Survey of Red Sea Urchin Populations in the Tofino Area, British Columbia, 2000

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V9T 6N7

2003

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2630

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Fisheries and Aquatic Sciences 2630

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SURVEY OF RED SEA URCHIN POPULATIONS IN THE TOFINO AREA, BRITISH COLUMBIA, 2000

by

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Cat. No. Fs 97-4/2630E ISSN 0706-6473

Correct citation for this publication:

Tzotzos, D., A. Campbell, and D. Bureau. 2003. Survey of red sea urchin populations in the Tofino area, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2630: 17 p.

ABSTRACT

Tzotzos, D., A. Campbell, and D. Bureau. 2003. Survey of red sea urchin populations in the Tofino area, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2630: 17 p.

A survey of red sea urchin populations in the Tofino area, parts of Pacific Fishery Management (PFM) Areas 24 and 124, was conducted in September 2000. A total of 56 randomly placed transects were surveyed by SCUBA divers. Estimated mean density was 2.39 urchins per m^2. Estimated mean biomass was 621.9 g/m^2. Overall, 12.5% of the total number of urchins measured were ≤50 mm test diameter (TD) whereas 46.7% were of legal size (≥ 90 mm TD) for the commercial fishery.

RÉSUMÉ

Tzotzos, D., A. Campbell, and D. Bureau. 2003. Survey of red sea urchin populations in the Tofino area, British Columbia, 2000. Can. Manuscr. Rep. Fish. Aquat. Sci. 2630: 17 p.

Un relevé des populations d'oursins rouges de Tofino, qui fait partie des secteurs d'exploitation des pêcheries du Pacifique 24 et 124, a été réalisé en septembre 2000. Des plongeurs autonomes ont effectué ce relevé sur 56 transects placés aléatoirement. La densité moyenne estimée s'élevait à 2,39 oursins par m^2. La biomasse moyenne était estimée à 621,9 g/m^2. Dans l'ensemble, le diamètre du test de 12,5 % du nombre total d'oursins mesurés était ≤ 50 mm, alors que 46,7 % 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). The red sea urchin is found throughout shallow rocky subtidal habitats of British Columbia (BC) (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, 2003b, 2003c).

Fishery managers requested that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. The Tofino area [parts of Pacific Fishery Management (PFM) Area 24, sub-areas 2, 6, and 8, and PFM Area 124, sub-area 3], along the west coast of Vancouver Island (Figure 1, Figure 2), was selected for survey through discussion between DFO and PUHA. 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).

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in the area between Sydney Inlet and Templar Channel. The survey was completed in PFM sub-areas 24-2, 24-6, 24-8, and 124-3. Transect locations were selected and plotted on a marine chart prior to the survey to avoid biases in the

field. 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.

Transect layout along the shoreline was done by systematically placing transects along shore 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 September 19 and September 29, 2000, aboard the vessel "Gin", a commercial red sea urchin fishing vessel. The PUHA provided a crew of six people. The vessel tied up in Tofino 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 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. In such cases, 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:

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

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

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:

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

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 percent 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).

RESULTS

SURVEY LOGISTICS

A total of 56 transects were surveyed in 10 days (Table 1, Figure 1, Figure 2). A total of 5566 red sea urchins were counted, and 2883 were measured in 1919 quadrats on the 56 transects. Total transect length surveyed was 4679 m, for an average transect length of 84 m. One transect, number 39, was not surveyed by SCUBA divers, as it consisted entirely of sand substrate. Twenty-three (23) transects were located in the commercial red sea urchin beds

recorded from 1997 to 2000. Of the 56 transects surveyed, 9 (1 in beds) were in PFM sub-area 24-2, 26 (14 in beds) were in PFM sub-area 24-6, 8 (5 in beds) were in PFM sub-area 24-8, and 12 (3 in beds) were in PFM sub-area 124-3.

SUBSTRATE AND HABITAT

The primary substrate was rock in 49.9%, sand in 50.0%, and mud in 0.1% of the 1919 quadrats sampled.

Out of a total 5566 red sea urchins counted, 88.8% were observed between 0.0 m and 10.0 m (Table 2). Of the total, 5178 (93.0%) urchins were observed on transects with high exposure. Of the 56 transects sampled, 40 were in areas of high exposure. The highest mean number of red sea urchins was observed between 0.0 m and 2.5 m (Table 2). The depth range of 0.0 - 2.5 m also had the highest mean percent canopy and encrusting algae cover.

SIZE FREQUENCY DISTRIBUTIONS

The overall mean size of red sea urchins measured was 84.0 mm TD (Table 3, Figure 3). The smallest and largest urchins measured were 8 mm and 176 mm TD, respectively. The overall percent of legal sized urchins (≥90 mm TD) was 46.7%, whereas the overall percent of urchins ≤50 mm TD (R_T) was 12.5%. Of the sublegal urchins, the percent that were ≤50 mm TD (R_S) was 23.5%. Red urchin size frequencies by PFM sub-area are shown in Figure 4.

DENSITY AND BIOMASS ESTIMATES

For transects that fell within recorded red sea urchin beds, the estimated mean density of urchins of all sizes was 2.39 urchins m^{-2}, and 1.17 urchins m^{-2} for legal sized urchins (Table 4). The estimated mean biomass of red sea urchins of all sizes was 621.9 g/m^2, and 469.2 g/m^2 for legal sized urchins (Table 4). For all transects combined, the estimated mean density and biomass for urchins of all sizes was 2.35 urchins m^{-2}, and 578.5 g/m^2 respectively, and 1.06 urchins m^{-2}, 418.1 g/m^2 for legal sized urchins (Table 4).

DISCUSSION

The size frequency distribution of red sea urchins from the current survey indicated a recruitment of R_T=12.5%, R_S=23.5% (Table 3, Figure 2), which falls within the 0% to 27% range observed for southern British Columbia (Adkins et al. 1981; Breen et al. 1976, 1978; Sloan et al. 1987).

PFM sub-area 124-3, where all the transects had exposure values of 8, had one of the highest recruitment rates in the survey, and the highest densities of red sea urchins (Table 3, Table 4). The high densities of mature urchins could provide some measure of protection for juveniles. 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).

The percentage of legal sized urchins (≥90 mm TD) in the present survey was 46.7% (Table 3), which is lower than the value observed during the 2001 Becher Bay survey (Tzotzos et al. 2003a).

Density and biomass estimates from the current survey (2.39 urchins per m^2; 621.9 g/m^2) were higher than the values observed during the Becher Bay survey conducted in 2001. Density and biomass estimates for the Becher Bay survey were 0.33 urchins per m^2, and 194.6 g/m^2, respectively (Tzotzos et al. 2003a).

There are some interesting differences in the density and biomass estimates between the transects that fell within the recorded red sea urchin harvest beds and those that were outside the beds. In PFM sub-areas 24-2 and 124-3, the densities of urchins ≥90 mm TD was higher within the beds than outside the beds (Table 4). In the same sub-areas, the estimated biomass of urchins ≥90 mm TD was lower within the beds than outside the beds (Table 4). This inverse relationship results from a lower mean TD for the ≥90 mm size range, and may be an effect of past harvesting. The standard errors of the mean density and biomass estimates for several of the PFM sub-areas were high due to the low number of transects surveyed (Table 4). A more intensive survey could help to provide more accurate information on changes in the population structure of red sea urchins in harvested areas.

Sea otter populations may be expanding in the Tofino area, and may become a significant influence on red sea urchin populations in the near future. Continued surveys in the area could yield important information on the effects of the growing sea otter population on stocks of commercially fished red sea urchins.

ACKNOWLEDGEMENTS

We thank Cory Carmen, Edith Kraus, Clint Ridgway, and Brian Crawford, for participating in the dive survey, Ken Ridgway Jr. for boat tending, the PUHA for providing financial and logistical support for the survey, and Wayne Hajas for statistical analysis support.

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Table 1. Summary of transects surveyed during the 2000 red sea urchin (RSU) population survey in the Tofino area. 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)		Time		Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
				Minimum	Maximum	Start	End							
1	24-2	49 22.593	126 15.489	-1.49	11.34	13:23	13:36	13	33	17	21	1.24	201.05	
2	24-2	49 21.664	126 15.148	1.10	11.92	12:00	12:16	16	21	11	68	6.18	1247.80	
3	24-2	49 23.483	126 14.004	-2.10	11.61	13:46	13:57	11	39	20	13	0.65	184.04	
4	24-2	49 22.435	126 13.747	-1.43	7.16	13:01	13:10	9	73	8	0	0.00	0.00	
5	24-2	49 21.772	126 13.959	-1.28	5.24	12:31	12:45	14	91	46	54	1.17	176.54	
6	24-2	49 21.194	126 14.054	0.79	9.57	11:26	11:47	21	99	49	50	1.02	136.91	
7	24-2	49 20.289	126 14.275	4.30	12.71	10:53	11:09	16	55	28	0	0.00	0.00	
8	24-2	49 20.155	126 14.446	1.83	13.20	10:40	10:46	6	25	13	0	0.00	0.00	
9	24-2	49 19.49	126 14.405	2.65	13.53	10:11	10:30	19	55	28	31	1.11	257.04	✓
10	24-6	49 15.705	126 9.016	3.87	10.67	10:14	10:46	32	147	74	58	0.78	147.67	
14	24-6	49 14.499	126 6.521	1.65	11.70	11:22	11:52	30	51	26	204	7.85	973.55	
19	24-6	49 14.659	126 4.129	-0.21	4.91	10:45	11:07	22	103	52	63	1.21	221.10	✓
20	24-6	49 15.119	126 3.291	-0.55	4.15	11:23	11:35	12	113	12	0	0.00	0.00	✓
22	24-6	49 13.656	126 5.484	1.16	8.38	9:24	9:54	30	183	92	139	1.51	209.37	
25	24-6	49 13.378	126 3.91	-0.34	3.35	11:54	12:10	16	63	32	106	3.31	463.12	✓
26	24-6	49 13.503	126 2.92	0.34	12.98	9:40	10:17	37	83	42	161	3.83	700.18	
27	24-6	49 13.946	126 1.055	7.77	12.22	12:34	12:52	18	23	12	40	3.33	745.43	
28	24-6	49 14.47	125 0.231	-0.46	3.57	15:02	15:15	13	163	11	0	0.00	0.00	✓
29	24-6	49 13.996	125 59.128	0.73	5.03	14:05	14:37	32	109	55	86	1.56	418.84	✓
30	24-6			-0.27	13.11	10:30	10:41	11	39	20	17	0.85	432.28	✓
31	24-6			-0.06	12.68	10:03	10:15	12	19	10	34	3.40	1715.54	
32	24-6	49 13.507	125 57.642	-0.46	12.89	9:41	9:53	12	21	11	12	1.09	640.89	
33	24-6	49 12.592	125 55.903	-0.64	13.29	11:22	11:43	21	159	15	0	0.00	0.00	
34	24-6	49 12.682	125 57.294	0.52	13.41	13:09	13:31	22	133	67	27	0.40	144.61	✓
35	24-6			1.31	8.99	12:24	12:44	20	191	12	0	0.00	0.00	
36	24-6	49 13.1	126 0.785	0.79	9.63	11:42	12:02	20	173	11	0	0.00	0.00	✓

Continued next page

Table 1 (cont'd)

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
37	24-6			3.81	13.23	10:49	11:10	21	165	82	94	1.15	238.66	✓
38	24-6	49 12.565	126 2.405	0.09	7.62	9:16	10:05	49	151	76	278	3.66	559.46	✓
39	24-6							0	0	0	0	0.00	0.00	
40	24-6	49 10.927	126 2.757	0.43	12.47	10:39	11:23	44	163	82	343	4.18	480.57	✓
41	24-6			1.28	13.08	11:52	12:14	22	21	11	32	2.91	601.95	
42	24-6	49 11.403	126 4	2.50	11.03	14:21	14:43	22	51	26	176	6.77	440.22	
43	124-3	49 11.106	126 4.674	2.50	13.78	13:57	14:07	10	21	11	11	1.00	524.48	
44	124-3			2.16	13.69	13:19	13:45	26	43	22	210	9.55	1039.63	✓
45	124-3	49 10.04	126 5.424	4.18	12.95	12:34	12:58	24	49	25	108	4.32	304.84	
46	124-3	49 9.765	126 3.091	1.95	14.39	13:13	13:33	20	49	25	30	1.20	111.73	
47	124-3	49 9.39	126 2.676	1.77	13.44	12:00	12:59	59	115	58	651	11.22	721.62	
48	24-6	49 10.067	126 1.599	-0.58	8.17	13:56	14:19	23	85	43	150	3.49	400.96	
49	124-3	49 9.823	126 1.51	-0.15	6.49	14:31	15:02	31	91	46	352	7.65	527.72	
51	124-3	49 9.421	126 1.229	0.94	8.29	16:25	16:49	24	71	36	158	4.39	577.43	✓
52	124-3	49 9.037	126 1.531	1.62	13.44	11:22	11:39	17	35	18	68	3.78	259.10	✓
53	124-3	49 8.975	126 1.179	1.77	12.41	10:53	11:04	11	29	15	4	0.27	68.23	
54	24-8	49 9.389	125 59.901	-0.24	9.17	14:20	15:20	60	145	73	281	3.85	607.79	
55	24-8	49 8.761	125 59.34	0.40	10.33	12:47	13:56	69	57	29	339	11.69	1739.21	✓
56	124-3	49 8.599	125 59.415	4.66	13.59	12:07	12:32	25	41	21	38	1.81	407.95	
57	124-3	49 7.521	125 58.397	1.98	12.34	10:29	10:35	6	27	14	1	0.07	14.62	
58	124-3	49 7.125	125 56.77	6.25	12.07	9:37	10:19	42	89	45	91	2.02	525.90	
59	24-8	49 7.357	125 55.929	3.75	13.44	13:38	14:45	67	149	75	702	9.36	721.28	✓
60	24-8	49 7.688	125 55.769	2.19	8.60	12:58	13:16	18	155	78	27	0.35	104.05	✓
61	24-8	49 8.591	125 56.039	-0.24	4.91	12:20	12:39	19	147	74	1	0.01	8.65	
62	24-8	49 7.699	125 55.921	1.43	5.43	15:03	15:24	21	95	48	80	1.67	292.06	✓
64	24-6	49 12.731	125 59.757	-1.31	5.76	13:14	13:23	9	101	6	0	0.00	0.00	✓
65	24-6	49 12.678	125 59.483	-0.49	4.11	13:34	13:41	7	81	5	0	0.00	0.00	✓
66	24-6	49 12.779	125 57.939	-0.58	10.12	13:59	14:08	9	17	9	60	6.67	557.77	✓
67	24-8	49 8.906	126 56.845	-1.77	3.99	14:35	14:50	15	105	53	2	0.04	18.99	
68	24-8	49 8.165	126 56.982	2.16	5.03	15:10	15:35	25	67	34	95	2.79	721.39	✓

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 the Tofino area. 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	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	0.64	28	1.00	5.71	20.18	52.21	19.46	61.07
0.0 - <2.5 m	6.72	188	1.32	6.05	29.47	27.74	9.11	66.59
2.5 - <5.0 m	3.24	436	1.62	6.39	13.86	18.02	8.86	58.98
5.0 - <7.5 m	2.86	440	1.51	7.37	4.58	3.73	3.76	57.96
7.5 - <10.0 m	2.42	417	1.50	7.57	0.76	0.88	2.35	51.40
10.0 - <12.5 m	1.48	292	1.51	7.62	0.00	0.29	1.42	63.11
12.5 m	1.51	113	1.43	7.47	0.00	0.07	1.14	54.43

Table 3. Number of red sea urchins measured and percent of urchins ≤50 mm TD and ≥90 mm TD for each Pacific Fishery Management (PFM) sub-area surveyed in the 2000 population survey in the Tofino area. R_T = percent of urchins of all sizes that were ≤50 mm TD. R_S = percent of sublegal urchins that were ≤50 mm 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	
24-2	80.2	14	165	187	38	84	20.3	36.9	44.9
24-6	88.8	8	176	1142	107	629	9.4	20.9	55.1
24-8	84.0	13	170	785	93	344	11.8	21.1	43.8
24 Total	86.2	8	176	2114	238	1057	11.3	22.5	50.0
124-3	78.0	10	146	769	123	289	16.0	25.6	37.6
Survey Total	84.0	8	176	2883	361	1346	12.5	23.5	46.7

Table 4. Estimates of density and biomass of red sea urchins (RSU), by Pacific Fishery Management sub-area, for the 2000 survey in the Tofino area. 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
24-2	Within Beds	1	55	1.11	0.46	--	--	257.0	151.7	--	--
	Outside Beds	8	436	0.93	0.42	0.35	0.19	211.5	163.8	90.4	75.2
	All	9	491	0.95	0.43	0.31	0.17	216.6	162.4	80.1	66.2
24-6	Within Beds	14	1574	1.35	0.82	0.48	0.27	402.0	328.8	130.8	102.1
	Outside Beds	12	1034	1.91	0.87	0.68	0.29	483.6	352.5	161.9	117.6
	All	26	2608	1.57	0.84	0.38	0.19	434.4	338.2	98.3	75.3
24-8	Within Beds	5	523	4.70	2.05	2.34	0.84	1188.6	868.0	507.7	334.6
	Outside Beds	3	397	1.42	0.59	--	--	341.8	220.0	--	--
	All	8	920	3.29	1.42	1.49	0.56	823.2	588.4	333.2	223.2
24 Total	Within Beds	20	2152	2.16	1.11	0.71	0.29	589.5	455.3	165.1	115.4
	Outside Beds	23	1867	1.58	0.71	0.43	0.18	389.9	280.3	102.6	72.3
	All	43	4019	1.89	0.92	0.43	0.18	496.8	374.0	101.5	71.6
124-3	Within Beds	3	149	5.73	2.01	--	--	1091.0	669.9	--	--
	Outside Beds	9	511	4.98	1.87	1.79	0.70	1072.1	691.9	333.9	244.5
	All	12	660	5.15	1.91	1.38	0.57	1076.3	686.9	268.3	200.6
Survey Total	Within Beds	23	2301	2.39	1.17	0.68	0.28	621.9	469.2	157.1	109.8
	Outside Beds	32	2378	2.31	0.96	0.63	0.25	536.5	368.7	131.7	90.3
	All	55	4679	2.35	1.06	0.46	0.19	578.5	418.1	101.5	70.6

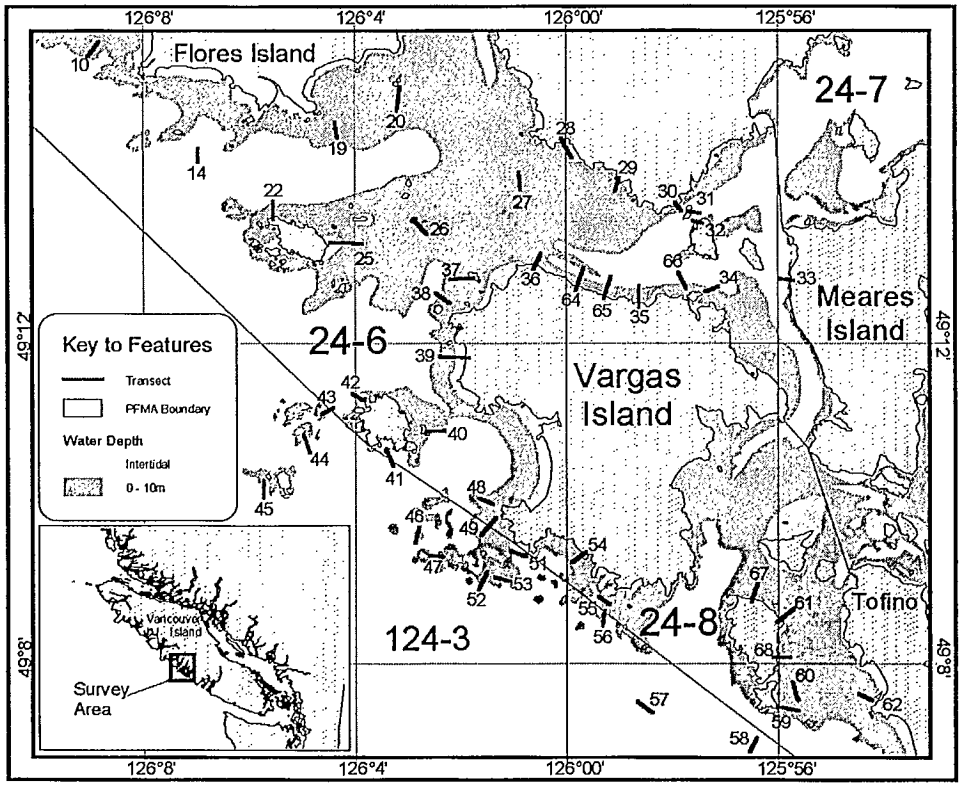

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted in the Tofino area, 2000. Hyphenated numbers indicate Pacific Fishery Management sub-areas and other numbers identify transects. Inset map indicates survey location.

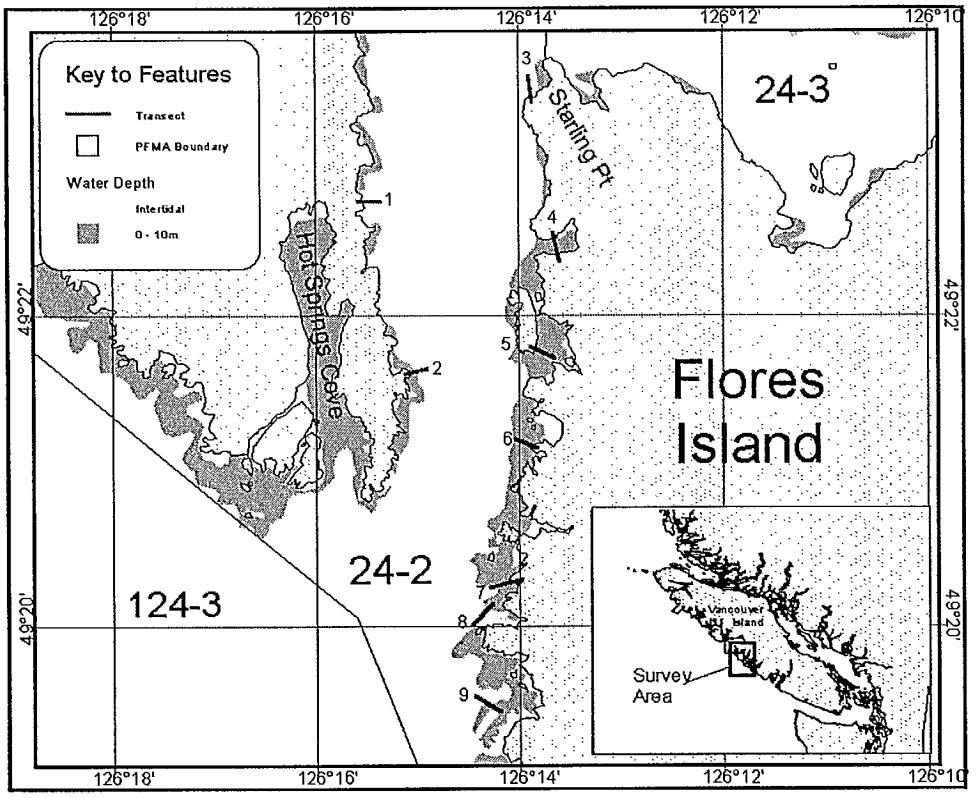

Figure 2. Map of survey area and transect locations for the red sea urchin population survey conducted in the Tofino area, 2000. Hyphenated numbers indicate Pacific Fishery Management sub-areas and other numbers identify transects. Inset map indicates survey location.

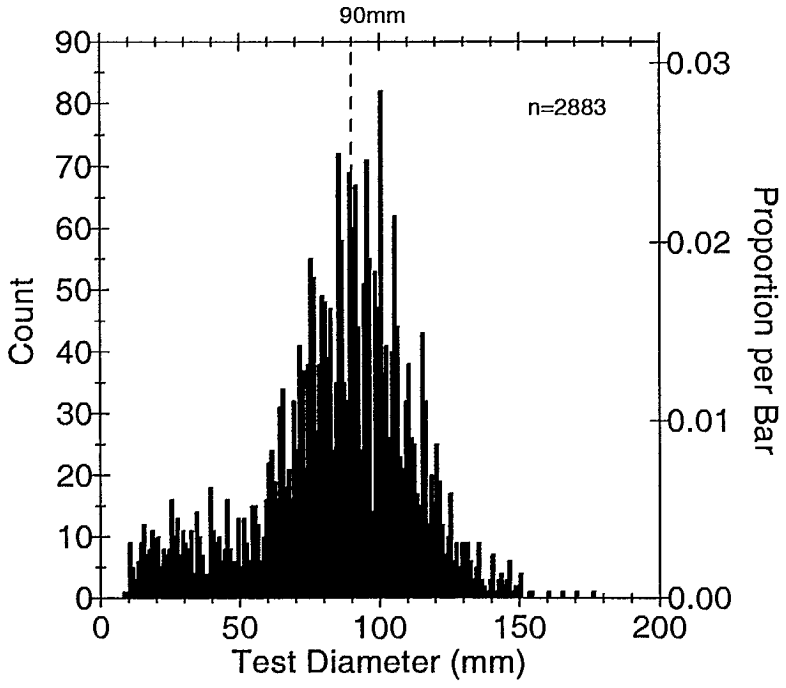

Figure 3. Size frequency distribution of red sea urchins measured on all transects during the 2000 survey in the Tofino area (n=2883). The dashed vertical line represents the 90 mm legal commercial size limit.

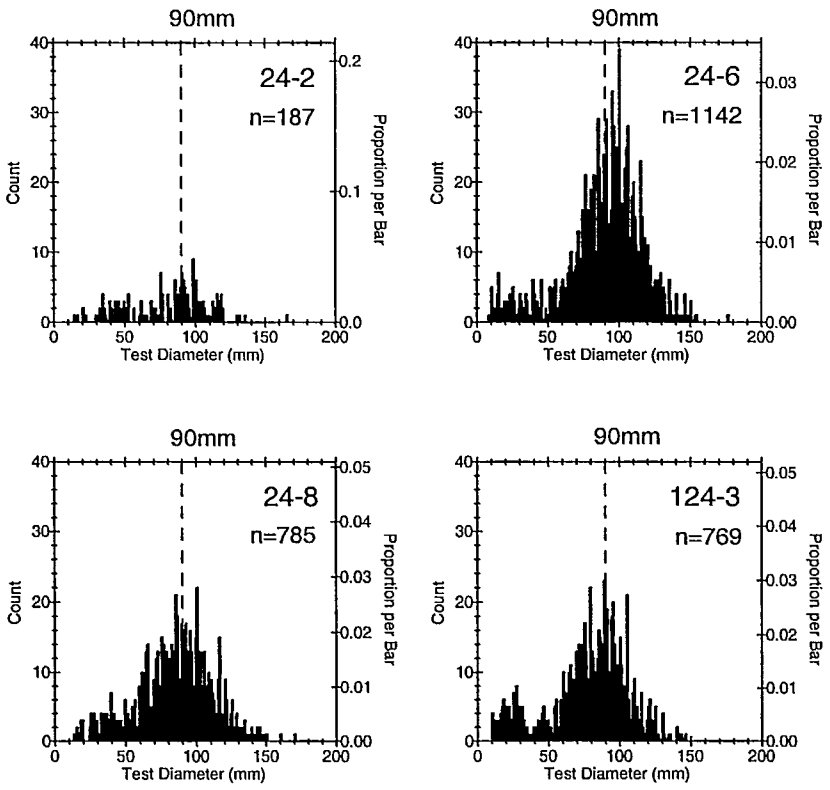

Figure 4. Size frequency distribution, by PFM sub-area, of red sea urchins measured on all transects during the 2000 survey in the Tofino area (N=2883). The dashed vertical line represents the 90 mm legal commercial size limit.