2009 Annual Report to the Northeast Consortium

for the project:

Examining Fishing Practices of Divers in the Maine Sea Urchin Fishery
2008 Cooperative Research Award 09-019

June 30, 2009

for the period September 18, 2008 – June 30, 2009

Photo by Kerry Lyons, 4/15/09

Project Leader: Margaret Hunter
Maine Department of Marine Resources
PO Box 8
West Boothbay Harbor ME 04575
Phone: (207) 633-9541
Fax: (207) 633-9579
E-Mail: margaret.hunter@maine.gov

Additional Key Project Participants:

Name: Marcus Jones
Address: 166 Village Road
City, State, Zip: Steuben, ME 04680
Phone: (207) 546-9757

Project Objectives and Scientific Hypotheses

Background

The near-shore coast of Maine supports a valuable green sea urchin (*Strongylocentrotus droebachiensis*) fishery, but landings have declined steadily since the mid 1990s. The decline in the fishery has been linked to a decline in stock abundance due to fishing (Harris and Tyrell 2001; Chen and Hunter, 2003; Steneck et al 2004, Grabowski et al. 2005).

About 60% of the catch is made by divers, the rest by draggers. There is a legal minimum size limit of $2^{1}/_{16}$ inches (52.4 mm) and a maximum size limit of 3 inches (78.2 mm). The size limits do not prevent the taking of small and over-sized urchins – harvesters are allowed to take an illegal animal as long as it is "culled on board immediately after harvesting and is liberated alive into the marine waters" (Maine Title 12, Ch. 623, §6749-A). Divers often pick up sub-legal urchins, sending them in bags to the surface where they are culled from the fishing vessel, which may be anchored over deeper, non-productive bottom.

Some divers harvest selectively, and take very little of this under-sized bycatch, while others harvest non-selectively ("straight-raking") and take extensive bycatch, which is later culled overboard.

Studies have shown the importance of maintaining a minimum density of urchins, to ensure their reproductive success (Wahle and Peckham 1999, Harris et al. 2001). Maintaining an adequate density also prevents loss of sea urchin habitat. Sea urchins – important herbivores – play a determining role in controlling community structure in the rocky subtidal zone (reviewed by Scheibling and Hatcher 2001). In Maine, due to fishing, hard bottom that was once carpeted with grazing sea urchins has become open to successional processes (Harris and Tyrell, 2001) and is now dominated by kelp and other macroalgae, including invasive species, which thrive when sea urchins are no longer there to remove them. These algal beds are home for small crabs (*Cancer* sp., *Hyas* sp.) and other urchin predators (McNaught 1999, Steneck et al. 2004). This means that once an urchin bed is gone it is very difficult for urchins to reestablish themselves in an environment that has become inhospitable (Scheibling et al. 1999, reviews in Scheibling and Hatcher 2001 and Andrew et al. 2001). This algal-dominated community becomes an alternate stable state (Scheibling 1986, Steneck et al. 2004). The decline of urchin stocks, the loss of urchin habitat, and increasing algal cover have been documented on the western Maine coast (McNaught 1999; Harris and Tyrell 2001; Vavrinec 2003) and are advancing eastward (Vavrinec 2003; Hunter et al. 2005).

Project Objectives

In this project, working collaboratively with industry divers, we plan to:

1) Evaluate impacts of non-size-selective harvesting by divers, or "straight raking", as compared with size-selective harvesting practices, by simulating harvest methods observed in the current fishery and then comparing long-term effects with control areas.
2) Increase the number of industry divers who have been trained in field assessment techniques.
3) Evaluate the effectiveness of translocating (replanting) culled urchins, using techniques available to any harvester.
4) Inform industry members, managers, and the public of our findings.

The project will add to our understanding of sustainable commercial fishing practices in Maine's sea urchin fishery. We hope to find out whether the decline of Maine's sea urchin stock may have been due in part to destructive fishing practices, and to explore possible solutions. By addressing the urchin bycatch issue, it may be possible to halt potential stock declines and begin rebuilding this valuable fishery without further reductions in fishing effort.

Scientific Hypotheses

We are conducting a controlled experiment that compares the impact of size-selective harvesting by divers to non-size-selective harvesting (straight raking). Impacts to be measured are reductions in urchin densities, and increases in understory and canopy algal cover, compared with control sites. The scientific hypothesis that we are testing is that there is no significant difference in either sea urchin density (particularly the density of sub-legal-sized urchins) or algal cover between selectively fished sites, non-selectively fished sites, and control (unfished) sites five months after harvesting. We are also conducting a translocation (replanting) experiment to learn whether using culled urchins to restock depleted areas can be successful. Success will be measured in terms of the percentage of urchins that survive a translocation for five months.

Changes from original proposal

- We originally proposed monitoring the harvested and replanted sites for 6 months, but have changed that to 5 months, because the 2009-2010 fishing season will open in the study area almost a month earlier than in past years (September instead of October), leaving a closed period of April 1 - September 8, 2009.
- We had also planned to divide the harvest treatment sites into depth strata of 0-5, 5-10, and 10-15 m, the same depth stratification used in the annual Maine spring sea urchin survey, but the sites chosen for the experiment only had urchins to depths of about 10 m. so depth stratification will not be employed here.
- We proposed evaluating algal cover using the same three categories used by the annual Maine spring sea urchin survey – encrusting, understory or turfing, and canopy (Vavrinec 2003; Steneck and Dethier 1994) – but decided to further subdivide the turfing category into green, red filamentous, and red fleshy, in order to provide more detailed information on algal type.

Companion Project

In addition to evaluating the effects of non-size-selective fishing, it is important to learn the prevalence of this practice, in order to estimate its overall impact. In a related project, we are evaluating the extent of the practice of non-selective harvesting, by estimating the number of culled vs. kept urchins from commercial catches, using our existing port-sampling and harvester interview process (Hunter et al. 2007).

Methods and Work Plan

We plan to compare the impacts of straight raking with size-selective fishing and applied each fishing method as a treatment, along with an untouched control treatment, replicated at three study sites. The non-legal-sized urchins harvested from the study sites were used for a translocation experiment, simulating a commercial harvest-replant strategy.

Design summary:
Three small sites with harvestable populations of sea urchins in Maine's urchin management Zone 2 were selected, marked, and split roughly into three lanes (plots) each, for a total of nine experimental plots. Each lane was evaluated for urchin density and algal cover. At each site, one of the three lanes was randomly assigned to be harvested size-selectively, one was straight-raked (non-size-selective), and the third serves as a control, untouched plot. Immediately after harvest, the six harvested lanes were re-evaluated for urchin density. A fourth nearby site, chosen for its lack of urchins and its isolation from other urchin populations, was evaluated for urchin density and algal cover. All non-legal-sized (mostly under-sized) urchins from the harvested plots were dropped onto this site from the surface. The replanted site was evaluated for urchin mortality about one week after the transfer. An area at this site just outside the replanted area was selected as a control. All sites will be evaluated for urchin density and algal cover after about 2½ months (early July, 2009), and again after another 2 months (early September 2009). During the September sampling, all urchins from four 1-m^2 quadrats in each plot will be collected and measured for test diameter.

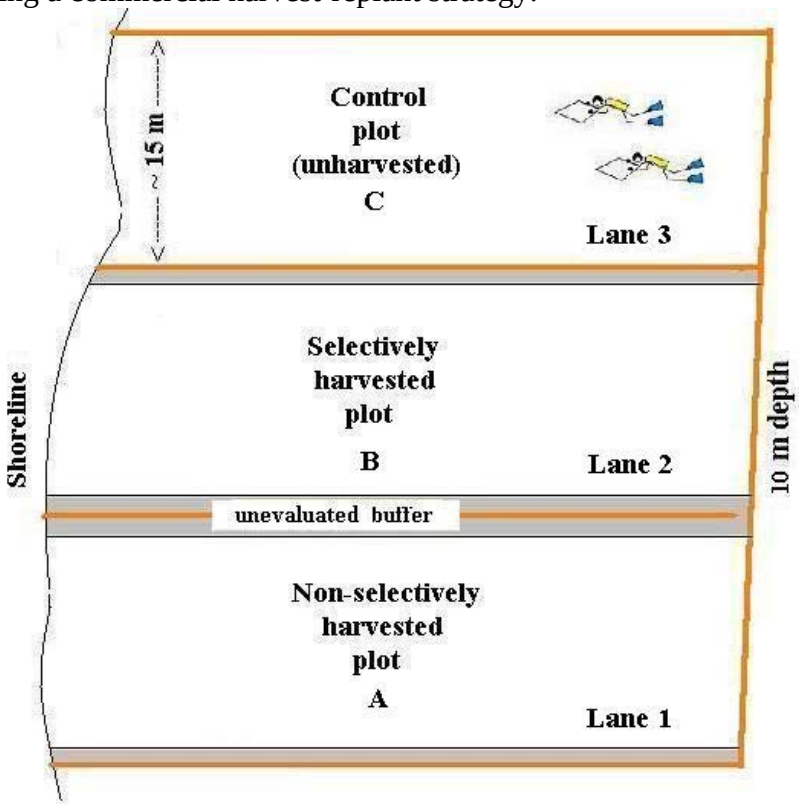


Diagram of one of the three experimental sites, not to scale.

The sea-urchin fishing season will be closed throughout the 5-month duration of the experiment (April to early September). Although we plan to monitor the sites over a longer time period, we

will not be closing the sites when the urchin season reopens. However, we hope to supplement this project by visiting the sites in June 2010 to do follow-up evaluations (during the annual Maine sea urchin survey). If the sites have been disturbed in the meantime, it should be evident at the control plots.

Work Completed to Date

Site Selection and Marking: During late March, 2009, divers explored several near-shore sites in the Winter Harbor (Hancock County, Maine) area, and selected three sites for the experimental harvest treatments and one site for the translocation experiment.

Type of Site	Name	Latitude	Longitude
Harvest Treatment	Winter Harbor	44° 23.14″	68° 04.79″
Harvest Treatment	Hancock Point	44° 27.81″	68° 13.93″
Harvest Treatment	Frasier Point	44° 22.2″	68° 04.69″
Translocation	Bean Island Ledge	44° 28.79″	68° 12.0″

The three harvest treatment sites were roughly rectangular areas spanning about 45 m (150 ft) of shoreline and extending out to about 10 m (30 ft) depth, or about 75 m (250 ft) from shore. Each site was selected to have commercially-harvestable densities of legal-sized urchins with a good mix of under-sized urchins, distributed as uniformly as possible. The sites were sloping with no steep drop-offs (which are difficult to evaluate) or other large irregular features. To minimize the chance of disturbance, known urchin, scallop, quahog, mussel, and sea cucumber dragging areas were avoided. Each of the three harvest treatment sites were split roughly into three plots or lanes running perpendicular to shore, each lane with about 15 m along the shore, out to about 10 m depth (see diagram above). The plots were permanently marked by eye-bolts on the corners on shore and submerged anchors and floats on the off-shore corners. The underwater boundaries of the plots were marked by temporary ground lines.

A fourth site was selected to receive the translocated urchins. It was near the harvest sites but with few urchins present and isolated from other urchin populations (by sand bottom) to minimize urchin immigration and emigration. It was a fished-out site previously known to have commercial densities of urchins, lying along a shallow (about 2-6 m) depth contour. It was marked by two buoys (one at each end) with a ground line running between them. An area just beyond (east of) this line will serve as a control and is separated from the treatment site by sand.

Site evaluation

During April 6-11, 2009, shortly after the fishing season had closed, all sites were marked and evaluated for urchin abundance and algal cover. Two industry divers were trained in urchin and algal cover evaluation techniques by working side-by-side with a DMR staff diver prior to the experiment. The nine experimental harvest plots were evaluated for sea urchin density and algal cover by the three divers prior to harvesting. Two of the divers, each carrying 1x1 meter square frames made of ¾-inch diameter PVC pipe, began at the deep end of a lane, about 5 meters apart, and swam a compass course toward the shoreline boundary of the plot (swimming two roughly parallel transects, see diagram above). They each counted urchins and evaluated algal cover in

30 haphazard (blind toss) 1x1 meter quadrats, for a total of 60 m^2 quadrats per lane. All urchins 10mm or larger in each quadrat were counted. Percent algal cover for each of five functional groups (encrusting, turfing green, turfing fleshy red, turfing filamentous red, and canopy) in each quadrat were recorded. The protocols for urchin and algal evaluation are the same as those used by the annual Maine sea urchin dive survey (Hunter et al. 2007; Grabowski et al. 2005) except for the addition of algal turfing sub-categories.

The replanting site and its control were also evaluated for urchin density and algal cover using the same methods, with the divers swimming on either side of the ground line, from one marker buoy to the other.

All lanes at all sites were also video-taped under water.

Harvest treatments

Treatments were designated A=straight raking (non-size-selective), B=size-selective fishing, and C=Control (unfished). The lane arrangements ABC, CAB, and BCA (left to right when looking at the lanes from the sea toward shore; see figure above for the ABC arrangement) were randomly assigned to the three experimental sites, which turned out to be Hancock Point, Winter Harbor, and Frasier Point respectively.

The harvest treatments were applied April 15 (Winter Harbor) and April 16 (Hancock Point and Frasier Point), 2009. At the size-selective plots (B), one of the two industry divers (Marcus) began at the deep end of the lane and made his way to shore, harvesting mostly only the legal-sized sea urchins, using the techniques of size-selective divers. At the non-selective plots (A), the other industry diver (Greg) harvested all sea urchins that a straight-raker would take. That is, clumps of urchins that all appeared too small were passed over, but groups that contained at least one urchin that might be legal were entirely harvested. The third plot (C) at each site was untouched. The divers were video-taped to document the two fishing styles. Standard 2¼-inch stretch mesh catch bags were used throughout.

Counting, Measuring, and Replanting

Harvested urchins were picked up by the fishing vessel (a 38-ft lobster-type boat with only 3.5 ft draft). On the vessel, all harvested urchins were separated by treatment and size (sub-legal, legal, over-sized), counted, and put in 80-lb (36 kg) plastic fish totes. The determination of size was made by an experienced commercial sea urchin culler. Test diameters were also measured for forty urchins chosen at random from each tote. The totes were only about two-thirds full to minimize crushing and spine puncture, and periodically hosed with sea water.

When harvesting was finished each day, sub-legal and over-sized urchins were moved to the replanting site at Bean Island Ledge and dropped onto it from the surface, over the ground line between the two marker buoys (see photo, right). Legal-sized urchins were returned to the sea at a site well away from any of the experimental sites.

Re-evaluation

After harvest (later the same day), the harvested plots were re-evaluated for urchin density as above. The replanted site was also re-evaluated for urchin density as above at the end of the last day of replanting (April 16, 2009).

On April 24, a little over a week after translocating, the replanted site (Bean Island Ledge) was evaluated for urchin mortality by counting healthy-appearing urchins and moribund or broken ones in 60 random quadrats.

Results to Date

Site Evaluation: See Tables 1-7 for preliminary results of the pre-harvest site evaluations for sea urchin density and algal cover. At the replanting site at Bean Island Ledge, mean sea urchin density was 1.77/m^2, mean encrusting algal cover was 72%, mean turfing algal cover (mostly fleshy reds) was 40%, and mean canopy cover was 54%. At the harvest treatment site at Winter Harbor, mean urchin density for each of the three lanes ranged from 10.48-16.58/m^2 with highest densities occurring in 5m depth or shallower. Mean encrusting algal cover varied from 70-80%, turfing cover from 22-31%, and canopy cover from 13-18%. At Hancock Point, mean urchin density ranged from 2.64-7.63 /m^2 with an interesting band of high-density (>20/m^2) at the shallowest depths. This band was narrowest in Lane 1 and widest in Lane3 (Table 4, see darker shaded areas). Mean encrusting algal cover varied from 18-42%, turfing cover from 5-10%, and canopy cover from 6-9%. Note that in the high-density urchin band, encrusting algal cover was higher (>51%) than in the low-density urchin area of each lane, where encrusting algal cover was usually less than 25% (Table 5). At Frasier Point, mean urchin density ranged from 7.70-18.3/m^2. Mean encrusting algal cover varied from 74-83%, turfing cover from 11-32%, and canopy cover from 15-29%. Data on the size of the urchins sampled were entered into a computer but have not been added to the database or evaluated yet.

Harvest Treatments – Counts and Measurements: See the table below for a summary of the number of sea urchins harvested at each site, by size category as determined by the commercial urchin culler on board (Legal, Oversized, and Undersized), where treatment A=straight raking (non-size-selective), B=size-selective fishing, and C=Control (unfished). Data on the sizes of the urchins measured have not been evaluated yet.

	Winter Harbor			Hancock Point			Frasier Point			Totals
Lane	1	2	3	1	2	3	1	2	3	
Treatment	C	A	B	A	B	C	B	C	A	
Size										
Legal		1,082	1,124	206	222		603		1,222	4,459
Oversized		9	11				9		5	34
Undersized		7,765	53	1,071	12		15		4,072	12,988
Totals		8,856	1,188	1,277	234		627		5,299	17,481
% undersized		88%	4%	84%	5%		2%		77%	

Note that the size-selective diver (treatment B) harvested 2-5% undersized urchins, while the non-size-selective diver (treatment A) harvested 77-88% undersized, by count.

Replanting: All of the 12,988 undersized and 34 oversized sea urchins (see table above) that were harvested at the three harvest treatment site were relocated to the Bean Island Ledge replant site.

Re-evaluation: We are in the process of entering the re-evaluation data in the computer and have not analyzed most of them yet. However, at the Bean Island Ledge replant site, about a week after replanting, only 5 dead urchins were observed, in the 60 m^2 quadrats that were randomly evaluated, which suggests that initial mortality was low.

Future work

All sites will be evaluated for urchin density and algal cover in early July, 2009, and again in early September 2009. During the September sampling, all urchins from four 1-m^2 quadrats in each plot will be collected and measured for test diameter. Further data analysis will be conducted as described in our proposal, in order to evaluate any long term effects of the harvest treatments, and assess the success of the urchin translocation experiment. We also hope to visit the sites again in June 2010.

Impacts and applications

It is too early to know what the impact of the experiments will be, since the follow-up evaluations for the project have not been done yet.

Related projects

In a companion project, during our routine port sampling, we asked harvesters to estimate the number of urchins they had culled from their catches at sea. We did this during the 2008-09 season, and will do so again during 2009-10, in order to estimate the prevalence of non-size-selective harvesting. Data collected to date have not been analyzed yet.

Partnerships

This project was suggested by the partnering commercial harvester, who also selected the study sites, provided the vessel, and hired the other commercial diver and boat crew (tender and cullers). The two commercial divers did most of the site evaluations and all of the harvesting, and will do all of the evaluations in the coming months. Other scientists included DMR diver Robert Russell, and Kerry Lyons, a scientist observer on the fishing vessel who also conducts our port sampling during the fishing season. Dr. Larry Harris, University of NH and Maine Sea Urchin Zone Council member, advised us on algal cover evaluation categories.

Presentations

No formal presentations have been made yet. A brief verbal description of the project to date was given to the Maine Sea Urchin Zone council at its June 18, 2009 meeting.

Published reports and papers

No reports (other than this one) or papers have been prepared, yet.

Literature Cited

Andrew, N.L., Y. Agatsuma, E. Ballesteros, A.G. Bazhin, E.P. Creaser, D.K.A. Barnes, L.W. Botsford, A. Bradbury, A. Campbell, J.D. Dixon, S. Einarsson, P. Gerring, K. Hebert, M. Hunter, S.B. Hur, C.R. Johnson, M.A. Juinio-Meñez, P. Kalvass, R.J. Miller, C.A. Moreno, J.S. Palleiro, D. Rivas, S.M.L. Robinson, S.C. Schroeter, R.S. Steneck, R.I. Vadas, D.A. Woodby and Z. Xiaoqi. 2002. Status and management of world sea urchin fisheries. *Oceanogr. Mar. Biol. Annu. Rev.* **40**: 343-425.

Chen, Y. and Hunter, M. 2003. Assessing the green sea urchin (*Strongylocentrotus droebachiensis*) stock in Maine, USA. *Fis. Res.* **60**: 527-537.

Grabowski, R.C., Windholz, T., and Chen, Y. 2005. Estimating exploitable stock biomass for the Maine green sea urchin (*Strongylocentrotus droebachiensis*) fishery using a spatial statistics approach. *Fish Bull.* 103: 320-330.

Harris, L.G., Tyrrell, M.C., Williams, C.T., Sisson, C.G., Chavanich, S., and Chester, C.M. 2001. Declining sea urchin recruitment in the Gulf of Maine: is overharvesting to blame? In: M. Barker (ed) *Proceedings of the 10th Echinoderm Conference*. A. A. Balkema, Lisse, pp 439-444.

Harris, L.G. and M.C.Tyrrell. 2001. Changing community states in the Gulf of Maine: synergism between invaders, overfishing and climate change. *Biological Invasions* 3: 9-21.

Hunter, M., Lyons, K., and Russell, R. 2005. Completion report, interjurisdictional fisheries research monitoring and assessment. Maine Dept. of Marine Resources, W. Boothbay Harbor, Maine. 70p, http://www.maine.gov/dmr/rm/seaurchin/research.htm

Hunter, M., Lyons, K., and Russell, R. 2007. Annual report, interjurisdictional fisheries research monitoring and assessment. Maine Dept. of Marine Resources, W. Boothbay Harbor, Maine. 34p, http://www.maine.gov/dmr/rm/seaurchin/research.htm

McNaught, D.C. 1999. The indirect effects of macroalgae and micropredation on the post-settlement success of the green sea urchin in Maine. Ph.D. Dissertation. University of Maine, Orono, Maine. 161 p.

Scheibling, R.E. 1986. Increased macroalgal abundance following mass mortalities of sea urchins (*Strongylocentrotus droebachiensis*) along the Atlantic coast of Nova Scotia. *Oecologia* 68:186-198.

Scheibling, R.E., Hennigar, A.W., and Balch, T. 1999. Destructive grazing, epiphytism, and disease: the dynamics of sea urchin-kelp interactions in Nova Scotia. *Can. J. Fish. Aquat. Sci* **56**: 2300-2314.

Scheibling, R.E. and Hatcher, B.G. 2001. The ecology of *Strongylocentrotus droebachiensis*. In: J. M. Lawrence (ed) *Edible sea urchins*. Elsevier Science, Amsterdam. pp 271-306.

Steneck, R. S., and M. N. Dethier. 1994. A functional group approach to the structure of algal-dominated communities. *Oikos* 69: 476-498.

Steneck, R.S., Vavrinec, J., and Leland, A.V. 2004. Accelerating trophic level dysfunction in kelp forest ecosystems of the western North Atlantic. *Ecosystems* 7: 323-332.

Vavrinec, J. 2003. Resilience of green sea urchin (*Strongylocentrotus droebachiensis*) populations following fishing mortality: marine protected areas, alternate stable states, and larval ecology. Ph.D. Dissertation. University of Maine, Orono, Maine. 130p, http://www.library.umaine.edu/theses/pdf/VavrinecJ2003.pdf

Wahle, R. A., and Peckham, S.H. 1999. Density-related reproductive trade-offs in the green sea urchin, *Strongylocentrotus droebachiensis*. *Marine Biology* 134: 127-137.

Table 1. Sea urchin abundance (count/m^2, left) and percent algal cover (right) by quadrat, with depth (ft), for two diver evaluations at **Bean Island Ledge**, April 11, 2009, prior to urchin relocation. "Cru"=Encrusting, "Tur"=Turfing, "Can"= Canopy.

	Greg		Marcus	
Quadrat	Depth	Abundance	Abundance	Depth
1	10	0	0	15
2	11	0	0	13
3	8	0	0	13
4	8	3	0	15
5	7	1	2	13
6	7	7	0	12
7	7	2	6	12
8	7	19	0	12
9	11	3	1	12
10	11	19	0	15
11	8	0	2	16
12	8	0	0	18
13	8	18	0	18
14	9	0	0	20
15	11	0	0	19
16	11	0	0	19
17	12	1	0	19
18	10	0	0	19
19	8	0	0	18
20	6	0	2	18
21	6	0	0	18
22	8	0	0	10
23	10	2	0	10
24	10	0	0	10
25	12	0	0	9
26	13	0	0	8
27	19	0	8	8
28	17	0	0	8
29	18	0	0	8
30	16	0	10	8
Totals		75	31	
Mean	10.23	2.50	1.03	13.77
Median	10	0	0	13
Variance		32.26	6.24	
N		30	30	
Both divers				
Total		106		
Mean		1.77		
Median		0		
Variance		19.47		
N		60		

	Greg				Marcus			
Quadrat	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth
1	10	90	40	60	95	21	40	15
2	11	50	30	50	100	50	95	13
3	8	90	40	50	50	40	90	13
4	8	80	65	60	90	10	100	15
5	7	50	60	20	90	10	90	13
6	7	70	40	35	90	10	100	12
7	7	45	35	25	90	10	75	12
8	7	30	10	50	95	30	95	12
9	11	70	35	60	95	50	100	12
10	11	80	40	50	95	20	95	15
11	8	80	35	90	95	40	70	16
12	8	80	35	90	90	40	80	18
13	8	85	45	80	95	50	80	18
14	9	75	50	70	100	50	50	20
15	11	70	30	30	90	60	10	19
16	11	30	15	30	95	50	10	19
17	12	30	25	30	95	50	20	19
18	10	45	55	20	75	30	50	19
19	8	80	65	25	75	20	75	18
20	6	85	55	40	90	40	50	18
21	6	55	85	30	90	20	90	18
22	8	75	50	70	60	10	50	10
23	10	50	40	40	60	20	20	10
24	10	40	40	65	30	10	30	10
25	12	30	40	70	75	30	30	9
26	13	20	30	35	70	50	90	8
27	19	15	15	15	80	70	30	8
28	17	90	40	30	70	80	30	8
29	18	80	60	15	70	90	70	8
30	16	80	50	15	70	60	70	8
Mean	10.23	62	42	45	82	37	63	13.77
Median	10	70	40	40	90	40	70	13
N			30			30		
Both divers		Cru	Tur	Can				
Mean		72	40	54				
Median		80	40	50				
N			60					

Abundance Legend	
count/m^2	
	0
	1 - 10
	11 - 20
	21+

Algal Cover Legend					
Crust % cover		Turf % cover		Canopy % cover	
	0%		0%		0%
	1 - 25%		1 - 25%		1 - 25%
	26 - 50%		26 - 50%		26 - 50%
	51% +		51% +		51% +

Table 2. Sea urchin abundance (count/m^2) by quadrat, for two diver evaluations in each lane, by depth (ft), shallow to deep, at **Winter Harbor**, April 11, 2009, prior to urchin harvest.

	Lane 1 (C)				Lane 2 (A)				Lane 3 (B)			
	Robert # 1		Robert # 2		Greg		Marcus		Greg		Marcus	
Quadrat	Depth	Abundance	Abundance	Depth	Depth	Abundance	Abundance	Depth	Depth	Abundance	Abundance	Depth
30	4	28	6	2	4	30	47	2	-1	31	30	1
29	5	24	31	2	4	13	16	5	1	14	20	2
28	4	6	26	3	5	30	18	5	1	38	54	3
27	4	40	8	3	5	6	13	4	1	20	39	3
26	5	27	5	3	5	45	9	4	2	26	47	3
25	5	15	16	5	5	43	5	4	2	31	42	4
24	0	10	20	5	5	14	25	4	2	16	18	4
23	5	26	5	6	6	10	33	4	2	17	32	6
22	5	8	13	4	6	17	13	4	2	20	34	6
21	5	12	7	4	7	5	12	4	3	7	23	7
20	6	7	7	5	7	5	12	9	4	25	17	7
19	6	18	4	5	8	1	5	10	4	14	33	7
18	6	6	12	6	9	32	27	10	3	23	21	7
17	6	3	30	6	9	12	12	8	7	7	45	7
16	7	21	6	7	10	11	4	8	8	16	21	8
15	8	20	10	7	10	4	36	8	8	15	4	6
14	9	11	17	8	10	15	9	9	12	5	7	7
13	9	3	16	8	12	18	13	9	12	3	15	8
12	10	14	10	9	12	13	22	9	12	3	44	9
11	12	17	27	12	13	4	14	12	12	19	10	9
10	14	2	29	17	14	7	34	12	12	35	4	9
9	15	0	1	16	13	2	1	13	13	16	3	9
8	16	0	1	16	14	2	5	13	12	4	16	10
7	17	0	2	17	15	1	11	13	12	0	0	13
6	16	0	0	17	17	0	1	15	13	1	4	16
5	19	0	0	18	18	0	1	17	14	0	0	16
4	19	0	0	19	18	7	0	19	18	2	0	20
3	18	0	0	20	20	0	0	19	19	0	0	20
2	17	2	0	19	20	0	0	20	20	0	3	20
1	16	0	0	20	21	0	2	21	20	0	1	21
Totals		320	309			347	400			408	587	
Mean	9.60	10.67	10.30	9.63	10.73	11.57	13.33	9.80	8.33	13.60	19.57	8.93
Median	7.5	7.5	7	7	10	7	12	9	8	14.5	17.5	7
Variance		117.33	101.53			160.25	150.02			133.42	281.91	
N		30	30			30	30			30	30	
Both divers												
Total		629				747				995		
Mean		10.48				12.45				16.58		
Median		7				11				16		
Variance		107.61				153.30				213.20		
N		60				60				60		

Abundance Legend
count/m^2
0
1 - 10
11 - 20
21+

Table 3. Percent algal cover by quadrat, for two diver evaluations in each lane, by depth (ft), shallow to deep, at **Winter Harbor**, April 11, 2009, prior to urchin harvest. "Cru" = Encrusting, "Tur" = Turfing, "Can" = Canopy.

	Lane 1 (C)								Lane 2 (A)							Lane 3 (B)							
	Robert # 1				Robert # 2				Greg				Marcus			Greg				Marcus			
Quadrat	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth
30	4	85	5	20	95	5	70	2	4	70	5	5	95	70	10	2	-1	90	20	0	95	20	0	1
29	5	90	0	0	90	10	10	2	4	80	10	10	90	10	10	5	1	70	5	30	95	60	10	2
28	4	95	0	10	95	1	15	3	5	75	5	30	90	30	10	5	1	80	5	10	95	60	10	3
27	4	90	1	15	90	1	15	3	5	70	5	0	90	0	0	4	1	50	5	0	95	50	10	3
26	5	90	5	10	95	5	10	3	5	75	25	35	100	10	0	4	2	70	5	15	95	60	10	3
25	5	95	0	1	90	1	10	5	5	80	5	0	100	20	0	4	2	70	5	10	95	30	10	4
24	0	90	1	10	95	0	1	5	5	70	20	10	95	20	10	4	2	80	0	10	90	20	20	4
23	5	95	5	70	85	10	5	6	6	80	15	0	100	1	0	4	2	80	5	5	90	20	20	6
22	5	90	1	60	90	5	1	4	6	80	20	40	100	21	1	4	2	80	10	5	90	30	10	6
21	5	90	20	55	95	0	5	4	7	70	0	90	95	60	0	4	3	80	0	5	75	0	10	7
20	6	95	15	70	90	5	20	5	7	75	15	70	90	50	40	9	4	90	10	5	60	21	1	7
19	6	90	5	70	95	5	0	5	8	50	15	10	90	40	40	10	4	90	15	0	60	30	0	7
18	6	95	1	40	90	10	5	6	9	70	10	0	70	10	10	10	3	90	30	10	60	10	0	7
17	6	90	0	5	90	5	10	6	9	80	0	0	60	41	0	8	7	80	10	35	90	0	30	7
16	7	90	5	20	95	5	50	7	10	65	25	10	100	10	0	8	8	80	10	30	75	10	40	8
15	8	90	1	15	90	5	20	7	10	80	30	40	100	10	0	8	8	70	5	50	95	20	20	6
14	9	90	10	30	95	10	10	8	10	90	25	30	100	2	10	9	12	60	20	0	95	21	1	7
13	9	90	21	15	90	5	10	8	12	40	25	10	100	21	1	9	12	60	15	30	95	30	1	8
12	10	60	40	10	95	10	5	9	12	80	20	15	100	21	10	9	12	40	5	10	95	20	0	9
11	12	50	55	20	90	5	25	12	13	65	40	10	95	20	10	12	12	70	5	10	95	20	10	9
10	14	25	60	45	75	50	5	17	14	40	35	20	75	70	20	12	12	80	15	5	95	40	10	9
9	15	70	75	20	80	65	20	16	13	90	60	15	75	70	10	13	13	70	10	10	95	50	10	9
8	16	25	60	30	75	71	15	16	14	80	40	10	95	30	10	13	12	90	25	5	95	41	10	10
7	17	15	75	5	70	66	10	17	15	80	55	40	95	50	10	13	12	80	35	50	80	80	10	13
6	16	5	70	0	50	36	15	17	17	50	60	50	90	90	40	15	13	70	30	10	90	60	1	16
5	19	0	70	0	60	50	10	18	18	40	40	20	90	100	20	17	14	75	40	20	90	80	10	16
4	19	0	60	0	35	21	10	19	18	80	25	40	70	80	20	19	18	75	45	50	70	90	10	20
3	18	0	65	10	0	5	5	20	20	70	20	15	70	70	20	19	19	70	15	30	80	90	10	20
2	17	15	50	50	0	1	0	19	20	5	20	10	70	70	0	20	20	50	35	20	80	60	10	20
1	16	10	80	10	0	0	5	20	21	5	10	15	70	90	1	21	20	50	15	15	70	60	10	21
Mean	9.6	64	29	24	76	16	13	9.6	10.7	66	23	22	89	40	10	9.8	8.3	73	15	16	86	39	10	8.9
Median	7.5	90	13	15	90	5	10	7	10	73	20	15	93	30	10	9	8	75	10	10	90	30	10	7
N			30			30				30			30					30			30			
Both divers		Cru	Tur	Can						Cru	Tur	Can						Cru	Tur	Can				
Mean		70	22	18						77	31	16						80	27	13				
Median		90	5	10						80	21	10						80	20	10				
N			60								60								60				

Algal Cover Legend					
Crust % cover		Turf % cover		Canopy % cover	
	0%		0%		0%
	1 - 25%		1 - 25%		1 - 25%
	26 - 50%		26 - 50%		26 - 50%
	51% +		51% +		51% +

Table 4. Sea urchin abundance (count/m^2) by quadrat, for two diver evaluations in each lane, by depth (ft), shallow to deep, at **Hancock Point**, April 11, 2009, prior to urchin harvest.

	Lane 1 (A)				Lane 2 (B)				Lane 3 (C)			
	Greg		Marcus		Greg		Marcus		Robert # 1		Robert # 2	
Quadrat	Depth	Abundance	Abundance	Depth	Depth	Abundance	Abundance	Depth	Depth	Abundance	Abundance	Depth
30	6	9	13	9	7	5	16	5	7	14	5	4
29	7	30	28	9	7	1	35	5	7	29	7	4
28	11	26	25	11	8	37	3	6	5	10	20	6
27	12	1	15	12	9	27	28	7	4	8	6	6
26	13	0	0	14	10	26	11	7	6	24	12	7
25	14	0	0	15	12	24	43	10	6	14	14	7
24	14	0	0	15	14	2	47	11	7	32	2	8
23	16	0	0	16	14	0	9	11	7	16	1	8
22	16	0	0	17	15	0	9	12	8	19	14	9
21	17	0	0	18	15	0	8	13	9	8	22	10
20	17	0	0	19	15	0	0	14	11	21	6	12
19	18	0	0	19	16	1	4	16	12	18	21	12
18	18	0	0	20	16	0	0	17	14	26	12	13
17	19	0	0	20	17	0	0	17	15	15	19	14
16	19	0	0	21	19	0	0	17	16	9	9	16
15	20	0	0	21	19	0	0	19	17	1	0	17
14	20	0	0	21	19	0	0	19	19	0	0	18
13	20	0		22	20	0	0	20	20	0	0	20
12	20	0	0	22	21	0	1	20	20	0	0	21
11	20	0	0	22	21	0	0	21	22	0	0	22
10	21	0	0	23	22	0	1	22	23	0	0	23
9	23	0	0	23	22	0	0	23	23	0	0	23
8	23	0	9	23	23	0	0	23	24	0	0	25
7	23	0	0	25	24	0	0	24	25	0	0	25
6	24	0	0	26	24	0	0	24	26	0	0	27
5	24	0	0	27	24	0	0	25	27	0	0	28
4	25	0	0	27	25	0	0	26	27	0	0	29
3	25	0	0	27	26	0	0	26	28	0	0	28
2	27	0	0	27	26	0	0	27	28	0	0	29
1	27	0	0	27	26	0	0	27	29	0	0	30
Totals		66	90			123	215			264	170	
Mean	18.63	2.20	3.10	19.93	17.87	4.10	7.17	17.13	16.40	8.80	5.67	16.70
Median	19.5	0	0	21	19	0	0	18	16.5	4.5	0.5	16.5
Variance		52.17	57.31			99.20	177.80			106.99	56.37	
N		30	30			30	30			30	30	
Both divers												
Total		156				338				434		
Mean		2.64				5.63				7.23		
Median		0				0				1		
Variance		53.96				138.54				82.79		
N		60				60				60		

Abundance Legend
count/m^2
0
1 - 10
11 - 20
21+

Table 5. Percent algal cover by quadrat, for two diver evaluations in each lane, by depth (ft), shallow to deep, at **Hancock Point**, April 11, 2009, prior to urchin harvest. "Cru" = Encrusting, "Tur" = Turfing, "Can" = Canopy.

	Lane 1 (A)								Lane 2 (B)								Lane 3 (C)							
	Greg				Marcus				Greg				Marcus				Robert #1				Robert #2			
Quadrat	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth
30	6	60	45	60	90	50	20	6	7	70	55	30	50	60	1	5	7	90	5	1	95	1	5	4
29	7	80	14	30	90	20	20	7	7	70	35	50	80	80	1	5	7	85	21	5	95	6	0	4
28	11	90	21	40	90	11	40	11	8	70	30	20	70	31	1	6	5	85	30	0	90	15	0	6
27	12	10	0	0	75	2	20	12	9	80	5	10	70	41	1	7	4	95	1	1	95	11	0	6
26	13	20	1	0	20	30	0	13	10	80	5	40	70	20	10	7	6	90	15	0	90	25	0	7
25	14	25	1	15	20	20	1	14	12	80	10	40	90	20	30	10	6	80	25	10	25	30	0	7
24	14	10	2	0	40	30	0	14	14	5	5	0	90	20	10	11	7	85	15	20	60	30	0	8
23	16	1	2	0	10	11	0	16	14	5	5	0	80	11	20	11	7	80	10	10	75	15	0	8
22	16	5	1	0	5	1	0	16	15	10	5	15	60	11	10	12	8	60	1	5	50	10	5	9
21	17	5	0	1	10	1	0	17	15	5	5	10	75	30	10	13	9	85	5	10	90	5	5	10
20	17	5	0	0	20	20	0	17	15	5	0	0	10	1	0	14	11	90	0	25	85	0	40	12
19	18	10	2	3	50	30	10	18	16	10	5	0	30	11	0	16	12	90	1	50	90	1	10	12
18	18	5	6	2	20	21	0	18	16	5	5	0	10	1	0	17	14	85	0	30	85	0	20	13
17	19	5	6	0	20	11	0	19	17	5	5	0	10	1	0	17	15	75	5	40	90	1	30	14
16	19	15	2	1	20	10	0	19	19	5	0	0	10	10	0	17	16	80	0	35	85	6	25	16
15	20	10	2	1	10	1	0	20	19	5	5	0	20	1	0	19	17	60	0	40	20	1	15	17
14	20	15	2	1	10	11	0	20	19	5	0	0	10	1	0	19	19	0	0	1	1	1	1	18
13	20	5	2	0	10	2	10	20	20	5	0	0	10	1	0	20	20	0	0	1	1	0	5	20
12	20	20	2	2	10	10	1	20	21	5	0	0	10	11	0	20	20	0	0	5	1	1	0	21
11	20	10	2	0	10	0	0	20	21	5	0	0	10	1	0	21	22	0	0	5	0	5	0	22
10	21	1	2	10	1	1	0	21	22	5	5	0	10	2	0	22	23	0	0	1	1	0	10	23
9	23	1	10	0	1	1	0	23	22	5	5	0	1	2	0	23	23	0	5	0	0	0	10	23
8	23	5	1	0	1	1	0	23	23	5	0	0	20	1	0	23	24	0	0	1	1	0	1	25
7	23	10	1	0	0	1	0	23	24	5	5	0	10	20	0	24	25	5	2	5	0	0	1	25
6	24	25	0	20	1	1	0	24	24	5	5	0	10	2	0	24	26	0	0	1	0	0	1	27
5	24	0	1	0	0	1	0	24	24	5	0	0	1	1	0	25	27	1	0	5	0	0	5	28
4	25	0	1	0	0	1	0	25	25	10	0	10	10	10	0	26	27	0	0	5	0	0	0	29
3	25	0	1	0	0	10	0	25	26	10	0	10	10	1	0	26	28	1	0	5	0	0	1	28
2	27	0	1	1	0	5	0	27	26	5	0	0	1	1	0	27	28	0	0	5	0	0	1	29
1	27	0	1	0	10	0	25	27	26	5	0	0	1	0	0	27	29	0	0	10	0	0	1	30
Mean	18.6	15	4	6	21	10	5	18.6	17.9	20	7	8	31	13	3	17.1	16.4	44	5	11	41	5	6	16.7
Median	20	7.5	2	0	10	7.5	0	19.5	19	5	5	0	10	6	0	18	17	60	0	5	23	1	1	16.5
N		30			30					30			30					30			30			

Both divers	Cru	Tur	Can
Mean	18	7.4	5.6
Median	10	2	0
N	60		

Both divers	Cru	Tur	Can
Mean	25	10	5.5
Median	10	5	0
N	60		

Both divers	Cru	Tur	Can
Mean	42	5.1	8.7
Median	38	1	5
N	60		

Algal Cover Legend						
Crust % cover		Turf % cover		Canopy % cover	
	0%		0%		0%
	1 - 25%		1 - 25%		1 - 25%
	26 - 50%		26 - 50%		26 - 50%
	51% +		51% +		51% +

Table 6. Sea urchin abundance (count/m^2) by quadrat, for two diver evaluations in each lane, by depth (ft), shallow to deep, at **Frasier Point**, April 11, 2009, prior to urchin harvest.

	Lane 1 (B)				Lane 2 (C)				Lane 3 (A)			
	Greg		Marcus		Robert # 1		Robert # 2		Greg		Marcus	
Quadrat	Depth	Abundance	Abundance	Depth	Depth	Abundance	Abundance	Depth	Depth	Abundance	Abundance	Depth
30	4	0	12	1	-1	4	2	1	4	0	2	0
29	5	0	6	4	1	3	6	0	5	3	2	1
28	5	0	8	5	1	5	3	-1	5	19	0	2
27	8	6	25	6	3	10	15	-1	5	24	1	3
26	9	8	6	6	4	14	0	-2	5	1	3	3
25	9	33	22	9	6	5	1	-2	8	16	10	3
24	12	25	0	9	8	0	0	-2	12	11	30	5
23	12	43	24	10	10	3	1	2	12	24	6	6
22	12	24	10	10	7	7	3	3	14	16	31	10
21	12	0	68	10	8	20	10	5	15	3	13	10
20	13	0	6	10	10	6	5	4	16	2	9	11
19	13	5	17	11	10	0	0	6	16	0	84	13
18	15	5	13	11	11	16	1	6	16	0	16	13
17	15	3	27	14	12	18	18	7	17	15	29	15
16	17	20	59	14	13	10	18	8	16	35	89	15
15	17	6	55	16	14	15	13	8	16	39	52	16
14	18	6	30	17	13	7	20	9	18	10	77	16
13	18	30	16	21	14	6	24	9	19	22	36	18
12	19	29	2	22	15	19	27	10	20	2	8	18
11	20	15	6	22	16	16	20	11	23	19	9	21
10	22	1	22	24	17	5	12	12	24	56	3	22
9	23	16	24	24	19	0	1	16	24	3	28	22
8	23	0	0	25	20	1	14	17	24	4	14	23
7	27	47	4	26	20	3	1	18	25	10	52	22
6	28	1	18	26	20	1	2	19	26	9	27	23
5	28	0	12	26	21	8	2	21	27	65	40	24
4	28	8	12	28	21	5	0	21	27	1	23	25
3	28	4	1	26	20	2	12	22	28	0	20	26
2	29	9	6	29	20	0	8	22	28	0	3	29
1	30	2	0	29	19	14	0	23	29	0	4	29
Totals		346	511			223	239			409	721	
Mean	17.30	11.53	17.03	16.37	12.40	7.43	7.97	9.07	17.47	13.63	24.03	14.80
Median	17	6	12	15	13	5.5	4	8	16.5	9.5	15	15.5
Variance		185.43	297.76			39.29	68.52			278.65	622.79	
N		30	30			30	30			30	30	
Both divers												
Total		857				462				1130		
Mean		14.28				7.70				18.83		
Median		8				5				10.5		
Variance		245.19				53.06				470.58		
N		60				60				60		

Abundance Legend
count/m^2
0
1 - 10
11 - 20
21+

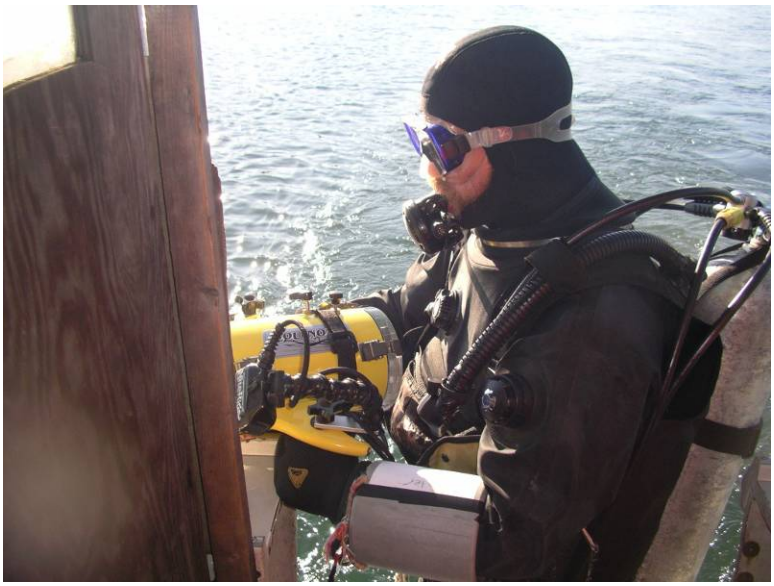
Table 7. Percent algal cover by quadrat, for two diver evaluations in each lane, by depth (ft), shallow to deep, at **Frasier Point**, April 11, 2009, prior to urchin harvest. "Cru" = Encrusting, "Tur" = Turfing, "Can" = Canopy.

	Lane 1 (C)								Lane 2 (A)							Lane 3 (B)							
	Greg				Marcus				Robert #1				Robert #2			Greg				Marcus			
Quadrat	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth	Depth	Cru	Tur	Can	Cru	Tur	Can	Depth
30	4	80	85	30	95	100	40	1	-1	90	11	40	80	25	60	1	4	80	70	20	80	100	10	0
29	5	80	90	30	90	90	20	4	1	85	16	5	75	45	40	0	5	80	80	20	75	100	50	1
28	5	85	60	90	90	60	40	5	1	90	10	5	80	26	50	-1	5	80	60	30	80	100	70	2
27	8	80	60	90	90	40	30	6	3	95	5	15	65	30	30	-1	5	80	60	10	75	100	70	3
26	9	80	25	40	90	40	10	6	4	95	1	10	50	125	0	-2	5	80	60	20	90	100	80	3
25	9	80	35	60	90	40	40	9	6	95	1	50	70	45	40	-2	8	90	35	20	90	81	50	3
24	12	50	15	30	50	20	50	9	8	80	6	25	85	35	80	-2	12	90	40	10	80	40	30	5
23	12	80	15	10	80	70	40	10	10	75	1	5	95	46	55	2	12	80	30	15	90	11	10	6
22	12	90	105	70	90	10	40	10	7	90	1	10	90	20	60	3	14	80	40	35	90	60	10	10
21	12	90	60	90	95	21	20	10	8	95	1	5	95	15	80	5	15	70	30	10	95	10	10	10
20	13	90	50	90	95	60	75	10	10	95	1	0	90	10	80	4	16	40	20	5	95	20	10	11
19	13	90	60	90	95	60	10	11	10	80	1	0	90	21	55	6	16	15	10	0	90	0	0	13
18	15	90	50	80	95	20	50	11	11	90	6	15	90	11	30	6	16	5	0	0	90	0	10	13
17	15	90	30	60	95	20	1	14	12	95	0	5	90	10	5	7	17	60	0	0	90	0	0	15
16	17	90	35	30	90	2	20	14	13	90	1	30	95	6	5	8	16	80	5	5	80	0	0	15
15	17	90	35	20	90	30	10	16	14	95	10	15	95	5	10	8	16	90	10	20	95	0	10	16
14	18	70	50	5	95	0	10	17	13	90	10	0	90	1	20	9	18	80	5	15	95	0	10	16
13	18	90	35	10	95	0	10	21	14	95	5	20	95	0	40	9	19	80	10	5	90	0	10	18
12	19	90	15	0	70	0	10	22	15	90	5	10	90	1	5	10	20	80	10	5	95	0	20	18
11	20	90	5	10	80	0	10	22	16	80	11	20	95	5	10	11	23	90	5	0	95	10	10	21
10	22	70	15	30	80	10	20	24	17	90	0	60	95	5	0	12	24	70	15	10	90	0	0	22
9	23	80	25	35	95	0	1	24	19	80	1	50	20	10	1	16	24	60	5	5	50	10	10	22
8	23	15	15	0	45	1	1	25	20	60	0	80	90	5	1	17	24	40	10	15	70	0	0	23
7	27	40	10	30	95	11	1	26	20	55	1	20	90	5	0	18	25	30	15	10	90	0	10	22
6	28	30	15	30	95	10	0	26	20	50	1	35	85	1	10	19	26	70	10	10	100	0	10	23
5	28	40	5	25	95	10	0	26	21	65	0	30	15	5	10	21	27	30	10	10	100	0	10	24
4	28	60	15	60	90	20	20	28	21	70	0	10	50	1	10	21	27	15	20	10	100	10	10	25
3	28	80	25	0	90	30	0	26	20	90	1	0	95	1	15	22	28	10	15	5	95	0	10	26
2	29	90	20	10	90	20	10	29	20	95	2	15	90	0	10	22	28	15	15	10	95	0	20	29
1	30	90	20	0	90	20	0	29	19	80	1	15	95	10	0	23	29	10	5	0	95	10	0	29
Mean	17.3	76	36	39	88	27	20	16.4	12.4	84	4	20	81	18	27	9.1	17.5	59	23	11	88	25	18	14.8
Median	17	80	28	30	90	20	10	15	13	90	1	15	90	10	13	8	16.5	75	15	10	90	5	10	15.5
N		30			30					30			30					30			30			
Both divers		Cru	Tur	Can						Cru	Tur	Can						Cru	Tur	Can				
Mean		82	32	29						83	11	24						74	24	15				
Median		90	21	20						90	5	15						80	10	10				
N		60								60								60						

Algal Cover Legend					
Crust % cover		Turf % cover		Canopy % cover	
	0%		0%		0%
	1 - 25%		1 - 25%		1 - 25%
	26 - 50%		26 - 50%		26 - 50%
	51% +		51% +		51% +

Photo 1 and 2. Loading SCUBA tanks (above), and marking the Bean Island Ledge site (below).

Photos 3-5. DMR diver Robert Russell with video camera housing (yellow) and recording cylinder on sleeve (above), commercial divers Marcus Jones (left) and Greg Smith (right).



Photos 6-7. Size-selective catch above and non-size-selective catch (straight-raked) below.

Photos 8-9. Commercial cullers sorting the catch.

Photos 10-11. Above: Size-selective catch with 4 totes of legal product (right) and a few over- and undersized urchins (left).
Below: Non-size-selective (straight-raked) catch with 4 totes of legal product (left) and 10 totes of over- and undersized urchins (back and right).