Introduction and Overview

Annual Review Workshop for SONGS Reef Mitigation

April 8, 2013

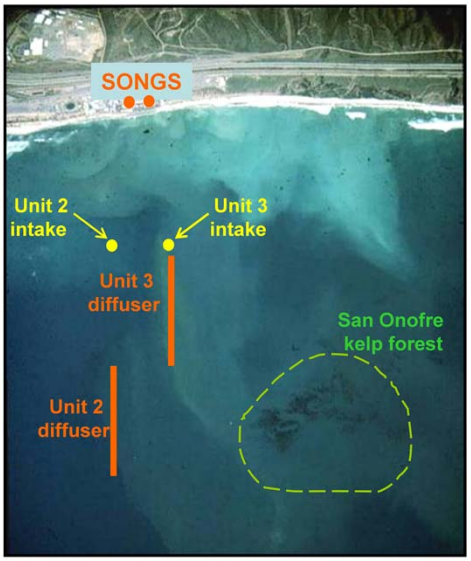
SONGS Mitigation Monitoring Project
Marine Science Institute, University of California Santa Barbara

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 are cooled by seawater that is taken in by large intake pipes and discharged back to the ocean via 2 diffuser lines

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

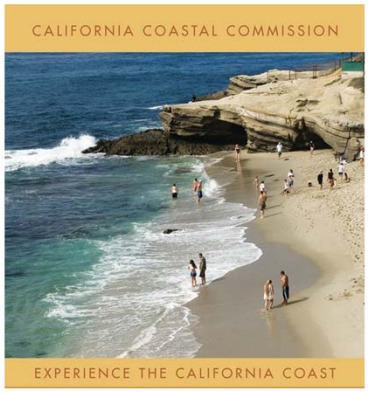


The SONGS artificial reef mitigation project is linked to the adverse effects of the SONGS single pass seawater cooling system on the San Onofre kelp forest, which is located directly offshore of the power plant.

- The nuclear reactors of Units 2 and 3 are cooled by sea water that is taken in through large intake pipes located in about 30 feet of water offshore of the power plant
- The water is elevated 19^{o} F above ambient as it is circulated through the plant and then discharged through an extensive diffuser system designed to dissipate the heat
- To dissipate the heat the diffusers entrain and mix 10 times the volume of water that is discharged.
- Mixing of the discharged cooling water with the surrounding seawater results 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 has been implicated for causing a substantial reduction in area of the San Onofre kelp forest.

The California Coastal Act Requires Mitigation of SONGS Marine Impacts

Enforcement resides with the California Coastal Commission (CCC)



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.**
2. **Provide funding for scientific oversight and monitoring of mitigation projects that is *independent* of SCE.**

- Adverse impacts caused by SONGS are in violation of the coastal act and thus require mitigation.
- Enforcement 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.

Key Elements of the SONGS Artificial Reef Mitigation Project

Goal

Replace the kelp forest resources lost due to the operation of SONGS Units 2 and 3

- *Artificial reef located near SONGS, but outside its influence*
- *Artificial reef configured to look like the low-relief boulder reef at San Onofre*
- *Artificial reef to perform for a period of time equal to the operating life of Units 2 & 3*

Performance Standards

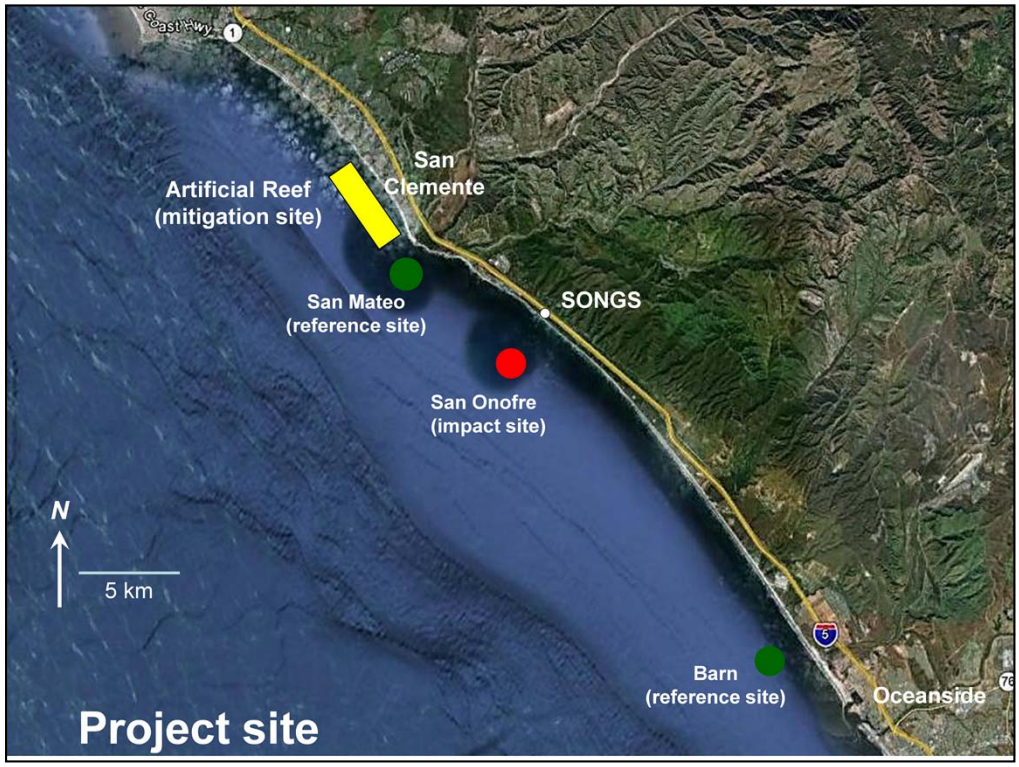
Physical and biological standards were established to judge the performance of the artificial reef.

Evaluation

Data from independent long-term monitoring used to determine:

1) whether the performance standards are met
2) the causes for any failures to meet the standards
3) the most appropriate methods for remediation if required

- The goal of the SONGS artificial reef mitigation is to provide in-kind compensation for the loss of kelp forest habitat over a period of time equal to the operating life of SONGS Units 2 and 3.
- It was decided that this goal would most likely be met if:
    1. The artificial reef was built in the near vicinity of SONGS, but outside its influence. This will ensure that the compensation for the lost resources will occur locally rather than at a distant location far from the impacts
    2. The artificial reef was configured to resemble the natural reef at San Onofre, which is a low relief boulder field.
- Determining whether the project goal is met is based on whether the mitigation reef meets certain well defined Performance Standards that are based on the physical and biological attributes of the reef.
- Evaluation involves long-term independent monitoring to determine whether the performance standards are met.



- This map provides a general overview of the project site and shows the locations of the artificial reef and the nearby natural kelp forests.
- The San Onofre kelp forest located directly offshore of SONGS is the kelp forest where the impacts from SONGS operations are occurring.
- San Mateo and Barn are the two natural kelp forests being used at reference sites to judge the performance of the Artificial Reef.

Kelp Forest Mitigation in Two Phases

Phase 1: Experimental Reef
Short-term (1999-2004), small scale (~ 22 acres) to test different reef designs

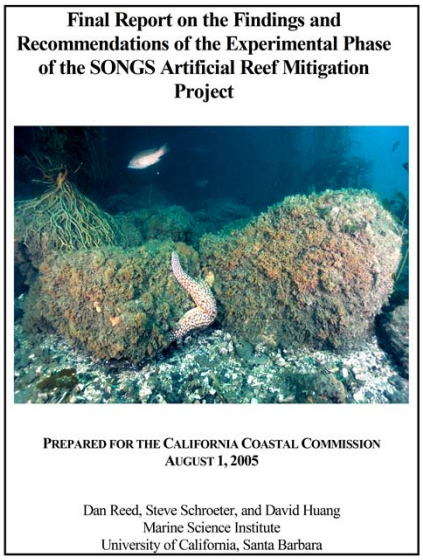
Phase 2: Mitigation Reef
Long-term (> 30 y), large scale (> 150 acres) to compensate for resources lost due to SONGS operations

Information gained from the Phase 1 Experimental Reef used to design the Phase 2 Mitigation Reef

- Mitigation for SONGS impacts to the San Onofre kelp forest is being done in two phases:
  1. A short-term, small-scale experimental phase for testing different reef designs, and
  2. A longer-term, large-scale mitigation phase intended to compensate for the resources lost due to SONGS' operations.
- Information gained from the first phase was used to design the second phase.

Conclusions from Phase 1 Experimental Reef

All reef designs tested showed a near equally high tendency to meet many of the performance standards established for the Phase 2 Mitigation Reef



Recommendations for the Phase 2 Mitigation Reef

Reef Location
- **Near San Clemente, CA**

Reef Topography
- **Low relief, < 1 m high**

Substrate Type
- **Quarry rock or rubble concrete boulders**

Substrate Coverage
- **At least 42%, but no more than 86%**

- A final report on the five-year Phase 1 study was prepared by UCSB scientists and submitted to the California Coastal Commission (CCC) in 2005.
- The monitoring results suggested that all reef designs tested showed a near equally high tendency to meet many of the performance standards established for the Phase 2 Mitigation Reef.
- Recommendations adopted by the CCC included a low relief artificial reef to be located near San Clemente, CA that was composed of either quarry rock or concrete rubble that covered at least 42% but no more than 86% of the bottom.

Design of Phase 2 Mitigation Reef

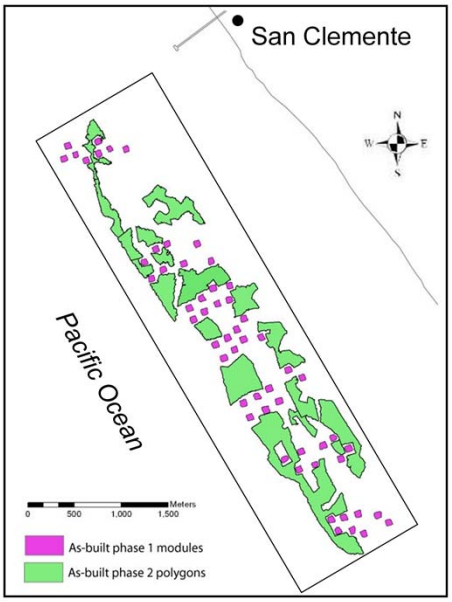
Constructed in Summer 2008

153 acres
- *18 polygons of variable size*
- *Extends along 3.5 km of coast*
- *Avoided experimental modules*
- *Avoided natural hard bottom*

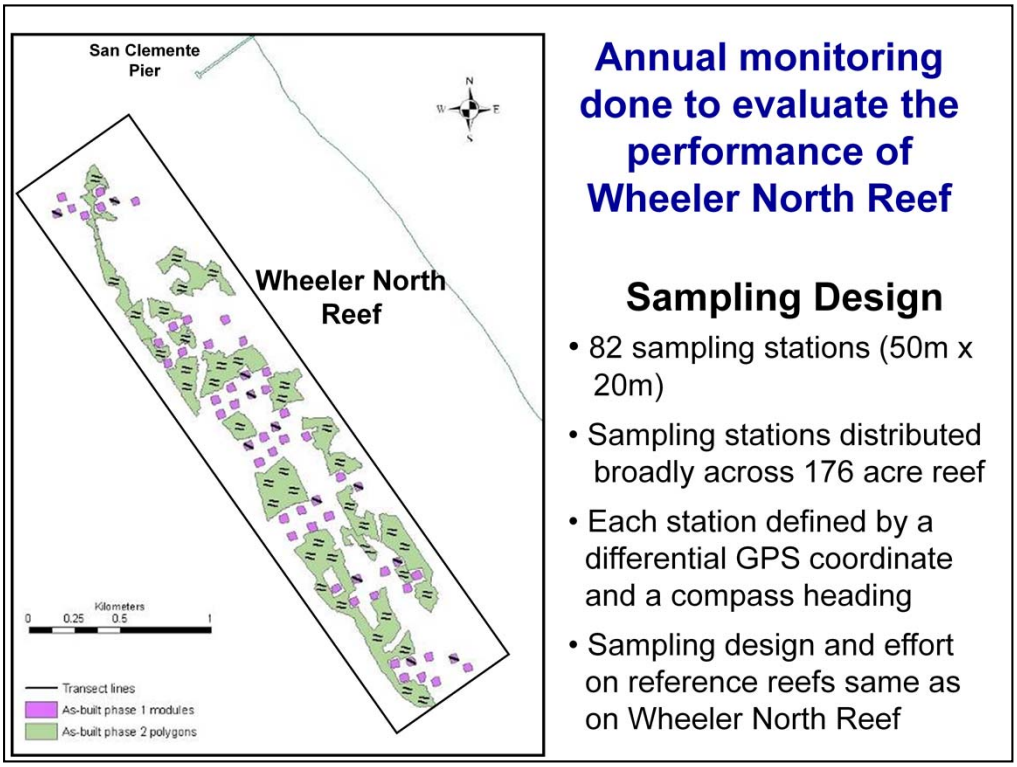
One type of material
- *Quarry rock boulders*
- *126,000 tons of rock*

One bottom coverage
- *~42%*
- *Low relief < 1m tall*

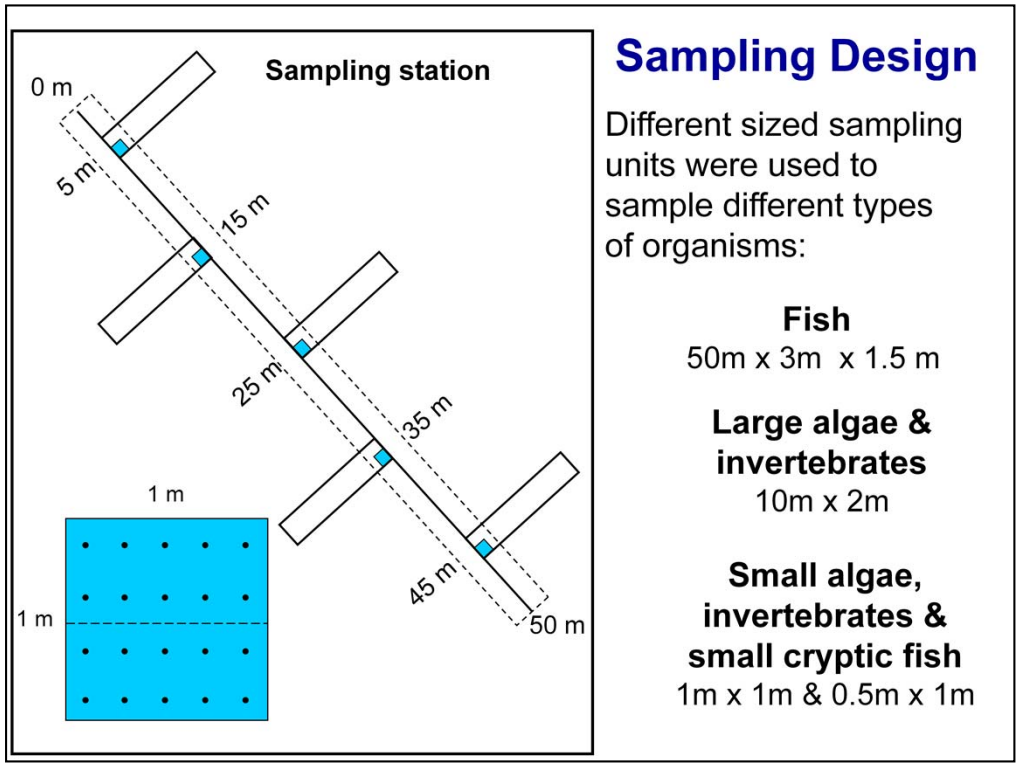
Phase 1 + Phase 2 = Wheeler North Reef



- The second phase of the mitigation entailed the construction and monitoring of the full mitigation reef.
- Construction of the Phase 2 Mitigation Reef was completed in October 2008.
- Together, the Phase 1 Experimental Reef and the Phase 2 Mitigation Reef comprise the Wheeler North Reef.



- 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, together these constitute the 176 acre Wheeler North Reef.
- The 82 sampling stations shown as black lines. The sampling stations are arranged in 35 pairs spaced 50 m apart on the Phase 2 polygons and as single stations on 12 of the Phase 1 modules.
- A similar sampling design of 82 stations spaced 50 m apart is used for the two reference reefs.



- This shows is a schematic diagram of each of the sampling stations on the WNR and the two reference reefs.
- Different sized sampling units are used to sample different performance variables.
- Fish are sampled in 50m x 3m band transects outlined with the dotted line, which extends 1.5m off the bottom.
- Adult giant kelp > 1m tall, large understory algae, and large mobile invertebrates are counted in the five 10m x 2m bands positioned perpendicular to the main transect at 10 m intervals.
- The % cover of invertebrates, algae and substrate is estimated using a grid of 20 points in the five 1m x 1m quadrats shown in blue.
- Smaller mobile invertebrates and small cryptic fish are counted either in 1m x 1m or 1m x 0.5m quadrats depending on their size and abundance.

Giant kelp

Key species of interest and is the only species singled out in the SONGS permit with its own performance standard

- **World's largest alga**
- **Grows rapidly (up to 18 inches per day) to produce a floating canopy at the sea surface**
- **Foundation species that many other species depend on**

A major goal of the Wheeler North Reef is that it sustain a population of giant kelp

Giant kelp *Macrocystis pyrifera*

- The giant kelp, *Macrocystis pyrifera* is the world's largest alga.
- It displays some of the fastest elongation rates on Earth.
- Once established small plants grow rapidly into large adult plants that extend throughout the water column to produce a floating canopy at the sea surface.
- It is considered the foundation species of the kelp forest because it provides food and shelter for a wide diversity of species.
- A primary goal in designing the Wheeler North Reef was to make it suitable for the establishment, growth, and persistence of giant kelp.

Giant kelp

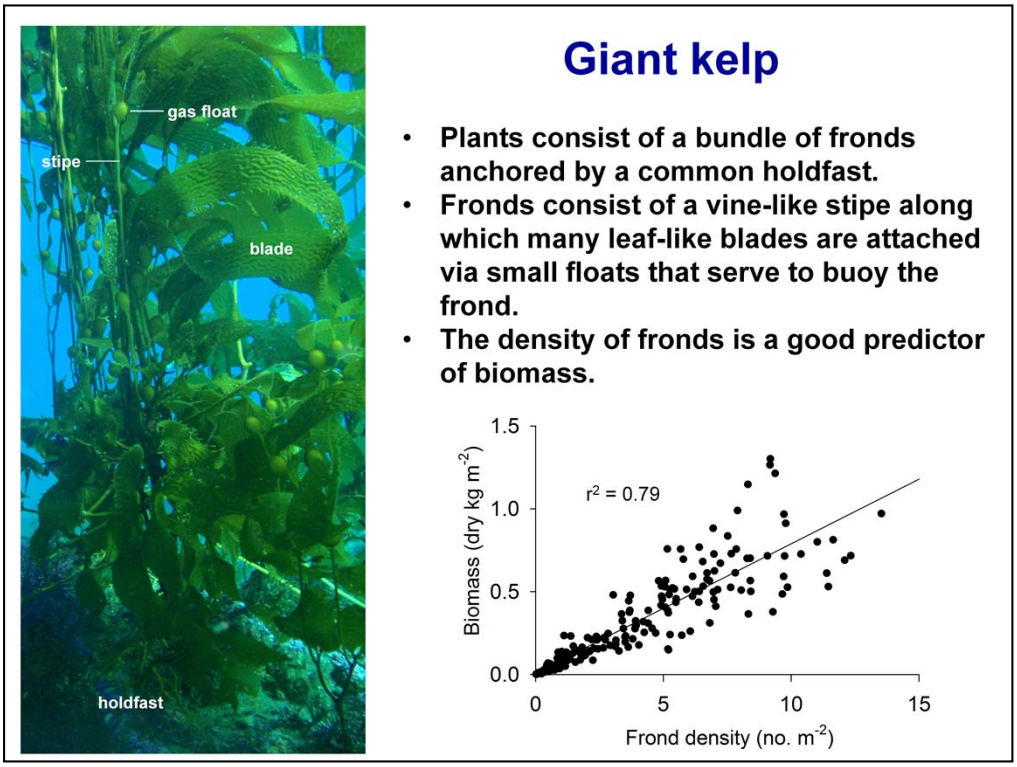
High colonization of giant kelp observed throughout the Wheeler North Reef during the first year following construction

- Colonization of giant kelp occurred across the entire Wheeler North Reef in 2009, within 1 year of construction.
- All of the newly constructed polygons were colonized by giant kelp regardless of location
- Kelp colonization was lowest on the experimental modules where adult kelp was already established.

Giant kelp

Dense surface canopy of giant kelp present on Wheeler North Reef within 2 years of construction

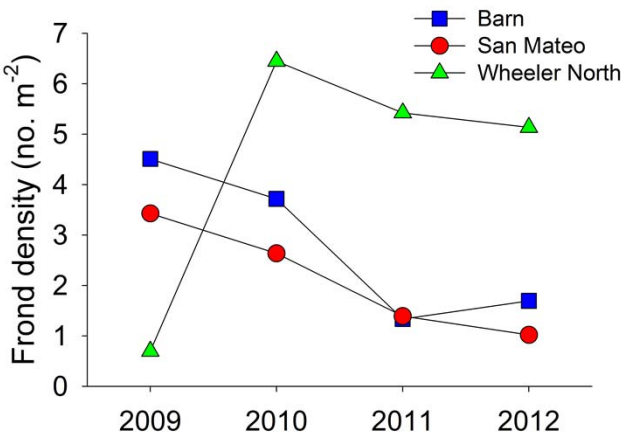
- Surface canopy of giant kelp (shown in red) on Wheeler North Reef in May 2010 as viewed from 438 miles in space



- A giant kelp plant consists of a bundle of vine-like fronds anchored by a common hold fast.
- Each frond consists of a cylindrical rope-like stipe along which many leaf-like blades are attached via small gas bladders that serve to buoy the frond.
- The density of kelp fronds on a reef is a good measure of the biomass of giant kelp.

Giant kelp

Biomass of giant kelp is higher at Wheeler North Reef than at nearby natural reefs



- This graph plots the density of kelp fronds at Wheeler North Reef and the nearby reefs at San Mateo and Barn.
- Frond density increased dramatically at WNR in 2010 as a result of the growth of plants that colonized in 2009 and it has remained high since then.
- In 2011 and 2012 the density of kelp fronds at WNR was 3-4 times higher than that at San Mateo and Barn.

Life beneath giant kelp

Many different species of plants and animals grow attached to the bottom beneath the surface canopy of giant kelp

Many species of low lying plants and animals grow attached to the bottom beneath the canopy of giant kelp

Understory algae

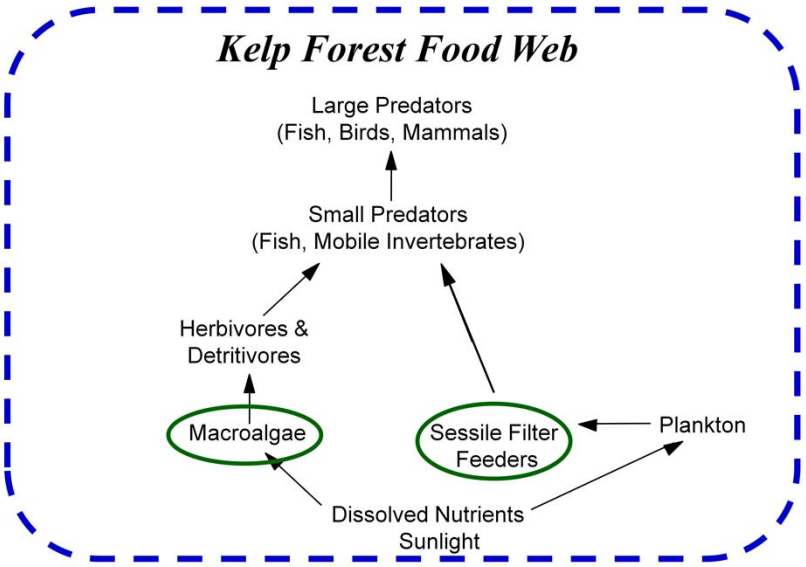
Red algae Brown algae Green algae

- A variety of low lying species of red, brown and green algae are common in kelp forests of southern California.
- These marine “plants” capture sunlight as energy for photosynthesis and are important primary producers in kelp forest.
- Because they occur beneath the canopy of giant kelp they are often referred to as understory algae.

Sessile Invertebrates

- In addition to understory algae, many sessile animals that filter plankton from the water are also found attached to the reef beneath the kelp canopy.
- These include organisms such as sponges, sea anemones, feather duster worms, bryozoans, rock scallops and a wide diversity of sea squirts or tunicates.

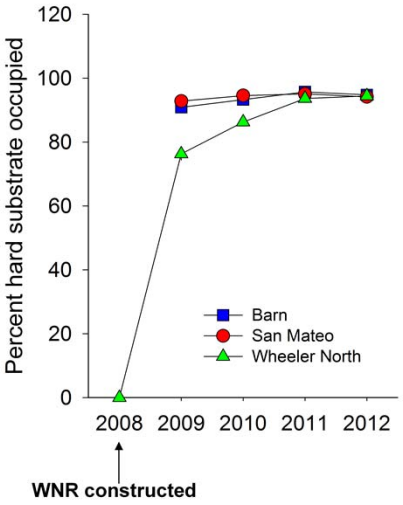
Understory algae and sessile invertebrates are an important food source in the kelp forest



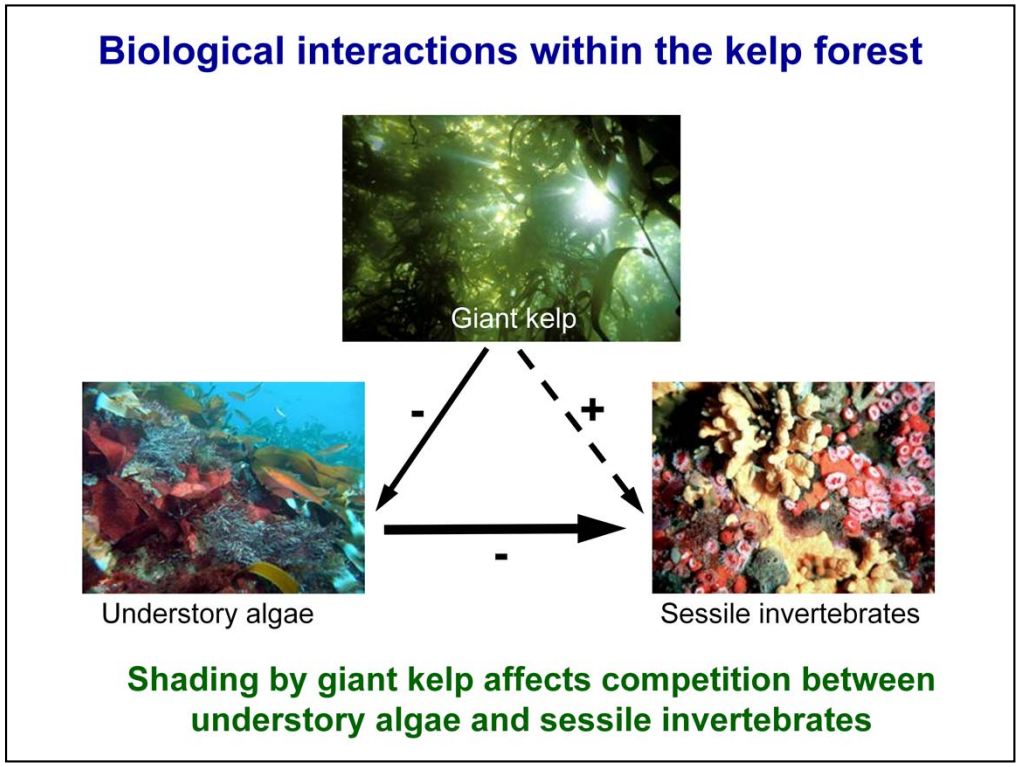
- Understory algae and sessile filter feeders are the primary occupiers of space.
- They serve as important sources of food for mobile invertebrates and fish that comprise the higher tropic levels of the kelp forest food web.

Wheeler North Reef was quickly colonized by understory algae and sessile filter feeding invertebrates

Wheeler North Reef – September 2009

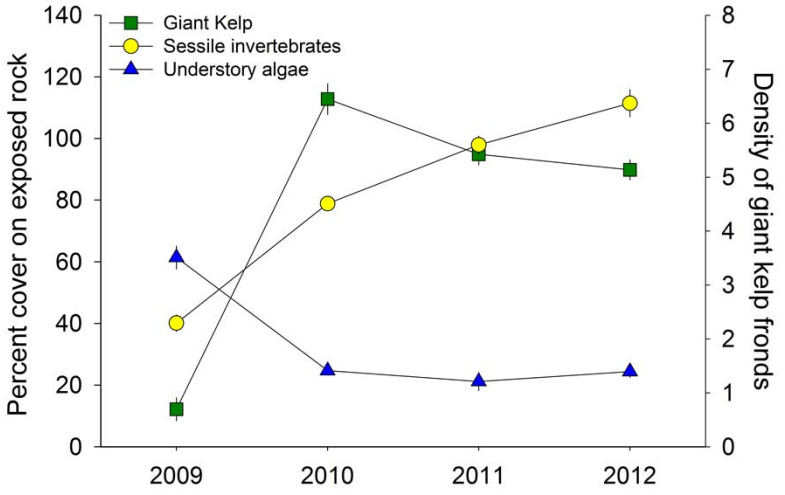


- The amount of the rock that becomes occupied by algae and sessile invertebrates increases over time during the normal development of a kelp forest community.
- Plotted here is the percent of the rock occupied by algae and invertebrates at the Wheeler North Reef, San Mateo and Barn.
- There has been a substantial increase in the percent cover of the benthic community at Wheeler North Reef since it was constructed in 2008, and in 2012 it was nearly identical to that observed at Barn and San Mateo.



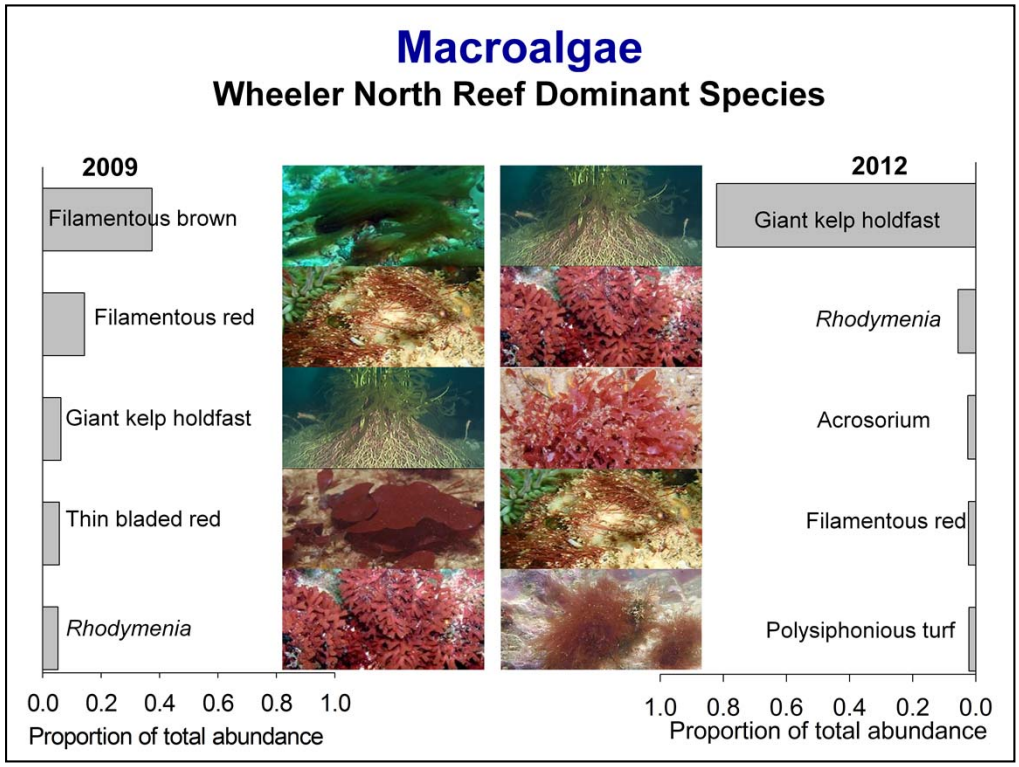
- It turns out that understory algae and sessile invertebrates compete for hard substrate on the bottom.
- When left uncontrolled algae tends to overgrow and out compete sessile invertebrates, which is indicated by the direction of the arrow going from algae to invertebrates and the minus sign.
- The 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. This is indicated by the arrow going from giant kelp to understory algae and the minus sign.
- By shading out understory algae, giant kelp in turn has a indirect positive effect on sessile invertebrates, which is indicated by the dashed arrow going from giant kelp to sessile invertebrates and the plus sign.
- 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 or giant kelp.

Giant kelp affects the abundance of understory algae & sessile invertebrates at Wheeler North Reef

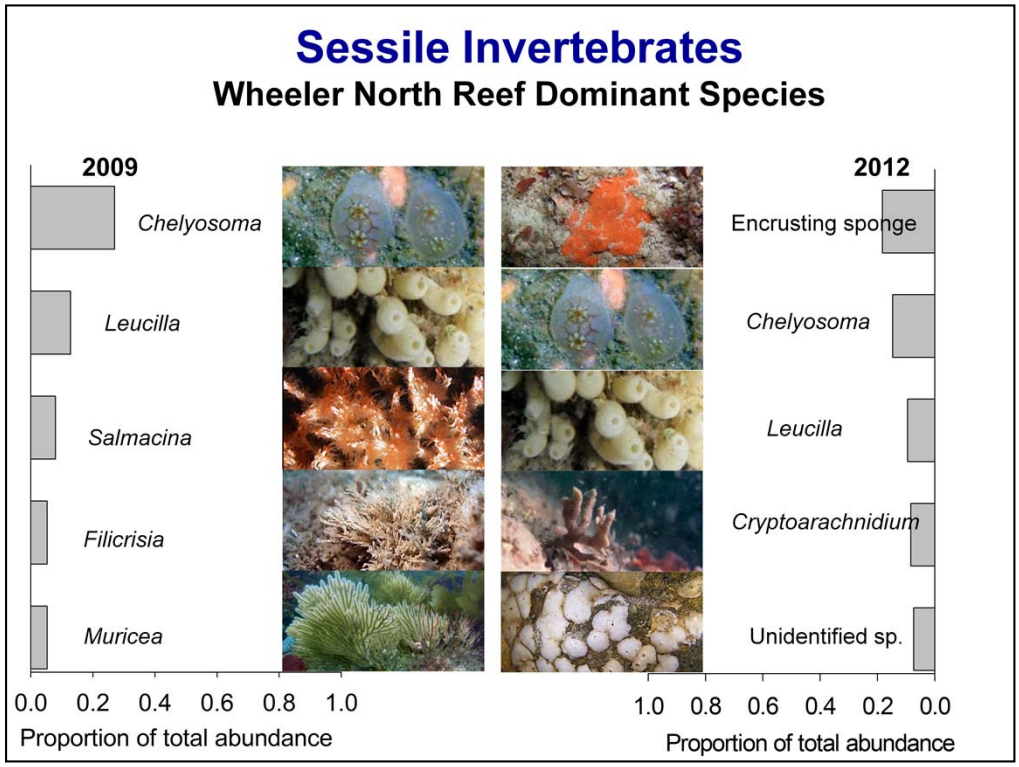


The large increase in giant kelp in 2010 was accompanied by a decrease in understory algae and an increase in sessile invertebrates

- The large increase in giant kelp observed at WNR in 2010 was accompanied by a decrease in the percent cover of understory algae and an increase in the percent cover of sessile invertebrates
- These results 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.



- Not only did the percent cover of algae decline from 2009 to 2012, but it also changed in species composition.
- In 2009 when the percent cover of algae on the bottom at Wheeler North Reef was about 30%, the most abundant algae were annual species of filamentous brown and red algae, which together accounted for about 50% of all algae observed.
- Other abundant algae that occupied space on the bottom were the holdfasts of giant kelp, several species of thin bladed red algae, and the branching red alga *Rhodymenia.*
- Collectively these five tax accounted for 69% of all algae observed in 2009.
- In 2012 the when the overall cover of algae declined to about 11% of the bottom, short lived filamentous species had disappeared and the holdfasts of giant kelp accounted for 82 % of all algal cover.
- *Rhodymenia*, thin bladed branching and filamentous red algae accounted for most of the other algae on the reef.
- Collectively these five taxa accounted for 95% of all algae observed in 2012.

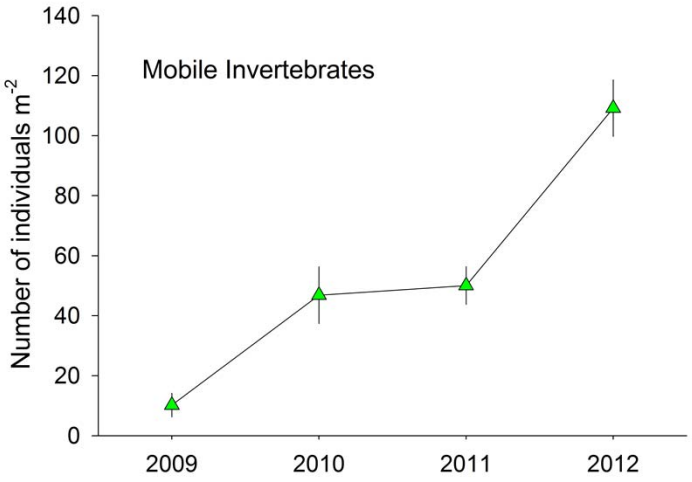


- Unlike with the algae whose percent cover was dominated by one species. The most abundant species of sessile invertebrate accounted for only 26 % of the total coverage in 2009 and 18% in 2012.
- The top 5 species of sessile invertebrates accounted for 57% of the total invertebrate cover in 2009 and 58 % in 2012.
- The species assemblage of sessile invertebrates at WNR has not changed appreciably over time as the sea squirt *Chelyosoma* and the small white urn-shaped sponge *Lucilla* were two of the most abundant species in both 2009 and 2012.
- All of the species shown here with the exception of the sea fan *Muricea* and possibly the orange encrusting sponge are believed to be relatively short-lived.
- This suggests that the high percent cover of sessile invertebrates at WNR is maintained by replacement via the colonization of new individuals rather than by the survival of older long-lived individuals.

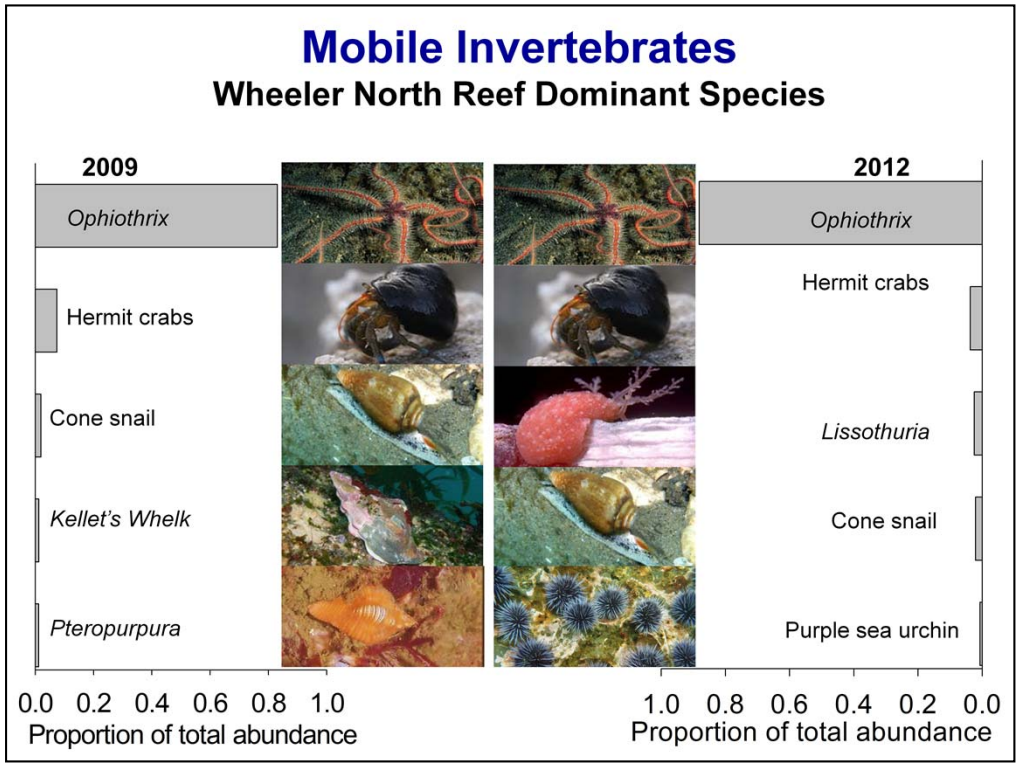
Mobile Invertebrates

- A wide variety of mobile invertebrates are also common on kelp forested reefs.
- This includes a variety of herbivorous and predatory snails, octopus, crabs and lobster, and many different kinds of brittle stars, sea stars and sea urchins.

The density of mobile invertebrates at Wheeler North Reef has increased dramatically since 2009



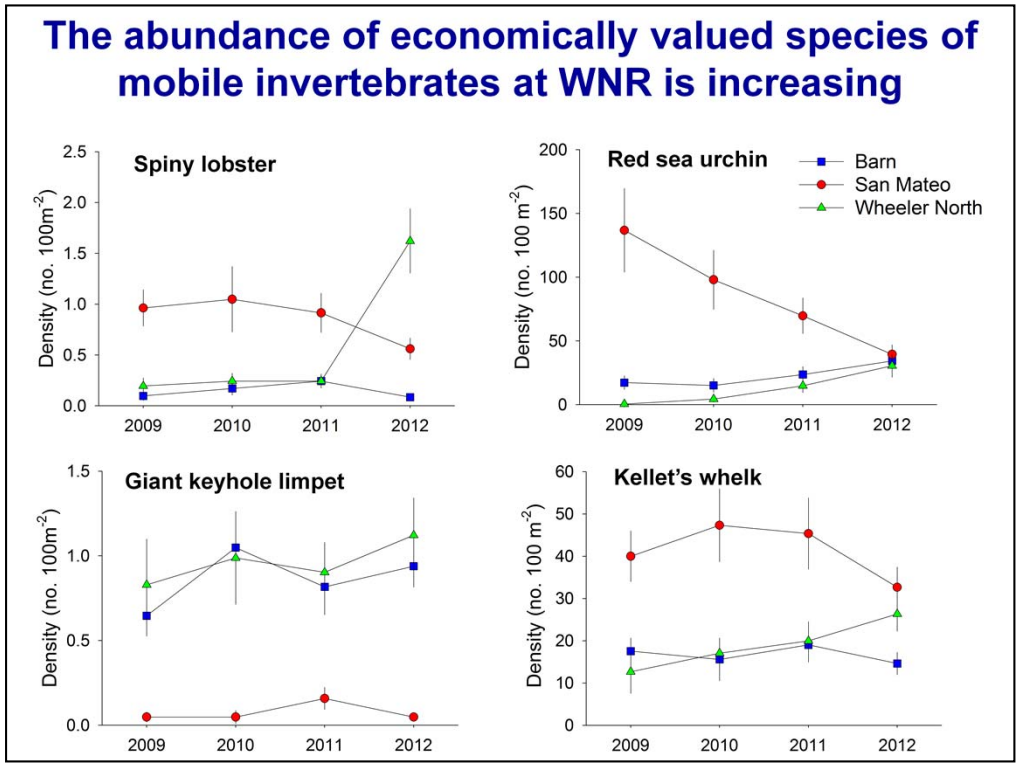
- Much like percent cover of sessile invertebrates the density of mobile invertebrate grazers and predators have also increased substantially at Wheeler North Reef during its first four years of existence.



- This increase in mobile invertebrates is due primarily to an increase in the dominant species which have largely stayed the same over the last 3 years.
- It stands to reason that the most abundant species on a reef are species that are relatively small, which is what we observed.
- The single most abundant species of mobile invertebrate at WNR is the spiny brittle star *Ophiothrix*, which by number accounts for about 80% of all mobile invertebrates on the reef.
- Brittle stars commonly inhabit the holdfasts of giant kelp and the increase in the percent cover of kelp holdfasts on WNR has led to a large increase in the density of brittle stars.
- Other abundant species that consistently round out the top five include hermit crabs and cone snails, Kellet's whelk.
- Purple sea urchins have been increasing in abundance at WNR and in 2012 they were the 5th most abundant species of mobile invertebrate at WNR.
- All of these species are relatively small in size.

Wheeler North Reef is providing habitat for economically valued species of mobile invertebrates

- The Wheeler North Reef is also providing habitat for larger species of mobile invertebrates that are economically valued.
- These include: spiny lobster, red sea urchins, giant key hole limpets and Kellet's whelk.



- Shown here are time series plots of the density of these four species at Wheeler North Reef.
- All 4 species have increased in abundance over time. Some like spiny lobster dramatically so.
- The density of lobster at WNR in 2012 was about 3x that at San Mateo and ~100 x higher than that at Barn.
- The high densities of lobster at WNR is attractive to commercial and recreational fishermen alike.
- Red sea urchins densities at WNR have tracked those at Barn, both have showed a steady increase over the last four years. In contrast red urchins have declined dramatically at San Mateo to densities in 2012 that were very similar to those at WNR and Barn.
- Giant keyhole limpets and Kellet's whelk have both shown modest increases in density on WNR over the last couple of years.

Kelp Bed Fishes

- The most mobile predators in the kelp forests are reef fishes, which come in a large variety of shapes and sizes ranging from small gobies that lie on the bottom and eat tiny shrimp to large fish-eating basses that can reach several feet in length and several hundred pounds in weight.

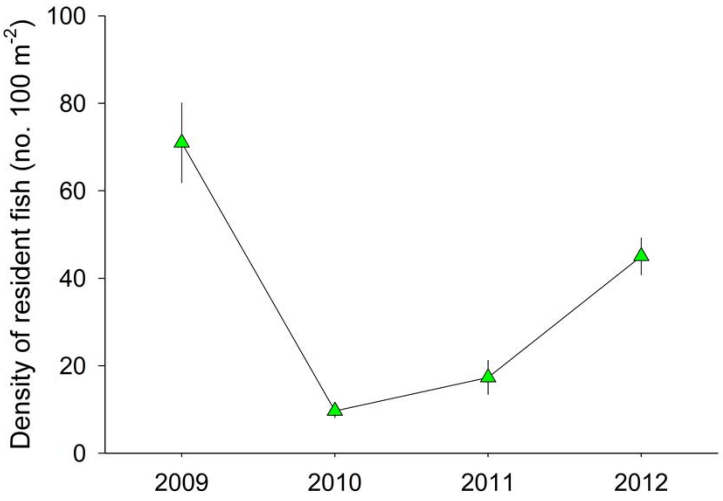
Kelp bed fishes rapidly colonized Wheeler North Reef

Larger (older) individuals migrated from natural reefs

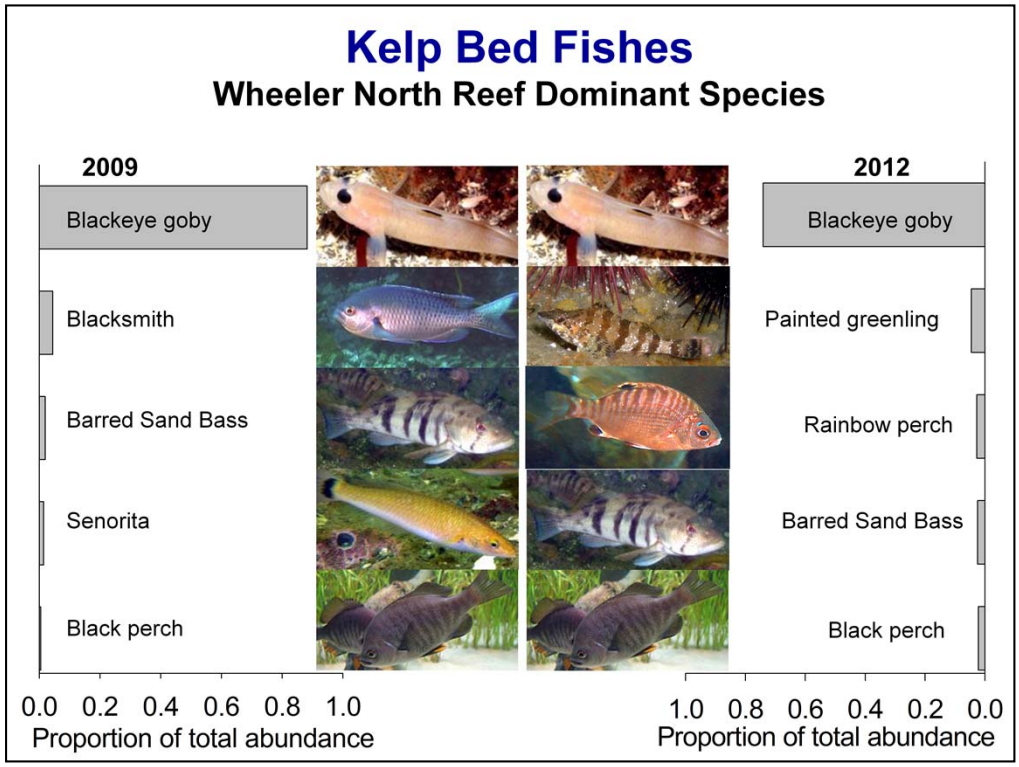
6 months post construction | 14 months post construction

- Kelp bed fish colonized the Wheeler North Reef almost immediately
- The photo on the left shows the Wheeler North Reef within 6 months of being constructed.
- The large fish in the foreground are barred sand bass that are about 16-20 inches in length, which makes them several years old.
- Similarly, the photo on the right taken 14 months after construction also shows fish of a number of species that are several years old.
- These larger older fish had to have migrated from natural reefs as adults.

The abundance of kelp bed fishes at Wheeler North Reef has varied greatly since 2009



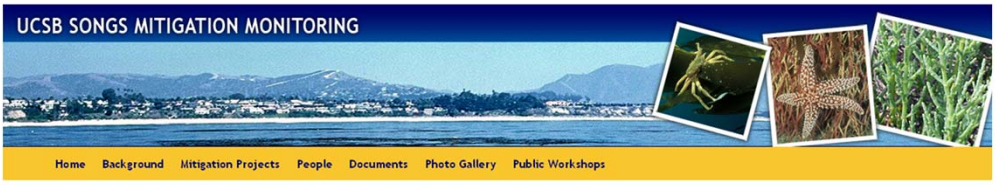
- The abundance of kelp bed fishes living near the bottom at WNR have fluctuated greatly over the last four years.
- Fish were most abundant in 2009, only one year after the reef was built.
- Densities declined precipitously in 2010 and have gradually increased since then.



- The fish assemblage has changed little at the Wheeler North Reef since 2009 in terms of the most numerically abundant species.
- The black eye goby, a small fish that lives on the bottom and feeds on small crustaceans has consistently been the most abundant species, accounting for 88% of the fish observed in 2009 and 74% of the fish in 2012.
- Other species that have been consistently abundant include:
    1. Barred sand bass, which is a large predatory species that feeds near the bottom on invertebrates and other fish,
    2. Black surfperch, which are considered “pickers” that feed on small invertebrates living on the bottom.
- Collectively, the top five species accounted for 96% of the fish observed at Wheeler North Reef in 2009 and 86 % in 2012.

Wheeler North Reef - Key Findings

- Within 1 year after construction there was rapid colonization by a complex suite of algae, invertebrates and fish
- Similar to the Phase 1 Experimental Reef, a dense kelp canopy formed on the Phase 2 Mitigation Reef within 2 years following construction
- The subsequent decline in understory algae and increase in sessile invertebrates on the Phase 2 Reef likely resulted from a dense surface canopy of giant kelp (a similar pattern occurred during Phase 1 and has been observed elsewhere on natural reefs)
- WNR is currently providing habitat for ecologically and economically important species



For more information go to: http://marinemitigation.msi.ucsb.edu/