Introduction and Overview

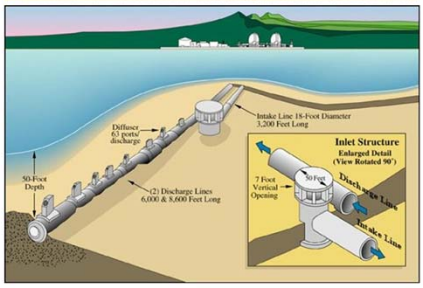
Annual Review Workshop for SONGS Reef Mitigation

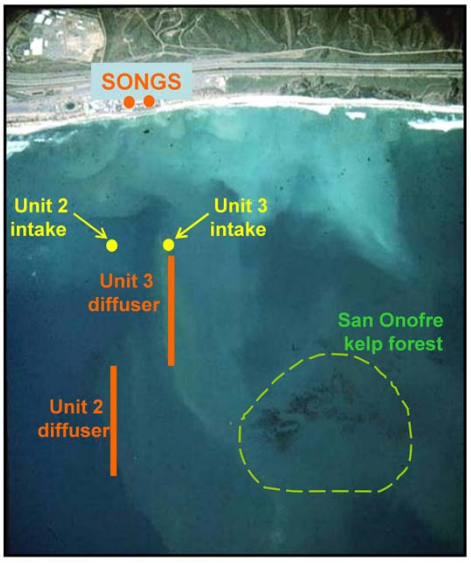
April 9, 2012

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

Coastal Mitigation Linked to the Effects of the SONGS Cooling Water System

(San Onofre Nuclear Generating Station = SONGS)





Some background on the project is important for understanding the purpose and rationale for the SONGS artificial reef mitigation project.

•The SONGS reactors are cooled by a single pass seawater system.

•Units 2 and 3 have separate intake lines that are located in about 30 feet of water offshore of the power plant

•The volume of water taken in each day by these two intake lines when Units 2 and 3 are operating together measures about a square mile 12 ft deep.

•The water is elevated 19 deg F above ambient in the plant and then discharged through an extensive diffuser system designed to dissipate the heat

•The performance of the diffuser system in dissipating the heat relies on entraining 10 times the volume of water that is taken in.

•Mixing caused by the diffuser system 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.

•SONGS impacts to living marine resources result from both the intakes and the discharge of this single pass cooling system.

Adverse Effects Attributed to SONGS Cooling Water System Include:

- **Losses of immature fish in the cooling water intake system are projected to cause substantial reductions in populations of adult fish in the S. California Bight**
- **In-plant losses of juvenile and adult fish led to reductions in the local abundance of mid-water fish populations in near vicinity of SONGS**
- **The discharge plume caused a substantial reduction in size of the kelp forest community at San Onofre that resulted in losses of kelp, fish, & invertebrates**

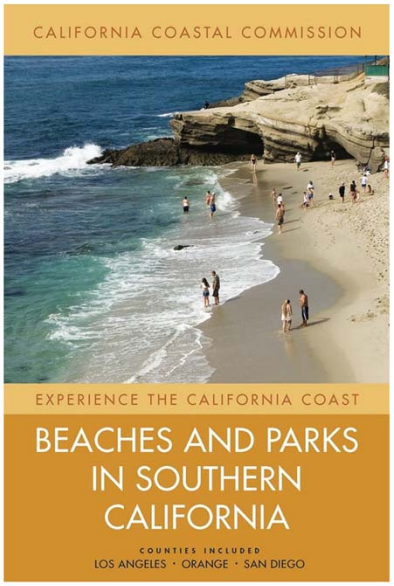
•After detailed studies the CCC concluded that the SONGS cooling water system for Units 2 and 3 had major adverse impacts to the coastal environment which included:

•Projected reductions in bight-wide populations of adult fish based on in-plant losses on immature fish.

•Measured reductions in local populations of adult fished caused by losses inside the power plant.

•A substantial reduction in the size of the giant kelp forest and associated community adjacent to the SONGS diffusers.

Adverse Impacts caused by SONGS is in violation of the California Coastal Act



California Coastal Act

- **Includes policies that address many coastal issues including "marine habitat protection"**
- **Enforcement resides with the California Coastal Commission (CCC)**
- **CCC is responsible for ensuring that the adverse impacts to the marine environment caused by SONGS are adequately mitigated**

•Adverse impacts caused by SONGS are in violation of the coastal act and thus requires 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.

Mitigation required by the CCC for the impacts caused by SONGS cooling water system includes four conditions:

Condition A: Wetland Mitigation

Out-of-kind mitigation to compensate for in-plant losses of immature fish.

Condition B: Behavioral Barriers Mitigation

In-kind mitigation to reduce in-plant losses of juvenile & adult fish.

Condition C: Kelp Reef Mitigation

In-kind mitigation to compensate for losses of kelp and kelp bed fish and invertebrates.

Condition D: Administrative Structure

Provides for scientific oversight and monitoring of mitigation projects that is independent of SCE.

- The CCC determined that the adverse marine impacts caused by SONGS operations could be adequately compensated for by a mitigation package that included 4 conditions.
- Wetland mitigation to compensate for the losses of immature fish inside the power plant.
- This condition is being met by a large wetland restoration project that is being carried out at San Dieguito Lagoon. A separate workshop will be done to discuss the progress and findings of this project.
- Modifications in plant operations that alter the behavior of fish to minimize losses of adult fish inside the power plant.
- The construction of an artificial reef to compensate for the adverse effects on the San Onofre kelp forest.
- Performance monitoring of the mitigation projects that is done independently of SCE.

Condition C: Kelp Reef Mitigation

Duties and Requirements

- **SCE to construct artificial reef that creates a minimum of 150 acres of kelp forest habitat**
- **CCC to provide scientific oversight and monitoring of the artificial reef project that is independent of SCE**

- SCE and the CCC have clear and distinct roles in the kelp reef mitigation.

Key Elements of the SONGS Artificial Reef Mitigation Project

Goal

In-kind compensation for the loss of kelp forest habitat and associated biota caused by the operation of SONGS 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

- It was decided that the goal of in-kind compensation for the marine resources lost due to SONGS operations will most likely be met if:
    1. The artificial reef is 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 is configured to look like the natural reef at San Onofre, which is a low relief boulder field.
- Determining whether the project goal is met will be 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.

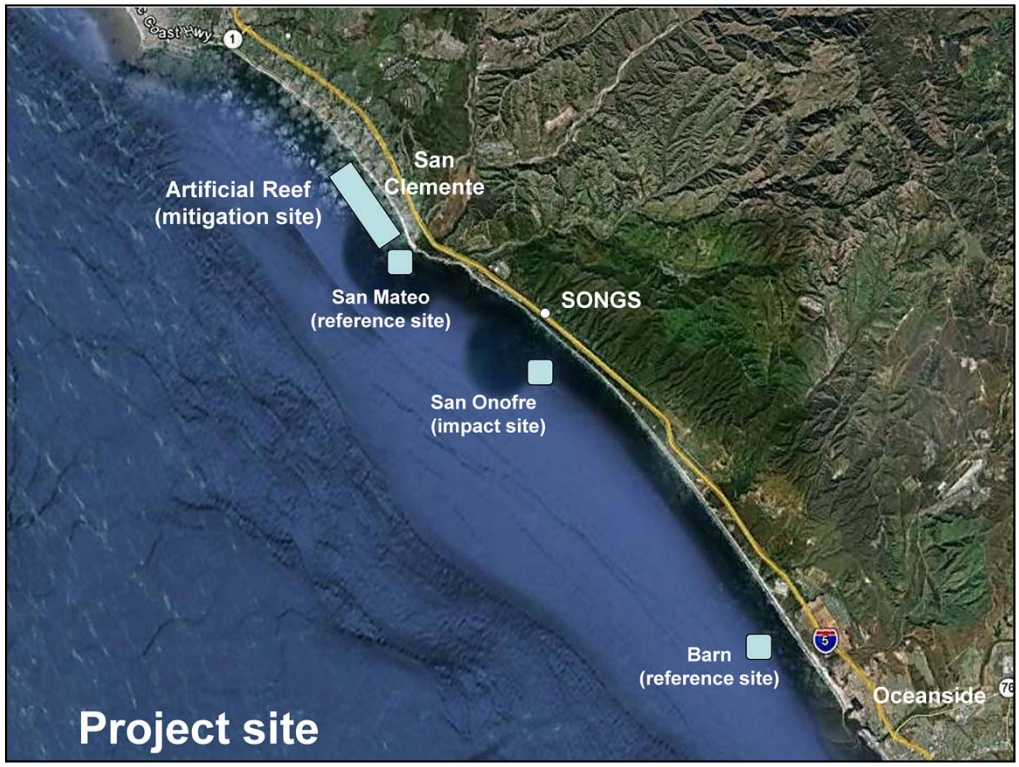
Kelp Forest Mitigation in Two Phases

Phase 1: Experimental Reef
Short-term, small scale to test different reef designs

Phase 2: Mitigation Reef
Long-term, large scale to compensate for resources lost due to SONGS operations

Information gained from the Experimental Reef used to design the 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.



• This map provides a general overview of the project site and shows the locations of the artificial reef and the nearby natural kelp beds

• San Onofre kelp bed located directly offshore of SONGS is the bed where the impacts occurred

• The San Mateo and Barn are the two natural kelp beds being used at reference sites to judge the performance of the Artificial Reef

Design of Phase 1 Experimental Reef

Constructed in summer 1999

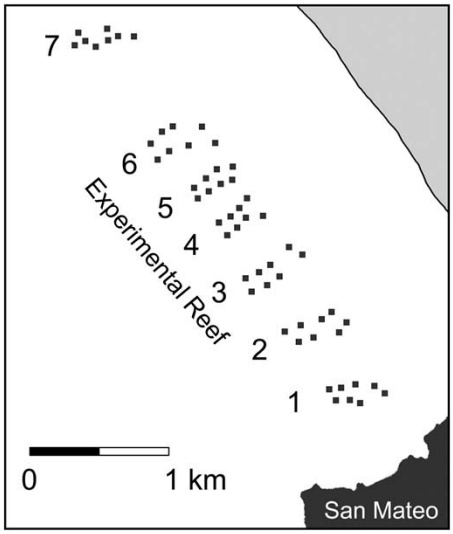
22.4 acres
- *56 uniformly sized modules*
- *Module size = 40 m x 40 m*

Two types of material
- *quarry rock boulders*
- *recycled concrete rubble*

Three bottom coverages
- *low (~40%)*
- *medium (~60%)*
- *high (~80%)*

Stratified block design
- *7 replicate blocks of 8 reef designs*

Duration of Experiment
- *5 years*



The experimental phase of the kelp reef mitigation began in 1999 and lasted for 5 years.

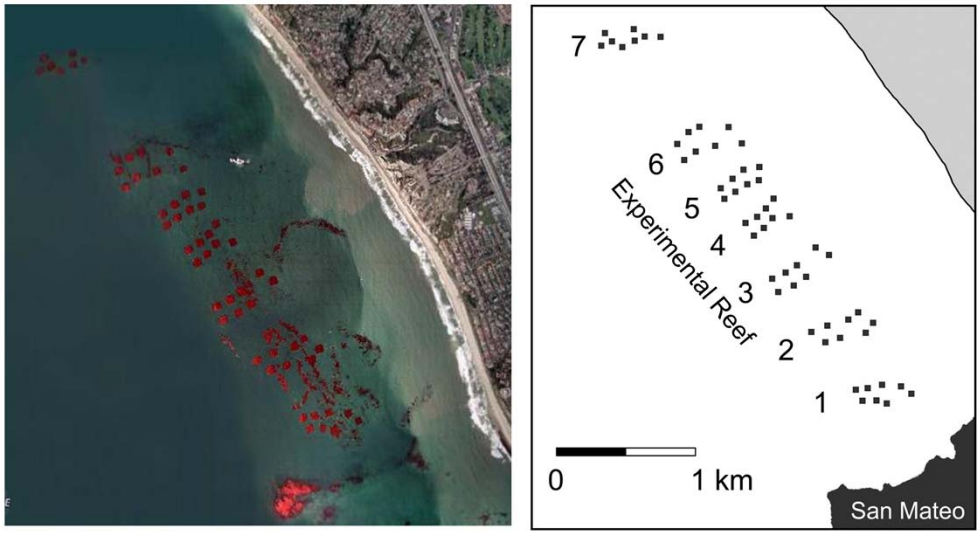
Data from annual monitoring of physical and biological reef attributes were used to evaluate the different reef designs

UCSB biologists made 8521 dives totaling 6058 hours underwater during the five-year Phase 1 study

- An intensive monitoring program was set up to collected data on various physical and biological attributes of the artificial reef and nearby natural reefs used for reference.
- Monitoring data were used to evaluate the different experimental reef designs with respect to their ability to meet predetermined performance standards established for Phase 2 Mitigation Reef
- UCSB scientists made 8521 dives (totaling 6058 hours underwater) on the artificial and natural reference reefs during the 5-year Phase 1 study

The experimental reef modules were rapidly colonized by algae, invertebrates and fish and provided habitat for abundant marine life.

Google image (left) showing the surface canopy of giant kelp (in red) on the 56 experimental reef modules in 2003. Illustration (right) shown for reference.

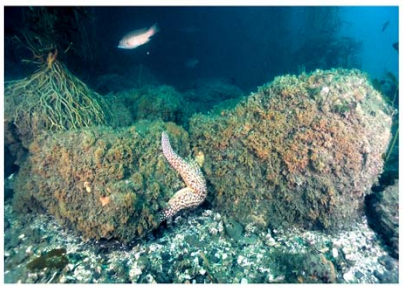


A dense surface canopy of the giant kelp *Macrocystis pyrifera* became established on all 56 artificial reef modules within 2 years of construction.

Conclusions from 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

Final Report on the Findings and Recommendations of the Experimental Phase of the SONGS Artificial Reef Mitigation Project



PREPARED FOR THE CALIFORNIA COASTAL COMMISSION
AUGUST 1, 2005

Dan Reed, Steve Schroeter, and David Huang
Marine Science Institute
University of California, Santa Barbara

Recommendations for the Mitigation Reef

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

Reef Topogragphy
- **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 leas 42% but no more than 86% of the bottom.

Design of Phase 2 Mitigation Reef

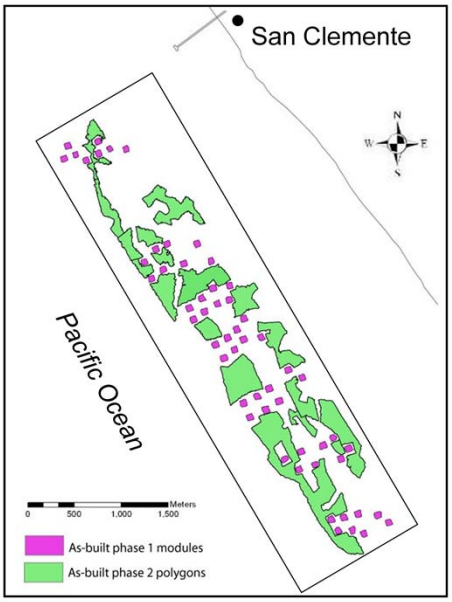
Constructed in Summer 2008

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 < 1 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.

1.Rock boulders of the desired size were stockpiled at the quarry and then trucked down to the loading pad.

2.Boulders were loaded by crane onto a barge, which was then towed across the Channel to the mitigation site off San Clemente.

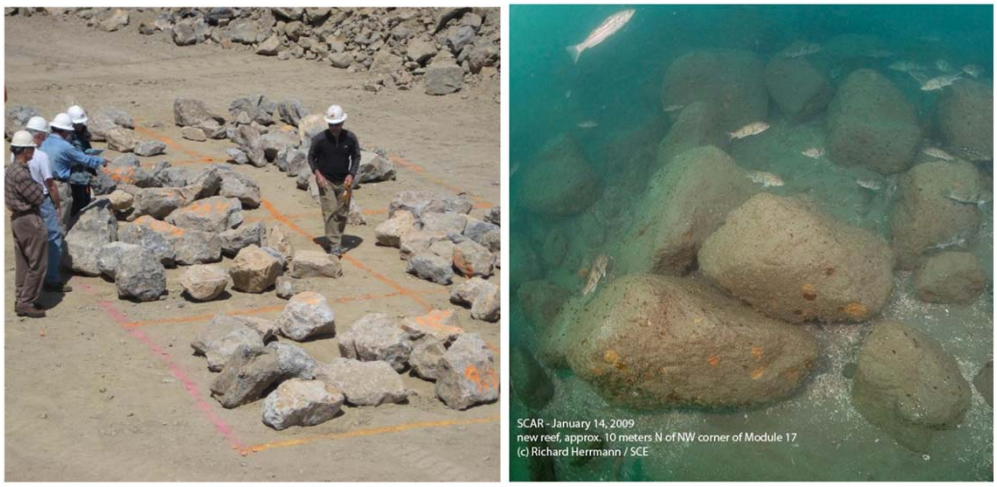
3.The rock barge was tied alongside a derrick barge, which served as the control point for the construction.

4.GPS on the derrick barge was used to maneuver the rock barge into position within an accuracy of 6 feet.

5.Once in position rocks were systematically dumped over the side of the barge by a skip loader.

6.Approximately 126,000 tons of rock were deployed in this manner over a 94 day period between June and August 2008.

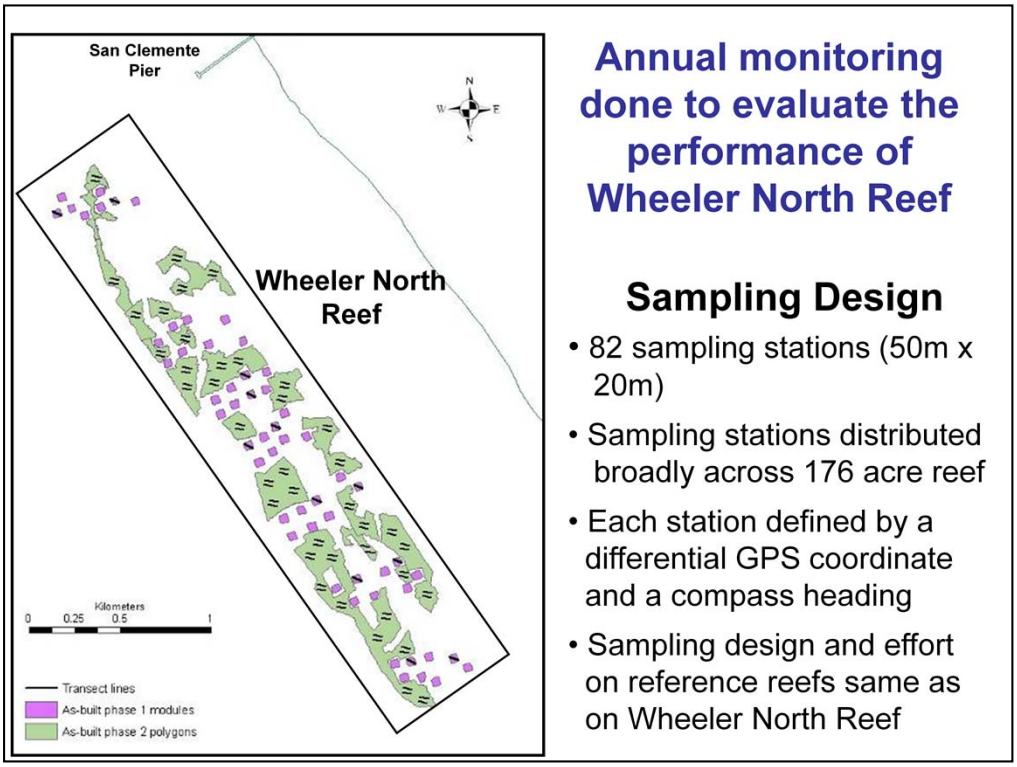
Quarry rock was distributed in a single layer to form a low-relief boulder reef



•Rock was distributed in a single layer on the bottom to form a low-relief boulder reef that was designed to mimic the natural reefs in the area.

•The photo on the left was taken at the quarry and was a demonstration to show the sizes of rock that would be used to build the Wheeler North Reef and how they would be distributed on the bottom to attain the desired coverage of 42 %.

•The photo on the right shows what the distribution of rocks on the Wheeler North Reef looked like ~ 5 months after it was built.

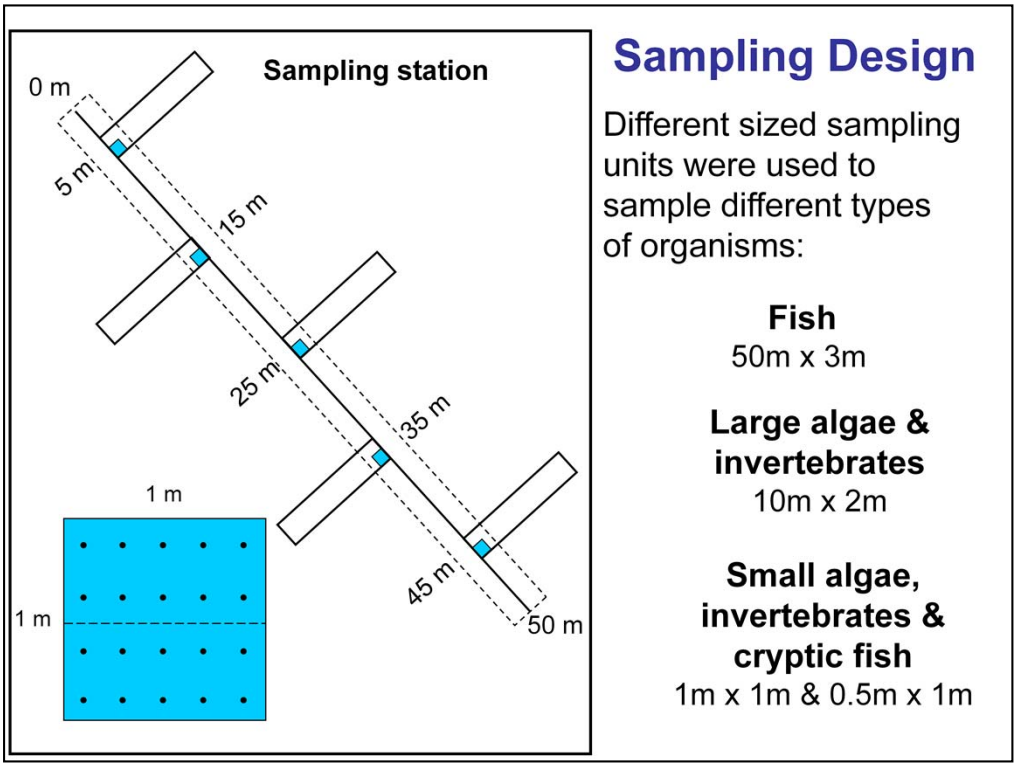


•This diagram summarizes the sampling design for the monitoring and shows the distribution of sampling stations on the Wheeler North Reef.

•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 sustain populations 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

•The recruitment of giant kelp in 2009 was observed across the entire Wheeler North Reef.

•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.

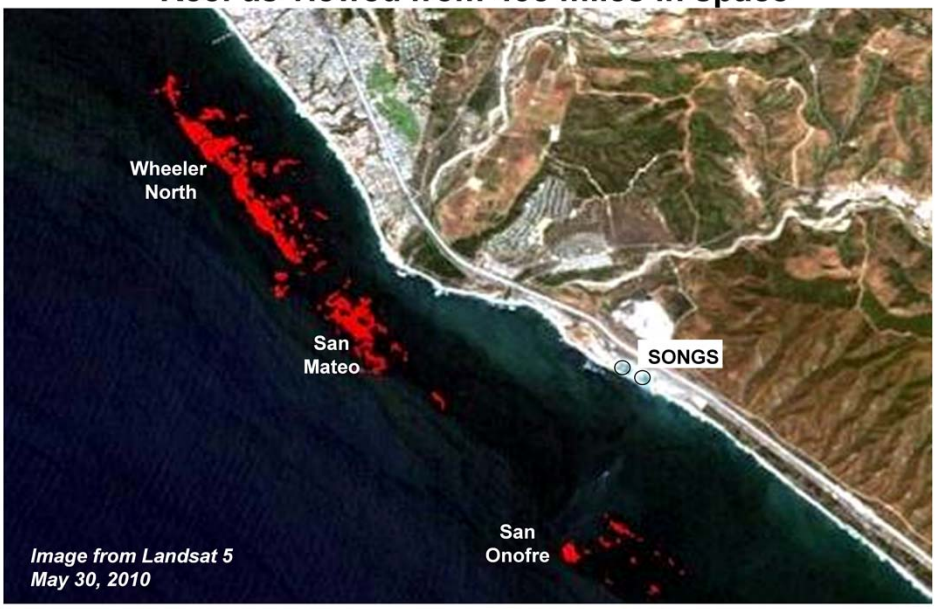
Giant kelp

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

- Young small plants that colonized the Wheeler North Reef in 2009 rapidly grew into large adult plants and by 2010 giant kelp formed a dense canopy at the sea surface over the entire reef.
- The open channels between kelp patches were a design feature that allowed for boats to more easily navigate the reef

Giant kelp

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



- This is a image taken from the Landsat satellite in May of 2010. The red in the image is a false color representation of the surface canopy of giant kelp.
- The image shows the large extent of giant kelp on the Wheeler North and San Mateo Reefs.
- This is in contrast to the rather small canopy of kelp at San Onofre, which is the kelp bed impacted by SONGS operation.

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.

•They marine “plants” capture sunlight as energy for photosynthesis and are important primary producers in kelp forest.

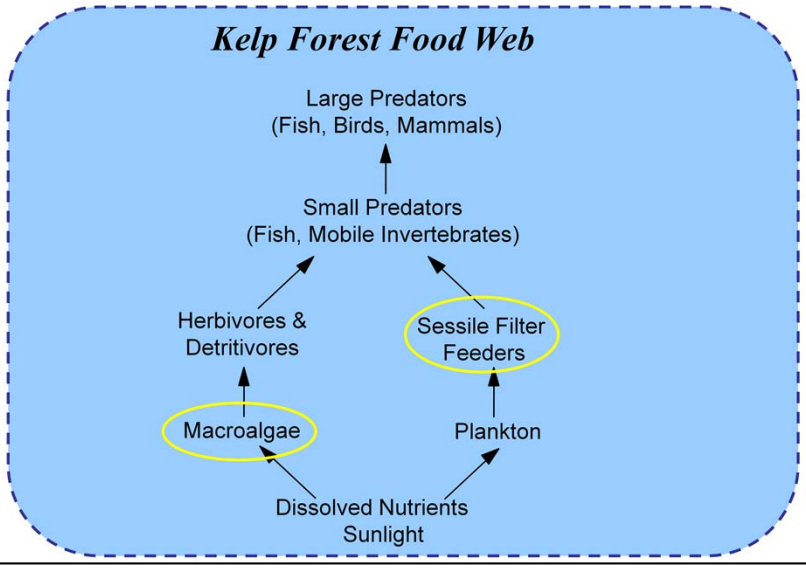
•Because they occur beneath the canopy of giant kelp they are often referred to as understory algae.

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.

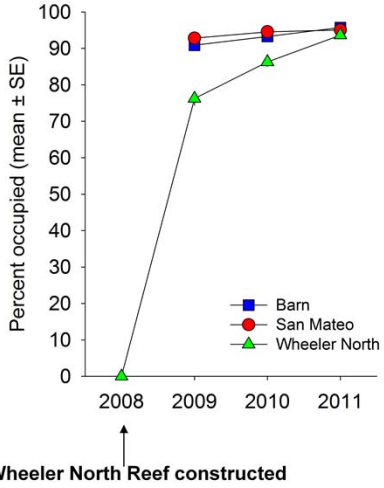
Understory algae and sessile invertebrates are an important food source for mobile herbivores and predators in the kelp forest



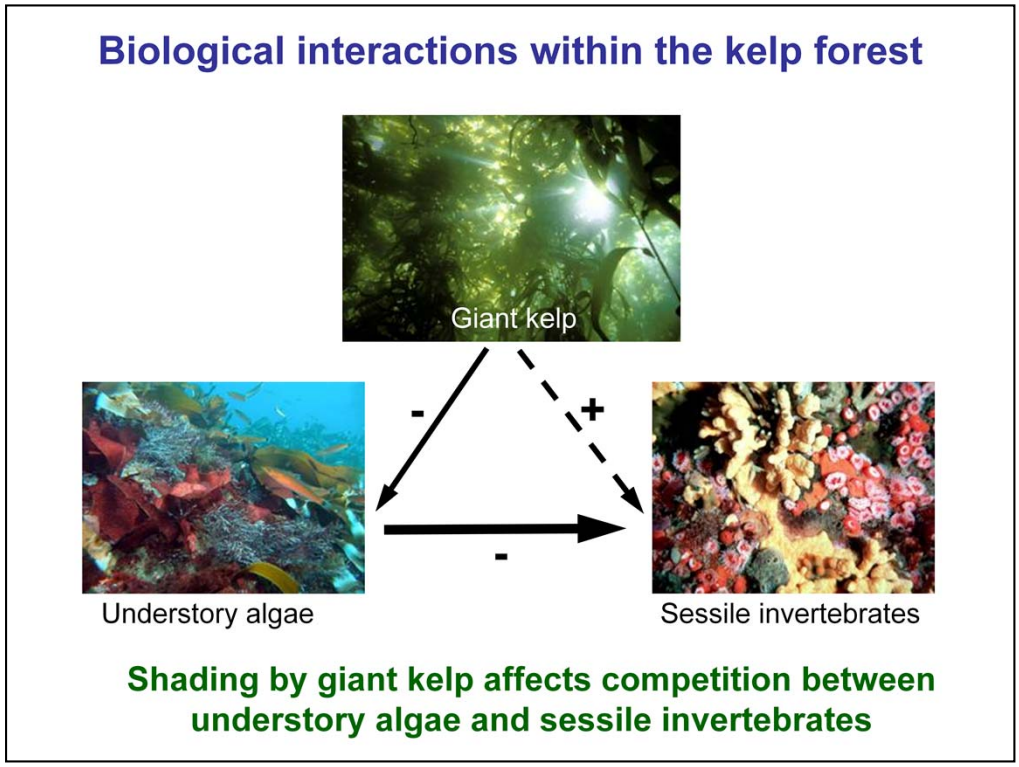
Understory algae and sessile filter feeders serve as important sources of food for mobile invertebrates and fish that comprise the higher tropic levels of the kelp forest food web.

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 on 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 it is rapidly approaching 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.

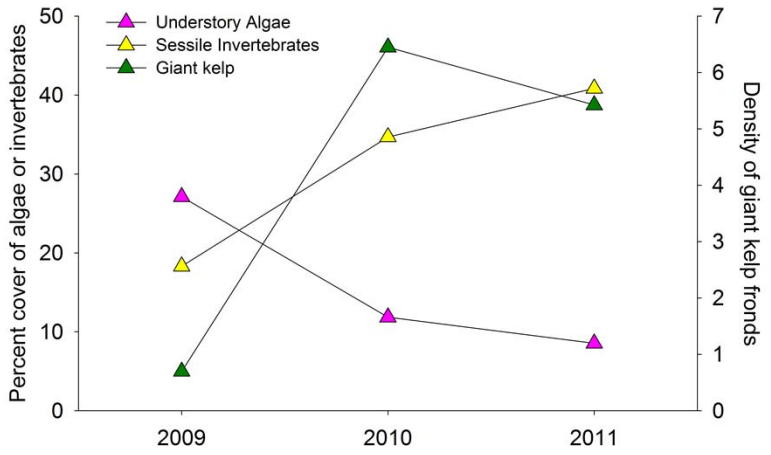
•The surface canopy of giant kelp significantly reduces the amount of light reaching the bottom, and thus has a negative effect on understory algae, which require light to grow.

•In doing so giant kelp has a 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.

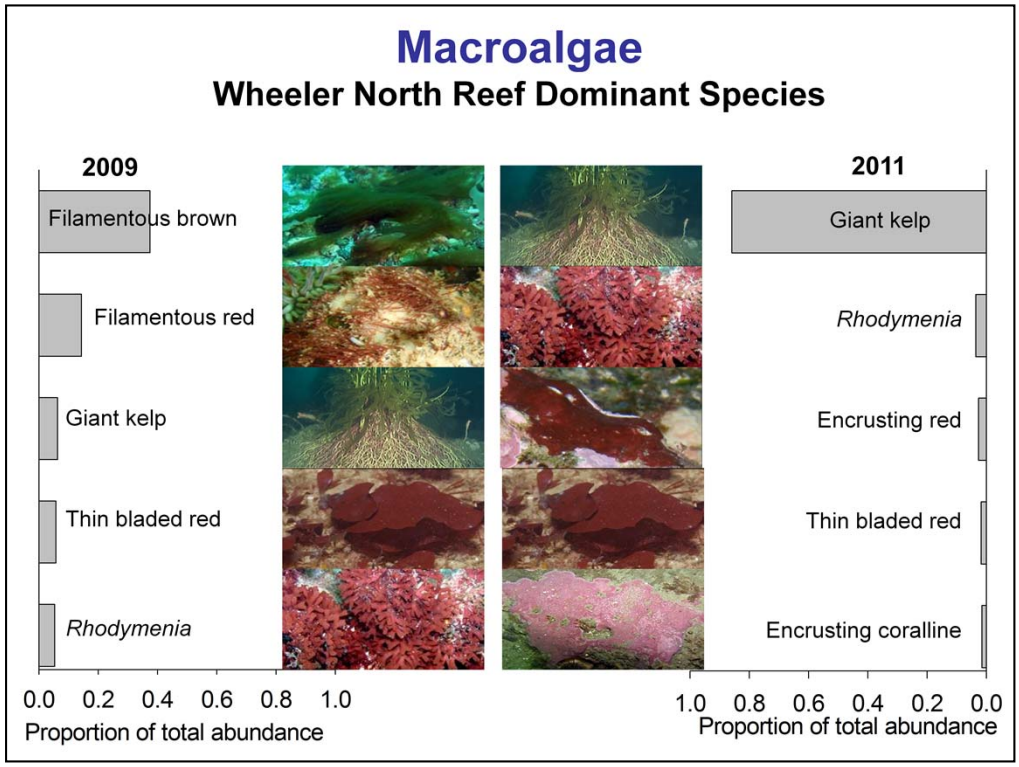
•Understory algae are favored in the absence of giant kelp, while invertebrates are favored in the presence or giant kelp.

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

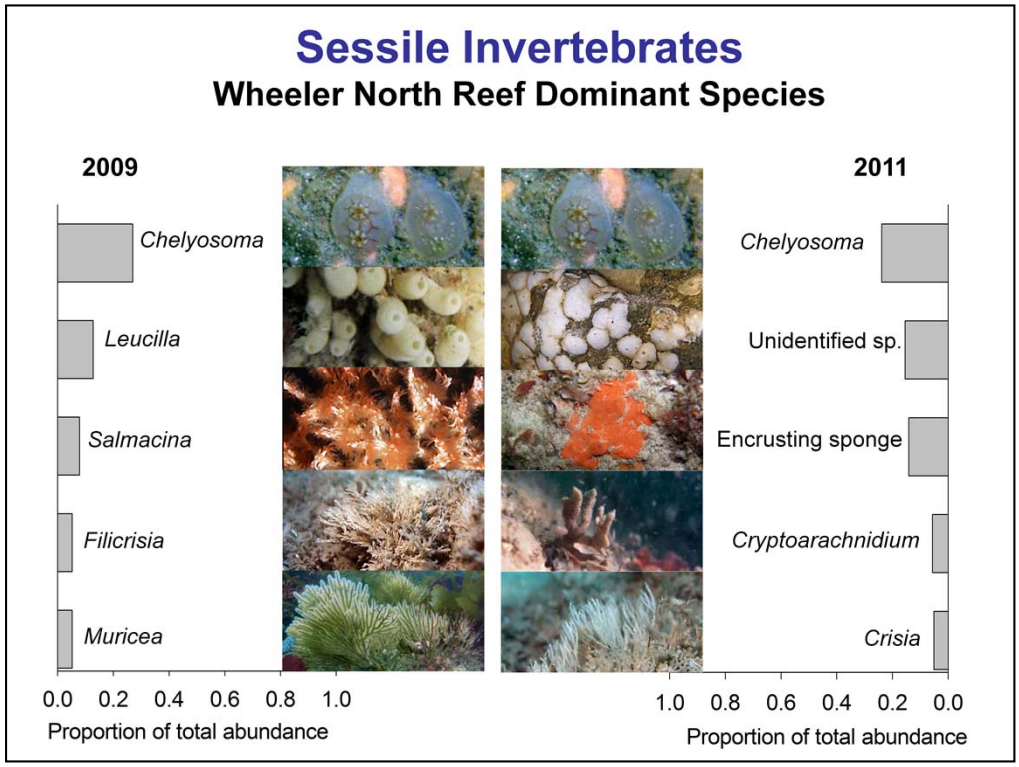


The increase in giant kelp in 2010 was accompanied by a decrease in understory algae and an increase in sessile invertebrates

- Results from the first 3 years 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.



- Not only did the percent cover of algae decline from 2009 to 2010, but it also change 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 comprised 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 2011 the when the overall cover of algae declined to about 8% of the bottom, short lived filamentous species had disappeared and the holdfasts of giant kelp accounted for 86 % of all algal cover.
- Rhodymenia, thin bladed red algae and several encrusting forms accounted for another 10 % of the algae.
- Collectively these five taxa accounted for 95% of all algae observed in 2011.

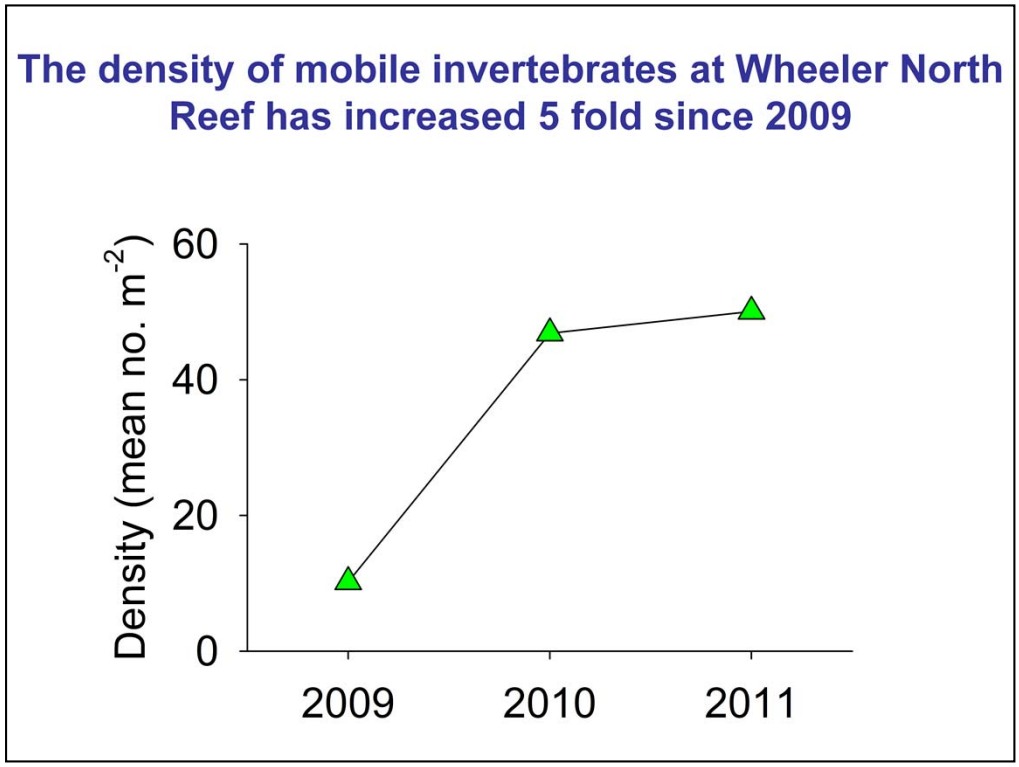


- In both 2009 and 2011 the most abundant sessile invertebrate on Wheeler North Reef was the tunicate or sea squirt *Chelyosoma* which accounted for 20-25 % of the cover of all sessile invertebrates in both years.
- The white sponge *Lucilla*, the red tube building worm *Salmacina*, branching bryozoan *Filicrisia* and the sea fan *Muricea* were the next abundant species in 2009 and collectively accounted for an additional 30 % of the invertebrate cover.
- In 2011 a white encrusting species that we have not yet identified showed up on Wheeler North Reef and accounted for 15% of the invertebrate cover.
- 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.
- The top 5 species accounted for 57% of the cover in 2009 and 62 % in 2011.

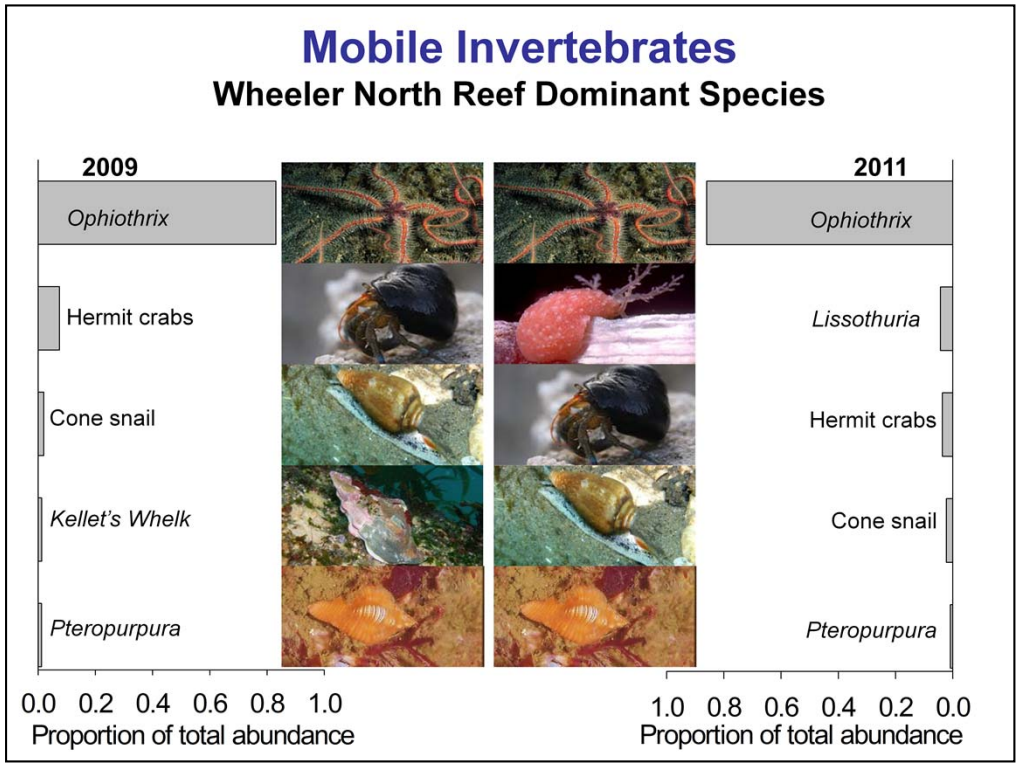
Mobile Invertebrates

•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.



- 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 three years of existence.



- This increase has been due primarily to an increase in the dominant species which have largely stayed the same over the last 3 years.
- The single most abundant species of mobile invertebrate is the spiny brittle star *Ophiothrix*, which by number accounts for about 80% of all mobile invertebrates on the reef.
- Other abundant species that round out the top five include hermit crabs, cone snails, Kellet's whelk, the small red sea cumber *Lissothuria*, and the predatory whelk *Pteropurpura* .
- All of these species are relatively small in size

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

Larger individuals of slower growing species likely migrated from nearby reefs

- The Wheeler North Reef is also providing habitat for larger species of mobile invertebrates that are economically valued.
- Most of these species are slower growing and the large sizes of many that have been observed suggest that they likely migrated to Wheeler North Reef from natural reefs in the area.

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

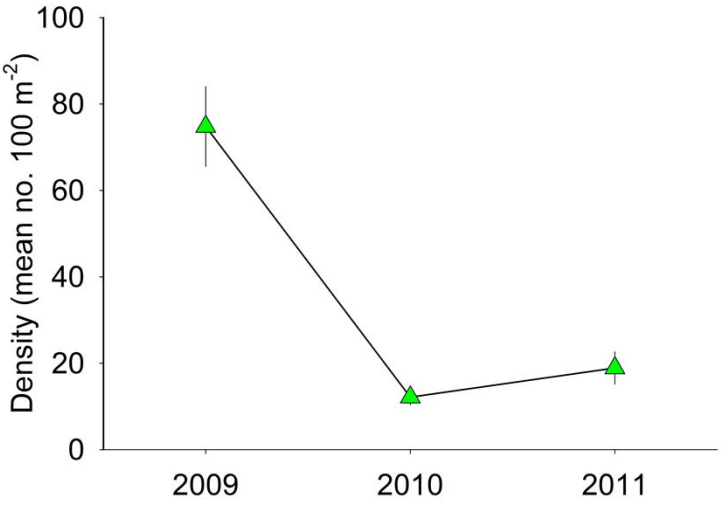
Larger (older) individuals migrated from natural reefs

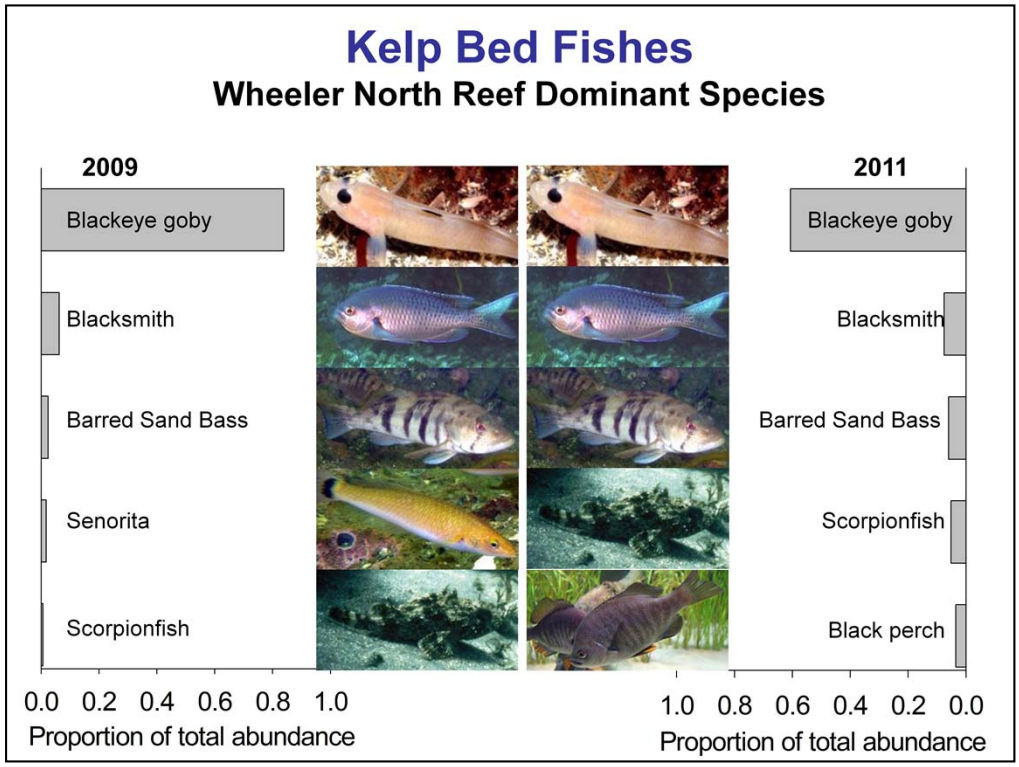
6 months post construction

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 density of kelp bed fish at Wheeler North Reef has decreased 4 fold since 2009





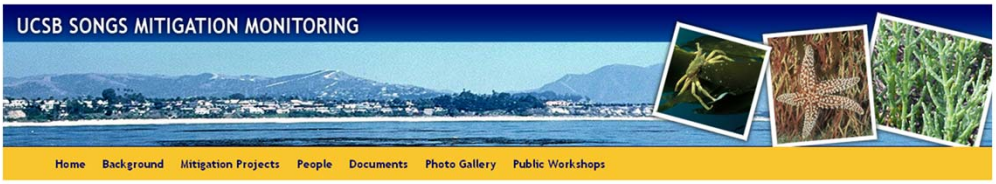
- The fish assemblage has changed little on the Wheeler North Reef since 2009 in terms of the most numerically abundant species.
- The black eye goby, a small fish that lives on the bottom and feeds on small crustaceans has consistently been the most abundant species.
- Other abundant species include:
    - Blacksmith, which spends most of its time in the water column eating plankton,
    - Barred sand bass and scorpionfish, large predatory species that feeds near the bottom on invertebrates and other fish,
    - Senorita and black perch, which are considered “pickers” that feed on small invertebrates
- Collectively these species accounted for 96% of the fish observed on Wheeler North Reef in 2009 and 83 % in 2011.

Wheeler North Reef is providing habitat for economically and ecologically valued species of kelp bed fish

- Large predatory species of fish that valued both economically and ecologically are also common on Wheeler North Reef.
- This includes the California halibut, California sheephead and kelp bass that are important to commercial and recreational fisheries, and the giant sea bass, which is a protected species.
- Giant sea bass can reach lengths of 5 feet and weigh over 500 pounds.
- The photo of a giant sea bass show here was taken of a large individual during one of our fish surveys
- They are a top predator in the kelp forest and were extensively fished to near extinction, but are making a comeback due to their protected status

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/**