

# Agenda

## Annual Public Workshop

San Onofre Nuclear Generating Station Artificial Reef Mitigation Project  
Ocean Institute, Dana Point, CA  
April 4, 2016

- 1:30 – 2:00 Introduction to project and summary of the performance of the Wheeler North Reef– *Dan Reed, UCSB*
- 2:00 – 2:30 The need and potential options for expanding the Wheeler North Reef - *Steve Schroeter, UCSB*
- 2:30 – 3:00 General Discussion

UCSB SONGS MITIGATION MONITORING



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## **Introduction and Overview**

### **Annual Review Workshop for SONGS Reef Mitigation**



**April 4, 2016**

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

Welcome to the annual public workshop to review the status and findings of the reef mitigation project for the San Onofre Nuclear Generating Station

Compensating for losses to the San Onofre kelp forest is one component of the mitigation that is being done to offset damages to coastal resources caused by the operations of SONGS units 2 and 3

Other components include:

1. Wetland restoration to compensate for damages caused by the entrainment of fish eggs and larvae by the cooling water system
2. Modifications of plant operations to reduce the number of adult fish killed in the power plant by the sea water cooling system

We will not be discussing these other mitigation projects in today's workshop. A separate workshop will be held May 9, 2016 in Del Mar to review the status and findings of the wetland mitigation project, which is being done at San Dieguito Lagoon

## Reef Mitigation Linked to the Adverse Effects of the SONGS Cooling Water System

(San Onofre Nuclear Generating Station = SONGS)

The nuclear reactors of SONGS units 2 and 3 were cooled by seawater that is taken in by large intake pipes and discharged back to the ocean via 2 diffuser lines

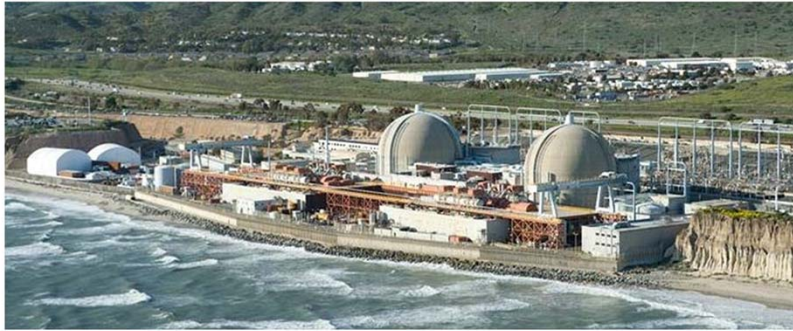
A turbidity plume associated with SONGS diffusers has been implicated as the cause of a substantial reduction in size of the San Onofre kelp forest



The SONGS artificial reef mitigation project is linked to the adverse effects of the SONGS single pass seawater cooling system on the San Onofre kelp forest, which is located directly offshore of the power plant

- The nuclear reactors of Units 2 and 3 were cooled by sea water that is taken in through large intake pipes located in about 30 feet of water offshore of the power plant
- When operational the water was elevated 19° F above ambient as it's circulated through the plant and then discharged through an extensive diffuser system designed to dissipate the heat
- Mixing of the discharged cooling water with the surrounding seawater was found to result in the formation of a turbid plume in the vicinity of the San Onofre kelp forest which is located adjacent to the two diffuser lines
- The turbid plume was implicated for causing a substantial reduction in area of the San Onofre kelp forest

## SONGS Units 2 & 3 Operating Conditions



**1983: Unit 2 operations begin**

**1984: Unit 3 operations begin**

**2012: Units 2 and 3 operations suspended**

**2013: Units 2 and 3 operations permanently ceased**

**Transfer of fuel to spent fuel pool**

**Operating license modified**

- No operation of reactors
- No fuel in reactors
- "Possession Only" license

[www.songscommunity.com](http://www.songscommunity.com)

- Operations of SONGS Units 2 and 3 began in 1983 and 1984, respectively
- Operations of SONGS Units 2 and 3 were suspended in January 2012 due to premature wear of replacement steam generators
- SCE decided to permanently shut down the plant in June 2013
- SCE's operating license has been modified to "possession only" and they are no longer authorized to operate the reactors

## SONGS Units 2 & 3 Intake Flows



### **Full Operational Flow (1983 -2012)**

- 1,287 Million Gallons per Day (MPD) per unit = 2,574 MGD total
- Represents total allowable flows

### **Current Offline Flow**

- 49 MGD per unit = 98 MGD total

### **Projected offline Flow (2016)**

- 42 MGD per unit = 84 MGD total

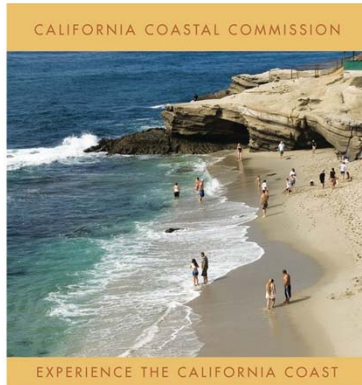
*Data provided by SONGS*

- Under normal operation conditions the flow rate of the cooling water systems of each Unit was about 1200 million gallons per day
- This amounted to 2.4 billion gallons a day for both units which is equivalent to a volume of water that is a 1 square mile 12 feet deep
- Since the shutdown, the flow in each unit has been reduced to about 49 million gallons a day or roughly 4% of the normal operating flow



# The California Coastal Act Requires Mitigation of Marine Impacts

The California Coastal Commission (CCC) is responsible for implementing the Coastal Act



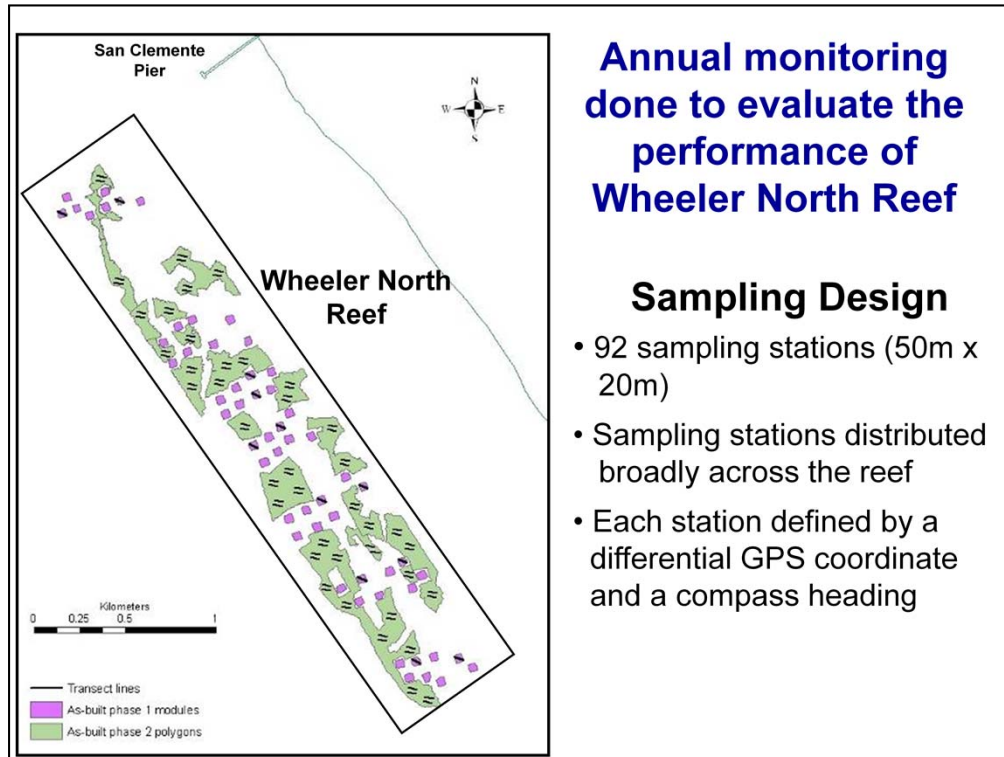
As mitigation for the impacts to the San Onofre kelp forest caused by SONGS the CCC required SCE to:

1. Construct an artificial reef that creates a minimum of 150 acres of kelp forest habitat to compensate for losses of kelp and kelp bed fish, invertebrates and algae.
2. Provide funding for scientific oversight and monitoring of the mitigation project that is *independent* of SCE.

- The California Coastal Act requires mitigation for impacts to the marine environment such as those caused by SONGS
- Implementation of the Coastal Act resides with the California Coastal Commission (CCC)
- The CCC is responsible for ensuring that the adverse impacts to the marine environment caused by SONGS are adequately mitigated
- As mitigation for the impacts to the San Onofre kelp forest caused by SONGS the CCC required SCE to: (1) Construct of an artificial reef that creates a minimum of 150 acres of kelp forest habitat to compensate for losses of kelp and kelp bed fish and invertebrates, and (2) Provide funding for scientific oversight and monitoring of mitigation projects that is *independent* of SCE
- Independent monitoring is done by marine scientists at UCSB who report directly to the CCC



- This map provides a general overview of the project site and shows the locations of the artificial reef
- Wheeler North Reef was constructed in 2 phases
- Construction of Phase 1 was completed in October 1999 and consisted of 56 modules that tested different bottom coverages of quarry rock and rubble concrete
- Information obtained from the 5 year Phase 1 period was used to guide the design of the Phase 2
- Phase 2 was completed in September 2008 and consisted of 18 polygons of low relief quarry rock which totaled 152 acres
- The Phase 1 and Phase 2 reefs combined constitute the 176 acre Wheeler North Reef
- Data were collected during annual monitoring surveys to judge the performance of the Wheeler North Reef in meeting its objective, which is to compensate for kelp forest resources lost due to the operation of SONGS



- This diagram summarizes the sampling design for the monitoring that is being done to evaluate the performance of the Wheeler North Reef
- The experimental Phase 1 modules constructed in 1999 are shown in purple; the new Phase 2 polygons constructed in 2008 are shown in green
- The 92 sampling stations are shown as black lines. The sampling stations are arranged in 40 pairs spaced 50 m apart on the Phase 2 polygons and as single stations on 12 of the Phase 1 modules



## **Performance Standards**

*Used as a measuring stick to evaluate whether the Wheeler North Reef compensates for kelp forest loss caused by SONGS*

**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.

### **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.

### **Method of Evaluation**

The evaluation of each absolute performance standard is based on the value for the current year, or the 4-yr average value calculated from the current year and the previous three years, *which ever is higher*.

## 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**

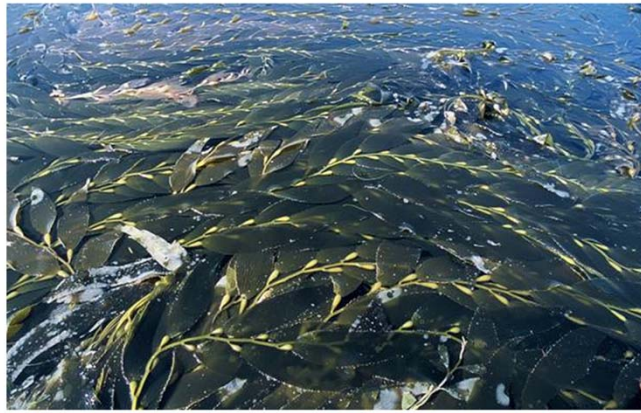
*At least 90 percent of the exposed hard substrate must remain available for attachment by reef biota*



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

## 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 more than 4 adult plants 100 m<sup>2</sup>
- 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 m<sup>2</sup>
- 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



## **Performance Standard: Fish Standing Stock**

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

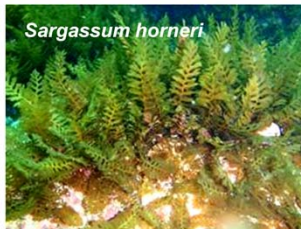


The performance standard for fish biomass requires the Wheeler North Reef to support at least 28 US tons of fish, which is the estimated reduction in the biomass of kelp bed fish caused by SONGS operations

## 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

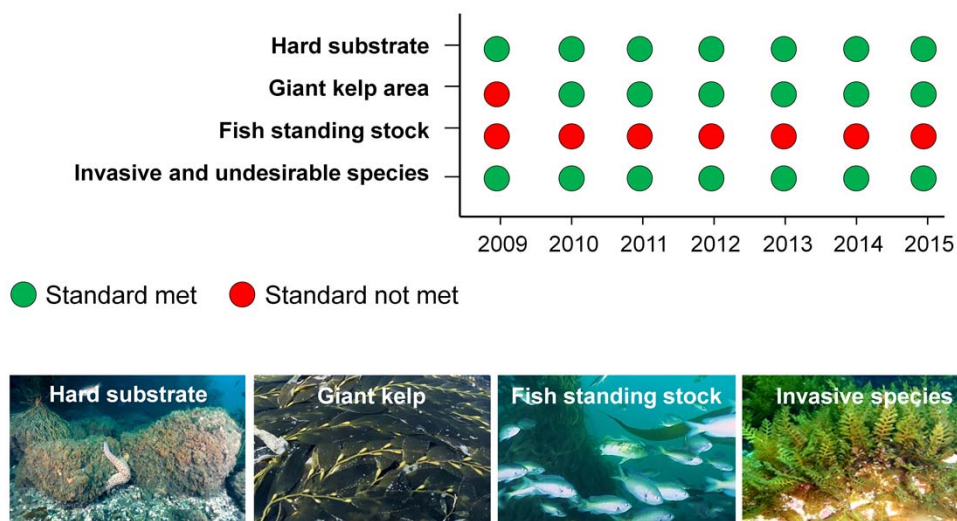


Undesirable or invasive species that are of potential concern include:

- 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 overgraze 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

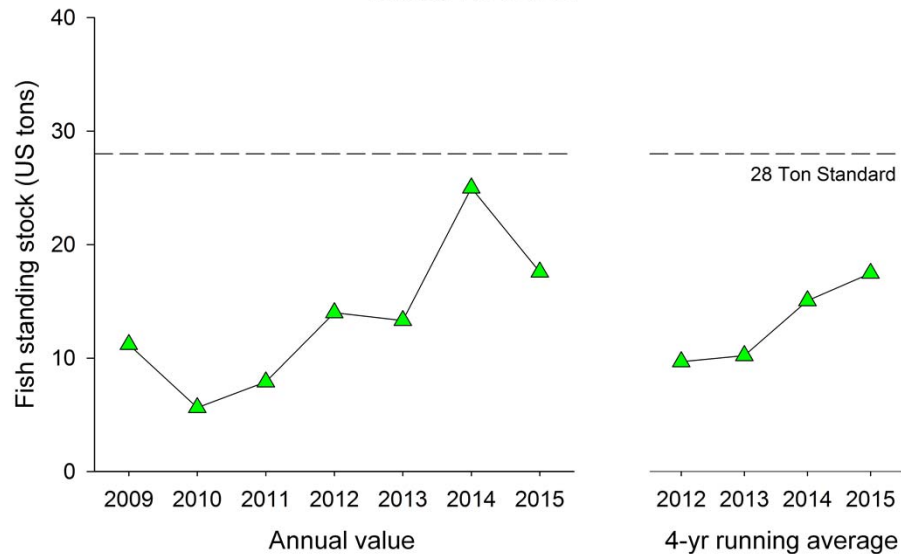
## Absolute Performance Standards



- Shown here is a chart summarizing whether or not the Wheeler North Reef met each of the four absolute performance standards during each of the past seven years
- Green circles indicate that a standard was met in a given year and red circles indicate that a standard was not met
- The standard for area of adult giant kelp was not met in the first year. (2009)
- Although giant kelp was very abundant at Wheeler North Reef within 1 year after construction, it largely consisted on juvenile plants that had not yet grown to adulthood causing the kelp standard not to be met in 2009
- Since 2010 adult giant kelp have been abundant at Wheeler North Reef and the kelp standard has been met every year since then
- The most notable deficiency at Wheeler North Reef has been its consistent failure to meet the performance standard for fish standing stock

## Performance Standard: Fish Standing Stock

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



- This graph shows a time series of fish standing stock at Wheeler North Reef for each year on the left and for the 4-y running average on the right
- The annual value for each year and the four-year running average have been below 28 tons each year
- The fish standing stock reached ~ 25 tons in 2014 due in part to the occurrence of several very large giant sea bass that were sighted on the transects
- The standing stock declined to 17.5 tons last year and the 4-year running average was also 17.5 tons

**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
- The nearby kelp forests at San Mateo and Barn were selected because they had:
  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





This map shows the locations of San Mateo and Barn relative to the Wheeler North Reef and SONGS

## ***What counts as similar when assessing the relative performance standards?***

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

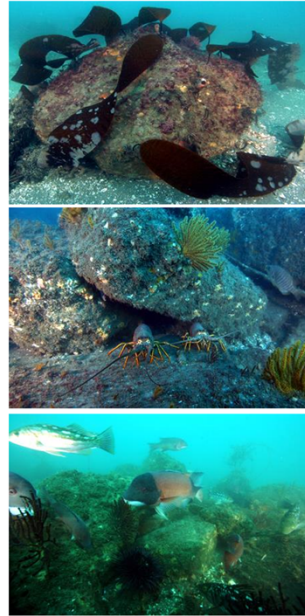
### ***Rationale:***

- 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

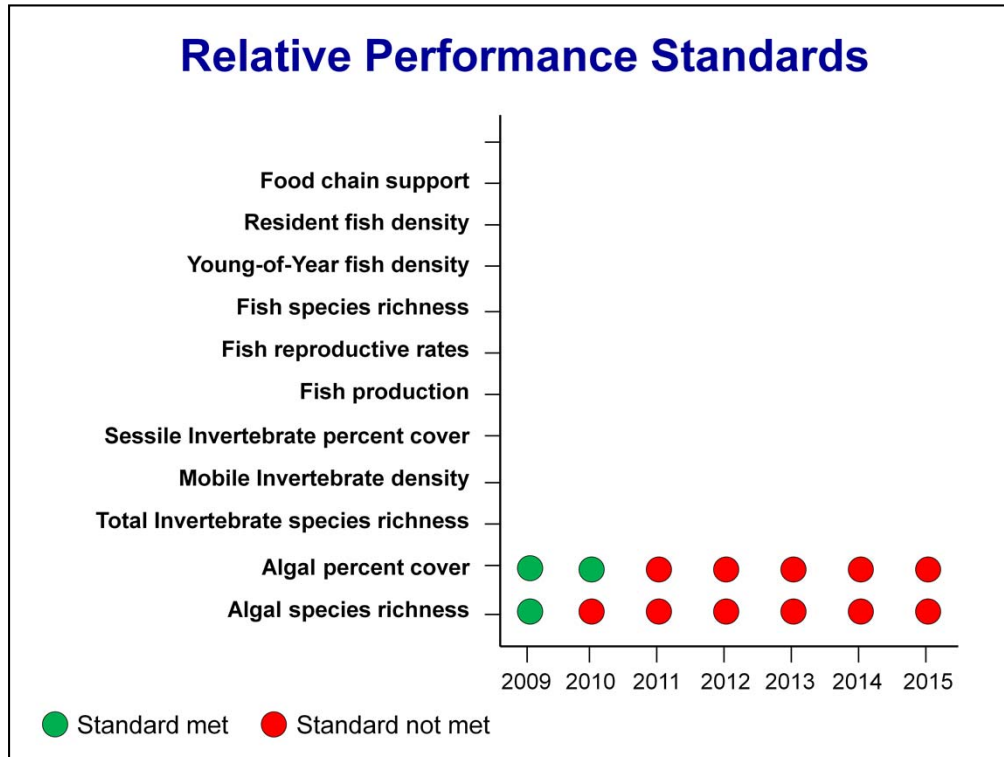
- The SONGS Coastal Development Permit envisioned a quantitative definition of “similar” for evaluating the performance of the reef mitigation projects relative to reference sites, and it specified that the measure of similarity be defined in the monitoring plan for the project
- After considerable discussion 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 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

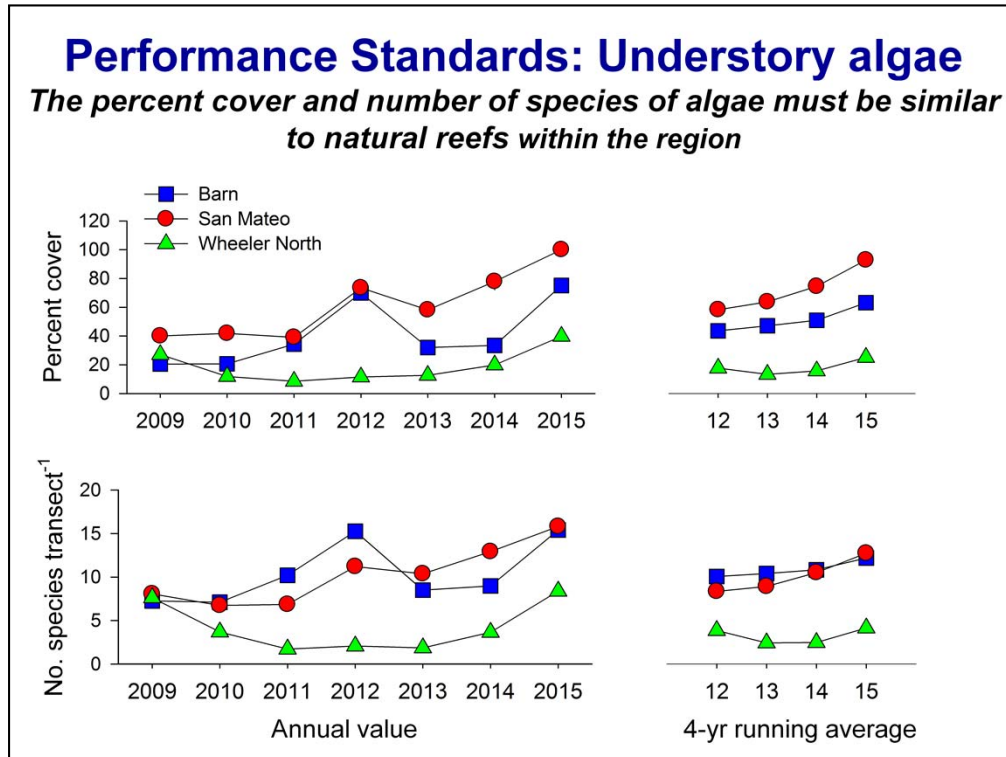


- Shown here are the 11 relative performance standards that are used to judge the Wheeler North Reef
- Standards 1-5 pertain to the benthic community of algae and invertebrates
- Standards 6-10 pertain to reef fishes
- Standard 11 integrates the benthic community of algae and invertebrates with reef 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 has performed with respect to these 11 standards since it was first constructed in 2009



Shown here is an annual summary of the performance of understory algae at Wheeler North Reef

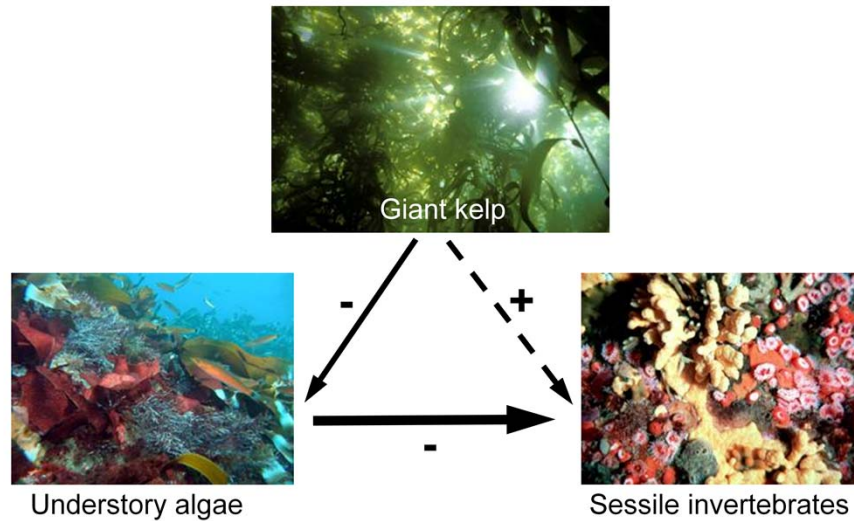
- A green circle means a standard was met in a given year and a red circle means that the standard was not met
- Algae quickly colonized the Wheeler North Reef soon after it was built and the percent cover of algae and number of algal species at Wheeler North Reef was similar to that at the nearby reference reefs by the first year (2009).
- This pattern quickly disappeared and the Wheeler North Reef has been under performing with respect to algae species richness since 2010 and algal percent cover since 2011.



- Plotted here are time series of algal percent cover in the top graph and algal species number or richness in the bottom graph at the Wheeler North Reef, Barn and San Mateo
- The graphs on the left are annual values whereas those on the right are 4-year running averages
- In 2009 the percent cover and species number at Wheeler North Reef, San Mateo and Barn were quite similar, but quickly diverged as algae started to decline at Wheeler North Reef.
- Algal cover and species number have increased at all three sites since 2013 but are still significantly lower at Wheeler North Reef compared to the two reference reefs



## Ecological interactions within the kelp forest

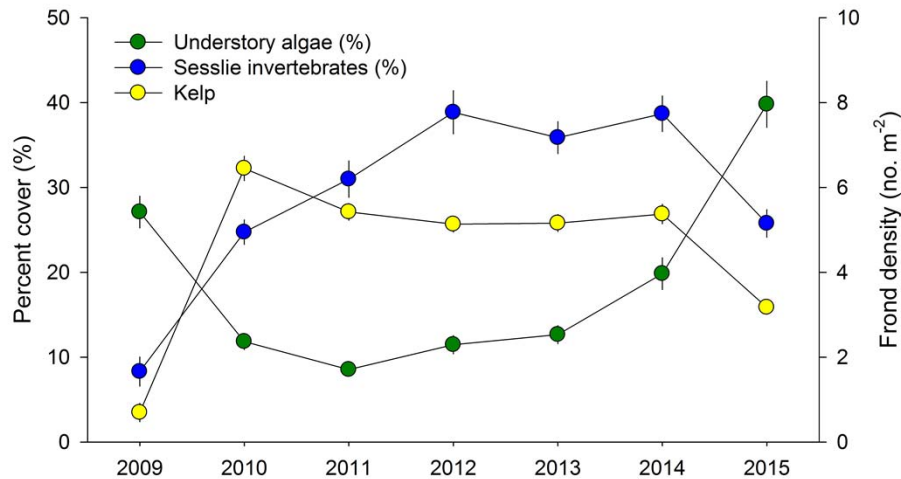


**Shading by giant kelp affects competition between understory algae and sessile invertebrates**

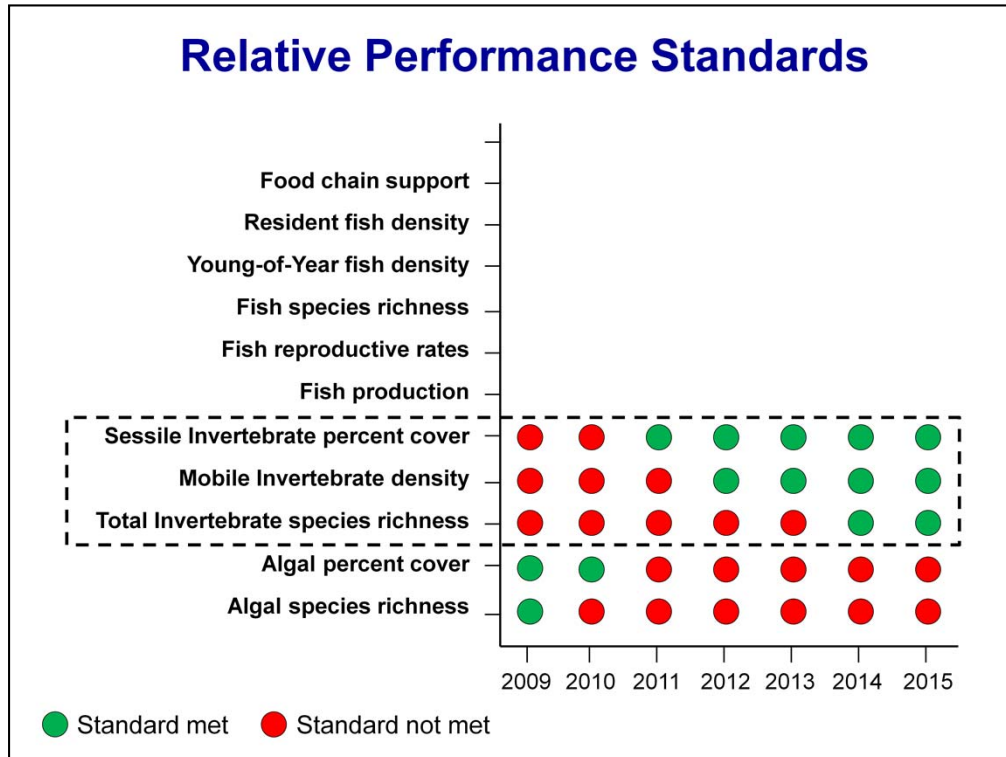
- The patterns of algae abundance and diversity at Wheeler North Reef can be explained by ecological interactions in the kelp forest
- Understory algae and sessile invertebrates compete for hard substrate on the bottom
- When left uncontrolled algae tends to overgrow and out compete sessile invertebrates, which is indicated by the direction of the arrow going from algae to invertebrates and the minus sign
- The surface canopy of giant kelp significantly reduces the amount of light reaching the bottom, and thus has a negative effect on understory algae, which require light to grow
- In doing so giant kelp has an indirect positive effect on sessile invertebrates
- Thus the relative abundance of understory algae and sessile invertebrates on a reef is greatly affected by the presence of giant kelp
- Understory algae are favored in the absence of giant kelp, while invertebrates are favored in the presence of giant kelp

## Interactions with understory algae at WNR

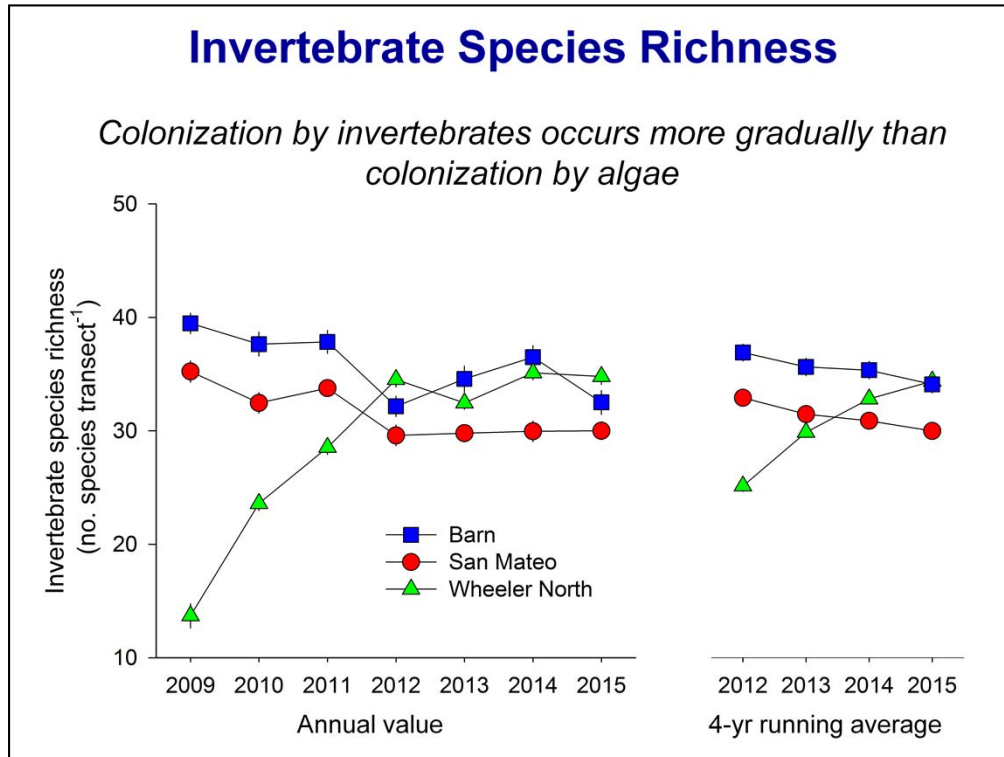
*The percent cover of understory algae at Wheeler North Reef has varied inversely with the percent cover of sessile invertebrates and the density of giant kelp*



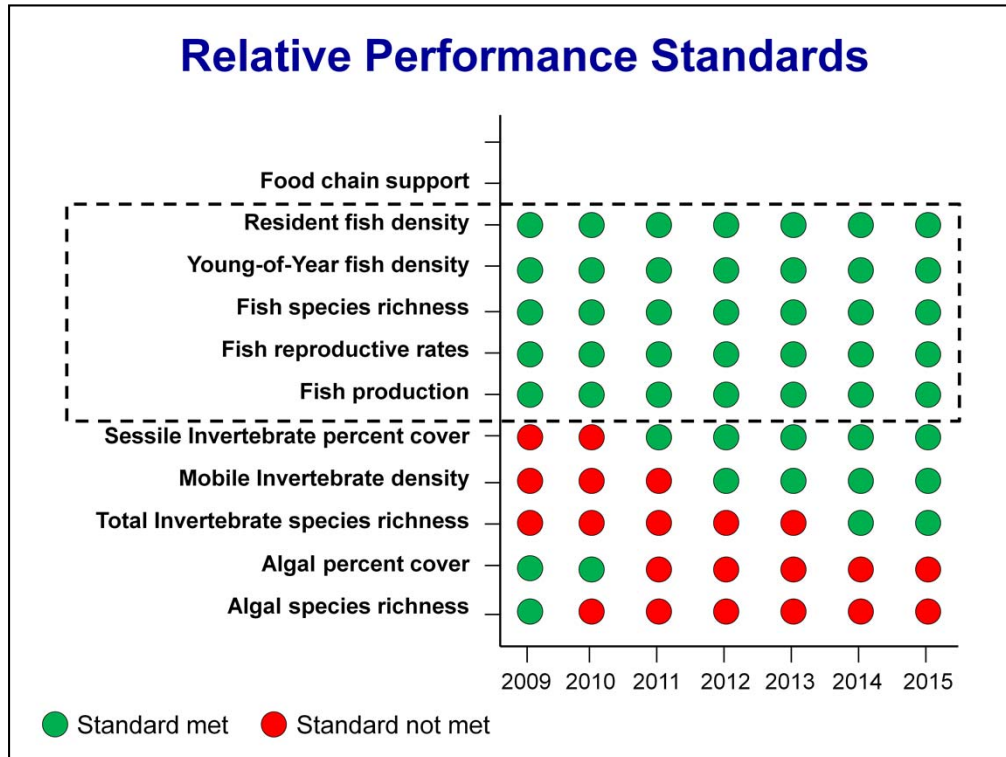
- Results of monitoring of the Wheeler North Reef support the hypothesis that giant kelp has a direct negative effect on the percent cover of understory algae by shading and an indirect positive effect on the percent cover of sessile invertebrates resulting from reduced competition for space with understory algae
- This time series graph plots the percent cover of algae (shown as green) and sessile invertebrates (shown as blue) on the left hand axis and the density of giant kelp (shown as yellow) on the right hand axis for each year since 2009
- It shows that the rapid decrease in the percent cover of understory algae at Wheeler North Reef coincided with a rapid increase in the density of kelp fronds and a corresponding increase in the percent cover of sessile filter feeding invertebrates



- Highlighted within the dotted lines is an annual summary of the performance of invertebrates at Wheeler North Reef
- The performance standard for sessile invertebrate cover was not met in the first 2 years but has been met every year since
- This is the exact opposite pattern observed for algal percent cover which is consistent with previous slide showing the ecological interactions between algae, sessile invertebrates and kelp
- The Wheeler North Reef also underperformed with respect to density of mobile invertebrates and the number of species of all invertebrates early in the time series, but this trend has reversed in recent years and the Wheeler North Reef has met both of these standards the last couple of years



- This graph shows a time series of invertebrate species richness at Wheeler North Reef, San Mateo and Barn using annual values on the left and the 4-y running average on the right
- It took four years before the species richness of invertebrates reached levels similar to those observed at the natural reference reefs
- This contrast with algae whose species richness at Wheeler North Reef was similar to that of the reference reefs in the first year following construction

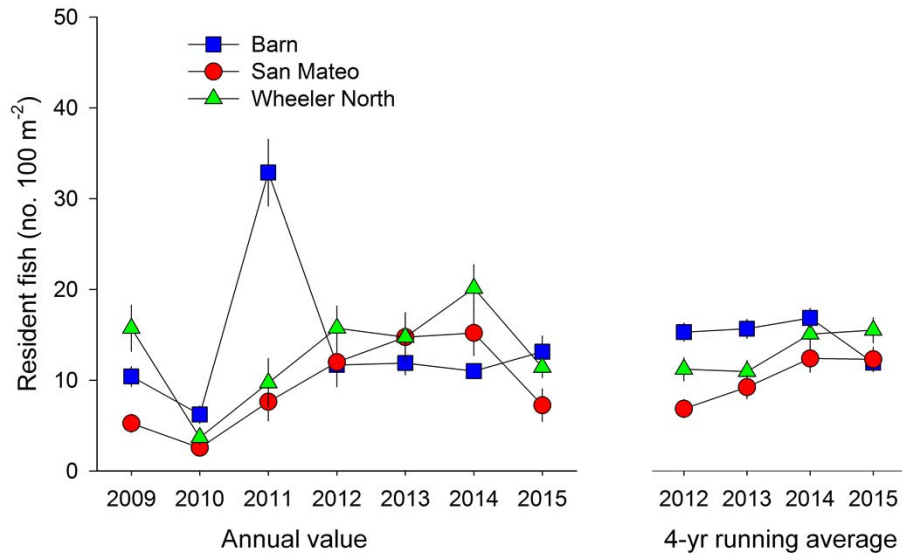


The Wheeler North Reef has performed quite well with respect to the relative performance standards pertaining to reef fish having met all 5 standards in all 7 years of monitoring

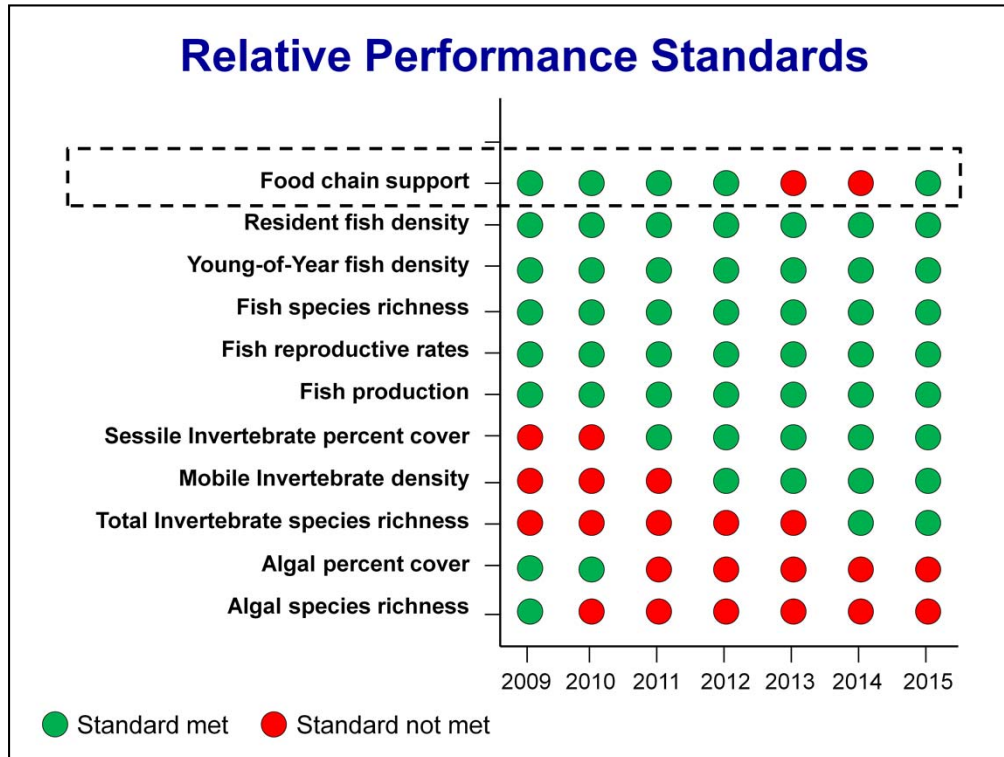


## Performance Standard: Resident Fish

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



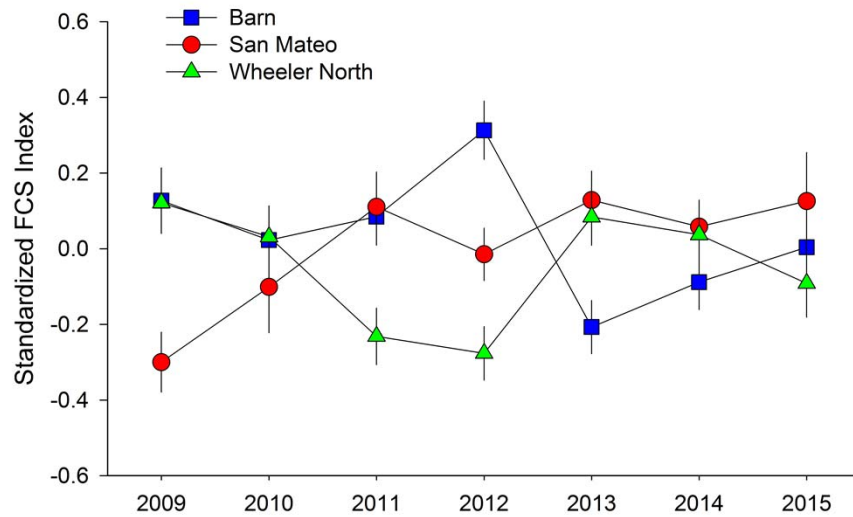
- The performance standard for resident fish density illustrates this favorable result
- Show here are annual data on the density of resident fish, which are defined as reef associated species 1 year of age or older
- The density of resident fish on Wheeler North Reef has been consistently above or within the range set by the reference reefs at Barn and San Mateo



- 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
- We evaluate this performance standard by measuring the weight of the food in the guts of two common species of fish that feed on the bottom: black perch and the California sheephead
- We use this information to calculate an index of food chain support that is scaled to the weight of the fish
- The relative performance of the Wheeler North Reef with respect to food chain support has varied inconsistently over time, but overall it has met this criterion in 5 of the 7 years

## Performance Standard: Food Chain Support

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



- This plot shows temporal trends for the standardized food chain support index for Wheeler North Reef, San Mateo and Barn
- The index at Wheeler North Reef was at least as high as the lowest performing reference reef in all years except 2011 and 2012
- In 2015 the mean FCS index of Wheeler North Reef was below the mean values of San Mateo and Barn, but not significantly so

## **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.

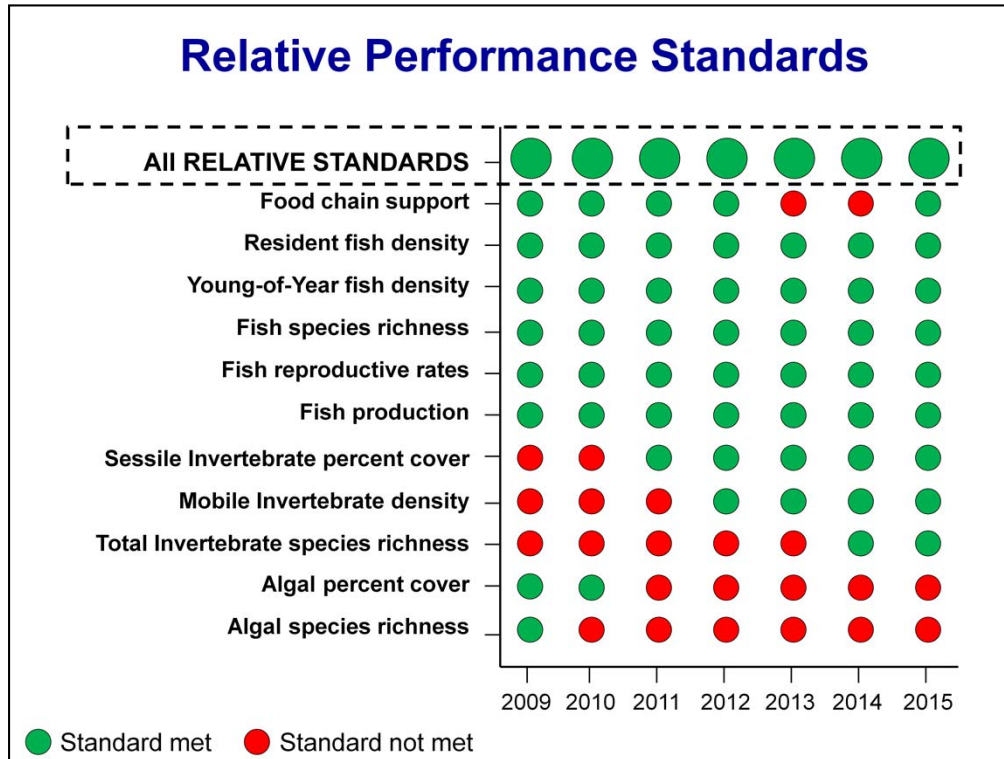
### **Rationale**

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.

### **Method of Evaluation**

WNR and the reference reefs are evaluated with respect to each other to determine whether they meet each relative standard and the total number of relative standards met by each reef is tallied and compared.

- The interactions among species in the kelp forest such as those shown for algae and sessile invertebrates and kelp at Wheeler North Reef greatly hamper its ability to meet all the relative performance standards in a given year
- Because natural kelp forests also vary greatly in their species composition and abundance over time and it is likely, that they too would not consistently meet all the relative standards in a given year
- Therefore, to avoid requiring the Wheeler North Reef to perform better than the reference reefs, the Wheeler North Reef is required to meet only as many of the relative standards as the lowest performing reference reef in a given year for that year to count towards mitigation credit
- This achieves the desired goal of Wheeler North Reef being similar to natural reefs without requiring it consistently outperform them

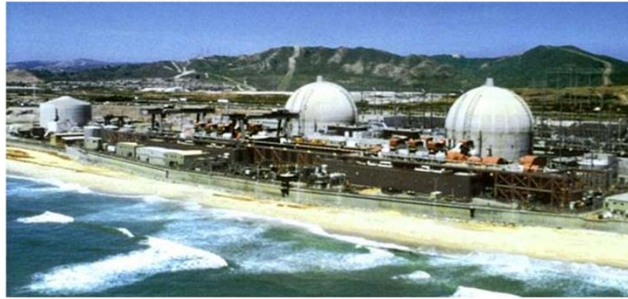


- The top row in this figure depicts the performance of Wheeler North Reef with respect to all 11 relative standards when viewed as a group
- It shows that the Wheeler North Reef has met as many relative standards as the lowest performing reference reef in all 7 years since it was constructed



## **SONGS Reef Mitigation Compliance**

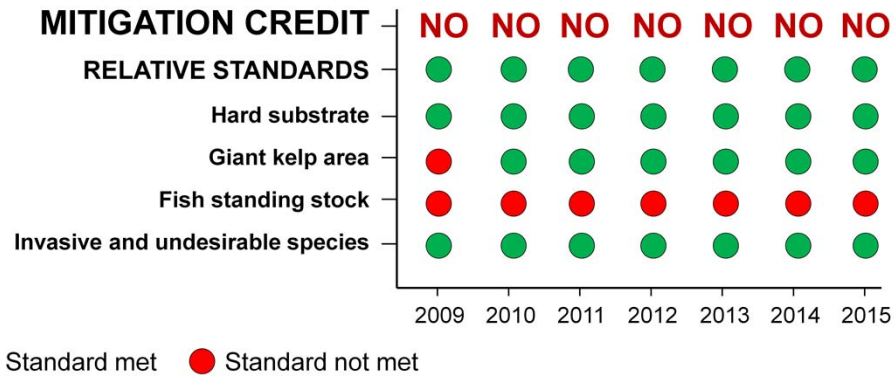
**Goal:** *Replace kelp forest resources lost by SONGS' operations*



- **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 are continuing discharges**

- The goal of the SONGS reef mitigation project is to replace the kelp forest resources that were lost due to the operations of SONGS Units 2 & 3
- One year of mitigation credit is given for each year that Wheeler North Reef meets the performance standards
- Wheeler North Reef is required to provide compensation for damages to kelp forest resources for a period of time equal to the lifetime operation of SONGS 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

## Project Compliance



**Number of years of credit *earned* = 0**

**Number of years of credit *needed* ~ 30**

- Show here is a summary of project compliance for the SONGS reef mitigation project
- As described in the previous slide project compliance requires that the Wheeler North Reef meet all 4 absolute standards and the collective group of relative standards in a given year for that year to count towards mitigation credit
- Because the Wheeler North Reef has failed to meet the performance standard for fish standing stock in every year it has not accrued any mitigation credit to date