RESTORATION OF A HISTORIC EELGRASS (*ZOSTERA MARINA*) BED AT FRENCHY'S COVE, ANACAPA ISLAND

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ABSTRACT—Frenchy's Cove, Anacapa Island, was chosen for a pilot restoration study of an eelgrass (*Zostera marina*) bed that had previously been decimated by white urchin overgrazing in the 1980s. The project was a cooperative effort between the non-profit organization Santa Barbara Channelkeeper, the Channel Islands Research Program (CIRP), and NOAA Fisheries' Community-based Restoration Program. Restoration efforts at Frenchy's Cove began in July 2002. Transplants were harvested by divers from large beds (Smugglers, Prisoners) near the east end of nearby Santa Cruz Island. Five-hundred shoots were planted at a variety of depths within the historic range of the Frenchy's Bed (6 to 12 m). The study site was visited every 1 to 2 months and numbers of shoots were counted. In addition, we documented the study with video. Coinciding with restoration efforts, we witnessed the spread of the brittlestar (*Ophiothrix spiculata*) up into shallow water at Frenchy's. Brittlestars (densities >1000/m^2) directly interfered with eelgrass survival and by December 2002 eelgrass mortality neared 95%. After winter storms brittlestars declined dramatically and by April 2003 new eelgrass shoots and young seedlings appeared. Sixteen months after transplanting, in the absence of disturbance from brittlestars, eelgrass shoots surpassed initial transplant densities in shallow plots. Results from this pilot study are promising for future restoration efforts around the Channel Islands and elsewhere.

Keywords: brittlestar, eelgrass, recruitment, restoration, white urchin, Zostera Marina

INTRODUCTION

Seagrass beds form important coastal habitats by supporting complex food webs, filtering out nutrients, and stabilizing sediments (den Hartog 1970, Fonseca et al. 1990). Species diversity in eelgrass (*Zostera marina*) beds can be nearly twice as high as on nearby sandy intertidal and subtidal habitats (Engle et al. 1995). In California, eelgrass beds are nurseries for many common and commercially important fishes, including rockfish (*Sebastes* sp.), surfperch (*Embiotocidae*) and kelp bass (*Paralabrax clathratus;* Hoffman 1986, Engle et al 1995).

World-wide, seagrass populations have declined, due primarily to human impacts including population growth, nutrient-loading and eutrophication, as well as from natural causes such as urchin grazing (Keller 1983, Valentine and Heck 1991, Short and Wyllie-Echeverria 1996). In southern California, eelgrass has been severely impacted by increased turbidity, dredging, construction and pollution within its habitat of shallow bays and coastal lagoons (Merkel 1991). Environmental laws such as the Clean Water Act require mitigation for any construction project that might impair eelgrass beds and wetland habitat, and eelgrass mitigation policies have required enhancement or restoration of beds at ratios of 1.2:1 (Southern California Eelgrass Mitigation Policy, National Marine Fisheries Service 1991). Between 1976 and 1997, there were 36 eelgrass transplant projects in California (National Marine Fisheries Service, Southwest Regional Office 1997). Almost without exception these projects occurred as mitigation for coastal development. Unfortunately, the same pollution associated with growing development pressures that impacts the native beds or habitat also negatively impacts the transplanted or restored beds; some report that as few as 10 to 60% of transplantation efforts are successful (Goforth and Peeling 1978, Thom 1990, National Marine Fisheries Service 1997). Moreover, there have been no restoration efforts conducted in relatively pristine waters; all work has been associated with coastal pollution (Short and Wylie-Echeverria 1996).

Though eelgrass commonly grows in bays and estuaries, and is an important intertidal resource throughout much of its range, beds occur only subtidally at the exposed Channel Islands where their depth and spatial distribution is limited by wave exposure. Unlike intertidal eelgrass beds where acreage can be documented by aerial photography, subtidal beds are surveyed using resource-intensive SCUBA techniques. A full description of the extent of island beds can be found in Engle et al. (1998) and Engle and Miller (2005). Compared to eelgrass along the mainland, beds at the mostly uninhabited Channel Islands face relatively few impacts. However, threats to these island beds include not only natural occurrences, such as storms, heavy surf and sediment movement, but also pollution and disturbances from visiting boats. The Channel Islands are a popular boating destination, both for pleasure and commercial interests, and the sheltered coves where eelgrass grows are desirable anchorages; cumulative impacts from dragging and pulling anchors can be significant.

The historic eelgrass beds at Frenchy's Cove and around Anacapa Island were decimated by overgrazing by the white urchin (*Lytechinus anamesus*) following an extraordinary post- El Niño recruitment event (Engle et al. 1995). We hypothesize that eelgrass has not returned to Frenchy's Cove because recruitment due to seed dispersal is poor at best, and most eelgrass beds spread from vegetative growth (Oleson and Sand-Jensen 1994). Urchins are known to be important in regulating seagrass beds around the world (Keller 1983, Valentine and Heck 1991). Now that urchin levels have dropped to more 'normal' densities at Frenchy's, the risk of overgrazing is slim; however eelgrass, unlike kelp, has not recruited successfully. Our pilot project, described here, tested the relative success of transplanting adult plants from nearby Santa Cruz Island.

We chose pristine Anacapa Island for eelgrass restoration for several compelling reasons. First, island populations can be seen as genetic refugia against coastal extinctions. Second, island populations do not face the intense urban pollution that eelgrass in much of southern California does. Third, although the Channel Islands Marine Sanctuary and National Park boundaries provide a certain amount of protection for sensitive species, they cannot change the fact that human pressure has altered the marine community structure. The last few decades have seen a dramatic decrease in urchin predators, including sea otters (*Enhydra lutris*), lobsters, and large fish such as sheepshead (*Semicossyphus pulcher*), due to increasing human fishing pressures. Eelgrass, like giant kelp (*Macrocystis pyrifera*), can be decimated by urchins whose populations boom due, in part, to lack of predator control (Keller 1983, Valentine and Heck 1991). When the Science Panel of the Channel Islands Sanctuary Advisory Council met in 2002 to discuss the size and shape of Marine Reserves around the Channel Islands, eelgrass beds were given high priority as critical habitat.

Our project site at Anacapa Island historically supported a healthy eelgrass bed. In the early 1980s there was a dense bed occurring between 6 and 12 meters depth (Engle pers. comm., Engle and Miller 2005). After the 1983 El Niño, the white urchin, normally less than $1/m^2$, experienced heavy recruitment and boomed to greater than $63/m^2$. An urchin front moved upslope from depths of 18 meters and began to devour the eelgrass meadow, and by 1991, all of the eelgrass (and other benthic growth) was gone. Subsequent Channel Island Research Program (CIRP) yearly surveys of Frenchy's Cove described the gradual decline of urchin population through starvation and disease; by 2000 densities stabilized at 0.4 $urchins/m^2$.

The primary objective of this pilot study was to test eelgrass restoration techniques in a relatively pristine habitat, free from human-induced disturbance. As a community-based restoration project, we involved the public by inviting them to participate as volunteer divers. This paper reports the progress from our pilot restoration of eelgrass at Anacapa Island.

METHODS

Site Description

Anacapa Island, the eastern-most and smallest of the northern California Channel Islands, is comprised of three small islets and is about 20 miles south of Ventura, California. Frenchy's Cove

(N 44 00.595' W 119 24.690') is located on the north side of the west end of Middle Anacapa (Fig. 1). Frenchy's Cove is a small cove at the junction of Middle and East Anacapa islets. The bottom is sandy and slopes gradually offshore. All depth contours discussed here are relative to approximate Mean Lower Low Water. Inshore of the 6-m contour, the sand turns to gravel, rocks and shells and is generally not suitable for eelgrass. East Anacapa Island offers some protection from the prevailing swell and wind but the anchorage is not very secure. Our site is on the border of a seasonally closed brown pelican fledgling area and is now within the Anacapa State Marine Conservation Area created in 2003. In 1992 the CIRP established a permanent 60-m transect in Frenchy's Cove parallel to shore at the 9-m contour, at what had been the middle of the historic bed. This transect was established primarily to monitor for eelgrass recruitment and has been surveyed yearly (usually in June/July) by band transect and quadrat for density and percent cover of major species. The information collected during the surveys and from diver observations showed clearly that eelgrass has failed to recruit to Frenchy's. By 2001, CIRP researchers agreed that conditions at Frenchy's were ideal for a pilot eelgrass restoration project.

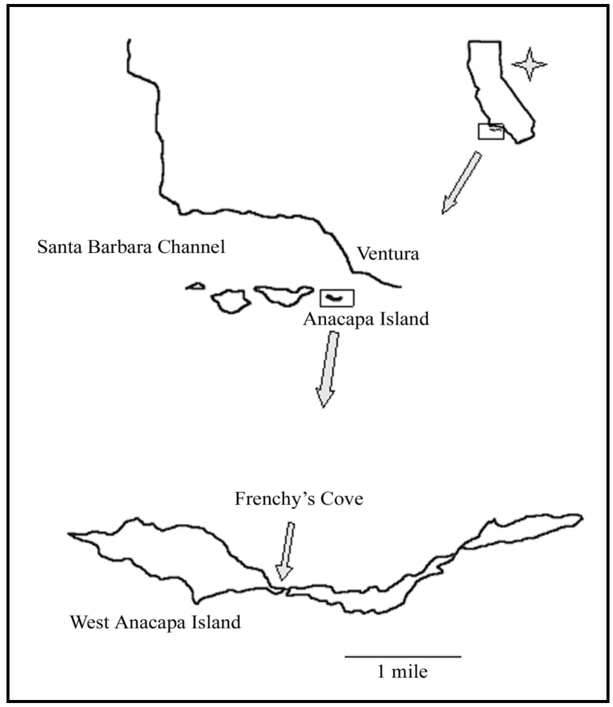

Figure 1. Location of Frenchy's Cove, West Anacapa Island, site of pilot eelgrass (*Zostera marina*) restoration project.

Harvesting at Donor Beds

Both harvesting and transplanting work occurred on 2 July 2002. Transplants were harvested by divers from large beds (Smugglers Cove, Prisoners Harbor) near the east end of nearby Santa Cruz Island. These beds were selected based on their proximity to Anacapa, and their large size. The donor beds differed in exposure and depth range. Both beds experienced frequent disturbance from anchoring, heaviest during the summer.

Plants were harvested from three locations within each bed (shallow edge, middle of bed, and deep edge) to maximize genetic diversity (Williams and Davis 1996). To harvest plants, divers selected a shoot and after working their fingers down around the rhizome, gently shook it free of the sediment until a piece of rhizome could be broken off. Individual shoots allow for spreading collections throughout the bed to maximize genetic diversity. In addition, planting single shoots would allow us to account for individual plant growth or mortality during monitoring surveys. Each shoot had a rhizome at least 4 in. (101.6 mm) long; multiple shoots on one rhizome were not targeted. Care was taken to ensure that roots remained intact on the rhizome nodes. Divers swam at least three kicks between harvesting plants and were careful not to disrupt the remainder of the bed. Robust plants were chosen and plants with flowers were neither targeted nor discarded. As the plants were harvested, they were put into mesh bags and once on ship, placed in covered buckets of sea water or into the ship's live well. Plants were held for a period of several hours as the ship moved to Anacapa Island, and were replanted the same day.

Planting

An estimated 500 eelgrass shoots were transplanted on 2 July 2002. The general location within Frenchy's Cove was on the edge of the State Conservation area, as vessels are not allowed within the pelican closure area from January 1st to October 31st. Eelgrass was planted into four different areas corresponding to depth: 'deep' (9 m depth), 'shallow' (7 m depth), 'swath' (running perpendicular to shore from 6 to 12 m depth) and the 'genetic study' (7 m depth). The idea was to cover a representation of the area and depth range of the historic bed. The experimental 'genetic study' area received an array of tagged plants for a study whose results are not discussed in this paper. In the swath and the genetic study, shoots were spaced about 1 m. In the shallow and deep patch areas, shoots were spaced about 30 cm. The shallow and deep patches received about 100 shoots each, the genetic study 36 shoots, and the swath the remainder (approximately 250). Ultimately, approximately 300 m^2 were planted at these identified densities.

We used an adaptation of a planting technique developed by Orth et al. (1999). To prepare the sediment for the rhizome, divers used a knife or other objects to dig a small trench, about 3 to 5 cm deep. Once this sediment was loosened by the knife, a shoot was pushed into the trench so that the root hairs and rhizome were in the loose sediment and the shoot was erect. A metal anchor made of a piece of bailing wire bent into a "v" was pushed in over each rhizome to hold the plant down. Before leaving the area divers ensured that all rhizomes were buried in sediment.

Monitoring

Not all areas were counted on all surveys due to weather and other factors. Beginning in April 2002, we counted the brittlestar (*Ophiothrix spiculata*) in small quadrats at each depth. The study site was sampled for eelgrass shoot counts 13 times between July 2002 and October 2003 (approximately every 1 to 2 months, not including initial site surveys and set-up visits). Divers included Channelkeeper's staff biologists, research divers from local universities, agency biologists and volunteers from the local community. At each survey, divers counted all of the number of shoots present in each restoration area. To aid in counting shoots during surveys, plastic spoons were pushed into the sediment adjacent to each shoot. Roving divers carefully swam each area in turn until all shoots were marked. Then, the spoons were removed and either brought to the boat for counting or counted underwater. Divers also collected and removed from the immediate area any obvious grazers, which were relocated nearby. In addition, we documented the study with video and still photography.

RESULTS

Transplants initially appeared healthy and shoots elongated; however, an unprecedented event had immediate and adverse effects. By December 2002 (Day 155) eelgrass mortality neared 95% in all plots combined (Fig. 2). Plants survived for different lengths of time among the areas, with those shoots spaced further apart (swath, genetic study) disappearing fastest. Those plants in shallow water appeared to persist the longest.

Coinciding with restoration efforts, we witnessed the spread of the brittlestar up into shallow water at Frenchy's (Fig. 3). Although brittlestar experienced heavy recruitment to deeper (>15 m) rocky reefs around Anacapa and eastern Santa Cruz Islands in the mid-1990s, this brittlestar was only occasionally noted along the sandy CIRP Frenchy's transect and there was no obvious explanation for the sudden and dramatic increase in density at this site. By August 2003, brittlestars occurred at densities of >1000/m^2 at depths as shallow as 7.6 m.

Several grazers, including the wavy-top snail (*Lithopoma undosa*), and two species of sea urchin *(Stronglyocentrotus purpuratus* and *S. franciscanus)*, became common at the site in the immediate months following the transplants. These grazers were re-located out of the immediate area during diver surveys, and declined in overall numbers over time. The white urchin was only occasionally observed. Injured plants seemed especially

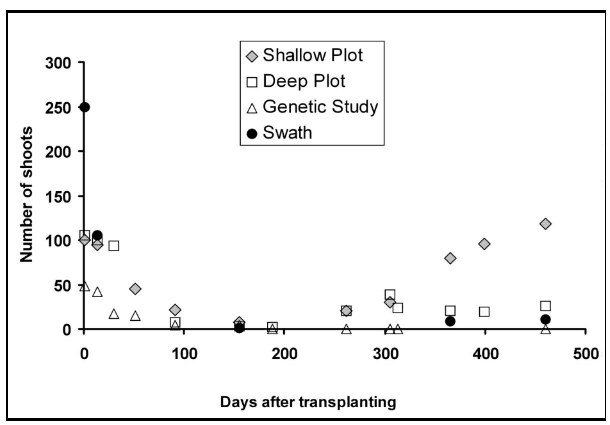

Figure 2. Number of eelgrass shoots over time for four planting areas at Frenchy's Cove, West Anacapa Island. Day 0 = 2 July 2002, Day 460 = 14 October 2003.

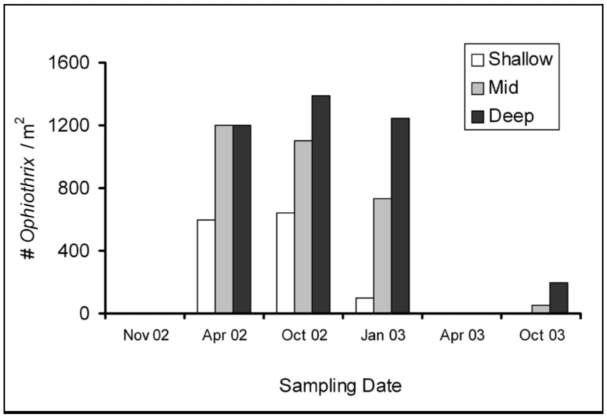

Figure 3. Density of the brittlestar *Ophiothrix spiculata* at three depths at Frenchy's Cove, Anacapa Island.

attractive to grazers: shoots obviously injured or abraded were also observed being actively grazed. Urchins grazed the entire shoot and leaves, while snails lopped shoots off at their base.

After winter storms in January 2003, brittlestars declined dramatically, and by March 2003 (Day 262) were almost completely absent from the site. Concurrently, new eelgrass shoots and young seedlings appeared in both the shallow and deep areas. Some plants were flowering when transplanted and appeared to set seeds in both the shallow, deep and swath locations, although as expected most reproductive plant material had disappeared by October 2002. Diver observation estimated seedling survival at about 10% in deeper areas and <30% in shallow areas. Only a few scattered shoots re-grew along the swath in shallow water, and no shoots reappeared in the genetic study. By October 2003, shoot counts in the shallow site had surpassed the initial planting. Several single shoots appeared along the swath in July 2003 and by October 2003 had grown to small individual patches of 9 to 12 shoots each. No plant was observed flowering during 2003.

DISCUSSION AND FUTURE ACTIONS

Mortality (defined here as shoot loss) seemed attributable to several factors, including interference from brittlestars, grazing by urchins and snails, losses from bat ray feeding and disturbance to the sea floor by ship's anchors. However, brittlestars directly reduced eelgrass survival in several ways: by pinning shoots to substrate, shading shoots and preventing photosynthesis, abrading shoot surfaces, and by physically interfering with sediment deposition and rhizome growth. Brittlestars did not eat the eelgrass, as they are suspension feeders; rather, they climbed up the shoots and knocked the plants over (Fig. 4). Once held down, the shoots became even more vulnerable to grazers. However, once brittlestar densities declined after the onset of winter storms, re-growth from transplants and seedlings from flowering transplants grew rapidly. Less than five months in the absence of disturbance from brittlestars, eelgrass shoots were approaching initial transplant densities in shallow plots.

Given 'normal' site conditions (i.e., in the absence of brittlestars), it seems likely that shoot survival would be much higher than we initially found. We were surprised by the number of seedlings that appeared after March 2003. Eelgrass can produce an extremely large number of seeds, most of which never successfully germinate (Orth et al. 1994). Short-term seedling survival at Frenchy's ranged from 10 to 30% of the number counted; this number of seedlings seems greater than expected given typically high seed mortality and suggests favorable germination conditions. Unfortunately we were unable to track the fate of all seedlings; in the future measuring the distance and bearing from permanent markers would help

Figure 4. Photo of surviving eelgrass and brittlestars in "Deep" transplant area.

map each seedling and allow for individual evaluation.

Brittlestars were not observed at any other Channel Islands eelgrass bed and it seems an anomaly that they occurred at such high densities in shallow, soft-bottom habitat in the first place. We will continue to follow the pilot restoration at Frenchy's at regular intervals and may initiate more transplants if conditions warrant.

CONCLUSIONS

Brittlestars had an unexpected, direct and immediate effect upon transplanted eelgrass shoots. The stresses associated with being covered with brittlestars appeared to make the plants more susceptible to grazing pressure. In addition, wholesale loss due to disturbance from bat rays and anchors was also an occasional problem. However, shoot densities rapidly increased in absence of brittlestars and rhizomes were able to regenerate many months (>8) after complete grazing of all above-sediment tissue. In the absence of disturbance from brittlestars and grazers, the transplanted shoots in shallow water spread quickly. Seedlings first found in March 2003 surveys continued to appear into early summer and survival was better than expected, although rhizomes exposed by sediment erosion appeared to be one potential cause for seedling loss. Regardless of the early difficulties, we retain a positive outlook for patch reestablishment via continuing shoot regeneration and recruitment of seedlings. Monitoring will continue at the site at regular intervals to track survival and growth of the pilot bed, and to more closely track seedling survival in the future. Based on the findings thus far, we expect to see further expansion of the patches in shallow water. Results from this pilot study are promising for future restoration efforts around the Channel Islands.

ACKNOWLEDGMENTS

This work was funded through NOAA Fisheries' Community-based Restoration Program award NA17FZ1518, and by an anonymous California foundation who provided matching funding. Thanks to J. Engle and the Tatman Foundation's Channel Islands Research Program for guidance and donating ship-time on the R/V Cormorant. We had help collecting and transplanting eelgrass from the following Foundation staff and CIRP divers: J. Engle, H. Chomeau, R. Ambrose, J. Carroll, J. Wible, J. Coyer, D. Richards, L. Roberson, S. Lee, S. Dejong, D. Smith and C. Bungener. Thanks to other community volunteers, including S. Allen, J. McConnell, B. Gwinn, C. Gwinn, B. Freidman, R. Frodsham, J. Murray, B. Rydgig, G. Helms, W. McGowan, C. Metzenberg, P. Buskin, K. Weiglass, B. Reed, C. Gotschalk, M. Murray and S. Hastings. Thanks to the Channel Islands National Park, the California Department of Fish and Game for granting us a harvesting permit and the staff of the Channel Islands National Marine Sanctuary for providing a research permit and moral support. Finally, much thanks to NOAA Fisheries' Community-based Restoration Program staff for their belief in this project.

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