Figure 1. Kaplan Cove, Fall 2009

PHOTO: MARK CORCORAN, STARCREST PRODUCTIONS

Giant Kelp Community Restoration in Santa Monica Bay

TOM FORD AND BRIAN MEUX

To address the loss of approximately 80% of the giant kelp forests (MBC Applied Environmental Sciences 2009, Wilson and North 1983) in Santa Monica Bay, the Santa Monica Baykeeper has been engaged in the ecological restoration of kelp forests off Malibu and the Palos Verdes Peninsula. Two techniques are applied in this effort, sea urchin relocation and sporophyll bag stocking and deployment. To date, efforts off Escondido Beach in Malibu have resulted in a spatially and temporally stable kelp forest since 2004. Similar success has been documented in Long Point, Palos Verdes, with the rapid return of giant kelp and other algae to the reef once sea urchin densities were reduced to 1 to 2 per square meter in 2008 and again in 2009. In total, 7.5 acres of giant kelp communities have been reestablished.

DR. WHEELER NORTH WAS A PIONEER of giant kelp restoration, and he originally found the density of one to two sea urchins per square meter to be indicative of spatially stable forests in Southern California in the 1970s (W. North, pers. comm.). Dr. North, the California Department of Fish and Game, and hundreds of volunteer SCUBA divers attempted to restore giant kelp to the Palos Verdes Peninsula. In this instance, ten years were spent literally smashing sea urchins with hammers underwater and transplanting kelp from Malibu and Catalina Island. In the end, this effort was quite successful, and the Palos Verdes Peninsula for the first time since the 1940s had a stable kelp forest. Both the North-led efforts in the 1970s and the Santa Monica Baykeeper efforts in the late 1990s and 2000s focused on reducing grazing pressure by sea urchins on these reefs. The hypothesis tested was that if sea urchin grazing was reduced the kelp would be able to recruit and grow.

Giant kelp (*Macrocystis pyrifera*) is a large brown alga found along the coasts of Alaska, central and Southern California, and in many places in the Southern Hemisphere. Giant kelp typically grows from the ocean floor to the surface in 3 to 24 meters (10 to 80 feet) of sea water (Abbott and Hollenberg 1976), and in ideal circumstances may grow two feet per day. In most cases, giant kelp attaches itself to rocks on the bottom with a holdfast, or haptera that anchors this buoyant giant in place. Giant kelp in Southern California has a fairly short life span; one to three years is typical. During this short life span, a giant kelp plant is a source of food, shelter, or substrate for numerous species. Many kelp plants drift up and down our coastline following currents and waves with many of these species still attached or associated with the plant (Dayton 1985; Foster and Schiel 1985; Hobday 2000).

In Southern California, the giant kelp forest community supports roughly 716 described or known species, encompassing marine mammals, birds, fishes, and invertebrates (Graham 2004). For giant kelp to persist, the ecosystem, of which the kelp is the foundation, must be resilient to disturbance and have the proper environmental conditions and ecological controls. The environmental conditions can be simplistically described by ocean climate and chemistry: clear, cool nutrient-rich water (Jackson 1977; Zimmerman and Kremer 1986). Ecological controls are specific to the interaction between the various individuals living on the reef and in the kelp. Assuming there has not been a huge change in the ocean,

Figure 1. Pre-Restoration: Site Dominated by Purple Urchins


PHOTO: MARK CORCORAN, STARCREST PRODUCTIONS

Figure 2. Quadrant Species Count


PHOTO: BAYKEEPER

Figure 3. Urchin Removal


PHOTO: DAVE WITTING, NOAA

Figure 4. Lift Bag


PHOTO: BAYKEEPER

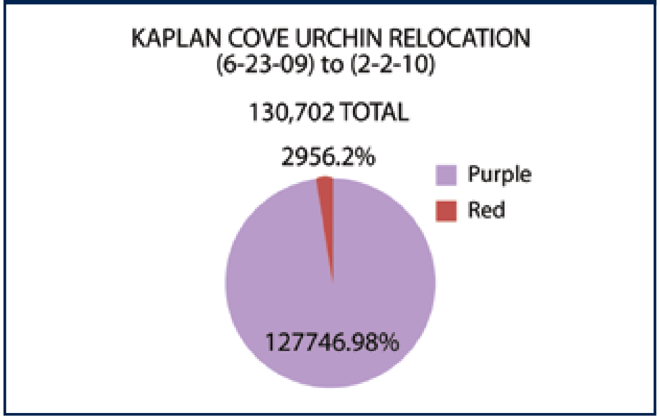
the fish and wildlife play key roles (Edwards 2004; Harold and Reed 1985). Predators keep herbivore populations in check through depredation, competitors jostle for food and space, etc. When most of the players are present, the system has a set of checks and balances that regulate the structure and function of the ecosystem, and it remains robust through time and space (Edwards 2004; Harold and Reed 1985).

The numerous stressors affecting the kelp beds in Santa Monica Bay are not an isolated phenomenon. Studies of kelp communities around the globe demonstrate kelp loss due to the changing climate, overfishing, habitat loss, invasive species, and pollutants (Steneck et al. 2002). In most places, too many urchins now graze the rocky reefs, removing giant kelp before the next generation can grow while marginalizing the health of standing adults (Steneck et al. 2002). Control of the urchin population in Southern California was maintained by three principal predators: the southern sea otter (*Enhydra lutris nereis*), California spiny lobster (*Panulirus interruptus*), and California sheephead (*Semicossyphus pulcher*). The southern sea otter was locally extirpated by Russian furriers in the mid-1800s (Jackson 2001). Both sheephead and lobster are intensively fished by recreational and commercial fisheries (California Department of Fish and Game 2001; California Fisheries Fund 2009). Notably, in the newly established marine reserves in the northern Channel Islands, where fishing is prohibited, the sheephead and lobster are relatively abundant, and the kelp forest is larger, denser, and more stable (Behrens and Lafferty 2004; Airame and Ugoretz 2008).

The principal method used to restore kelp forests in this project mimics the effect of the predators that naturally limit or control their prey. So if the otters are locally extinct and the lobster and sheephead are scarce, humans were needed to remove the sea urchins from the system. The target density for our project over the past ten years has been to reduce sea urchin densities to one or two per square meter. Recent research from Chile, New Zealand, and South Africa determined this sea urchin density to be the threshold between a stable kelp forest and one destined to become or remain an "urchin barren." An urchin barren is a reef supporting not much more than the urchins themselves (Figure 1). As further cause for restoration, urchin barrens have the potential to last for many years in an ecological and economically depauperate condition (Steneck et al. 2002; Tegner and Dayton 2000).

The earliest phase of fieldwork involves the establishment of sites on the rocky reefs. These sites will serve as the controls, references, and restoration sites for this experiment. Through this experimental design, we are able to describe the natural trends affecting all of our sites and determine if our restoration efforts are producing a result. Over time, our monitoring has undergone some modifications to improve its accuracy and increase its applicability to other efforts. In short, various monitoring methods are employed at each established site before restoration actions, during restoration, and following restoration for a period of five years. Monitoring methods include fixed and random quadrats (1 meter square, 12 pairs) (Figure 2) and band transects (2 meters by 30 meters). The

Figure 5. Relocated Urchins: Quantity and Type



quadrats and band transects target benthic organisms from different trophic levels. These organisms are selected for a few reasons: 1) for their known ecology, 2) rarity, 3) species likely to benefit or respond to kelp restoration efforts, and 4) invasive or non-endemic species. The relationship between giant kelp and sea urchins requires extra scrutiny. Therefore, giant kelp and sea urchin size and frequency sampling is performed to describe the density of these organisms and to infer less specific information regarding age class, fecundity, and responses to a variety of biotic and abiotic factors or events.

In efforts to advance the applicability of our monitoring and compliment monitoring efforts throughout Southern California, we are increasingly using Cooperative Research and Assessment of Nearshore Ecosystem (CRANE) methods. These methods are applied in whole or in subsets to quantify and qualify many of the same characteristics that our other monitoring achieves. With the addition of CRANE methods, the relative ecological values for all our sites can be compared with other reefs throughout Southern California and in some areas of the central coast (Point Conception to Santa Cruz). In summary, these methods are used to track key species and ascertain the presence or absence of certain ecosystem functions and structure. Underwater photography has been a wonderful tool used in this project to document conditions, demonstrate progress, and assist our public outreach and volunteer training.

The first method employed involved the relocation of sea urchins to reduce the densities from, in extreme cases, 70 sea urchins per square meter to 1 to 2. Urchin relocation for three acres of sea floor in Escondido totaled 32,428 individuals. This work is done by manually plucking or prying the sea urchins off the rocks, placing them in large nylon mesh bags, and floating them to the surface with lift bags (Figures 3 and 4). Lift bags are large bladders that are inflated at depth from SCUBA tanks or other air sources. Once at the surface, the bags are collected at the side of the boat and hoisted on board with a crane. All the sea urchins were typed by species and counted. The sea urchins were then distributed across broad areas of the ocean floor away from the reefs where the sea urchins had been collected.

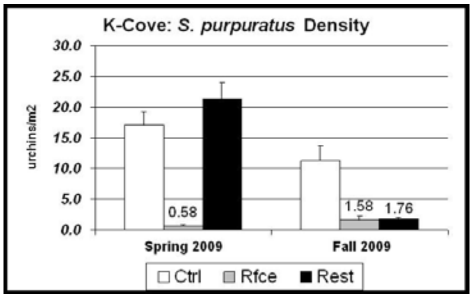
The second method involved the deployment of sporophyll bags. Sporophyll bags replicate the production of spores in the absence of a mature kelp plant. A sporophyll bag is a mesh bag containing 50 to 80 ripe sporophylls anchored to and floating at one meter above the bottom. Giant kelp reproduction starts with the production of spores. These spores are generated in sporangia located in sporophylls, specialized reproductive blades found near the holdfast (Abbot and Hollenberg 1976). In cases where the giant kelp adults are too far away or they have been absent for a few years, enhancing the dense settlement of kelp spores would expedite the reestablishment of the kelps. After placing the sporophyll bags strategically and repeatedly restocking them over periods of two weeks to one month, we were able to enhance the dense settlement of kelp spores on the rocky reef, a key step in the restoration of a kelp forest.

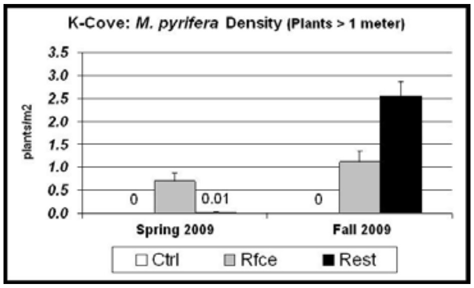
In 2005, the Kelp Project focused this suite of restoration techniques on a section of reef off Long Point, Palos Verdes. This area was larger, has greater exposure to winter storms, and contained higher relief substrate than the reefs off Escondido Beach. Restoring giant kelp to this reef would be a good test of the applicability of our techniques. Persistent red tides in 2005 and 2006 and a 200-year wave event greatly limited our access to the site and reduced our operational windows dramatically. By September 2008, 281,710 sea urchins were relocated from Long Point to restore three acres of kelp forest. In April 2009, restoration immediately up coast from our first Long Point site began, and within a few short months, the ecologists and volunteers of the Kelp Project relocated 118,092 urchins from a 1.5-acre area (Figure 5). In November 2009, giant kelp was already returning to this last site at or above the target densities (Figure 6).

Figure 6. K-Cove: Six Months Post-Restoration

PHOTO: BAYKEEPER

Figures 7 & 8. Restoration Results





CONTROL

REFERENCE

RESTORATION

The densities of urchins and kelp at Kaplan Cove (K-Cove) are depicted in Figures 7 and 8.

Both the Malibu and Palos Verdes Kelp Projects have demonstrated the success of these techniques when applied to the restoration of historic kelp forests. The barren reefs are transformed, benefiting the natural community of fish and wildlife, tourism, recreation, and local fisheries. Areas once dominated by urchins are now full of life, increasing the quality of life for the people of Los Angeles that pursue hobbies and other activities in or around the kelp forests.

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