

Status of the Wheeler North Reef 2010 Monitoring Results



Wheeler North Reef, July 2010

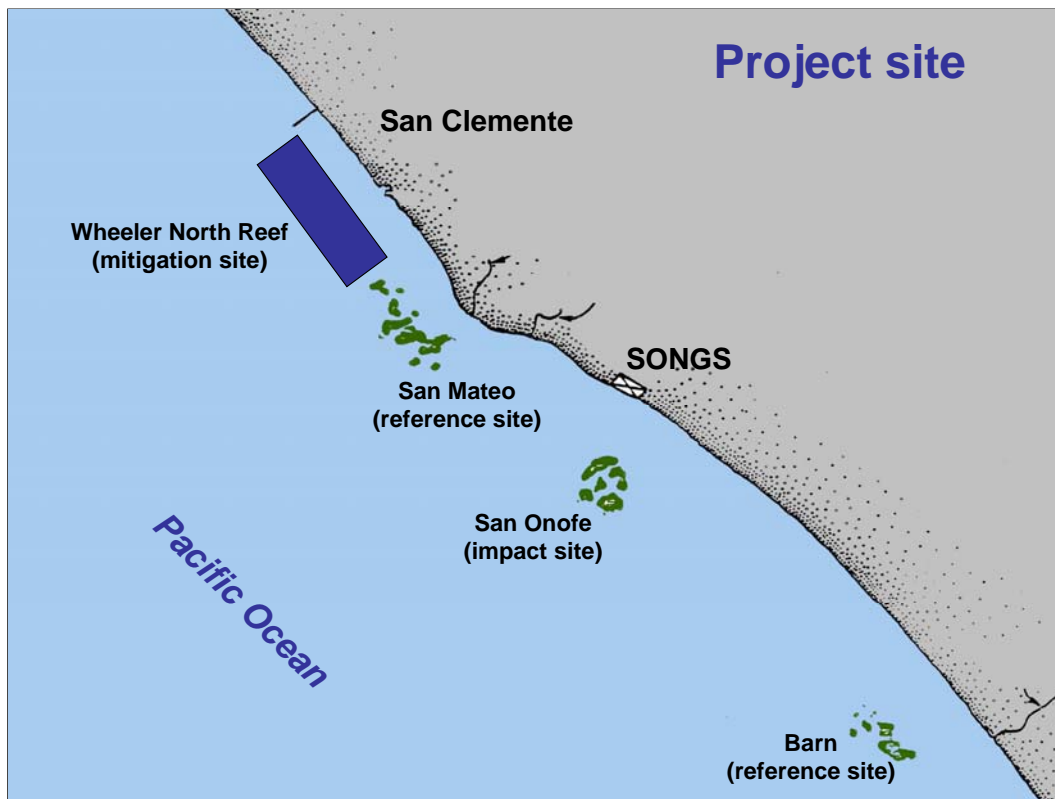
**SONGS Mitigation Monitoring Project
Marine Science Institute, University of California Santa Barbara**

- This presentation provides a status update on the Wheeler North Reef and the two reference reefs over the past two years.

Outline

- **Project location**
- **Reef construction**
- **Sampling design**
- **Monitoring results from 2009 and 2010**

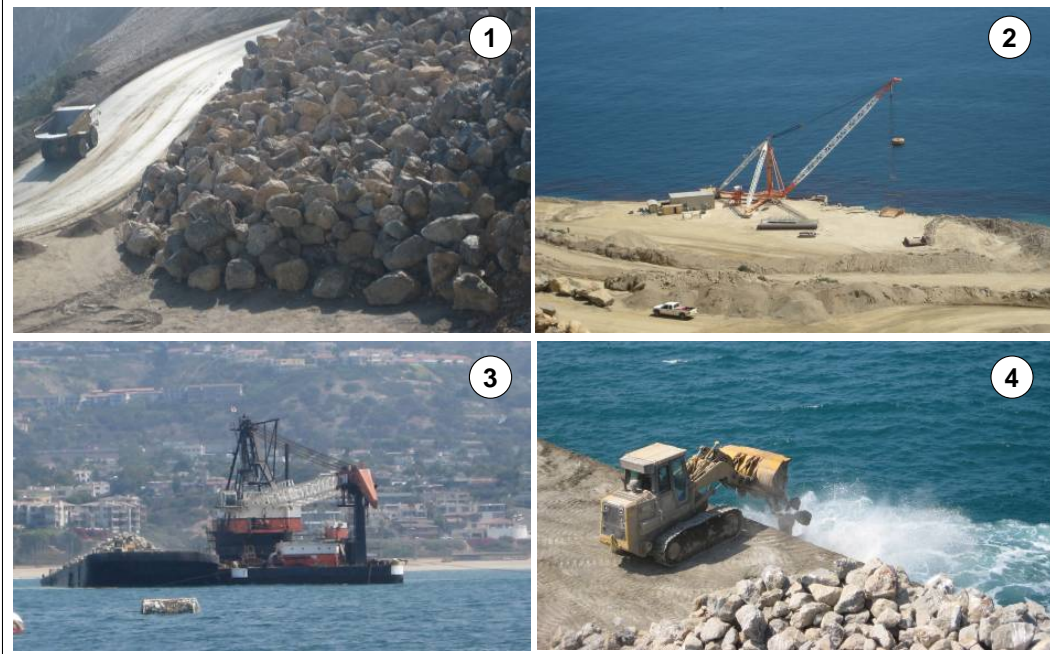
• In this presentation we briefly describe the location and construction of the Wheeler North Reef, the sampling design that we use to monitor it, and the results of our monitoring in 2009 and 2010 that show how the kelp forest community is developing on the Wheeler North Reef relative to natural reefs in the area.



This slide shows the location of the mitigation site where the Wheeler North Reef is located in relation to:

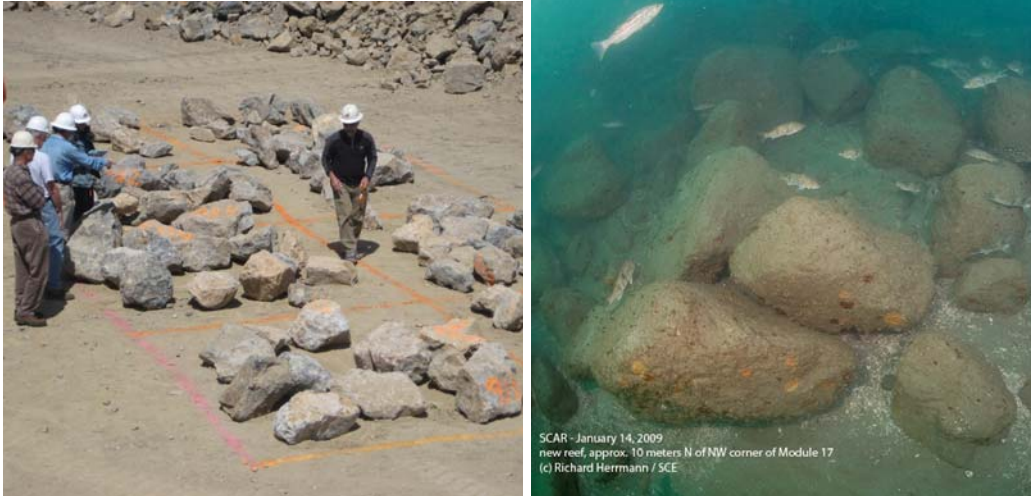
- the city of San Clemente,
- the kelp bed off San Onofre that is being damaged by the San Onofre Nuclear Generating Station, and
- the nearby natural kelp beds at San Mateo and Barn, which are used as reference sites.

Quarry rock primarily from Catalina Island was used to construct the Wheeler North Reef

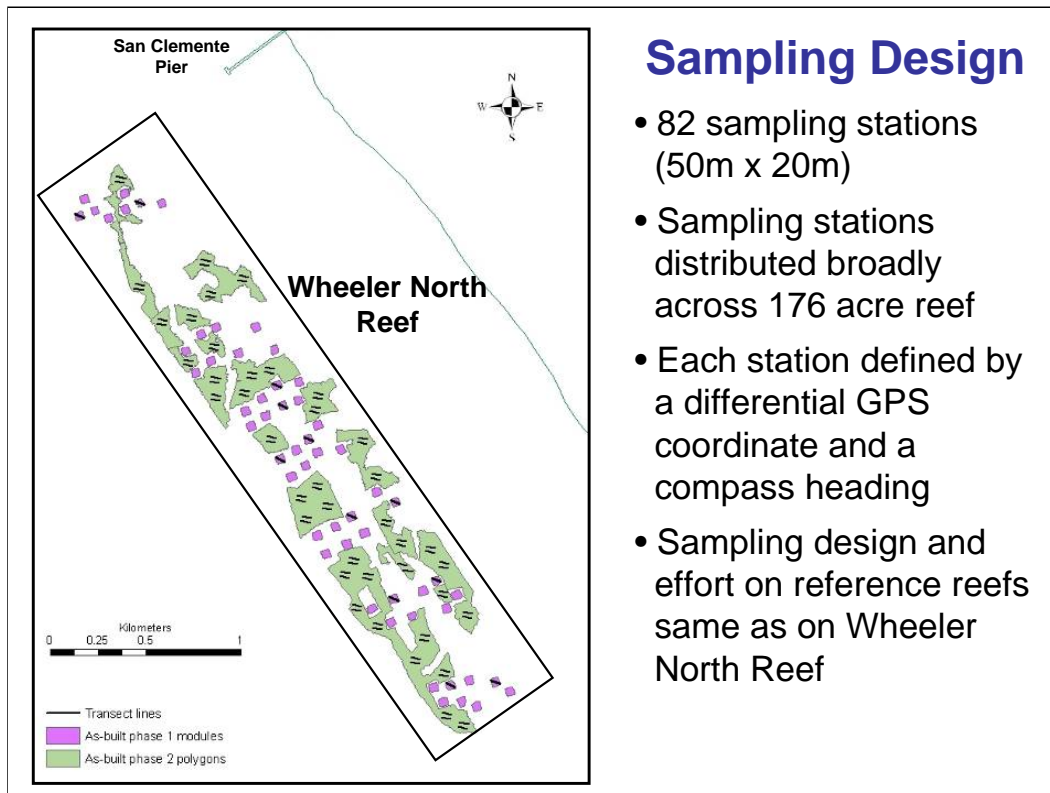


1. Rock boulders of the desired size were stockpiled at the quarry and then trucked down to the loading pad.
2. Boulders were loaded by crane onto a barge, which was then towed across the Channel to the mitigation site off San Clemente.
3. The rock barge was tied alongside a derrick barge, which served 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.

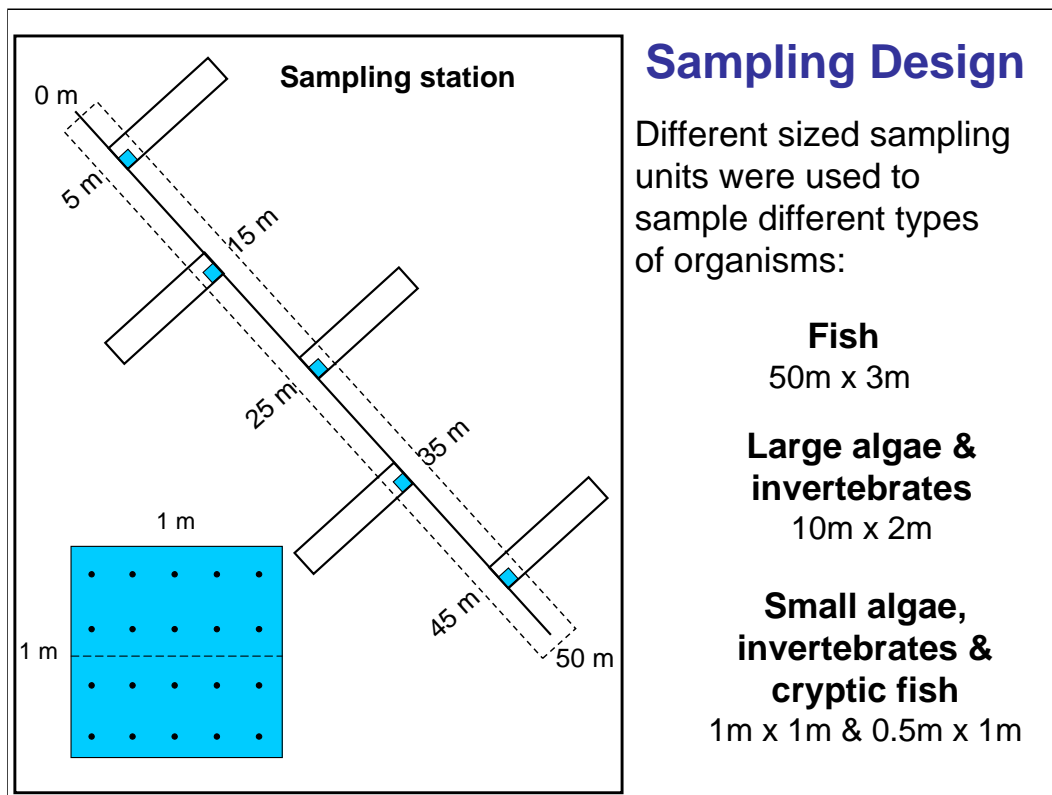
Quarry rock was distributed in a single layer to form a low-relief boulder reef



- 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.



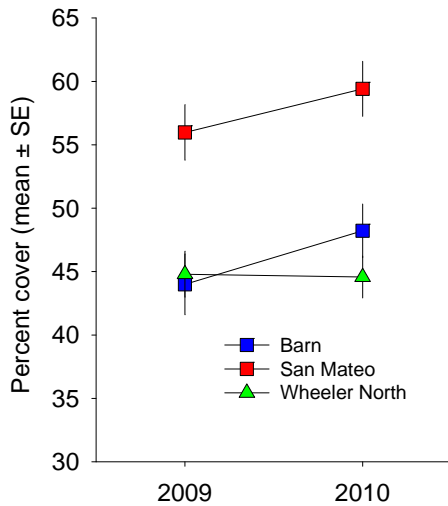
- This slide summarizes the sampling design for the monitoring and shows the distribution of sampling stations on the Wheeler North Reef.
- The experimental Phase 1 modules constructed in 1999 are shown in purple; the new Phase 2 polygons constructed in 2008 are shown in green, together these constitute 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 slide 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.

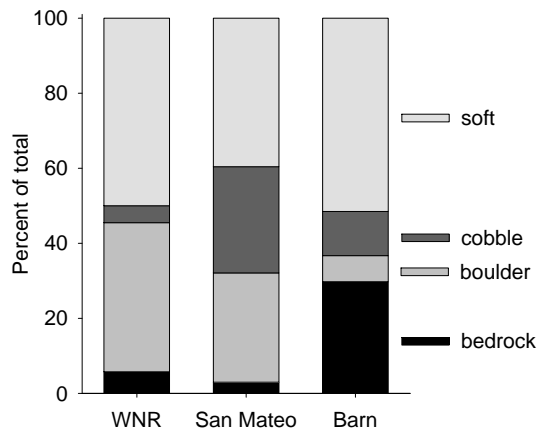
HARD SUBSTRATE

Percent of bottom covered by rock



- Exposed hard reef substrate is necessary for the establishment and persistence of giant kelp and other reef biota.
- Knowledge about its amount and persistence is essential to understanding how the Wheeler North Reef will function over the long term.
- Shown in this graph are data on the percent of the sea floor covered by rock on the Wheeler North Reef and nearby reefs at Barn and San Mateo.
- The vertical lines running through the symbols represent the standard error of the mean, which gives an indication of the variability in the data around the average.
- The general format of this graph in which the means and standard errors for Barn in blue, San Mateo in red and Wheeler North Reef in green is used for the subsequent graphs that follow.
- In 2009 the % cover of rock on Wheeler North Reef was about 43%, which was similar to that at Barn and less than that at San Mateo.
- The percent cover of rock on the bottom can decline as a result of sedimentation and burial, or increase due to scour caused by waves.
- Between the period 2009-2010 we saw about a 10% increase in the cover of rock at San Mateo and Barn, whereas the cover of rock at Wheeler North Reef remained relatively constant.

BOTTOM SUBSTRATE COMPOSITION



- This graph shows the relative amounts of the different types of substrates on Wheeler North Reef, San Mateo and Barn.
- Not surprising the hard substrate on Wheeler North Reef is mostly boulder, which is what was produced at the quarry.
- San Mateo is the most similar to Wheeler North Reef in that it has little bedrock and is mostly boulder and cobble, whereas most of the hard substrate at Barn is bedrock.

GIANT KELP

- **World's largest alga**
- **Young small plants grow rapidly (up to 18 inches per day) into large adult plants that extend throughout the water column to produce a floating canopy at the sea surface**
- **Considered a foundation species because it provides food and shelter for wide diversity of plants and animals that inhabit the kelp forest**



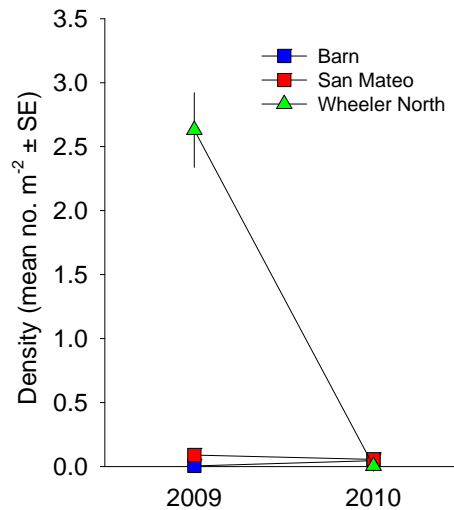
Giant kelp *Macrocystis pyrifera*

- 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



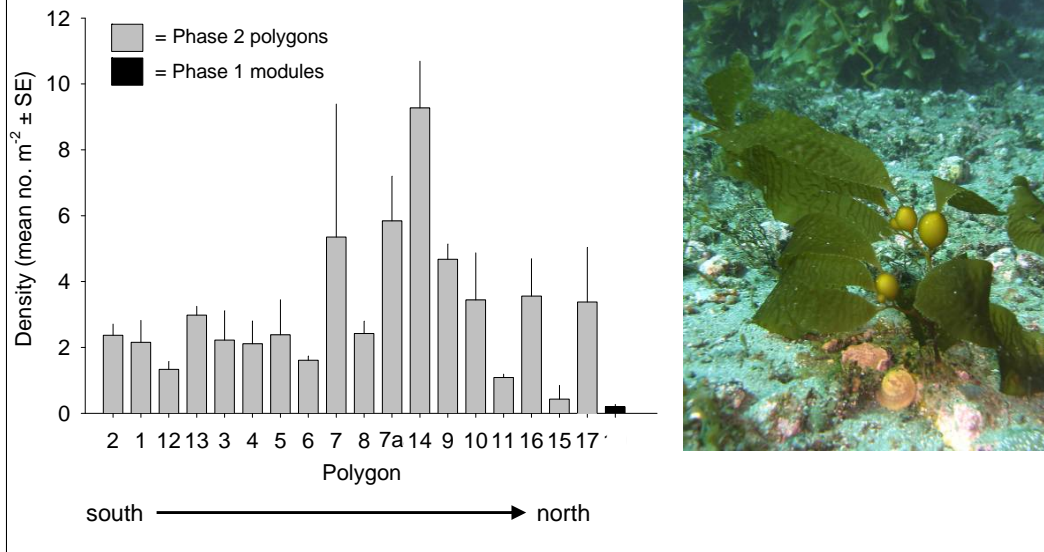
New Plants (recruits)



- Results from the Phase 1 reef indicated that giant kelp would readily colonize the newly constructed Phase 2 Reef and that transplanting kelp would not be needed to insure it became established.
- We found this to be true. Plotted here is the average density of small young kelp (typically referred to as recruits).
- In the first year following construction (2009) we observed very high densities of giant kelp recruits on the Wheeler North Reef.
- In contrast there were very few kelp recruits on the natural reefs, which mostly likely reflected the presence of adult kelp inhibiting the establishment of young kelp due to shading by the adult canopy.
- This past year 2010, kelp recruitment on the Wheeler North Reef dropped considerably to levels observed on San Mateo and Barn.
- This decrease in new plants observed in 2010 was expected as young plants grow up to shade out new plants in subsequent years.

GIANT KELP

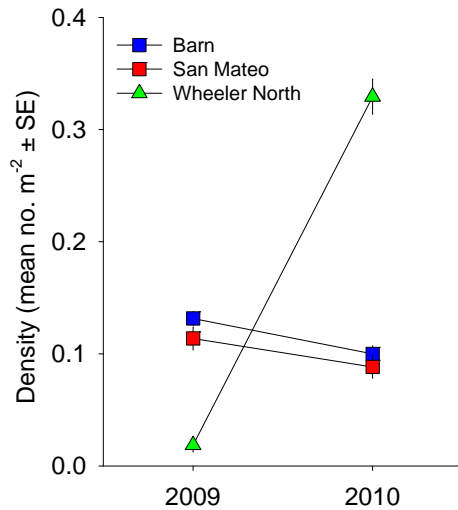
Distribution of new recruits on Wheeler North Reef in 2009



- The recruitment of giant kelp in 2009 was observed across the entire Wheeler North Reef.
- This graph shows the mean number of kelp recruits on the newly constructed polygons which are arranged from south to north going from left to right on the graph.
- The black bar is the average number of recruits on the Phase 1 modules, which were constructed 10 years prior to this sampling.
- The graph shows that all of the newly constructed polygons were colonized by giant kelp regardless of location, and that kelp recruitment was lowest on the experimental modules where adult kelp was already established.

GIANT KELP

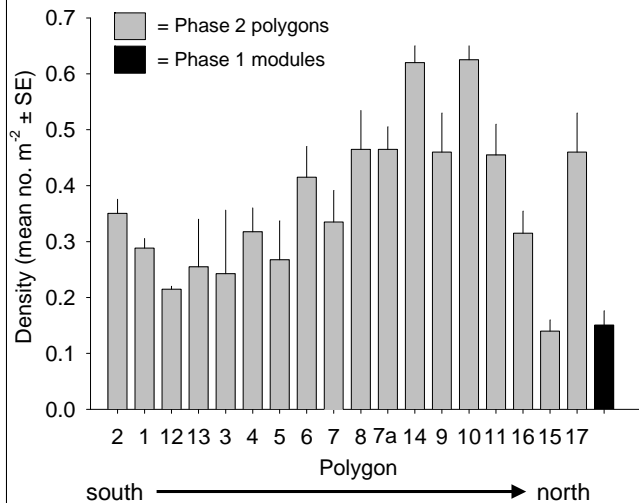
Older large plants



- This graph shows the density of older large kelp plants that are greater than 1 year old.
- The large recruitment event on Wheeler North Reef in 2009 led to a large cohort of older plants in 2010.
- The average density of older kelp on Wheeler North Reef was about 3 times that observed at San Mateo and Barn, which in contrast to Wheeler North Reef showed a slight decline in the density of older kelp from 2009-2010.

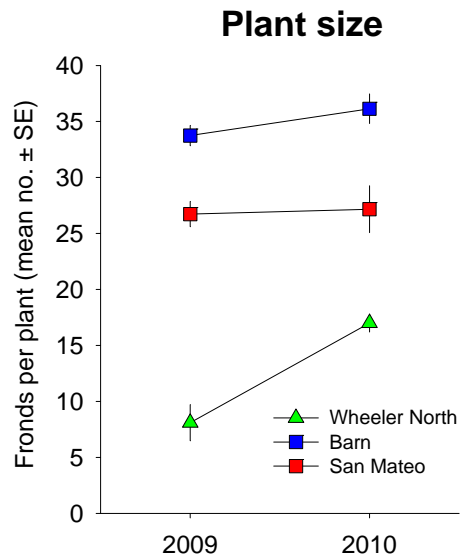
GIANT KELP

Distribution of older large plants on Wheeler North Reef in 2010



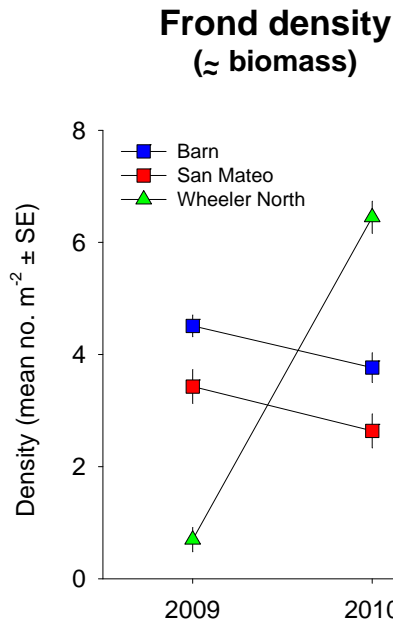
- The distribution of older kelp on Wheeler North Reef in 2010 followed that of kelp recruitment in 2009.
- High densities of older kelp were observed on all of the Phase 2 polygons as well as on the Phase 1 modules.

GIANT KELP



- Kelp plants are made up of individual fronds, which consists of a rope like stipe to which blades are attached via a small gas filled float.
- The number of fronds per plant is a good indication of a plant's size.
- This graph shows the mean number of fronds per plant at the 3 sites
- As expected the average size of kelp plants increased dramatically at the Wheeler North Reef from 2009 – 2010 as small plants grew into adults.
- Nonetheless, kelp plants on Wheeler North Reef were still on average smaller than those at Barn and San Mateo, which were presumably older.

GIANT KELP



- Because giant kelp plants can differ greatly in size from small recruits to large adults, the density of fronds tends to be a better predictor of giant kelp biomass than the density of plants.
- Plotted in this graph is the density of giant kelp fronds on the 3 reefs.
- The biomass of kelp as indicated by the density of fronds increased 6 fold on the Wheeler North Reef from 2009-2010, whereas it showed about a 12% decline at San Mateo and Barn.
- On average the density of fronds on the Wheeler North Reef in 2010 was about twice that on Barn and San Mateo.



- 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.

UNDERSTORY ALGAE



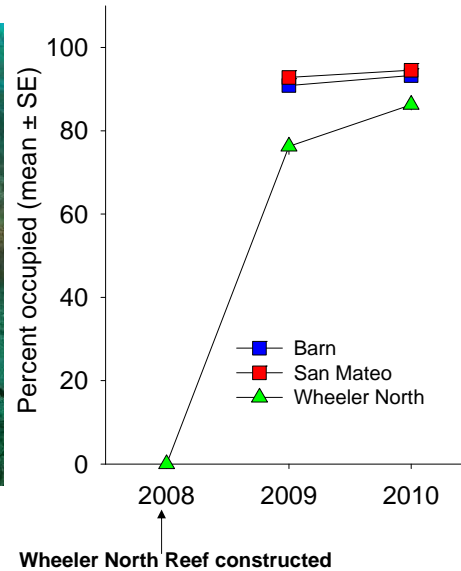
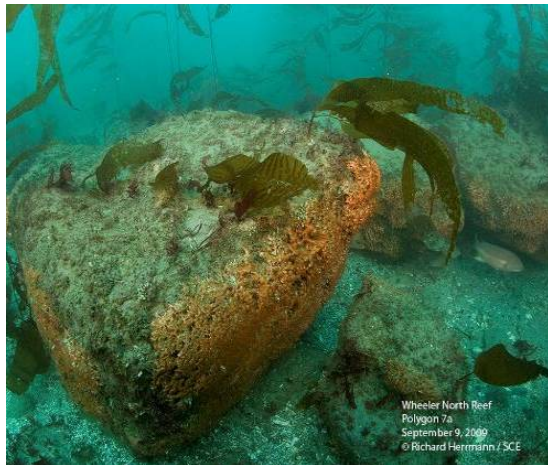
- In addition to giant kelp, shallow reefs off California are colonized by a diverse group of low-lying red, brown and green algae that occur on the bottom beneath the canopy of giant kelp.
- They are often referred to as understory algae.

SESSILE INVERTEBRATES



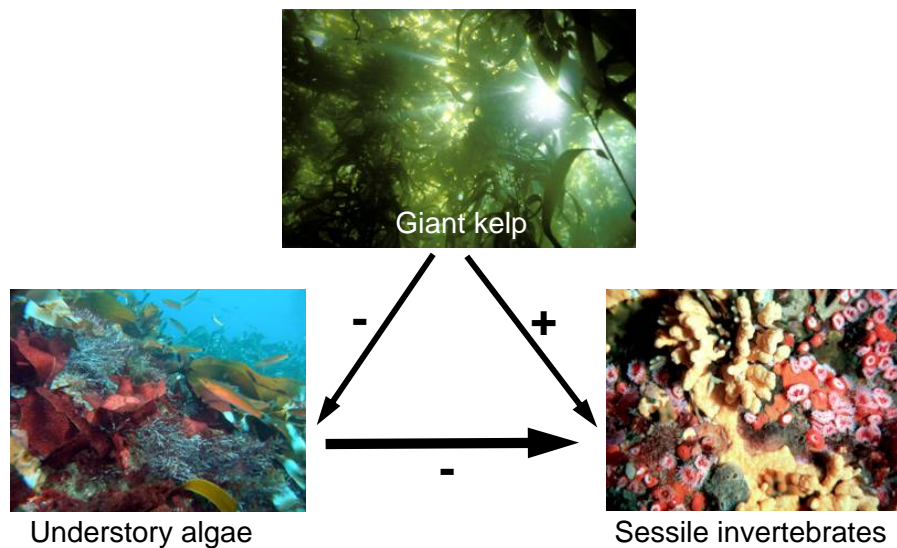
- In addition to understory algae, many sessile animals that filter plankton from the water are also found attached to the reef.
- These include organisms such as sponges, sea anemones, feather duster worms, bryozoans, rock scallops and a wide diversity of sea squirts or tunicates.

PERCENT OF HARD SUBSTRATE OCCUPIED BY SESSILE REEF BIOTA



- 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.

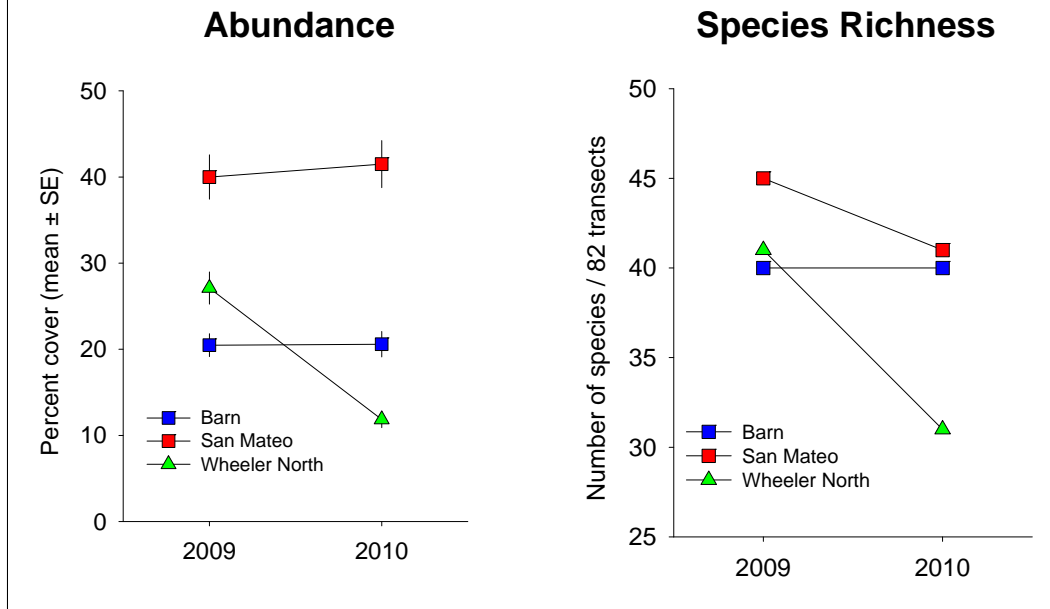
Biological interactions within the benthic community



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

- 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 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.

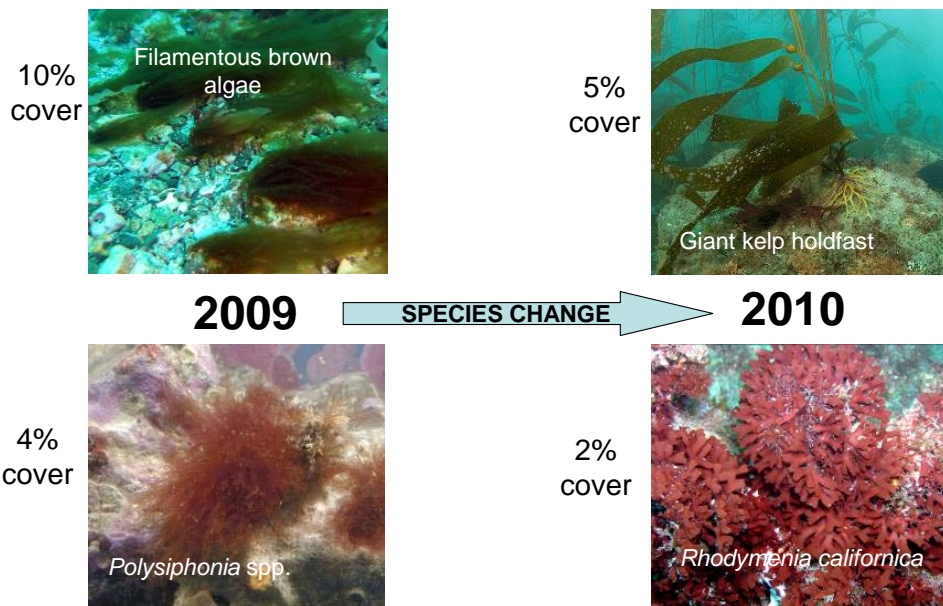
UNDERSTORY ALGAE



- Shown here on the left are data on the abundance of understory algae plotted as percent cover of the bottom.
- The percent cover of algae on the Wheeler North Reef declined from 2009 to 2010, whereas there was very little change in the percent cover of understory algae at San Mateo and Barn.
- This decline on the Wheeler North Reef is to be expected given that dramatic increase in the abundance of adult giant kelp that occurred from 2009 -2010.
- The graph on the right shows the total number of species of algae observed in the 82 transects on each of the three reefs (this is commonly referred to as species richness).
- Not only did the abundance of algae decline on the Wheeler North Reef in 2010, but so did the number of species of algae.

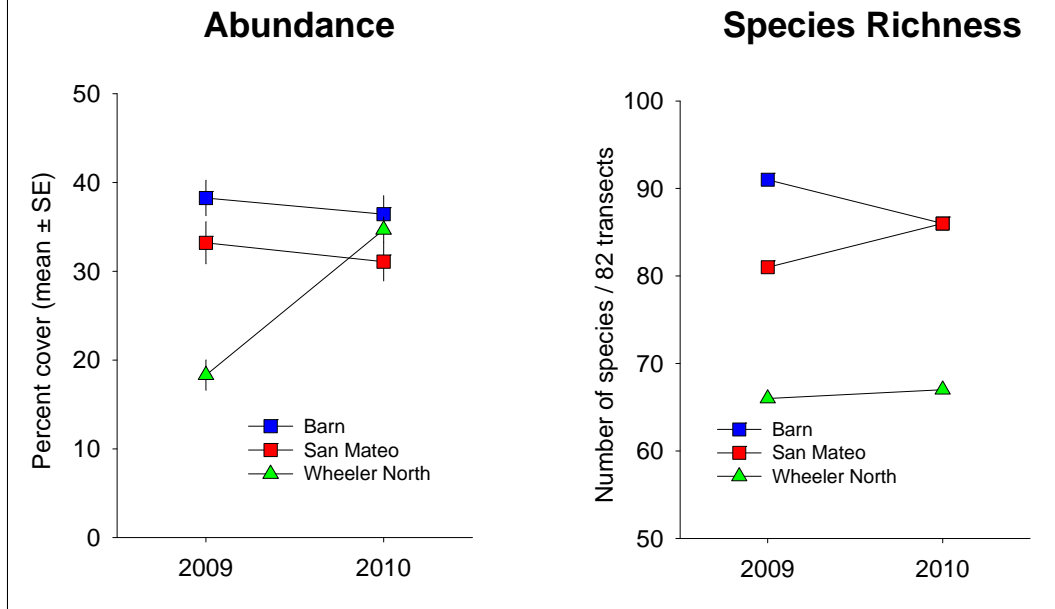
UNDERSTORY ALGAE

Wheeler North Reef Dominant Species



- The decrease in understory algae on the Wheeler North Reef resulted largely from a change in the species composition.
- Ephemeral filamentous brown and red algae are commonly some of the first species to colonize a reef and they were the most abundant algae on Wheeler North Reef in 2009.
- These short-lived species were replaced by perennial species in 2010.
- The holdfasts of giant kelp were the single most abundant species in terms of percent cover on Wheeler North Reef in 2010, followed by the small bladey red alga *Rhodomenia*.

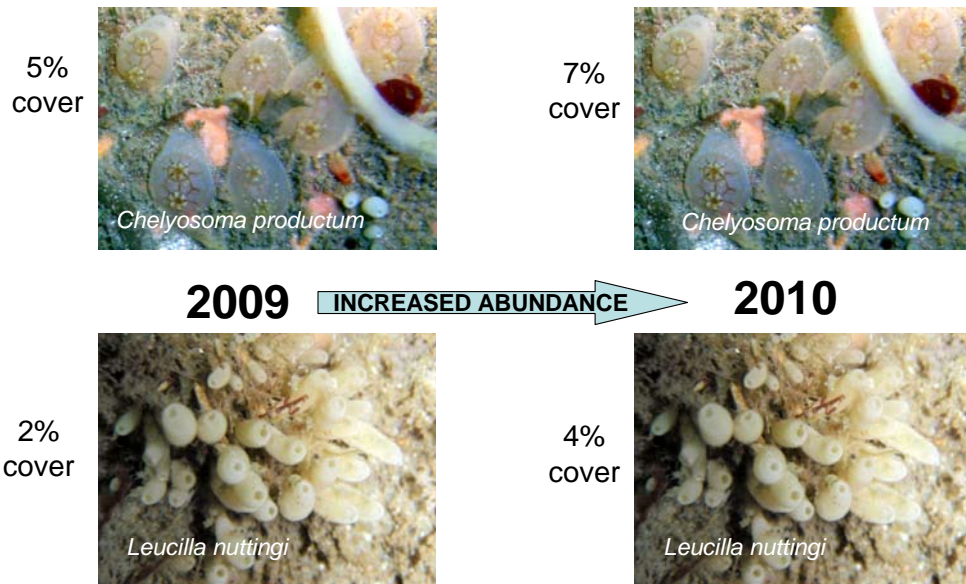
SESSILE INVERTEBRATES



- Shown here on the left are data on the abundance of sessile invertebrates plotted as percent cover on the bottom.
- The abundance of sessile invertebrates on the Wheeler North Reef showed the opposite pattern of understory algae; their abundance nearly doubled from 2009 to 2010 reaching levels that were within the range observed on San Mateo and Barn.
- Interestingly the total number of species of sessile invertebrates observed in the 82 transects on Wheeler North Reef did not change from 2009 and 2010 and was still substantially less than that observed at San Mateo and Barn.

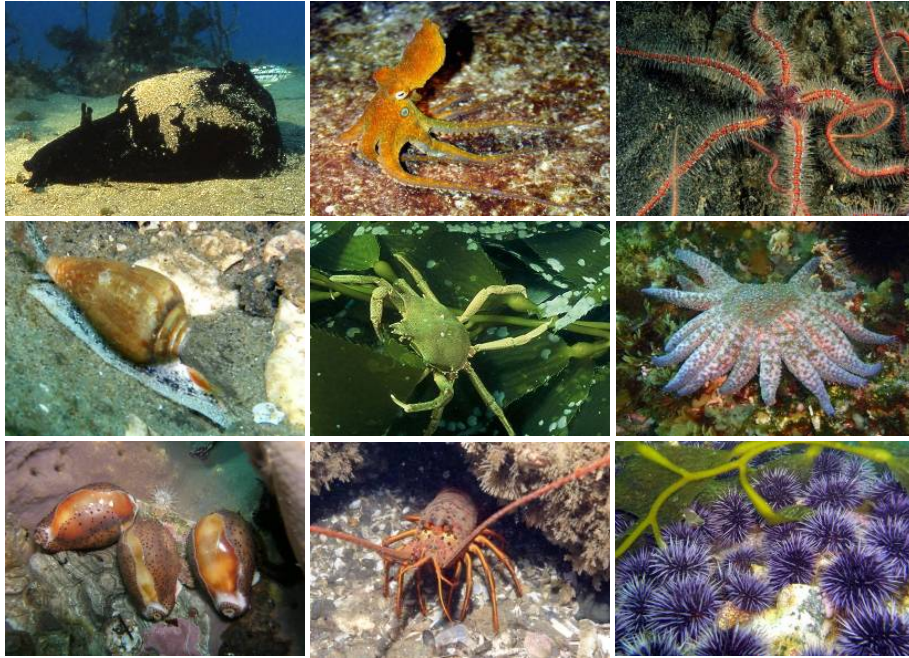
SESSILE INVERTEBRATES

Wheeler North Reef Dominant Species



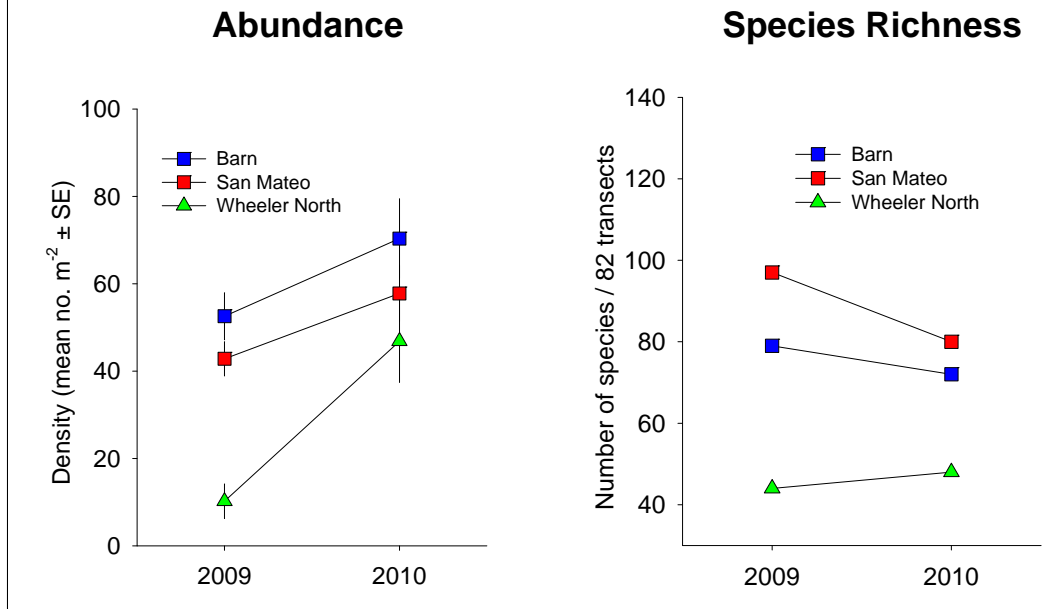
- The changes in the sessile invertebrate community on Wheeler North Reef are summarized in this slide.
- The mix of species of sessile invertebrates remained relatively constant from 2009-2010, but their overall abundance increased.
- The sea squirt *Chelyosoma* and the sponge *Leucilla* were dominant species in both years and the abundance of both of these species increased in 2010.

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.

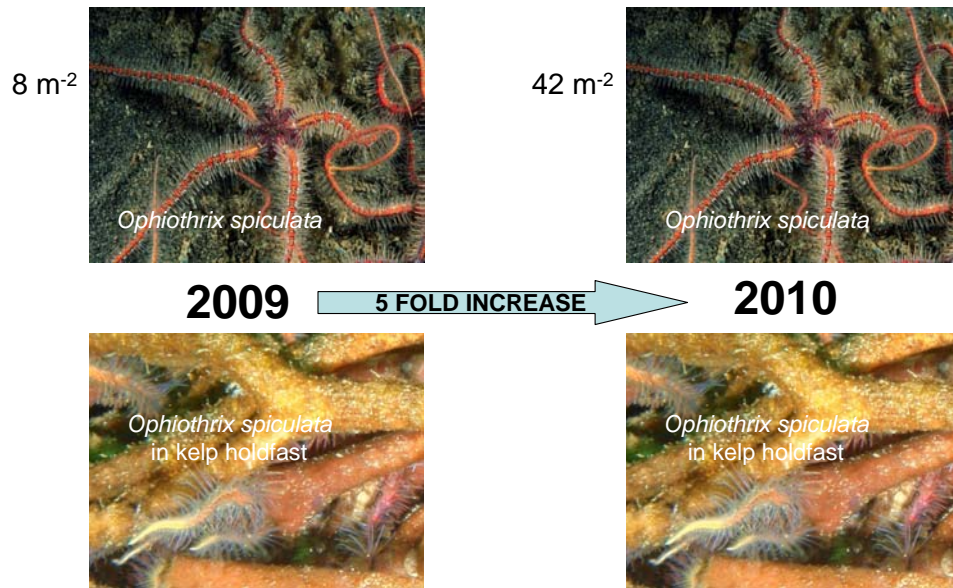
MOBILE INVERTEBRATES



- Shown here on the left are data of the mean density of mobile invertebrates on the 3 reefs.
- Like sessile invertebrates, the abundance of mobile invertebrates on the Wheeler North Reef increased dramatically (nearly 5 fold) from 2009 to 2010 reaching densities that were approaching those observed on San Mateo and Barn.
- In contrast the total number of species of mobile invertebrates observed in the 82 transects on Wheeler North Reef showed only a slight increase from 2009 and 2010, and was still substantially less than that observed at San Mateo and Barn.

MOBILE INVERTEBRATES

Wheeler North Reef Dominant Species



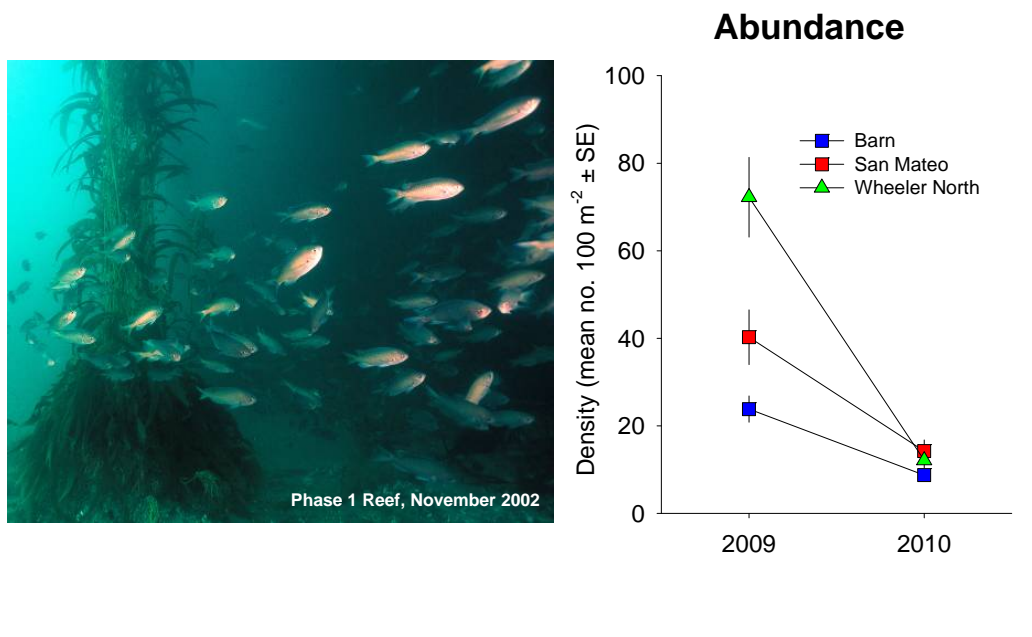
- The five-fold increase in the density of mobile invertebrates resulted primarily from an increase in the density of the brittle star *Ophiothrix*, which went from an average density of 8 m⁻² in 2009 to 42 m⁻² in 2010.
- This brittle star is very common in the holdfasts of giant kelp and its increased abundance may have been due in part to an increase in the abundance of giant kelp.

KELP BED FISHES

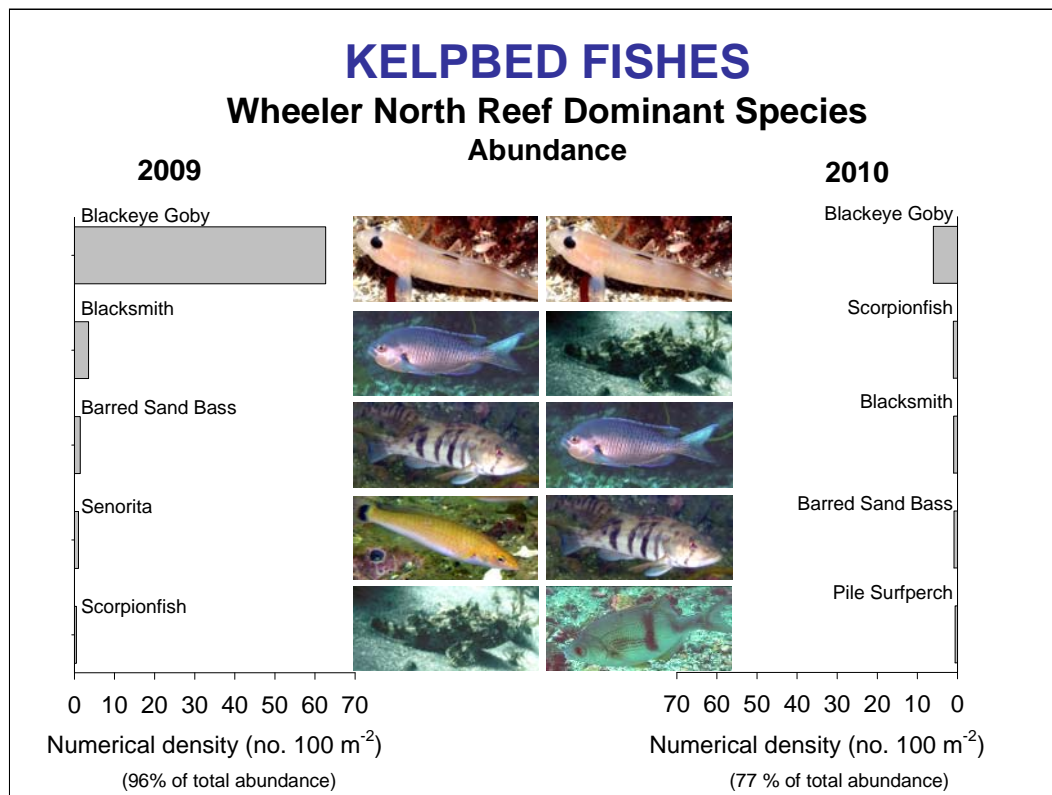


- The most mobile predators in the kelp forests are reef fishes, which come in a large variety of shapes and sizes ranging from small gobies that lie on the bottom and eat tiny shrimp to large fish-eating basses such as kelp bass and black sea bass.
- The latter which can reach several feet in length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

KELPBED FISHES

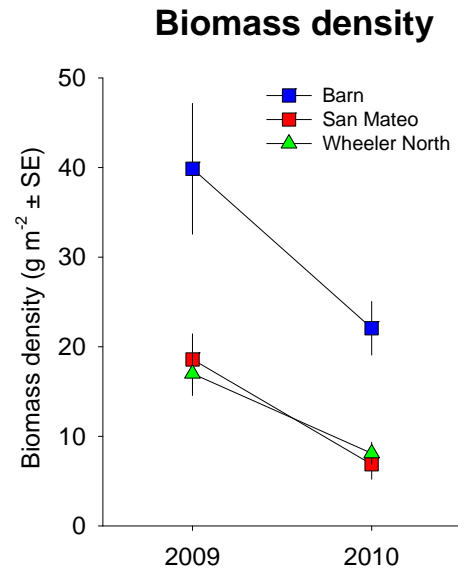


- Plotted here are the average number of fish observed near the bottom in 3m wide swath along the 50 m transects.
- In the first year following construction densities of reef fish were 2-3 times higher on the Wheeler North Reef compared to San Mateo and Barn.
- Large decreases in fish abundance were observed on all three reefs in 2010 with a proportionally larger decrease on Wheeler North Reef.
- This resulted in similar densities of kelp bed fishes on all three reefs in 2010.

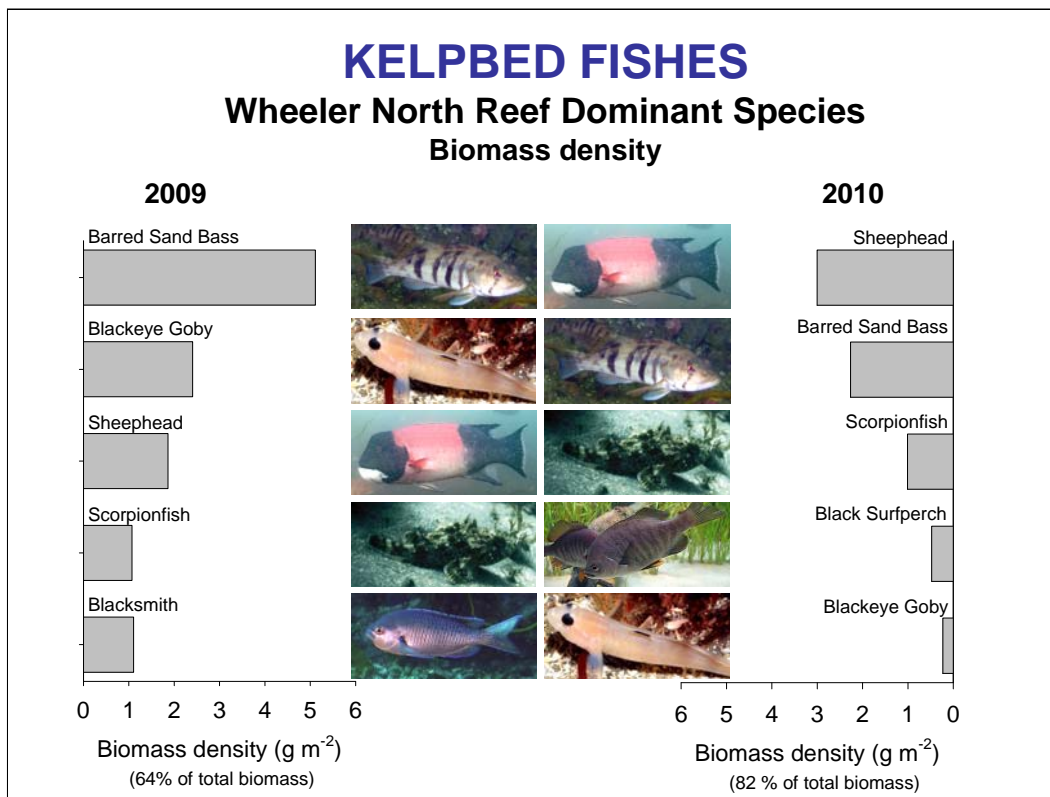


- Shown here are densities of the five most abundant species of fish on the Wheeler North Reef in 2009 and 2010 arranged from top to bottom.
- The high densities observed in 2009 were due to large numbers of the small blackeye goby, which attained an average density of $\sim 65 \text{ m}^{-2}$.
- The next 4 most abundant species in 2009, Blacksmith, Barred Sand Bass, Senorita, and Scorpionfish averaged < 5 individuals 100 m^{-2} .
- Collectively, these five species accounted for 96% of all fish counted on the transects at Wheeler North Reef in 2009.
- The large decrease in overall abundance of kelp bed fish in 2010 was due primarily to a 10 fold reduction in the density of blackeye gobies.
- Four of the five most abundant species in 2009 remained in the top 5 of the most abundant species in 2010.
- The only change was that senorita were replaced by pile perch.
- In contrast to 2009, the top five species in 2010 accounted for only 77 % of the all fish counted as different species of fish were more evenly distributed in abundance.

KELPBED FISHES

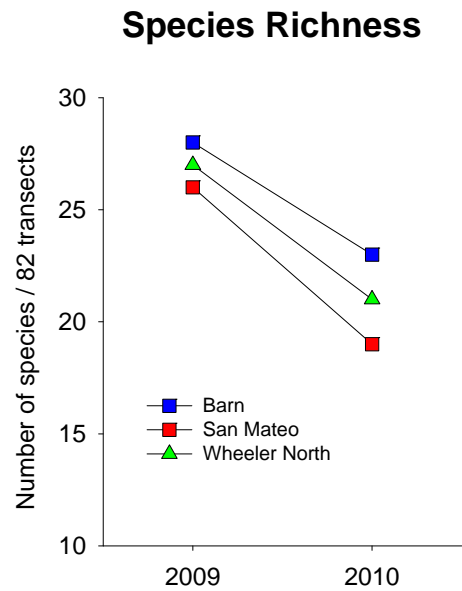


- Because different species of fish vary tremendously in size it is often desirable to know something about the amount of biomass of fish in a given area.
- This term is often referred to as biomass density to distinguish it from numerical density, which is the number per unit area.
- Shown here is the biomass density of kelp bed fish on the 3 reefs in 2009 and 2010.
- As observed for numerical density the biomass density of fish declined on all three reefs in 2010 and did so at approximately the same rate.
- In contrast to numerical density, the biomass density of fish on Wheeler North Reef was similar to that on San Mateo, but considerably less than that on Barn.



- The relatively low biomass density on Wheeler North Reef in 2009 when the numerical density was extremely high can be explained by the fact that blackeye gobies, which were the most abundant species are relatively small and on average weigh only about 3 grams.
- Consequently, even though gobies were almost 50 times more abundant than Barred Sand Bass, they only accounted for roughly half the biomass of Barred Sand Bass.
- Four of the five most dominant species on Wheeler North Reef in 2009 in terms of biomass density declined in biomass in 2010.
- The lone exception was Sheephead, which nearly doubled in biomass density to become the most dominant species in 2010.
- This species is relatively uncommon on Wheeler North Reef, but because of its large size it accounted for a substantial amount of the fish biomass on the Wheeler North Reef in 2010.

KELPBED FISHES



- The plot shows the total number of species of kelp bed fish counted on the 82 transects on each of the 3 reefs.
- Species richness declined on all three reefs from 2009-2010 at approximately the same rate.
- The number of species on the Wheeler North Reef was intermediate between Barn and San Mateo in both years.

QUESTIONS?

