Title
Strongylocentrotus franciscanus: Cryptic OpportUNIties

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Publication Date
2013-04-01

Abstract

The goal of my capstone project was to address a portion of the goals set forth by the Sea Grant proposal, The sustainability and fine-scale management of a sea urchin fishery and the ecology of exploitation in a southern California kelp forest. It documents a tagging trial essential to initiate sea urchin movement studies to and from cryptic habitats, establishes a baseline study for the newly created South La Jolla State Marine Reserve, and served as a vector to compile and analyze recruitment data collected over many decades in Point Loma and La Jolla, California. It also discusses the upcoming use of QR codes to grab the attention of the public and direct it to sea urchin research and sustainability.

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6/12/2013

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I. Brief Fishery History

The California sea urchin fishery began in 1971 as an attempt by the National Marine Fisheries Service to create a market for underutilized species (Kalvass and Rogers-Bennett 2002). By 1987 the fishery had grown to be California's second most valuable, with a landing value of $13.7 million (Tegner 1989). It continues to be one of California's most valuable fisheries and has expanded to fully exploit sea urchins throughout their entire range. The red sea urchin (*Strongylocentrotus franciscanus*) fishery peaked in 1981, raking in 25 million pounds from southern California alone. The following years were less productive due to an El Nino phase, but by 1990 the sea urchin population recovered and led to another peak in the industry equating to a 27 million pound yield (CDFG 2102).

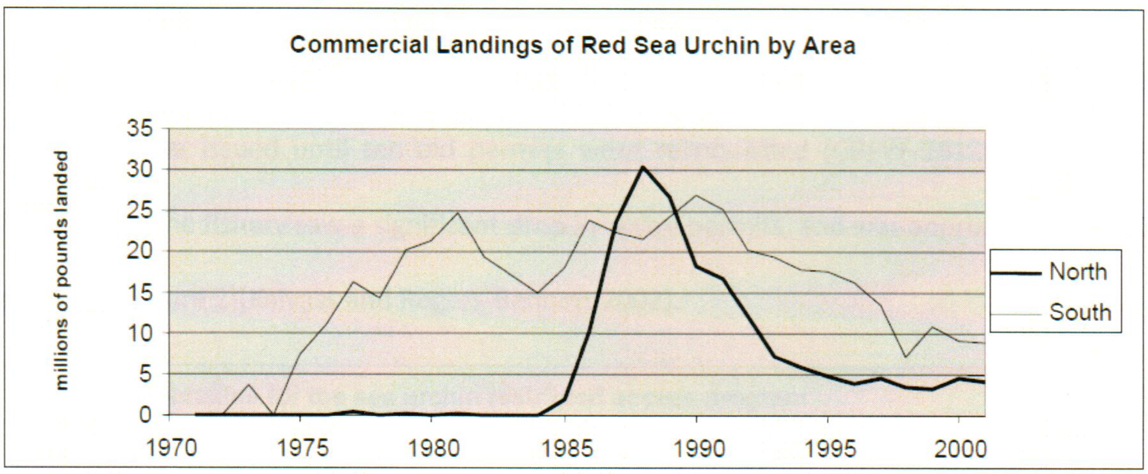


Figure 1 Commercial landings of red sea urchin in pounds per year (Kalvass and Rogers-Bennett 2002).

At first, the fishery was managed directly by the Californian Legislature and later handed over to the Fish and Game Commission in 1973 (Kalvass and Rogers-Bennett 2002). Unlike most other fisheries, the main objective was to increase, rather than decrease, the exploitation of sea urchins. No regulations were set in place and fishers were encouraged to harvest freely (Kalvass and Rogers-Bennett 2002).

By the early to mid 1980's fishing effort had increased to levels that threatened the stability of sea urchin populations. In response, a permit system was established in 1984 which required urchin divers to purchase permits in order to participate in the fishery. The addition of this single regulation did not result in a significant decrease in effort or harvest; possibly because California legislation originally aimed to issue 400 permit but issued as many as 938 and in 1987. Soon after Fish and Game ceased the issuance of new permits altogether. The following year, size restrictions redefined the harvestable sea urchin pool. In 1990, seasonal closures were established in an effort reduction scheme (Kalvass and Rogers-Bennett 2002). After the regulation reformations, a new goal was set to reduce the number of active permits to 300. In order to reach the goal and thus reduce fishing effort, it was decided that not a single permit would be issued until ten old permits were relinquished (CDFW 2012). From 1987 through 2002, the fishery saw a significant drop in active permits, and was approaching the 300 permit goal (Figure 2)(Kalvass and Rogers-Bennett 2002).

Historical timeline for the sea urchin restricted access program

1973	State Legislature delegates authority to the Fish and Game Commission for managing the sea urchin fishery.
1984	State Legislature authorizes a permit for the sea urchin fishery, but does not make it restricted access.
1986	State Legislature gives the Fish and Game Commission authority to limit the number of sea urchin diving permits.
1987	Fish and Game Commission places a moratorium on new permits.
1989	Restricted access program begins.

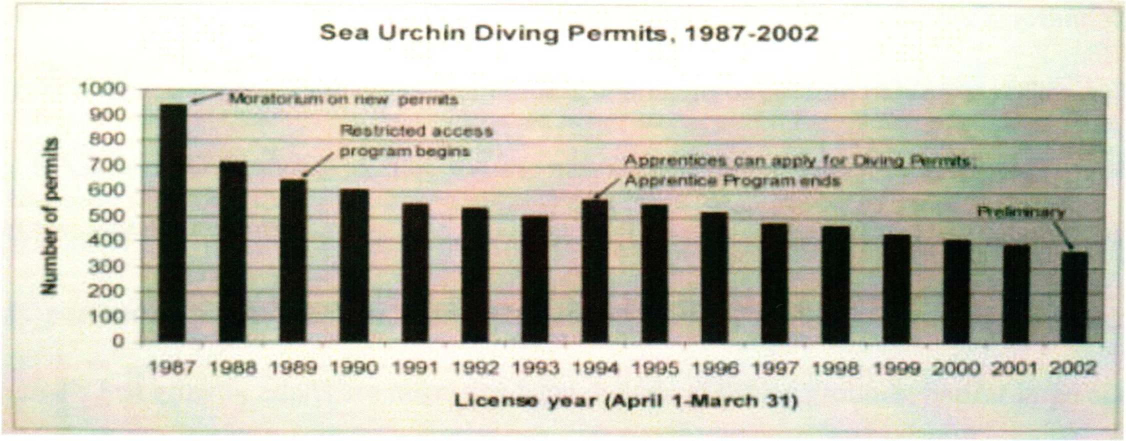


Figure 2 Number of active sea urchin diving permits issued by year, from Kalvass and Rogers-Bennett 2002.

II. Ecological Interactions

Sea urchins are a dominant herbivore within kelp forests, preferentially feeding on detrital kelp but also capable of crazing live foliage. Release from predation via predator overfishing leads to well documented instances of destructive overgrazing on kelp forests. In extreme cases overgrazing can lead to urchin barrens, which are defined by a lack of foliose alga and usually accompanied by high densities of sea urchins. Barrens are areas of low biodiversity relative to healthy kelp forests (Smee 2012). The dynamics of their onset, persistence, and disappearance and dissolution are not fully understood but area associated with physical disturbance and trophic interactions (Gutierrez 2010).

Within barrens, urchin divers are continuously able to collect sea urchins of legal size. Despite sea urchins being long lived and thought to be slow growing, the population of harvestable sea urchins is replaced every few months based on the continued success of urchin divers' catch rates (California Ocean Protection Council 2008). What is the source of fishery recruitment? How is it possible that sea urchin densities seem to go unaffected by limitless exploitation? Researchers are beginning to question the legitimacy of a fishery's potential for sustainability in the absence of limits on numbers of animals or amount of biomass taken.

A substantial concern is that the estimated recruitment rates data appear less than harvest rates (Parnell, personal communication 2012). This suggests four possibilities: only a small portion of the total population is harvested each year, there are localized areas of extremely fast growth, adults are migrating from outside of fishing grounds, and/or large adults are emerging from cryptic habitats, perhaps in response to decreased densities due to harvesting (California Ocean Protection Council 2008). The last two suggest that while sizable sea urchins are present during frequent repeat visits, they are originating from the existing population and are not due to surplus population growth. If true, the sea urchin fishery may actually be reducing the stock faster than the catch data suggest.

III. Addressing Critical Knowledge Gaps

Until recently, relatively little was known about the life history of red sea urchins. Research is currently being done to examine growth rates, reproduction, recruitment, movement, feeding patterns, and population dynamics. In 2009, Paul Dayton, Steve Schroeter, and Ed Parnell were granted funding through Sea Grant California to address these issues. Their proposal, *R/FISH-209, The sustainability and fine-scale management of a sea urchin fishery and the ecology of exploitation in a southern California kelp forest,* set forth means by which to further investigate red sea urchin life history in order to better understand how to employ efficient, ecosystem based management of the sea urchin fishery.

The overarching goal in R/FISH-209 is to determine whether the fishery is benefiting from surplus production by documenting movements to and from cryptic habitats and examining localized recruitment data dating back to the creation Matlahuayl (MSMR) and Point Loma State Marine Reserves. The foci of this project were to initiate the movement patterns and cryptic habitat component by testing the effectiveness of a new tagging system, to collect, compile, and analyze sea urchin density and size data to serve as a baseline measurement of the newly established South La Jolla State Marine Reserve (SLJSMR), to compile and analyze recruitment data along San Diego's Coast, and to offer the information to the public through a new twist on QR codes.

IV. Tagging Trial

Understanding movement patterns in red sea urchins would aid in understanding the source of the harvestable stock. Tagging and tracking sea urchins will potentially reveal their movement patterns and their emergence into the fishery and help explain whether adults are migrating in from areas outside of typical fishing grounds or emerging from cryptic habitats within the fishing grounds.

Photo plots will be set up inside well established barrens, on the frontline of the barrens, and in the nearby kelp forest community. By deploying tags and utilizing automated underwater cameras programmed to photograph the plots every 15 minutes, the Parnell lab hopes to recognize patterns in sea urchin behavior and movement with respect to the barrens, the surrounding habitat, and benthic topography.

IV. A. Methods

The first step in tracking the movements of individual sea urchins was to create an appropriate tagging system. For the purposes of this experiment we require a tag that is highly visible to divers and in photos, cost effective in parts/time/ labor, results in low mortality rates, and has the durability to function for two weeks, or the estimated battery life of the automated camera systems.

Gamble (1965) and Hereu (2004) tagged sea urchins by placing plastic wire tubing over individual spines. While this method had no recorded negative effects on sea urchin vitality, it was effective for only a few days before the tubing dislodged. Mattison et al. (1977) employed a similar strategy, differing only in his use of plastic straws. His trials showed similar results, reporting very few negative short term effects but the duration of effective tag life proved only a few days. Passive integrated transponder (PIT) tags are commonly used in laboratory experiments because they are effective in long term retention and result in low mortality (Hagen 1996). However, for the purposes of this study they would not provide the visibility required for camera work and diver detection. Other external tagging devices such as screws and nylon monofilaments strung through holes in the test have been tested with relative success, but do not provide the required visibility and are time and cost consumptive (Duggan and Miller 2001). For an extensive review of other tested tagging methods see Hagen (1996).

For the best visibility, cost per unit, and time effectiveness we chose to experiment with a semi-elastic, external test wrap. S'getti™ lacing, hollow plastic tubing used in children's crafts, and the Tuckahoe surgical slipknot were used to create bands that encircle the test of the sea urchin at the widest point. The bands are fit between the spines, tightened, and locked into place using long needle nose pliers.

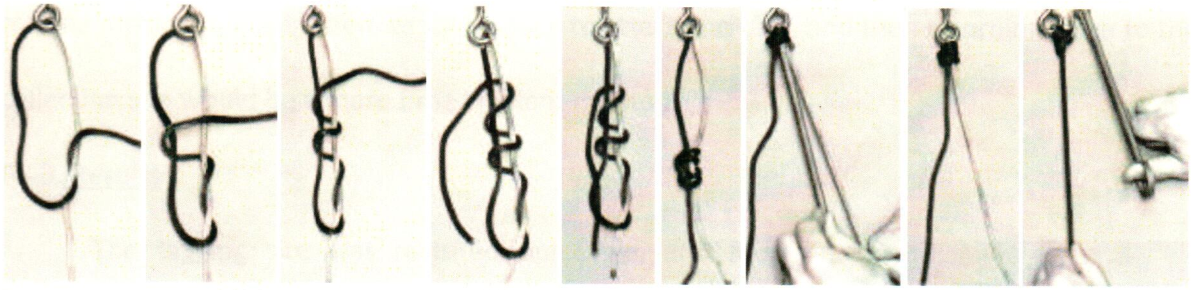


Figure 3 **1.** White strand is the post. Make an overhand throw over the post. **2.** Make an overhand throw over both strands. **3.** Make a second overhand throw over both strands. **4.** Bring the loop strand back underneath both strands. **5.** Feed the loop strand into the space between the first and second throws. **6.** The knot is set. **7.** Pull on the post strand until the knot is seated. **8.** The knot pusher is placed on the post strand and pushed until the knot is fully seated and tight. **9.** Tension is kept on the post strand while past pointing with the knot pusher and the loop strand is pulled to lock the knot.

The testing site was located well within the Matlahuayl State Marine Reserve to limit the possibility of fishers harvesting the sea urchins. Three divers were initially able to tag 72 urchins in 80 minutes by first preparing the bands on land and securing them around aluminum tubing. The tubes with the bands were taken underwater with the divers where the tagging took place. While this method improved in efficiency over time, it is suspected that collecting

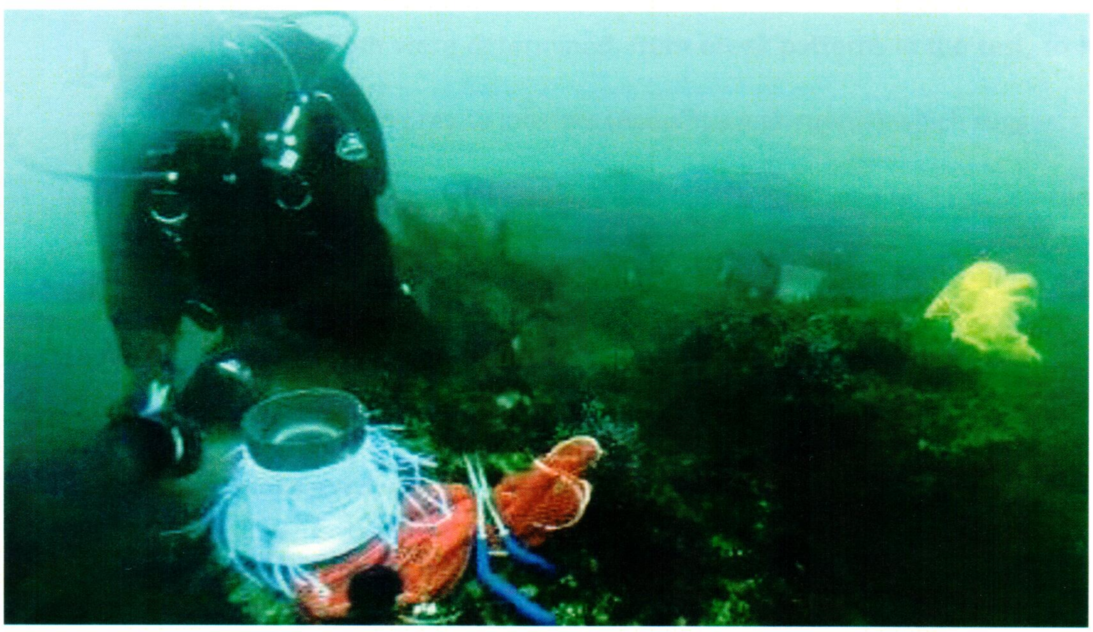


Figure 4 Underwater work site with pliers aluminum tube holding pre-fabricated tags. Photo by Bryan McGrory

the sea urchins, bringing them to the surface to attach the tags, and then returning them to the collection site would be a more time efficient method.

IV. B. Results

The tagging site was revisited one, two, and four weeks following the initial tagging event to evaluate mortality rates, divers' ability to relocate tagged sea urchins, and physical condition of the tags. Week one showed promising results as 30 tagged sea urchins were observed with no physical signs of damage to the test or spines. Two intact derelict bands were found on the ocean floor, presumably the result of the bands coming loose and the sea urchins "wiggling" out. Two dead, tagged sea urchins where found within the site. Both had tags that had slipped up the test, restricting the spines and distorting spine canopy. Both were determined, from break patterns in the test, to have fallen prey to lobsters (*Panulirus interruptus*) which suggests that improperly placed or insufficiently tightened tags causing canopy distortion leave the sea urchins vulnerable to predation.

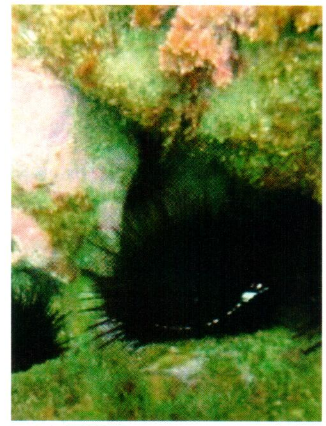


Figure 6 Red urchin wearing tag. Photo by Bryan McGrory

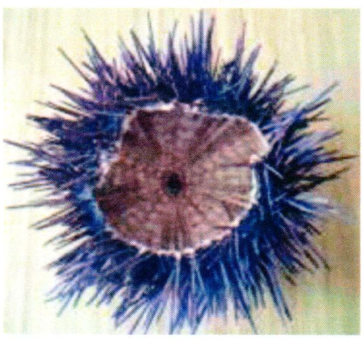


Figure 5 Ragged break lines suggest consumption by lobster. Photo by H. Krish

Week two showed similar results: 20 apparently healthy, tagged sea urchins were observed, three intact derelict bands were found on the bottom, and one dead, tag-less sea urchin was found. The lack of tag made it impossible to know whether it was originally tagged and if so whether the tag was a factor in the mortality. This

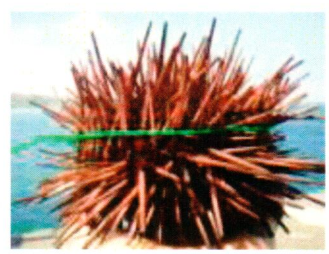


Figure 7 Example of canopy distortion caused by tag. Photo by H. Krish.

sea urchin also appeared to have been consumed by lobster. During week two about a third of the tagged sea urchins spotted appeared to be in the beginning phase of tag loosening, some to the extent that the spine canopy was distorted.

Based on week two's last observation, it was unsurprising that week four showed the highest mortality rate. 11 dead sea urchins were found. All were without tags and appeared to have died recently, judging by the condition of remaining spines and test. Only four live, tagged sea urchins were found and three intact derelict bands were found on the bottom. A few fragments of broken bands were also found. For a visual summary of the tagging results see Figure 8.

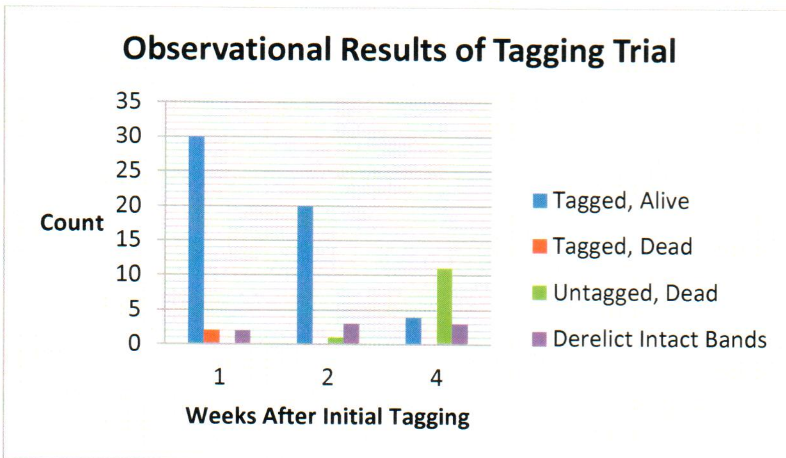


Figure 8 Results of tagging trial.

IV. C. <u>Conclusion</u>

Based on this trial, the data show that for up to two weeks after initial tagging, the sea urchins experienced minimal negative effects and were easily identifiable to divers. Beyond two weeks, sea urchins suffered increased mortality rates and either lost the tags or moved into cryptic habitat where divers were not able to locate them. Because this method proved cost and time effective and presented low mortality rates within the planned duration of tracking, it was deemed most appropriate for the time scale of interest.

V. A Baseline Study for the South La Jolla State Marine Reserve

A marine protected area (MPA) provides locations for research and education while safeguarding ecosystem structure and function (Dayton et al. 2000). Protected areas provide rare opportunities to study habitats that are under localized control of human impacts, which can provide important baseline data to fisheries management as well as information quantifying MPA efficacy (Dayton et al. 2000). Reserves are, however, sometimes created devoid of ecological baseline data which makes measurements of efficacy difficult at best. With limited means of comparing present ecosystem conditions to those prior to the establishment of MPA's, researchers are restricted in their ability to provide managers with conclusive data demonstrating stock status as influenced by MPA establishment.

Parnell et al. (2005) demonstrated the complications of reserve assessment when baseline data is lacking. In an effort to measure the success of the Matlahuayl State Marine Reserve (MSMR), he and his lab conducted a series of comparisons between analogous microhabitats inside and outside the reserve. They concluded that inside/outside comparisons are inadequate because they lack control for temporal changes in habitat over time as well as adequate control for anthropogenic alterations such as coastal development and overfishing (Parnell et al. 2005). Comparing two present day microhabitats does very little when trying to compare ecosystem vitality through time because the comparison lacks any historical benchmark of ecosystem health.

The recent establishment of the south La Jolla State Marine Reserve (SLSMR) on January 1, 2012 provides an excellent opportunity to establish red and purple (*Strongylocentrotus purpuratus*) sea urchin size/density baseline data. Collecting this data now would provide future monitoring efforts a benchmark by which to compare the health and status of future sea urchin populations within this area.

To do this, Ed Parnell chose seven sites within the SLJSMR that would serve as sampling sites for baseline data establishment (C in figure 9). To get a better assessment of the general area, six sites outside of the SLJSMR were selected (B in figure 9), as were six sites inside the Matlahuayl SMR (A in figure 9). The surveys began in spring of 2013. At each site SCUBA divers collect all sea urchins, red and purple, from randomly placed, one meter squared plots until 100 sea urchins of each species are obtained. The number of plots required to reach 100 sea urchins is recorded. The urchins are then brought to the surface, measured, counted, and checked for disease. To avoid unnecessary risk of predation, the sea urchins are then returned, via SCUBA, to the bottom rather than being dumped overboard. This method is consistent with that of the sampling method accepted and used in the red and purple sea urchin monitoring in the City of San Diego's ocean monitoring program of the kelp forest habitat off of Point Loma.

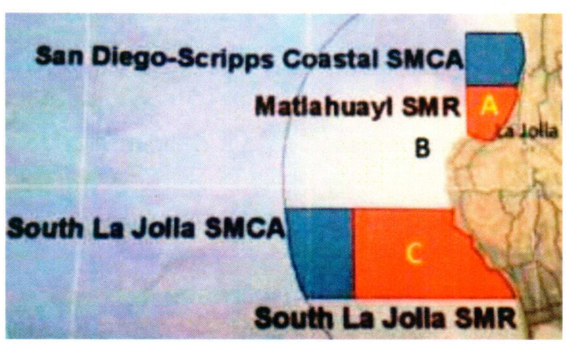


Figure 9 Survey location sites. A is the Matlahuayl SMR. B is an area outside of any reserve. C is the new South La Jolla Reserve.

Latitude N	Longitude W	Decimal Degrees (WGS84)		Location Description
32 49.477	117 17.391	32.80436	-117.28235	SLJSMR
32 48.198	117 16.721	32.80330	-117.27869	SLJSMR
32 48.419	117 17.117	32.80698	-117.28529	SLJSMR
32 48.145	117 16.588	32.80242	-117.27647	SLJSMR
32 49.477	117 17.391	32.82461	-117.28985	SLJSMR
32 49.530	117 17.146	32.82550	-117.28577	SLJSMR
32 49.499	117 17.304	32.82499	-117.28840	SLJSMR
32 51.217	117 16.214	32.85361	-117.27023	MSMR
32 51.224	117 16.167	32.85373	-117.26945	MSMR
32 51.205	117 16.229	32.85341	-117.27049	MSMR
32 51.284	32 51.284	32.85474	-117.27068	MSMR
32 51.254	117 16.185	32.85424	-117.26975	MSMR
32 51.263	117 16.238	32.85438	-117.27064	MSMR
32 50.723	117 17.140	32.84538	-117.28566	Out of Reserve
32 50.392	117 17.355	32.83987	-117.28925	Out of Reserve
32 51.058	117 16.978	32.85097	-117.28297	Out of Reserve
32 51.051	117 17.233	32.85085	-117.28722	Out of Reserve
32 51.203	117 16.978	32.85338	-117.28297	Out of Reserve
32 50.299	117 17.267	32.83831	-117.28779	Out of Reserve

Figure 10 Coordinates of the 19 baseline survey sites in the South La Jolla State Marine Reserve, Matlahuayl State Marine Reserve, and outside of any reserve.

Figure 11 is a comparison between data collected prior to the establishment of the North La Jolla Reserve or the fishery, data collected in 2003 in the North La Jolla Reserve (A in figure 9), data collected in 2013 from the North La Jolla reserve (A in figure 9), data collected outside of any reserve in 2003 (B in figure 9), and data collected from 2004 through 2012 in what is now the South La Jolla Reserve (C in figure 9).

The green line represents data collected by W. North in the 1960's in La Jolla, prior to the establishment of the sea urchin fishery or the North La Jolla Reserve. The resulting curve illustrates an unexploited population with a size distribution ranging from very small to well over 200mm. The red lines both represent data collected outside of any reserve and well after the establishment of the fishery, therefore illustrating fully exploited sea urchin populations. Both datasets lack distribution of individuals above 150mm. This is a typical pattern in fished populations as large individuals are targeted by sea urchin divers. The dataset correlating to the solid red line was collected in 2003 in area outside of any reserve (B in figure 9). The dashed red line is a compilation of data collected from 2004 up until the end of 2012 in what is now the South La Jolla Reserve (C in figure 9). Logically, its curve closely follows the shape of the exploited size/density curve as the reserve was only established in January, 2012. The time between establishment and this study was not sufficient to reflect recovery from exploitation and is intended to serve as baseline data for the South La Jolla Reserve. The blue curves represent data collected from inside the old North La Jolla reserve, later modified to the MSMR (A in figure 9). The solid blue line is data taken in 2003 and the dashed blue line represents

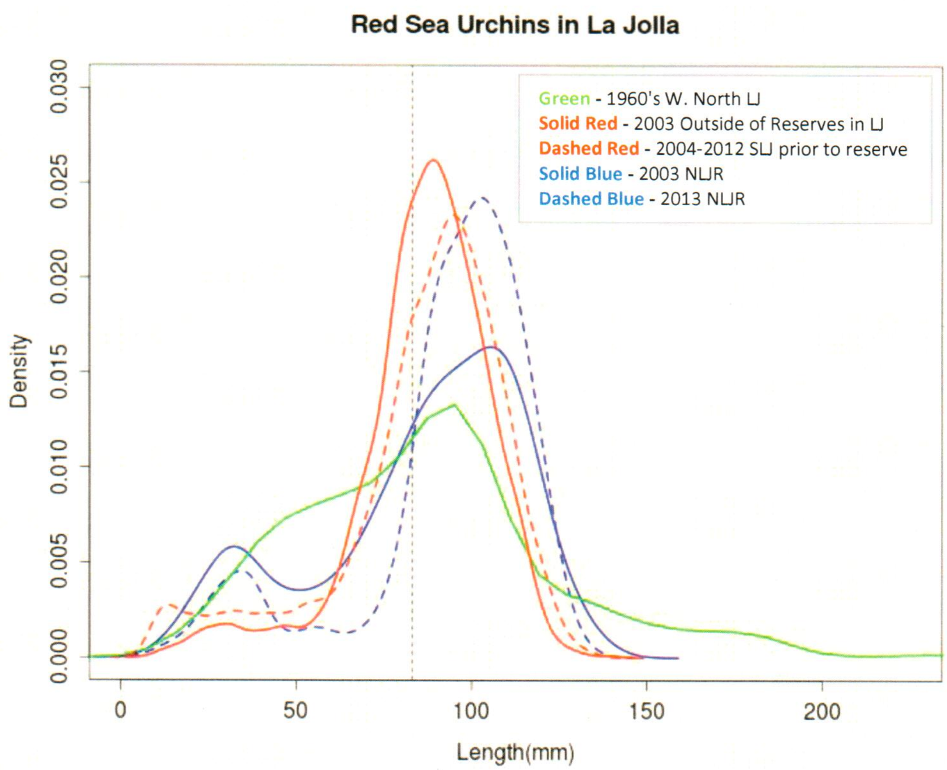


Figure 11 Size/density cures of different populations located inside (Blue) and outside (Red) of reserves. The green line is a dataset representing an unexploited population of sea urchins and was taken in prior to the establishment of the fishery or reserves.

data collected in 2013 from the same area. A significant finding of this study demonstrated that the size/density curves in this area still closely resemble those of fully exploited populations despite being well inside the boundaries of a reserve that dates back to the early 1970's. There continues to be a truncated distribution of individuals, with no individuals reaching historically large size classes. With no natural predators capable of taking sea urchins of this size, the data strongly suggest that poaching is preventing this population from recovering despite being protected by law. This finding demonstrates the importance of enforcement in MPA effectiveness.

VI. <u>Recognizing Recruitment Patterns</u>

Understanding stock dynamics is paramount to understanding stock stability. This translates to understanding the three key components of sea urchin dynamics; recruitment, natural mortality, and fishing mortality. Currently, much of the data used to analyze urchin fishery sustainability is sourced from fishery dependent catch data, or fishing mortality. By studying size/density curves through time, researchers are now gaining momentum in understanding recruitment patterns that will help to predict future sea urchin populations for a more holistic understanding of stock flow.

VI. A. <u>Settlement Recruitment</u>

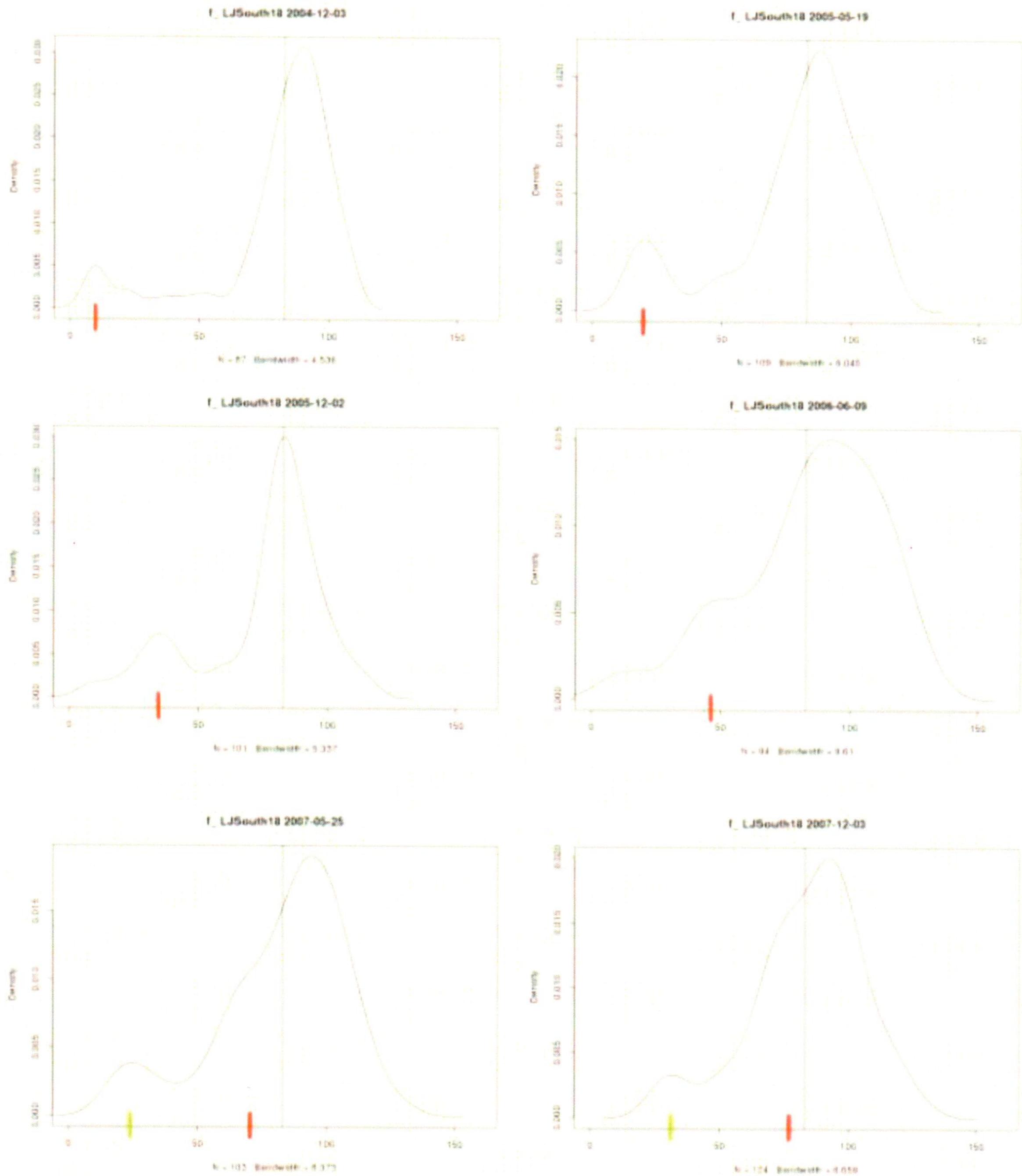
Southern California consistently has a higher recruitment rate than northern California, yet even in southern California recruitment rates are temporally and spatially patchy (Kato and Schroeter 1985). Depending on ocean temperature, red sea urchins spend between six and eight weeks in a planktonic form before settling out in near shore, coastal habitats (Johnson 1930). Recruits (sea urchins smaller than 35mm) are significantly more abundant outside the boundaries of well defined kelp beds than within for reasons that are not completely understood. Pearse et al. (1970) offered two pre-settlement based explanations. The first being active larval selection for areas outside kelp beds due to the higher densities of large adults which serve as protection to recruits. The second being passive larval concentration in areas without kelp due to muted water flows and thus reduced larval influx into kelp beds, or larval filtering. The alternative hypothesis was a post-settlement explanation suggesting that the amount of settlement is the same in both areas but that recruits within the kelp bed are exposed to higher rates of mortality due to predation. A higher concentration of predators within the kelp and a lower concentration of large adult sea urchins, or protected habitat, leave recruits highly exposed (Pearse et al. 1970). After further experimentation, Cameron and Schroeter (1980) found that post settlement behaviors are most likely the determining factor in higher recruit density outside of kelp beds. They found that post settlement migrations towards adults leading to utilization of spine canopies led to lower predation and thus higher survival rates than recruits that were unable to seek canopy refuge.

Recruits emerge from the spine canopies when they reach approximately 40mm in test diameter (Tegner and Dayton 1981). Mortality rates increase dramatically for sea urchins ranging from 40-80mm as they are extremely vulnerable to California sheephead (*Semicossyphus pulcher*) and California spiny lobster (Tegner and Dayton 1983). Once test diameter reaches 80mm, the sea urchins become too large for easy manipulation by predators and risk of predation and mortality rate drops significantly (Tegner and Dayton 1983). Varied mortality rates with respect to size gives red sea urchin size/density comparisons a bimodal curve peaking first around 25mm and second around 110mm (Tegner and Dayton 1981). The first peak is an indicator of recruitment within the past two years and the second is the accumulation of growth of many cohorts (Tegner and Dayton 1983).

By tracking site specific size/density data through time, researchers are able to identify years of high recruitment. Recruitment rates are temporally patchy, as some years experience no recruitment and others intense recruitment. By identifying oceanic patterns coinciding with high recruitment years, it may be possible to recognize environmental cues that could be used to predict recruitment rates in the future.

VI. B. <u>Growth Recruitment</u>

Growth rates of sea urchins vary widely, ranging from 13-25mm in test diameter per year with small sea urchins experiencing more rapid growth (Kato and Schroeter 1985). The nutritional value and abundance of food sources strongly influences growth, with consumption of preferred algae (*Macrocystic* in southern California and *Laminaria* in northern California) leading to quickest growth rates (Kato and Schroeter 1985). By studying water quality parameters affecting kelp quality in combination with recruitment rate data, researchers may be able to better predict growth rates in areas of interest. Devoid of kelp quality comparison, it is possible to track high recruitment events through time to see their eventual incorporation into the adult and legal size classes. Below is a series of size/density surveys done in the SLJSMR (prior to the establishment of the reserve) at 18 meters in depth from 2004 through 2007. This data set illustrates the growth and incorporation of recruits into larger size classes through time, as seen by the rightward shift in size of the recruitment cohorts. Size/density graphs allow researchers to track the growth of recruitment cohorts from settlement, providing data on site specific growth rates.



Data taken from the SLJSMR, prior to its establishment, at a depth of 18m. The first peak represents a recruitment cohort. Growth of the recruitment class is measurable by the rightward procession of the peak until its assimilation into the second peak (red line on x axis). The second peak represents the accumulated growth of multiple cohorts through time. The vertical line denotes the legal size limit of red sea urchins (83mm). Note the second recruitment pulse in May of 2007 (green line on x axis).

The data presented here are a minute subset of that collected and analyzed across the southern California coast. They will be combined with data collected categorizing habitat type, water temperature, and benthic topography to recognize recruitment patterns with respect to varying habitats and oceanic conditions, allowing fishery managers to better employ ecosystem based management rather than management based solely on fishery dependent data.

VII. Connecting to the Public

With scientific findings being locked away in journals and written in styles that are not digestible to the general public, there is a huge discrepancy between documented research and disseminated knowledge. Even the most interested and curious members of the public are having a hard time making informed decisions in the market place because they are not able to interpret or even find information that would increase their decisive powers.

Lack of information to the public opens the door for businesses rather than consumers to make decisions that affect our markets and societies. The money making decisions driving industries are often not harmonious with the desires of an informed public. In order to put the consumers back in control of markets and the ethics behind them, interdisciplinary groups are working hard to develop creative and effective ways to disseminate critical information to the public.

VIII. A. Rob Ruiz

Chef Robert Ruiz is a San Diego native, born in Oceanside. He moved to Hawaii at 17, where he was introduced to the restaurant business. His hard work, determination, and unparalleled passion grabbed the attention of Alan Wong at the five star Haulalai Resort. Wong brought in Japanese sushi chef Etsuji Umezu as the executive chef of Haulalai and named Rob

Etsuji's apprentice. Rob quickly jumped through the ranks, learning the traditional Japanese art of sushi preparation and was soon serving high profile guests including the princess of Japan (Robert Ruiz personal communications 2013).

After his return to San Diego he prepared sushi for Sushi on the Rocks for two and a half years, only to move on to become executive sushi chef at Harney Sushi. He has won countless awards for his creative combinations of flavor and texture including being named "Chef of the Fest" by the American Culinary Federation and San Diego Bay Wine and Food Festival in 2010.

Even more impressive than his award winning dishes is his passion for changing the way the seafood and sushi industry caters to the public. He is at the forefront of ensuring that his guests receive nothing but the best quality seafood by refusing to serve any product that does not meet sustainability criteria. Rob is continuously joining forces with customers, scientists, seafood distributors, fishermen, and media among many others to creatively address sustainability issues and questions surrounding seafood. He has big plans and promising ideas that intend to connect his customers to the facts behind the food choices they are making.

VIII. B. <u>QR Codes</u>

Quick response codes (QR codes) were originated in Japan in 1994 as a means for tracking automobile parts through manufacturing. They were created by The Denso Wave Company and became an instant marketing phenomenon in the Japanese market (Online QR Lab 2103). A decade ago, the QR code reached the United States and has since exploded in the U.S. market, advertising products ranging from cars to vacation rentals. They work by creating a two dimensional code of black squares on a white background. Consumers are able to "scan," or photograph QR

Figure 12 Example of QR code.

codes via their smartphones. A smartphone application created to decode the QR codes then links customers directly to which ever multimedia digital content is linked to the code (Orange Collar Media 2012). In simple terms, QR codes instantly direct consumers to uniform resource locators (URLs) on the internet which display information about the product.

VIII. C. Connecting the Science to the Consumer

As executive chef, Rob has creative free range over the menu and atmosphere of Harney Sushi. He is constantly striving to bring an enlightening experience to his guest by providing a delicious meal while simultaneously educating them about the menu items. One of his most recent strategies is to incorporate QR codes into the menu and on the sushi itself. He has the capability to print QR codes using edible ink on the rice paper. When guests are served, they can scan the codes to instantly be linked to a website full of facts about the menu item they ordered.

Figure 13 Edible QR code on Poke served by Harney Sushi at Poke Festival 2013. Photo by H. Krish

Harney Sushi introduced the edible QR codes on their poke samples offered to guests at the 2013 Poke Festival at Bali Hai (Figure 13). They were a big crowd pleaser, drawing people to ask questions and take pictures. Harney Sushi went on to tie for first place in the Poke competition. We are all hoping that apical publicity like this will help to not only draw people into Harney, but also create a cloud of curiosity around the QR codes and the sushi they correspond to. Species by species, Rob and Harney are building up their QR arsenal and eventually plan on having an informative piece linked to every species they serve in their restaurants.

Chef Rob and I are collaborating to create the website encoded in the uni QR code. On the site we plan to addresses everything a person could want to know about uni, sea urchins, and the sea urchin fishery. Written in a style targeting the general public, information regarding red and purple sea urchin life history, the difference between the different species, maps of fishing grounds, pictures and videos of sea urchins in their natural habitat, stock status updates as made available, and links to California Fish and Wildlife catch information will be included. We are also looking to create an informative page about the progression of research under the *R/FISH-209, The sustainability and fine-scale management of a sea urchin fishery and the ecology of exploitation in a southern California kelp forest* funding. We plan to include a “frequently asked questions” section as well as an “ask a biologist” section, providing an interactive way for the public to ask us questions directly.

Rob and I are currently in the process of buying a domain name. With some wonderful suggestions from the Dayton lab, we are making final decisions on a name that would be easy to remember but also scientifically respectable. Once the domain is secured, I will be responsible for acquiring or authoring information to be posted, as well as updating it as necessary. Ultimately, it will be run by Rob’s multimedia public relations expert. For further exposure, we have been granted permission to link the site to Harney Sushi’s website.

With the public’s demonstrated interest in the codes at the Poke Festival, Rob and I are very excited to get this project up and running as soon as possible. We are hopeful that this innovative attempt to capture public interest in the QR codes, the uni, and ultimately sustainable seafood will slowly grow in popularity and be the next step in Rob's journey to changing the way San Diego thinks about and consumes seafood.

VIII. Acknowledgements

I would like to specially thank the Dayton lab, particularly Ed Parnell and Kristin Riser for letting me hijack all of their sea urchin gear. I would also like to thank them for answering my endless questions, particularly those that took place really early in the morning! A special thanks goes out to Ed for dedicating so much time putting almost 200,000 data entries into Matlab and being an R expert in data analyses. Clearly, I could not end this thank you without thanking him and his lab for their domain name suggestions, both for being creative and sometimes hilarious. I would also like to thank Bryan McGrory for helping me with all of the diving and being an excellent boat launcher and skipper. Thank you all, it has been a great experience meeting and working with you.

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