APPENDIX I-A-1

REPORT ON SEA URCHIN STOCK ASSESSMENT WORKSHOP JULY 14-16, 2006

JULY 14, 15 2006
HOLIDAY INN BAYSIDE, SAN DIEGO, CALIFORNIA
By: Dr. Ray Hilborn and Dr. Steve Schroeter

Attendance

Jenny Wolf (UCSB), Steve Schroeter (UCSB), Ray Hilborn (UW), Nicolas Gutierrez(UW), John Lynham (UCSB), Michael Robinson (UCSB), Chris Miller (CTLA), John Ugoretz (CDFG), Kristine Barsky (CDFG), Carrie Culver (CA Sea Grant), Jonathan Hardy (State Sen. Ducheny staff), Dave Rudie (San Diego Sea Urchin Processor & CSUC) and San Diego sea urchin divers Chris Sparks, Jerry Beverino, Kent Schellin, Dave Datz, Mike Neil, Susan Buck, Gary Harle, and Peter Halmay.

Agenda

1. Review of data
2. Biological hypotheses
3. Model exploration
4. Process and role of Assessments
5. Objectives
6. Harvest strategies

Meeting Objectives

1. Review the role of stock assessment in a management process
2. Review data available for sea urchin assessments especially as related to the proposal "The San Diego Sea Urchin Fishery as a model for the expansion of the role of Fishermen/Managers in science-based management and value-added marketing" submitted to Ocean Protection Council.
3. Review objectives of a management plan and alternative harvest strategies
4. Determine where and how data will be assembled
5. Evaluate alternative types of assessments, and alternative biological assumptions that might be used in an assessment.
6. Identify issues needing to be resolved
7. Assign working tasks emerging from this meeting

Review of the role of stock assessment in the management process

Ray Hilborn provided an overview of the role of stock assessment, and how it relates to the management process. Steve Schroeter presented the status of the Barefoot protocol sampling design, and Nicolas Gutierrez provided an overview of ongoing work on an individual-based RSU population mode.

The purpose of a stock assessment is to evaluate the consequences of alternative management actions and normally includes estimation of current stock size, estimation of productive potential of the stock. Assessments may involve estimation of the history of stock abundance, productivity and exploitation.

Traditional types of stock assessment models include (1) Biomass dynamics models which track total abundance, (2) Size Structured models which track numbers at size using size transition probability table, and size frequency data, and (3) Age structured models, which track numbers at age primarily fitting to observed age distribution.

Each of these kinds of stock assessments must have catch and some index of population abundance and assume that all changes in abundance result from catch interacting with the productivity of the stock. These methods can use other indicators such as size or age distribution, tagging, etc. when available, and may relate productivity to environmental factors such as food, predators or physical environmental variables, like temperature.

Differences between traditional fin-fish assessments and those for sedentary invertebrates are that invertebrate assessments are (1) often size structured rather than age structured, (2) the spatial scale of the "stock" is often much smaller, and (3) the link between "stock" and subsequent recruitment is less direct. This lack of stock-recruitment relationships is due to the fact that recruitment to stocks in small areas is usually driven by a much larger population so that the spawning stock abundance of a single managed stock has little impact on subsequent recruitment and the observation that for many invertebrates it appears that recruitment is limited more by habitat and environmental conditions rather than by spawning stock.

Review of data available for RSU and Pt. Loma assessments

Catch and removals data: We have red sea urchin catch data for the Pt. Loma kelp bed from 1974 onwards. Catch data from other areas in S. California are also available. We do not at present have any estimates in hand of RSU killed by quicklime in the 1966-1980 period.

A time series of index-of-abundance is problematic. There are no fishery-independent surveys; we might attempt to reconstruct a CPUE series, but this would be problematic because the fishermen are able to search for and find the concentrations of uni-bearing (i.e. gonads of requisite quality) urchins and we would not expect the CPUE to decline proportionally to abundance. It might be possible to assume that some constant high fraction of the uni-bearing urchins are harvested, but the dramatic changes in effort over the years, especially in the years following the 1983 El Nino make this assumption dubious. We discussed assuming that the faction of uni-bearing urchins harvested was some function of effort, and this appears to be the most reasonable starting assumption.

There is no data (fishery independent or fishery dependent) on the history of abundance of non uni-bearing red sea urchins, and as it seems that this is a critical portion of the population, we expect to have severe limits on the extent to which we can reconstruct the history of the total RSU population. Collection on current abundance of non uni-bearing red sea urchins both in fished areas and in unfished areas is a high priority.

All parties agreed that kelp abundance has a critical role in providing uni-bearing red sea urchins, and possibly in affecting recruitment, growth and survival. We do have some time series data on kelp abundance, but there are gaps. Further these data cover only the surface canopy kelp and don't include several other types of kelp (elk and palm kelp) that are thought to be very important in the dynamics of RSU.

Data gaps identified

A number of data gaps were identified that need filling in order to implement further modeling on stock assessment (Hilborn) and individual-based models of red sea urchin populations (Gutierrez). The following table describes these gaps and the people who are tentatively assigned to fill them.

Table 1. Summary of some data gaps and person(s) responsible for filling them

Description	Tentative list of Person(s) responsible for filling gap
Number of RSU killed by quicklime 1966-1980(Pt Loma and La Jolla)	Pete Halmay; John Duffy; Dale Glantz
Quantify abundance of sub surface kelps (elk, palm)	Steve Schroeter & Mike Robinson
Separate RSU harvests by kelp bed (i.e. 1,2,3,4 and North County)	Kristine Barsky & John Ugoretz assisted by Barefoot Ecologist tech
Obtain average price of RSU for San Diego for 1988-2006 by month	Dave Rudie
Using CDFG log books and receipts obtain CPUE (catch per diver day)	Kristine Barsky & John Ugoretz assisted by (certified) Barefoot Ecologist tech
Using CDFG log books obtain number of boats (La Jolla and Point. Loma over the threshold of over 20 landings or over 8000 lbs. in any year)	Kristine Barsky & John Ugoretz assisted by (certified) Barefoot Ecologist tech
Literature regarding RSU abundance and size distribution in San Diego (Segars, Kelco reports etc.)	Steve Schroeter & Dale Glantz
Develop assessment methodology using calibrated ROV surveys for deep water RSU.	Steve Schroeter & Donna Schroeder
Literature regarding bioenergetic parameters for sea urchin growth, mortality, and gonadal maturation	Steve Schroeter & Nicolas Gutierrez

Review objectives of a management plan and alternative harvest strategies

Discussed at the meeting were overall objectives of a management plan and a consideration of alternative harvest strategies. The RSU fishery is unusual in that the market is local for fresh uni, and thus a year round fishery is essential despite seasonal variation in uni content, and that the harvest is of uni, not sea urchins, so that it is the availability of uni-bearing urchins that is critical to the harvest. The following were identified as major objectives of participants.

1. Ecological sustainability
2. Year round supply
3. Economic viability of harvesting sector
4. Maintenance of local harvesting fleet

Determine where and how data will be assembled

See Work Tasks below.

Evaluate alternative types of assessments, and alternative biological assumptions that might be used in a red sea urchin stock assessment.

As a result of work performed during the workshop, it appears that we may be able to fit a model to the data to explain the history of abundance and removals of uni-bearing red sea urchins. However as the data collected so far in the barefoot-ecologist program suggest that most uni-bearing red sea urchins are recruiting into the fishery at reasonably large size, it is accepted that most of these individuals are non uni-bearing individuals who transform into the uni-bearing classes when feeding conditions are appropriate. As we have no data on the history of non uni-bearing red sea urchins this means we cannot attempt to estimate the history of recruitment to the whole population.

At best, therefore, with the addition of sampling outside commercially fished areas, and in deep water, we should be able to determine the abundance of both uni-bearing and non uni-bearing red sea urchins at present, and hopefully determine if there is a significant amount of spawning taking place outside of fished areas, from deeper urchins or more offshore urchins.

If we conclude that there is a significant amount of spawning taking place either outside fished areas, or by individuals below the size limit, then the assessment can concentrate on the dynamics of the uni-bearing red sea urchin population for yield purposes and assume that there are no concerns about recruitment overfishing.

If, however, it appears that the majority of spawning is coming from the fished population then an assessment model and harvest strategy will need to be designed to assure that sufficient spawning stock is protected to assure sustainability.

During the workshop some alternative model structures were discussed, and it seems likely that an appropriate model would include at least two pools of individuals, uni-bearing and non uni-bearing sea urchins, and that some classes of size/age would be useful.

It would seem appropriate to build assessment models under the two assumptions of (1) recruitment limited by harvested population and (2) recruitment not limited by harvested population.

A range of hypotheses regarding the role of kelp in maturation, recruitment and survival were discussed and would be included in assessment models.

Identify issues needing to be resolved

Assessment issues are discussed in the previous section. Data needs are discussed in the following section. The workshop discussed institutional changes needed to move the fishery from a competitive fishery where it is not in an individual divers' interest to leave urchins behind to increase their uni-content, to a non-competitive fishery where yields and quality could be increased. It is recognized that there are a range of ways this could be done including cooperatives, area based fishing privileges, and catch shares. These options were discussed, but the main focus of the workshop was stock assessment under the assumption that an effective stock assessment is necessary for evaluating the efficacy of alternate harvesting and management strategies.

Assignment of working tasks emerging from this meeting

Table 2. Working tasks and assignment of responsibility for implementing them

Task	Description	Responsible party & estimated time required
I. Methods of Assessment	Limited calibration work indicates that the Barefoot protocol may be more accurate than the CRANE (CDF&G) protocol for estimating densities and size distributions, but more calibration work needs to be done to see if this is the case. Specifically, the goal of calibration would be to see how biases vary with patchiness and density. This information will be used to tailor the Barefoot sampling design to minimize The data collected to date suggests that the problems of bias and accuracy could be overcome by collecting large numbers of samples with the Barefoot protocol. Estimates of density sufficiently precise to detect 10% changes in density from year to year could be gotten from 1000-1500 Barefoot samples per year. Given the past history of Barefoot data collection with a single diver, this is a very reasonable goal. Ongoing Barefoot Assessment in the short-term, must persuade at least two more divers in San Diego to begin.	Steve Schroeter & Pete Halmay August 2006-December 2006
2.Certification of Barefoot Ecologists	Certification" process to allow new divers to participate and will encourage participation	Ray Hilborn August 2006-October 2006
3.Permitting	Permit process to allow take of urchins for research off-season and outside size limits.	John Ugoretz & Peter Halmay August-September 2006
4.Characterizing urchin populations in non-kelp habitat (deep habitat offshore of historical harvest grounds)	Look at deep habitat and where deep urchins may exists. Determine the gonadal condition of urchins in these habitats and whether they are spawning. Determine size range and whether or how it differs from that in the historical harvest grounds (i.e. kelp habitat) Explore the use of ROVs and kelp baited traps to characterize size, age, and gonadal condition and thus proportion of uni-bearing RSU in the deeper populations.	John Ugoretz/Steve Schroeter/Donna Schroeter/Chris Miller Plan: September/October 2006; Field work: November 2006-November 2007
5.Assess Kelp persistence in	Contact John Ugoretz and Dennis Bedford for the CDF&G kelp data. Contact Larry Deysher and Jan	Dennis Bedford, John Ugoretz, Larry

La Jolla and Point Loma Kelp beds	Svejkovsky (Ocean Imaging). Larry has created kelp canopy persistence maps using data from NPDES monitoring of the southern California Bight by Wheeler North & MBC's aerial overflights in region 9 (Orange & San Diego Counties). The Point Loma/La Jolla database goes back to 1967. This work should start with La Jolla, Point Loma, and Imperial Beach beds. These data should be combined with kelp biomass estimates compiled by Dale Glantz and available through the UCSB LTER program. Michael Robinson will help with GIS work	Deysher, Michael Robinson & Steve Schroeter August - October 2006
6.Track uni price time series	Track of price/per year by area (possibly done already, if not easy to do). Is price driving catch more than population? How does price drive effort?	Dave Rudie August-October 2006
7.Track CPUE from logbooks	Catch Per Unit Effort from logbooks (moderately easy to do, need CDFG staff). How does CPUE change with time? How are CPUE and effort related?	Kristine Barsky/Pete Halmay, CDF& G & Barefoot technician August-October 2006
8.Barefoot Ecologists	Expand barefoot Ecologist program to Imperial beach, La Jolla and North San Diego County	Peter Halmay & existing Barefoot Ecologists September 2006 – September 2007
9.Characterize red sea urchin movements -I	At the kelp bed level determine how red sea urchins move based on information from divers with more than 20 years of experiential knowledge	San Diego Barefoot Ecologists/Nicolas Gutierrez/Steve Schroeter/Pete Halmay. September 2006
10.Characterize red sea urchin movements -II	Movement Study (new work, involve divers in experimental design and monitoring). Use a combination of trapping, mass-marking and time-lapse video cameras to assess movement rates both within the historic harvest grounds and between the historic grounds and hypothesized non-harvest ground (e.g. deep habitats) habitats. Properly designed this work would allow comparison of RSU movements as a function of depth, topography and food (giant kelp and understory kelps) availability. It could address the important questions such as: Is food limiting/enhancing movement? What other factors determine movement look at episodic nature of large movements (e.g. local topographic relief, storms, unusual changes in temperature	Nicolas Gutierrez/Ray Hilborn/Steve Schroeter/Pete Halmay. Design: August-October 2006. Implement October 2006 – October 2007
11.Characterize	As part of the movement study we will use data on	Nicolas

red sea urchin movements –II (contd.)	known growth and mortality rates to filter out the effects of growth and mortality from movement. These data (along with data on the bioenergetics of growth, maturation and mortality) will be used to parameterize an individual based RSU population model.	Gutierrez/Ray Hilborn/Steve Schroeter/Pete Halmay. Design: August-October 2006. Implement October 2006 – October 2007
12.Stock Assessment	Using all of the above, select the most appropriate scale and nature of assessment and conduct an assessment (COPC proposal from SDWA, appendix A)	Ray Hilborn December 2006-March 2007
13.Policy	How is leadership for institutional change in management developed to allow for innovative fishery tactics?	California Ocean protection Council/Rod Fujita

APPENDIX I-A-2

REPORT ON SEA URCHIN STOCK ASSESSMENT WORKSHOP MARCH 19-20 2007

March 19-20 2007
Portuguese Social Hall, SAN DIEGO, CALIFORNIA
By: Dr. Ray Hilborn, Dr. Steve Schroeter, Nicolas Gutierrez

Attendance

Ray Hilborn Professor (UW), Steve Schroeter, Ecologist (UCSB), adjunct Professor (SDSU), Mitch Hobron SDWA diver (San Diego), Debbie Aseltine-Neilson Fish and Game (data research collaborations), John Lynham UCSB grad student, Deanna Pinkard NOAA fisheries (ROVs), Jenny Wolf UCSB (larva settlement studies), John Duffy Consultant (BE program data coordinator), Kathy Viatella The Nature Conservancy, Kirk Schoonover diver (Dana Pt.), Dan Williams diver (Ventura), Cliff Hawk diver (San Diego 29 years exp. - marketing interest), Jim Kinkade diver (San Diego 29 years exp.), Dave Datz SDWA diver (San Diego), Nico Gutierrez Doctoral candidate (UW), Pete Kalvass CDFG (Invertebrate fisheries team leader), Greg Wells Environmental Defense John Butler, Fisheries Biologist NMFS La Jolla, Dave Rudie processor Catalina Offshore Products, Mike Neil SDWA diver (San Diego), Kent Schellin diver (San Diego), Travis Buck CDFG biologist, Paul Brown ROV surveys, Peter Halmay SDWA diver (San Diego 37years exp.).

Initial data available

Kelp and catch Steve Schroeter and Peter Halmay had prepared, prior to the workshop, an estimate of the total catch for Kelp Beds 2&3 at Pt. Loma and the maximum kelp abundance. These data are shown in Table 1.

Table 1. Catch and maximum kelp abundance in the Pt. Loma kelp beds 2&3

Year	Catch in lbs	Maximum kelp abundance	Year	Catch in lbs	Maximum kelp abundance
1974	92,189	6,000	1991	509,775	2,500
1975	148,172	30,000	1992	658,114	2,000
1976	220,000	5,000	1993	793,731	1,200
1977	840,000	8,750	1994	641,256	10,000
1978	841,627	4,000	1995	577,645	9,000
1979	988,656	10,000	1996	671,023	5,000
1980	1,094,656	6,750	1997	338,177	2,000
1981	1,248,638	4,500	1998	141,257	100
1982	1,068,813	4,400	1999	243,314	3,500
1983	172,000	300	2000	275,870	2,500
1984	194,000	2,000	2001	344,308	8,000
1985	126,887	2,800	2002	593,243	8,000
1986	119,800	7,500	2003	450,018	5,000
1987	168,117	8,000	2004	403,920	900
1988	189,703	3,000	2005	314,769	2,400
1989	371,532	8,000	2006		1000
1990	602,077	10,000			

The key characteristics of these data are (1) the initial expansion of the fishery in the late 1970s, (2) the decline in the catch in the early 1980s, and (3) the decline in catch in the late 1990s. The consensus of divers and scientists is that the declines in both 1980s and late 1990s were due to El Nino leading to low kelp abundance and a major reduction in number of uni-bearing urchins (i.e. urchins with gonad size and quality suitable for harvesting). The major drop in catch was said to be exaggerated by a major exodus of divers from San Diego to other Ports in the mid 1980s.

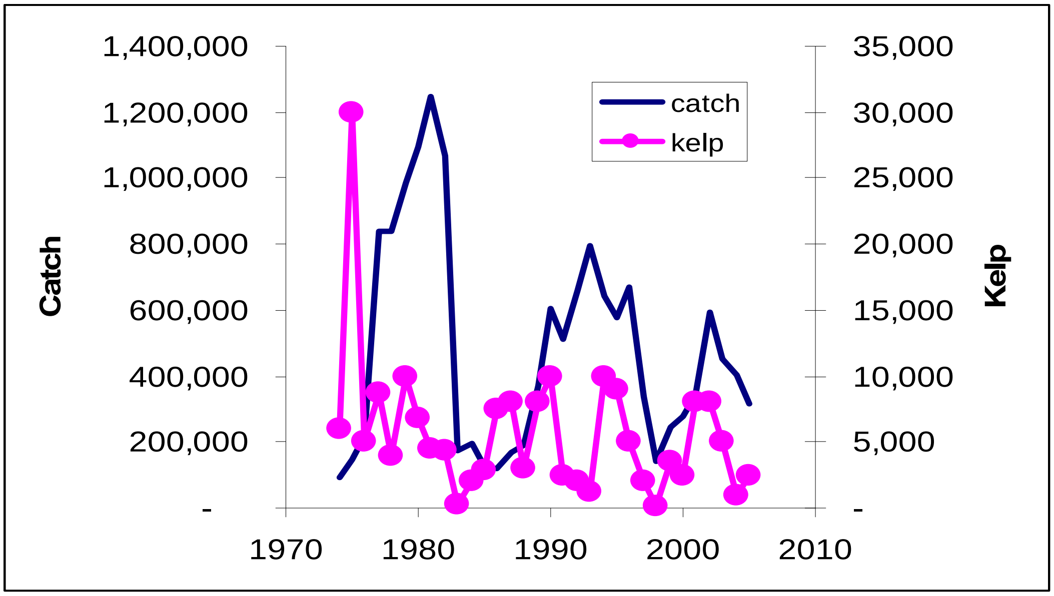


Figure 1. Trends in catch and maximum kelp biomass

Summary of BE data

Data collected by the Barefoot Ecologists is of two kinds: fishery dependent or catch (catch, effort, CPUE, catch size distributions, gonad yield and quality) data, and fishery independent (density and size distributions independent of catch) data. A GPS position was associated with every data point (fishery dependent or independent) collected in the field. Data collection began in 2003 and has continued through the present. Divers' expertise and knowledge about the resource allowed the inclusion of more variables each year, contributing to the general perception of the system (e.g. kelp composition and bottom type; Table 2). The sampling program is almost entirely confined to the Point Loma kelp bed (Figure 2a), where some areas were intensively sampled, and others where only visited once in the whole period (2003-2006; Figure 2b). Major modifications during this period included a shift from variable to fixed (band transects measuring 10m x 4m) sampling units in 2004 for fishery independent density and size data; a computer program for entering and storing data in the field in (2004); and samples outside of the nominal harvest grounds in 2005. The latter was done to address the fact that the previously collected fishery independent data were collected on the harvest grounds and could provide a biased estimate total population size if there were significant areas within the Point Loma kelp bed that were for some reason not harvested. Table 3 summarizes the sampling effort (number of sites sampled or visited) since BE data have been collected. Figure 3 shows size frequency distributions of commercial or legal urchins and total population for the whole period 2004-2006 (a) and by years (b). Mean size for commercial urchins increased with year (93.7, 96.0, 99.6 mm for 2004, 2005, and 2006 respectively) and for the total population also increased from 2004 (85.0 mm) to 2005 (86.3 mm), but decreased in 2006 (81.7 mm). For 2006, a larger proportion of sub legal urchins was noticeable.

Table 2. Variables recorded by the Barefoot Ecologist Program from 2003 to 2006.

Variable	2003	2004	2005	2006
Date	X	X	X	X
Latitude	X	X	X	X
Longitude	X	X	X	X
Depth		X	X	X
Bottom type		X	X	X
Algae composition		X	X	X
Visibility			X	X
SST			X	X
Bottom Time		X	X	X
Catch (lbs)	X	X	X	X
Catch (ind)	X	X	X	X
Area Harvested (m^2)		X	X	X
Mean Size (tot)		X	X	X
Mean Size (com)		X	X	X
Size Frequency Distributions (tot, com)		X	X	X
Density (lbs and ind per m^2)		X	X	X
Gonad Yield (%)		X	X	
Quality Rate (% grade A)			X	

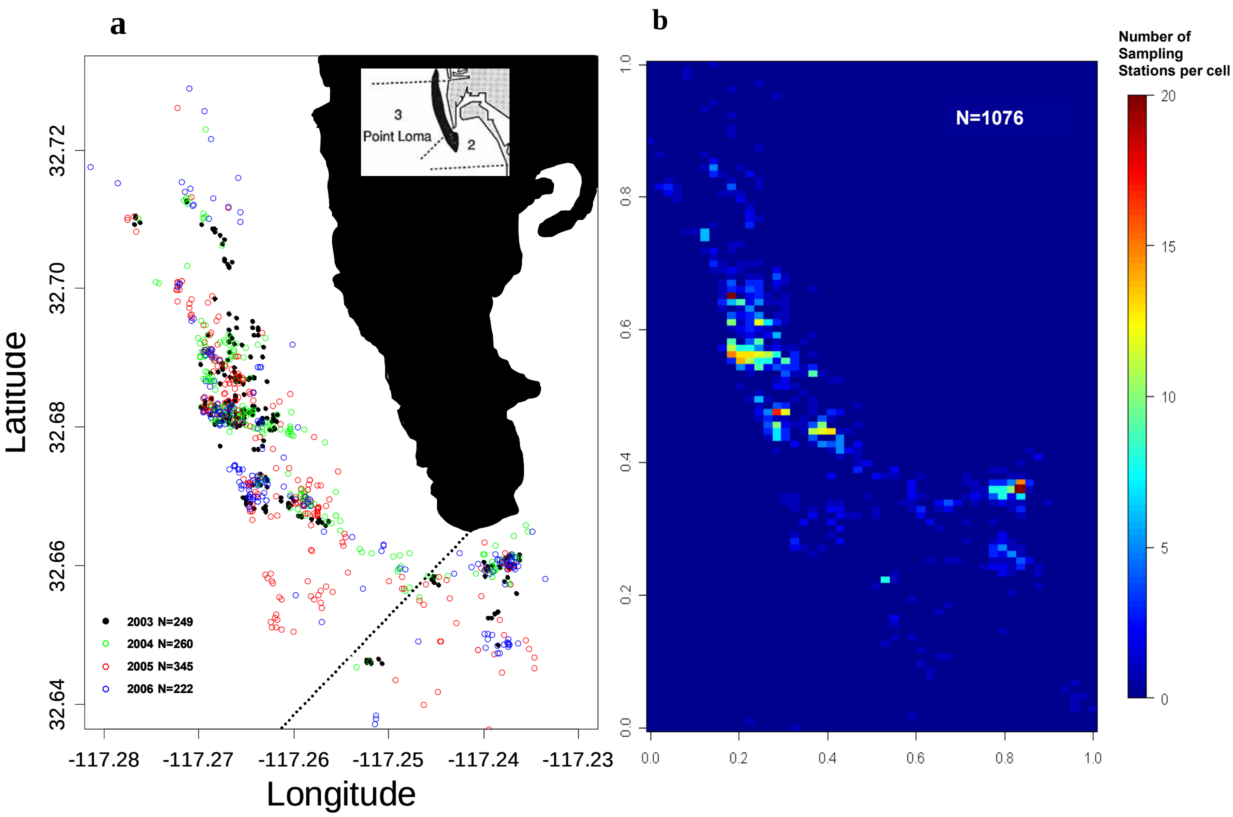


Figure 2. Sampling stations under the Barefoot Ecologist program: (a) total samples by year and (b) density of samples per cell (100x100 m) for the entire period 2003-2006. The dashed line in (a) divides kelp beds 2 and 3 following CDF&G designation. Coordinates are given in centesimal units.

Table 3. Barefoot Ecologist (BE) sampling effort by year in the Point Loma kelp bed.

	Total Sites Visited		Sites with		Sites with Random Densities	
Year	On Grounds	Off Grounds	Catch Number	Catch Densities	On Grounds	Off Grounds
2003	248	0	248	0	0	0
2004	262	0	107	61	32	0
2005	353	76	274	274	127	31
2006	221	0	221	142	118	0
	1084	76	850	477	277	31

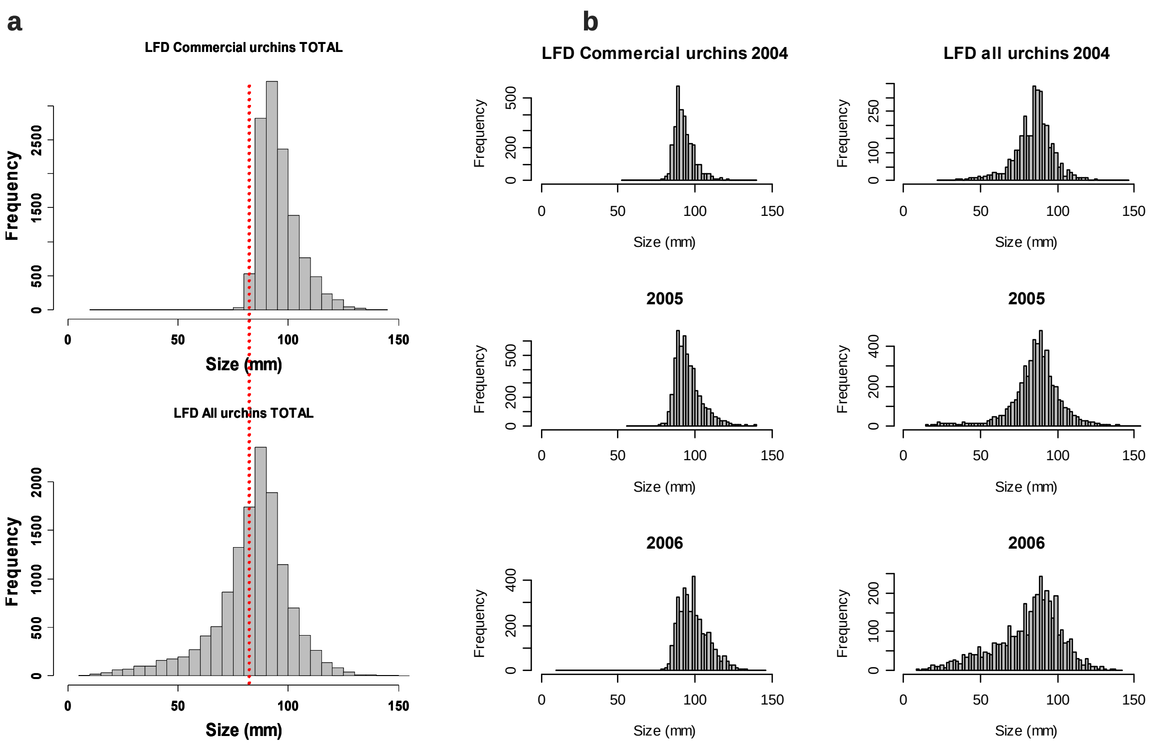


Figure 3. Size frequency distributions of commercial (legal) and total urchins for (a) the entire period 2004-2006; and (b) by year. Dashed line in (a) represents the commercial or legal size limit (82.55 mm).

Figure 4 (on next page) shows trends in the fishery dependent measures of yield (a modified percentage of landed weight recovered as roe (aka "uni") and the catch per unit effort derived from the BE samples. The two measures are correlated over the three year period, perhaps reflecting the fact that less effort is expended on searching and field testing when gonad yield is higher.

Figure 4. Yield (%) and Catch per Effort (Pounds/Minute)
for Red Sea Urchins in Point Loma

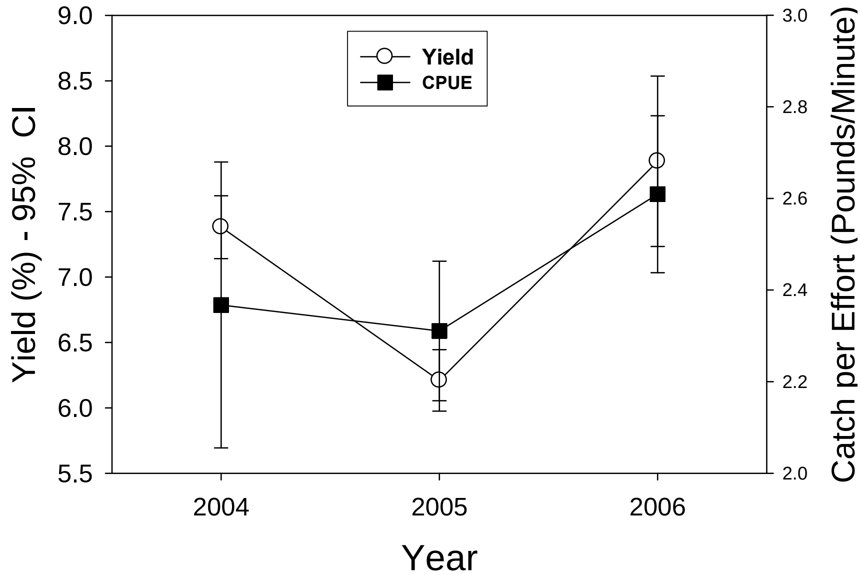


Figure 5 shows densities measured in two ways: 1) random sampling units placed prior to harvesting activities, and 2) estimates derived from estimates of the number of urchins harvested at a site and the estimated area from which the harvest was taken. The harvest method was explored since it requires less effort and resulted in more samples than the random method (see Table 1). Random samples were taken in the harvest grounds in 2004-2006; in 2005 they were also taken in areas outside of the harvest grounds during that year. There is a downward trend in total density for the random estimates; an opposite trend for the harvest estimates. Density estimates were similar for both methods in 2005, and were much higher than the samples from off the harvest grounds. The differing trends for the random and harvest methods could reflect targeting of dense patches during the harvest, although it is puzzling that the random estimates tended to be higher than the harvest method estimates in 2004 and 2005. Although the catch-dependent harvest-based estimates may still to be valuable and will continue to be collected, future efforts will focus on more random samples. The approach will be to collect samples in a stratified-random design by collecting truly randomly placed samples in a uniform grid of cells covering the Point Loma kelp bed. The grid size will be small (on the order of 100-200 meters) to ensure adequate coverage of the kelp bed.

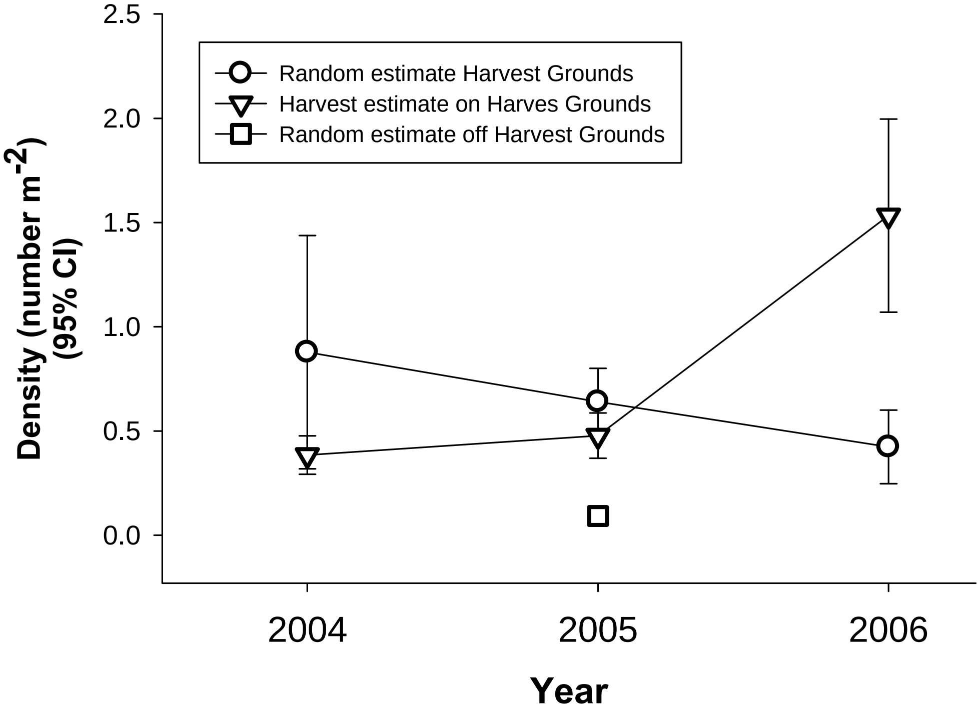


Figure 5. Red sea urchin density estimates from two methods.

Table 4 shows the number of random samples that would be required to detect 10% and 20% changes in total density (and therefore total population size) for each year that Barefoot Ecologist data have been collected. Based on this analysis, we determined that 1500 samples distributed in a stratified random design would enable detection of changes in population size somewhere between 10% to 20%, very small differences by the usual standards of stock assessment. Obtaining estimates of such precision will be a valuable tool in both constructing and calibrating the different stock assessment models we are working on.

Table 4. Yearly mean densities of red sea urchins in the Point Loma kelp bed and the number of random samples required to detect 10% and 20% changes in density from year to year with a probability of 80%.

				Number of samples required to detect a change in density of:	
Year	**n**	**mean**	**sd**	**20%**	**10%**
2004	32	0.88	1.614	499	1990
2005	127	0.64	0.919	311	1452
2006	118	0.42	0.979	928	3705

Estimates of trend in uni-bearing urchin abundance from diver memory

In order to make some progress during the workshop on model fitting, we needed some trend in abundance to use as a target for model fitting. During discussions on the 1st afternoon we asked the divers that were present to provide personal opinions on the change in abundance of uni-bearing urchins. We chose 5 reference years, 1978 to mark the initial beginning of the fishery, 1985 when catch was at the low point, 1993 when catches peaked again, 1997 when catches declined again with an El Nino, and 2002 when catches had rebounded. We asked each diver to use 1978 as a reference year where abundance was 1.0, and then rank the relative abundance in other years. The results are shown in Table 5 below.

Table 5. Diver estimates of relative density of uni-bearing urchins.

	Diver				
	#1	#2	#3	#4	Average
1978	1.00	1.00	1.00	1.00	1.00
1985	0.10	0.15	0.20	0.50	0.24
1993	0.30	0.60	0.50	0.70	0.53
1997	0.10	0.40	0.40	0.50	0.35
2002	0.30	0.50	0.40	0.80	0.50

During the initial data presentations, Pete Kalvass said that CPUE series were available from logbooks, but we did not have that data assembled during this workshop, so for out initial model explorations we used the average trend in abundance calculated in Table 5.

Assessment work and results

Assessment results from inspection

While stock assessments tend to depend primarily on formal model fitting, we began our analysis with some simple analysis from inspection. Given the low natural mortality rate of sea urchins, we can assume that during the initial fish down period, from 1974 to 1985, the ratio of harvest to net production was high, and that we can think of this period as a depletion experiment in the Leslie-Delury sense. During this time roughly 7 million pounds of urchins were harvested. This gives us a rough estimate of the initial stock biomass. If we accept the divers estimates that the 1985 biomass was roughly ¼ of the initial biomass, and ignoring net production from 1974 to 1985, we have an estimate of the initial biomass of very roughly 10 million pounds.

Secondly there are three sources of data that suggest biomass has been, on average, stable or increasing from 1993 to present. Dave Rudie presented CPUE on recent trends, the BE data that has been collected shows no long term downward trend (Figure 4, above), and the divers estimates in Table 2 show a roughly stable population since 1993. The key point is that if the stock has been stable or increasing, then the surplus production during this period is at least as high as the catch during this period. The average catch during this period was 462,000 lbs. This provides an estimate of the sustainable yield for Pt. Loma kelp beds 2&3. Further, if we use our depletion estimate of 10 million pound initial biomass, with current biomass at 24% of that, then we have 2,400,000 tons of current biomass being harvested on average at about 20%, and this level of population size and harvest appears to be sustainable as it has been maintained for 14 years with no downward trend in abundance.

Initial model results

We constructed a simple delay-difference model that includes two population components, immature (I_t), and mature (M_t), each of which is assumed to be of legal size, but the immature individuals do not have enough uni to make them of commercial value. We assume that individuals recruit to the immature population component 6 years after birth some fraction (m_t) of immature individuals become mature each year both mature and immature individuals are subject to natural mortality, parameterized as a survival rate all catch is removed from the mature population in some years there was a urchin control program that removed immature and mature urchins in relation to their abundance, with the total removals Q_t. recruitment in year t is a Beverton-Holt function of mature biomass in year t

(1)
$$I_{t+1} = I_t s_i + R_{t-6} - I_t m_t - Q_t \frac{I_t}{I_t + M_t}$$

$$M_{t+1} = M_t s_m + I_t m_t - C_t - Q_t \frac{M_t}{I_t + M_t}$$

$$R_t = \frac{M_t}{\frac{1}{p} + \frac{M_t}{c}}$$

We assumed that the survival rate of immature was 0.9 and of mature individuals was 0.95. This leaves 2 key parameters of the spawner-recruit curve, and the determinants of the maturation rate m_t over time. The simplest assumption is that m_t is constant over time, and we also explore hypotheses that m_t is related to the kelp abundance.

We assume that the population is in the unfished state in 1974. Thus the parameter *c* will determine the absolute size of the population, parameter *p* will determine how sensitive recruitment is to spawning stock.

Figure 7 shows a fit to the data when we set m_t=0.5 and estimate the two stock recruitment parameters. The key element in this fit is that the parameter *p* is estimated to be high enough so that recruitment is constant.

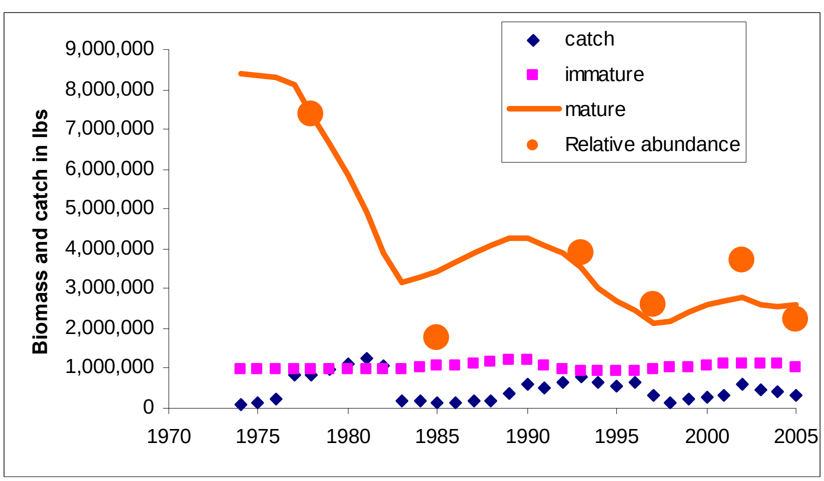


Figure 7. Trends in mature, and immature biomass when fitted to the diver index of abundance data.

From the trends in abundance we can calculate the historical trend in surplus production:

(2) $$P_t = (I_{t+1} + M_{t+1}) - (I_t + M_t) + C_t + Q_t$$

In Figure 8 we see the trend in surplus production, and not surprisingly since recruitment is fit to be constant, surplus production increases as the stock has been fished down.

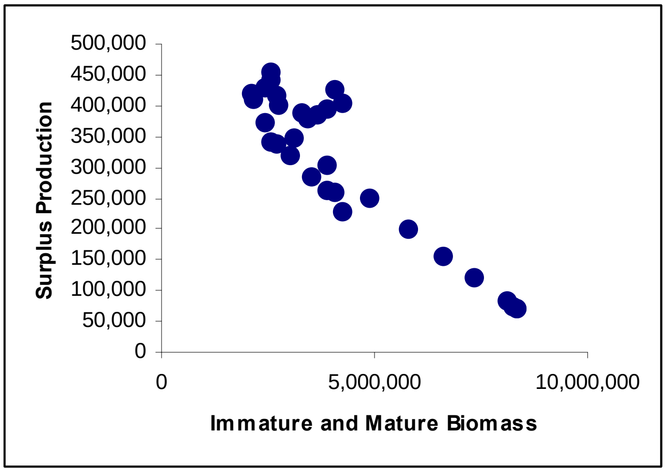


Figure 8. Trends in surplus production from model fit in Figure 7

We then explored a model in which the rate of movement from the immature to mature portions of the population depended on the kelp biomass according to equation 3.

(3) $$m_t = \overline{m} + d(K_t - \overline{K})$$

Where $\overline{m}$ is the proportion maturing at the average kelp biomass, d is the amount maturity increases as kelp biomass increases, and $\overline{K}$ is the average kelp biomass.

We can see we obtain an excellent fit to the index data which is obtained by having an effective threshold with no maturity below the average kelp abundance and 100% maturing when the kelp biomass is above the average.

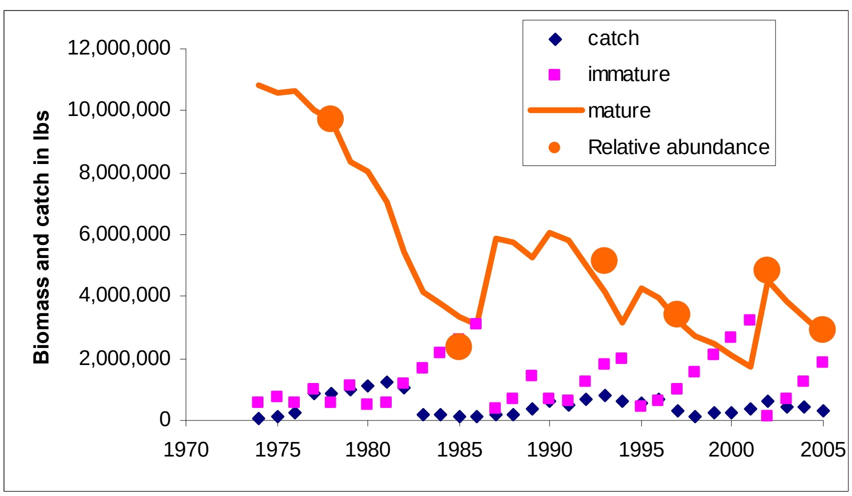


Figure 9. Fit to the data when maturity is a function of kelp biomass.

Shown in Figure 10 is the estimated trend in surplus production.

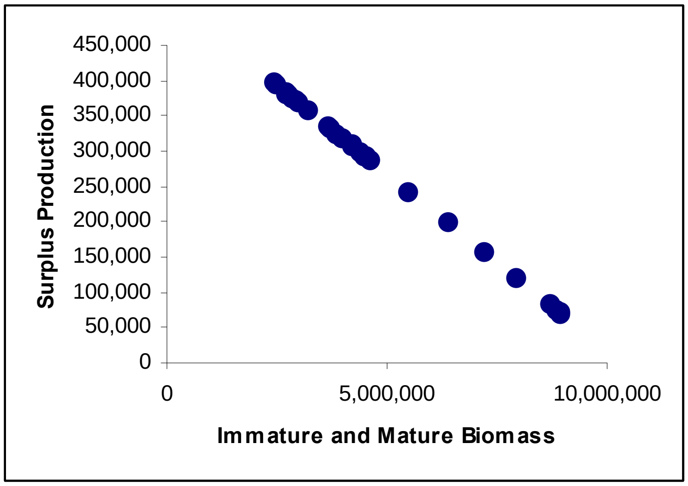


Figure 10. Trend in surplus production from model fit shown in Figure 9.

The modeling we did during the workshop suggested that we should be able to develop an assessment model that can account for trends in the fishery, and provide an understanding of the relationship between biomass and surplus production. This in turn will allow us to develop reference points and a management plan.

Moving towards a management plan

On the afternoon of March 15 the workshop discussed objectives and methods for developing a Pt. Loma sea urchin management plan. The two key objectives of the management plan would be to assure sustainability, and to maximize the economic return from the sustained production from the sea urchin resource. In summarizing the discussion we grouped the elements of discussion into those associated with assuring sustainability, and those associated with increasing the economic value of the resource.

Sustainability

Elements to assure sustainability include a monitoring program to track changes in abundance, reference points to guide changes in management action, and innovative management actions that can be implemented to improve the sustainability of the resource.

The primary tool for ongoing monitoring of abundance would appear to be expansion of the Barefoot Ecologist program, and the workshop discussed how to expand and improve this program. The most significant result of the presentations of the first day and the data analysis presented was the need to obtain truly random samples, and a preliminary target of 1,000 random quadrats a year would be chosen as a target. The SDWA is organizing a certification program so that divers can be trained and certified as Barefoot Ecologists, and it is estimated that these 1,000 random quadrates could be obtained with 40 days of diver time, each diver paid $500 per day, thus costing $20,000 per year. These funds would hopefully come initially from external grants, then be provided from ongoing revenue from the fishery.

As part of the stock assessment we can calculate both exploitation rate and biomass reference points. Given the importance of kelp in driving mature urchin abundance, the reference points might be derived either from estimates of kelp abundance, or perhaps scaled to abundance in protected reference areas.

Additional sustainability measures that could be part of the management plan include:

1. Leaving "brood stock" behind, target minimum urchin density in fished areas
2. Maximum size limit: leaving all urchins above a certain size behind until some target abundance of large urchins was reached
3. Rotating closures
4. Depth closures and surveys of those depths: we have very incomplete information on the abundance of immature and mature urchins at depths below about 90 feet. These areas could be closed and surveys in those depths conducted by ROV to determine the contribution of those depths to the target biomass levels
5. Establishment of permanent closed areas within the Pt. Loma area: these would need to be coordinated with other consumptive users

Increased economic performance

The following items were discussed as ways that the economic performance of the Pt. Loma kelp beds could be improved by a local management plan. All of these are predicated on the assumption that a cooperative of divers would have exclusive access to these fishing grounds and that governance arrangements could be found to make this cooperative move away from competitive fisheries to planned cooperative harvesting.

1. Optimizing roe yield on individual grounds by coordinated harvesting resulting from elimination of the competitive fishery
2. Potential of post harvest feeding: effectively ocean ranching
3. Potential of translocation to put urchins with low uni content in good feeding grounds and potentially to reestablish productive locations
4. Improved marketing including possibly MSC certification
5. Flexible seasons – choice of when to fish
6. Transferable rights
7. General harvesting efficiency by effort allocation/reduction.
8. Potential development of local small scale additional fisheries

Next steps

The following assignments were made for further action.

CPUE trend: Nicolas to obtain from Pete Kalvass. Log book from 1987 on prior to that voluntary log book, plus CMASTER catch records from 79 to develop CPUE series for use in modelling.

Kelp Abundance: Steve S. will talk to Dale Glantz – Steve also check with CFG canopy areas

Density estimates from quicklime projects: Bed-wide estimate 1975: 1.44 urchins/square meter from 1 m^2 4282 quadrats (Seagers et al. 1975). Kelco fixed site urchin densities: Peter H. to see Dale Glantz about this.

BE data, what area to apply the density estimates we have: Peter H, Steve S and Nicolas
Size distribution Market sample data late 80s to present All Sd landings: explore by Pete K and Dave R.

Abundance off harvest grounds: ROV data; explore with cost of looking at tapes to see urchin abundance in abalone surveys: Deanne P.

SST data and bottom temperature: Steve S.

Future data collection

Size frequency collection at the plant : Dave R and Steve S

Expand BE to random sample sites 1500 per year; Pete H. also sample 30 or more for length and quality: need estimate of rugosity: need then to go sample some for cryptic individuals. Sampling design Steve S.

Kelp: drive boat around the kelp bed coordinate with F&G: Steve S. will coordinate with Dave Datz

F&G logbook ongoing CPUE data – Pete K. & Pete H.

Appendix I Agenda

Monday 19 March

9AM – 12PM Presentation of results of July 2006 meeting

1. Historical catches from the records of California Fish & Game, Pete Kalvass
2. average price of RSU for San Diego for 1988-2006 by month, Dave Rudie
3. Number of RSU killed by quicklime 1963-1980, John Duffy
4. Quantify abundance of sub surface kelps (elk, palm at Pt Loma and La Jolla)
5. Previous biomass estimates of sea urchins, Steve Schroeter
6. Recent data on density and size from samples collected by San Diego Fishermen in the "Barefoot Ecologist" program. These data come from both commercially fished areas, and samples taken on grounds that are not normally commercially fished, Steve Schroeter
7. Historical records of kelp abundance from the records of the commercial kelp harvesters, Halmay/Schroeter
8. Discussion of red sea urchin patchiness and movement also the persistence of some areas relative to others, SD divers
9. ROV surveys by NOAA and implications for future work, John Butler/Deanna Pinkard
10. Summary of literature search regarding RSU size and abundance, Steve Schroeter
11. Literature regarding bioenergetic parameters for sea urchin growth, mortality, and gonadal maturation, Schroeter/Gutierrez
12. Presentation and discussion of any previous attempts at assessments for sea-urchins., Pete Kalvass CDFG

12-1pm Lunch

1-5 pm

Present, evaluate and discuss alternative forms of stock assessment for Pt. Loma sea urchins: Ray Hilborn

1. A simple biomass dynamics model, with no explicit age/size structure or spatial structure
2. Models that explicitly track classes of urchins in size and roe content, to evaluate the hypotheses that kelp biomass is a major influence on roe content.
3. Spatially explicit models to allow for the abundance of urchins at depths beyond those normally fished.

PM group dinner/social

Tuesday 20 March

9am – 12

Evaluate alternative hypotheses consistency with data available. In this session we will have the alternative models running and test their ability to match the available data.

We will see if there are any hypotheses that can be excluded, or any additional data that might provide a mechanism to exclude hypotheses.

12:00-1:00 Lunch

1:00-5:00

Follow up on morning session.

APPENDIX I-A-3

ASSESSMENT OF RED SEA URCHIN IN THE PT.LOMA KELP BEDS

Ray Hilborn, Nicolas Gutierrez, Steve Schroeter

Executive Summary

We used several methods to assess the trends in abundance and net productivity of the red sea urchin resource in the Pt. Loma kelp bed. The available data suggest the population is now at 37-51% of the population size when the fishery began in the 1970s and the depletion occurred in the early years of the fishery, with fluctuations but no significant trend since the mid 1980s. Estimation of surplus production shows the highest surplus productions have occurred in recent decades, thus no indication of overfishing. The size distribution data show the modes of the length frequency well above the legal size limit indicating either very low exploitation rates or very significant immigration of legal sized urchins to the harvested population. The data do not help us determine if the Pt. Loma kelp bed population is a self-sustaining population or depends on larval input from elsewhere.

Introduction

The purpose of this document is to present the data available to assess the current stock size and potential productivity of the red sea urchin population in the Pt. Loma kelp beds #2&3 off San Diego (Figure 2.1) and use these data to determine trends in abundance and stock productivity.

In the last decade assessments of semi-sedentary invertebrates such as abalone, lobsters and sea urchins have tended towards use of statistical size-transition models, fitting indices of abundance such as CPUE and observed length frequency data. This type of model has been applied for green sea urchins in Maine (Chen et al. 2003; Grabowski and Chen 2004; Kanaiwa et al. 2005), lobsters in Maine (Chen et al. 2005), lobsters in Australia (Punt and Kennedy 1997; Hobday and Punt 2001), lobsters and abalone in New Zealand (Breen et al. 2003; Breen et al. 2006) lobster in South Africa (Bergh and Johnston 1992; Johnston and Butterworth 2005) , crabs in Alaska (Zheng et al. 1995). For Pt Loma we have only limited length frequency data, and there are naturally questions regarding the relationship between CPUE and stock abundance. As this is the first assessment for sea urchins in this area, and one of the first assessments for sea urchins in California, we are going to explore a range of assessment tools, rather than selecting an individual assessment model. First let us consider the major issues associated with the dynamics and biology of sea urchins in Pt. Loma.

The Pt. Loma urchin fishery began in the early 1970s and expanded rapidly. By 1980 over 1 million pounds per year of urchins were being landed, but the landings crashed in 1983 when less than 200,000 lbs were landed. There is general agreement among commercial divers active in that period that the urchin population had been significantly depleted, and the decline in landings was made stronger because most divers who had been active in the Pt. Loma area moved to other parts of California where the fishery was just developing. Commercial divers express conviction that part of the lack of urchins of commercial value was the decline in kelp in that era and scientific data Tegner and Dayton 1991 show that the el Nino led to much lower kelp biomass and urchin recruitment. Since 1989 landings in the fishery have recovered to an average of about 500,000 lbs per year, with ups and downs, but in the long term reasonably stable landings. Given the long life and slow growth of urchins, questions remain as to whether the current fishery is based on a sustainable balance of recruitment and fishing mortality, or possibly the fishery is still “mining” a large population and current yields are not sustainable. That is one of the key questions this assessment addresses.

Fishermen believe they take a reasonably high proportion of the urchins in the areas they fish, that is they go to a site, and take most of the legal sized urchins. The spatial coverage of their individual dives is such that effectively all parts of the Pt. Loma beds are intensively harvested. Yet divers often return to exactly the same spot several times in the same year, and each time normally find a new crop of legal sized urchins. Given that urchins are slow growing, and it is effectively impossible that a significant portion of the sub-legal sized urchins fished on one trip have grown into the legal size on the next trip, that most of the commercial harvest is coming from urchins that have either emerged from hiding in cracks and crevasses between visits by divers, or they have moved into this site from other areas not harvested.

Almost all assessments of invertebrates are confounded by questions of spatial scale. Most assessment models assume a homogeneous stock within the area modeled. The question then is at what spatial scale can we consider the stock homogeneous, especially with respect to growth rates, recruitment etc. The Pt. Loma area that is fished for urchins is quite small, a few square kilometers, yet scientists and commercial divers recognize a great deal of spatial structure within this area with respect to the physical structure of the bottom, kelp coverage, urchin density, and the proportion of urchins that have commercial quantities of uni. While it is possible to explore biological models on very small spatial scales (10s of square meters), we cannot imagine an assessment model working at that scale, and for the purposes of this document we will consider, in all of our models, a single area, Pt. Loma kelp beds #2 and 3. We will explore models that distinguish between uni-bearing and non-uni-bearing urchins, and size or age structure. We recognize that data coming from commercial divers will be biased because within our assessment area they will chose to go to areas of relatively high urchin density.

As we shall see, the length frequency of urchins in the Pt. Loma bed shows a high frequency of large urchins, a length frequency that is inconsistent with a high fishing mortality rate of individuals recruiting to the commercial fishery at the legal size limit. We have data from tagging studies to determine annual growth increments. Unfortunately the majority of this tagging data does not come from Pt. Loma, and it is possible that the Pt. Loma population grows considerably faster than other places in California. Further, it is also possible that there is temporal or small scale spatial variation in growth. For example in years with good kelp abundance we might expect growth to be more rapid.

An important assessment issue is the relative abundance of “recruited” and non-recruited individuals. Divers primarily take legal sized uni-bearing urchins. In any dive site there are usually sub-legal sized urchins that are left, and in some sites many if not most individuals might have low uni content and be left. Furthermore experience shows that in many habitats many urchins are hidden in crevasse and inaccessible to normal commercial diving, and that in other areas, often deeper areas, there are significant concentrations of urchins that are either have little uni or are commercially undesired (perhaps due to depth). Divers believe that years of high kelp abundance cause a greater proportion of the total population to have commercial quantities of uni. In the models explored below we will address the dynamics of non-recruited and recruited individuals and the potential role of kelp.

Biological studies in the 1970s have shown that many small urchins can recruit under the spine canopy of larger urchins, and have suggested that recruitment to the population may be facilitated by a large standing stock of large urchins forming spine canopies. Fishing policies will generally lead to the depletion of any large concentrations of urchins, and thus it has been suggested that some areas should be protected to maintain large spine canopies and facilitate recruitment (Tegner and Dayton 2000).

Data Available

Growth and survival rates

Growth rates were estimated for red sea urchins during a series of 18 1-year mark and recapture experiments conducted between 1989 to 1984 from Washington to southern California (Ebert et al. 1999), using approximately 120 to 700 individuals. Growth was measured for "jaws" (components of the Aristotle's lantern) using a tetracycline tag and fit to the Tanaka growth function Tanaka 1982), a three parameter growth function that best models the main features of red sea urchin growth. Test growth was calculated using the allometric relationship between jaw and test diameter. Survival rates were higher in southern California than at more northern sites and so we present maximum and minimum growth and survival figures for southern California that can be used to bracket these parameters for Point Loma beds 2 and 3

Table 3.1.1 Growth and mortality parameters estimated from Ebert 1999.

		Tanaka parameters				survival
Growth Rate	Site	f	a	d	years to legal size	$1\text{-}Z\ yr^{-1}$
Minimum	Anacapa Island	2.315	-1.302	32.124	11.25	0.801
Maximum	San Miguel Island	7.328	-0.182	4.669	5.75	0.635
Overall	18 sites	8.233	-0.222	7.772	8.75	n/a

Additional analysis that estimate growth or mortality are found in other papers shown in table 3.1.2 and Table 3.1.3.

Table 3.1.2 Maximum likelihood estimates of growth and mortality parameters from red sea urchin data from three 'unfished' locations in northern California. Taken from Morgan et al. 2000 (Table 1).

Location	Growth increment (*N*)	Size distribution (*N*)	μ_L	σ_L	Growth coefficient *K*	Natural mortality *M*	Objective function: Size frequency	Objective function: Growth increment	AIC
Full models									
CC	50	1636	126.6 (1.3)	9.7 (0.8)	0.27 (0.01)	0.21 (0.01)	91.9	217.4	317.3
SP	48	2628	102.0 (0.6)	13.5 (0.4)	0.32 (0.03)	0.00 (0.01)	54.1	238.5	300.6
BMR	157	2251	118.1 (0.6)	10.0 (0.4)	0.22 (0.01)	0.08 (0.01)	316.6	602.9	927.5
CC/SP/BMR	255	6515	112.5 (0.6)	12.8 (0.4)	0.28 (0.01)	0.09 (0.01)	1094.9	1072.9	2175.8
CC/BMR	207	3887	120.6 (0.6)	10.3 (0.4)	0.25 (0.01)	0.13 (0.01)	530.3	851.2	1389.5
CC									
1995	50	666	108.0 (2.7)	15.8 (1.5)	0.34 (0.02)	0.12 (0.02)	50.3	222.7	281.0
1996	50	651	126.3 (1.8)	8.4 (1.1)	0.27 (0.01)	0.23 (0.02)	153.0	217.9	378.9
1997	50	319	136.9 (2.3)	7.6 (1.5)	0.24 (0.01)	0.20 (0.02)	184	222.5	414.5
SP									
1994	48	663	102.4 (1.3)	15.3 (0.7)	0.31 (0.03)	–0.02 (0.02)	106.4	240.6	355.0
1995	48	648	95.4 (1.4)	13.4 (0.8)	0.38 (0.02)	0.06 (0.02)	64.4	243.9	316.3
1996	48	653	102.6 (0.98)	13.1 (0.6)	0.31 (0.02)	–0.10 (0.02)	45.7	237.7	291.4
1997	48	664	102.0 (0.88)	10.8 (0.6)	0.32 (0.01)	–0.04 (0.02)	32.5	236.1	276.6
BMR									
1994	157	657	113.0 (1.1)	7.9 (0.7)	0.25 (0.01)	0.10 (0.008)	114.6	598.0	720.6
1995	157	592	121.8 (1.0)	9.1 (0.7)	0.21 (0.01)	0.05 (0.01)	91.1	605.8	704.9
1996	157	670	111.5 (1.4)	13.5 (0.9)	0.25 (0.01)	–0.003 (0.01)	94.4	602.0	704.4
1997	157	332	126.3 (2.1)	4.4 (1.8)	0.19 (0.01)	0.17 (0.01)	461.2	611.7	1080.9

Note: Full models include all of the data collected at those sites in all years. Fits from individual-year size distribution data are listed separately. Standard errors are given in parentheses. The estimates of standard errors were obtained using a reliable numerical method (see Smith et al. 1998). CC, Caspar Closure; SP, Salt Point; BMR, Bodega Reserve.

Table 3.1.3 Taken from Smith et al. 1998; Table 2).

Table 2. Parameter estimates (with SEs in parentheses) for those analyses illustrating the use of (*i*) growth increments alone, (*ii*) size frequencies alone and size frequencies with growth increments for the unharvested site (Point Cabrillo Marine Reserve), and (*iii*) size frequencies with growth increments for the harvested site (near Fort Bragg, Mendocino County).

Analysis	*p*	μ_L (mm)	σ_L (mm)	μ_K (year^{-1})	σ_K (year^{-1})	*Z* (year^{-1})	*F* (year^{-1})	$\sigma_{M,l=100}$ (%)	μ_ψ (mm)	σ_ψ (mm)
Growth increments (Fig. 2)	0.02	72.1 (6.0)	18.3 (2.3)	1.14 (0.19)	0 (—)	—	—	2.4 (0.2)	—	—
Unharvested site (Fig. 3)										
Size frequencies only[a]	>0.1	113.1 (1.5)	14.4 (0.9)	4.9 (1.2)	—	—	—	—	13.2 (2.4)	7.4 (2.4)
Size frequencies and increments	>0.1	110.4 (1.7)	16.5 (1.2)	0.61 (0.2)	—	0.064 (0.03)	—	3.4 (0.3)	11.4 (2.3)	6.6 (2.1)
Harvested site (Fig. 3)										
Size frequencies and increments (unconditional)	>0.1	78.3 (3.8)	19.7 (0.9)	0.98 (0.08)	—	0.80 (0.61)	0 (—)	2.4 (0.2)	1576 (1058)	164 (83)
Size frequencies and increments (conditional)	>0.1	110.4 (—)	16.5 (—)	0.61 (—)	—	0.064 (—)	0.36 (0.04)	3.4 (—)	43 (6)	26 (5)

Note: For the harvested site, one analysis attempts to estimate all parameters (unconditional) and the other is conditional upon the growth and natural mortality estimates. Note that *F* refers to $F(l)$ where $l \geq$ 76 mm, the minimum legal size.

[a]For this case with just size frequency data, μ_K refers to the ratio μ_K/Z.

Table 3.1.4 Total mortality rates (from Ebert et al. 1999)

Table 5. *Strongylocentrotus franciscanus.* Size data and allometric parameters for diameter as a function of jaw length (cm) that were used to estimate the instantaneous mortality rate, $Z\ yr^{-1}$, using Eq. (12); small sea urchins were collected from surrounding areas and added to some of the study sites; measurements are in cm; S_R is the size at recruitment for each size distribution

Site	N	α	β	S_R	Mean	$Z\ yr^{-1}$
Stomach Bay, AK, 1993	192			2.50	10.144	0.047
Additional small ind.	53				2.841	
Collection 1994	623	4.926	1.175	2.75	9.855	0.054
Blank Island, AK, 1993	184			1.8	8.253	0.064
Additional small ind.	74				3.779	
Collection 1994	746	4.852	1.145	2.0	9.691	0.038
North Shaw Island, WA 1991	225			3.25	13.225	0.038
Additional small ind.	46				4.522	
Collection 1992	390	5.535	1.248	3.25	13.076	0.040
West Shaw Island, WA ,1991	210			4.50	13.153	0.031
Additional small ind.	35				4.934	
Collection 1992	409	5.575	1.228	3.00	13.608	0.022
Halftide Rock, WA, 1991	124			9.0	14.364	0.016
Additional small ind.	54			3.5	5.628	
Collection 1992	530	5.352	1.248	6.5	13.372	0.023
Selness Reef, WA, 1990	235			5.00	12.699	0.033
Additional small ind.	88				5.501	
Collection 1991	533	5.403	1.200	2.00	12.273	0.025
Long Brown Rock, OR, 1992	409			3.5	8.743	0.085
Additional small ind.	76				4.111	
Collection 1993	1757	4.584	1.140	1.5	8.005	0.080
Nellie's Cove, OR, 1992	379			3.75	10.397	0.099
Additional small ind.	335				3.362	
Collection 1993	660	5.329	1.212	2.75	9.292	0.133
Van Damme State Park, 1993	197	5.236	1.257	2.50	7.031	0.204
Pt. Cabrillo Mar. Res., CA, 1989	88			1.5	7.797	0.065
Collection 1990	356	4.542	1.174	1.5	7.412	0.077
Pt. Cabrillo Mar. Res., CA, 1990	203			1.7	7.980	0.060
Collection 1991	288	4.292	1.241	1.5	8.384	0.049
Pt. Cabrillo Mar. Res., CA, 1992	261	4.679	1.188	3.0	6.723	0.158
Caspar Mar. Res., CA, 1992	222	5.089	1.104	3.5	10.076	0.067
San Miguel Island, CA, 93	385			1.75	5.002	0.401
Collection 1994	351	5.059	1.209	1.75	5.256	0.365
Anacapa Island, CA, 1992	148			1.5	5.256	0.203
Collection 1993	359	4.730	1.204	1.7	5.418	0.204
Anacapa Island, CA, 1993	224			2.0	4.774	0.241
Collection 1994	327	4.877	1.183	2.0	5.261	0.199
San Nicolas Island, CA, 1989	188				6.098	
Collection 1990 (Cosign)	231	4.441	1.244	2.80	5.658	0.106
San Nicolas Island, CA, 1989	151				7.014	
Collection 1990 (NW Point)	152			2.80	7.015	0.088
San Nicolas Island, CA, 1990	276			1.80	5.242	0.292
Collection 1991(Block 1)	281	4.896	1.214	1.80	5.501	0.264
San Nicolas Island, CA, 1990	232			1.80	4.931	0.330
Collection 1991(Block 2)	249			1.80	5.028	0.317
San Mateo Point, CA, 1989	45				4.188	
Collection 1990	188	4.996	1.214	2.75	5.760	0.334
San Mateo Point, CA, 1993	173				5.065	0.147
Collection 1994	628	4.409	1.168	2.75	5.212	0.133

The key feature of all of these data and estimates is that natural mortality rates are low, and urchins are reaching the legal size at a minimum of about 6 years.

Catch

Table 3.2.1 shows the catch data for the Pt. Loma kelp beds, compiled from the statistics of California Department of Fish and Game.

Table 3.2.1. Catch in the Pt. Loma kelp beds 2&3

Year	Catch in lbs	Year	Catch in lbs	Year	Catch in lbs
1974	92,189	**1985**	126,887	**1996**	671,023
1975	148,172	**1986**	119,800	**1997**	338,177
1976	220,000	**1987**	168,117	**1998**	141,257
1977	840,000	**1988**	189,703	**1999**	243,314
1978	841,627	**1989**	371,532	**2000**	275,870
1979	988,656	**1990**	602,077	**2001**	344,308
1980	1,094,656	**1991**	509,775	**2002**	593,243
1981	1,248,638	**1992**	658,114	**2003**	450,018
1982	1,068,813	**1993**	793,731	**2004**	403,920
1983	172,000	**1994**	641,256	**2005**	314,769
1984	194,000	**1995**	577,645	**2006**	

Kelp abundance

ISP Alginates (formerly Kelco Co.) has collected information on the abundance of giant kelp (Macrocystis pyrifera) in California and Mexico from routine aerial surveys since 1957. The standard protocol consists of an observer visually estimating the amount of harvestable giant kelp biomass within designated kelp beds from a small fixed-wing aircraft. Observations were recorded on paper data sheets in the field and archived in notebooks housed at ISP Alginates. With cooperation from ISP Alginates, the Santa Barbara Coastal Long Term Ecological Research project (SBCLTER) converted ISP Alginates' long-term records of giant kelp biomass into a digital format. The database consists of a data table containing kelp biomass and a catalog of maps. The format ISP Alginates used to report kelp abundance data changed periodically over the course of the collecting period. These details, plus descriptions of designated kelp beds are described in the protocol document.

Table 3.3.1. Maximum kelp abundance in the Pt. Loma kelp beds 2&3

Year	Maximum kelp abundance	Year	Maximum kelp abundance	Year	Maximum kelp abundance
1974	6,000	**1985**	2,800	**1996**	5,000
1975	30,000	**1986**	7,500	**1997**	2,000
1976	5,000	**1987**	8,000	**1998**	100
1977	8,750	**1988**	3,000	**1999**	3,500
1978	4,000	**1989**	8,000	**2000**	2,500
1979	10,000	**1990**	10,000	**2001**	8,000
1980	6,750	**1991**	2,500	**2002**	8,000
1981	4,500	**1992**	2,000	**2003**	5,000
1982	4,400	**1993**	1,200	**2004**	900
1983	300	**1994**	10,000	**2005**	2,400
1984	2,000	**1995**	9,000	**2006**	

Indices of abundance

CPUE has been collected from logbooks maintained by California Department of Fish and Game (provided by Pete Kalvass.) and are shown in Table 3.4.1. and is measured in lbs landed per hour?

Table 3.4.1 Average catch per hour in Pt. Loma kelp beds 2&3 from CDF&G logbook data

Year	CPUE	Year	CPUE	Year	CPUE
1974		**1985**		**1996**	151
1975		**1986**		**1997**	150
1976		**1987**		**1998**	123
1977	344	**1988**	193	**1999**	130
1978	451	**1989**	235	**2000**	163
1979	429	**1990**	194	**2001**	163
1980	353	**1991**	199	**2002**	182
1981	359	**1992**	209	**2003**	181
1982	350	**1993**	186	**2004**	188
1983	381	**1994**	166	**2005**	205
1984	180	**1995**	249	**2006**	212

Length frequency

Length frequency data have been collected since 2004 in the Barefoot Ecologist program, in which commercial divers lay out a 10m x 4m quadrat at their anchor site, count the total abundance of urchins in the quadrat, and send the first 30 urchins encountered to the surface to be measured for length frequency. These data are shown below. The Barefoot Ecologist program also samples the commercial catch. California Department of Fish and Game also samples commercial landings.

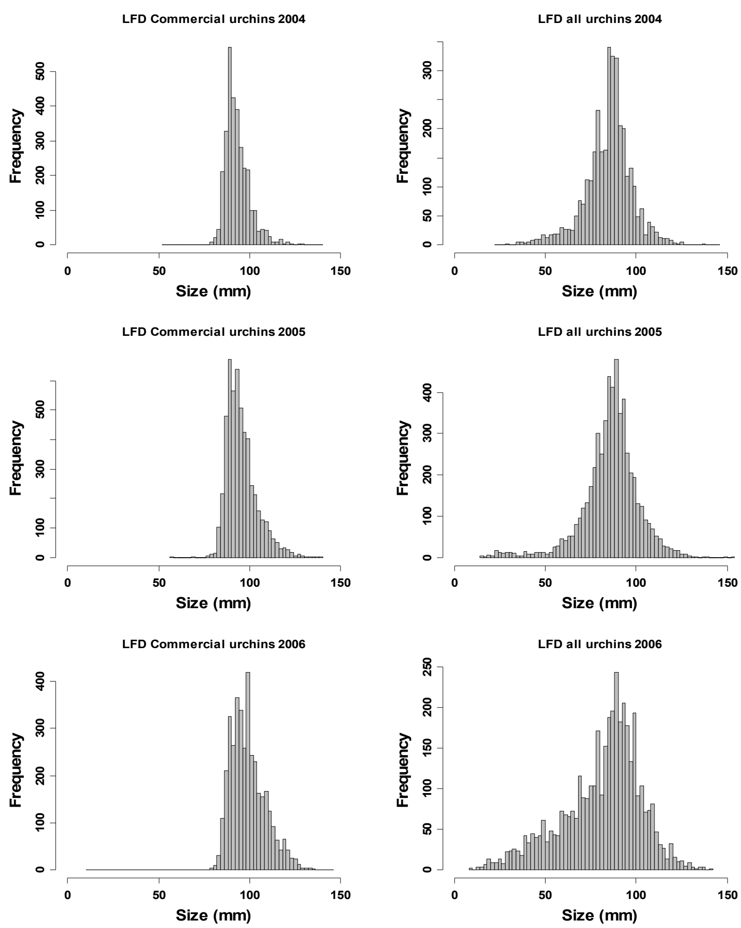
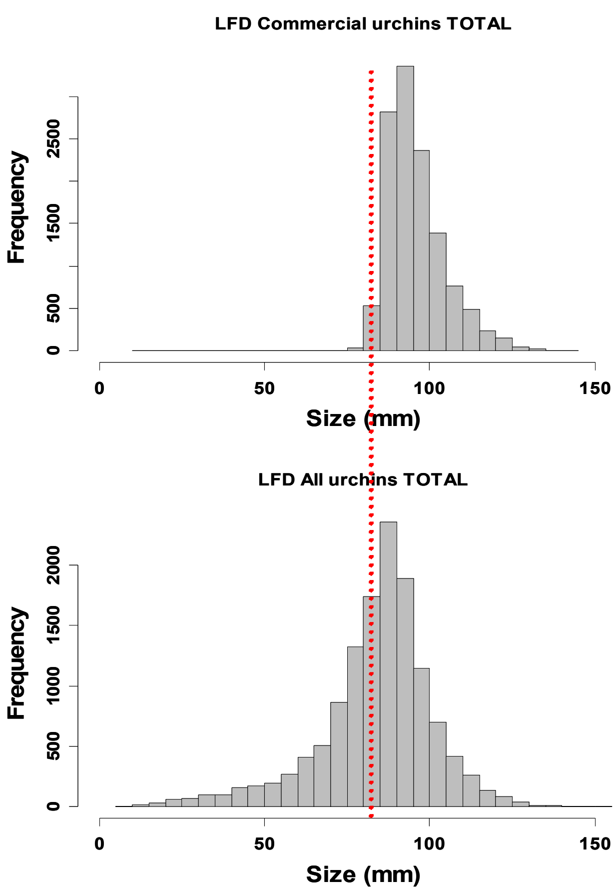


Figure 3.5.1 Length frequency distribution for the total population and catch of red sea urchin by year (2004-2006) from the Barefoot Ecologist program.



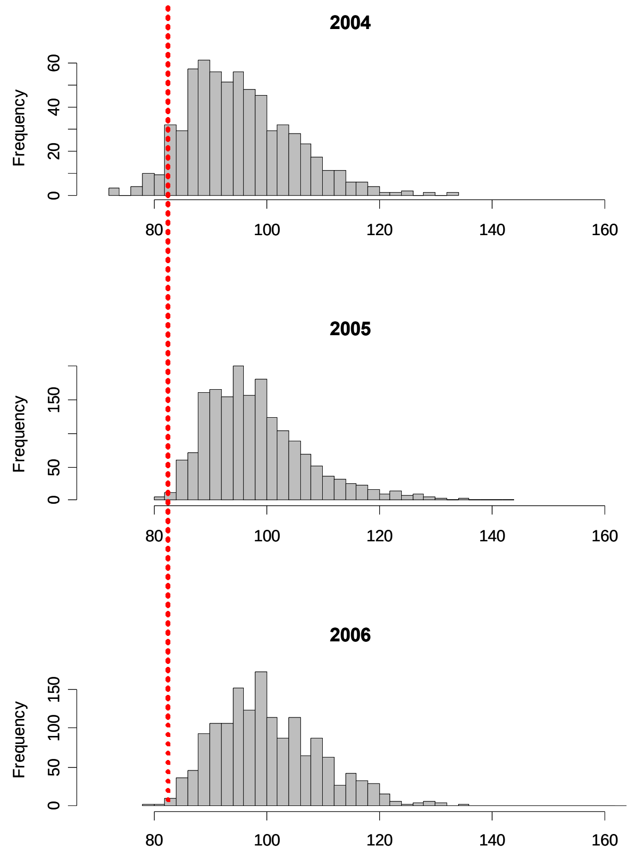


Figure 3.5.2 (left) Length frequency distribution for the total population and catch of red sea urchin for all years (2004-2006) from the Barefoot Ecologist program. The red dotted line represents the legal sea urchin size limit (82.55 mm).

Figure 3.5.3 (right) Length frequency distribution of the catch by years (2004-2006) from the CDF&G sampling program. The dotted red line represents the legal sea urchin size (82.55 mm).

Absolute abundance estimates

Population abundance and size distributions for Point Loma beds 2 and 3 have been estimated by the Barefoot Ecologist Program in 2004 to the present and data are presented from 2004 through 2006. Briefly, densities are estimated by quasi-randomly placed band transects measuring 10m x 4m within areas harvested. The transects are deployed prior to harvesting in the general area where the harvest takes place. All non-cryptic red urchins are counted and thirty (30) urchins are collected and measured. In 2005, sites deemed to be off of the harvest grounds in recent years were also sampled. Densities but not size distributions were estimated with the same methods used for the "harvest ground" samples in 2004 through 2006. Data are also presented from samples taken in 1975 prior to any significant harvesting of red sea urchins (Seagars et al. 1975). Densities were estimated in a large number 1 m^2 quadrats (n=4282) placed in a stratified haphazard design throughout beds 2 and 3. Size distributions were estimated from two 1 m2 quadrats at a subset of the sites. These data were used to calculate the total population densities. Total population size was calculated by multiplying density estimates by the maximum area of kelp canopy as a proxy for suitable red sea urchin habitat (7,991,900 m^2). (note: no confidence intervals for 1975 total population size)

In the tables below we explore several comparisons abundance from the two methods.

Table 3.6.1 Comparison of density and size between 1975 and 2005/2006.

	1975	**2005/2006**
Proportion of urchins > 100 mm	20.5%	14.4%
Mean size (mm)	73.1	81.6
Total density (urchins/m²)	1.44	0.53

Each of these comparisons is interesting. The proportion of larger urchins is smaller now than it was 30 years ago, mean density is roughly 1/3, and mean size is larger. The barefoot ecologist sampling protocol could explain the increase in mean size. The sites for the BE program are not randomly selected but are commercial diving sites, and heavily crevassed or sites where many small urchins are found may be avoided. The BE program design may also overestimate mean abundance because of its non-random nature. The decline in proportion over 100 mm is understandable based on the fishery removals.

Table 3.6.2 Comparison of densities for 1975, 2004, 2005 and 2006.

	All Sizes		Legal (>= 82.55 mm test diameter)			
Year	Mean (m^{-2})	sd	Mean (m^{-2})	sd	95% CI	n
1975	1.44	4.15	0.59			4282
2004	0.88	1.61	0.57	1.76	0.64	29
2005	0.64	0.92	0.43	1.10	0.19	122
2006	0.42	0.98	0.25	1.22	0.22	117

Table 3.6.3 Estimated total population size.

	Total Population Size		
Year	mean	95% CI	Source
1975	11,508,336	993,397	Seagars et al. 1975
2004	7,017,887	4,469,612	Barefoot Ecologists
2005	5,117,648	1,277,313	Barefoot Ecologists
2006	3,384,705	1,412,378	Barefoot Ecologists

Table 3.6.4 Estimates of legal population size

	Legal Population Size		
Year	mean	95% CI	Source
1975	4,752,943		Seagars et al. 1975
2004	4,541,460	5,114,959	Barefoot Ecologists
2005	3,402,432	1,557,699	Barefoot Ecologists
2006	2,007,934	1,768,821	Barefoot Ecologists

Urchins killed by quicklime

CDF&G conducted a series of pre and post-treatment surveys to monitor the effects of quicklime (CaO) used in sea urchin control at Point Loma, San Diego. Estimates of the number of red sea urchins killed were computed as the difference in pre and post-treatment densities times the area limed. Since this resource is extremely patchy, these number might be inflated (Table 3.8).

Table 3.7.1. Area (in acres) limed and number of red sea urchins killed by year (1975-1979).

Year	Area (Acres)	Urchins killed
1975	28	89,050
1976	28	392,632
1977	41	144,854
1978	42	570,133
1979	120	713,900

Alternative Models

At one level, this assessment for Pt. Loma sea urchins would be considered "data limited." We do have a time series of landings and logbook CPUE which we can treat as an index of abundance, but we do not have a time series of length frequency data, and there are reasons to suspect that CPUE could be not proportional to abundance due to the searching behavior of fishermen. There are also two major unknowns about basic stock biology: (1) is there a large proportion of the population not vulnerable to harvesting because either they are in crevasses or in deep water or do not have any uni, and (2) does recruitment of small urchins come from the local stock, or from larval drift from outside the Pt. Loma area. Thus there are some major structural uncertainties in our modelling efforts, and whereas many invertebrate assessments now routinely use a size-structured statistical catch-at-size model, this is not an option in our analysis.

Our approach is to explore four different assessment modelling frameworks to try to capture the extent to which the data available support alternative hypotheses about the underlying dynamics of the Pt. Loma sea urchin fishery and its status and future productivity. These four approaches are (1) a model free analysis in trends in surplus production using CPUE as an index (not necessarily a linear one) of abundance, (2) a simple delay-difference model that tracks the numbers of urchins with and without uni, (3) an age structured model that allows kelp to determine the relative maturity and harvest of the urchins, and (4) analysis of recent length frequency data to see what information can be extracted on the exploitation rate and size of recruitment from the LF data in recent years.

Model free analysis of trends in surplus production

Hilborn 2001 described how the surplus production from a stock could be calculated from catch and an index of abundance. This provides us with a model-free method for determining if the population of urchins in recent years has been less productive than it was when the fishery started – in other words a direct question to whether there is an indication that the stock is currently overfished and higher standing stocks of urchins would result in higher surplus production.

The essence of the method is to note that we can convert an index of abundance to absolute abundance through the usual assumption of linearity

(4.1.1) $$B_y = \frac{\hat{I}_y}{q}$$

and that surplus production is the net change in stock abundance between years added to the catch.

(4.1.2) $$P_y = B_{y+1} - B_y + C_y$$

We can then construct hypotheses about the level of exploitation from 1990 to 2005 ($u_{1990-2005}$), which can be converted into a *q* as follows:

(4.1.3) $$q = \frac{\bar{C}_{1990-2005}}{u_{1990-2005}\bar{I}_{1990-2005}}$$

We can also explore the consequences of the CPUE data not being linearly proportional to abundance by letting our index be the CPUE raised to a power

(4.1.4) $$\hat{I}_y = CPUE_y^{\beta}$$

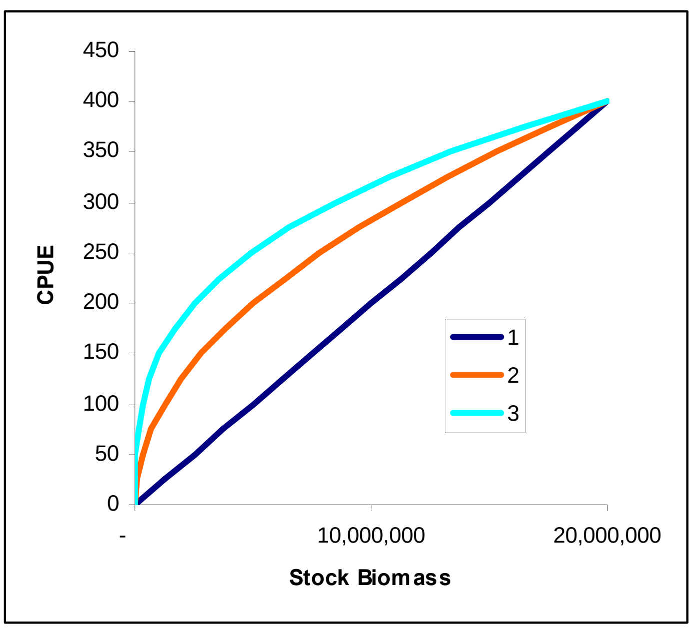


Figure 4.1.1. Relationship between stock biomass and CPUE for three different values of the parameter beta.

When the parameter β has values greater than 1 then we have hyperstability in our CPUE which Harley et al. 2001 found to be a common characteristic of CPUE series when compared to scientifically designed survey data. We would expect this to be the case (CPUE declines less rapidly than abundance) because fishermen have the ability to seek out and find concentrations of urchins.

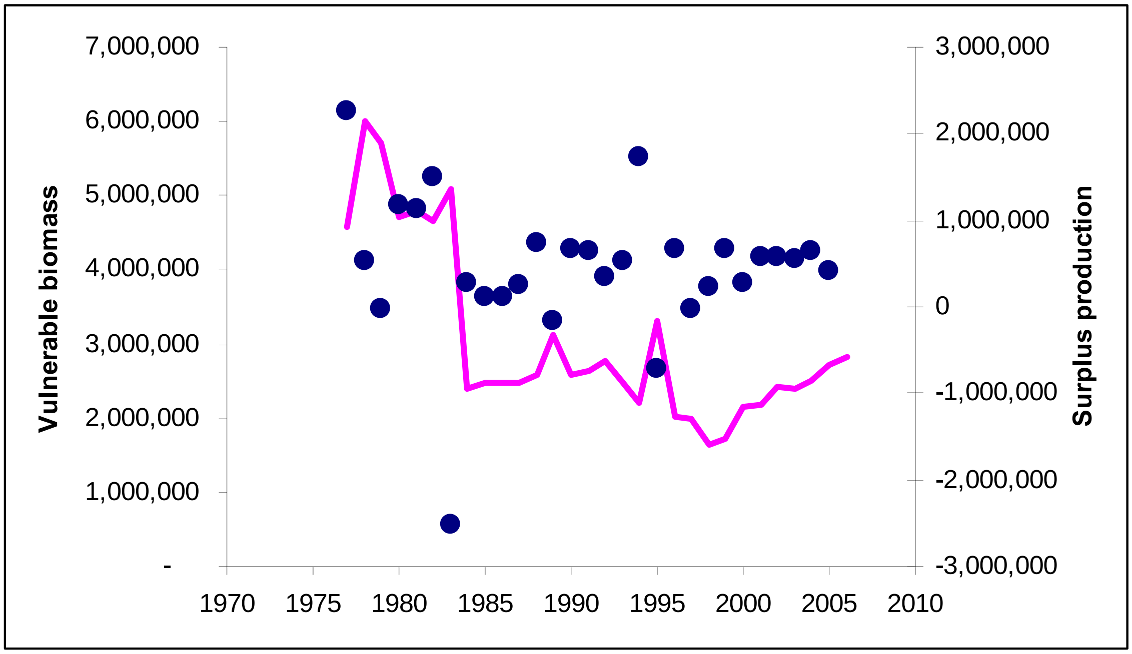


Figure 4.1.2 Projected stock abundance (solid line) and estimated surplus production (dots) when we assume CPUE is proportional to stock abundance and the average exploitation rate after 1990 was 0.2.

Figure 4.1.2 shows the case where β is set to 1 (CPUE proportional to abundance) and $u_{1990-2005}$ is set to 0.2. We can see the predicted vulnerable biomass is generally stable at about 5 million lbs until 1983 when CPUE dropped dramatically, and has been in the range of 1.5 to 3 million lbs. The surplus production over the entire period averaged about 450,000 lbs, with there being a large negative pulse in surplus production in 1983 when the CPUE dropped dramatically. If we compare surplus production in the fishing down period of high abundance (up to 1984) and after we find the surplus production is almost exactly the same; 559,000 lbs before 1984 and 554,000 after 1984. Table 4.1.1 shows this ratio of production (after/before) for a range of values of β and $u_{1990-2005}$.

Table 4.1.1. The ratio of surplus production after 1984 to surplus production before 1984 for different levels of hyper depletion (β) and current exploitation.

		β	
$u_{1990-2005}$	1.00	1.50	2.00
0.10	1.90	-5.41	-0.93
0.20	0.99	1.60	8.16
0.30	0.85	1.09	1.76
0.40	0.79	0.94	1.25
0.50	0.76	0.86	1.06

An important result of this analysis is that if we specify beta greater than 1, then the decline in actual abundance in 1983 was larger in absolute terms, and the decline in surplus production in that period is even larger, suggesting the surplus production in the entire initial period was negative. This could be true if that abundance had been generated from particularly good recruitments in the 1970s. From this table we can see that current levels of surplus production are less than historical levels only when the current levels of exploitation are high, and the more we hypothesize hyperdepletion, the more productive the current levels of biomass are.

In Table 4.1.2 we can see that some of these hypotheses suggest unrealistic levels of exploitation in the historical trend. For instance with beta = 2, and post 1990 exploitation rates average 0.5, the exploitation rate would have reached 100% in some years. This analysis suggests that the higher end of average exploitation rates (0.4 and 0.5) may be unrealistic.

Table 4.1.2. The maximum exploitation rate estimated for different levels of hyper-depletion (β) and current exploitation.

		β	
$u_{1990-2005}$	1.00	1.50	2.00
0.10	0.17	0.18	0.20
0.20	0.33	0.37	0.40
0.30	0.50	0.55	0.60
0.40	0.67	0.73	0.81
0.50	0.83	0.91	1.00

We can evaluate the trends in this fishery in some other “model free” ways. First if we accept that the stock was largely depleted in the fishing down phase prior to 1983, and that the long life of the stock suggests that annual recruitment is a low fraction of initial biomass, then the total removals during fishing down would be a large fraction of the initial biomass.

Catches prior to 1983 were 6.5 million lbs. Thus the initial biomass could be estimated as 6.5 million divided by the fraction of the stock remaining. Using the CPUE data the 1984 CPUE was 40% of the highest CPUE prior to that time. Thus we would estimate the initial biomass at roughly 11 million lbs, with 4 million lbs remaining in 1984. CPUE since the mid 1980s has been on average stable, with annual landings since 1990 averaging almost 500 thousand pounds, predicting a harvest rate of a little over 10%. The general stability of the CPUE data would further suggest a general level of sustainability over recent decades.

Delay difference model

We constructed a simple delay-difference model that includes two population components, immature (I_t), and mature (M_t), each of which is assumed to be of legal size, but the immature individuals do not have enough uni to make them of commercial value. We assume that

1. individuals recruit to the immature population component 6 years after birth
2. some fraction (m_t) of immature individuals become mature each year
3. both mature and immature individuals are subject to natural mortality, parameterized as a survival rate
4. all catch is removed from the mature population
5. in some years there was a urchin control program that removed immature and mature urchins in relation to their abundance, with the total removals Q_t.

6. recruitment in year t is a Beverton-Holt function of mature biomass in year t

$$I_{t+1} = I_t s_i + R_{t-6} - I_t m_t - Q_t \frac{I_t}{I_t + M_t}$$

(4.2.1) $$M_{t+1} = M_t s_m + I_t m_t - C_t - Q_t \frac{M_t}{I_t + M_t}$$

$$R_t = \frac{M_t}{\frac{1}{p} + \frac{M_t}{c}}$$

We assumed that the survival rate of immature was 0.9 and of mature individuals was 0.95. This leaves 2 key parameters of the spawner-recruit curve, and the determinants of the maturation rate m_t over time. The simplest assumption is that m_t is constant over time, and we also explore hypotheses that m_t is related to the kelp abundance.

We assume that the population is in the unfished state in 1974. Thus the parameter *c* will determine the absolute size of the population, parameter *p* will determine how sensitive recruitment is to spawning stock.

Figure 4.2.1 shows a fit to the data when we set m_t=0.5 and estimate the two stock recruitment parameters. The key element in this fit is that the parameter *p* is estimated to be high enough so that recruitment is constant.

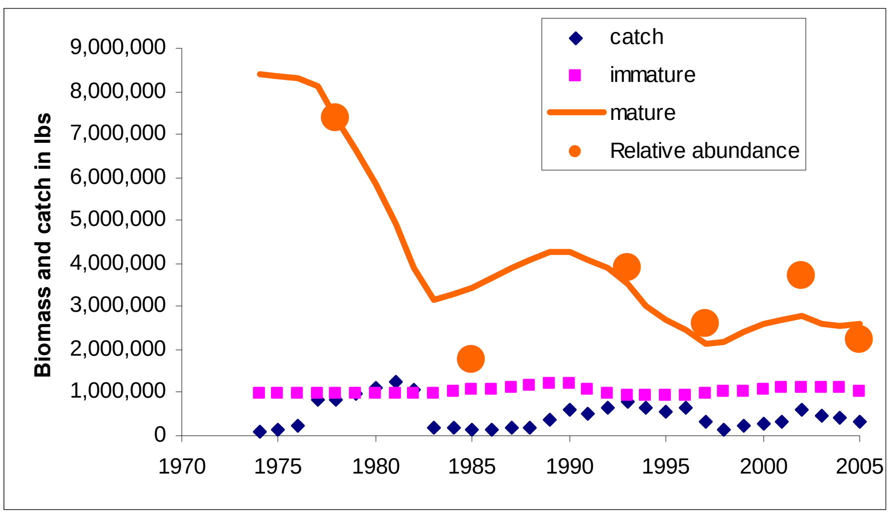


Figure 4.2.1. Trends in mature, and immature biomass when fitted to the diver index of abundance data.

From the trends in abundance we can calculate the historical trend in surplus production:

(4.2.2) $$P_t = (I_{t+1} + M_{t+1}) - (I_t + M_t) + C_t + Q_t$$

In Figure 4.2.2 we see the trend in surplus production, and not surprisingly since recruitment is fit to be constant, surplus production increases as the stock has been fished down.

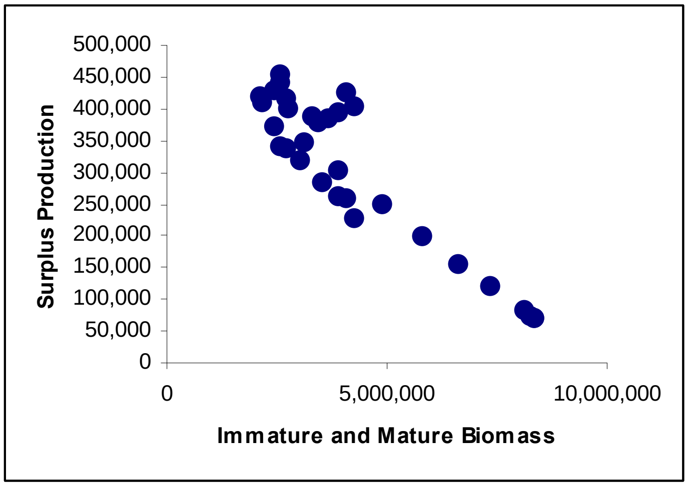


Figure 4.2.2. Trends in surplus production from model fit in Figure 4.2.1

We then explored a model in which the rate of movement from the immature to mature portions of the population depended on the kelp biomass according to equation 3.

(4.2.3) $$m_t = \overline{m} + d\left(K_t - \overline{K}\right)$$

Where $\overline{m}$ is the proportion maturing at the average kelp biomass, d is the amount maturity increases as kelp biomass increases, and $\overline{K}$ is the average kelp biomass.

We can see we obtain an excellent fit to the index data which is obtained by having an effective threshold with no maturity below the average kelp abundance and 100% maturing when the kelp biomass is above the average.

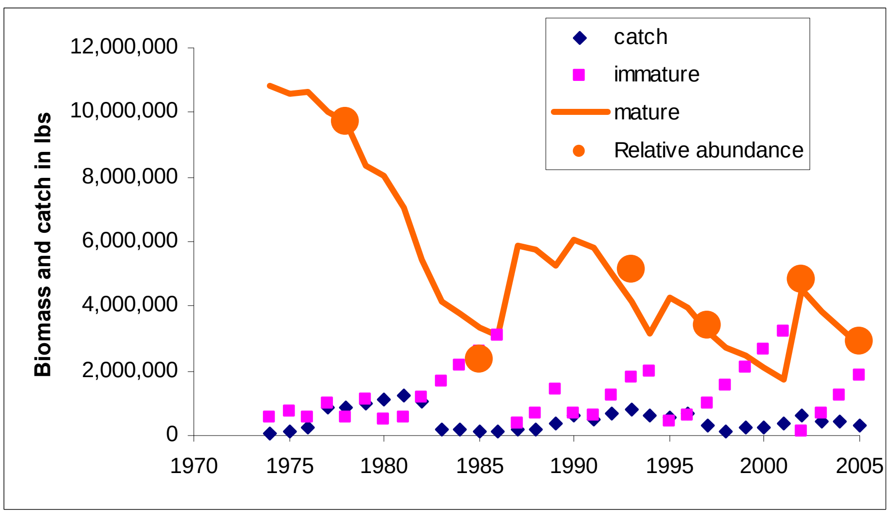


Figure 4.2.3. Fit to the data when maturity is a function of kelp biomass.

Shown in Figure 4.2.4 is the estimated trend in surplus production.

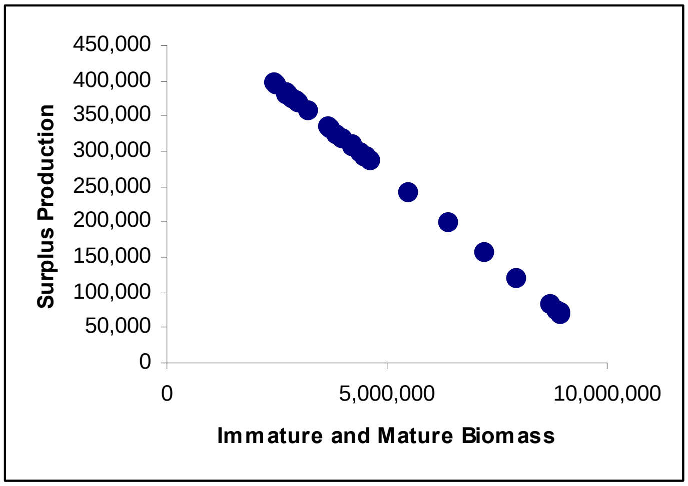


Figure 4.2.4. Trend in surplus production from model fit shown in Figure 4.2.3.

However, the fits still suggest that there are 3-4 million pounds of mature biomass, with annual catches of 300-500 thousands pounds, so exploitation rates on mature individuals is 10% more or less. This is totally at variance with the perception of divers that they take a significant portion of the standing stock of urchins each year.

This model poses challenges for biological interpretation, primarily because of the apparent low exploitation rates. If there are really almost 10 times the annual landings of urchins available, where are they? The data do suggest that surplus production is now higher than at any time in the past, consistent with the results of section 4.2.

Full age structured model

We use a standard age structured model, whose state variables is the number of animals alive at each age N_a. The parameters are:

w_a the weight of individuals age a
m_a the proportion mature at age a
v_a the relative vulnerability to fishing at age a
s the survival from natural mortality
a a parameter of the Beverton Holt spawner recruit curve
b a parameter of the Beverton Holt spawner recruit curve

We used the Beverton Holt spawner recruit curve where R is recruits and S is spawning stock biomass

(4.3.1) $$R = \frac{S}{a + bS}$$

Where the a and b parameters are defined in terms of
R_0 the recruitment in the unfished state
z the steepness of the spawner recruit curve
S_0 the spawning stock biomass in the unfished state

(4.3.2) $$a = \frac{S_0}{R_0}\left(1 - \frac{z-.2}{.8z}\right)$$

(4.3.3) $$b = \frac{z-.2}{.8zR_0}$$

S_0 is the numbers at age in the equilibrium unfished state N_a^*, times the weight at age times the proportion mature at age

(4.3.4) $$\begin{aligned} N_1^* &= R_0 \\ N_a^* &= N_{a-1}^* s \quad \text{for } 1 > \text{a} > \text{n} \\ N_n^* &= N_{n-1}^* \frac{s}{1-s} \\ S_0 &= \sum_a N_a^* w_a m_a \end{aligned}$$

Where n is the maximum age considered (the plus group) where all individuals are assumed to have the same weight, maturity and vulnerability at age n and older.

The initial numbers in the first year (1974) are assumed to be those of the unfished state described above.

We allow for the amount of kelp to impact the proportion of individuals who could be mature at age a (m_a) to be mature (p_y). If p_y was 1 then the maturity schedule would be the same as m_a, if p_y was 0 then no individuals would be mature. We also assume that only individuals with roe are captured.

The relationship between kelp abundance and proportion with roe is a logistic, with an example shown in Figure 4.3.1

(4.3.5) $$p_y = \frac{1}{1 + \exp\left(-\ln(19) * \frac{K_y - k_{50}}{k_{steep}}\right)}$$

Where k_{50} is the value of K_y where p_y is 0.5, and k_{steep} determines the slope of the line through the point (k_{steep}, 0.5).

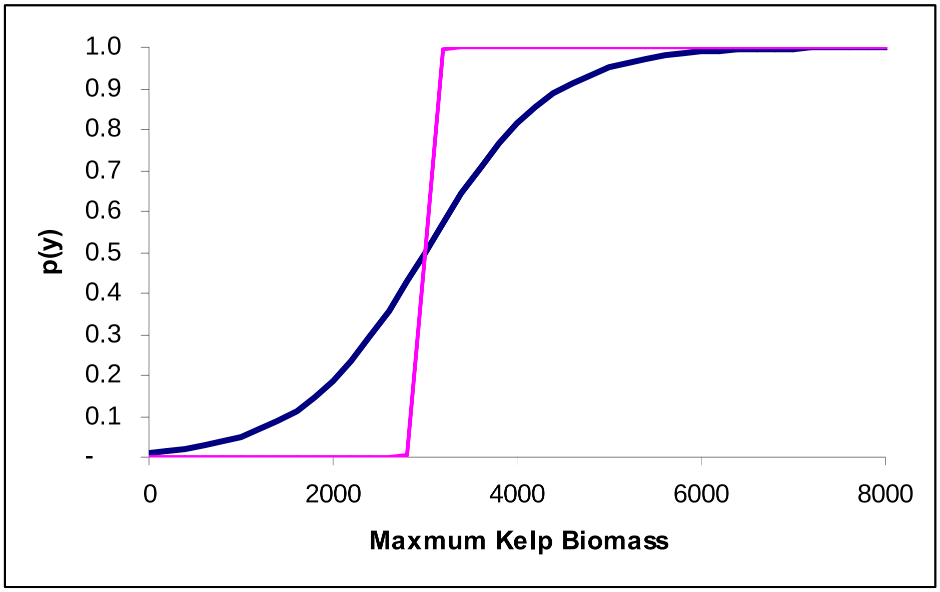


Figure 4.3.1 Relationship between p_y and maximum kelp biomass. In both cases k50 is 3000. The difference in the two lines is the value of k_{steep}.

Numbers in all other years of the simulation are

(4.3.6)
$$N_{1,y} = R_{y-1}$$
$$N_{a,y} = N_{a-1,y-1} s\left(1 - u_{y-1} v_{a-1} p_{y-1}\right) \quad \text{for } 1 > \text{a} > \text{n}$$
$$N_{n,y} = N_{n-1,y-1} s\left(1 - u_{y-1} v_{n-1} p_{y-1}\right) + N_{n,y-1} s\left(1 - u_{y-1} v_n p_{y-1}\right) \quad \text{for a} = \text{n}$$

Spawning stock biomass in any year is

(4.3.7)
$$S_y = \sum_a N_{a,y} w_a m_a p_y$$

Recruitment in any year is

(4.3.8)
$$R_y = \frac{S_y}{a + bS_y}$$

We assume that the catch in any year (C_y) is known, and the harvest rate in any year is then calculated as the ratio between the known catch and the simulated vulnerable stock biomass (B_y)

(4.3.9)
$$B_y = \sum_a N_{a,y} w_a v_a p_y$$
$$u_y = \frac{C_y}{B_y}$$

The model is fit to the CPUE data, and as earlier we allow for there to be a non-linear relationship between CPUE and abundance.

(4.3.10) $\hat{I}_y = q\left(B_y\right)^{\beta}$

We assume deterministic stock dynamics and the differences between the predicted and observed indices are due to observation error. We assume the observation error is multiplicative and thus the deviations are lognormal

(4.3.11) $v_y = \ln\left(\frac{I_y}{\hat{I}_y}\right)$

We then assume a normal likelihood for the deviates

(4.3.12) $L(v_y \mid \text{model parameters and data}) = \frac{1}{\sigma_v \sqrt{2\pi}} \exp\left(-\frac{(v_y)^2}{2\sigma_v^2}\right)$

The likelihood for the entire data series is simply the product of all the individual likelihoods.

For time series of relative abundance indices there is an analytic formula for the maximum likelihood estimate of the scaling parameter q when a multiplicative error is assumed. This estimate is

(4.3.13) $q = \exp\left(\frac{1}{nt}\sum \ln\left(\frac{I_y}{B_y}\right)\right)$

Where *nt* is the number of observed observations of *I*. and is only calculated for years where there are observed indices.

This is simply the geometric average of the ratio between the observed index and the predicted biomass. (note that when an additive error is assumed then we use the arithmetic average).
We also use the maximum likelihood estimate of σ_v.

(4.3.14) $\hat{\sigma}_v = \sqrt{\frac{\sum (v_t^2)}{nt - 1}}$

Model Fits

In our most basic run of the model we assume CPUE is linearly proportional to abundance, and that there is no impact of kelp Figure 4.3.2 shows the trend in the CPUE data and the best fit, along with the estimated exploitation rates in the top panel, and the reconstructed surplus production in the bottom panel. This model fit estimates the steepness parameter at 1.0, thus making recruitment constant. The total negative log likelihood is 1.047. Key characteristics of this fit are that there is a continuous downward decline in abundance, no dramatic decline in the early 1980s and no rebuilding either after that or from 2000 to 2004.

Figure 4.3.2. Trends in mature abundance and fit to CPUE data (thick line and dots) and harvest rate (light line) in the top panel, and reconstructed surplus production (bottom panel) for fit with steepness = 1.0.

In contrast we can fix the value of steepness to 0.3 and then estimate only the scaling parameter R0. This is shown in Figure 4.3.3, and the negative log likelihood is 1.267. The fit is marginally worse, but the main difference is this scenario implies that the entire history of this stock is one of fishing down a large unproductive biomass.

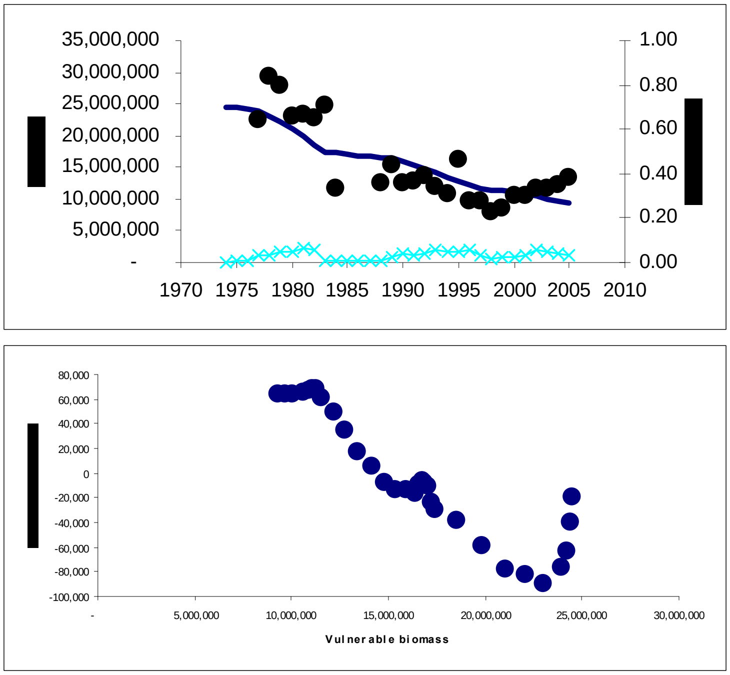


Figure 4.3.3. Fit to the data when steepness is set to 0.3.

In Figure 4.3.4 we see what happens if we allow for hyperstability by fixing β=2., so that the real abundance declined much more than the CPUE indicates. The real index of abundance (CPUE corrected for hyperstability) declines dramatically in the early years, but the model fit is unable to capture this. The likelihood of this fit is 5.09, much worse than when we assumed CPUE proportional to abundance.

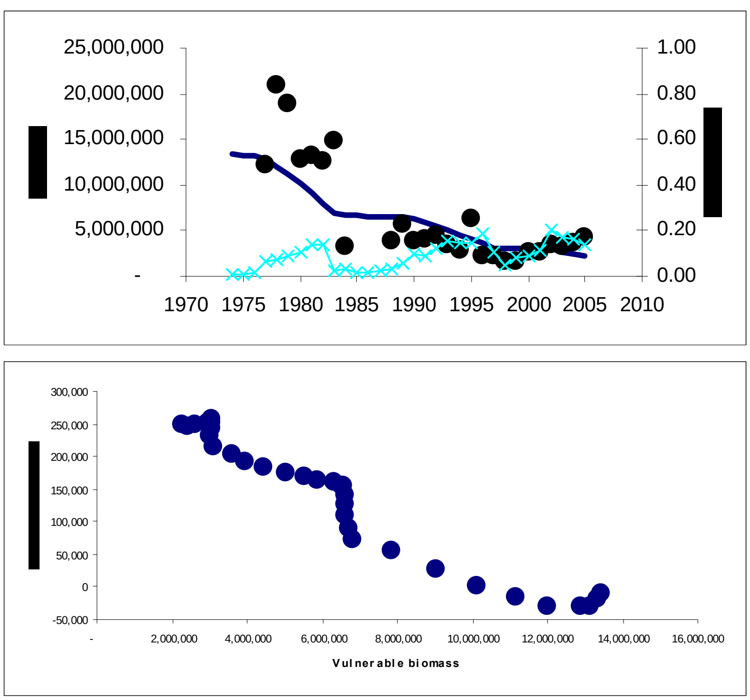


Figure 4.3.4. Model fits with hyperstability.

We have not been able to obtain any improved fits of this model to the data using the kelp abundance impacting the maturity level of the urchins. We also explored having kelp abundance impact recruitment, and again did not find any improvements to model fit. All fits are unsatisfactory in that they predict a continuous decline in abundance rather than capturing the pattern of the CPUE data.

This model has also been unable to replicate the CPUE trend, especially the increase in the last decade. If we were to estimate annual recruitments as parameters in the model, we could obviously fit the CPUE perfectly and at this point it would seem pointless to do so. As with our earlier delay difference this model consistently estimates very low exploitation rates. The analysis of hyperstability suggests that larger declines in abundance are even more difficult to explain.

Size structured models

Equilibrium analysis of a size structured model

In this model we fit the current size distribution based on growth transition data, and estimate recruitment to the population at size, the fishing mortality rate and the size specific vulnerability to harvest.

The basic size structured model can be written as

(4.4.1) $$N_{t+1} = \mathbf{X_t} N_t + R_t$$

Where

N_t is a vector of numbers in each size class at time t

$\mathbf{X_t}$ is a size transition matrix, giving the probability of moving from size class i to size class j in year t including the probability of survival from natural and fishing mortality

R_t is a vector of the recruitment to each size class at time t

The transition matrix $\mathbf{X_t}$ can be constructed as follows

(4.4.2) $$X_{i,j,t} = X'_{i,j} s(1 - v_i u_t)$$

Where

$X'_{i,j}$ is the probability of growing from size group i to size group j

s is the survival from natural mortality

v_i is the relative vulnerability to harvest of size class i

u_t is the exploitation rate on fully vulnerable sizes in time t

This model could provide the framework for a time-dynamic assessment if we had a time series of size distributions, but for the current analysis we are using this framework for a static equilibrium analysis using the LF data from the barefoot ecologist program in 2004-2006.

The size transition matrix was constructed from the annual growth increment data described earlier. We fixed *s* at 0.95. We assumed that *R* was constant over time and was normally distributed across sizes with two parameters $\bar{R}$ the average size of recruits and σ_R, the standard deviation of size at recruitment.. The vulnerability at age was assumed to be logistic using the formula

(4.4.3) $$v_i = \frac{1}{1 + \exp\left(-\ln(19) * \frac{L_i - L_{50}}{L_{steep}} \right)}$$

Where

L_i is the mean length of individuals in the ith size class

L_{50} is the length at which 50% of individuals are vulnerable

L_{steep} determines how knife-edged the selectivity curve is

We also assumed that the exploitation rate u_t was the same in all years.

We fit the observed length frequency to the equilibrium predicted length frequency. The parameters to be estimated are the recruitment parameters $\overline{R}$ and σ_R, the selectivity parameters L_{50} and L_{steep} and u.

The best fit we found is shown in figure 4.4.1. In this fit the mean size at recruitment is 79.5 mm, just below the minimum commercial size limit (82.55 mm), selectivity is 50% at 91 mm, and the annual exploitation rate is 38%. In this scenario the majority of individuals are already sexually mature before they recruit to the population being surveyed, and once there are subject to a significant exploitation rate.

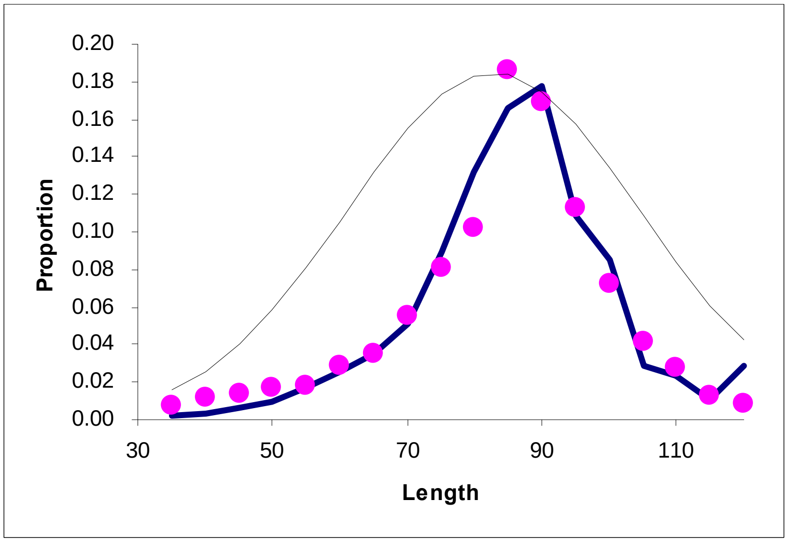


Figure 4.4.1. Best model fit. The dots are the observed length frequencies, the thick solid line is the best fit. The thin solid line is the relative recruitment at length.

Analysis using Botsford/Smith Model

This method was first developed by Smith and Botsford 1998 and then applied by Smith et al. 1998 (and Morgan et al. 2000 to red sea urchin length frequency (LF) and growth increment (GI) data from Northern California, simultaneously. The authors developed a maximum likelihood procedure for estimating growth and natural mortality for unharvested sites and then fishing mortality rates were calculated for harvested sites. In our study, LF distributions from the BE program for 2004-2006 and the urchin GI data described earlier were used to fit the model.

This model differs from the size model in section 4.4.1 because it assumes all individuals recruit at a very small size, and there is an ogive of probability of detection as a function of size.

The LF model uses von Bertalanffy growth with variability because the observed growth increments for the red sea urchin decline approximately linearly with size, and assumes steady-state conditions (constant recruitment) for length distributions; hence it does not depend on age modes in the distribution. Smallest individuals in a sea urchin population are usually underrepresented because they are difficult to collect. Thus, the model also estimates a cumulative Gaussian selectivity curve and its likelihood is defined as:

$$\Theta_1(\mu_L, \sigma_L, \mu_K, \sigma_K | l, \Delta t) = \sum_{j=1}^{v} \ln\left(\sqrt{2\pi}\sigma_{I_j}\right) + \frac{(I_j - \mu_{I_j})^2}{2\sigma_{I_j}^2} + \ln(1 - \zeta$$

The GI model includes measurement error but negative growth, as seen in sea urchin, cannot be accommodated. Its log-likelihood is defined as:

$$\Theta_2(\mu_L, \sigma_L, \mu_K, \sigma_K, \sigma_{M,l=100} | l, \Delta t) = \sum_{j=1}^{v} \ln(2\pi\sigma_{M,I_j}\, \sigma_{I_j}) - \ln\left(\int_{I_j=0}^{I_j=\infty} e^{-\left(\frac{(\tilde{I}_j - I_j)^2}{2\sigma_{M,I_j}^2} + \frac{(I_j - \mu_{I_j})^2}{2\sigma_{I_j}^2}\right)}\right) + \ln(1 - \zeta_l)$$

Figure 4.4.2 shows the best fit of the model for both size increment and length frequency data sets simultaneously. Parameter estimations are shown in Table 4.4.2. L_∞ was rather low given that the largest sea urchins found in the data set were between 130 and 140, whereas growth coefficient k was similar than values found in the literature for this species in Southern California.

Figure 4.4.2. Model fit for (a) growth increment and (b) length frequency data.

The LF distribution shows no evidence of fishing, both because (1) the distribution is close to L_∞, and (2) the mode of the LF distribution is well above the legal size limit. Estimates of fishing mortality were close to 0. The catch data (Figure 3.6.2) indicated the urchin divers were being successful at catching large urchins (i.e. >90 mm), even more than smaller urchins. This could also suggests that fishing rate is low. If fishing rate were high, then only urchins a bit larger than 83 mm would be available to catch.

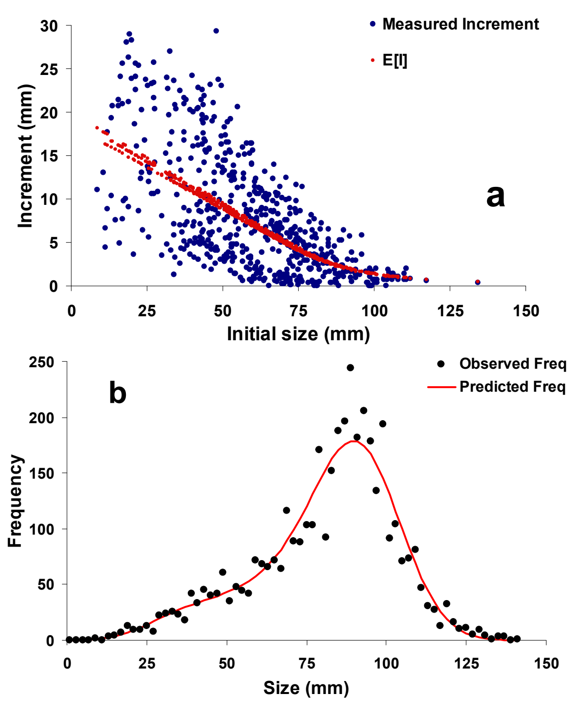


Table 4.4.1 Estimated parameters and log-likelihood for growth increment and length frequency data.

PARAMETER	
mean of L_∞	**96.7**
SD of L_∞	**12.6**
mean of k	**0.217**
SD of k	**0.132**
instantaneous natural mortality	**0.003**
instantaneous fishing mortality	**<0.001**
mean of Gaussian selectivity for LF data	**23.9**
SD of Gaussian selectivity for LF data	**9.2**
-2ln[L]	**570**
AICc	**343**

Table 4.4.2 Parameter estimates for different values of fishing mortality (fixed F)

F	-2lnL	M	Linf	k
0	570.77	0.0030	96.68	0.22
5.00E-08	570.30	0.0032	96.85	0.22
1.00E-07	570.28	0.0032	96.85	0.14
5.00E-07	570.29	0.0032	96.68	0.22
1.00E-06	570.30	0.0032	96.85	0.22
5.00E-06	570.44	0.0031	96.79	0.22
1.00E-05	570.75	0.0028	96.76	0.22
5.00E-05	570.79	0.0028	96.77	0.22
1.00E-04	570.84	0.0030	96.71	0.22
0.001	570.88	0.0038	96.94	0.22
0.005	574.99	0.0038	96.94	0.22
0.100	587.58	0.0025	99.65	0.21

This analysis shows that the model assumptions and data are most consistent with little impact of fishing. This result is intuitively obvious from the basic data. If fishing mortality rates were high, then there would be few individuals one or two years larger than the legal size limit. At the legal size limit urchins are growing at only a few mm per year, yet the mode of the size distribution is in the mid 190s, several years growth above the legal size limit. Further the fact that 14% of the individuals are over 100 mm is inconsistent with the growth data and any significant exploitation rate.

Testing growth assumptions

Emerging from the two length models is the apparent conflict between the length frequency distribution and the growth transition data. One possibility is that the growth rates in Pt. Loma are (or at least have been recently) higher than the growth transition data (collected elsewhere) indicate. Dr. L. Botsford suggested we explore how high growth rates would have to be in order to fit the length frequency data and have a high fishing mortality rate. We used a model similar to that in section 4.4.1 except that we assumed that all recruitment occurs at small sizes, and there is an ogive of visibility/vulnerability that is a function of size.

The basic size structured model can be written as

(4.4.4) $$N_{t+1} = \mathbf{X_t} N_t + R_t$$

Where
N_t is a vector of numbers in each size class at time t
$\mathbf{X_t}$ is a size transition matrix, giving the probability of moving from size class i to size class j in year t including the probability of survival from natural and fishing mortality
R_t is a vector of the recruitment to each size class at time t

The transition matrix $\mathbf{X_t}$ can be constructed as follows

(4.4.5) $$X_{i,j,t} = X'_{i,j} s(1 - u_{i,t})$$

Where
$X'_{i,j}$ is the probability of growing from size group i to size group j
s is the survival from natural mortality
v_i is the visibility of size class i
$u_{i,t}$ is the exploitation rate on size *i* in time t

Visibility is a logistic function of size

(4.4.6) $$v_i = \frac{1}{1 + \exp\left(-\ln(19) * \frac{L_i - L_{50}}{L_{steep}}\right)}$$

Where
L_i is the mean length of individuals in the ith size class
L_{50} is the length at which 50% of individuals are vulnerable
L_{steep} determines how knife-edged the selectivity curve is
The number seen in any size class is the number in the size class times the visibility.

The exploitation rate depends upon u_t, and v_i as follows

(4.4.7) $$\begin{aligned} u_{i,t} &= u_t \mathrm{v_i} && \text{if } L_i \geq 82.55 \\ u_{i,t} &= 0 && \text{if } L_i < 82.55 \end{aligned}$$

We modeled the growth transition matrix as follows. We assumed as in panel a of figure 4.4.2 that the growth increment declines linearly until a threshold size is reached, and beyond that size the growth increment is constant. This is described in the following equation with three parameters

(4.4.8) $$\begin{aligned} \bar{I}_i &= -(T - L_i)\Delta + I^* && \text{if } L_i < T \\ \bar{I}_i &= I^* && \text{if } L_i \geq T \end{aligned}$$

Where
T is the threshold length above which the increment is constant
I^* is the increment for all individuals above length T
Δ is the slope of the increment curve below T

We assume that the growth increment at length *i* is normally distributed about $\bar{I}_i$ with a cv that is a free parameter. We then fixed ut at 0.5 and asked what growth curve would it take to fit the data well.

Initial model runs obtained excellent fits to the data, but involved vulnerabilities for individuals above the legal size limit that were much less than 1, thus the actual exploitation rate was not the target 50%. So we modified the visibility so that all individuals above the legal size limit have v_i=1.

Figure 4.4.3 shows the MLE fit to the data. In all cases we only fit the data above 50mm.

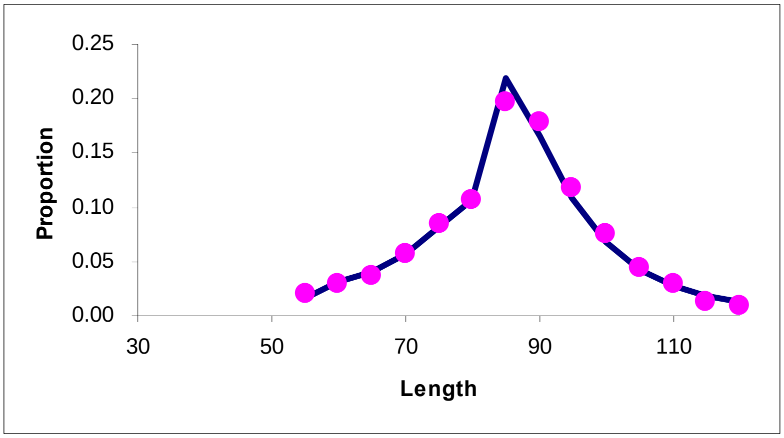


Figure 4.4.3 Proportions in each 5 mm length class (dots) and best fit proportions solid line.

Figure 4.4.4 shows the visibility curve for this model

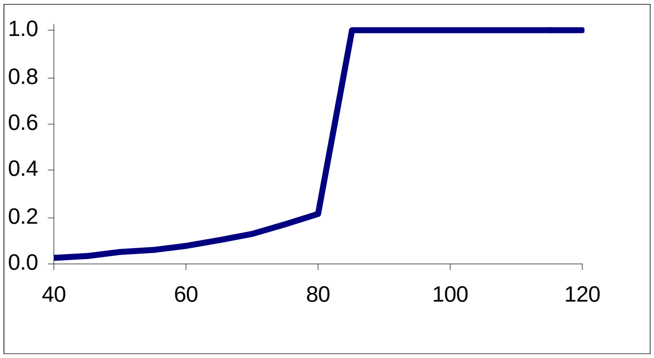


Figure 4.4.4. Visibility curve estimated for MLE fit to the data.

Figure 4.4.5 shows the growth increment fit

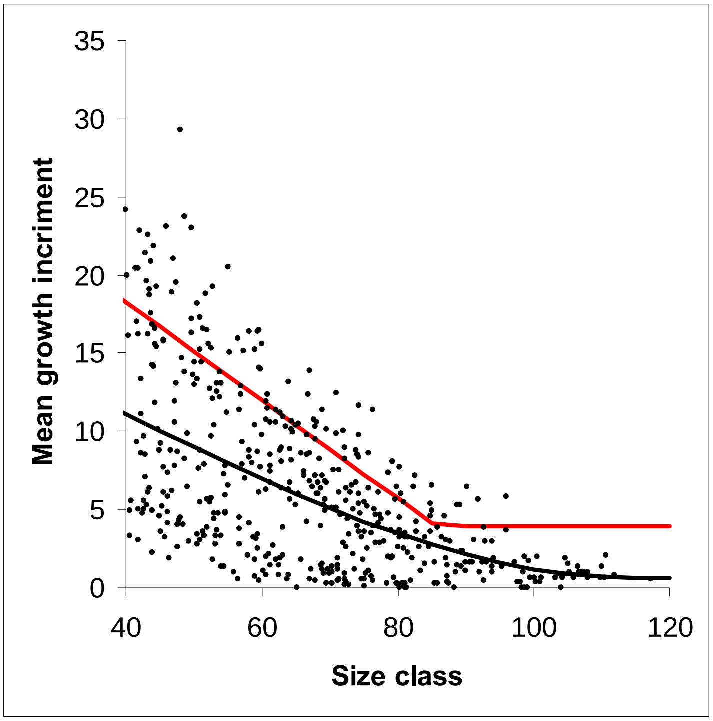


Figure 4.4.5. Best fit growth increment curve for MLE fit to the length frequency data shown in red. Shown as dots are the growth increment data and the black line is the best fit to the data. It is clear that growth in Pt. Loma would need to be much higher than in other sites to be consistent with the length frequency data.

In comparison to the best fit from the growth increment data the average increment at larger sizes is about twice as big, and the growth at 50mm is also considerably larger.

We also explored what range of growth increments would still fit the data by fixing the increment at larger size classes and the transition size, and letting the slope change. We could fit the data almost equally well with a broad range of increments for larger sea urchins simply by making the slope steeper and having the sea urchins grow into the 90mm and larger size classes more quickly. We conclude that the length frequency data are consistent with high fishing mortality rates if growth rates are significantly higher than those measured in the growth increment data we have available, and recommend some specific growth studies in Pt. Loma.

Discussion

The data available

There are obvious limitations in the data we have available for the assessment. The most obvious is abundance trends. We have explored the use of CPUE and divers perception of changes, but we recognize that none of these is probably the true trend in abundance and it seems highly unlikely that we will be able to reconstruct any index that truly represents changes in abundance, even in the commercially fished areas of the Pt. Loma kelp bed. Uncertainty about trends in abundance of unfished areas must therefore be even greater.

Density estimates from the Barefoot Ecologist program are constrained by their close connection to decisions about where to dive, thus are non-random samples, and are also limited by the number of individuals involved in the program. The absolute number of samples is not necessarily limiting, but obtaining a more even coverage over all of Pt. Loma would improve confidence in the data.

Historical kelp abundance data is also less than satisfactory. We have used simple annual maxima, but the inter-annual pattern of abundance, and the spatial pattern may both be important. If the scientists and divers continue to believe that kelp is a key driver in sea urchin recruitment and uni production then consideration should be given to a much more thorough data collection program on kelp.

Summary of assessment outputs strengths and weaknesses

We have explored four alternative approaches to assessing the history of stock production and current stock size and exploitation rate in the Pt. Loma sea urchin fishery. The first three methods all depend on either CPUE of fishermen's perceptions of changes in abundance and thus are not in any sense independent.

Table 5.2.1 Primary results from different analytic approaches.

Method	Current stock size in relation to pre-fishery	Current Exploitation rate (2000-2004)	Surplus production
CPUE data	51%		
Surplus production based on catch and CPUE	51%		471,000 lbs
Absolute abundance estimates	37%		
Delay difference model	49%	8%	336,359 lbs
Age structured model	43%	12%	346,482 lbs
Length frequency data		0%	

Table 5.1 summarizes the data and analysis we have used to estimate current stock size in relation to pre-fishery abundance, the current exploitation rate and surplus production.

Each of the time-dynamic methods provided robust estimates that surplus production in the last decades has been as large or larger than the level early in the fishery and thus that the current levels are sustainable and the stocks are not overfished. The model fits with the highest likelihood estimate constant recruitment to the population, and standing stock sizes now 43-49% of those in the 1970s when the fishery began.

However, an alternative fit of the basic time dynamic models using CPUE is that there is a very large population that is gradually being fished down and (Figure 4.3.3) is now at perhaps 50% of the biomass in the 1970s. The analysis of the length frequency data poses the same uncertainty. If there is substantial recruitment of large individuals maintaining the high average length, then this recruitment could be coming from a large standing stock that has never been significantly exploited. This standing stock would need to be currently on the order of 10 million pounds, many times the estimated stock size that is seen by divers. This population could be in deeper water, or in crevasse, but seems much larger than any current discussion of scientists and divers believe reasonable.

Perhaps the most surprising aspect of the length frequency analysis is that while we estimate very low overall exploitation rates for this population, the same methods, applied to other heavily fished California red urchin populations estimate significant exploitation rates. Ebert 1999 estimated total mortality rates of 0.2-0.4 for most of the Channel Island populations – what is different about Pt. Loma? The first two length based approaches both assume the growth increment data apply to Pt. Loma and are incompatible with significant exploitation rates. If we assume the "population" is all sea urchins and recruitment occurs at small sizes, then there cannot be any significant mortality. If we assume that the size at recruitment is estimable then the model wants the sea urchins to "recruit" at large sizes, thus implying a large unexploited population. We showed that the length frequency data is compatible with higher exploitation rates if growth rates are significantly higher.

While the three time-dynamic methods we used all are dependent on either CPUE or fishermen's perceptions of changes in abundance, our exploration of the impact of hyper-stability, suggested that if the true abundance has declined more than CPUE indicates, then the historical surplus production was lower relative to current surplus production.

All of our assessment approaches support the hypothesis that there are no major sustainability concerns for this stock at its current level of exploitation and productivity. The trend in CPUE suggests stable populations in recent years, and the length frequency data are most consistent with reasonably low fishing pressure.

The only interpretation of the data that suggests non-sustainability is the hypothesis that the Pt. Loma population is receiving immigrants from a very large standing stock that has been gradually reduced over the last 40 years. This hypothesis is difficult to support because there are no evidence of such a large biomass, especially at times like 1983-1984 when there should have been, under this hypothesis, a near unfished biomass of urchins.

None of the models we used are truly satisfactory, the length frequency data suggest recruitment at a large size from an unknown population, and the biomass dynamics and age-structured models cannot explain the stability of the stock biomass in the last decade. Earlier workshops suggested and research work suggests a strong connection between kelp and urchins, but we were unable to find ways to use the kelp data available to significantly improve our fit and biological understanding. This may be because of the poor resolution of the kelp data.

Our models also fail to capture other biological issues such as the role of spine canopy in facilitating recruitment, and the spatial dynamics of growth variability. It is certainly a fair critique to say that none of the models used in this assessment capture the most important aspects of sea urchin biology. It is possible, that with more years of detailed spatial data from the barefoot ecologist program, and simultaneous collection of kelp data, that a much more realistic biological model could be developed.

At present several significant uncertainties remain. The foremost of these is the relation of the Pt. Loma red sea urchin population to other populations of red sea urchins. Is Pt. Loma a closed self-recruiting population, or is it a source or a sink to a meta-population structure. Perhaps recruitment to Pt. Loma is totally driven by urchins farther north. This seems unanswerable at present.

More answerable, but still uncertain at present is the source of the large sea urchins in the catch. Table 5.2.2 summarizes the major uncertainties.

Table 5.2.2 Uncertainties regarding stock dynamics and status

Major uncertainties
Source of large urchins recruiting to the fishery
Source of recruitment of small urchins, local population or influx from outside Pt. Loma
Abundance of sea urchins outside of commercially fished areas
Growth rates of sea urchins in Pt. Loma
Role of kelp in recruitment and uni-production

Future data and assessments

This assessment suggests that the current status of this fishery is sustainable and that continued monitoring of trends in abundance and length frequency could be used as the basis for an ongoing management program. As more years of length frequency data were collected it would be possible to start to apply a statistical size-transition model. However, it would be far from satisfactory so long as the assessment suggests most recruitment comes from large individuals from an unknown population. Until the source population for the apparent recruitment of large individuals is identified the assessment will be unsatisfactory.

Thus the primary need at present is to obtain abundance samples from outside the fishing grounds, and to identify if there are large populations of cryptic individuals within the fishing grounds. We would recommend expansion of the barefoot ecologist program or other directed surveys to non-fished areas as the highest priority. If closed areas are set up within what are now normally fished grounds, then the abundance and size distribution in the closed areas would need to be monitored as well.

Another high priority would be Pt. Loma specific studies of growth. We need to determine if the growth increment data that are available are representative. Ideally, growth experiments would be established with a spatial and temporal element to determine the extent to which the amount of variability in growth could be determined and the role of any factors such as kelp, temperature, sea urchin density etc. in affecting growth rates established.

Other data that need to be collected on an ongoing basis are length frequency of the catch, and kelp abundance. The elements in an ongoing monitoring program are listed in Table 5.3.1

Table 5.3.1. Data elements in a monitoring program.

Data Element	Method
Effort and spatial location of effort and catch	Logbooks, ideally with GPS location by dive expanded to all divers
Density and length frequency inside fished areas	Barefoot Ecologist Program
Density and length frequency in unfished areas (both protected areas and non-commercial areas)	Expanded Barefoot Ecologist, contracted research dives and exploratory ROV surveys in deeper water
Commercial catch volume and length frequency	Barefoot Ecologist and/or sampling at processor
Growth rates	Dedicated research program
Kelp abundance	Dedicated research program could be routinely conducted by divers.
Other environmental data	Needs to be discussed

The role of assessments in future management

If the data elements in Table 5.3.1 were put in place, it would provide an ongoing index of abundance inside and outside of fished areas, and estimates of recruitment to the fishery from the length frequency data and catches. Discussions of possible management strategies at the March 2007 workshop included the possibility of closed areas with Pt. Loma, maximum size limits, and possible transplantation of red sea urchins into areas of high kelp abundance. Each of these actions would pose some challenges to the normal assessment models, and while it would undoubtedly be possible to create a spatially structured model that attempted to capture these dynamics, we do question if such a complex assessment would be necessary for sustainable management or worth the financial expense.

The data program described in Table 5.3.1 would provide the data needed to monitor trends in abundance without needing to use a formal assessment model. A management strategy could be devised that was based on the data directly rather than using a statistical assessment model. Certainly it would seem very useful to update the kind of models used here, or to implement a statistical size-transition model as soon as Pt. Loma specific growth data and estimates of abundance outside fished areas are available. Such an analysis would be required to try to reconstruct the history of the fishery, but would not seem necessary to set up a sustainable ongoing management program.

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B. Smith provided the code used for the length frequency and growth increment analyses and some useful comments about the nature of the data.

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APPENDIX I-A-4

REVIEW OF THE ASSESSMENT OF RED SEA URCHIN IN THE PT.LOMA KELP BED-
RECOMMENDATION FOR FUTURE ACTION FOR THE SAN DIEGO WATERMEN'S ASSOCIATION

Jeremy Prince, Louis Botsford and Ana Parma

The following comments and recommendations derive from the SDWA assessment review held 14th June 2007 in San Diego.

Overall comments about the assessment

The relative stability of the CPUE over the last 15 years indicates that current levels of catches appear to be sustainable. However, the assessment models explored do not present a coherent picture. The main limitations of the assessment are clearly recognized in the assessment document and derive from uncertainties about (1) trends in overall abundance given the lack of a reliable index and problems in interpreting CPUE, (2) the appearance that there is a "reservoir" of urchins that are not vulnerable to fishing but that provide a source of adult recruitment to the vulnerable stock, and (3) the degree of isolation/connectivity of the Punta Loma stock with other populations of red sea urchins outside the area.

In addition, the growth model estimated from tagging data, the majority of which does not come from Pt. Loma, appears to be inconsistent with the size-composition data which shows sizes larger than expected from estimated growth rates. As a consequence the analysis of size structure results in fishing mortality estimates close to zero when much larger mortalities might be estimated under higher growth rates.

The highly dynamic nature of the local cycles of depletion and replenishment of the mature sea urchins, and their relation to kelp abundance, is a distinctive feature of this stock which deserves further research. The size-structure data collected by the barefoot ecologist program were consistent with the divers' empirical observations in supporting the existence of pulses of recruitments of adult sea urchins into the fishing grounds. Investigating the source of these urchins and their contribution to local recovery relative to growth of local sublegal urchins is critical. A combination of surveys, local experiments involving pulse fishing, closed areas, and monitoring of recoveries could be designed to investigate this dynamics.

Immediate Future

Short-term assessment recommendations

A number of alternatives to the modeling analysis presented during the review were suggested for exploration:

- Further analyses of growth data to: (i) evaluate variability between-sites and/or time-periods in the existing size-increment data to determine the range of plausible growth models in the available data (random-effects models could be used for this purpose); (ii) evaluate the possibility of using diver observations of growth from current recruitment to estimate growth rates.
- Explore what kind of growth curves would be needed to explain the size-structure data. The growth model used by Botsford-Smith, which assumes a variable L_∞, would be appropriate for this evaluation.

- Evaluate the sensitivity of two dynamic models to an assumption that the fishery is catching almost all of annual recruited biomass, or that recent exploitation rates have been high. Assume fishing mortality is proportional to effort.
- The last two size-structured models, although based on the same size data and equilibrium assumptions, lead to very different conclusions in terms of harvest rates, presumably a result of the different assumptions about size at recruitment. However, because the models also vary in other ways (e.g. continuous versus discrete growth and actual growth rates), it is difficult to represent a continuum of hypotheses that would bridge the two extreme results. We suggest merging the two models so that the main drivers for the results can be better examined, for example by changing the size at recruitment in the first model. We expect that the exploitation rate estimated while treating the mean and variance of the size distribution of recruits as free parameters (the first model) is very uncertain.
- It was emphasized that the estimates of F provided by Botsford/Smith method can be uncertain unless a size composition corresponding to F=0 is also used to contrast the size structure of the exploited population. According to Botsford and Smith, this is the case even when data on growth increments are used jointly to estimate growth rates. We recommended the use of the early size-composition data to estimate the fishing mortality required to produce a reduction in the proportion of large urchins comparable to the change observed between 1975 and 2005-2006, under a range of plausible growth models.
- Modify the delay-difference model that treats the mature and immature as two separate compartments to assume that (i) vulnerable or mature biomass (Bvul) has a carrying capacity (K_t), perhaps a function of kelp biomass, (ii) fishing mortality on the mature biomass is proportional to effort and (iii) transition from immature to mature (and the reverse) is a function of depletion Bvul/K_t (or Bvul exceeding K_t). The motivation was to examine if such a model would be consistent with high harvest rates in recent years without forcing extremely high catches during the fishing down phase, as catch rates would be limited by K. Similar to the 2-compartment model presented in the document, unless de index of abundance applies to the whole population, there is no information to estimate the size of the invulnerable stock, which can be "as large as needed" to replenish the vulnerable stock.
- Editorial: equation 4.1.3 is upside down.

<u>Data collection and development of Co-operative Management Framework - SDWA</u>

- Continued barefoot ecologist (BE) monitoring using two tiers of data collection.
    - Tier 1 - GPS positions, Transects, Before & After Samples, Area Swept Catch rates
    - Tier 2 – GPS positions, Before &/or After Samples, Area Swept Catch rates
- Expand the BE program or supplement by other means the collection of density data in areas outside the prime fishing grounds.
- Expand efforts to calibrate abundance indices.
- Evaluate feasibility of collecting kelp data using GPS.
- Develop proposals for Voluntary Closed Areas for the purpose of:
    - Encourage San Diego capacity for co-operative management action.
    - Positioning San Diego for future MLMPA process.
    - Build up sources of recruitment.
    - Study unfished population structure and growth & compare with areas open to fishing.
    - Monitor recovery through growth and immigration following closure by implementing some of the closures in heavily fished sites (pulse fishing).

Longer-term Future

Research recommendations

- Conduct further tagging studies in Punta Loma, perhaps using PIT tags, to evaluate local growth and possibly movement rates.
- Dave Datz and Nicolás Gutierrez to co-operate in developing an analysis of the Datz data set to evaluate information about the small-scale dynamics of depletion-recovery and maturation.
- Investigate availability of urchin in areas not reached by divers by conducting ROV surveys of urchin density in deeper water outside 100'.
- Investigate immigration rates by assembling existing data on bathymetry and bottom type to identify areas where immigration occurs. Such data could be used to design a tagging study of movement rates and growth during recruitment to vulnerable areas.
- Investigate the existence of better historical kelp data or the use of sea-surface temperature as a proxy of nutrients and kelp area. Continue analysis of relationship between kelp and sea urchin recruitment and uni production.
- Continue research on quantification of the benefits of cooperative management that would allow sea urchins to fully mature before being harvested.

Developing Co-operative Management Framework - SDWA

- Continued development of local high-end markets for premium live product.
- Continued discussion of management mechanism that will foster local management of uni quality and value.

APPENDIX I-A-5

COMMENTS ON THE STOCK ASSESSMENT OF RED SEA URCHINS IN THE PT.LOMA KELP BEDS

By Loo Botsford

For Peter Halmay and the sea urchin fishermen

The authors did an excellent job of exploring the limited data, then drew conclusions regarding whether overfishing is occurring. It is to their credit that they used several different modeling approaches, and the fact that the results from each led to the same conclusion strengthens their conclusions. I think their analyses are correct, however I interpret them more cautiously.

One can view the overfishing question as a question of how many sea urchins do we have now, as compared to the number we started out with. In this case, neither of these abundances is known, but we can assume that catch per hour fished is proportional to abundance, and that that relationship is the same now as it was in the 1970s, i.e., that an hour of fishing nowadays will yield the same fraction of the total available abundance that it did in the 1970s. That was the initial assumption Hilborn, et al made in their first analysis, though they also allowed it to vary as shown in Fig. 4.1.1.1. To get a rough idea of how this might be expected to come out, one can look at the catch per hour data on p. 9. It is up near 400 until 1984when it dropped to less than half of that value, and it has remained near that value since then. I don't know why abundance would drop by half in one year, but after returning home from the review I noticed that is about the time that $/Yen jumped by more than 50 percent. This suggests that other factors, in addition to abundance, have affected catch per hour, and this should be investigated.

From the facts that the total catch up to 1983 was 6.5 million pounds, and CPUE dropped to 40 percent of it highest value, Hilborn, et al. concluded that the initial abundance was roughly 11 million pounds and there was about 4 million remaining, an amount that has been fairly constant since then. From this and an average catch since then of 500 thousand pounds, they concluded that the harvest rate has been a little over 10 percent per year.

In their second model (section 4.2), they fit the same data, but they use a model that has recruitment depending on current sea urchin abundance and kelp abundance. Results regarding the decline in abundance and harvest rate of around 10 percent were similar. In the third model they again fit the same catch and catch per hour data, but this time they used a model that keeps track of how many sea urchins there are at each age. Results were similar.

The next model few models used a different source of data, size distributions. The first (Section 4.4.1) fit a size transition matrix model to a local size distribution allowing recruitment at large size. Recruitment at large sizes is, of course, unusual in fishery models, but here it reflects the potential influx of sea urchins from inaccessible locations, possibly greater depth. With regard to the model they used here, in my work I prefer not to use these size matrix models because sea urchins grow continuously from one size to a slightly larger one, they do not move as a fraction from one size category to the next.

The next model (Section 4.4.2) uses the Botsford/Smith model, but not in the way that we recommend it be used. To estimate fishing mortality rates from a size structure, we recommend that the model first be fit to a size distribution from an unfished population, so that the growth rates and natural mortality rate can be determined. Then the model with those estimates in it can be used to estimate just the fishing mortality. The reason for this is that fishing mortality rate has such a small effect on the shape of the size distribution and so many other factors affect that shape. The model fitting has a difficult time sorting out which factor is doing what. Age distributions are much easier to fit.

Another important fact about size distributions is that information on size is needed to estimate mortality rates. In their final version of the assessment, Hilborn , et al examined the effects of size distribution on their estimate, but they did not have a local, unfished size distribution, and they used a size transition matrix. For the reasons just given, it is difficult for me to interpret their results.

Replacement

The assessment by Hilborn, et al. used the decline in abundance and the estimated fishing mortality rate to evaluate whether the population was overfished, and they felt that they did not have enough data to pursue another approach that calculates replacement. The concept of replacement is simple, that a population will remain constant or grow as long as each individual in the population replaces itself. For humans, we are all familiar with the idea that if each couple has two kids in their lifetime the population will remain roughly constant. The problem with using that idea for fish populations is that we don't know what the minimum number per lifetime is. It is basically two, of course, but what is that in terms of eggs or larvae, most of which will die before reproduction? Fisheries biologists have established a minimum percentage of natural (unfished) lifetime reproduction, rather than a minimum number in a fish's lifetime. That percentage is about 35 percent, but it is highly uncertain. The other problem with replacement is that you need to know quite a bit to calculate it, i.e., growth rate, mortality rate, and the dependence of fecundity on size. That is why Ray, et al., did not use this approach.

In our assessment of the northern California fishery we did have enough information to calculate the current percentage of natural lifetime egg production. It was about 20 percent. The reason we had enough information to calculate this is that we conducted growth studies and obtained size distributions at several unfished locations. The harvest rate we estimated in northern California varied around a value of 60 percent per year.

I am attaching a copy of a recent paper that has a plot of urchin catch around the world, on which there is a plot of $/Yen. It describes our assessment of the northern California fishery briefly.

Conclusions

I am a bit more cautious than Hilborn, et al. They are correct that the fact that the catch per hour has only declined to 40 percent of its original value is a good thing. However, I think that more work should be done on the question of how well does catch per hour indicate abundance, i.e., has there really been only a 60 percent decline in abundance? One question that needs to be addressed is how did a change in the value of the Yen affect the index of abundance, in addition to the effect of abundance?

A second slightly different response that I have regards the apparent influx of large individuals into the population. That was regarded by Hilborn, et al as a good thing, as it was keeping the population at high levels. However, I would wonder where the large urchins are coming from, and what their dynamics are. If you were running a business and you reviewed your books to see how you were doing, and found that you had quite a bit of money, but it had simply appeared on the books mysteriously, would you feel good about that or bad? I like the idea of more research on the source of those individuals and their dynamics. Ultimately the dynamics of that pool of unfishable, legal individuals needs to be included in the model. You need to estimate the abundance of the individuals too deep to be fished soon.

With regard to the modeling, I think that there is a lot of information in size distributions, but that you need growth measures and unfished size distributions to get it out. You need growth increment studies and an unfished reserve. I would have your request and rationale ready when the MLPA comes south.

I think that further work on the dependence of production on kelp abundance is well worthwhile, not necessarily as a sustainability issue, but rather as a way of managing for greater return. Managing harvest with an eye to the current market price is another potential way of managing for greater return. Somebody needs to work on making this kind of management by the fishermen possible in California. Though I stress that it does not answer the sustainability question of how much can we fish and still maintain replacement.

Lastly, on the positive side regarding sustainability, you are now monitoring abundance, and that buys you a lot of insurance. I recommend keeping that up, and trying to work in some growth studies and studies of unfishable urchins, if possible.

APPENDIX I-B-1

CALIBRATION OF SAMPLING PROTOCOLS USED ESTIMATE THE ABUNDANCE OF RED SEA URCHINS (STRONGYLOCENTROTUS FRANCISCANUS) IN THE POINT LOMA KELP BED

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Executive Summary

Estimates of both accuracy and precision of density and abundance are critical in evaluating sampling data used for red sea urchin stock assessment. Whereas precision of a given sampling protocol can be assessed from repeated sample points, estimates of accuracy require sampling in locations where abundance is known without error. We evaluated the accuracy and precision of three sampling protocols at 5 plots in the Point Loma kelp forest ranging in area from 0.25 to 4 hectares (0.6 to 9.9 acres) and these three plus an additional protocol at a single 0.6 hectare site. Plot densities encompassed bed-wide values in red sea urchin density as determined from extensive sampling over a 3 1/2 year period. Plot sizes were chosen to encompass biologically meaningful spatial scales. Three protocols were developed by the San Diego Watermen's Association. SDWA-1 consisted of 10-m x 4-m quadrats or band transects sampled immediately before harvesting operations. These were placed haphazardly with regard to direction and location. SDWA-2, consisted of censuses in delineated and sub-divided sections of 50-m x 50-m plots (0.6 acre); SDWA-3 was a rapid assessment based on methods employed by some divers in the fleet during normal harvesting operations. The final protocol, CDF&G/CRANE was a modification of the California Department of Fish and Game and CRANE (Cooperative Regional Assessment of Nearshore Ecosystems) protocols in which red sea urchins were counted in 30-m x 2-m band transects placed uniformly and parallel to the shoreline were sampled. Accuracy, and precision were estimated for each protocol based on data from the calibration plots. In addition, precision (expressed as margin of error or MOE) was determined based actual or projected sampling effort of existing data collection programs in the Point Loma kelp bed.

On average all of the sampling protocols underestimated the true value as determined by censuses (3 to 51 % below true value). Considering precision and accuracy together, all three SDWA protocols performed better than the CDF&G/CRANE protocol. SDWA-1 was slightly more precise and more accurate. SDWA-2 and SDWA-3 protocols were more accurate and precise. A major caveat for evaluating the effectiveness of SDWA-3 was that it was calibrated only once, and requires more work to accurately determine its operating characteristics.

Based on actual sampling effort either already expended or planned in the near future, our studies show that SDWA-1 and SDWA-2 protocols provide much better estimates of red sea urchin stocks than the CDFG/CRANE protocol. Practical logistical constraints are considered in making recommendations about effort allocated among the SDWA protocols in a community-based data collection program.

Introduction

Fishery-independent estimates of density, abundance, and size structure of exploited populations are vital for stock assessment. For nearshore invertebrates, including red sea urchins, these data are typically obtained by diver counts along transects or in quadrats. The San Diego

Watermen's Association (SDWA) has developed a sampling protocol (described below) that allows working divers to collect random samples of density and size distributions during the course of normal harvesting operations. The idea behind this protocol is to collect accurate "random" samples throughout the Point Loma kelp bed in areas subject to the full range of harvesting intensity and variations in red sea urchin density and size structure. Since each sample requires relatively little effort, it is possible to accumulate many samples throughout the kelp bed during any given year. If these samples produce accurate estimates of density (number per unit area) and abundance (population or stock size) it would be possible to make both accurate and precise estimates of changes in these parameters from year to year. Combining density estimates with size data will enable estimates of changes in whatever size class is of interest, including young-of-year and harvest-sized individuals.

Since reliable information on growth and reasonable estimates of mortality rates are available (Ebert et al. 1999), the data collection program proposed here can provide robust estimates not only of abundance and size structure in a given year, but also of sustainability (e.g. Hilborn et al. 2007).

Estimates of both accuracy and precision are critical in evaluating sampling data used for red sea urchin stock assessment. Whereas precision (i.e. the degree of closeness of repeated estimates) of a given sampling protocol can be determined from repeated sample points, estimates of accuracy (the degree of closeness to the true value being estimated) require sampling in locations where abundance is known without error. Estimating precision is relatively straightforward given sampling data. Accuracy is much more difficult to estimate, since it requires knowledge of the true value of the quantity being estimated, and can be problematic, particularly when dealing with populations of nearshore benthic invertebrates such as sea urchins, which have highly clumped spatial distributions. Here we report on work that estimates accuracy as well as precision at six sites within the Point Loma kelp forest. These sites encompass a range of red sea urchin densities and spatial patchiness We estimated the accuracy of four sampling protocols by comparing their estimates to either: (a) a large number of samples taken uniformly, or (b) complete censuses at sites consisting of square plots ranging from 2,500 to 40,000 m^2 (0.6 to 9.9 acres) in area. We also estimated the precision of the various protocols and expressed it in two ways: (a) the number of spatial samples required to detect a 20% reduction in red urchin abundance with a significance level of 0.20 and power of 80%, and (b) the margin of error (e.g., Wombold, 2008; US Census Bureau, 2006) for specified sample sizes with a significance level of 0.20 and power of 80% (i.e. $\pm$ x individuals per m^2. The significance and power levels we used set type I and type II errors (falsely accepting or rejecting, respectively) equal to 0.20, and the specified effect size as a 20% decline in density.

The protocols include the SDWA protocol mentioned above, three modifications of this protocol, and the protocol used by the California Department of Fish and Game (http://www.dfg.ca.gov/marine/fir/sss.asp#crane). The goal of this work is to compare the accuracy, precision, and effort required from each protocol to measure density (and abundance in a specified area of habitat of red sea urchins.

Methods

The locations of the calibration plots and a schematic diagram of sampling layouts for the different sampling protocols are given in Figures 1 and 2. Table 1 summarizes plot characteristics and the percentage of total plot area sampled by the different protocols, which are described below.

Estimating the true density. To estimate accuracy of density estimates it is necessary to know the true density value. We obtained this by gridding plots of know areas on the sea floor (ranging from 2,500 to 40,000 m^2 - 0.6 to 9.9 acres) and censusing or counting in large uniform samples (comprising 15 to 100 % of total plot area) all red sea urchins in the plot. We then sampled these plots using various protocols described below and compared these sample estimates to the "true" (censused) value to estimate accuracy.

Several methods were used to delineate and census the sites. In all of them, the corners of the plots were marked by weights or weighed lobster traps. Marked lines or meter tapes were then stretched between two parallel edges of a plot (usually the offshore and inshore edges). Additional marked lines or meter tapes were extended perpendicular to these two baselines at regular intervals. Counts were then made at regular intervals on both sides of these perpendicular lines using 1.5 or 2-m fiberglass rods as a scale (see Figure 1, table 2 for details). Initially (at Sites A and B) the perpendicular band transects did not encompass the entire plot area. Subsequently, lines perpendicular to the base lines were arranged so as to form parallel bands 5 meters wide that covered the entire plot area (Figure 2). Initially, the lines delineating plots and sub-plots were put in place by divers on the bottom. Subsequently, lines were laid out by first attaching them to weighted lobster traps which were deployed from the surface and then adjusted on the bottom by divers. This latter procedure greatly reduced the time required to delineate plot boundaries.

Four sampling protocols were examined: SDWA-1, SDWA-2, SDWA-3, and California Department of Fish and Game (subsequently referred to as CDF&G/CRANE).

SDWA-1. The SDWA-1 protocol consists of a 10-meter x 4-meter band transect "randomly" positioned at a sampling or harvest site. A 10-meter lead line is attached to the anchor or a weight dropped prior to harvesting and its direction (azimuth) is determined by lay of the anchor line (Figure 2). In practice this results in a haphazard distribution of transect directions relative to the shoreline or isobath. The predominant wind direction in the San Diego area is from the northwest (about 45 degrees to the shoreline) consequently approximately 60% of all transects lay in the northwest direction. The remaining 40% of transects varied in directions ranging from north and south (parallel to the shoreline) as well as west (perpendicular to the shoreline). All individuals are counted in a 2-meter swath on either side of the transect. During data collection, the first 30 individuals encountered are collected and their test diameters measured to the nearest 0.1mm. Size data were not included in the calibration study.

SDWA-2. The SDWA-2 protocol rapidly censused plots by counting contiguous strips of varying widths that covered the entire plot and were delineated with lead lines and weights.

SDWA-3. The SDWDA-3 protocol consisted of counts made over the entire calibration plot done in the same way as two of the investigators assess numbers over large areas during harvesting operations. It requires less time that the SDWA-2 protocol because it does not depend on first delineating counting areas. This method was used on a single calibration plot.

CDF&G/CRANE. The CDF&G/CRANE (California Department of Fish and Game/Cooperative Research and Assessment of Nearshore Ecosystems) protocol consisted of 30-meter x 2-meter transects divided into three 10-meter segments. Each transect is oriented along the isobath, which in the Point Loma kelp bed generally results in an orientation parallel to the shore. Species that occur in high densities (which include both red and purple sea urchins) are sub-sampled as follows. If the count exceeds 30 individuals in any of the three 10-meter segments the diver records the meter mark at which this occurs, stops counting and uses the count and the meter length to estimate density in the segment by extrapolation. This extrapolation adds to the variance in estimates and could produce significant upward bias if urchins are abundant and patchily distributed on a scale less than 10-meters, a situation which commonly occurs. To avoid these potential problems, we employed a modified CRANE protocol that was used by the CDF&G biologists in their cooperative work with us which eliminated the "sub-sampling" rule. We did, however, maintain the positioning along the isobaths (i.e. parallel to the shore). This positioning rule is a potential source of bias because the substrate in the Point Loma kelp forest consists of ridge and trough structures that are parallel to the shore in which sea urchins are often concentrated.

Census and sample data were used to estimate accuracy (percentage deviation of sample from census estimates of density) and precision. Protocol precision was examined by comparing the number of samples required to detect a 20% change in density setting the significance or type I error (probability of a false positive) and type II error (probability of a false negative) at 0.20. Power, the probability of correctly detecting a specified change is equal to 1-type II error (i.e. 0.80). Both precision estimates were based on protocol means averaged by year (2005 or 2007).

Results

Calibration plot areas varied from 0.25 to 4 hectares (0.6 to 9.9 acres, Table 1).

Table 1. Plot sizes and areas (m^2) sampled or censused by different protocols. † indicates large uniform sample.

		Area (m^2) Sampled by Protocol				
Date	Site Code	Plot Area	CENSUS	CDF&G CRANE	SDWA-1	SDWA-2 & SDWA-3
6/29/2005	SITE B†	40000	6000	2400	440	--
9/20/2005	SITE A†	10000	2400	--	360	--
8/9/2007	Census01	2600	2600	200	160	2600
12/14/2007	North PL Low	2500	2500	180	200	2500
12/15/2007	South PL High	2500	2500	180	200	2500
1/18/2008	High-D	2500	2500	180	300	2500

Determination of "true" densities in two of the plots (A and B) were not based on censuses but rather large uniform samples which covered 24% and 15% of the total plot area, respectively (Table 2).

Table 2. Percent of total plot area censused or sampled by protocol or "census".

			% of Total Plot Area Sampled			
Date	Site Code	Plot Area	CENSUS	CDF&G CRANE	SDWA-1	SDWA-2 & 3
6/29/2005	SITE B	40,000	15	6	1.1	--
9/20/2005	SITE A	10,000	24	--	3.6	--
8/9/2007	Census01	2,600	100	7.7	6.2	100
12/14/2007	North PL Low	2,500	100	7.2	8	100
12/15/2007	South PL High	2,500	100	7.2	8	100
1/18/2008	High-D	2,500	100	7.2	12	100

The remaining 4 plots were censused (Table 2). Plot densities ranged from 0.037 to 1.468 m^{-2} (Table 3) and are representative of the range of sampled densities encountered throughout the Point Loma kelp samples taken in the fished areas (mean = 0.50 m^{-2}; 99.9% confidence limits = 0.35 to 0.93 m^{-2}; based on 382 samples taken from 2004 through 2007).

Table 3. Total red sea urchin density by date, site, and protocol.

		Density (number m^{-2}) by protocol				
Date	Site Code	CENSUS	CDF&G CRANE	SDWA-1	SDWA-2	SDWA-3
6/29/2005	SITE B	0.363	0.470	0.359		
9/20/2005	SITE A	0.594		0.278		
8/9/2007	Census01	0.212	0.140	0.194	0.346	0.380
12/14/2007	North PL Low	0.037	0.072	0.015	0.038	
12/15/2007	South PL High	1.468	1.411	0.780	1.500	
1/18/2008	High-D	0.951	0.289	1.630	0.760	

Protocol ranking on mean accuracy (% deviation from censused value) from highest to lowest was SDWS-3 > SDWA-2 > CDF&G > SDWA-1. On average, both the CDF&G and SDWA-1 protocols underestimated true densities (by 42.6 and 16.4%, respectively), compared to SDWA-2 and SDWA-3 protocols which overestimated densities (by 9.9% and 80.1%, respectively); (Table 4). By contrast to average values, the range of inaccuracy for CDF&G (-229% to 48.5%) was greater than that of either the SDWA-1 or SDWA-2 protocols (SDWA-3 was only conducted once, so evaluation of its performance is limited). The CDF&G protocol overestimated densities 40% of the time compared to the SDWA-1 protocol which overestimated 17% of the time (Table 4).

Table 4. Bias (% deviation from census value) by date, site, and protocol.

		% Deviation from Census Value				
Date	Site Code	CENSUS	CDF&G CRANE	SDWA-1	SDWA-2	SDWA-3
6/29/2005	SITE B	0.363	22.7	-1.1		
9/20/2005	SITE A	0.594		-53.2		
8/9/2007	Census01	0.212	-51.6	-8.7	63.0	80.1
12/14/2007	North PL Low	0.037	48.5	-59.7	-5.9	
12/15/2007	South PL High	1.468	-4.0	-46.9	2.2	
1/18/2008	High-D	0.951	-229.1	71.4	-20.1	

The ranking of protocol by mean precision based on samples required to detect a 20% decline in density with 80% confidence interval and 80% power was SDWA-3 > SDWA-2 > SDWA-1 > CDF&G > SDWA-1 (Table 5).

Table 5. Average and standard deviation of density (number m^{-2}) by protocol and year; bias (% deviation from census value); samples (n) required to detect 20% decline with 80% confidence and 80% power and margin of error (MOE in units of number m^{-2}) based on 80% confidence interval and 80% power. Data from High-D (sampled 1/18/2008) was combined into the 2007 data.

Year	Protocol	mean	stdev	n	CENSUS	Bias (%)	n for es=20%	MOE
2005	CENSUS	0.48	0.16	2	- -	- -	9	0.02
2007	CENSUS	0.67	0.66	4	- -	- -	72	0.24
2005	CRANE	0.23	0.48	47	0.48	-51.4	298	0.10
2007	CRANE	0.35	0.61	19	0.67	-47.0	213	0.13
2005	SDWA-1	0.32	0.59	20	0.48	-32.6	232	0.05
2007	SDWA-1	0.49	0.92	31	0.67	-26.4	248	0.07
2007	SDWA-2	0.65	0.63	7	0.67	-3.2	70	0.12
2007	SDWA-3*	0.38	0.00	2	0.67	-42.7	2	0.00

If we scale protocols (ignoring SDWA-3) by precision based on the number of actual samples that either have been taken in the past (SDWA samples from 2003 through 2008} or are planned in the near future (CRANE samples that will be taken in the Point Loma kelp bed during the Bight 08 survey; D. Pondella, pers. comm.) the ranking becomes: SDWA-1 > SDWA-2 ≥ CRANE (Table 6).

Table 6. Average and standard deviation of density (number m^{-2}) by protocol and year detectable effect sizes (% es) and margins of error (MOE in units of number m^{-2}) based on projected sample sizes (see Methods) with 80% confidence interval and 80% power. Data from High-D (sampled 1/18/2008) was combined into the 2007 data.

Year	Protocol	mean	stdev	n	CENSUS	projected n	% es	MOE
2005	CENSUS	0.48	0.16	2	- -	20	13	0.03
2007	CENSUS	0.67	0.66	4	- -	20	43	0.14
2005	CRANE	0.23	0.48	47	0.48	16	89	0.10
2007	CRANE	0.35	0.61	19	0.67	16	75	0.13
2005	SDWA-1	0.32	0.59	20	0.48	120	28	0.05
2007	SDWA-1	0.49	0.92	31	0.67	120	29	0.07
2007	SDWA-2	0.65	0.63	7	0.67	20	38	0.12
2007	SDWA-3*	0.38	0.00	2	0.67	120	1	< 0.01

Conclusions

The four sampling protocols tested in this study differ significantly in both their accuracy and precision. SDWA-3 is the most accurate protocol, but this assessment is based on a single calibration, and in this one case it overestimated true density by 80%. Of the remaining protocols, SDWA-2 protocol is potentially much more accurate and precise than either SDWA-1 or CDF&G/CRANE. The latter two protocols are similar with regard to average accuracy and precision (CDF&G is on average slightly less accurate and precise than SDWA-1), however CDF&G/CRANE has a much greater range of positive (overestimating error) and negative (underestimating error) than SDWA-1.

Considering only precision and accuracy, both SDWA protocols are superior to CDFG/CRANE, with the SDWA-2 protocol much the superior. When deciding how to allocate effort between SDWA-1 and SDWA-2, however, there are important logistical consideration. An advantage of SDWA-1 is that the cost per sample is low and it can be quickly taught to divers to carry out with high confidence in quality assurance and control. SDWA-2, while more accurate and precise than SDWA-1 has higher unit cost and requires special training and experience. SDWA-3 is the most precise protocol, but accuracy was poor and in a non-conservative direction (80% overestimate). If properly calibrated it is potentially of great use, however, since one of us, (Dave Datz) has developed this method with a colleague (Mike Neil) over many years and has a long-term database (beginning in the 1980's), which could prove valuable in stock assessment and management. To be effectively used, the SDWA-3 protocol will require dedicated resources for training, quality assurance, and implementation. In the meantime, all divers in the SDWA can be quickly taught SDWA-1. This and the small unit cost makes it likely that the program will continue in over the long term and can be used as a complement to the SDWA-3 protocol when it has been fully developed and implemented.

In summary, our work has shown that the SDWA protocols are clearly superior to the CDF&G/CRANE protocol for collection of density (and thus abundance) data on red sea urchins and can, in combination, produce estimates of total red sea urchin densities with known accuracy and high to very high precision.

Figures

Figure 1. Schematic map of calibration study sites.

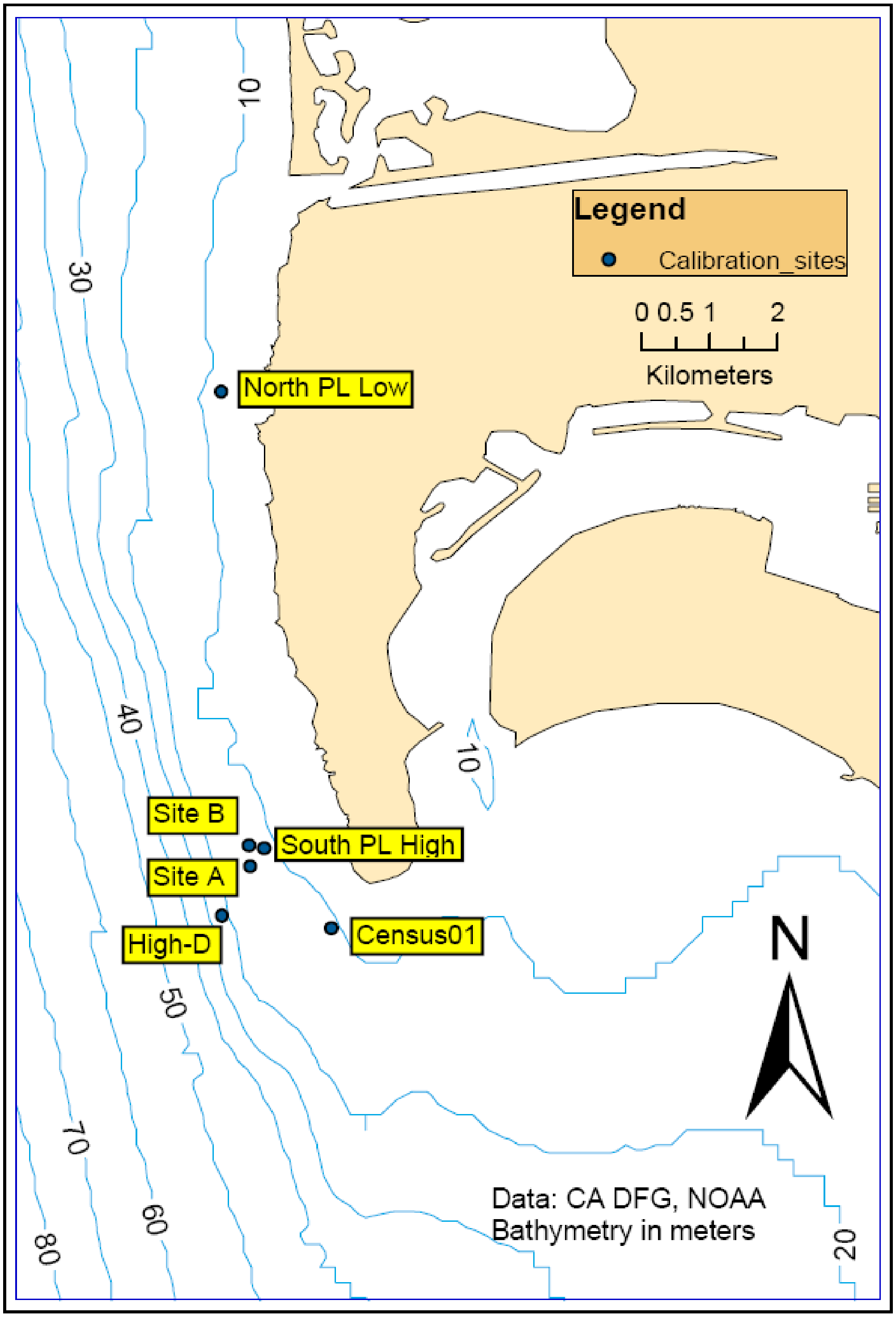
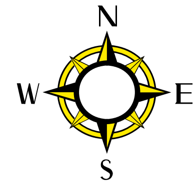
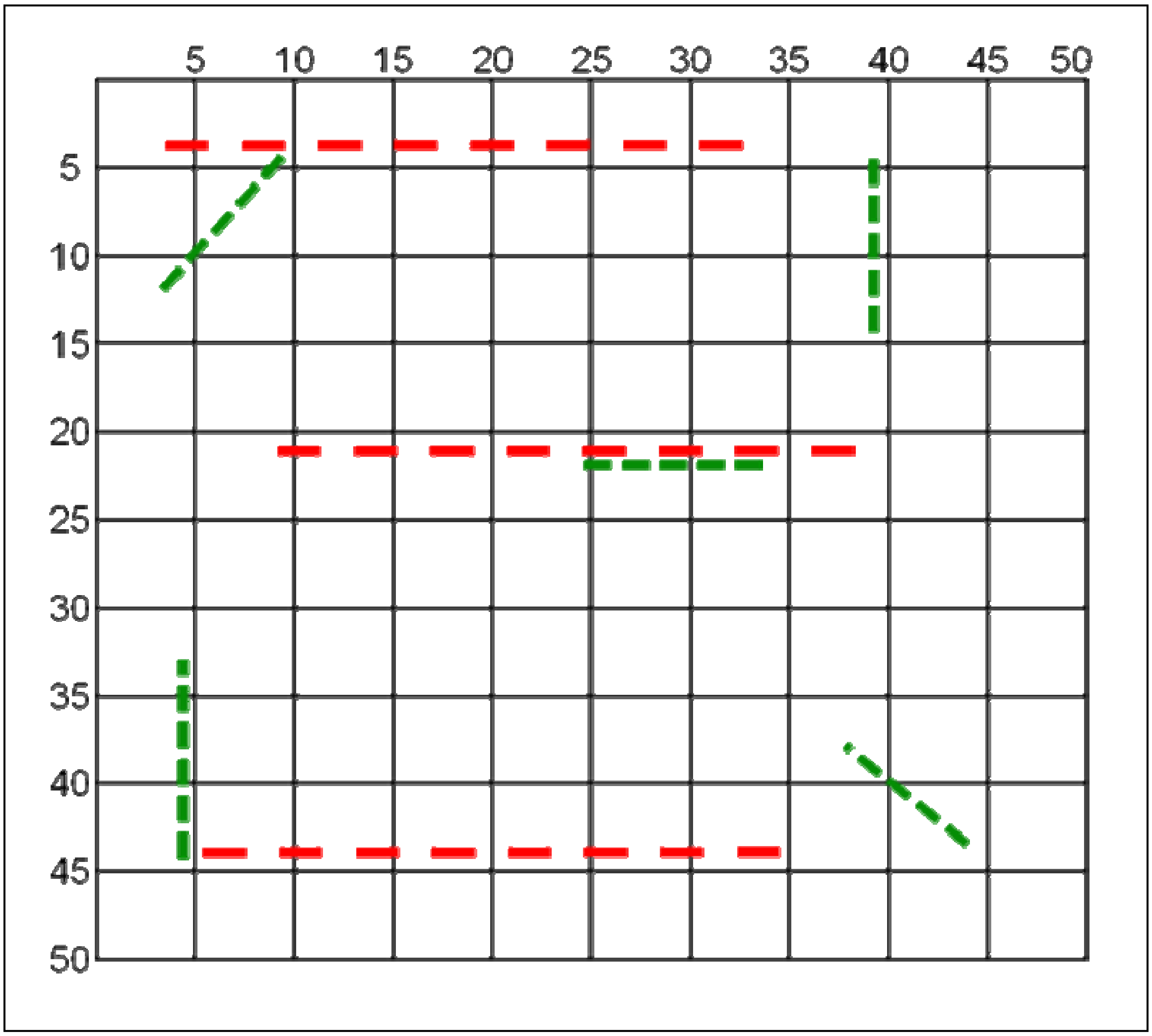


Figure 2. Schematic drawing of sampling layout for Census or large uniform samples, SDWA, and CDF&G/CRANE protocols. Schematic shows a 50-meter x 50-meter plot with grid points at 5-meter intervals. Census counted all red sea urchins in each sub-square.



SDWA:

CRANE/CDF&G:



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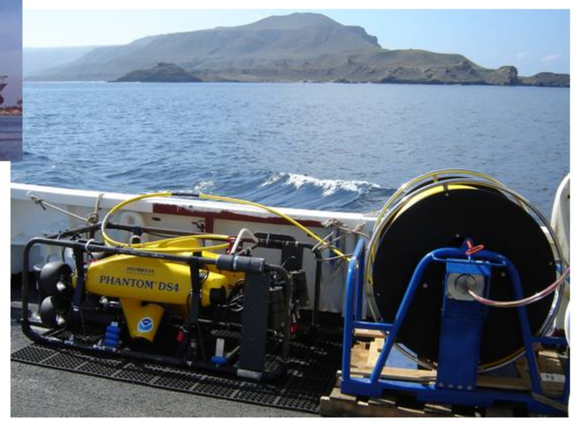
Acknowledgements

I thank Pete Halmay, Mich Hobron Dave Datz, and Mike Neil sea urchin divers and members of the San Diego Watermen's Association and John Duffy, formerly with the California Department of Fish and Game, for help in the design of the calibration experiments and implementation in the field. Kristine Barsky, Ian Taniguchi, Matt Kay, and Briana Brady of the California Department of Fish and Game collected CRANE samples during the 2005 studies. Dave Datz assisted with data quality assurance and control, and Dave Datz, Pete Halmay, and Dr. Mark Page provided helpful comments on drafts of the report.

APPENDIX I-C-1

OPTICAL SURVEYS USING A REPOTE OPERATED VEHICLE (ROV)

Optical Surveys Using a Remotely Operated Vehicle (ROV)



Methods- Optical Surveys

- Video strip transect surveys with an ROV
- All video tapes and data examined post-dive

- Species id
- Count
- Size category and fork lengths
- Depth
- Temperature
- Height off bottom
- Substrate type….

Methods- Optical Surveys

Substrate assessed visually and categorized broadly for comparisons with sonar classifications:

Sand

Mud flat

Cobble (rocks < 30 cm)

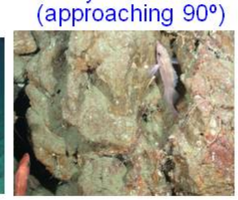
Low relief reef (< 3 m)

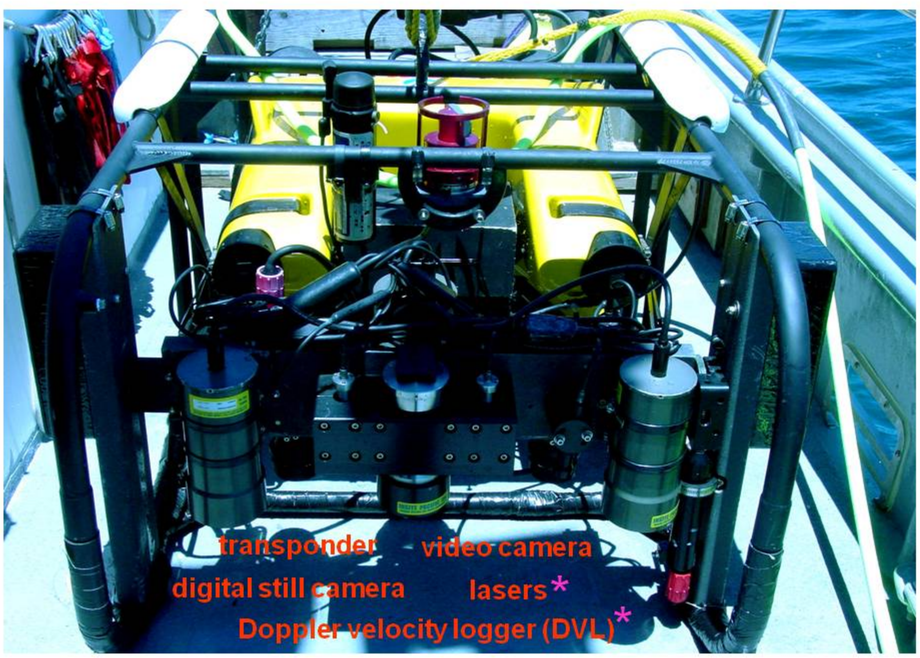
Low relief reef w/sand channels

High relief reef (> 3 m)

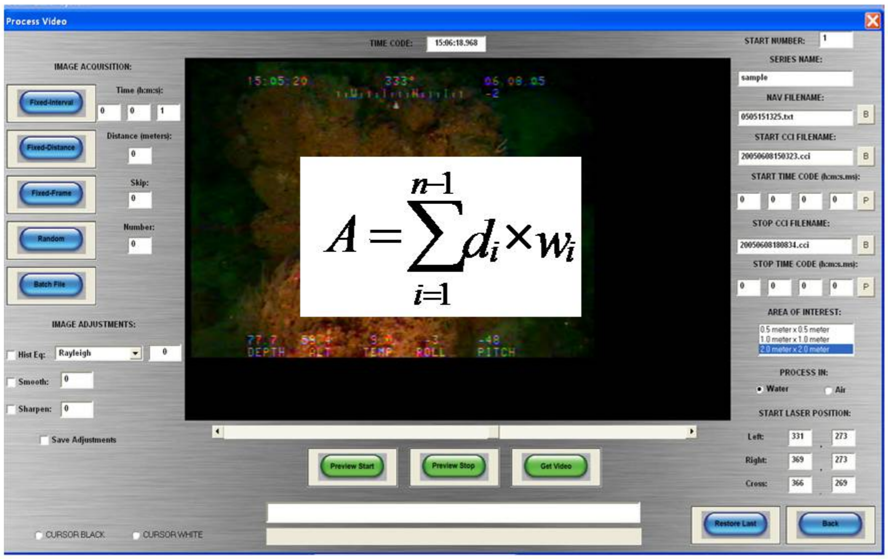
High relief reef w/sand channels

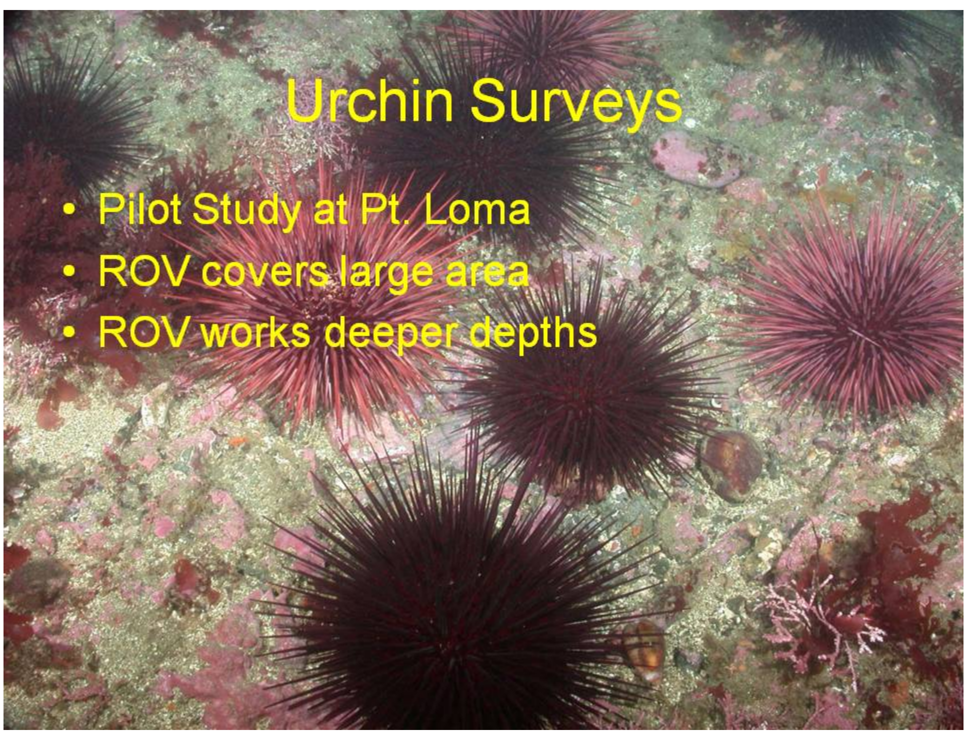
Rocky vertical face (approaching 90º)

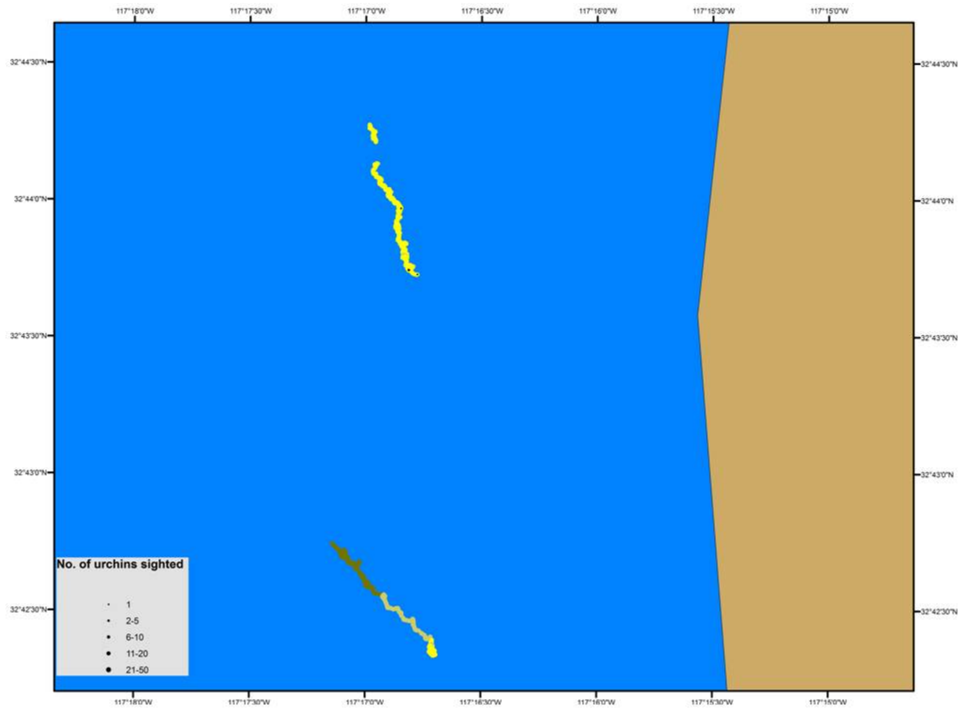


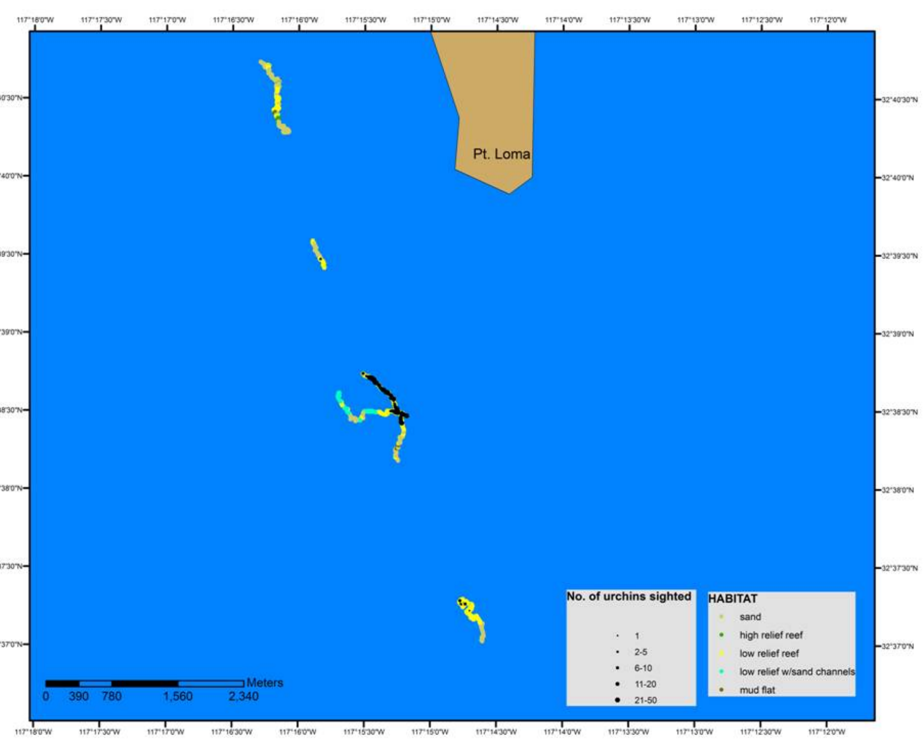


Area Surveyed Calculations





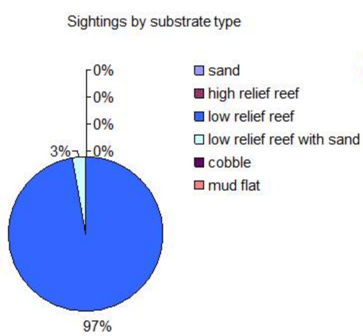

117°18'0"W
117°17'30"W
117°17'0"W
117°16'30"W
117°16'0"W
117°15'30"W
117°15'0"W
32°44'30"N
32°44'0"N
32°43'30"N
32°43'0"N
32°42'30"N
No. of urchins sighted
1
2-5
6-10
11-20
21-50


117°18'0"W
117°17'30"W
117°17'0"W
117°16'30"W
117°16'0"W
117°15'30"W
117°15'0"W
117°14'30"W
117°14'0"W
117°13'30"W
117°13'0"W
117°12'30"W
117°12'0"W
32°40'30"N
32°40'0"N
32°39'30"N
32°39'0"N
32°38'30"N
32°38'0"N
32°37'30"N
32°37'0"N
Pt. Loma
No. of urchins sighted
1
2-5
6-10
11-20
21-50
HABITAT
sand
high relief reef
low relief reef
low relief w/sand channels
mud flat
0 390 780 1,560 2,340
Meters

Urchin Densities at Pt. Loma

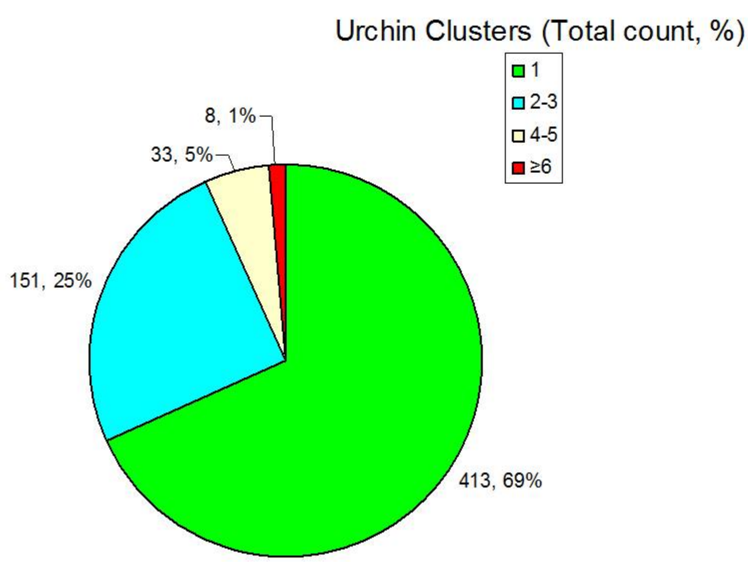
All substrates

dive	area searched (m^2)	total no. urchins	no. urchins/m^2
05-104A	874	0	0.000
05-104B	975	0	0.000
05-104C	210	2	0.010
05-104D	862	4	0.005
07-030A	2,661	1066	0.401
07-030B	2,374	210	0.088
07-030C	3,057	26	0.009
		Mean no./m^2	0.073
		SE no./m^2	0.052



Low relief reef and low relief reef with sand *only*

dive	area searched (m^2)	total no. urchins	no. urchins/m^2
05-104A	106.8458004	0	0.000
05-104B	418	0	0.000
05-104C	81.43494187	2	0.025
05-104D	844.0217255	4	0.005
07-030A	1976.00365	1066	0.539
07-030B	665.5072982	210	0.316
07-030C	2240.810671	26	0.012
		Mean no./m^2	0.128
		SE no./m^2	0.075



APPENDIX II-A-1

DATA COLLECTION WORKSHOP JULY 11, AND12, 2008

Introduction

The San Diego Watermen's Association (SDWA) received a grant from Sand County Foundation to develop social capital in the San Diego sea urchin fishery. We contracted with the University of Washington to manage the data collected by San Diego sea urchin divers and develop a spatially explicit data collection program that will satisfy the requirements of CDFG as well as stock assessment modelers. The data collection program began in earnest at the signing of the contract in February 2008.

There are presently six sea urchin divers regularly collecting data. However the data manger, Nicolas Gutierrez, has noted that the data are of variable quality. It was decided to hold a workshop to discuss the field methods to develop data that can be used to estimate sea urchin abundance.

Design of Workshop

We invited Nicolás Gutiérrez, a UW graduate student in fishery sciences, Michael Robinson, a UCSB graduate student in geography, and Dr. Steve Schroeter, a UCSB adjunct professor in marine ecology, to participate in the workshop.

The Workshop was divided into two parts:
Small group meetings
Large general meeting

Small group Meetings

In order to make the divers more comfortable, willing to share their information, and able to communicate on a personal level with the researchers we arranged six half-hour meetings. They were held in a small office at Driscoll's Wharf marina and each meeting was attended by one to four divers. All fourteen active San Diego sea urchin divers were invited and we achieved 100% participation at the meetings. Additionally, one lobster fishermen attended one of the meetings. The attendance list is shown as Appendix A below.

Individual divers expressed specific concerns:

- Who are Nicolas, Michael and Steve working for?
- Who will see the data?
- How will the data be used?
- How will the data be presented?
- Could the data be used against us?
- Do I have to collect all the data or can I do only a part?
- What other data should we collect (i.e. water temperature, overgrazing potential)?
- Can I use the data/analyses for my own business?

These questions were answered to most divers' satisfaction. Nicolas showed each diver sample presentations of data that had been collected by divers so far. Michael demonstrated typical uses of Geographic Information System (GIS) data by using samples of Point Loma kelp bed and sea urchin fishery data.

These small group meetings proved to be very effective as individual diver's concerns were addressed. Nicolas and Michael gave each diver their email address and agreed to discuss any issues directly and in a timely manner.

Results of small group meetings

Divers got a better understanding of why data is collected and were able to develop a direct communication system with researchers via email or phone.
Ten sea urchin divers indicated that they would begin filling out the Tier 1 forms (Figure 1).
Two others said they would submit their personal logs for the past several years.

Large General Meeting

A general meeting was held to recap the results of the previous day's meetings.
Six sea urchin divers and one processor attended the meetings and listened to presentations by Nicolás Gutiérrez, Michael Robinson, and Dr. Steve Schroeter.
The presentations focused on the lessons learned the day before. It was decided that the data collection program, and the sea urchin density calibration would provide the basis for a Power point presentation to be prepared at the Sea Grant sponsored Workshop, "Managing Data Poor Fisheries: Case Studies, Models, and Solutions" to be held on December 2008 in Oakland California.

Appendix A Small Group Meetings Attendance

TIME	NAME	LOCATION
9:30-10:00	Henry Davis, Gerry Beverino/Jim Kinkade	Driscoll's
10:00-10:30	Mitch Hobron/Peter Halmay, Erik Krebs	Driscoll's
11:00-11:30	Chris Sparks/Gary Harle, Susan Buck/Cliff Hawk	Driscoll's
11:30-12:00	Bob Moran	Driscoll's
12:00-12:30	Rob Case	Driscoll's
2:00-5:30	Visit dive sites, Nicolas/Steve/Dave/Peter/Ken	Pt. Loma kelp beds
6:00-6:30	Dave Datz/Mike Neil	Dave's house

APPENDIX II-A-2
LETTER FROM CELESTE BENHAM, SCRIPPS INSTITUTE OF OCEANOGRAPHY

June 22, 2008

San Diego Watermen's Association
11103 hwy 67
Lakeside, CA 92040

To the San Diego Watermen's Association :

I, Celeste Benham, am writing to acknowledge the contribution that Peter Halmay has made to my Master's degree thesis project entitled "ASSESSING CONNECTIVITY OF RED URCHIN (*STRONGYLOCENTROTUS FRANCISCANUS*) POPULATIONS USING AFLP AND MICROSATELLITE MARKERS." The goal of the project is to analyze genetic markers of red urchins from at least six locations along the California coast as a way of assessing the connectivity among populations. I have asked for the support of urchin divers and processors to help me collect the urchins, as well as taken the necessary steps to begin collecting urchins myself.

Peter's involvement in this project has been invaluable and is much appreciated. He has provided me with about 150 urchins of various sizes from the kelp forest off Point Loma, and he has given me intellectual advice and support regarding the background and potential applications of the work. He has also referred me to other urchin divers who are willing to help me with the remainder of the collections. Peter's enthusiasm for the project has made it a joy to work with him and is also much appreciated.

For questions please email me at cbenham@ucsd.edu.

Sincerely,

Celeste Benham
Candidate for Masters Degree of Science
Division of Biology, UCSD; Scripps Institution of Oceanography
BIOL 0348
La Jolla CA, 92093 0348

APPENDIX III-A-1

RED SEA URCHIN GONAD COLOR REPORT – DEC 2007 AND MARCH 2008 23 JUNE 2008

Prepared by:
Susan Schlosser
University of California Sea Grant Program
2 Commercial St., Ste. 4
Eureka, CA 95501
Phone: 707/443/8369
Email: scschlosser@ucdavis.edu

Introduction and Background

Sea urchin fishermen in San Diego, California participate in a valuable fishery for the red sea urchin, *Strongylocentrotus franciscanus*, resource. In this Southern California fishery, red sea urchins have an abundant food supply and spawn year round. Oceanic sea urchin diets consist mainly of algae. Sea urchin gonad quality is directly related to the animals' food supply and quality. While carotenoid pigments in the food are known to determine the sea urchin gonad color, understanding annual variability in red sea urchin gonad color from the fishery population has not been examined. Additionally, fishermen and processors are interested in exploring the possibilities of quantifying seasonal red sea urchin gonad color and in determining a range of colors that correspond to industry grades A, B and C.

Color can be quantified using international standards. One of the most commonly used systems is the L*a*b* color space, a tristimulus system devised in the 1950's which is widely used in the food industry today and has been applied to analysis of sea urchins. Our approach was to analyze sea urchin gonad color using this standard food science method.

Methods

Processed red sea urchin gonads were shipped overnight to the UC Davis Food Science Laboratory in on 7 December 2007 and on 20 March 2008. In both cases, the temperature of the sea urchin gonads at packaging was 52°F. Temperature loggers recorded temperature every five minutes during shipment. The temperature range in shipping containers was 43.2-50.9 °F and 39.7-53.4 °F for the December and March samples, respectively. In December the sea urchin gonads were packaged at 10:34 am on 6 December and opened at 11:59 on 7 December 2007. In March, sea urchin gonads were packaged at 7:42 am on 20 March and were opened at Davis at 14:27 on 21 March 2008. Sea urchin gonads were packaged individually in numbered plastic bottles. In December there were 64 samples and in March there were 47 processed samples and 10 unprocessed samples. The unprocessed samples are not part of this report.

Lightness and color of sea urchin gonads were measured independently with a Hunter Lab Scan T1 as defined by the Commission Internationale de l'Eclairage color space system. Readings were calibrated against both a white and black plate. Readings of standard green and red tiles were used as an instrument test. Port size was 1.27 cm, port view 1.78 cm, observer angle 10^o, and mean specimen size was 6.5 x 1.5 cm. Total color difference between grades A, B and C of processed roe (grade assigned by the sea urchin processor) was calculated as:

$$E_{ab}^* = [(L^*_o - L^*_{sample})^2 + (a^*_o - a^*_{sample})^2 + (b^*_o - b^*_{sample})^2]^{1/2}$$

where L^*_o is the lightness of the target sample ($L^* = 60$ is white), a^*_o is the amount of red (+0 to 60) in the target sample, and b^*_o is the amount of yellow in the target sample. The National Bureau of Standards One defines one unit of difference of E_{ab}^* as a unit of acceptable commercial color difference. The unit approximates the least perceptible color defined by the CIE. The mean value of L*, a, b, and L of processed San Diego Grade A *S. franciscanus* roe were used as the target values in total color difference calculations. Total color difference, E_{ab}^*, indicates the degree of color difference between the sample and the target color, but does not give the direction of the difference. Individual measurements L_{sample} , a_{sample} , and b_{sample} were analyzed to compare difference between lightness, red and yellow composition of the sea urchin gonads.

Figure 1. The Hunter Lab Scan color measuring system includes the sea urchin gonad sample, under the can in the middle of the photo, and computer software that gives the color readings. Each gonad sample is scanned three times by the Hunter Lab Scan and the average of those three values gives the sample color in red, yellow and lightness.

In the December samples, P. Halmay included information on the grade assigned to each sample. We were able to use this information and assign a range of values to Grades A, B, and C from the Hunter Lab Scan output. We then used the average a, b and L values for the "sample" value in the equation above. This means that individual red sea urchin Hunter Lab Scan values were compared to this value. This calculation shows relative differences of each sample to the mean value of Grade A. We used the San Diego Grade A mean for the calculation of the March samples also. We compared our a, b, L and E_{ab} values of red sea urchin gonads using a One Way Analysis of Variance for the December and March.

Results

Table 1. The sample numbers from P. Halmay showing the Hunter Lab Scan grade selection for 47 processed red sea urchin gonads received in March 2008. For this analysis, we did not know the grades assigned by the fishermen and processors. P. Halmay did tell us how many gonads were in each grade. The lab analysis showed 12 Grade A, 13 Grade B, and 22 Grade C compared to P. Halmay's sample of 13 Grade A, 16 Grade B, and 18 Grade C. The numbers in the table are the sample numbers provided by P. Halmay on each individually marked sea urchin gonad test container.

PLEASE NOTE SAMPLES 1-12 were unprocessed samples NOT included in this analysis. There was no SAMPLE NUMBER 56.

COUNT	Grade A	Grade B	Grade C
1	15(B)	18(C)	13(C)
2	17(B)	20(B)	14(B)
3	30(A)	22(B)	16(C)
4	34(C)	25(B)	19(C)
5	35(A)	26(B)	21(A)
6	38(C)	28 (B)	23(C)
7	41(A)	29(B)	24(C)
8	42(A)	37(B)	27 (B)
9	46(A)	43(B)	31(C)
10	55(A)	48(A)	32(C)
11	58 (A)	49 (A)	33(C)
12	59 (B)	51(C)	36(C)
13		60 (C)	39(A)
14			40(B)
15			44(C)
16			45(B)
17			47(C)
18			50(B)
19			52 (A)
20			53 (C)
21			54(A)
22			57(C)

Halmay Note: The grade assigned by the Processor for each sample is shown in parentheses. We found matches 28 out of 47 samples between the Hunter lab scan grade selection and the grade assigned by the processor.

In December the One Way ANOVA results showed:

"L" or lightness:

Grade A was significantly lighter than Grade B and Grade C.
Grade B was not significantly different from Grade C.

"a" or red:

Grade A and Grade B were significantly more red than Grade C.
Grade A and Grade B were not significantly different in red.

"b" or yellow:

All grades were significantly different from each other.
Grade A was significantly greater than Grade C and Grade B.
Grade B was significantly greater than Grade C.

"E_{ab}*" Overall color difference between mean Grade A values and individual samples:
All grades were significantly different from each other in overall color and lightness.

In March, One Way ANOVA results showed:

"L" or lightness:

All three grades were significantly different.
Grade A > Grade B > Grade C

"a" or red:

Grade A was significantly higher in red than Grade C.
There were no significant differences between Grades A and B nor between Grades B and C.

"b" yellow:

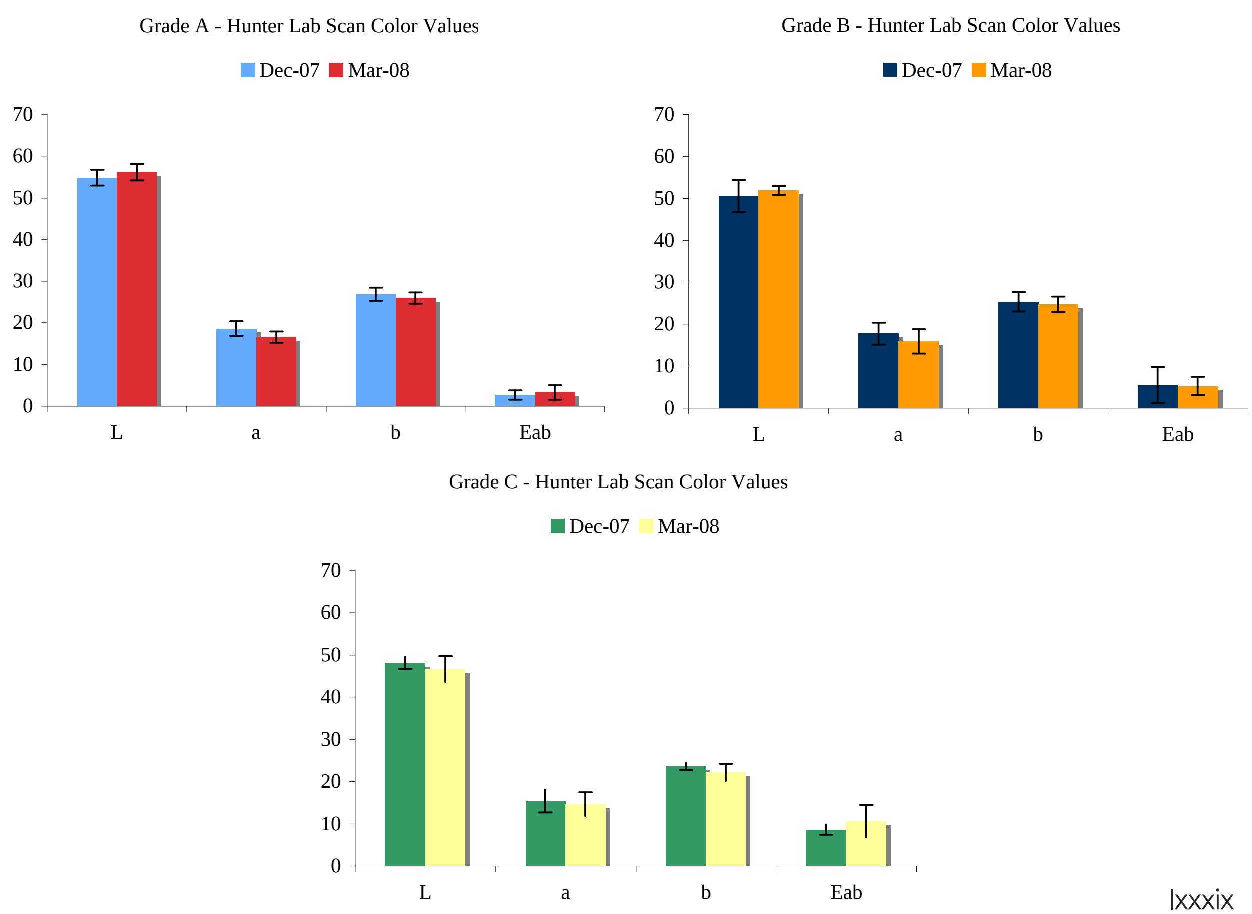
Grade A and Grade B had significantly more yellow than Grade C.
Grade A and Grade B were not significantly different in yellow.

"E_{ab}*" Overall color difference between mean Grade A values and individual samples:
Grade A and Grade B were significantly than Grade C in overall color and lightness.
Grade A and Grade B were significantly different in overall color and lightness.

Table 2. Color and lightness results for red sea urchins showing the range of red, yellow and lightness of the processed gonads.

December 2007					
Grade	**L (lightness)**		**a (red)**	**b (yellow)**	**L*(color difference)**
A	Mean	54.9	18.6	26.8	2.69
	Range	51.4 - 57.5	16.8 - 22.4	24.9 - 30.4	0.62 - 5.17
B	Mean	50.6	17.8	25.4	5.46
	Range	45.1 – 55.3	13.0 - 22.2	21.9 – 27.8	1.8 – 11.46
C	Mean	48.2	15.39	23.6	8.62
	Range	46.9 – 50.4	12.9 – 22.2	21.8 – 24.8	7.11 – 11.51
March 2008					
Grade	**L (lightness)**		**a (red)**	**b (yellow)**	**L*(color difference)**
A	Mean	56.1	16.6	25.9	3.32
	Range	54.1 -60.65	14.4-18.3	22.9-27.6	0.91-6.42
B	Mean	51.9	15.9	24.7	5.28

Figure 2. Winter (Dec. 2007) and spring (March 2008) red sea urchin gonad color and lightness. "L" is lightness, "a" is red, "b" is yellow, all measured on a relative scale of 0 to 60. E_{ab} is the overall color difference of individual samples to mean value of Grade A from December.



Discussion

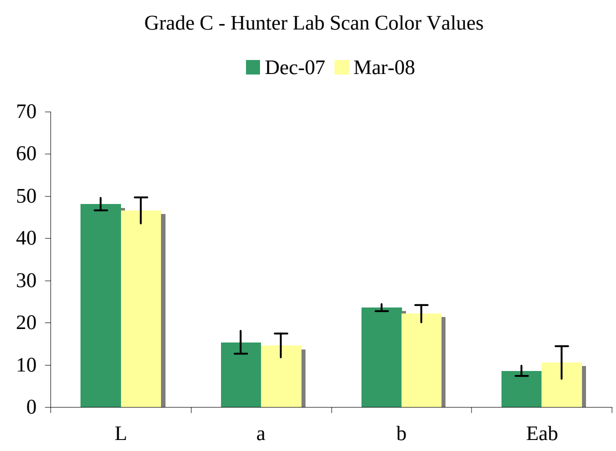
Seasonal differences

Red sea urchin gonads were slightly lighter in overall color and lightness March compared to December. This can be explained by the lower values for "redness" and "yellowness" in both the mean and range. Grade A and B sea urchin gonads in the March sample were overall lighter in color and had a greater color difference from mean December Grade A values of L, a, and b. So while red and yellow were lower in Grade A roe in March, lightness was greater as a higher value means a lighter overall color.

Grade C gonads from March samples were also lower in red and yellow color, but overall lightness was lower (samples were darker) in March than December.

Using color analysis at the dock

While our test case in March shows the lab analysis is not 100% accurate when compared to fishermen and processing grading, there may be applications to using small, hand held color meters at the dock. Fishermen could assess the quality of the landed sea urchins. If gonad color is quantified this would lead to increased understanding of sea urchin product quality and may assist with development improved handling guidelines. In today's market, quality is the most important factor, especially in small domestic markets where quantity is not the issue. This would help fishermen and processors understand differences that may occur between landing the sea urchins, holding period at the plant (if any) and after processing.



The ability to assess sea urchin gonad quality in the field would refine observations of sea urchin gonad color and would benefit fishermen and processors. Changes in quality over seasons has been observed for years, this would allow at least the sea urchin gonad color to be quantified. Overtime, fishermen could use their sea urchin gonad color data to schedule their fishing for optimal times and places of harvest.

Quantifying sea urchin gonad color may also lead to much improved understanding of other quality factors such as taste, size, and texture. It will refine the fishery and provide modernize the industry.

Color comparisons

The ranges of red, yellow or brightness were similar in winter and spring, suggesting this is a useful and relatively simple tool to use for grading sea urchin gonads. While other factors such as taste, shape, and texture are important for grading sea urchin roe, color is perhaps the single most important as it is linked at least to taste.

I envision each processor, sea urchin landing facility, and/or fisherman to have a hand held color meter, a computer and the associated software. The instruments are relatively easy to calibrate and use. Accumulating a data base of sea urchin gonad color may prove to reduce tension between fishermen and processors over quality and/or to suggest where product handling needs improvement. Everyone would benefit from this and it is essential to use the color data as a learning tool to improve the sea urchin fishery.

With today's communication capacity, fishermen and processors could communicate with their customers and tell them exactly what they have in fresh from the sea. This would enable chefs to plan menus, direct marketing by fishermen, and processors could better serve their customers, especially those who may want a small amount of a certain grade of urchin product for a special event or other need.

Actual numbers collected over time will also empower the fishermen and processors. They will have improved information to present to managers, better proposals for funding opportunities, and overall increased understanding of the sea urchin resource. Future studies linking sea urchin gonad color to taste, size, texture, and reproductive condition would be useful and add to a sea urchin gonad quality database.

APPENDIX III-B-1
CDFG AUTHORIZATION LETTER

State of California – The Resources Agency **ARNOLD SCHWARZENEGGER, Governor**

DEPARTMENT OF FISH AND GAME
http://www.dfg.ca.gov
1416 Ninth Street
Sacramento, CA 95814
(916) 657-2355

July 23, 2008

Pete Halmay
San Diego Watermen's Association (SDWA)
11103 Highway 67
Lakeside, CA 92024

Dear Mr. Halmay:

Thank you for your June 21, 2007 letter regarding the SDWA proposal, "The San Diego Sea Urchin Fishery as a Model for the Expansion of the Role of Fishermen/Managers in Science-Based and Value-Added Marketing". Congratulations on receiving California Ocean Protection Council funds for your association's proposal.

Pursuant to Section 120.7(a)(2), Title 14, CCR the five commercial fishermen named below are authorized to test several models of sea urchin enclosures to augment quality and minimize mortality for the period August 1, 2007 through July 31, 2008. Testing will include all the elements listed below:

1) SDWA members registered with the Department pursuant to Element 10 below, may harvest up to 3,000 pounds of red sea urchins from the Point Loma study area, as defined in Element 11 below;
2) Such harvested red sea urchins may be placed in temporary enclosures on the sea floor within the Point Loma study area;
3) Such enclosed red sea urchins may be fed to determine if feeding will increase the yield of sea urchin roe;
4) Up to 200 pounds of the red sea urchins held in enclosures may be taken once a week for the purpose of determining roe quality (percent recovery and other variables) of those red sea urchins;
5) Up to 5,000 pounds of red sea urchins may be harvested from areas of poor quality (roe recovery equal to or less than four percent by weight) and may be transplanted to an area of good habitat, as determined by SDWA, within the Point Loma study area;
6) Up to 250 pounds of such transplanted red sea urchins may be harvested once a week for the purpose of determining roe quality;
7) Up to 60 individual red sea urchins may be brought aboard a vessel for the purpose of measuring to determine the nominal test diameter of those animals during calibration;
8) This authorization shall be valid for one year from the date of issuance and shall be valid without respect to days normally closed to fishing;

9) The largest temporary sea urchin enclosure will measure 4' X 6' X 2'. The enclosures will be marked with a tag "SDWA research call (619) 697-2912". Some of the enclosures will be made of wood and plastic, whereas others will be made of welded wire. All temporary sea urchin enclosures used in this study shall be removed from the water not later than 15 days after this authorization expires;

10) SDWA members and their vessels that will participate in this study are listed below. Any changes to the list shall be provided to the Department, in writing, at 2419 E. Harbor Blvd., #149, Ventura, CA 93001 or via fax to (805) 382-6755. All persons aboard the vessels shall have either a commercial sea urchin permit (diver or crewmember), a scientific collecting permit, or be registered in the vessel logbook as an observer. A copy of this letter of authorization issued under subsection 120.7(a)(1), Title 14, CCR, must also be aboard each vessel;

Fishing Vessel	F&G No.	Operator/Diver	License No.
Taxi	37911	Mitch Hobron	L30912
Desperado	35846	Mike Neil	L02513
Makena	51823	Dave Datz	L09842
High Roller	27614	George McConnell	L25468
Erin B	32770	Peter Halmay	L30685

11) The Point Loma study area is bounded on the north by the westward extension of the Ocean Beach pier, on the west by the 120 foot depth contour, on the east by the shoreline of Point Loma, extended to the seaward end of the Zuniga Jetty and continuing along the jetty and Coronado and on the south by a line drawn due west magnetic from 32 degrees 37 minutes N, 117 degrees 8 minutes W. All in-water activity authorized in this letter shall take place within these boundaries. Once you have selected the sites for each of the activities, you will notify the Department of the exact location (Lat/Long) of each site.

12) The SDWA shall notify the Department at (805) 985-3114 or via fax at (805) 382-6755 not later that 5 p.m. on the 25th of the month prior to any proposed activity authorized by this letter for the following month. Such notice shall include the names and vessels of participating members, as well as the days/dates, times and nature of the proposed activity.

I appreciate your willingness to keep my staff informed of your activities pursuant to this authorization. We look forward to receiving a complete report of the results of your study next year.

If you have any questions or need additional information, please contact Ms. Kristine Barsky, Senior Biologist in the Department's Marine Region by phone at (805) 985-3114.

Sincerely,

Tony Warrington
Regional Manager
Marine Region

cc: Captain Martin Maytorena, DFG-MR, Los Alamitos, California
Mr. Tom Barnes, DFG-MR, La Jolla, California
Ms. Kristine Barsky, DFG-MR, Ventura, California

APPENDIX III-B-2

TRANSPLANT EXPERIMENTS TO DETERMINE GROWTH, MORTALITY, AND MOVEMENT OF SUBPOPULATIONS IN THE POINT LOMA KELP FOREST

III.1 Rationale

Estimates of growth, recruitment, and mortality rates would be valuable in modeling red sea urchin population dynamics. Combined with estimates of fishing mortality, such information would enable estimates of population recovery and sustainability. Properly designed, such studies could also provide estimates of movement, which, if significant could affect estimates of densities as well as vital rates. Past experience in the Point Loma kelp forest suggests that rates of movement may be significant, although the lack of information on somatic growth cannot rule out the possibility that evidently high recovery rates of large individuals could be due to very high growth rates. To address these questions we designed an experiment to estimate vital rates and movement. Data from this (or similar) experiments would also allow us to determine conditions under which translocation would be successful in reestablishing sub-populations.

III.2 Methods

A random sample of about 999 red sea urchins was collected on December 15, 2007 at a site in southern Point Loma (Fig. III-B-1). Test diameters were measured to the nearest millimeter (Figs III-B-2 & III-B-3) and each urchin was injected with a small amount of tetracycline hydrochloride following the protocols in Ebert et al. 1999.

The urchins were then immediately transported by boat to a receiver site about 6 km north of the source site. The receiver site, a square plot measuring 50-meter x 50-meter, had previously been censused and sampled and all individuals removed. It was marked so that it's perimeter could be clearly delimited on subsequent surveys. The 999 transplanted urchins were placed in the center of the plot. The SDWA and its science advisor plan to resample the plot in one year to determine: 1) net rates of movement to and from the transplant location by noting the proportions of tagged and untagged individuals at ever increasing distances from the center of the transplant site; 2) individual growth rates of tagged individuals using the protocols developed by Ebert et al. 1999; and 3) estimates of recruitment and mortality rates gotten by comparing initial and final size distributions.

To gauge the likely number of tagged individuals that will be present one year after the transplant, we harvested 5 live red sea urchins and a dead test near the marked center of the transplant site on July 12, 2008 (210 days after the transplant). We measured test diameters and collected and processed the mouthparts in preparation to measuring growth in the laboratory using the protocols of Ebert et al. 1999. Growth of tagged urchins was estimated by examining the "jaws" (the demi-pyramids, which compose the Aristotle's lantern) under an epi-flourescent dissecting scope. Tagged jaws glow under the scope and define the dimension of the jaw at the time of tagging. Any untagged (non-glowing) material has been added by growth since tagging. The total length of the jaw includes original material plus any growth that occurred between tagging and collection. Thus it is possible to plot the sizes of the jaws at the time of tagging and some time interval after the tagging as well as original size and growth over the period of the experiment. In past work (Ebert et al. 1999) we converted jaw lengths to test diameter by fitting an allometric equation relating jaw length to test diameter and so expressed growth in terms of both jaw and test diameter growth. Fitting an allometric relationship requires many measurements of test diameter and jaw length over a representative range of urchin sizes, and varies significantly among sites (Ebert et al. 1999). Since the preliminary post-transplant survey only collected 5 live individuals, we could not estimate the parameters necessary to convert jaw length to test diameter and so present data on jaw length only. To get a sense of red sea urchin growth at the receiver site, we compared both "corrected" and raw measures of initial versus final jaw length in this small sample to those made in 18 year-long growth experiments conducted from Alaska to southern California between 1989 and 1994. The corrected measure was a linear extrapolation of final jaw size to what it would have been after a year (compared to the actual 210 day period). Since growth could be seasonal, such an extrapolation could overestimate the final jaw size (and thus growth). Completing the experiment (on December 15, 2008) after a full year will eliminate this uncertainty.

III.3 Results

All five red sea urchins collected near the transplant site had internal tags, suggesting that the recovery rate after 1 year will be very high. The most striking result is the much higher annualized growth compared to the range of growth observed by Ebert et al. 1999 (Figure III-B-5). As mentioned in this methods section, this result could be an artifact due to extrapolation of annual growth based on a period of less than 2/3 of a year. If we assume that observed growth represented the entire year's growth, the growth rates fall within the values observed in previous studies (see Figure III-B-5).

III.4 Conclusions and Next Steps

Previous data on changes in size distributions combined with extensive existing data on growth rates of red sea urchins from Alaska to southern California made during the early 1990's led us to conclude the appearance of large individuals in areas depleted by harvesting within a year of the harvest must have been due to immigration and not growth. Preliminary results of the translocation could either be interpreted as confirming (if we use un-extrapolated growth estimates) or falsifying (if we use extrapolated growth rates). To decide between these alternatives it is necessary to complete the present experiment and collect tagged urchins one year after the transplanting and tagging.

While it is critical to complete the growth experiment to determine the relative importance of growth and movement to red sea urchin dynamics, it is also critical to start additional experiments to characterize growth in different areas of the Point Loma kelp forest. Both Ebert et al. 1999 and Morgan et al. 2000 demonstrated significant differences in growth rates of red sea urchin subpopulations in northern and southern California at spatial scales that were on the order of those separating southern from northern Point Loma. In addition, SDWA and others (pers. obs) have observed large differences in red sea urchin sub-populations between northern (low densities, high mortality, low recover rates) and southern (high densities, low apparent mortality, high recovery rates). These observations suggest that experiments comparing growth in these two areas would be both interesting and informative.

See Cited Figures on Next Page III.5 Figures.

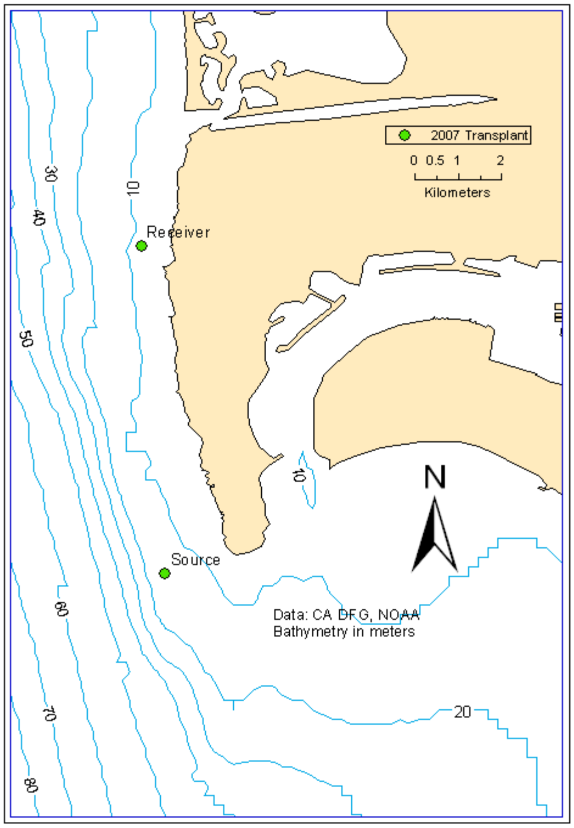


Figure III-B-1. Schematic map of transplant Source and Receiver sites. Transplant on December 15, 2007. Interim sample on July 12, 2008 (210 days after transplant).

Figure III B-2. Measuring and tagging sea urchins prior to translocation From left Mitch Hobron, Steve Schroeter, Ken Jeavons

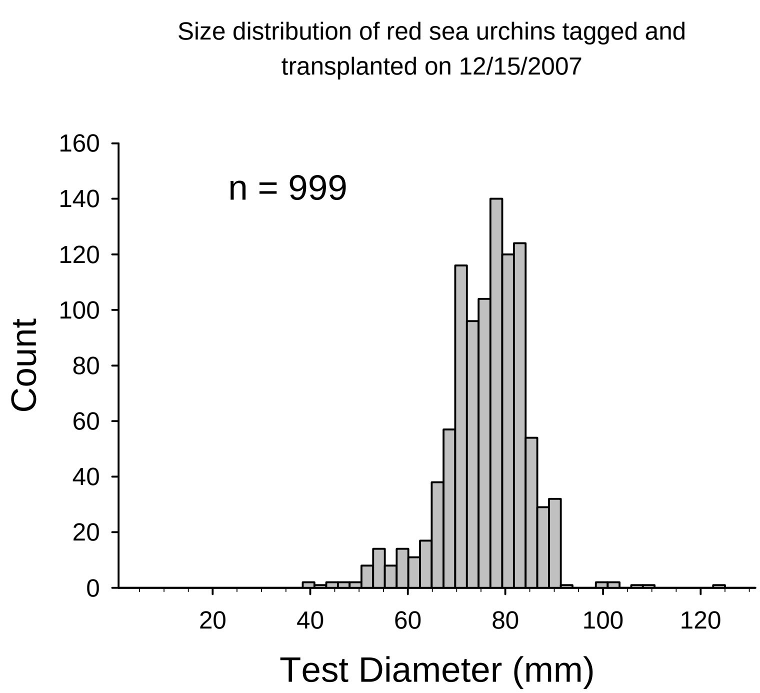


Figure III-B-3. Size-frequency distribution of sizes (test diameters) of red sea urchins tagged and transplanted on December 15, 2007.

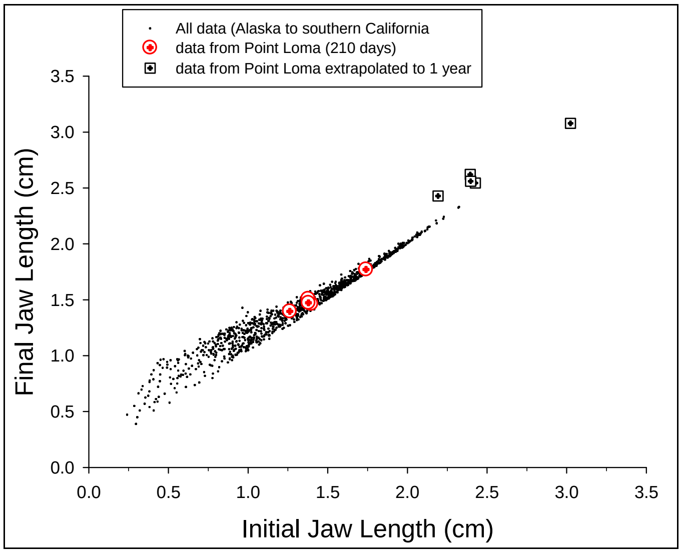


Figure III-B-4. Actual and extrapolated (to one year) growth in jaws of red sea urchins tagged and transplanted on December 15, 2007 compared to growth of red sea urchins at other north American sites tagged in multiple experiments from 1992 to 1995.

III.6 Literature Cited

Thomas A. Ebert, T.A., J. D. Dixon, S.C. Schroeter, P. E. Kalvass, Neil T. Richmond, A. Bradbury, D.A. Woodby. 1999. Growth and mortality of red sea urchins *Strongylocentrotus franciscanus* across a latitudinal gradient.Marine Ecology Progress Series 190: 189-209.

Morgan, L., Wing, S.R., L.W. Botsford, C.J. Lundquist, and J.M. Diehl. 2000. Spatial variability in red sea urchin (Strongylocentrotus franciscanus) recruitment in northern California. Fisheries Oceanography 9: 83-98.

APPENDIX III-C-1

MEDIA EXPOSURE

The following contains several examples of media exposure from:

- FoodBUZZ Rress Release
- LATimes Online
- Marcie Rothman Blog
- Media for ILCARPACCIO Dinner March 26, 2008
- San Diego Reader: Kiss of the Sea Urchin
- The Food Paper.com, Gayot
- Sea Urchins, San Diego Feature on Gayot
- Stories Restaurant Review
- ZAGAT Buzz
- Vino e Ricci

FoodBUZZ Press Release

http://www.foodbuzzsd.com/blog/2008/02/15/unique-dinners-feature-black-truffles-and-uni/

Unique Dinners Feature Black Truffles and Uni

Friday, February 15th, 2008

(No Ratings Yet)

...

Fresh sea urchin roe (uni) as Buzz noted isn't just a sushi bar treat. If you want to taste uni done the way Italians like it, **Baci Ristorante** plans an all uni (or ricci as it is known in Italy) dinner on March 5 that will include dishes featuring ricci: seafood bisque, pasta, seabass with lemon cream and more, all paired with Italian wines. The dinner is $85 and includes tip and tax. For information and reservations: 619-275-2094.

LATimes Online

http://www.tableconversation.com/

March 28,2008

Startlingly Spiny Seafood

This is the most astonishing dish that I have eaten this week, this month, this year.

What looks like a porcupine splayed on a plate is a spiny sea urchin shell. The cavity in the center holds seafood risotto, a soft, chewy mixture crowned with a luxurious dollop of pure fresh sea urchin.

Antonio Mure, chef/owner of Il Carpaccio in Pacific Palisades, came up with the idea for a dinner that showed off sea urchin (uni) brought to the restaurant straight from the fisheries off San Diego.

There was sea urchin sauce over carpaccio of seabass cut as fine as tissue paper. There was sea urchin on garlic crostini in the center of thick fennel soup. There was sea urchin dressing on involtini di pesce spada (rolled sword fish) on a bed of caramelized shallots. No sea urchin in the dessert, lemon tart with fresh berry puree. But there was more to come--little glasses of limoncello and sea urchin on the front counter, a sweet and briny shooter to down on the way out.

Il Carpaccio, 538 Palisades Drive, Pacific Palisades, CA 90272. Tel: (310) 573-1411. Open for dinner only, 5 p.m. to 10 p.m. Sunday through Thursday; 5 p.m. to 10:30 p.m. Friday and Saturday.

Marcie Rothman Blog

Uni: More Than Just Sushi
Wednesday, January 9th, 2008

If you love sushi you've likely experienced uni, the roe from the spiny creature called sea urchin. These days, uni dishes go way beyond laying it on a mound of rice to be eaten in one bite. Recipes that incorporate this prized ingredient into everything from sauces and soups to savory mousses and more appear in French, Italian, Asian and American cookbooks.

From San Diego to Ft. Bragg, California is home to sea urchin divers who bring the creatures to processors who in turn ship it to sushi bars and restaurants worldwide, mostly to Japan and the United States. Recently, Philanthropy Roundtable organized a trip to San Diego to go on the boats with the divers and see first-hand the sea urchin harvesting. The group saw the urchin processing at San Diego's Catalina Offshore Products, followed by dinner and no, it did not take place at a sushi bar.

Pete Halmay is a diver with a mission: Get these sustainably grown urchins beyond the sushi bars and into restaurants such as Tony D'Amato's well-known Baci Ristorante on Morena Boulevard. D'Amato hails from Sicily where sea urchin, known as ricci di mare, is as much a staple as pasta.

D'Amato served a sampler of urchin dishes that began with drinks and an incredibly simple bruschetta: Bread rounds brushed with a bit of garlic infused olive oil, topped with a "tongue" of roe. At the table, an amuse bouche of roe served in the spiny test (its shell) with prosecco and eaten with a teaspoon. Note that these two presentations allow the roe to stand alone, much like it does in sushi. In dishes like these, the roe's delicate sea taste and creamy texture meld in the mouth, unhampered by too many other flavors.

Next came uni bisque with mussels, scallops and uni also served in the test. The sampler finished with a classic Italian dish of spaghetti mixed with a hint of olive oil, garlic and pinch of red pepper and barely warmed roe.

If you think sushi is the only way to experience this lovely delicacy, think again. Resources include http://www.calurchin.org/ and http://www.catalinaop.com/ as well as http://www.epicurious.com/. Photos by Marcie Rothman.
Article by Marcie Rothman
http://www.foodbuzzsd.com/blog/2008/01/09/uni-more-than-just-sushi/

Media for ILCARPACCIO Dinner March 26, 2008

Hello!
The media AND "the buzz" is happening...

Media attending:
(1) GAYOT PUBLICATIONS (and put an announcement on their internet site) Alain Gayot
(2) VENICE MAGAZINE and other publications Andrea Rademan (and Alan)
(1) LOS ANGELES MAGAZINE, LOS ANGELES TIMES, Linda Burum
(1) LOS ANGLELES TIMES (internet), Barbara Hansen
(1) ANGELENO MAGAZINE, Kristin Viola
(2) American Radio Network (radio interview with Tony and with Pete that night), Gerry Garner +sound man
(1) VIDEOGRAPHER for footage requested by Food TV Network, Travel Channel and KNBC, Ken Furth (yes, my brother), not sure he will eat

Palisadian Post, Daily News Food Editor, Chef Jamie Gwen of KABC still trying to come
ZAGAT writer, Merrill Shindler, put the announcement up on the internet
The wine companies put the announcement up on the internet as well
Please add two guests (Rick McCarthy and Danny Fischer)
There are also a couple of Pacific Palisades residents who will phone you to make reservations, who I talked to today.

Thanks,
Gerry Furth-Sides
10567 National Blvd. Studio 2
Los Angeles, Ca 90034
(310) 202-6412 mobile: (310) 701-6412

San Diego Reader: Kiss of the Sea Urchin

Restaurant Review
The Kiss of the Sea Urchin
By Naomi Wise | Published Wednesday, April 2, 2008
Baci Restaurant
1955 West Morena Boulevard, San Diego

Sushi lovers think of sea urchin roe as the Japanese delicacy called uni, a coral-colored, spongy-velvety, sexy-tasting maritime fluff perched atop a puck of seasoned rice. Few Americans realize that it's also savored worldwide wherever the temperate seas will nurture the critters.

Tony D'Amato, owner of Baci Restaurant (1955 West Morena Boulevard, 619-275-2094) in the Bay Park district, wants more Americans to learn to love these exquisite morsels. "Everybody in Italy eats ricci di mare," he says. "They sell them on the streets in Sicily. You cut them in half and scoop them out and serve them on bread. And I'm sure they're aphrodisiac…But the one difficulty is, Americans don't always like them. They say, 'They seem live, the spines are moving!' And they don't like that. Sometimes we serve them as a special on a Monday, and we [the staff] end up eating them ourselves. We're going to have to educate the people, like we did with calamari. Squid were about two cents a pound when we opened this restaurant in 1979. Americans said, 'They're just bait, we don't eat that!' Now every Italian restaurant serves calamari, and when you buy them raw, they're $5 a pound."

To start introducing sea urchins to a wider "eat-ience" than just sushi fans, Baci held a five-course special Mediterranean-style feast of fresh local seafood, featuring sea urchins, paired with fine Italian wines on March 5. At $85, including matched wines and tip, it was an irresistible deal. The minute I read about it on Marcie Rothstein's super-hip food blog **(foodbuzzsd.com),** I called to make a reservation for two. Then I emailed Sam, the most adventurous palate of all the posse: "Uni feast at Baci. MUST GO. Come with me?" Of course.

"We got the urchins from a professional diver, Peter," Tony told me later. "Peter usually sells them to Catalina Offshore [the seafood wholesaler in the Morena District, source of most local sushi uni]. You buy it there, you can buy out of the shell, it's already cleaned. Peter wanted to promote it. His idea was to see it on more menus, not just Japanese but in American restaurants, Italian restaurants, all types of restaurants."

I asked him whether the urchins had to be transported in seawater to keep them alive until serving. "No, you just put them in a cooler. They're alive until you cut them in half. After that, the fibers are often still moving, but they're not alive anymore."

If you're reading this, you deserve to eat the very best (and sea urchin is certainly one of the most splendid foods on the planet) and not to be put off by appearances. And heaven knows, the appearance of a sea urchin is off-putting! Ever see the classic **Star Trek** episode, "The Trouble with Tribbles"? A local sea urchin looks like an un-cute tribble, a featureless, hard-shelled globe about the size of a grapefruit, covered with purple-black porcupine quills instead of fur. So before we get to the Baci dinner, let's talk for a bit about the global embrace of sea urchins and the tough truths about their anatomy.

Along with Sicilians, the French love sea urchins and use them joyously in custards and soufflés or mixed with cream as sauces for seafoods. South Americans savor them, too. My first taste of sea urchin, long before I ever tasted sushi, was in Chile. Friends from Santiago took me on an excursion to the charming port of Valparaiso, famed for its funicular cable car climbing to the top of the coastal cliffs. One of the local specialties at the seaside restaurants was sea urchin stew, with onions, tomatoes, and fish stock. "Be careful, though," Pilar warned, "a lot of people get a little sick if they eat too many urchins at once." The urchins in the stew had a faint iodine flavor (either because they were a bit too old, or maybe because the pollution of the port waters had affected their flavor). But I fell in love with the airy-spongy-lush texture and…ate too many. The next day I was green around the gills, indeed. Pili nursed me with the standard South American digestive remedy of coca-leaf tea. (How stupid our drug laws are! All over western South America, people use coca leaves as herbal medicine, and they don't get you high in the slightest — they're not "coke" until they're chemically processed with mineral lime into white powder. As a restaurant reviewer, I can't tell you how often I've yearned for coca-leaf tea!)

It's hard to imagine what prompted a land-based mammal to try collecting and eating hard spiky balls from the ocean floor — probably sheer hunger, same as what got us to try the heavily armored sea-bugs called lobsters. But maybe we learned about them from the lobsters. A few years ago, I bought a couple of local spiny lobsters and a half dozen urchins from a local fisherman. I put the lobsters in the left side of my divided kitchen sink, the urchins on the right. The lobsters grew so agitated by the smell of their favorite food, they rose up on their hind claws and tried to climb over the divide, no doubt yelling in lobsterlish, "Ms. Wise, tear down this wall!" (Perhaps some early human diver, snagging lobsters, noticed his prey feasting on this aquatic hedgehog and decided, "The prey of my prey is my prey." Smooth move, dude.)

Dealing with whole, live urchins that evening provided insight into their true nature. You put on heavy gloves (oven mitts or butcher gloves) to pick them up, take kitchen shears, and starting at the little hole on the top of the shell (that's the anus, not the mouth), you cut diagonally to the periphery, then continue cutting around the circumference until the top half of the shell can be lifted off. Inside, you find the lovely coral fluff, under a swamp of salty brown bilgewater to pour away. Not much else is in there. Checking Google ("sea urchin anatomy"), I learned that the sea urchin is all sex, literally no brain. Go ahead, make all the blonde jokes you want. About 20 percent of the total weight of a sea urchin consists of the male gonad or the female roe (please don't ask how to tell which is which, I didn't find that out). Minus the shell, roughly 80 percent of an urchin's internal contents are devoted to reproduction. The rest is for eating and excreting seaweed and barnacles and now and then moving along the ocean floor to find the next barnacle or kelp patch. It's so dumb, it can't even read Harlequin romances or **Penthouse.**

Since it's brainless, when you address a freshly opened, newly cleaned sea urchin on the half shell, the spines may still be waving. All that means is, the urchin doesn't really have a clue yet whether it's alive or dead — it doesn't have the intellectual equipment to realize there's an either/or distinction. When you eat a carrot freshly pulled from your yard, when does the carrot realize it's dead? How can you know? As an animal, the sea urchin is very nearly a vegetable, distinguished only by the lack of cell walls and its rudimentary abilities to move and eat. Judging by its anatomical proportions, it's not even all that interested in those functions — if it had a mind, it'd be a one-track mind, like that slobby letch you blind-dated once back in high school.

Back to the dinner: Baci means "kiss." The restaurant is a warren of warm, attractive, Italianate rooms — a bar and dining room at street level, two more rooms two steps up, and in back, a large patio that could pass for an upper-class courtyard in pre-eruption Pompeii, with handsome ornamental stonework at the periphery. The waiters are in tuxes, and the restaurant is known as a power-lunch spot for the city's honchos — but at dinner, the patrons' garb was tieless, shirt-sleeve casual. You get the flawless, tuxedoed service without having to be flawless yourself.

Ricci is Italian for uni — remember that when you go to the movies and see sexy Christina Ricci, who in many roles seems as louche as a spoonful of sea urchin roe. The first course began with ricci in the shell. The spines were still moving when the waiter delivered the course. It was not quite as pretty as Botticelli's **Venus on the Half-Shell,** but it was delicious — a purple-spined shell-basket containing chilled roe strewn with chopped chives, in a flirty broth mingling the maritime juices with Prosecco (a sparkling dry Italian wine resembling champagne, but not as aggressively bubbly). The accompanying wine was Insolia Grande Prosecco, perfectly apropos.

Simultaneously, we received tartines di ricci and tapenade, offering small, lightly toasted slices of baguette topped with urchin roe and what seemed like soft, salty black caviar resembling sevruga — it was actually black-olive tapenade, soaked by sea urchin juice until it tasted like sturgeon roe. It was salty-delightful, topped with plenty of chopped chives.
Next, with glasses of Sicilian Chardonnay, came more spiky shells, this time containing a bisque of mussel meats, bay scallops, and sea urchin. The creamy liquid bisque was rich and pale pink, all the seafoods tender. The house breads consisted of fingers of garlic toast, handy for sopping.

A right-sized portion of thick, succulent al dente linguine followed, dressed simply with olive oil, a bit of hot dried pepper, roasted whole garlic cloves for earthy sweetness, and teaspoonfuls of sea urchin introduced into the dish at the last moment before serving, just to warm. "You don't want to cook them too much," said Tony. This is one of the more traditional Italian dishes of the dinner, and in it, the precious roe was reduced to an important supporting role — an airy Ariel serving the charismatic Prospero of the pasta.

The entrée reduced the urchin still further, to a player snagging a vital bit part. Local swordfish, lightly floured with a crisp, browned surface, arrived in a citrusy sauce of lime juice, cream, and puréed urchin. The roe contributed only a subtle richness to the sauce, which made good sopping for the garlic bread. The wine was red Nero Davilo — yes, red wine is fine with meaty swordfish.

Cookbook author James Peterson, in his **Fish and Shellfish,** notes that he has a recipe for sea urchin ice cream — but he didn't include it in his book. And I'm sure that somewhere in New York or Chicago, an avant-garde chef is making uni-vanilla crème brûlée or anchovy-coconut gelato — but not here. We received two versions of "torta dello chef," one an airy white chocolate custard square over light cake, and the other its dark chocolate sibling. These came with glasses of grappa (the Italian equivalent of French marc or, um, bootleg brandy) mixed with limoncello liqueur — a bracing, energizing drink to steel us for reentry into the cold of night.

This isn't a review of Baci, just a report on an especially interesting dinner there. (The restaurant has a fine reputation, and I look forward to trying the regular menu one of these days.) I wish that more local restaurants made such interesting, courageous leaps beyond their regular menus into exploring fabulous, less-familiar foodstuffs like this. Baci is planning on holding another sea urchin dinner in a month or two, and Tony promised to alert me in advance. When I know, you'll know.

The Food Paper.com, Gayot

Sea Urchin Restaurants

We've selected the best restaurants around the country that feature sea urchin on their menus. Whether you live in Los Angeles or Chicago, you can sample tasty dishes like uni sashimi or sea urchin pan-fried with breadcrumbs.

CALIFORNIA

Los Angeles
- Asanebo
- Catch
- The Hump
- The Hungry Cat
- Il Carpaccio
- Il Grano
- Il Carpaccio
- Providence
- Water Grill

San Diego / La Jolla
- Baci Ristorante
- Sea Rocket Bistro
- Sushi Bar Kazumi

San Francisco
- Ame
- Baci Ristorante
- Ebisu
- Kabuto A&S
- Kyo-ya
- Sushi Ran
- Sushi Sam's
- Tokyo Go Go
- Tsunami
- Yoshi's

Sea Urchins, San Diego Feature on Gayot

From San Diego, CA:

Sea Urchins

Creatures of the Not-So-Deep

By Alain Gayot

A collection of sea urchins

According to legend, witches once believed that the five lines on a fossilized sea urchin represented the coven's much-treasured pentagram. First-century Roman historian Pline said that whoever licked one would find his gallstones broken. Considered an annoyance to some but an aphrodisiac to others, the pointy sea urchin is a creature that deserves a closer examination.

Dating back to the Ordovician period, the globular, spiny creature is a member of the phylum enchinodermata, which also includes starfish, sea cucumbers, brittle stars and crinoids. They lack arms, eyes and projecting rays, and rely on their spines to help them crawl. These spines are rooted in their shell, or "test," and can grow up to 8 centimeters. A mouth with five teeth on their underside helps them consume a diet of seaweed, kelp and algae.

The sea creatures, de-spined

California is home to the red sea urchin, which is found in the Pacific Ocean from as far north as Alaska to as south as Baja California. They prefer to live in shallow water on rocky ground that isn't subject to extreme waves or layers of sand and mud.

We caught up in San Diego, California, to talk with Peter Halmay about the sea urchin diving industry. Halmay has been diving for these spiny sea creatures since 1972, and he is one of over 300 licensed sea urchin divers in Southern California as well as a "Barefoot Ecologist," or a diver who oversees the urchin fishery program in the local area. He is also the president of the Sea Urchin Harvesters' Association in California, was a former president of the Urchin Producers' Marketing Association in San Diego, and helped organize the nonprofit organization called Institute for Fisheries Resources.

During the 1960s, Halmay said, sea urchins were especially considered a threat to fisheries, since the creatures would cut through and dislocate the healthy kelp forests that the fisheries rely on. Different measures were taken to try to eradicate them, such as crushing them with hammers and liming them.

"Barefoot Ecologist" Peter Halmay works aboard his boat, the Erin B.

But this changed in the 1970s when another use was utilized for the spiny echinoid: as culinary delight. The San Diego Fisherman's Association was formed in the 1970s, rallying enough support to convince authorities to allow for the fishery of sea urchins. Safe fishing practices currently exist now, and the industry is constantly working with the California Department of Fish and Game to maintain them.

With urchins running abundant across the coast of California, it might be easy to assume that the fishing trade is plentiful. Quite the opposite is so, however: sea urchin fishing can be a hazardous occupation. Divers must battle unreliable conditions under water, breathe through a hose of air that is attached to their boat far above in order to have both hands free for picking urchins, and often anchor their boats in rocky coastal areas. With a selective number of permits being released for this trade, there are only about 246 fishermen in Southern California, the younger generation of them pushing the age of 50.

Sea urchin served at a restaurant

While nearly all urchins were initially exported to Japan when the trade first started, now, one-third of the more than 800,000 pounds that are produced is consumed in the U.S. Because they are a high-ranked international delicacy, they are highly subject to "Best Fishing" restrictions, which ensure that only quality sea urchin is caught and served. The California Sea Urchin Commission requires that urchin must be efficiently processed and on its way to consumers within 48 hours of being unloaded from a diver's vessel. In addition, other "Best Fishing" practices also list specific conditions that list harvesting, handling, packing and temperature and sanitation restrictions. In Southern California, for instance, harvested urchins must be at least 3.25 inches, while in Northern California, they must be at least 3.5 inches.

Urchins are sought after for their gonads, the yellow-colored portion inside the shell and the only edible part of the creature. Known in Japan as "uni," there are 15 calories in every 2-teaspoon serving, which includes 48 milligrams of Omega-3 fatty acids, 1 gram of protein and 20 milligrams of fat. Most often served in sushi, they give off a salty ocean scent, and have a sweet, buttery taste with a firm texture. It's rare to find restaurants that serve or use live sea urchins in their menus, since most sushi bars serve them processed, Halmay said.

There are three different grades of the delicacy: "California Gold" is the highest grade, used mainly for top-quality sushi; "Premium California" are smaller but still intact uni, which are used for sushi, soups, salads, and other combination dishes, and "Select California" is the lowest grade, which is used in soups, sauces and dishes where uni is mixed with other ingredients, including other seafood.

Sea Urchins:

- are sought after for their gonads, the yellow-colored portion inside the shell and the only edible part of the creature
- must be kept safe from wind, rain and sun while in transit
- need to be refrigerated as soon as possible and must be held at a temperature colder than ocean temperatures when they are harvested
- have 48 milligrams of Omega-3 fatty acids, 1 gram of protein and 20 milligrams of fat in every 2-teaspoon serving

The Best Sea Urchin Restaurants
More on Sea Creatures: A New Wave in Seafood
The Abalone Farm
Top Seafood Restaurants
Pairing Seafood with Wine

Stories Restaurant Review

STORIES RESTAURANT REVIEW

North (Park) Sea

By Naomi Wise | Published Wednesday, Aug. 6, 2008

Sea Rocket Bistro
3382 30th Street, San Diego, 619-255-7049

Sea urchins are strong draws here — served "live" and raw in the shell, or in a bisque. (If you're passionate about them, call the restaurant before you go to see if they're available that night.) Truth is, once the top half of the shell is cut off and the blobby brown liquid inside drained away, leaving only the delectable sex organs, the urchin isn't really "live" anymore. Its tentacles may still wave by reflex, only because the creature's nervous system is too primitive to realize that its tiny soul has already passed on to the great kelp-bed in the sky. So go ahead and enjoy the sweet, soft meat spooned straight from the shell. (If you don't do it, a local lobster will.) The bisque, too, is served in halved urchin shells. The soup is creamy and rich, with wonderful flavor, but you'd better not lift the spiky "bowl" to your lips to drain it to the dregs. If you want your emptied shells, they'll give them to you. (They make beautiful household ornaments. For a couple of weeks, they're also pretty good at scaring off cats from newly seeded garden beds. Cats look at them, hunch their backs, hiss, and run away. In the sun, the spikes will eventually fall off, making mulch and leaving delicate white shell bowls behind.)

ZAGAT Buzz

Sea Urchin Dinner at Il Carpaccio
At a sushi bar it would be unusual enough to find a meal built around sea urchin (or *uni*), but to find one at a neighborhood Italian restaurant like Il Carpaccio is a total revelation. On Wednesday, March 26th, its five-course sea urchin (or in this case, *ricci di mare*) dinner will include dishes like Mediterranean sea bass with sea urchin and green onions, fennel soup with garlic crostini and sea urchin and risotto with clams and sea urchin, each served with a wine to match. The sea urchin will be freshly gathered from local waters and rushed to the restaurant by diver Pete Halmay, who'll be on hand all evening to speak about his trade (from 5 PM on; $70 per person; 310-573-1411).

Vino e Ricci

VINO e RICCI

March 5, 2008 at 7PM at Ristorante Baci

1955 Morena Blvd., San Diego.

A Mediterranean style feast of fresh local seafood, featuring sea urchins, paired with fine Italian wines.

Menu

<u>Antipasti</u>	<u>Vino</u>
Tartine di Ricci and tapenade	Insolia Grande
Ricci in the shell	Prosecco
<u>Zuppa</u>	
Bisque of mussels, scallops, and ricci	Sicilian Chardonnay
<u>Pasta</u>	
Pasta with ricci	
<u>Entree</u>	
Local fresh Seabass with lime cream and Puree of ricci	Red Nero Davilo
<u>Desserts</u>	
Torta dello chef	Grappa e Limoncello

The cost of the feast including wines is $85 incl. tip
Please contact Ristorante Baci at (619) 275-2094 for reservations.

Seating is limited to 35 so please call early

APPENDIX III-C-2

CDFG TABLE 21 SDPUB POUNDAGE AND VALUE OF LANDINGS BY PORT, SAN DIEGO AREA DURING 2006

System: CFIS
Tables16_21_pub

California Department of Fish and Game
Table 21sdPUB - Poundage And Value Of Landings By Port, San Diego Area During 2006

Page: 1
Date: 08/07/2007

Species	Pounds	Value
SAN DIEGO		
Swordfish	390,147	$1,261,950
Lobster, California spiny	79,523	$651,450
Prawn, spot	25,477	$170,240
Shark, thresher	85,012	$125,895
Crab, rock unspecified	48,559	$48,214
Opah	70,291	$43,471
Sheephead, California	7,974	$38,307
Seabass, white	16,449	$36,997
Whelk, Kellet's	45,179	$36,421
Shark, shortfin mako	31,016	$34,976
Halibut, California	7,722	$26,885
Crab, spider	13,342	$12,830
Tuna, albacore	11,611	$11,611
Yellowtail	7,406	$11,091
Louvar	1,640	$8,933
Rockfish, bank	4,661	$5,260
Barracuda, California	1,749	$5,247
Sea urchin, red	7,662	$4,597
Dolphin (fish)	923	$4,107
Tuna, yellowfin	2,193	$4,031
Rockfish, blackgill	1,545	$2,011
Thornyhead, shortspine	595	$1,911
Shark, bigeye thresher	2,407	$1,400
Cabezon	225	$1,346
Crab, box	277	$778
Scorpionfish, California	284	$768
Shark, soupfin	664	$625
Tuna, skipjack	2,506	$464
Sablefish	291	$433
Shark, leopard	388	$410
Bass, giant sea	142	$397
Rockfish, unspecified	367	$374
Rockfish, group shelf	166	$335
Rockfish, bronzespotted	116	$261
Grouper, broomtail	68	$170

System: CFIS
Tables16_21_pub

California Department of Fish and Game

Table 21sdPUB - Poundage And Value Of Landings By Port, San Diego Area During 2006

Page: 2
Date: 08/07/2007

Species	Pounds	Value
SAN DIEGO		
Rockfish, vermilion	74	$156
Opaleye	35	$140
Mackerel, Pacific	168	$114
Rockfish, chilipepper	44	$99
Rockfish, bocaccio	109	$93
Crab, king	24	$78
Rockfish, aurora	34	$76
Rockfish, group red	48	$64
Rockfish, group nearshore	10	$53
Lingcod	20	$52
Rockfish, gopher	9	$45
Bonito, Pacific	237	$36
Whitefish, ocean	24	$27
Rockfish, grass	7	$14
Tuna, bluefin	24	$12
Octopus, unspecified	5	$10
Rockfish, kelp	2	$7
Sole, petrale	3	$5
Rockfish, olive	16	$2
Halfmoon	1	$1
Shark, Pacific angel	12	$0
Port Totals:	869,481	$2,555,278
MISSION BAY		
Lobster, California spiny	161,429	$1,410,733
Sea urchin, red	488,508	$291,475
Prawn, spot	18,853	$208,522
Sablefish	27,949	$114,863
Thornyhead, shortspine	20,774	$85,897
Sheephead, California	17,464	$75,557
Swordfish	7,767	$54,586
Rockfish, blackgill	10,976	$11,286
Rockfish, group shelf	5,129	$10,282
Crab, rock unspecified	14,343	$10,203
Bonito, Pacific	6,798	$5,630
Yellowtail	2,244	$2,944

System: CFIS
Tables16_21_pub

California Department of Fish and Game

Table 21sdPUB - Poundage And Value Of Landings By Port, San Diego Area During 2006

Page: 3
Date: 08/07/2007

Species	Pounds	Value
MISSION BAY		
Cabezon	350	$2,025
Rockfish, group slope	1,635	$2,013
Lingcod	701	$1,989
Shark, shortfin mako	1,325	$1,493
Tuna, yellowfin	650	$1,453
Whelk, Kellet's	2,264	$1,356
Dolphin (fish)	726	$1,289
Shark, thresher	807	$1,192
Bass, giant sea	113	$1,045
Halibut, California	271	$963
Rockfish, bocaccio	819	$877
Rockfish, group red	342	$787
Barracuda, California	856	$721
Rockfish, group deep nearshore	291	$692
Mackerel, Pacific	1,041	$509
Opah	619	$478
Rockfish, vermilion	175	$448
Crab, spider	1,134	$422
Shark, leopard	379	$389
Rockfish, brown	126	$280
Rockfish, gopher	254	$271
Tuna, albacore	198	$251
Tuna, bluefin	158	$208
Jacksmelt	137	$130
Tuna, skipjack	128	$115
Sanddab	49	$109
Rockfish, grass	18	$105
Rockfish, aurora	103	$103
Whitefish, ocean	44	$77
Sardine, Pacific	137	$55
Rockfish, treefish	122	$53
Scorpionfish, California	31	$48
Guitarfish, shovelnose	38	$38
Rockfish, greenspotted	12	$29
Rockfish, kelp	5	$23

System: CFIS
Tables16_21_pub

California Department of Fish and Game

Table 21sdPUB - Poundage And Value Of Landings By Port, San Diego Area During 2006

Page: 4
Date: 08/07/2007

Species	Pounds	Value
MISSION BAY		
Rockfish, copper	9	$15
Shark, soupfin	14	$14
Octopus, unspecified	1,091	$8
Rockfish, starry	2	$6
Sole, petrale	13	$0
Thornyhead, longspine	38	$0
Rockfish, splitnose	1	$0
Whiting, Pacific	4	$0
Rockfish, group bolina	1	$0
Mussel	1,575	$0
Squid, market	954	$0
Crab, king	3	$0
Port Totals:	801,994	$2,304,052
OCEANSIDE		
Lobster, California spiny	65,083	$583,669
Thornyhead, shortspine	109,434	$400,251
Prawn, spot	29,379	$269,470
Sablefish	31,572	$61,764
Halibut, California	10,354	$51,503
Sheephead, California	7,228	$29,168
Crab, rock unspecified	26,535	$28,901
Sea urchin, red	24,532	$23,966
Seabass, white	9,696	$22,893
Shark, soupfin	16,055	$20,915
Shark, thresher	11,782	$20,832
Anchovy, northern	57,565	$15,073
Sardine, Pacific	38,895	$10,327
Thornyhead, longspine	4,676	$8,055
Eel, California moray	605	$5,523
Thornyheads	1,016	$3,721
Rockfish, blackgill	4,095	$3,603
Yellowtail	2,723	$3,203
Shark, shortfin mako	2,186	$3,002
Swordfish	477	$2,577
Crab, spider	2,263	$2,460

System: CFIS
Tables16_21_pub

California Department of Fish and Game

Table 21sdPUB - Poundage And Value Of Landings By Port, San Diego Area During 2006

Page: 5
Date: 08/07/2007

Species	Pounds	Value
OCEANSIDE		
Dolphin (fish)	329	$1,810
Whelk, Kellet's	2,044	$1,533
Bass, giant sea	498	$1,088
Cabezon	242	$822
Shark, leopard	502	$753
Squid, market	2,043	$547
Lingcod	117	$240
Whitefish, ocean	355	$232
Scorpionfish, California	94	$202
Tuna, albacore	115	$172
Tuna, yellowfin	46	$91
Sole, unspecified	32	$56
Rockfish, group red	17	$51
Barracuda, California	40	$40
Rockfish, treefish	50	$35
Rockfish, unspecified	8	$24
Rockfish, grass	3	$9
Escolar	40	$0
Rockfish, aurora	14	$0
Tuna, skipjack	26	$0
Bonito, Pacific	98	$0
Octopus, unspecified	3	$0
Sole, petrale	4	$0
Tuna, bluefin	11	$0
Port Totals:	462,879	$1,578,581
POINT LOMA		
Crab, spider	8	
Lobster, California spiny	28,313	$234,584
Sea urchin, red	299,887	$180,319
Swordfish	56,769	$157,917
Sheephead, California	3,921	$15,689
Seabass, white	6,725	$11,852
Shark, thresher	9,466	$11,539
Halibut, California	1,160	$4,398
Opah	4,180	$2,695

System: CFIS
Tables16_21_pub

California Department of Fish and Game

Table 21sdPUB - Poundage And Value Of Landings By Port, San Diego Area During 2006

Page: 6
Date: 08/07/2007

Species	Pounds	Value
POINT LOMA		
Shark, shortfin mako	1,893	$1,918
Sea urchin, purple	596	$1,713
Yellowtail	1,396	$1,640
Dolphin (fish)	1,066	$1,501
Tuna, yellowfin	790	$853
Tuna, bluefin	363	$727
Tuna, albacore	406	$413
Bass, giant sea	107	$214
Cabezon	49	$196
Shark, bigeye thresher	385	$193
Crab, rock unspecified	256	$168
Sole, unspecified	12	$48
Bonito, Pacific	18	$36
Barracuda, California	13	$18
Port Totals:	417,779	$628,628
IMPERIAL BEACH		
Sea urchin, red	683	$410
Lobster, California spiny	35	$315
Rockfish, group red	129	$239
Sheephead, California	39	$156
Rockfish, group shelf	19	$24
Port Totals:	905	$1,143
ALL OTHER PORTS		
Lobster, California spiny	58	$435
Sea hare	60	$360
Sea urchin, red	275	$165
Port Totals:	393	$960
San Diego Area Totals:	2,553,430	$7,068,641

******************* Total Records: 10,084

End of Report

APPENDIX III-E-1

SAN DIEGO WATERMEN'S ASSOCIATION STRATEGIC FRAMEWORK, JUNE 2008

San Diego Watermen's Association Strategic Framework June 2008

Prepared by ShoreBank Enterprise Cascadia
Consulting Services

SHOREBANK ENTERPRISE CASCADIA
Let's change the world.®

Table of Contents

Background

In the spring of 2008, the San Diego Watermen's Association (SDWA) engaged ShoreBank Enterprise Cascadia, (SBEC) in a brief planning effort to review the current local operating environment and clarify SDWA's mission, vision and activities in the context of this environment. Specifically, SBEC was asked to facilitate a planning retreat and assist in the development of a strategic framework to guide decision making regarding the organization's growth and development.

Given changes in their operating environment, the SDWA reached a point in their organizational development where a number of fundamental decisions regarding business structure, expansion of membership, and relationship to the broader San Diego fleet were required. The following strategic framework is intended to provide context for SDWA's short and mid-term decision making over the next 12 to 24 months.

It is the intent of the SDWA to utilize this strategic framework as a foundation for the development of a replicable model for the management of the sea urchin fishery based on science, community-based governance, and value-added markets.

Operating Environment

The following provides a brief snapshot of SDWA's current operating environment.

<u>Local Snapshot</u>
<u>(2006)</u>

- Local urchin fishery is small – approx $800,000 ex-vessel annually. It makes up a small percentage (5%) of the 300 permits statewide.

- Broader San Diego fisheries include net, trap, dive, hook & line, harpoon, troll, bait – primary product forms are live, fresh or frozen.

- Urchin fishery currently lacks diversity of market opportunities – other fisheries also appear mired in a stagnant, small commodity marketplace.

- Lack of value-added efforts, enthusiasm and motivation to innovate. Given relatively small size of individual fisheries, shore-side infrastructure for value-add processing, holding and distribution will likely require participation by multiple fisheries.

- Lack of trust to initiate change (internal and external) – leaving fisheries vulnerable to change occurring "to them" rather than "with them". Social capital must be developed to change from individual action to collective action.

- An opportunity to pursue co-management may be opening over next 24 months, but unclear how best to proceed.

- Urchin fishery is well positioned with local data and recent stock assessment, but undecided on how best to utilize.

- Port has initiated a working waterfronts planning project that will have implications on SDWA future options and opportunity.

- The Marine Protected Area planning and implementation process will have implications on SDWA's future options.

- San Diego lacks a local fishing organization representative of all fisheries that can provide a collective voice and is staffed to provide consistent leadership and representation on major issues.

Considerations

We have concluded that SDWA's current primary program areas, objectives and activities are still accurate. Additionally, we have concluded that the broader operating environment will impact our efforts at multiple levels. To address this we have included as an attachment a concept for discussion to explore the feasibility of initiating a broader San Diego fisheries organizing effort.

As with most organizing efforts, many questions arise as the process evolves. It is our intent to be flexible in our approach going forward and not get too far ahead of ourselves with generalized assumptions. The remainder of this document lays out the framework we will use to guide the ongoing process of developing SDWA as a sustainable institution representing the local urchin fishery. As we move forward in this framework, we will give consideration to the following:

- Broader Fishery Involvement
  - SDWA may risk marginalization if it does not actively participate in broader San Diego fishery issues.
  - Achieving the overall mission and vision of SDWA will likely require multiple activities with multiple partners. Who are the partners/allies that should be cultivated?
  - Utilizing SDWA as an entity to participate in or lead the development of a broader based organization may bring risks within the urchin fishery.
  - Does a broader fisheries focus become a distraction or set the stage for action in urchin fishery.
  - Working towards capitalizing a broader fishery effort may narrow SDWA's future funding options.

- Urchin Marketing Coop
  - What are the business structure options for evolving SDWA's current collaborative marketing effort?
  - What are the best options for adequately staffing the effort?
  - What are the mid-term capital needs and best options for capitalizing.

- Urchin Harvest Coop/Co-Management
  - What is the best approach for continuing to build the social capital required for change?
  - How can you best define "mutual benefit" or "rational economic self-interest" to motivate broader participation in efforts?
  - Can a harvest coop be established without co-management? What are the additional challenges this approach would bring?
  - What is the initial level of agreement required to authorize a small group to go forward as representative over next 24 months to move co-management process along?
  - What type of capital is required to move this process forward?

- Urchin Data Collection and Research
  - How best to build off of current data collection system and structure for optimal utilization going forward? Can there be different levels of participation?
  - Should current data collection system be pulled out as a separate service/activity and dealt with separately from other issues to respect any proprietary rights?

SDWA Strategic Framework

Organizational Mission and Goals

The San Diego Watermen's Association is a cooperative association that utilizes the San Diego Sea Urchin Fishery. The SDWA will utilize this strategic framework to guide the organization's growth and development over the next twelve to twenty four months. The current primary goals of the SDWA are:

- Proactive fishery research and management that results in a stable, healthy stock and improved product quality;
- Maximize the value of the fishery and diversify market opportunities; and
- Expand opportunity for the long-term protection of the resource, the local economy, and the local working waterfronts.

SDWA Membership

Current membership of the SDWA constitutes approximately one-third of the local San Diego based urchin fishery. It is the belief of the current membership that they must first demonstrate the methods and value of new approaches to management prior to successfully expanding their constituency.

To this end, the SDWA has started as a closely held cooperative with the intent of building their constituency in stages as other like-minded fishermen began to see the value of the work being performed. Expanded participation will require development of social capital and demonstrating success in:

- Data collection and research efforts;
- Using data to improve product quality and supply;
- Creation of new market opportunities and new products; and
- Articulating the rational self-interest and mutual benefit of cooperative approaches and collective action.

Collaboration

The SDWA cannot fully achieve its goals without the assistance of others. To succeed it must build off of its proven track record of success in its numerous collaborations and partnerships to date. Key partners include Environmental and Community-Based NGO's, Government Entities, Industry Groups, Foundations, and Universities/Science/Research Institutions.

Successful collaborations require a disciplined approach to relationship management. To this end, the SDWA will manage all partner relationships via the development of Memorandums of Understanding. These agreements will document the key elements of the relationships and act as a management tool to ensure all expectations are being met.

Elements of these agreements will include:

- Description of relationship and the mutual benefits of the relationship and value expected.
- Detailed description of roles, responsibilities, and expectations.

- Agreement on methods of communication both internal and external.
- Detail of any financial agreements.
- Expected timeline of activities.
- Terms and conditions of agreement.
- Method of evaluating success and measuring impacts.

Primary Program Areas

The SDWA is organized under three primary program areas:

- Collaborative Research;
- Market and Business Development; and
- Local Area Management.

A brief summary of these areas is provided below:

Collaborative Research

Several aspects of our work embody the Ecosystem Based Management (EBM) approach that guides the California Ocean Protection Council. The collaborative research we have initiated - planned, directed, and conducted by fishermen working closely with academic scientists - enhances stewardship and long-term vesting in the resource by fishermen and other stakeholders.

Reforms that are under consideration by the fishery will also create strong incentives for stewardship and rational harvesting. The development of value-added products will provide access to new markets, stabilizing and improving prices and revenue, and creating more incentives for good harvest management and stewardship.

All of these factors address the human dynamics of the fishery, in accordance with EBM principles. The San Diego sea urchin fishery can serve as a model for other fisheries, illustrating the benefits of local, grass-roots efforts, collaborative research, and stock assessment leading to improved fishery management. Primary objectives and activities will include:

- Continuation of our collaborative research efforts that has resulted in a peer reviewed stock assessment;
- Development of an on-going red sea urchin resource data collection management regime (quality and abundance);

- Development of ecosystem based monitoring that includes surface and sub-surface kelp;
- Develop a monitoring program for deep water red sea urchins;
- Continue to improve bathymetry maps using software designed for that purpose;
- Continue calibration of various methods of density assessment;
- Develop a Memorandum of Understanding with California Department of Fish and Game for data collection program.

Market and Business Development

Conservation and stewardship will benefit from long term business changes that add value to the harvest and "pull" future management reforms with market demand. The establishment of cooperative systems is necessary in order to conserve the resource and ensure diversification that results in adequate income for the fishing community during periods when environmental conditions result in lower than average harvests.

It is also necessary to redesign working harbors as the centers of fishing activity and commerce. Infrastructure and facilities need to be protected, modernized and upgraded for the supply, offloading, transporting and marketing of fish. Marketing must be expanded and diversified to include direct sales to processors, wholesalers, retailers and the public in both live and fresh products. Primary objectives and activities will include:

- Create a quality grading system and standards;
- Create a 'Brand' recognition for the product, including outreach and education efforts;
- Pursue avenues to increase local competition amongst buyers and results in diversified market opportunity;
- Negotiate pricing that results in an annual per pound increase over the next three years;
- Create local direct market opportunities;
- Create new product forms;
- Pursue and test harvest innovations to include translocation experiments and methods of holding live product for market;
- Initiate and support local efforts to protect and enhance our working waterfronts.

Local Area Management

Develop and implement a progressive, proactive fishery research and management effort that includes collaborative research, the development of management efforts suited to local conditions, adaptive management, cooperative harvesting and management of product quality, and marketing designed to maximize product value. This will require that a system of decision making centered around a harvesting cooperative be explored. Primary objectives and activities will include:

- Analyze existing cooperative management models and identify elements relevant to local operating environment;
- Develop a phased strategy for implementing cooperative management elements that build off of our research, conservation and marketing activities;
- Initiate discussions with California Department of Fish and Game regarding conceptual models for co-management.

Risk Management

Risk of failure is inherent with undertaking any change. The following is a preliminary list of risk points we have identified. This is not meant to be an exhaustive list. It is expected that additional risks will be identified during implementation of these recommended activities. These new risks will need to be identified and addressed in the course of moving forward.

- Planning Paralysis – Avoid this by setting small tangible benchmarks for implementation and recognize these achievements - manage to a series of end points (successes). While it's hard to identify in advance, there is a "sweet spot" between process and product.
- Mission Creep – Avoid losing sight of your core mission and purpose by measuring and evaluating your impacts in the context of your mission.
- Competing Expectations – Articulating and managing sometimes competing expectations (internal and external) will be crucial to success – i.e. attempting to please everyone – resulting in pleasing no one.
- Ownership – Failure to build broad enough base of consensus and ownership of vision. Understand that in organizing change, the ownership of the process (perceived and real), is usually more important than the final product.
- Reach Exceeding Grasp – Always make sure you understand and can articulate where you are before deciding where you want to go – keep efforts grounded and pragmatic.

- Control Pace of Change – Keep a finger on the "pulse" of the overall change process – Strong and consistent leadership is required to control expectations and the pace of change.

- Sufficient Capital: Attempting anything without sufficient business planning and a solid capital strategy will result in failure.

San Diego Fishing Federation

Concept for Consideration

During a recent San Diego Watermen's Association planning process it became clear that given changes in the overall operating environment for San Diego fisheries some thought should be given to a broader San Diego fisheries organizing effort. The following concept is intended to initiate discussion amongst local fishery leaders regarding the need and feasibility of such an effort.

Assumptions

- Broader San Diego fisheries include net, trap, dive, hook & line, harpoon, troll, bait – primary product forms are live, fresh or frozen. Total ex-vessel value in 2006 was $7,319,000.
- Many fisheries currently lack diversity of market opportunities.
- Lack of value-added efforts, enthusiasm and motivation to innovate. Given relatively small size of individual fisheries, shore-side infrastructure for value-add processing will likely require participation by multiple fisheries.
- Attempting to undertake any market or distribution activity designed to increase value, likely requires product diversity and volume beyond the reach of any single fishery.
- Lack of trust to initiate change (internal and external) – leaving fisheries vulnerable to change occurring "to them" rather than "with them". Social capital must be developed to change from individual action to collective action.
- Port has initiated a working waterfronts planning project that will have implications on future options and opportunity.
- The Marine Protected Area planning and implementation process will likely have implications on future options.
- San Diego lacks a local fishing organization representative of all fisheries that can provide a collective voice and is staffed to provide consistent leadership and representation on major issues.
- Federation concept would require individual fisheries organize at various levels around various issues. Getting out in front of pending issues and changes with a collective voice will keep fisheries from battling each.

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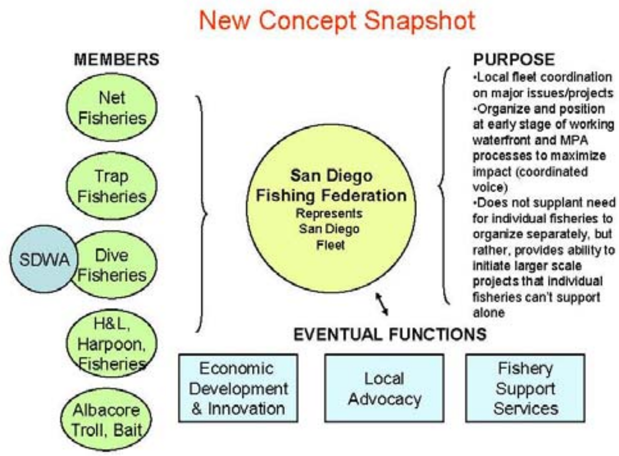
Potential Structure

The following graphic depicts preliminary thinking about how a local fishery organization could be structured.



Functions

The following is a preliminary list of ideas for potential functions for the Federation:

Economic Development and Innovation

- Utilize participation in working waterfronts planning process to identify opportunity for supporting and expanding collective infrastructure needs.

- Pursue planning and feasibility around shared distribution services for direct market activity.

Local Advocacy

- Utilize working waterfronts process as starting point to organize a collective voice.

- Potentially pursue a collective advocacy role in pending Marine Protected Area process.

Fishery Support Services

- Perform an assessment of potential services that bring value to all fisheries.

- Examples may include pooled healthcare, insurance, or retirement systems.

Feasibility

SDWA members propose to take the following steps:

- Schedule one-on-one meetings with other fishery leaders to gauge general interest, identify barriers and possible solutions, or conclude it's a non-starter.
- If sufficient interest arises, those willing would take it to the next level of planning and discussion.
- Initiate discussions with the Port and others regarding availability of potential funds to support initial planning needs.
- If concept a go and planning funds secured, utilize funds to determine business structure of various entities that best supports overall goal and develop a business plan for the organization.