FINAL REPORT: NATIVE OYSTER RESTORATION IN MUGU LAGOON, VENTURA COUNTY
TNC / NOAA Community-based Restoration Program
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ABSTRACT
Populations of Native (Olympia) Oysters (*Ostrea lurida*) in southern California have declined in the last century due to loss of habitat, increased sediment and poor water quality. Efforts are underway to expand remnant populations along the US west coast. Here we describe results obtained when six types of oyster substrates were deployed in Mugu Lagoon, Ventura County, California and adjacent areas. The substrates were used to increase appropriate substrate for oyster settlement and growth. The substrate types were: Wire mesh trays - 0.25m^2 wire mesh trays holding shell from Japanese oysters; Mini-Reefs - oyster shell in three wire mesh bags stacked in a pyramid (surface area 4.45 m^2); Spat Collector Sticks - 36 wooden stakes covered in cement with lime granules and partially inserted into the substrate (surface area 2.82 m^2); Oyster Futons – a single layer of oyster shell spread over 2.0 m^2 placed between two layers of galvanized wire mesh anchored to the substrate; Limestone Monoliths - pieces of limestone paving stones buried half way in the substrate allowing the upper half to protrude vertically (surface area 0.25 m^2); Stick and Bag - bags of oyster shell suspended 0.5 m above the bottom from a stake (surface area for two bags 3.0 m^2); Oyster Strings - individual oyster shells placed on strings at 20 cm intervals and suspended from floating docks (surface area 0.3 m^2).

Mini-Reefs, and Stick and Bag substrates recruited the largest number of oysters. Oyster spat collector sticks recruited fewer oysters. In 2012, 27 Mini-Reefs (shell surface area of 120.1 m^2) placed in the lagoon in March resulted in the recruitment and growth of 621 native oysters, which grew to an average shell length of 24.2 mm after 9 to 11 months. In 2013, 89.0 m^2 of Mini-Reefs remained in the lagoon, producing a population of 894 oysters with an average shell length of 38.2 mm. Nine Stick and Bag collectors produced 272 oysters. Oyster Spat Sticks produced only 29 oysters.

No recruitment was observed on the Limestone monoliths. Oyster Traysand futons became buried after several months, as did lower shells of the oyster Mini-Reefs.

During the two years of this study there was almost a doubling in the number of oysters on all substrates, from 740 in 2012 to 1,221 in 2013. This increase occurred in spite of a 40 per cent decrease in the amount of substrate surface area. Densities on the Mini-Reefs doubled from 5 to 10 oysters / m^2 of substrate from 2012 and 2013. In 2013, densities of oysters in the Stick and Bag substrates at 17 oysters / m^2 were almost double those on the Mini-Reefs.

In 2013, the 1,221 oysters on the substrates increased the oyster population in Mugu Lagoon by 17 – 23% over the 2009 estimate. Most of this increase can be attributed to the mini-reef and Stick and Bag collectors.

INTRODUCTION

Populations of oysters throughout the world have declined an estimated 85% during the last century due to overharvesting, loss of habitat, increased sedimentation, and poor water quality. Oysters filter food and sediments from the water column, forging a link between planktonic and benthic coastal communities. Recognizing the important role of oysters, efforts are underway in many coastal communities to restore this valuable resource. Saltmarshes in California have declined 75 – 90% with few remaining habitats for the Native (Olympia) Oyster (*Ostrea lurida*). Mugu Lagoon, located within Navy Base Ventura County, Point Mugu, is the largest remaining estuary and saltmarsh in southern California. Mugu Lagoon is one of The Nature Conservancy's (TNC) Ecoregional Portfolio Sites and is a priority site in the TNC Pacific southwest Ecoregional Plan.

Mugu Lagoon historically provided a rich shellfish fishery to Native Americans and later European settlers. The hydrology of Mugu Lagoon changed radically with the development of agriculture over 150 years ago. The lagoon became an estuary after Callegaus Creek was diverted into it to prevent flooding of the Oxnard Plain. The high sediment load carried by the creek and other human activities reduced the lagoon to half of its former extent.

Preliminary studies carried out in 2008 – 2009 (McCormick 10/2009 unpublished report to Naval Facilities Engineering Command) indicated that the population of Native Oysters in Mugu Lagoon was centered on the concrete and steel supports of a causeway that intersects the lagoon. Surveys of accessible portions of the causeway estimated that 5,400 to 7,100 Native Oysters may inhabit this structure. McCormick also suggested that lack of suitable oyster habitat within the lagoon may be a stressor. Here we described experiments where we deployed different substrates intended to increase the oyster population within Mugu Lagoon and at sites in the Channel Island Harbor and Edison Canal. The work was joined by student volunteers from Tierra Vista Elementary School and Oxnard College who learned about the role played by oysters in the estuary and saltmarsh ecosystem.

METHODS AND MATERIALS

Six types of experimental oyster substrates were deployed between December 2010 and October 2013. Numbers and locations of substrates placed within Mugu Lagoon was dependent upon water velocities and sediment types. In the 1940s a causeway was placed across the main arm of the lagoon, restricting water flow and creating a localized zone of extremely high water velocities with the changing of each tide. High water velocities around the causeway create bottom substrates high in sand, pebbles, and cobble. Sediments in other parts of the lagoon are largely composed of clay, silt, and sand. Good tidal flow and the lack soft silt sediments near the causeway made it a prime target for enhancement of Native Oyster stocks. Preliminary studies by McCormick (op. cit.) found the highest spat settlement and adult densities on or near the causeway structure. Additionally, seawater temperatures at the causeway were less extreme that in areas of the lagoon that were shallower of at greater distances from the mouth of the lagoon.

The timing of measurements of recruitment and growth were as follows. Preliminary studies (McCormick op. cit.) looked for recruitment on oyster shell every 4 – 6 weeks by examining each shell from all collectors. The smallest oyster spat, 6 - 10 mm shell length, were found in September and October of 2008 and 2009. A growth rate of 3 mm/month observed in the preliminary study would suggest that initial settlement had occurred between July and August.

In the present study, the initial design called for 0.25 m^2 oyster shell trays to be used. Problems with the shell tray led to the design of the mini-reef. Oyster recruitment using the mini-reef in 2012 was so successful, that a no-cost extension of the project was granted so that other type of substrates could be added and a second year of results gathered. Additional types of substrates were placed in the lagoon at different times as different collector designs were tested. Surveys of the number and size of oysters found on the collectors were undertaken in the fall of 2012 and 2013. Shell length, from the anterior hinge to posterior shell margin, was measured with a plastic ruler to the closest millimeter. Individual collector types are described below:

Oyster Trays– wire mesh platforms

Oyster tray (0.25 m^2) made from expanded wire mesh. Pocket knife is 3”.

Oyster Trayswere constructed of 14-Gage expanded wire mesh trays (5 cm (2”) diamond-shaped openings) with a flat area of 0.25 m^2 and 5 cm exterior walls. Wire mesh legs 4” high were designed to keep the platform above the substrate. The platform was filled with a single layer of oyster shells (approximately 60).

In April 2010, nine trays were deployed in Mugu Lagoon on both sides of the causeway. Trays were placed at sites that had a mix of sand, gravel, cobble and shell. This substrate type was chosen since it was indicative of areas where the velocity of tidal currents was great enough to prevent the build-up of silt. Elevations were approximately 0 – 1 ft. above Mean Lower Low Tide. Trays were checked monthly.

Spat Stick Collectors

Two sets of 36 spat collector sticks.

Spat Stick Collectors were constructed from 0.91 m (36") wooden survey stakes cut in half length-wise resulting in a 1.9 cm x 1.9 cm x 91 cm stake with one pointed end. The stake was coated with a mixture of equal parts Portland cement, sand, and pelletized garden lime (The Espoma Co, Milleville, NJ) mixed with sufficient water to make a thick slurry (Manley et al., 2008). Lime granules were placed in the mixture to simulate the calcium carbonate shells of oysters, stimulating settlement of oyster spat. Wooden stakes were soaked in fresh water for a day or more after which the slurry was applied by hand to coat the sticks. Stakes were allowed to dry for a week then deployed in groups of 36 in three rows of 12 stakes by driving the stakes vertically into the substrate to a depth of 1/3 of their length. 16 sets of 36 sticks were deployed in the lagoon. Several sets were lost due to high currents. Elevations were approximately 0 – 1 ft. above Mean Lower Low Tide. Spat Sticks were deployed beginning in October 2011, and in August, September and December of 2012. Sticks were checked for oyster settlement after the first three-month period, then again in the fall of 2012 and 2013.

Mini-Reefs

Six Mini-Reefs six months after deployment. Note rusted wire.

Mini-Reefs were constructed of three wire-mesh tubes (8" diameter, 25" long, wire was Stucco mesh, 17-Gage galvanized wire mesh 1-1/2" x 2-1/4") containing approximately 60 oyster shells with a surface area of 1.48 m^2 per bag and 4.44 m^2 per three-bag mini-reef. Mini-Reefs consisted of two bags placed parallel side-by-side on the substrate, with the third bag placed parallel to and on top of the two bottom bags. The reef was secured in place by 61 cm (24 inches) and 91 cm (36 inches) lengths of 1.2 cm (½ inch) metal reinforcing bar bent into a crook at one end. In March 2012, 27 Mini-Reefs were deployed in the lagoon adjacent to the causeway. Elevations were approximately 0 – 1 ft. above Mean Lower Low Tide. Initial oyster settlement and survival was measured from November 2012 to February 2013. A second survey was undertaken in September 2013.

Oyster Futons

One oyster futon in foreground and another in the distance. Oyster spat collector sticks in between.

The design of Oyster Futons was meant to emulate the thin veneer of oyster shell often found natural occurring beds of Natives Oysters. Oyster Futons were fabricated by taking two flat sheets of 17-Gage galvanized wire (mesh opening 3.8 x 5.7 cm or 1-1/2" x 2-1/4") measuring 2.9 m X 0.94 m (2.73 m^2) and wiring them together at the edges to contain 2.0 m^2 of oyster shells in a single layer. 60 cm lengths of 12 mm steel reinforcing bar bent into a crook at one end were placed through the mesh to anchor it to the substrate. Futons were placed in areas of the lagoon where the substrate consisted of gravel. This placement was chosen so that the higher velocity tidal currents found at these locations would sweep the shells free of sediment. In June 2012, thirteen Oyster Futons were deployed in the lagoon at elevations approximately 0 – 1 ft. above Mean Lower Low Tide. In July 2012, futons were only placed on substrates composed of pebbles, cobble, and shell. These sites were thought to have less sedimentation. Futons were surveyed one month after placement. If found to be covered with silt and sand, the futons were moved to other sites that had more gravel. Surveys, where possible, were carried out in March 2013 and September 2013.

Stick and Bag

Stick and Bag collector. Notice minimal scour at base of stick.

Stick and Bag cultivation has long been used by the oyster farming community. The advantage of this approach is that oysters, contained on bags attached to the top of a stick, are held above the bottom and are less susceptible to sedimentation. The footprint is small, with only one post placed in the substrate, thus preventing excess sediment buildup or scour of the bottom. Stick and Bag collectors were made of a 1.8 m (6') long 3.8 cm diameter (1-1/2") or 5 cm diameter (2") PVC pipe placed vertically into the substrate to a depth of 0.6 – 0.9 m. Two Vexar plastic mesh bags (20 cm (8") diameter, 64 cm (25") long with 3.7 cm (1-1/2") openings, were lashed to the top of the pipe with polypropylene or similar rope.

This attachment is made easier if two 12 – 18 mm (1/2" – ¾") holes are made near the top of the pipe through which the rope can be threaded. The bags containing a total of 3.0 m^2 of oyster shell surface area. This configuration kept the bags suspended above the bottom. 5 Stick and Bag collectors were deployed. The elevation of these bags, approximately 0.6 – 0.6 m (1 – 2 ft.) above Mean Lower Low Water, was slightly higher than that of other collectors, as the bags were suspended above the bottom. The elevation of the bags was similar to the Oyster Spat Sticks. A test Stick and Bag substrate was placed in the lagoon in January 2013, followed by four additional collectors in May 2013. Surveys were conducted in September of 2013.

Limestone Monolith

Limestone monoliths oriented parallel to currents.

As mentioned previously, the majority of Native Oysters in Mugu Lagoon are found on the concrete walls of the causeway that crosses the lagoon. Since oysters prefer to settle on hard substrates, and particularly on the calcium carbonate shells of other oysters, it was thought that slabs of calcium carbonate may make low-cost long-lasting substrates for oyster settlement. To test this idea, limestone monoliths consisting of limestone paving stones of varying size (Approx. 60 x 46 x 5 cm, 24" x 18' x 2") were buried vertically in the substrate to half their longest dimension. Surface area above the substrate was approximately 0.1 m^2. In January 2013 four limestone monoliths were deployed in the lagoon at elevations approximately 0 – 1 ft. above Mean Lower Low Tide. When it was observed that the stones remained erect after several months, an additional six stones were added in May 2013. Surveys were done in September 2013.

Oyster strings

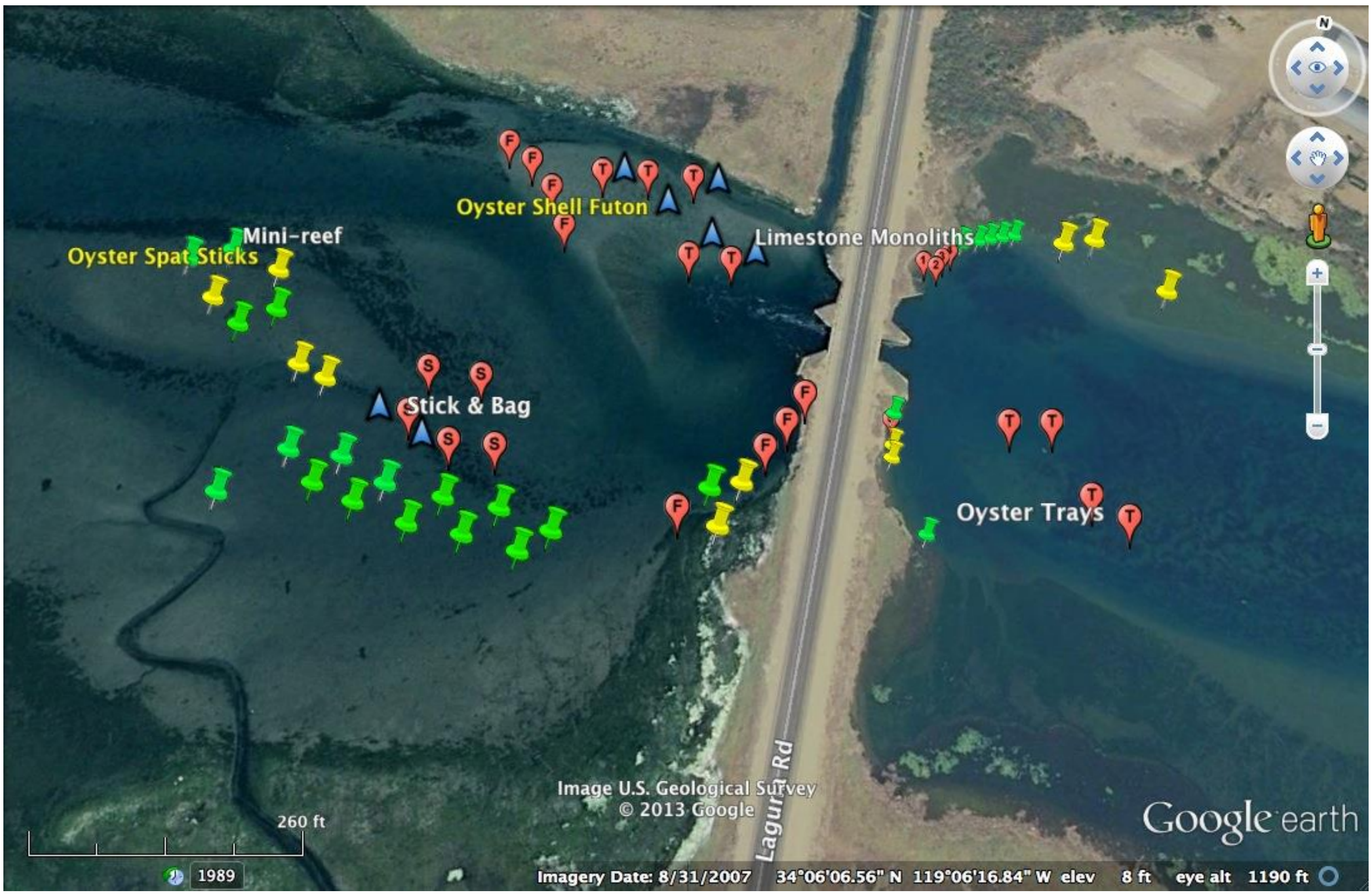
Oyster strings suspended from docks in Channel Islands Harbor

As a compliment to the work in Mugu Lagoon, oyster substrates were placed in the Channel Islands Harbor, whose mouth is 14 Kilometers (8.4 miles) from the mouth of Mugu Lagoon. Substrates were also placed at the terminus of the Edison Canal, which flows from the Channel Islands Harbor. Preliminary surveys had found Native oysters in the harbor and adjacent canal.

Oyster strings consisted of 2 m long strings with Japanese oyster shell strung at 15 cm (6 inch) intervals. The shell surface area for each string was 0.3 m^2. A hole was made in each shell to permit a string to pass through. Spacers to hold the shell apart were made of 15 cm sections of 1.2 cm (1/2 inch) polypropylene pipe.   Strings were suspended from docks in the Channel Island Harbor and Edison Canal. Eight oyster strings were deployed in the Channel Islands Harbor and another eight at the terminal end of adjacent Edison Canal.

Substrate Placement within Mugu Lagoon

In this work, substrates were deployed in Mugu Lagoon from 2011 through 2013. The image below shows deployment locations. Locations were chosen so that collectors were located on silt-sand, sand, pebble, or cobble substrates, not on soft mud.



Location of Oyster Substrates adjacent to Laguna Road causeway in Mugu Lagoon, Ventura County. Key: Green pin– Oyster Mini-Reefs, Yellow pin– Oyster Spat Sticks, Red balloon F – Oyster Futons, Red Balloon S – Stick and Bag, and Red Balloon T – Oyster Trays., Blue triangles - Limestone Monoliths.

Results

Review of oyster substrates

Oyster Trays– wire mesh platforms

Oyster Traysafter 30 days in Mugu Lagoon. High velocity currents removed almost all shell from tray on left. Low velocity currents deposited silt load on tray on left.

Oyster Trayswere not suitable for use in Mugu Lagoon. The above photos show Oyster Traysin Mugu Lagoon 30 days after deployment. High velocity currents removed shell from cages. Even when wire mesh was placed over the top of the oyster trays, the shells would be pushed to one side and algae, sticks, and other debris would become entangled on the tray. Cages moved to locations with slower currents were inundated with silt as is shown in the photo on the right. Trays did not perform well and were removed from the lagoon after a few months. No settlement of oyster spat in the cages was observed, since the shells were either swept out of the trays or covered in silt.

Spat Stick Collectors

Spat stick collectors were somewhat labor intensive to manufacture. The mixture of Portland Cement, sand, and granulated lime had to be applied to each stick by hand as seen below.

Coating sticks with cement, granulated lime, and sand mixture. At right coated sticks drying.

The quality of the coating varied somewhat from batch to batch. Spalling (flaking) of the cement coating occurred in two batches of sticks prior to deployment and they had to be recoated.

Spat stick collectors performed well in areas where tidal currents were not rapid, and were not inundated by silt as other settlement substrates were. However, when placed in locations with swift currents, the surrounding substrate would be scoured, undermining the stability of the sticks, as seen in the photo below.

Scouring of sediments around the bottom of spat collector occurred in areas of rapid water flows.

The surface of the sticks provided a suitable substrate for oyster, barnacles, and limpets as seen below. In summer the sticks would snag passing mats of algae (*Enteromorpha sp*.). Invertebrates such as Sea Hares (*Aplesia californica*) would spawn in the shelter of the spat stick, depositing their eggs in large masses.

Barnacles readily settled and grew on spat collector sticks. Algae carried by water currents was often deposited on the collectors.

Oyster settlement on the sticks was low relative to the min-reefs, with an average of 12 (range 4 - 35 oysters) oysters on each set of 36 sticks. The effective density of oysters was thus 4.3 oysters per m^2 of stick surface area.

Mini-Reefs

Construction of Mini-Reefs was relatively easy, requiring stucco wire to be cut, rolled, and fastened into tubes 8" in diameter by 24" long. Japanese oyster shell from commercial farms is available as substrate. While suitable for deployments of less than six months, the galvanized stucco wire rusted to the point of failure after that time. The rate of corrosion was accelerated between the bags or between the bags and the substrate. Movement of sand and silt was also a problem as they covered the lower portions of the

Mini-Reefs after several months. Even bags placed on a square piece of plywood became covered. The photos below show sand covering the Mini-Reefs.

Mini-reef buried to different extents by silt/sand after deployment for six months.

In spite of the sand movement, Mini-Reefs collected a large number of spat and promoted the growth of a large number of oysters. In 2012 the number of oysters on the Mini-Reefs was 621. In 2013 the number of oysters increased to 894 (a 44% increase), equivalent to 10 oysters per m^2 of oyster shell substrate.

Oyster Futons

Oyster Futons were easy to construct and deploy as seen in the pictures below.

Oyster futon construction and deployment in Mugu Lagoon.

Oyster Futons, a 2 m^2 two dimensional array of oyster shell held in place between two layers of stucco wire, did not perform well in Mugu Lagoon. These low-profile substrates were quickly covered by silt and sand. Even when futons were placed on areas of cobble, which is an indication of higher water current velocities, the complex surface texture reduced water velocities resulting in silt and sand deposits. Futons were buried in as little as 2 months, even if placed on top of cobble in areas with moderate water currents.

Partially buried oyster Futon

Oysters that did settle on shell in the oyster futon did not survive inundation by sand and silt, and only 26 and 43 Native Oysters were observed on the futons in 2012 and 2013.

Stick and Bag

Stick and Bag construction was straightforward, the components consisting of two plastic mesh bags tied to a single PVC pipe with polypropylene rope. Unlike all the other collectors, Stick and Bag components were made of plastic to extend the collector's useful life. Our experience with substrates containing metal showed that they are not suitable for long-term deployments in Mugu Lagoon.

In March 2013, shell for the Stick and Bag collectors was taken from Mini-Reefs that had been in place since 2012 and had Native Oyster densities of 5 oysters/m^2. By the time of the September 2013 census, the five Stick and Bag collectors with a total of nine shell bags accounted for 272 oysters. This is equivalent to an average density of 17 oysters /m^2 of oyster shell substrate, or almost twice the 10 oysters /m^2 density on the Mini-Reefs achieved in 2013. When making this comparison it should be kept in mind that usually half of the mini-reef would be covered in sand and silt, cutting the effective surface area in half. If only the number of oysters on the emergent portion of the Mini-Reefs is considered, the density of oysters there is equivalent to that on the Stick and Bag substrates.

Limestone Monolith

Limestone monoliths consisted of limestone paving stones available at a local building supply yard. Triangle shapes were selected to minimize the amount of algae that would catch on the edges. Monoliths were used as habitat by algae, barnacles, and limpets, see picture.

Limestone monoliths after six months with accumulation of algae and barnacles. Photo on left shows a limpet in lower area.

No oyster settlement was observed over the six months of deployment in 2013.

Oyster strings

Oyster strings were base on designs used by commercial oyster farmers. Only four oysters were observed at the Channel Islands Harbor location (1.7 oysters / m^2) with a similar number in the Edison Canal. Fouling by three species of tunicates as well as Bay mussles was heavy at the Edison Canal location.

Increase in Oyster population in Mugu Lagoon resulting from the addition of oyster substrates.

McCormick (2009) looked at settlement of native oysters throughout Mugu Lagoon and conducted surveys of hard substrates in areas where water quality supported oyster settlement and growth. The study estimated that the oyster population was between 5,400 and 7,100 oysters.

Our addition of oyster substrate to Mugu Lagoon in 2012 and 2013 resulted in a significant increase in the number of oysters found there. The number and square meter surface area of the oyster substrates placed in Mugu Lagoon over the course of this work is shown below:

Substrate Type	# Substrates	m^2	
Oyster Trays	9	2.25	
Mini-Reefs	27	120.2	
Spat Sticks	11	101.5	
Oyster Futons	14	28	
Stick and Bags	5	16	
Monoliths	10	1	
		269	m^2 of collector area

Substrates actually available for settlement and growth of oysters differed from the area of substrates deployed. This was due largely to inundation by sediments, or, in the case of the spat stick collectors, deterioration of the substrate. In the table below the number and surface area of intact substrates is shown as is oyster settlement and growth.

	2012					2013				
Substrate Type	# of Intact Collectors	Total Area of Collectors m^2	# of Oysters	Average Shell Length mm	# of Oysters per m^2	# of Intact Collectors	Total Area of Collectors m^2	# of Oysters	Average Shell Length mm	# of Oysters per m^2
Mini-Reefs	27	120	621	24	5	20	89	894	34	10
Spat Sticks	11	102	119	36	1	6	17	29	44	2
Oyster Futons	0	0	0	0	0	6	12	26	44	2
Stick and Bags	0	0	0	0	0	5	16	272	37	17
	m^2 of Substrate	222	740	# Oysters		m^2 of Substrate	134	1,221	# Oysters	

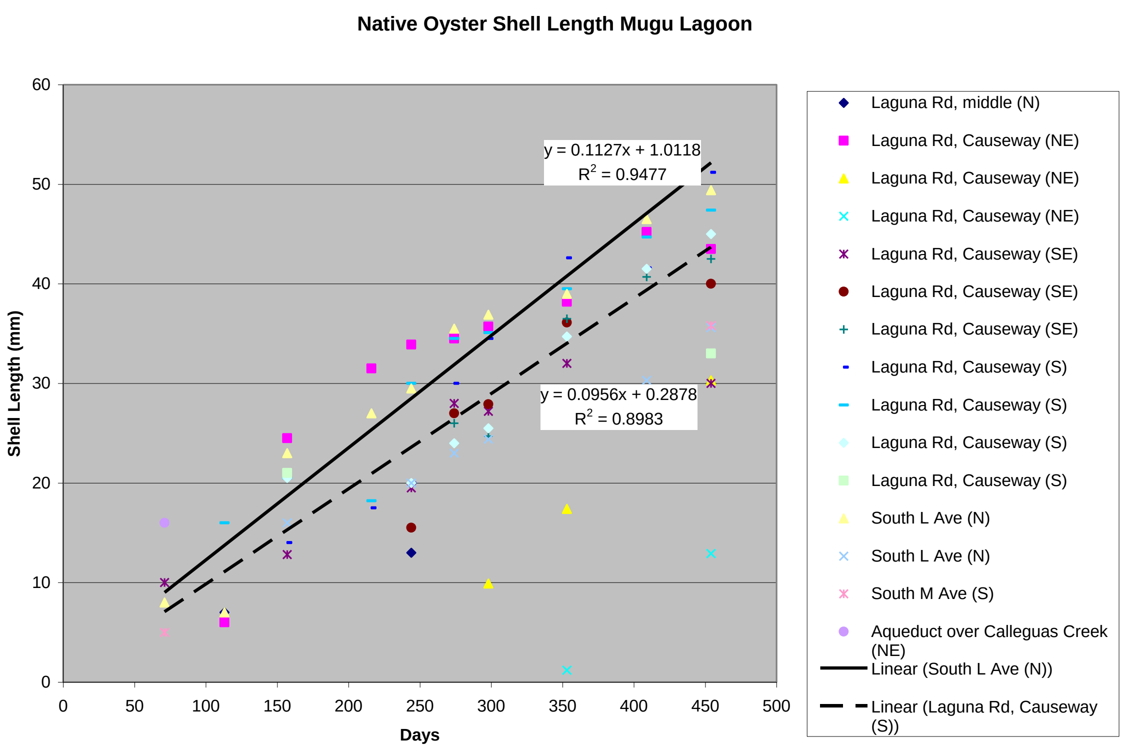
The table shows the change in the amount of substrate available each year. In the case of the Oyster Futons, even though 28 m^2 was originally placed in the lagoon, only 6 m^2 were still exposed after several months. Likewise, Oyster Spat Sticks, which had been put in place in August 2011, were rotting away by Fall 2013, resulting in less surface area.

The table shows almost a doubling in the number of oysters, from 740 in 2012 to 1,221 in 2013. This increase occurred in spite of a 40 per cent decrease in the amount of substrate surface area. Densities on the Mini-Reefs doubled from 5 to 10 oysters / m^2 of substrate. Densities of oysters in the Stick and Bag substrates increased from 5 oysters per m^2 in March 2013 to 17 oysters per m^2 in September 2013.

In 2013, the 1,221 oysters on the substrates increased the oyster population in Mugu Lagoon by 17 – 23 percent over the 2009 estimate. Most of this increase can be attributed to the mini-reef and Stick and Bag collectors.

Growth Rates

Growth rates of Native Oysters in Mugu Lagoon is shown in the following figure.



Newly settled spat were first observed at a shell length of 6 mm or larger. Over a period of 454 days starting in 2008, oysters grew to a shell length of 30 to 50 mm. The 50 mm maximum growth rate was equivalent to 0.11 mm per day, 3.4 mm per month, or 40 mm per year. The relationship between time and shell length for South L Avenue is:

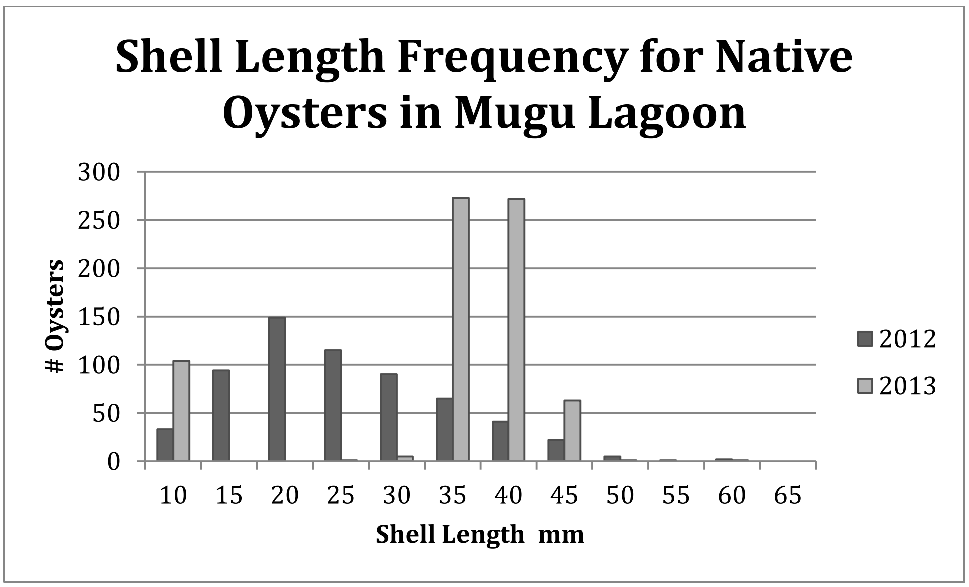
Shell length = 0.1127*Days – 1.0118

At a growth rate of 30 mm per year the relationship is:

Shell length = 0.0956*Days + 0.2878

At a growth rate of 3 mm per month, newly settled oysters 6 mm in length would be 2 months old. Couch and Hassler (1989) noted that after spawning, Olympia (Native) oysters brood fertilized eggs for 10 – 12 days. The larval veliger stage lasts another 11 – 16 days. Given this time-table, 6 mm spat first found in the collectors in September had grown in place for two months preceded by 3 – 4 weeks of egg and veliger development. This would place the first spawning in June. In Mugu Lagoon, spawning occurs throughout the year as evidenced by the continual presence of newly settled spat, 5 mm or larger, in the oyster collectors.

While growth rates may be as rapid as 3 mm per month, the median growth rate of the oyster population studied is less. The size frequency distribution of oysters on substrates in 2012 and 2013 is shown in the chart below.

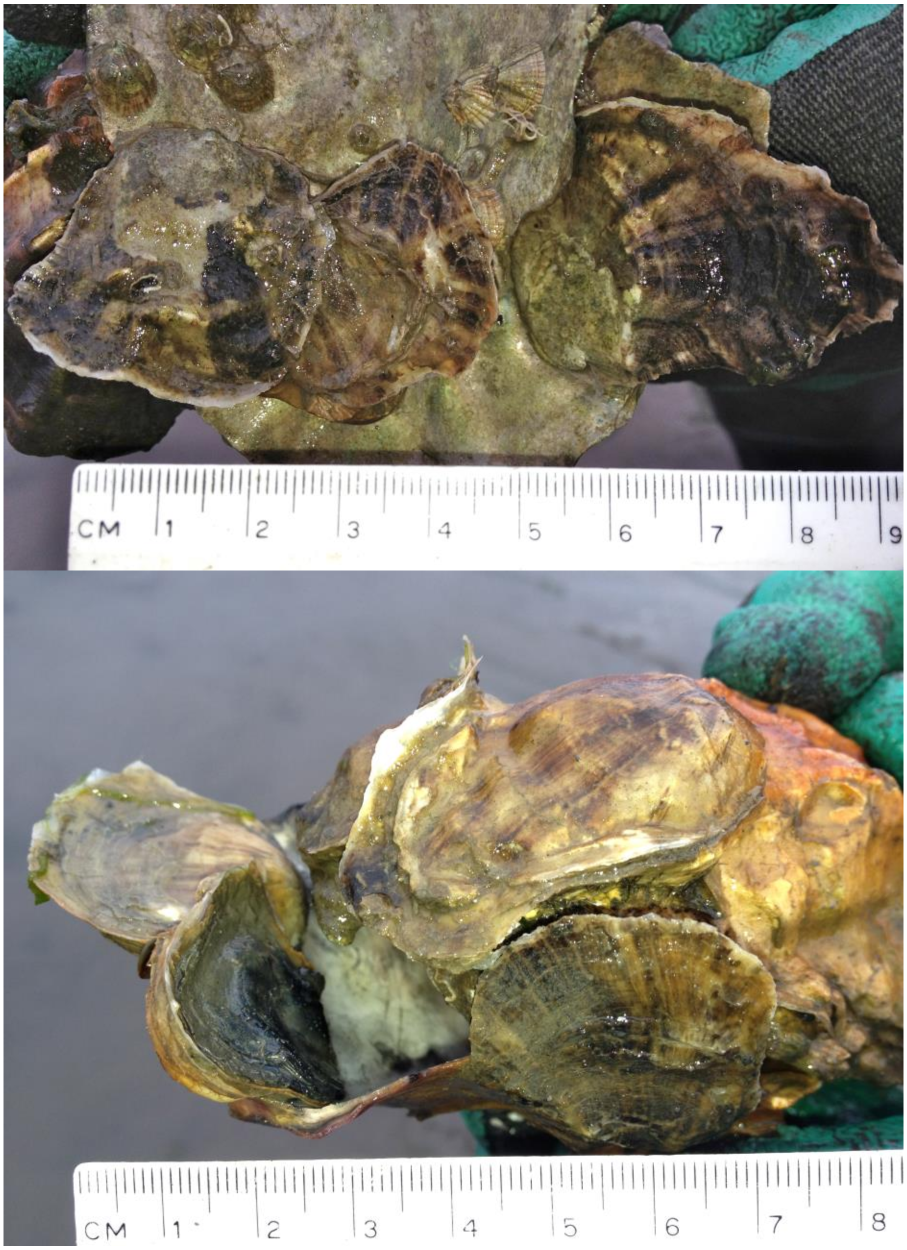


The size frequency chart shows a cohort of oysters increasing in size over two years. In 2012 the average shell length was 22 m. By 2013 it was 40 mm.

Surveys of oysters found on the collectors conducted in November and December 2012 found the median shell length of oysters on Mini-Reefs to be 22 mm (n = 621). If spawning occurred in June, these oysters would have been 6 to 7 months old, with a growth rate of 3.7 – 3.1 mm per month. Between December 2012 and September 2013, the median shell length had increased to 40 mm. The second year growth rate was 18 mm /year, or 1.3 mm / month (n = 894). A new cohort of 100 oysters with an average shell length of 10 mm is shown by the 2013 curve. These oysters would have been about three months old as of the September survey, yielding a growth rate of 3.3 mm / month.

Survival

Our observations of oyster survival from 5 mm spat to sizes 30 mm or larger indicate that survival at 80% is quite high. No predation of oysters was observed, with the greatest cause of mortality apparently attributable to inundation by sediments.



Native oysters growing on shell from Mini-Reefs, September 2013.

A note on Japanese oysters (*Crassostrea gigas*) in Mugu Lagoon.

Japanese oysters settled and grew on the substrates during this study. They were most noticeable in 2013 when their numbers made up 1 – 2% of the oysters observed. Their growth rate appears to be twice that of the Native Oysters, with many animals achieving a shell length of 60 – 95 mm by September 2013, see picture below.

Both Native Oysters (above) and Japanese oysters (below) settled and grew on the collection substrates.

Conclusions and Lessons Learned

Hydrology of Mugu Lagoon

Prior to European settlement, the abundance of shellfish, fishes, and birds, in and around Mugu Lagoon supported permanent habitation by the Native American Chumash people. In the 1880s the channeling of Callegaus Creek into the lagoon radically changed its hydrology, transforming it into an estuary. Heavy sediment loads carried by the creek coupled with other human activities reduced the size of the lagoon to half of its former extent. The Ventura County Flood Control District[1] estimates that Callegaus Creek delivers 240,000 tons of sediment to Mugu Lagoon each year. Silt is deposited throughout the lagoon, except in areas of high velocity water flow. Natural oyster beds that may have previously existed within the lagoon would have been buried under the sediment load.

Additional hydrologic changes were brought about by construction of a causeway for Laguna Road in the 1950s that constricted tidal flow to the western part of the lagoon creating a localized zone of high velocity seawater flows. The concrete, steel, and rock riprap structure of the causeway now provides hard substrate for an estimated 5,400 – 7,100 Native Oysters as well many more Bay and California mussels, barnacles, limpets and other invertebrates.

Hydrologic conditions within the lagoon present a challenge for enhancement of the Native Oyster population. Shallow intertidal locations at long distances from the mouth of the lagoon experience greater temperature fluctuations (8°– 25°C+) and typically have silt/mud bottoms, conditions that make them unsuitable for placement of oyster reefs. Seawater temperatures around the causeway are more moderate, but high-velocity water flows make some substrate types unstable. Rapidly shifting sediments within the lagoon can bury low-lying substrates within one lunar cycle or less.

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[1] Ventura County Flood Control District, http://www.calleguas.com/ccbrochure/flood.html

Oyster Substrates

Notwithstanding the present conditions within the lagoon, we have found that placement of suitable substrates in the intertidal areas of Mugu Lagoon close to the Laguna Road causeway can appreciably increase the population of Native Oysters. Of the five substrates tested, Mini-Reefs and Stick and Bag collectors performed the best. Average oyster densities on the Mini-Reefs were 5 per m^2 in 2012 increasing to 10 per m^2 in 2013. This number represents the upper range of the target density that we proposed in our original grant proposal. Placement of Mini-Reefs directly on the substrate makes them subject to inundation by moving silt and sand. They can become half buried after 6 months. Long-term burial of the lower shells of the mini-reef is fatal to oysters that have settled there. Additionally, the galvanized wire mesh used for the Mini-Reefs is unsuitable to hold oyster shells, as it rusts to the point of failure within 6 months. Even with these shortcomings, 120 m^2 of Mini-Reefs grew 621 Native Oysters in 2012, and 89 m^2 of Mini-Reefs grew 894 oysters in 2013.

Stick and Bag collectors, are the most suitable substrate tested in Mugu Lagoon. They are low cost, consisting of two Vexar plastic mesh bags roped to a single "stick" consisting of a six foot section of 2" Schedule 80 PVC pipe. One person with a sledgehammer can drive the pipe 50 – 60 cm (2 – 3 feet) into the substrate. Their design keeps bags of oyster shell above the substrate, avoiding problems with changing silt levels. Stick and Bag collectors can be placed where water velocities are sufficient to keep silt from covering the shell contained within the bag. The only footprint of this collector is the point where the stick enters substrate. This small footprint minimizes scour during high velocity water flows. Oyster densities in the Stick and Bag collectors were the highest observed in all of the collectors. Bags starting with shell taken from Mini-Reefs (5 oysters per m^2) in March

2013 had densities of 17 oysters per m^2 by September 2013. These densities were almost twice those of the Mini-Reefs. The five experimental Stick and Bag collectors (total surface area 16 m^2) grew 272 oysters in 2013.

Given the nature of the hydrology of Mugu Lagoon today, it does not appear possible to establish extensive low relief oyster beds. In most areas of the lagoon, shell used to construct such reefs would sink into the soft mud or be covered by new sediment. In areas near the causeway, high water velocities scatter shell and deposit sand, pebbles, as well as clam and mussel shells.

Engineered substrates can be used effectively to increase available surface area for oysters. In 2012 using 222 m^2 of substrates, we increased the estimated population of Native Oysters in Mugu Lagoon by 740 animals. In 2013, with 134 m^2 of substrates, we increased the estimated population by 1,221 oysters. These numbers represent an increase in the total oyster population by 17 – 20% in 2013. Using Stick and Bag collectors, the overall oyster population in the lagoon could be increased 20% by adding 18 - 24 collectors. A 50% increase could be achieved with only 45 – 58 collectors. Longevity of the plastic Stick and Bag collector may be five years or longer. Bags would have to be removed at intervals to remove fouling organisms such as mussels and to replace the rope that holds the bags to the stick. The Limestone Monoliths may yet prove to be a suitable substrate for oyster settlement and growth. Reef balls may provide another option, if they do not sink into the mud. Deployment would require some labor since they would have to be carried into the lagoon as there is no boat access.

Moving forward, we plan to move oyster shell from Mini-Reefs into Stick and Bag collectors. We will continue to monitor settlement and growth of oysters in the Stick and Bag collectors and on the Limestone Monoliths.

References

Couch, D and T.J. Hassler. 1989. Species profiles. Life histories and environmental requirements of coastal fisheries and invertebrates (Pacific Northwest). Olympia Oyster. U.S. Fish and Wildlife Service Biological Report 82(11.124), U.S. Army Corps of Engineers TR EL-82-4. 8 pp.

Manley J., A. Power, and R. Walker. 2008. Wild Eastern Oyster, *Crassostrea virginica*, spat collection for commercial grow-out in Georgia. Occasional Papers of the University of Georgia Marine Extension Service V.2, 16 pp.

McCormick, T.B. 2009. Final Report: Oyster Restoration for Mugu Lagoon – Preliminary Population Assessment. Prepared for Navy Facilities Engineering Command, Navy Base Ventura County, Point Mugu, CA 22 pp.

Geographic Coordinates (in decimal degrees):

Longitude (X-coord): 34°06'08.52"N
Latitude (Y-coord): 119°06'17".35" W

Are there multiple project sites for this award?* __ Yes X No

River Basin: Mugu Lagoon is located at the mouth of Calleguas Creek.

Geographic Identifier: Mugu Lagoon

Project Start Date: Spring 2011 Project End Date: Spring 2012

Amended Dates: Start August 5, 2011 end October 31, 2013

I. **Permit Status:** The U.S. Navy has contacted the Army Corps of Engineers for an extension of permits for the placement of oyster substrates within Mugu Lagoon.

II. **Species Benefitting:** Olympia oyster *Ostrea lurida.* Reef habitat will increase biodiversity within the lagoon, enhancing populations of invertebrates, fishes, birds, and mammals. Periodic movement of smaller species from the highly productive waters of Mugu Lagoon contribute to greater fish concentrations in the deeper waters of the Mugu Submarine Canyon.

III. **Project Partners:** U.S. Navy, nrg Energy (formally GenOn Energy), local colleges and schools.

IV. **Project Timeline**

A no-cost extension of this project enabled us to get two years of settlement and growth data, as well as to try alternative settlement and growth substrates including the Stick and Bag and Limestone Monoliths. The first of which has proved very successful. We are now working with the Navy to determine if some of the collector substrates can be left in the lagoon to enhance oyster populations.

V. **Monitoring and Maintenance Activities**: Monitor oyster settlement and survival on oyster substrates within Mugu Lagoon. Replace materials rusted wire in Mini-Reefs. Place new substrates in the lagoon in anticipation of spring and summer spawning events**.**

VI. **Community Involvement:**

We involved two different segments of the local school population in this work. Biology students from Oxnard College (a local junior college) and elementary students from Tierra Vista Elementary School learned about Native Oysters through classroom lectures and by visiting the site in Mugu Lagoon. There they learned about the intertidal lagoon habitat and its importance to aquatic and avian populations. Students also learned how Native Oysters create habitat and link planktonic and benthic communities. Students helped deploy substrates and participated in oyster surveys, gaining hands-on experience in field survey techniques and data collection.

	This reporting period:	To-date (cumulative):	Projected for completed award:
Volunteer Numbers:	126	217	500 - 700
Volunteer Hours:	137	396	447

Tierra Vista Elementary Students look at oysters in Mugu Lagoon.

VII. Outreach Activities: Students from Oxnard College and Tierra Vista Elementary School have been helping to deploy substrates and count oysters in Mugu Lagoon.

VIII. Supporting Materials Pictures included in this report, CIMRI Oyster Fact Sheet (attached).

IX. Project Budget and Expenditures (from Financial Report)
July 13, 2013 to October 31, 2013

CATEGORIES	Budget (A)	Prior Period Expenses (B)	Prior Period Adjustments (C)	Current Period Expenses (D)	TOTAL Project Expenses to Date (E=B+C+D)	Balance (F= A-E)
A. PERSONNEL	$22,000	18,738.06	-	6,046.78	24,784.84	(2,784.84)
B. FRINGE BENEFITS	$4,400	3,438.52	-	1,209.36	4,647.88	(247.88)
C. TRAVEL	$1,000	226.90	-	-	226.90	773.10
D. EQUIPMENT (over $5000)					-	-
E. SUPPLIES (Equip under $5K)	$2,150	886.46	-	-	886.46	1,263.54
F. CONTRACTUAL	$1,000	-	-	-	-	1,000.00
G. CONSTRUCTION					-	-
H. OTHER	1,850.00	1,500.00	-	350.00	1,850.00	-
I. TOTAL DIRECT COSTS	32,400.00	24,789.94	-	7,606.14	32,396.08	3.92
			-			-
K. TOTALS	32,400.00	24,789.94	-	7,606.14	32,396.08	3.92
				PERCENTAGE OF AWARD BUDGET SPENT	100%	

MATCH EXPENDITURES

CATEGORIES	Budget (A)	Prior Period Expenses (B)	Prior Period Adjustments (C)	Current Period Expenses (D)	TOTAL Project Expenses to Date (E=B+C+D)	Balance (F= A-E)
A. PERSONNEL		-	-		-	-
B. FRINGE BENEFITS		-	-		-	-
C. TRAVEL		-	-		-	-
E. SUPPLIES (Equip under $5K)		-	-		-	-
F. CONTRACTUAL		-	-		-	-
H. OTHER: Volunteer Hours	$10,400	6,917.17	-	1,714.14	8,631.31	1,768.69
H. OTHER: GenOn Lab Use	$12,000	21,004.11	-	3,000.00	24,004.11	(12,004.11)
H. OTHER: GenOn Contribution	$10,000	12,950.90	-	-	12,950.90	(2,950.90)
I. TOTAL DIRECT COSTS	32,400.00	40,872.18	-	4,714.14	45,586.32	(13,186.32)
		-				-
K. TOTALS	32,400.00	40,872.18	-	4,714.14	45,586.32	(13,186.32)
PROJECT TOTALS	**64,800.00**	**65,662.12**	**-**	**12,320.28**	**77,982.40**	**(13,182.40)**

Please explain any deviations from the approved budget (note that most budget changes require prior approval): Additional time was needed for final surveys of oysters in September 2013. Unexpended funds from Travel ($773.10), Supplies ($1,263.54), and Contractual ($1,000.00) were used for Personnel expenses.

Briefly describe the total project cost, including the source and value of other contributing funds (leverage that is not counting towards your official match):

Community engagement with the US Navy, NRG Energy (formally GenOn Energy - an electric company), as well as local colleges and elementary schools provide the leverage and additional funding needed to continue to work on this no-cost extension period of the project. Part of the value of these resources is reflected in the Budget as Match Funds. Support with permitting requirements, use of facilities, and community participation extend beyond he value shown in the budget sheet.

The undersigned verifies that the descriptions of activities and expenditures in this progress report are accurate to the best of my knowledge; and that the activities were conducted in agreement with the grant contract. I also understand that matching fund levels established in the grant contract must be met.

*Grantee Signature:*____

Grantee Name: Thomas. B. McCormick

Senior Scientist

Channel Islands Marine Resource Institute