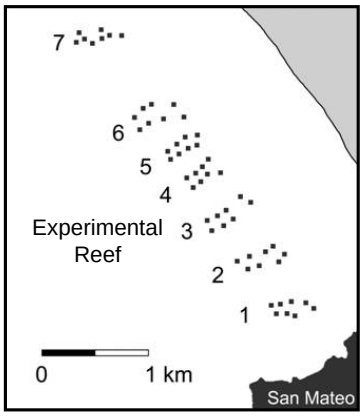
Experimental Reef: Ten Years After
1999 - 2009



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

In this presentation we discuss the results of ten year's of monitoring of the Experimental Reef which was constructed in 1999

Ten year time series of Experimental Reef development

What measured:
- Area and coverage of hard bottom substrate
- Abundances and sizes of kelp forest algae, invertebrates & fish
- Recruitment, growth, and mortality of potentially invasive sea fans

Where measured:
- 21 rock modules of Experimental Reef
- 9 sampling locations at San Mateo (reference site)
- 9 sampling locations at Barn (reference site)

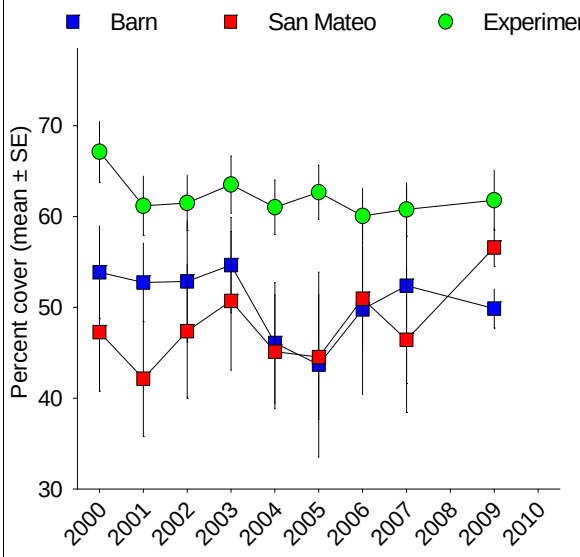
When measured:
- Annually in summer & fall from 2000 to 2009

Why measured:
- Provides information useful for adaptively managing the Wheeler North Reef, which will help to ensure that the reef mitigation adequately compensates for the loss of kelp forest resources caused by the operation of SONGS

•We measured physical and biological variables relevant to the performance standards upon which the performance of the WNR will be judged.

•We measured these variables on the experimental reef and the 2 reference reefs annually in the summer and fall from 2000 – 2009

Exposed Hard substrate



•What follows is a series of graphs of these physical and biological variables vs. time for the experimental reef and two reference reefs, Barn and San Mateo

• Exposed hard reef substrate is necessary for the establishment and persistence of giant kelp and other reef biota

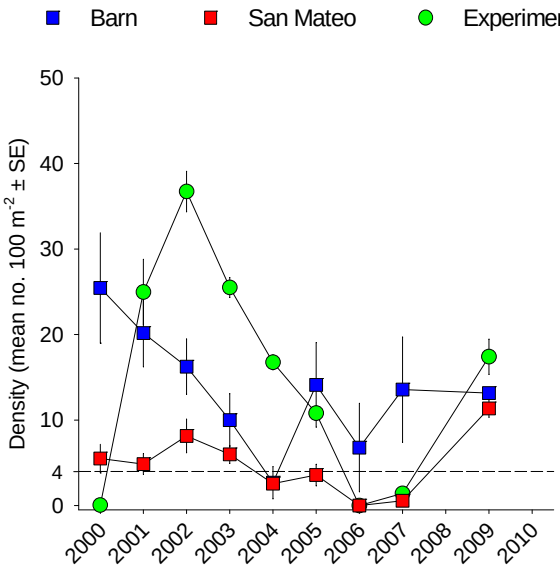
• Knowledge about its amount and persistence is essential to understanding how the WNR will function over the long term

• The percent cover of exposed hard substrate was higher and less variable on the Experimental Reef than on the two natural reference reefs

• The % Cover of hard substrate in summer of 2000 averaged 67%.

• It declined slightly after the first year and since then has remained fairly constant @ around 60%

Adult Giant Kelp



• Giant kelp is the foundation species of the kelp forest as it provides food and shelter for a wide diversity of species.

•The 150 acre minimum requirement for the artificial reef mitigation is based the estimated area of adult giant kelp that was lost due to the operation of SONGS

•Shown here is a graph of the mean abundance of adult giant kelp on the Experimental Reef and the two reference reefs over the last 10 years

•Giant kelp colonized the Experimental Reef shortly after it was built and the abundance of adult giant kelp quickly reached levels observed on the natural reefs

•kelp abundance peaked in 2002 and steadily declined to very low densities in 2006 due to natural thinning without replacement.

•The near complete absence of giant kelp on the Experimental Reef in 2006 and 2007 was mirrored at most kelp beds throughout Southern California and reflected regionally poor growing conditions.

•Barn kelp was an exception to this regional pattern.

•kelp recovered in 2008 at the Experimental Reef and other reefs in s. California

Adult Giant Kelp

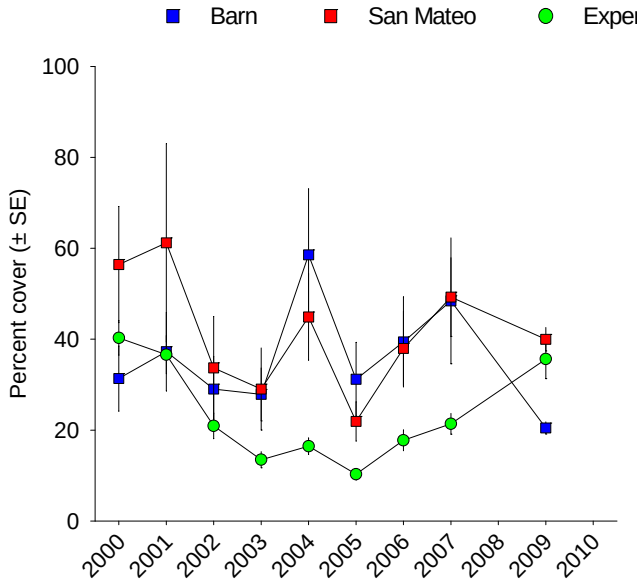
Satellite image of giant kelp (in red) on the Experimental Reef modules in 2004

•Evidence of abundant adult kelp on the Experimental Reef in 2004 can be seen in this satellite image

• The surface canopy of giant kelp is shown in red in this image

•a dense surface canopy of giant kelp is visible on every one of the 56 reef modules shown as squares

Abundance of Understory Algae



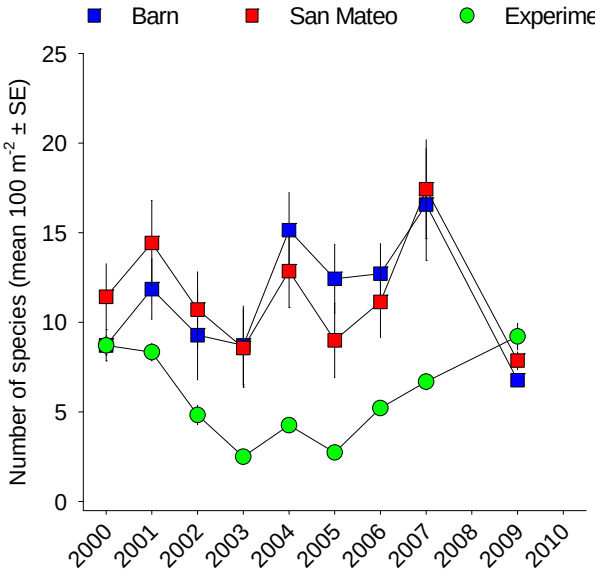
•The abundance of understory algae is measured as the percent of the bottom that it covers

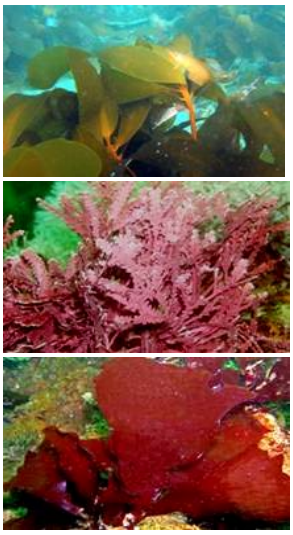
•understory algae, which include smaller kelps and an assortment of red, brown, and green algae, rapidly colonized the experimental reef and their abundance in the first year was within the range observed on the two reference reefs

• After the first year, the % of the bottom covered by understory on the Experimental Reef declined to a low point in 2005 when it was much lower than that observed on the natural reference reefs

• Since then the % cover of understory algae on the Experimental Reef has increased and by 2009 was again back within the range observed on the references reefs

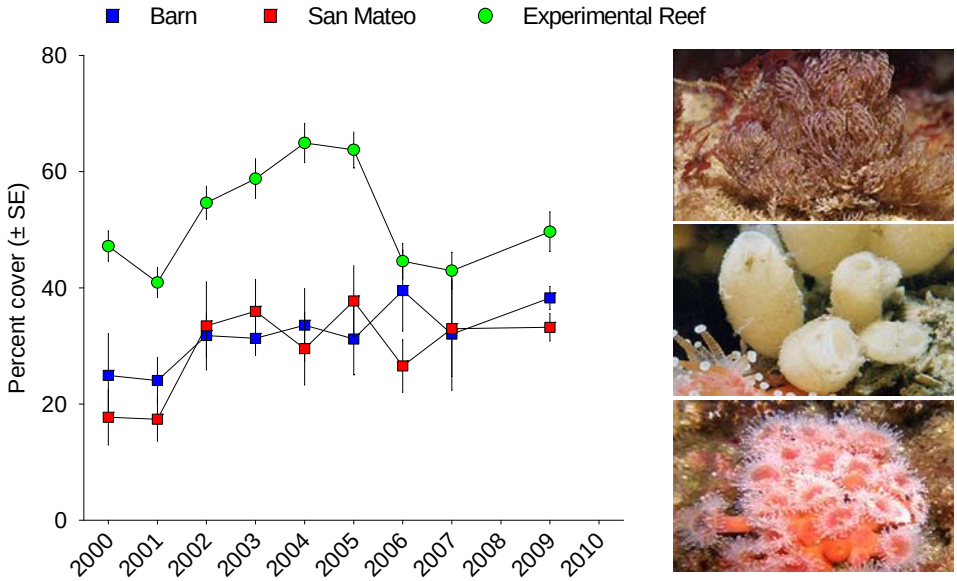
Species Richness of Understory Algae





- the number of species that occur at a given location is referred to as species richness
- we measured species richness as the average number of species per 100 m2 of bottom
- the patterns of species richness of understory algae resembled those observed for % cover of understory algae
- it started out within the range of the two reference reefs, reached a low in 2005, has increased since then, and is now slightly higher than at natural reference reefs

Abundance of Sessile Invertebrates

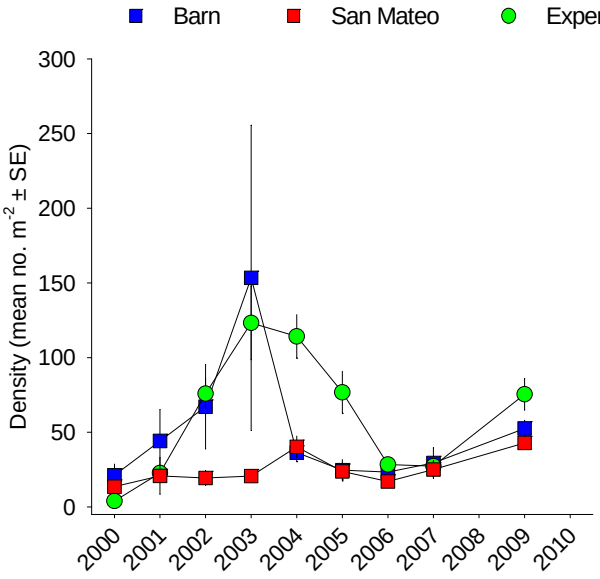


•understory algae compete for space on the bottom with sessile invertebrates that feed on plankton

• this includes organisms like sponges, sea anemones, sea squirts and clams

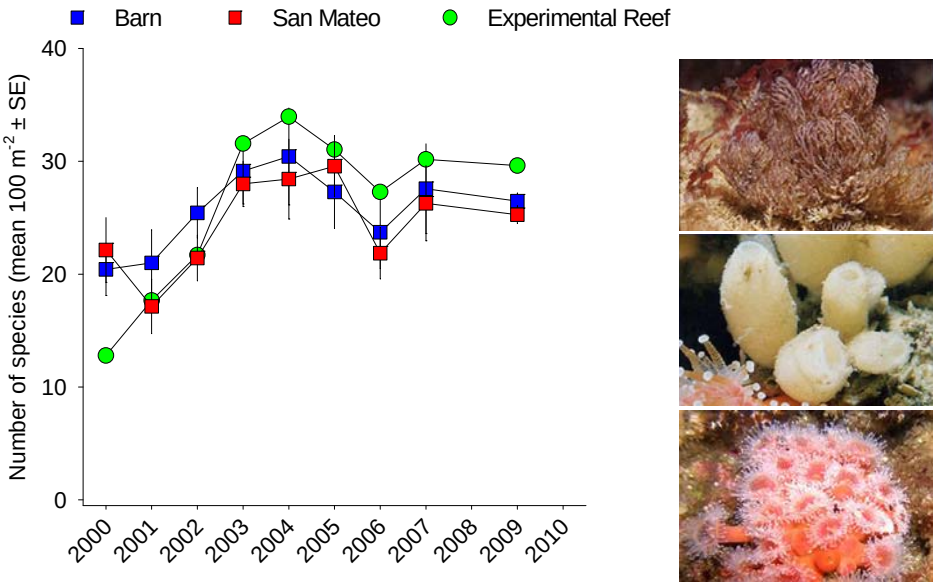
• in contrast to the understory algae, the % cover of these sessile invertebrates started out much higher on the Experimental Reef compared to the natural reefs and has remained so throughout the past 10 years

Abundance of Mobile Invertebrates



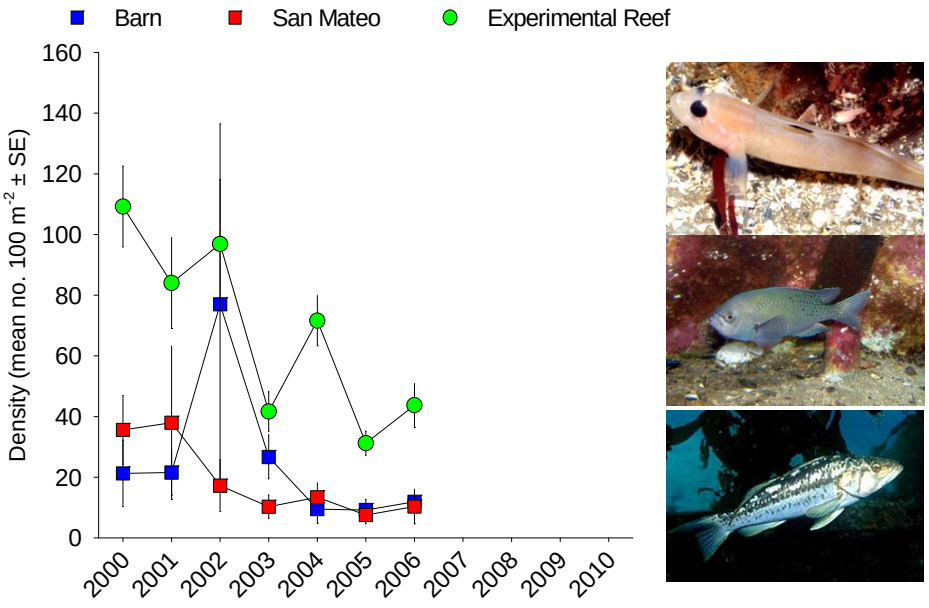
- many other invertebrates are mobile and search the bottom for food,
- this includes species like sea cucumbers, sea stars, and lobsters
- the abundance of mobile invertebrates on the Experimental Reef measured as the number per m2 was generally within or above the range of values observed on the natural reefs
- The very high numbers at both the Experimental and natural reefs from 2003-2005 reflected high numbers of brittle stars.

Species Richness of Invertebrates



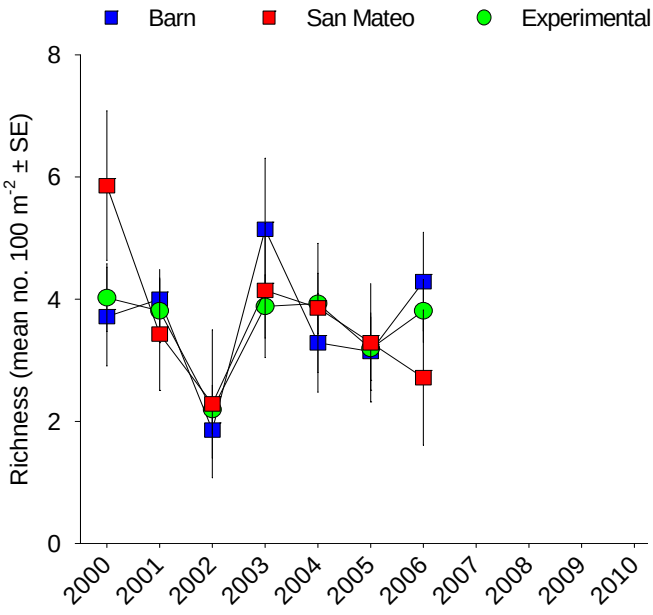
- the average number of all invertebrate species steadily increased on the Experimental Reef through 2004 exceeding values observed on either reference reef
- since then fluctuations in the number of species of invertebrates on the Experimental Reef have been similar to or slightly higher than those seen on the reference reefs

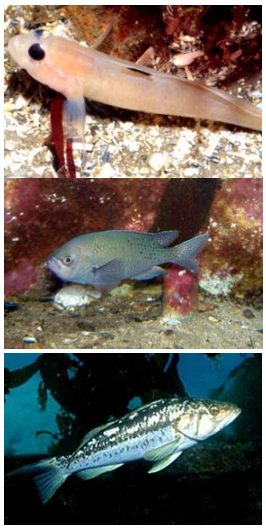
Abundance of Resident Fish > 1 y old



- many species of fish get their food and shelter from the reef
- we've defined individuals of such species > 1 year old as "resident" fish
- Shown here is the number of resident fish per 100 m2 of reef
- resident fish rapidly colonized the Experimental Reef and remained substantially higher there compared to the natural reefs
- this is evidence that older fish are initially attracted to newly constructed artificial reefs
- note that the time series ends in 2006, this is because we stopped sampling fish then due to constraints on time and effort

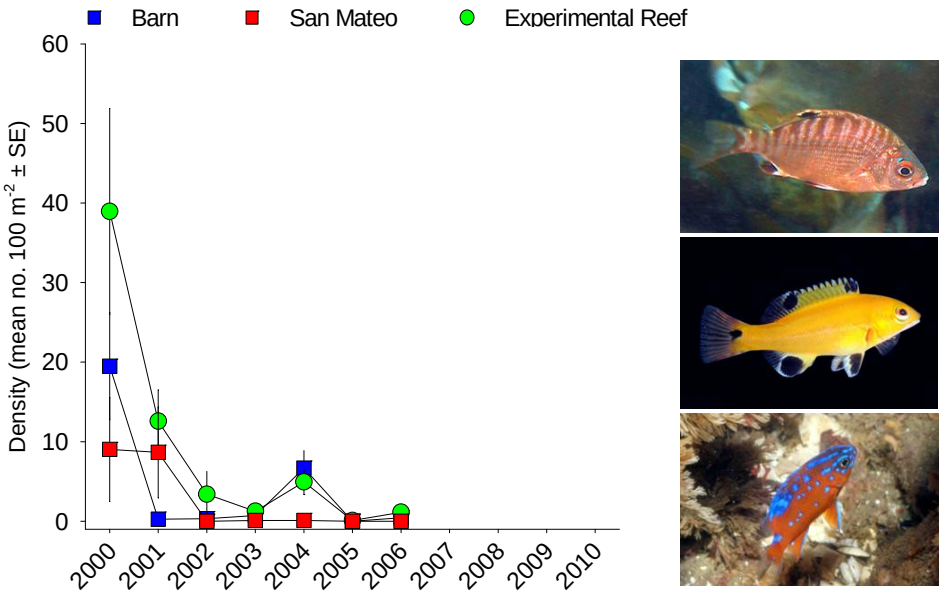
Species Richness of Resident Fish > 1 y old





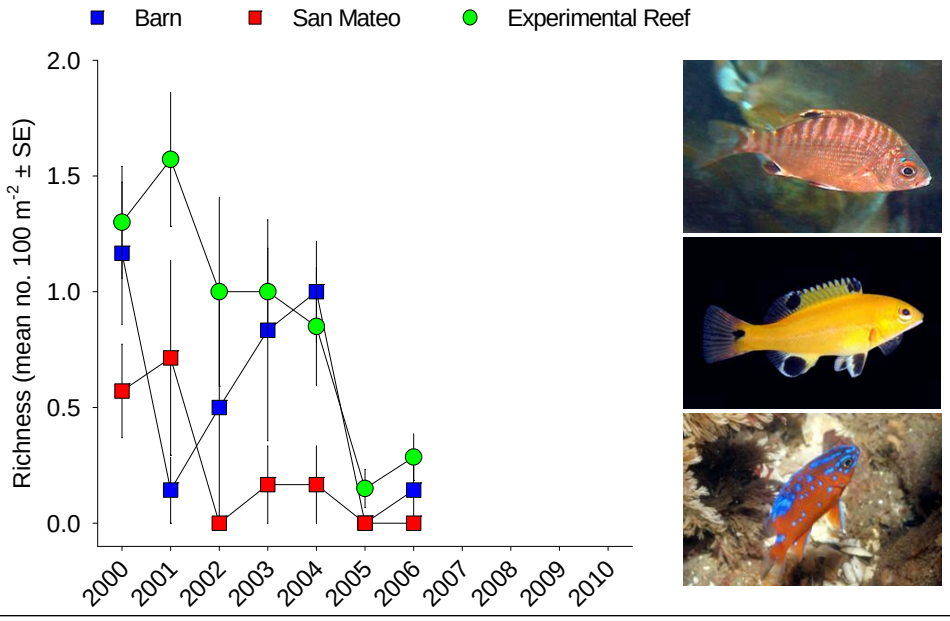
•The average number of species of resident fish per 100m2 of reef was similar among reefs over the seven years of sampling

Abundance of Young-of-Year Fish

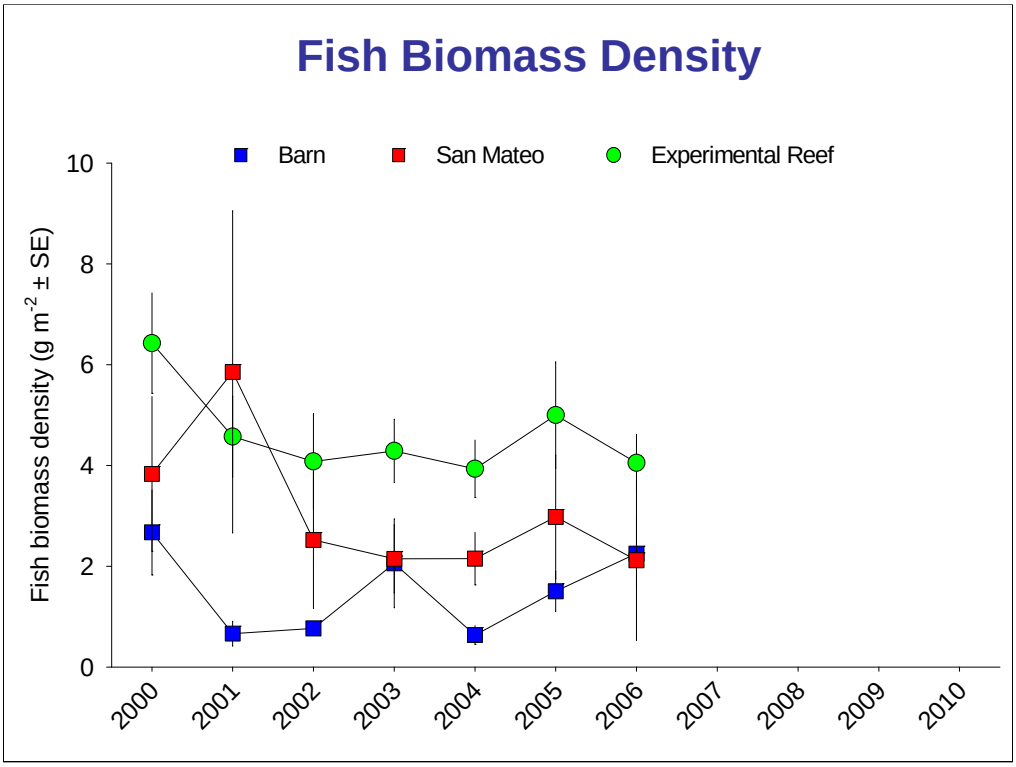


- Young-of year (YOY) are individual reef fish were born during the year that we sampled
- Their appearance on artificial reefs is an indication of how well the reef functions as a nursery habitat
- 2000 was a very good year for YOY in general
- during that year the average number of YOY on the Experimental Reef was 2 to 4 x greater than on the reference reefs
- The abundance of YOY was very low and similar on all reefs in most subsequent years

Species Richness of Young-of-Year Fish



- There were very few species of YOY observed on any of the reefs
- the average number of species of YOY fish tended to be highest on the Experimental Reef



• the biomass of a fish depends on its size (age) and species identity

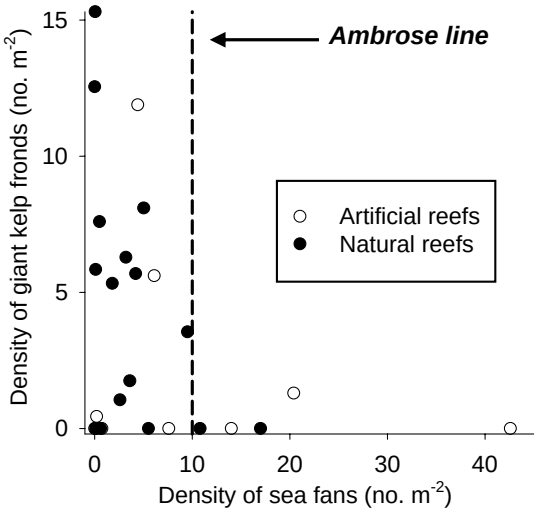
• the total biomass of all fish on a given reef reflects the capacity of that reef to provide fish with food and shelter

•One way to examine this capacity across reefs is to compare the biomass of fish for a given area of reef, which is something that we refer to as fish biomass density

•trends in fish biomass density reflected trends seen in fish abundance: i.e., biomass density on the Experimental Reef was typically greater than on the two reference reefs

Invasive Species: Sea Fans

High densities of sea fans may exclude giant kelp



data from Ambrose et al. 1987

•Invasive species, whether they are natives or non-natives, are those species that reach high abundance and have an adverse effect on the normal functions of a reef

• Invasive species have been known to adversely affect artificial reefs in southern California

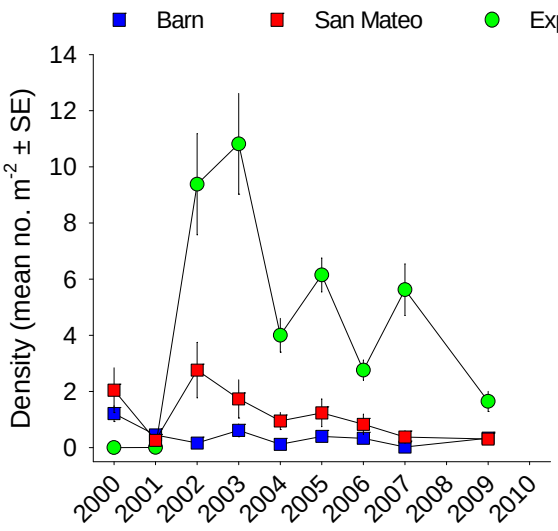
• Native sea fans are one such group of invasive species

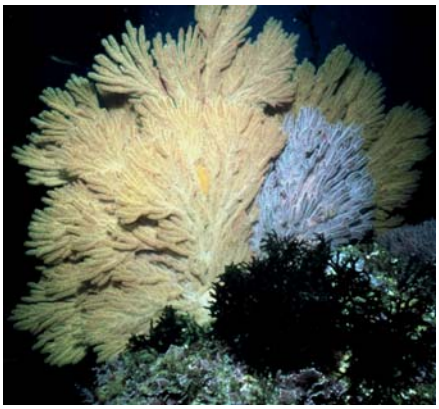
• Dr. Rich Ambrose and colleagues did a broad survey of artificial and natural reefs in southern California during the 1980's and found that giant kelp was rare or absent on reefs where sea fan abundance exceeded 10 per m2

• we've come to call a density of sea fans of 10 m2 the "Ambrose line" which indicates a potential problem for a reef to support giant kelp

Invasive Species: Sea Fans

High colonization of sea fans on Experimental Reef beginning in 2002

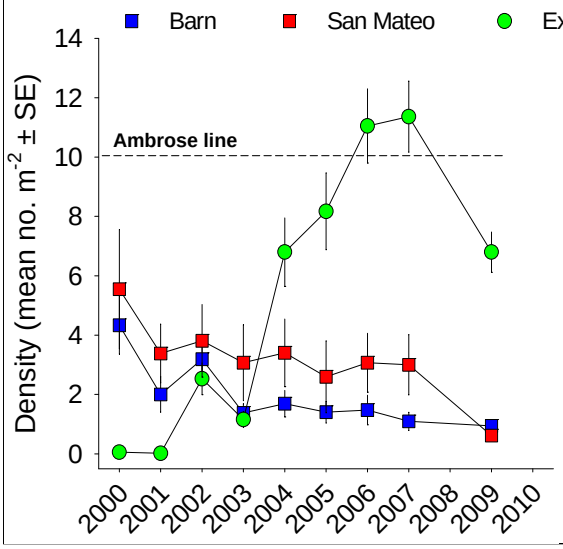




- Beginning in 2002 the colonization of sea fans was much higher on the Experimental Reef compared to the natural reefs
- Sea fan colonization on the Experimental Reef peaked in 2003, but has remained relatively high
- Similar high colonization was not observed on the natural reference reefs

Invasive Species: Sea Fans

High densities of sea fans on Experimental Reef



•The high colonization by sea fans combined with high rates of survival resulted in a steady increase in the abundance of sea fans on the Experimental Reef up until 2007

•In 2006 and 2007 total sea fan abundance on the Experimental Reef exceeded the Ambrose line and raised concern that high sea fan densities could greatly reduce the abundance of giant kelp on the artificial reef

•Densities of sea fans on the reference reefs remained relatively constant over this time and well below the “Ambrose line”

•This pattern of sea fan increase abruptly reversed in 2009 when sea fan densities dropped precipitously at the Experimental Reef and fell below the Ambrose line

•Declines in sea fan abundance were also seen on the reference reefs suggesting a region-wide mortality event

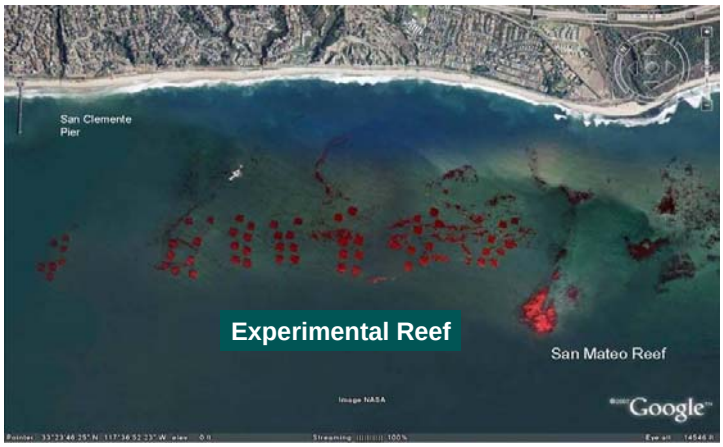
Invasive Species: Sea Fans

Large numbers of dead sea fans found in beach wrack near San Mateo Pt. following winter storms

* **Photos from December 2009**

- Following large storms in December 2009, large numbers of sea fans were found on the beach inshore of the artificial reef
- This observation suggests that mortality caused by storms in the winter of 2008 was responsible for the drop in sea fan abundance observed in the summer of 2009
- Given the large number of dead sea fans seen on the beach this past winter we expect to see continued declines in sea fan abundance on the Experimental Reef in our 2010 summer survey

Monitoring Plans for Experimental Reef in 2010



- **Continue monitoring hard substrate, kelp, understory algae & invertebrates**
- **Re-institute monitoring of fish to assess standing stock potential**
- **Suspend the sea fan removal experiment planned for 2010 that sought to determine the effects of sea fans on the performance of other kelp forest organisms**

•Trends observed in the Experiment Reef relative to the reference reefs over the past 10 years provide a means of determining expectations for the Wheeler North Reef over the long term

•The longer this time series the more it is likely to encompassed the range of conditions that the Wheeler North Reef will experience during time the it is required to mitigate the impacts of SONGS, which will lead to more informed decisions concerning adaptive management

•Therefore we plan to continue monitoring the Experimental Reef this summer