Survey of Red Sea Urchin Populations in Laredo Channel, British Columbia, 2000

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SURVEY OF RED SEA URCHIN POPULATIONS IN LAREDO CHANNEL, BRITISH COLUMBIA, 2000

by

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ABSTRACT

Tzotzos, D., A. Campbell, and T. Norgard. 2003. Survey of red sea urchin populations in Laredo Channel, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2629: 20 p.

A survey of red sea urchin populations in Laredo Channel, parts of Pacific Fishery Management (PFM) Area 6, was conducted in July 2000. A total of 86 randomly placed transects were surveyed by SCUBA divers. Estimated mean density was 1.33 urchins per m^2. Estimated mean biomass was 325.9 g/m^2. Overall, 31.7% of the total number of urchins measured were ≤50 mm test diameter (TD) whereas 42.3% were of legal size (≥ 90 mm TD) for the commercial fishery.

RÉSUMÉ

Tzotzos, D., A. Campbell, and T. Norgard. 2003. Survey of red sea urchin populations in Laredo Channel, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2629: 20 p.

Un relevé des populations d'oursins rouges du chenal Laredo, qui fait partie du secteur d'exploitation des pêcheries du Pacifique 6, a été réalisé en juillet 2000. Des plongeurs autonomes ont effectué ce relevé sur 86 transects placés aléatoirement. La densité moyenne estimée s'élevait à 1,33 oursins par m^2. La biomasse moyenne était estimée à 325,9 g/m^2. Dans l'ensemble, le diamètre du test de 31,7 % du nombre total d'oursins mesurés était ≤ 50 mm, alors que 42,3 % des oursins étaient de taille légale (diamètre du test ≥ 90 mm) pour la pêche commerciale.

INTRODUCTION

Red sea urchin (*Strongylocentrotus franciscanus*) distribution along the Pacific Coast of North America ranges from the southern tip of Baja California to Alaska (Kato and Schroeter 1985). In British Columbia (BC), the red sea urchin is found throughout shallow rocky subtidal habitats (Bernard 1977; Campbell and Harbo 1991). Red sea urchins are commercially harvested for their gonads (roe), which are sold mainly in Japan. Coastal First Nations communities harvest sea urchins as part of their food, social, and ceremonial fisheries. The commercial red sea urchin fishery started in the early 1970's and the total landed value for the 2000-2001 season was $8.4 million (Campbell et al. 2001), making the red sea urchin fishery one of the most valuable shellfish fisheries in BC.

The commercial red sea urchin fishery history and management are described in Campbell and Harbo (1991), and Campbell et al. (1999a). Currently, several approaches are used in the management of the red sea urchin fishery, including: a minimum commercial harvest size of 90 mm test diameter (TD); area licensing; individual vessel quotas; area quotas; and limited licence entry. Quota calculations are based on estimates of urchin density from field surveys, and estimates of urchin bed areas. Density estimates are therefore essential to the assessment and management of the red sea urchin fishery.

Early red sea urchin population surveys were conducted during the 1970's and 1980's by Adkins et al. (1981), Breen et al. (1976, 1978) and Sloan et al. (1987). Since 1993, red sea urchin population surveys have been conducted as a joint effort between the Pacific Urchin Harvesters Association (PUHA), First Nations, and Fisheries and Oceans Canada (DFO) (Jamieson et al. 1998a, 1998b, 1998c, 1998d; Bureau et al. 2000a, 2000b, 2000c, 2000d; Tzotzos et al. 2003a (in press), 2003b (in press)).

Fishery managers requested that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. Laredo Channel [parts of Pacific Fishery Management (PFM) Area 6, sub-areas 14 and 15], along the east coast of Aristazabal Island (Figure 1), was selected for survey through discussion between DFO, PUHA, and local First Nations. The objective of this paper was to present detailed survey results and to estimate current red sea urchin biomass for each PFM sub-area. These biomass estimates were converted into quota recommendations for each of these PFM sub-areas for management purposes by Campbell et al. (2001).

At the recommendation of the Pacific Urchin Harvesters Association (PUHA), PFM sub-area 6-14 was closed to commercial fishing during the 2000-2001 and 2001-2003 seasons. PFM sub-area 6-15 was open to commercial fishing during the 2000-2001 and 2001-2003 seasons, as part of quota area RU44 with an allocated quota of 200,000 pounds..

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in Laredo Channel. Transect locations were selected and plotted on a marine chart prior to the survey to avoid biases in the field (Figure 1). The number of transects assigned to each section was proportional to the surface area of water between 0 and 10 m below chart datum of each section over the total surface area of water between 0 and 10 m in the survey area. All depths have been corrected to chart datum.

Transects were systematically placed along the shoreline with a random starting point. Areas of sandy substrate were excluded from the survey area. Total shoreline length (TSL) of the survey area was measured using a digital curvimeter and marine charts. Position of the first transect was determined randomly, subsequent transects were then spaced evenly along the shoreline. Distance between transects was TSL/n where n is the number of transects along the shoreline. Since fluctuations in urchin density are unlikely to match the spacing of the transects, the systematic sample may therefore be treated as a random sample of transects (Jamieson and Schwarz 1998). Transects around islets were plotted by randomly choosing islets and then assigning a random compass bearing to determine the position and direction for each of the transects off an islet.

SURVEY LOGISTICS

The survey was conducted between July 22 and July 31, 2000, on the "Kynoch Surveyor", and the "Raider", Kitasoo Fisheries Program (KFP) research vessels, and the "Westport I", a commercial red sea urchin fishing vessel. The KFP provided a crew of four people, and the PUHA provided a crew of three. The KFP biologist, Tammy Norgard supervised the survey. The vessels anchored in nearby inlets each night.

DIVE SURVEY METHODS

Leadline transects were laid perpendicular to shore from the boat. Transects were laid out from shallow water to a depth of 15 m, so transect length was dependent on the slope of the substrate. A float was attached to the deep end of each transect. A two-diver team surveyed each transect from deep to shallow, one diver measured urchins while the other recorded data. A one meter squared (1 m^2) quadrat was placed on the bottom beside the transect and the test diameter (TD) of each red urchin present was measured to the nearest millimeter with calipers. The depth, substrate type, types of algae (and percent cover), and numbers of abalone (*Haliotis kamtschatkana*), green (*Strongylocentrotus droebachiensis*) and purple (*Strongylocentrotus purpuratus*) sea urchins present in the quadrat were also recorded. The quadrat was then moved 2 m forward along the transect and the process was repeated, so that every second meter of the transect was surveyed. In cases where the substrate was sand and no urchins were found at the deep end of transects, observations of depth, substrate and algae were recorded only every 20 m to minimize dive time. Skipped quadrats were assigned zero values for urchin counts before data were analysed. Once urchins were encountered, sampling was

conducted every 2 m until the intertidal zone or the surface was reached. On long transects with large numbers of urchins, measurements of test diameters were recorded in only a portion of the quadrats surveyed (usually half). The number of urchins measured on a transect could therefore be smaller than the number of urchins counted.

ESTIMATION OF DENSITY AND BIOMASS

Density and biomass estimates were calculated from the randomly placed transects which were located in red sea urchin beds recorded from 1997 to 2000. For comparison, estimates were also calculated for transects located outside of the recorded red sea urchin beds, and for all transects combined. The process involved in defining the commercially harvested urchin beds is described by Campbell et al. (2001).

Density and biomass were estimated for urchins of two size groups: a) all sizes; and, b) for urchins of legal size for the commercial fishery (≥90 mm TD). Estimates of mean density and biomass, per PFM sub-area, were calculated using the equations below.

Density estimates (d_{ts}) in numbers per meter squared for each transect (t) and size group (s) were calculated as:

$$d_{ts} = \frac{N_{ct}}{a_t} * \frac{N_{mts}}{N_{mt}}$$

where N_{ct} is the total number of urchins counted on transect t, N_{mts} is the number of urchins measured in size group s on transect t, N_{mt} is the total number of urchins measured on transect t, and a_t is the surface area of all quadrats surveyed on the transect t. Here a_t is equal to the number of all quadrats surveyed on the transect since each quadrat had a surface area of 1 m^2.

Overall mean density ($\overline{d}_s$) for a PFM sub-area for urchins of size group s was estimated as:

$$\overline{d}_s = \frac{\sum_t (d_{ts} * L_t)}{\sum_t L_t}$$

where L_t is the length of transect t (Campbell *et al.* 1999b).

The standard error (s_d) of estimated mean density was calculated as:

$$s_d = \sqrt{1 - \frac{n}{T}} * \sqrt{\frac{\sum_t (d_{ts} * L_t - \overline{d}_s * L_t)^2}{n * (n-1) * \overline{L}^2}}$$

where n is the number of transects surveyed, T is the total possible number of transects that can be sampled in a surveyed PFM sub-area and mean transect length ($\overline{L}$) was calculated as:

$$\overline{L} = \frac{\sum_t L_t}{n} \qquad \text{(Campbell } et\ al. \text{ 1999b)}$$

The expression $\sqrt{(1-(n/T))}$ was approximately equal to 1 since n was much smaller than T.

To calculate biomass, the weight of each urchin measured was calculated using the relationship between urchin weight (W) in grams and test diameter (TD) in millimetres (Campbell et al. 1999b, 2000).

$$W = 0.0012659 * TD^{2.7068} \quad \text{n= 167, } r^2=0.960$$

Biomass density (b_{ts} in grams per meter squared) of urchins of size group s, on a transect t, was estimated using a simplified form of the formula used in previous papers (Campbell et al. 2000). The formula was modified by Campbell et al. (1999b) to simplify computations:

$$b_{ts} = \frac{N_{ct}}{N_{mt}} * \frac{\sum W_{ts}}{a_t}$$

where ΣW_{ts} is the sum of the weights of urchins measured in size group s on transect t and a_t is the surface area of quadrats surveyed on the transect t.

Overall estimated mean biomass ($\overline{b}_s$) per surface area (grams per meter squared) was calculated for each PFM sub-area as:

$$\overline{b_s} = \frac{\sum_t (b_{ts} * L_t)}{\sum_t L_t} \qquad \text{(Campbell } et\ al. \text{ 1999b)}$$

The standard error of estimated mean biomass was calculated using the same formula used for standard errors of density, but d_{ts} and $\overline{d}_s$ were substituted for b_{ts} and $\overline{b}_s$, respectively.

Estimates of recruitment (R_T) into red sea urchin populations in BC have generally been expressed as the proportion of the total number of red sea urchins measured that were ≤50 mm TD (Adkins et al. 1981; Breen et al. 1976, 1978; Jamieson et al. 1998b, 1998c, 1998d; Sloan et al. 1987). We used the same method for comparison purposes. We also calculated recruitment as the percent of the total number of sublegal red sea urchins (<90 mm TD) that were ≤50 mm

TD (R_S). This method may provide a less biased measure of recruitment in areas where a commercial fishery has taken place, since the numbers of sea urchins ≥90 mm TD would be reduced due to the harvest (Tegner and Dayton 1981).

The data from Jamieson et al. (1998b, 1998c, 1998d) used for comparison to the current survey has undergone some reanalysis resulting in some quoted values being slightly different from those in the original papers.

RESULTS

SURVEY LOGISTICS

A total of 86 transects were surveyed in 10 days (Table 1, Figure 1). A total of 2560 red sea urchins were measured in 2303 quadrats on the 86 transects. Total transect length surveyed was 4509 m, for an average of 52 m per transect. Fifty-four (54) transects were located in the commercial red sea urchin beds recorded from 1997 to 2000. Of the 86 transects surveyed, 51 (26 in beds) were in PFM sub-area 6-14, and 35 (28 in beds) were in PFM sub-area 6-15.

SUBSTRATE AND HABITAT

Of the 2303 quadrats sampled, 51.5% had rock, 42.6% sand, and 5.9% mud as the primary substrate. Out of a total 2560 red sea urchins counted, 60.3% were observed between 0.0 m and 5.0 m depth, and 80.2% were observed on transects with high exposure (Table 2). Fifty-six of the 86 transects were in areas with high exposure. The shallow depths of <5 m also had higher mean percent canopy, understorey, turf, and encrusting algae cover (Table 2).

SIZE FREQUENCY DISTRIBUTIONS

The overall mean size of red sea urchins measured was 71.9 mm TD (Table 3, Figure 2). The smallest and largest urchins measured were 5 mm and 175 mm TD, respectively. The overall percent of legal sized urchins (≥90 mm TD) was 42.3%, whereas the overall percent of urchins ≤50 mm TD (R_T) was 31.7%. Of the sublegal urchins, the portion that were ≤50 mm TD (R_S) was 55.0%. Red sea urchin size frequencies by PFM sub-area are displayed in Figure 3.

DENSITY AND BIOMASS ESTIMATES

For transects lying within recorded red sea urchin beds, the estimated mean density of urchins of all sizes was 1.33 urchins per m^2, and 0.61 urchins per m^2 for legal sized urchins (Table 4). The estimated mean biomass of red sea urchins of all sizes was 325.9 g per m^2 , and 271.9 g per m^2 for legal sized urchins (Table 4). For all transects combined, the estimated

mean density and biomass for urchins of all sizes was 1.09 urchins m^{-2}, and 255.9 g/m^2 respectively, and 0.46 urchins m^{-2}, 213.0 g/m^2 for legal sized urchins (Table 4).

DISCUSSION

The size frequency distribution of red sea urchins from the current survey indicated a high recruitment of R_T=31.7%, R_S=55.0% (Table 2, Figure 2), which is higher than the 0% to 27% range observed for southern British Columbia (Adkins et al. 1981; Breen et al. 1976, 1978; Sloan et al. 1987).

Red sea urchin populations often have low recruitment (Bernard 1977; Sloan et al. 1987). There was a great deal of variability in recruitment levels within the current survey area (Figure 4). Transects 46 and 103 had high recruitment, and large numbers of urchins, and as a result had a large effect on the mean recruitment . High variability in recruitment levels within an area may be caused by many factors including predation on larvae and juveniles, interactions between juveniles and conspecific adults, and physical and oceanographic characteristics of the region (Kalvass 1992; Sloan et al. 1987). Laredo Channel is subject to a high degree of water movement. High current may play a major role in keeping local recruitment levels low.

The percentage of legal sized urchins (≥90 mm TD) in the present survey was 42.3% (Table 2), which is close to the values observed during the 2001 Price Island (46.6%) and Fitz Hugh Sound (48.7%) surveys (Tzotzos and Campbell unpublished data).

Comparing percentages requires caution since high recruitment could decrease the apparent proportion of legal-sized urchins even in the absence of harvest (Bureau et al. 2000a). In the current survey, there is an evident peak of juveniles in both PFM sub-areas (Figure 3), suggesting that the high proportion of small urchins is indeed due to recruitment. In most cases, surveys do not show such clear evidence of recruitment being responsible for a large proportion of small urchins in the population.

Density and biomass estimates from the current survey (1.33 urchins per m^2; 325.9 g/m^2) fell below the values observed during surveys conducted in the Central Coast in 2001. Density estimates for the Price Island and Fitz Hugh Sound surveys conducted in 2001 were 6.30 urchins per m^2, and 3.16 urchins per m^2, respectively (Tzotzos and Campbell unpublished data). Biomass estimates for the Price Island and Fitz Hugh Sound surveys conducted in 2001 were 1684.2 g/m^2, and 576.7 g/m^2, respectively (Tzotzos and Campbell unpublished data).

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Table 1. Summary of transects surveyed during the July 22-31, 2000 red sea urchin (RSU) population survey in Laredo Channel. Density in number per meter squared and biomass in grams per meter squared. PFM = Pacific Fishery Management. Depths have been corrected to chart datum. Check marks (✓) indicate transect lying within a known commercial RSU bed.

Transect	PFM Sub-Area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Time Start	Time End	Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
2	6-14	52 47.311	129 11.904	-1.10	12.74	11:53	12:38	45	261	131	0	0.00	0.00	✓
3	6-14	52 46.98	129 11.21	-0.15	13.62	13:31	14:06	35	37	19	61	3.21	1364.38	
5	6-14	52 46.255	129 10.209	-0.61	12.01	10:42	11:06	24	27	14	40	2.86	629.54	✓
6	6-14	52 46.097	129 9.777	-0.64	10.15	11:20	11:48	28	39	20	1	0.05	0.14	✓
8	6-14	52 45.449	129 8.761	-1.31	14.14	12:07	12:23	16	25	14	15	1.07	524.60	
9	6-14	52 45.157	129 8.745	-0.79	12.80	12:40	13:00	20	40	21	0	0.00	0.00	✓
11	6-14	52 44.467	129 6.645	-0.34	13.59	13:15	13:40	25	29	15	67	4.47	1939.63	✓
12	6-14	52 43.916	129 6.133	-2.53	12.28	11:20	11:37	17	23	12	19	1.58	728.90	✓
13	6-14	52 43.133	129 5.35	-1.98	12.50	11:50	12:15	25	47	24	25	1.04	303.27	✓
14	6-14	52 43.133	129 5.35	-1.31	12.83	12:42	13:25	43	33	17	2	0.12	0.43	
15	6-14	52 43.117	129 5.067	-1.22	13.14	14:10	14:42	32	31	16	51	3.19	947.92	✓
16	6-15	52 42.565	129 4.442	-1.01	12.95	16:56	17:06	10	23	12	0	0.00	0.00	✓
17	6-15	52 42.238	129 3.957	-2.01	13.11	17:17	17:32	15	25	18	5	0.28	30.29	✓
18	6-14	52 41.988	129 3.63	-0.73	13.44	14:10	14:45	35	41	21	0	0.00	0.00	✓
19	6-15	52 41.58	129 3.636	-3.38	-3.35	14:15	14:20	5	27	14	0	0.00	0.00	✓
20	6-15	52 42.038	129 2.898	-1.28	11.58	16:10	16:27	17	49	25	0	0.00	0.00	✓
21	6-15	52 42.038	129 2.898	-3.14	11.80	15:38	16:02	24	27	14	0	0.00	0.00	✓
22	6-15	52 42.308	129 3.063	-1.68	11.89	14:50	15:05	15	27	14	3	0.21	45.19	✓
23	6-15	52 41.988	129 2.315	-1.13	11.22	15:13	15:25	12	37	19	0	0.00	0.00	✓
24	6-15	52 41.335	129 3.054	-1.31	10.94	14:16	14:41	25	25	13	78	6.00	1785.61	✓

Continued next page

Table 1. continued

Transect	PFM Sub-Area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Time Start	Time End	Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
25	6-15	52 40.832	129 1.953	-1.25	10.94	13:25	13:30	5	21	11	0	0.00	0.00	✓
26	6-15	52 40.682	129 1.493	-1.92	10.88	12:40	13:08	28	39	20	60	3.00	676.87	✓
27	6-15	52 40.404	129 0.809	-1.89	9.78	12:08	12:30	22	17	9	77	8.56	1700.22	✓
28	6-15	52 40.192	129 0.64	-0.18	11.03	11:28	11:53	25	37	19	67	3.53	805.94	✓
29	6-15	52 39.989	129 0.117	-3.14	10.67	12:17	13:02	45	47	24	96	4.00	1239.91	✓
30	6-15	52 39.443	128 59.644	-2.38	11.58	11:32	12:02	30	31	16	65	4.06	1010.21	✓
31	6-15	52 39.265	128 59.378	-1.68	11.64	11:00	11:17	17	17	9	37	4.11	1142.17	✓
32	6-15	52 40.632	128 56.926	-2.50	11.09	12:56	13:47	51	141	71	53	0.75	248.26	✓
33	6-15	52 40.754	128 57.419	-2.32	11.83	12:08	12:36	28	127	64	2	0.03	1.89	✓
34	6-15			-3.78	-0.03	15:08	15:26	18	201	101	0	0.00	0.00	✓
35	6-15	52 41.196	128 58.174	-1.68	12.56	11:29	11:57	28	49	25	88	3.52	1234.04	✓
36	6-15	52 41.366	128 58.679	-3.81	10.67	13:52	14:30	38	29	15	118	7.87	1574.35	✓
37	6-15	52 41.707	128 59.551	-3.05	10.67	13:29	13:45	16	31	16	24	1.50	283.93	✓
38	6-15	52 41.94	129 0.17	-3.93	10.76	13:04	13:14	10	23	12	43	3.58	1260.35	✓
39	6-14	52 42.34	129 0.267	-2.32	1.37	14:32	14:51	19	91	46	0	0.00	0.00	✓
41	6-14	52 43.075	129 59.753	-0.58	12.47	13:55	14:08	13	31	16	0	0.00	0.00	
42	6-14	52 43.315	129 59.234	-1.19	12.44	13:02	13:17	15	41	21	0	0.00	0.00	
44	6-14	52 43.545	129 59.366	-0.70	12.01	13:29	13:43	14	31	16	0	0.00	0.00	
45	6-14	52 43.126	129 59.017	0.12	11.92	14:10	14:25	15	31	16	0	0.00	0.00	
46	6-15			-0.30	13.05	11:31	12:30	59	25	13	257	19.77	854.79	✓
47	6-15			-2.35	-2.13	11:00	11:10	10	51	26	0	0.00	0.00	
48	6-15	52 42.54	129 1.085	-2.38	11.43	11:56	12:27	31	43	22	37	1.68	254.35	✓
49	6-15	52 43.89	129 1.922	-2.29	12.10	11:11	11:33	22	23	12	86	7.17	1705.70	✓

Continued next page

Table 1. continued

Transect	PFM Sub-Area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Time Start	Time End	Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
50	6-15	52 43.371	129 2.465	-1.95	12.41	10:35	10:54	19	25	13	91	7.00	1683.81	✓
51	6-15	52 43.735	129 2.962	-0.58	13.23	10:05	10:27	22	23	12	95	7.92	1894.32	
53	6-14	52 44.6	129 3.968	-2.07	11.34	10:52	11:03	11	23	12	17	1.42	353.47	
54	6-14	52 45.051	129 4.119	-2.38	11.58	11:35	12:20	45	341	171	1	0.01	0.03	
56	6-14			-0.49	11.37	11:30	11:47	17	19	10	14	1.40	501.18	
57	6-14			-0.24	11.34	11:00	11:15	15	27	14	4	0.29	0.65	
59	6-14	52 45.845	129 4.866	-1.68	12.89	14:45	15:28	43	73	37	0	0.00	0.00	✓
60	6-14	52 45.649	129 6.782	-0.98	11.16	12:00	12:10	10	35	18	0	0.00	0.00	
61	6-14			-1.98	13.44	14:30	14:45	15	25	13	7	0.54	0.68	
62	6-14			-0.52	11.55	12:25	12:40	15	31	16	0	0.00	0.00	
63	6-14			-0.98	11.13	12:45	13:00	15	19	10	9	0.90	1.51	
65	6-14			0.40	11.31	13:10	13:20	10	19	10	2	0.20	0.07	
66	6-14			-0.61	12.98	14:48	15:07	19	31	16	0	0.00	0.00	
68	6-14	52 45.917	129 4.3	-1.74	12.47	14:22	14:35	13	27	14	4	0.29	1.46	
69	6-14	52 45.98	129 4.879	-2.13	11.80	12:53	13:09	16	43	22	11	0.50	182.23	✓
71	6-14	52 46.812	129 5.892	-2.04	12.41	13:00	13:27	27	65	33	9	0.27	32.31	✓
72	6-14	52 46.052	129 6.084	-2.41	12.16	12:23	12:35	12	21	11	21	1.91	353.69	✓
74	6-14	52 46.907	129 4.667	-1.10	12.68	15:32	15:40	8	17	9	0	0.00	0.00	
75	6-14	52 46.9	129 4.89	-1.77	12.53	10:53	11:03	10	19	10	0	0.00	0.00	

Continued next page

Table 1. continued

Transect	PFM Sub-Area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Time Start	Time End	Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
77	6-14	52 47.088	129 3.666	-2.77	11.40	11:15	11:38	23	109	55	0	0.00	0.00	
78	6-14	52 47.136	129 4.683	-1.86	12.59	15:08	15:22	14	27	14	0	0.00	0.00	
80	6-14	52 47.136	129 5.917	-2.53	10.06	13:48	14:26	38	87	44	39	0.89	189.18	
81	6-14	52 47.294	129 5.967	-1.01	12.98	12:52	13:17	25	121	61	0	0.00	0.00	✓
83	6-14	52 47.855	129 4.964	-1.71	12.25	11:22	11:34	12	41	21	0	0.00	0.00	
84	6-14	52 48.141	129 4.745	-1.22	14.17	10:55	11:15	20	71	36	4	0.11	0.42	
86	6-14	52 47.946	129 5.769	0.00	12.13	11:50	12:02	12	31	16	0	0.00	0.00	
87	6-14	52 47.603	129 5.936	-0.12	12.92	12:30	12:50	20	41	21	0	0.00	0.00	
88	6-14			-1.49	12.62	9:42	10:07	25	35	18	13	0.72	266.60	
89	6-14	52 47.922	129 6.877	-0.94	14.14	10:55	11:25	30	35	18	29	1.61	683.78	✓
90	6-14	52 42.256	129 7.048	-0.70	12.86	10:42	11:00	18	21	11	16	1.45	614.75	✓
91	6-14	52 48.994	129 7.332	-1.07	14.11	11:50	12:21	31	33	17	47	2.76	862.75	✓
92	6-14	52 49.292	129 7.467	0.06	12.13	11:18	11:42	24	27	14	64	4.57	1418.97	✓
93	6-14	52 49.78	129 7.717	2.50	14.75	13:02	13:21	19	25	13	10	0.77	357.17	✓
94	6-14	52 5.37	130 9.95	0.15	13.50	11:55	12:20	25	35	18	62	3.44	950.65	✓
95	6-14			0.91	14.14	12:56	13:30	34	35	18	67	3.72	1249.15	✓
96	6-14	52 51.127	129 8.22	-1.77	13.20	14:05	14:40	35	59	30	84	2.80	771.11	✓
97	6-14			-1.58	12.80	14:15	14:54	39	260	130	14	0.11	21.31	✓
98	6-14	52 51.42	129 7.808	-2.53	12.22	15:41	16:20	39	135	68	24	0.35	66.05	✓
99	6-14			-2.80	12.28	15:36	15:48	12	21	11	2	0.18	112.10	✓
100	6-14			-2.68	11.95	16:04	16:36	32	78	40	67	1.68	455.96	✓
101	6-14	53 43.247	129 4.881	-2.13	13.05	15:10	15:59	49	73	37	38	1.03	134.12	✓
102	6-14	52 43.169	129 4.769	-1.55	13.14	14:20	15:00	40	41	21	64	3.05	410.15	
103	6-15	52 42.792	129 4.209	-1.92	11.64	14:56	16:35	99	135	68	154	2.26	114.79	

Table 2. Mean percent cover by algae, substrate type, exposure, and number of red sea urchins for each depth category surveyed during the 2000 survey conducted in Laredo Channel. Depth ranges have been corrected to chart datum. Exposure values: 1=minimal sea movement; 2=well sheltered; 3=occasional current; 4=moderate exposure; 5=strong tidal flow; 6=high tide surge only; 7=ground swell normal; 8=high exposure. Substrate values: 1=rock; 2=sand; 3=mud. Canopy = tall, shading, surface-reaching algae. Understorey = 30cm to 2m in height. Turf = 5cm to 30cm in height. Encrusting = species forming a thin, crusty layer on rocks.

Depth Range (m)	Mean Number of RSU per Quadrat	Number of Quadrats	Mean Substrate Category	Mean Exposure	Mean Percent Cover by Algae			
					Canopy	Understorey	Turf	Encrusting
<0.0 m	0.91	395	1.29	5.25	19.08	63.74	9.80	27.89
0.0 - <2.5 m	2.72	375	1.28	5.89	34.19	54.75	7.19	56.15
2.5 - <5.0 m	1.33	396	1.52	5.66	12.42	45.15	4.68	47.08
5.0 - <7.5 m	0.82	401	1.78	5.75	5.69	31.95	3.31	38.66
7.5 - <10.0 m	0.60	391	1.69	5.87	3.11	30.12	2.68	33.13
10.0 - <12.5 m	0.28	292	1.73	6.05	0.00	25.78	2.82	21.51
12.5 m	0.17	54	1.54	6.00	0.13	16.30	0.43	16.30

Table 3. Number of red sea urchins measured and percent of urchins ≤50mm TD and ≥90mm TD for each Pacific Fishery Management (PFM) sub-area surveyed in the 2000 population survey in Laredo Channel. R_T = percent of urchins of all sizes that were ≤50mm TD. R_S = percent of sublegal urchins that were ≤50mm TD.

PFM Sub-Area	Test Diameter (mm)			Numbers Measured			Percent of Total Urchins Measured ≤50mm TD		≥90mm TD
	Mean	Minimum	Maximum	Total	≤50mm TD	≥90mm TD	R_T	R_S	
6-14	81.5	5	175	1024	224	531	21.9	45.4	51.9
6-15	65.5	5	159	1536	588	552	38.3	59.8	35.9
6 Total	71.9	5	175	2560	812	1083	31.7	55.0	42.3

Table 4. Estimates of density and biomass of red sea urchins (RSU), by Pacific Fishery Management sub-area, for the 2000 survey in Laredo Channel. Estimates are for transects within red sea urchin beds recorded between 1997-2000, for transects outside the beds, and for all transects combined.

PFM Sub-Area	Transects Used	Number of Transects	Sum of Transect Lengths (m)	Mean Density RSU/m^2		Standard Error of Mean Density		Mean Biomass of RSU g/m^2		Standard Error of Mean Biomass	
				All Sizes	≥90mm	All Sizes	≥90mm	All Sizes	≥90mm	All Sizes	≥90mm
6-14	Within Beds	26	1649	0.86	0.50	0.26	0.17	258.3	222.2	83.1	72.3
	Outside Beds	25	1219	0.46	0.16	0.21	0.08	119.2	103.8	60.47	54.1
	All	51	2868	0.69	0.36	0.17	0.10	199.1	171.9	53.4	46.7
6-15	Within Beds	28	1298	1.88	0.75	0.61	0.22	404.8	331.0	116.6	95.2
	Outside Beds	7	343	1.42	0.26	0.7	0.19	172.2	114.1	135.1	77.2
	All	35	1641	1.78	0.64	0.49	0.17	356.2	285.7	94.36	75.2
6 Total	Within Beds	54	2947	1.33	0.61	0.31	0.14	325.9	271.9	70.8	59.4
	Outside Beds	32	1562	0.67	0.19	0.26	0.08	130.8	106.1	55.64	45.1
	All	86	4509	1.09	0.46	0.22	0.09	255.9	213.0	49.5	41.3

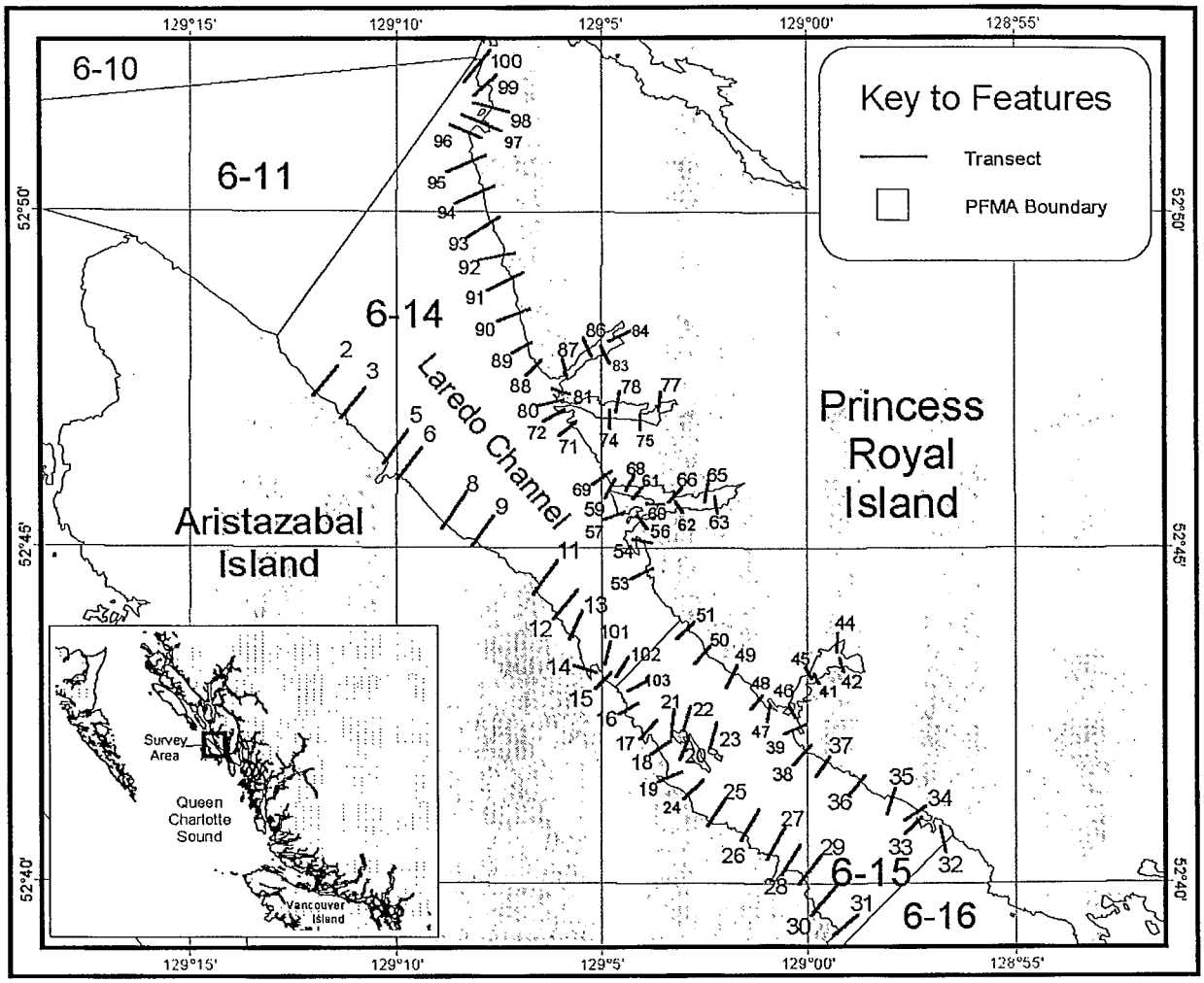

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted in Laredo Channel, 2000. Hyphenated numbers indicate Pacific Fishery Management sub-areas and other numbers identify transects. Inset map indicates survey location.

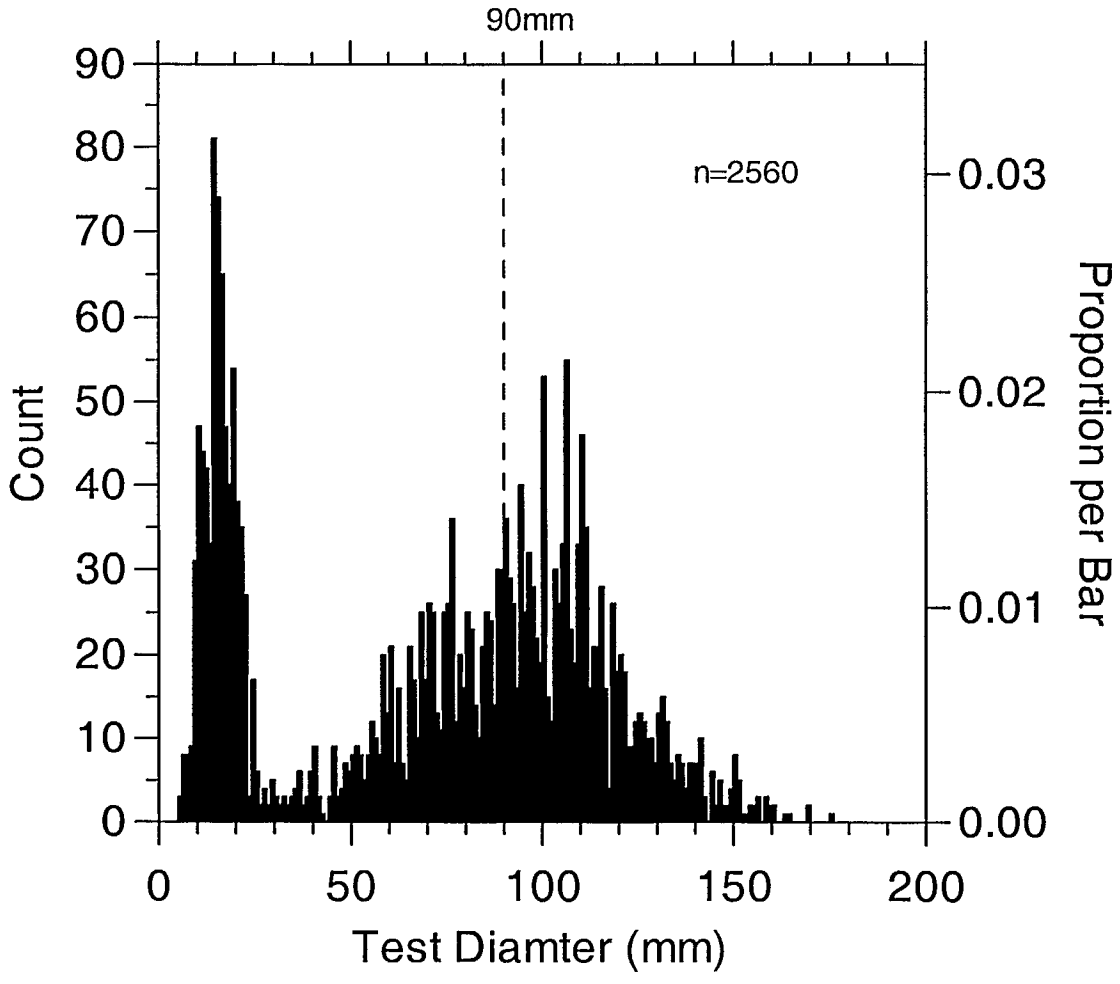

Figure 2. Size frequency distribution of red sea urchins measured on all transects during the 2000 survey in Laredo Channel (n=2560). The dashed vertical line represents the 90 mm legal commercial size limit.

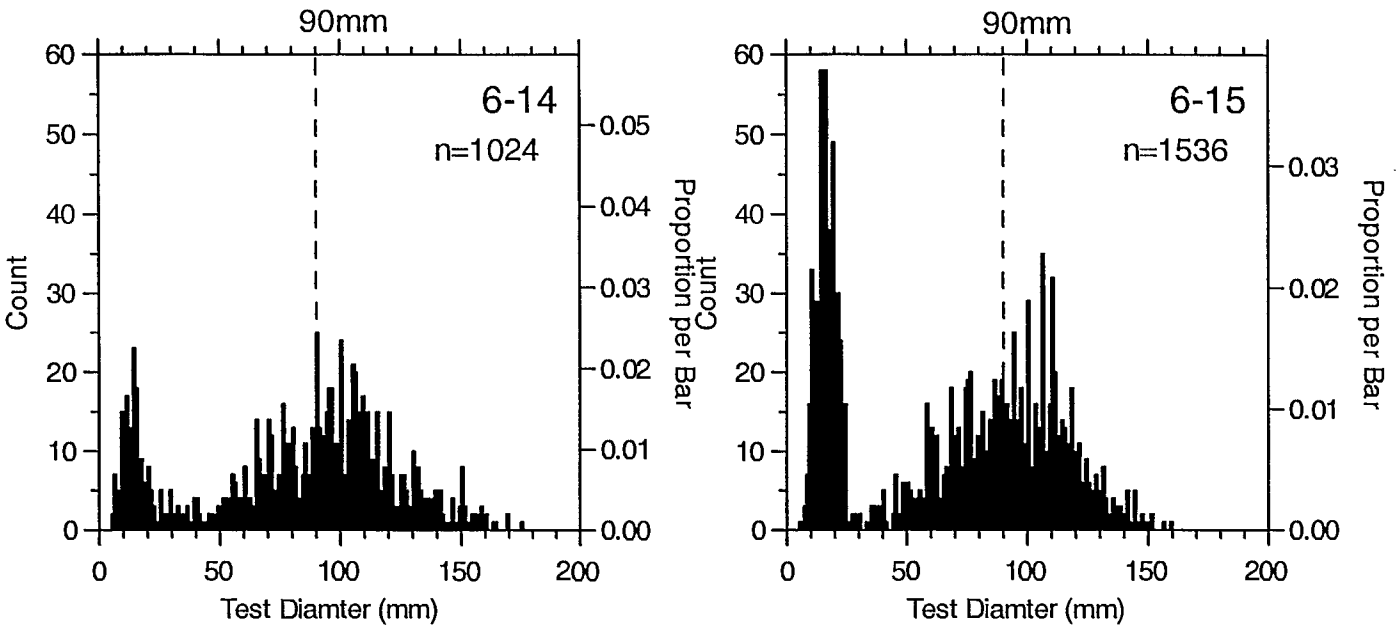

Figure 3. Size frequency distribution, by PFM sub-area, of red sea urchins measured on all transects during the 2000 survey in Laredo Channel (n=2560). The dashed vertical line represents the 90 mm legal commercial size limit.

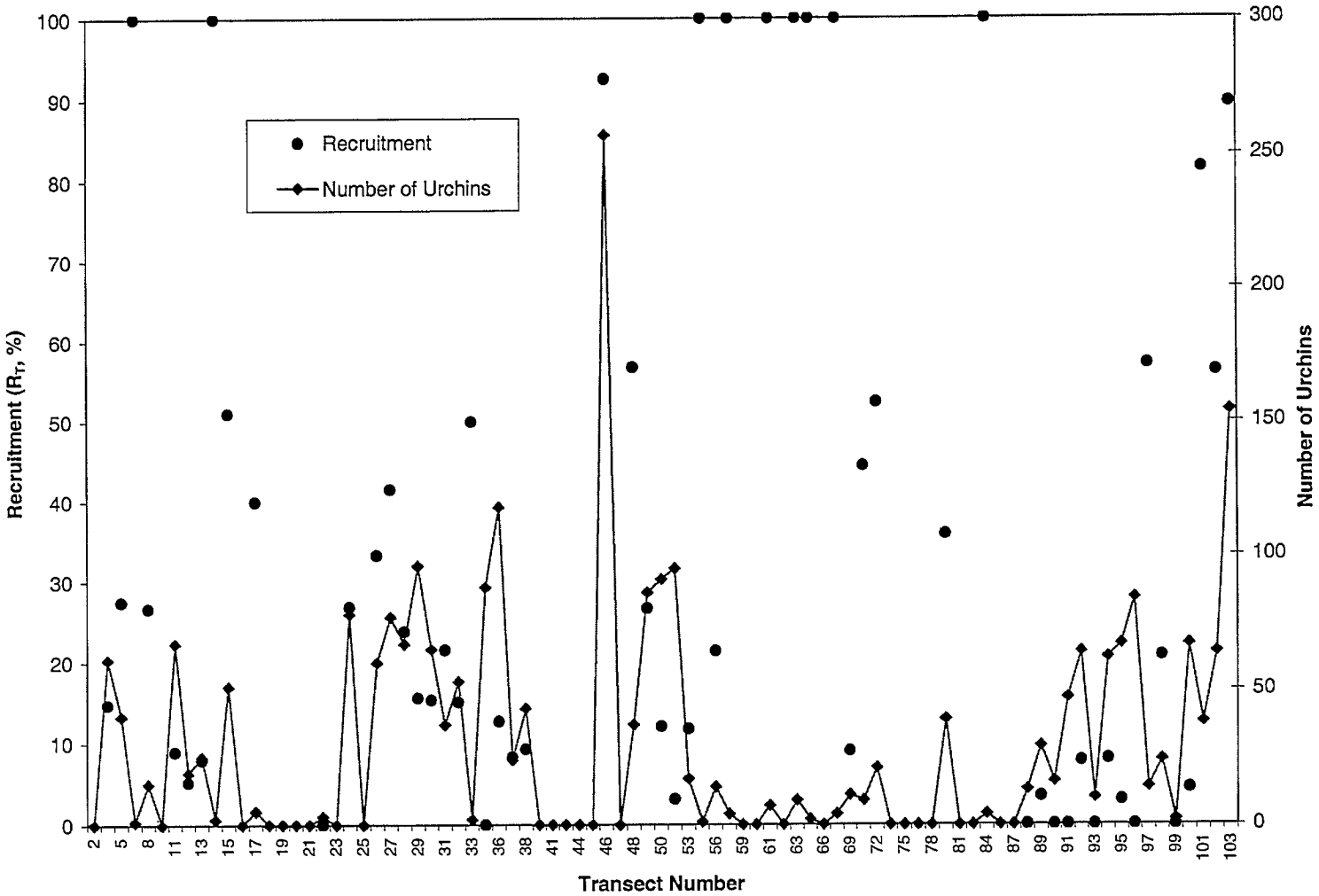

Figure 4. Recruitment and number of red sea urchins measured for each transect surveyed during the 2000 Laredo Channel broadbrush survey.