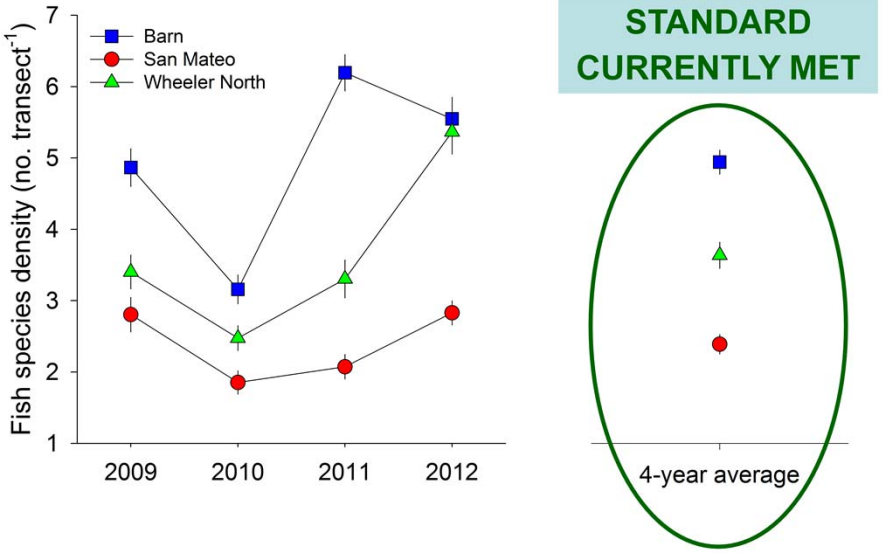
- There is also a performance standard that requires the density of young-of-year fish on Wheeler North Reef be similar to natural reefs
- Young-of-Year Fish are defined as reef associated fish that were born in the year that they were sampled.
- The rationale for this performance standard is that kelp 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.




- Plotted here are the average densities of young-of-year fish for Wheeler North Reef, San Mateo and Barn for 2009 -2012.
- Densities of young-of-year fish have been consistently low at all three reefs averaging only a few individuals per 100 $m^2$ transect.
- YOY densities at Wheeler North and San Mateo have been very similar and have steadily increased over the last four years.
- In contrast YOY density at Barn has shown alternating increases and decreases during this time much like that seen for resident fish.
- The four-year averages at Wheeler North Reef and San Mateo were nearly identical and larger than that observed at Barn.
- Thus, the Wheeler North Reef met the performance standard for YOY density in 2012.

## Performance Standard: Fish Diversity

***The number of species of fish shall be similar to natural reefs***




- Fish diversity is measured as the mean number of species of fish per transect and it includes fish of all ages (i.e., resident fish and young-of-year- fish)
- During the four-year sampling period fish diversity at Wheeler North Reef and San Mateo has followed a similar increasing trajectory with the number of species of fish per transect at Wheeler North higher than that at San Mateo.
- Fish diversity has been consistently higher at Barn during the four years of monitoring .
- Because the 4-yr average of fish diversity at the Wheeler North Reef was intermediate between Barn and San Mateo the Wheeler North Reef met the performance standard for fish diversity in 2012.

## 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 is a fixed standard that 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.
- Thus this is an absolute standard that is measured only at Wheeler North Reef.

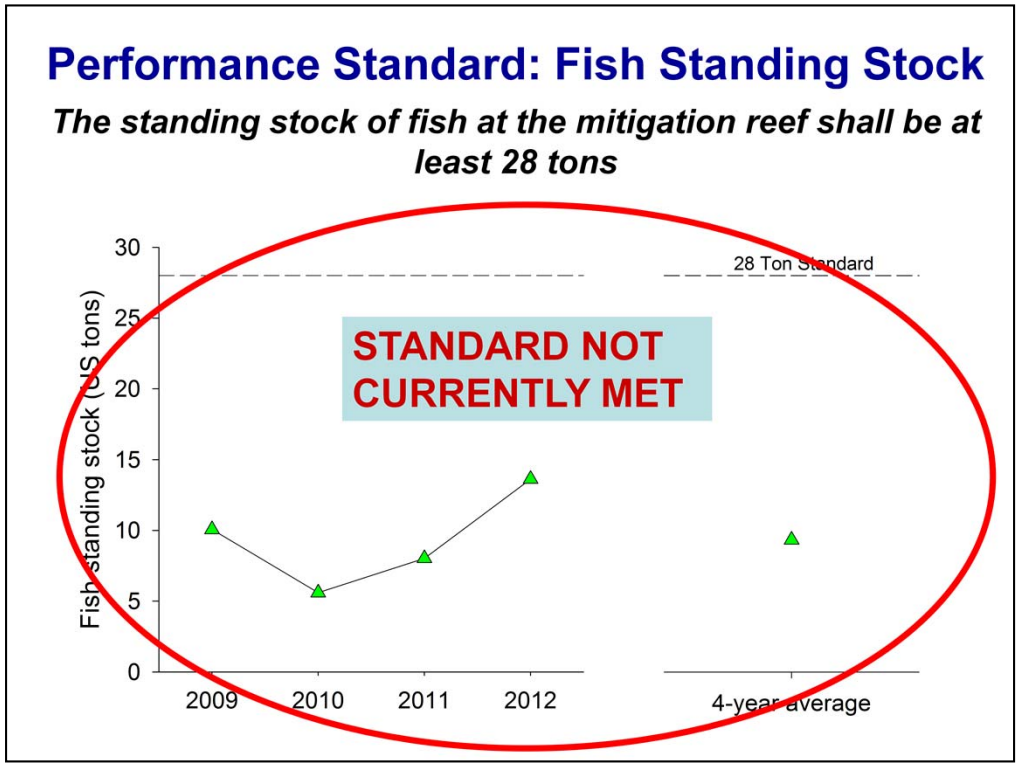
## Methods used to evaluate the standing stock of reef fish


1. **Apply species-specific length-weight relationships to data on fish density and size to calculate the average biomass density (biomass $m^{-2}$ reef) of all fish near the bottom from all transects.**
2. **Scale up estimates of biomass $m^{-2}$ to biomass for 176 acres to obtain an estimate of the standing stock of fish near the bottom on 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 weight of each fish counted is 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 176 acres to obtain an estimate of the standing stock of fish near the bottom at Wheeler North Reef.




- Plotted here are the estimates for standing stock of bottom reef fish at the 176 acre Wheeler North Reef for each of the four years of monitoring and for the average of the four years.
- Temporal trends in fish standing stock resemble those observed for the density of resident fish with a decline from 2009 to 2010 and an increasing trend since 2012.
- The Wheeler North Reef has been far below the absolute performance standard of 28 tons in all four years with the highest value reported for 2012 when standing stock was estimated at 14 tons, or half the tonnage needed to meet the standard.
- Thus, the Wheeler North Reef failed to meet the performance standard for fish standing stock in 2012, regardless of whether it is evaluated using data from 2012 or the 4-year running average.

## Performance Standard: Fish Reproductive Rates

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

**Goal :**

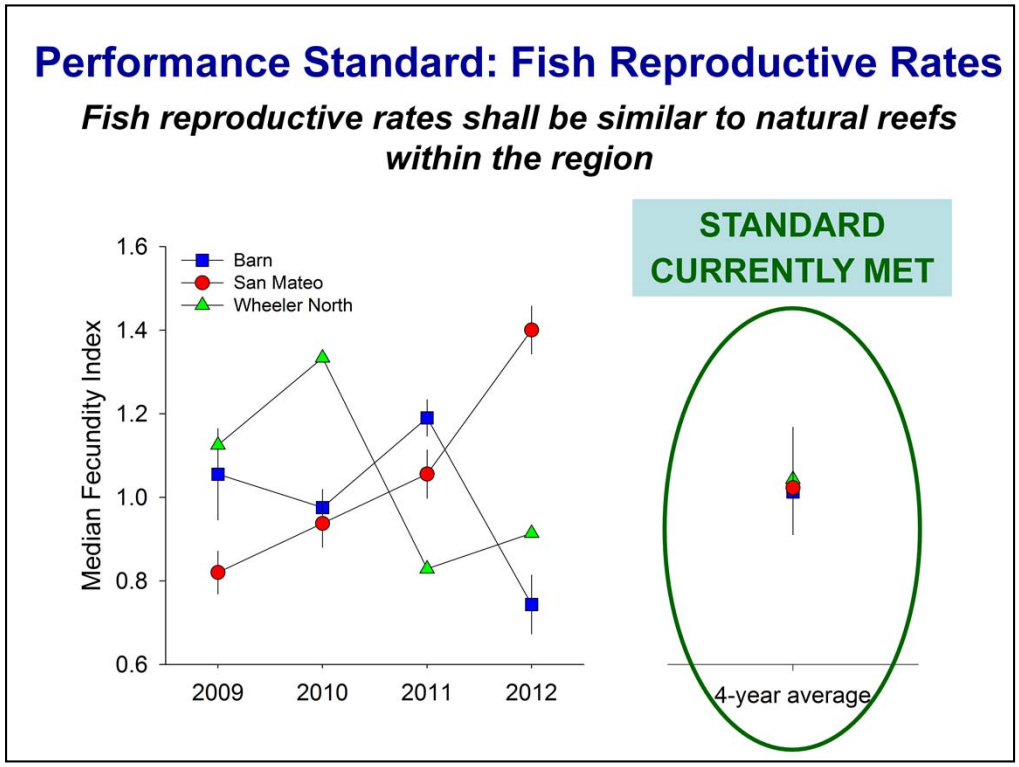
**Estimate annual egg production for three common "indicator" species**

**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.




- Plotted here is the Median Fecundity Index averaged across the three species for Wheeler North Reef, San Mateo and Barn from 2009 through 2012.
- Fish reproductive rates varied inconsistently among the three reefs during the 4-year period.
- We found that the value of the Median Fecundity Index was highest at Wheeler North Reef in 2009 and 2010, lowest at the Wheeler North Reef in 2011, and intermediate at the Wheeler North Reef in 2012.
- Barn showed similar erratic fluctuations in the Median Fecundity Index over time that varied asynchronously with Wheeler North Reef, while the Fecundity Index at San Mateo showed a consistent increasing trend.
- Despite all the erratic and asynchronous fluctuations in fish reproductive rates at the three sites their 4-year running averages of the Median Fecundity Index were nearly identical.
- Thus the Wheeler North Reef met the performance standard for fish reproductive rates in 2012.

## 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

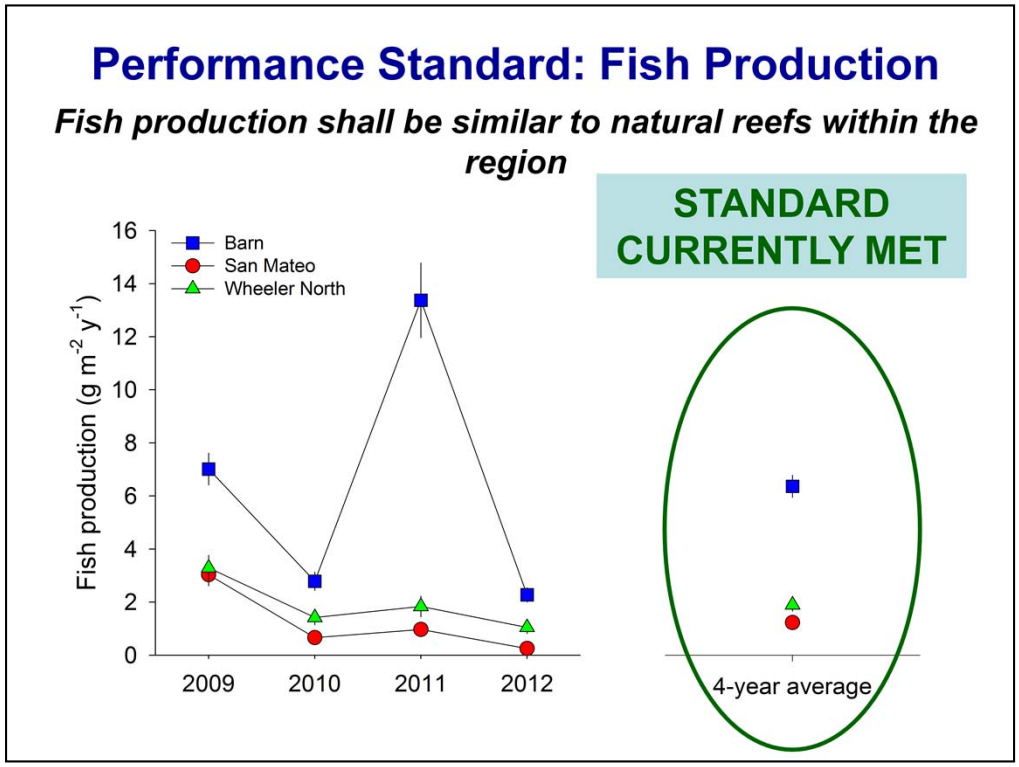
**Use information collected on fish density, size structure, and reproductive rates combined with estimates of somatic growth obtained from ear bones (otoliths) to calculate fish production in terms of the biomass of fish produced per unit area of reef per year**

- 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**

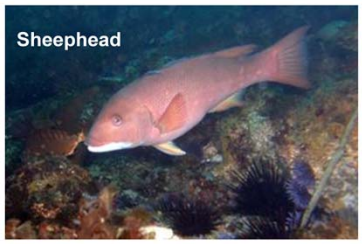

- We use five indicator species to estimate fish production on Wheeler North, San Mateo and Barn.
- These species were chosen because they are among the most common species of fish in the kelp forest and they represent different feeding guilds that use the reef in different ways.
- Blacksmith eat plankton 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, sheephead feed on larger invertebrates on the bottom, and kelp bass primarily feed on other species of fish.




- Plotted in this graph is the average annual production of these five species combined for Wheeler North, San Mateo and Barn for 2009-2012.
- 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 g $m^2$/y before declining to < 2 g $m^2$ / y in 2010.
- It has remained near this low value for the past three years at both sites
- It contrast fish production at Barn has fluctuated greatly over time, but nonetheless has been greater than that observed at Wheeler North Reef and San Mateo in each of the last four years.
- Because fish production at Wheeler North Reef has been intermediate between Barn and San Mateo in all four years 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 2012.

## Performance Standard: Food Chain Support

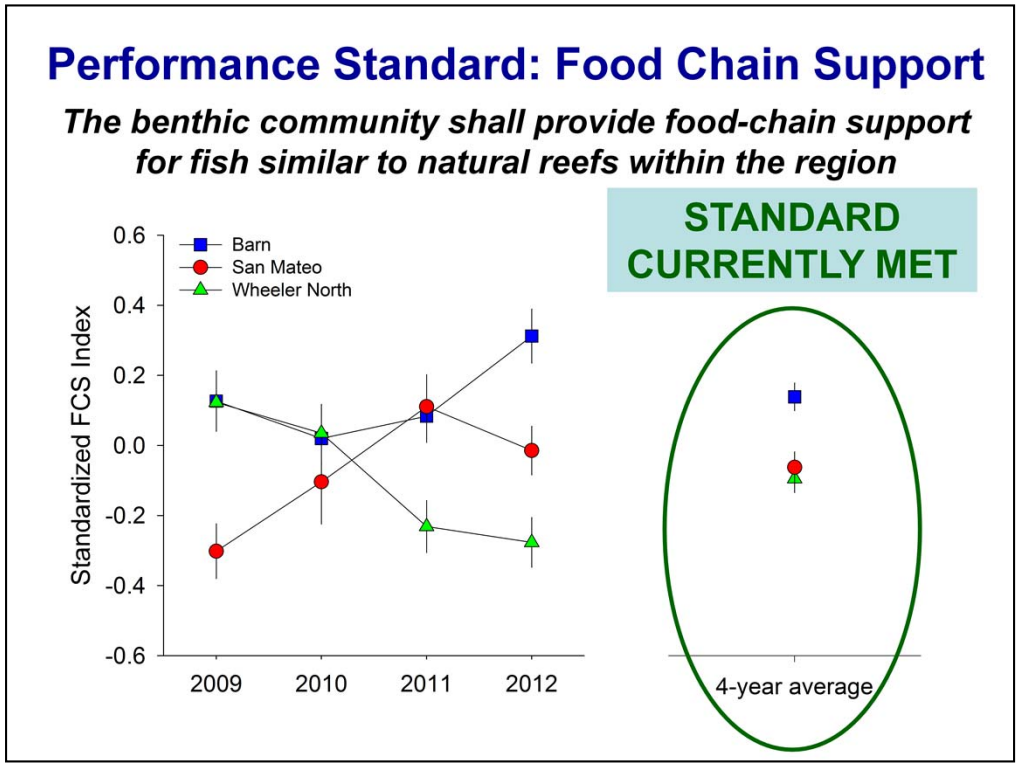
***The benthic community shall provide food-chain support for fish similar to natural reefs***


### Method of Evaluation:

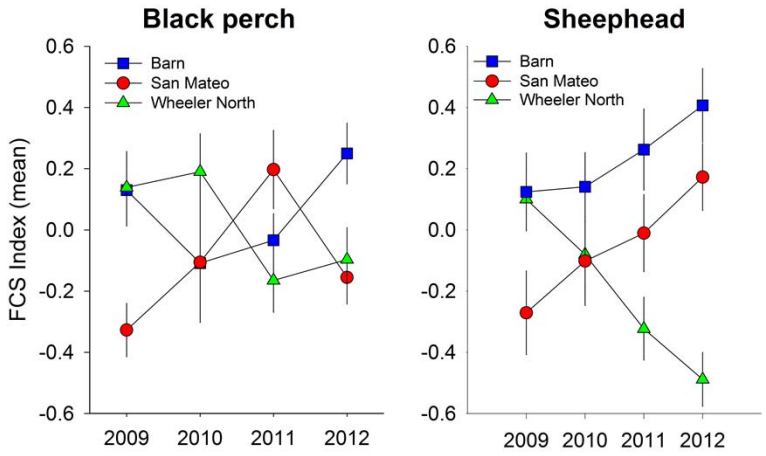
- **Weigh gut contents in two common species of reef fish that feed directly on the bottom**
- **Scale mass of gut contents to body mass of fish to calculate an index of Food Chain Support (FCS) for two indicator species**
- **Transform the values of the FCS index for each species into a single standardize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




- 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 has consistently declined in each of the last four years.
- In contrast the FCS index at San Mateo increased from 2009 – 2011 before showing a slight decline in 2012, while the FCS index at Barn remained relatively constant from 2009-2011 before increasing in 2012.
- The four- year running average of the FCS at Wheeler North Reef was lower than that of both reference reefs, but not statistically lower than that at San Mateo.
- Consequently, the Wheeler North Reef met the performance standard for food chain support in 2012.

## Performance Standard: Food Chain Support




**Declining trend in FCS at Wheeler North Reef due to a reduction in gut fullness in both species**

- Plotted here then are the mean FCS Indexes for black perch on the left and sheephead on the right, which are the two species used to calculate the standardized FCS Index.
- We wanted to examine the FCS indices of these two species separately to determine their contributions to the consistent declining trend in the standardized FCS Index observed at Wheeler North Reef.
- It turns out both species have shown a decline in their FCS Index since 2009.
- The decline in Black Perch is due to a sharp decline from 2010 to 2011, whereas the decline in Sheephead has been a consistent and substantial declining trend in each of the last four years.
- Much of the diet of these two species consists of relatively small mobile invertebrates that often associate with algae, so the decline in algae at Wheeler North Reef may have something to do with the declines in FCS observed at Wheeler North Reef in recent years.

## Performance Standard: Invasive Species

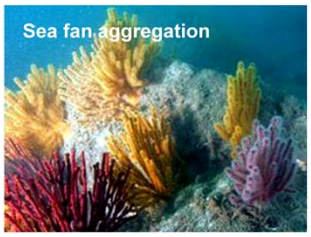
***The important functions of the reef shall not be impaired by undesirable or invasive benthic species***

- The final performance standard that is used to judge the success of the reef mitigation project was enacted to ensure that the important ecological functions of the Wheeler North Reef do not become impaired by invasive or undesirable species.

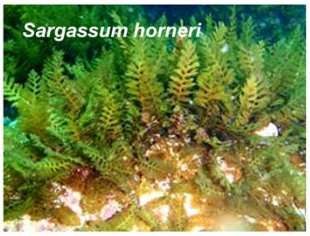
## Performance Standard: Invasive Species

**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**





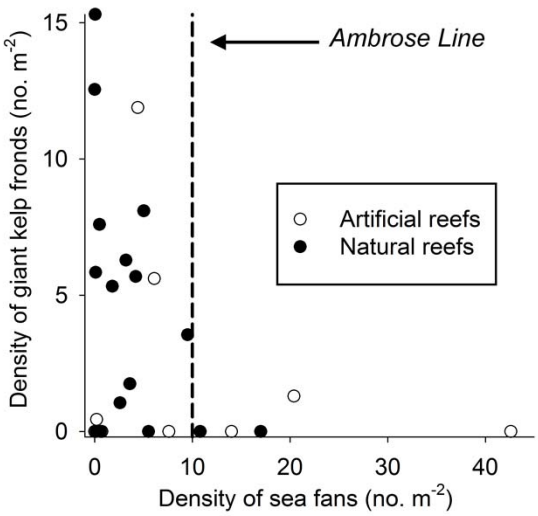

**Undesirable or invasive species that are of potential concern include**:

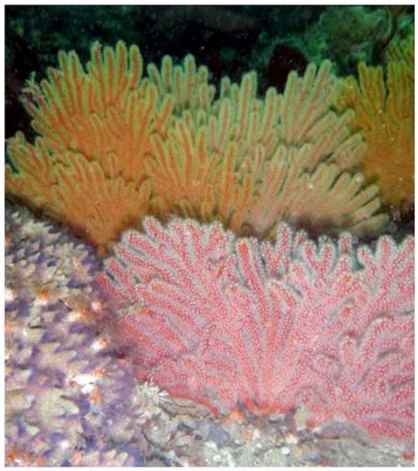
- **Sea urchins**
- **Sea fans**
- **Non-native algae (e.g., *Caulerpa*, and *Sargassum*)**

- 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.

## Invasive/Undesirable Species: Sea Fans

### High densities of sea fans may exclude giant kelp

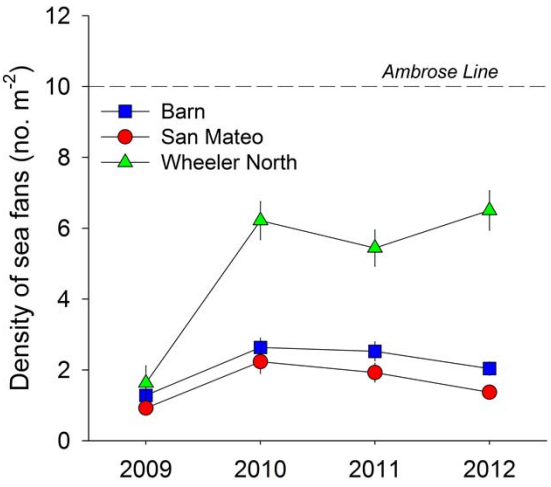


data from Ambrose et al. 1987

- Whether they are natives or non-natives, undesirable or invasive species are those species that attain abundances that are high enough to adversely effect the normal functions of a reef.
- Native sea fans are one such group of species and are know to attain high abundances on artificial reefs in California.
- Dr. Rich Ambrose and colleagues did a broad survey of artificial and natural reefs in southern California during the 1980's and found that giant kelp was rare or absent on reefs where sea fan abundance exceeded 10 per $m^2$.
- We refer to a density of sea fans of per 10 $m^2$ as the "Ambrose line" which indicates a potential problem for a reef with respect to its ability to support giant kelp.

## Invasive/Undesirable Species: Sea Fans

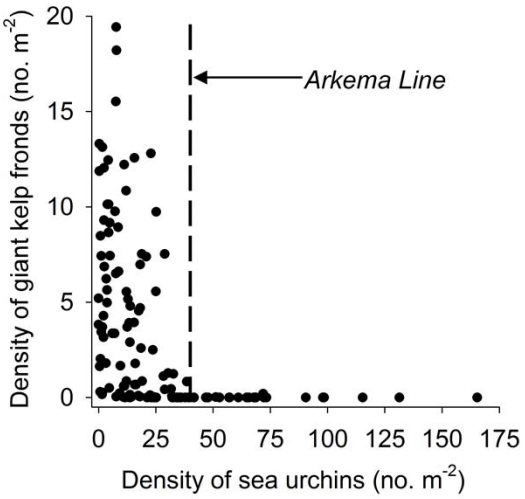



- **Initial colonization of sea fans in 2010, but little increase since**
- **Sea fan density still below *Ambrose line***
- **Sea fans cover < 2% of the bottom at Wheeler North Reef**

- Plotted here are the mean densities of sea fans at Wheeler North Reef for 2009 - 2011.
- 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 per $m^2$.
- There has been only a slight increase in sea fan density at Wheeler North Reef since 2010 suggesting little colonization by new sea fans during the last two years.
- Thus sea fan density on Wheeler North Reef remains below the Ambrose line of 10 per $m^2$.
- 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 bottom.
- In contrast, sea fans on Wheeler North Reef are mostly very small young individuals that do not yet occupy much space on the bottom (in 2012 sea fans covered < 2% of the bottom).

## Invasive/Undesirable Species: Sea Urchins

**High densities of sea urchins may over graze giant kelp**



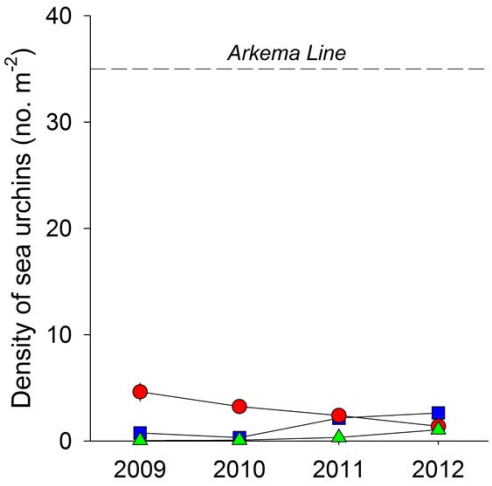


data from Arkema et al. 2009

- 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 per $m^2$.
- 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**

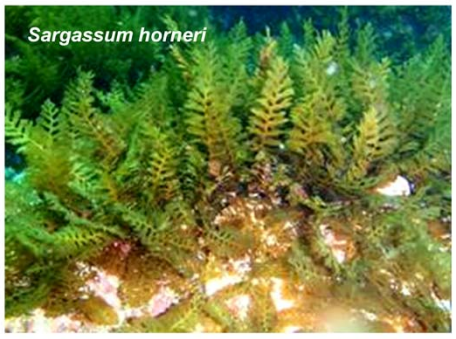




- Plotted here are the mean densities of sea urchins on the Wheeler North Reef, San Mateo and Barn for 2009 to 2012.
- We have observed very low densities of sea urchins at the Wheeler North Reef and the reference reefs so far, and the densities remain well below the Arkema line.

## 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 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

**STANDARD CURRENTLY MET**

- 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 three years.

## 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 2012

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

***Because WNR did not meet the absolute standard for fish biomass no mitigation credit was given for 2012***

- Shown here is a summary of the performance of the Wheeler North Reef for 2012 as measured by the 4 absolute performance standards and the 11 relative performance standards.
- The absolute performance standards are only measured at WNR using data from 2012 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.
- A “YES” means that a performance standard was met while “NO” means that a performance standard was not met.
- Wheeler North Reef met 3 of the 4 absolute standards; it failed to meet the standard for fish biomass.
- Wheeler North Reef met 8 of the 11 relative standards compare to San Mateo which met 7 and Barn which met 9.
- Thus Wheeler North Reef met as many or more relative standards than the lowest performing reference reef.
- However, because WNR did not meet the absolute standard for fish biomass it received no mitigation credit for 2012.

## Plans for Wheeler North Reef in 2013


- **Monitor the Wheeler North Reef and reference reefs as planned.**
- **Conduct additional analyses to better understand the reason(s) why the Wheeler North Reef has consistently failed to support 28 tons of fish biomass.**

The plan for monitoring in 2013 is to:

- Continue monitoring the Wheeler North Reef, San Mateo and Barn using the same methods as in previous years, and
- Conduct additional analyses in Conduct additional analyses to better understand how much acreage is needed for the Wheeler North Reef to consistently meet the performance standard
  for fish standing stock.