Survey of Red Sea Urchin Populations Near Robson Bight, British Columbia, 2001

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2006

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2755

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Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2755

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SURVEY OF RED SEA URCHIN POPULATIONS NEAR ROBSON BIGHT, BRITISH COLUMBIA, 2001

by

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Cat. No. Fs 97-4 /2755E ISSN 0706-6473

Correct citation for this publication:

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations near Robson Bight, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2755: iii + 23 p.

ABSTRACT

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations near Robson Bight, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2755: iii + 23 p.

A survey of red sea urchin populations was conducted near Robson Bight (Pacific Fisheries Management, PFM sub-areas 12-3 and 12-21) during August, 2001. A total of 60 transects were surveyed by SCUBA divers, and 957 red sea urchins were measured. The density of red sea urchins in PFM sub-area 12-3 and in PFM sub-area 12-21 for red sea urchins of all sizes was 0.83/m^2 and 0.63/m^2, respectively, and for legal-sized red sea urchins (≥90 mm test diameter, TD) the density was 0.69/m^2 and 0.53/m^2, respectively. No significant differences were observed in estimated mean density (number/m^2) and biomass (g/m^2) between red sea urchins found inside (12 transects) compared with outside (48 transects) previously fished commercial bed areas. Overall, 5.0% of the total number of red urchins measured were ≤50 mm TD whereas 83.9% were of legal size for the commercial fishery.

RÉSUMÉ

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations near Robson Bight, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2755: iii + 23 p.

Un relevé des populations d'oursins rouges a été réalisé en août 2001 près de la baie Robson (sous-secteurs 12-3 et 12-21 de gestion des pêches du Pacifique). Au total, 60 transects ont été couverts par des plongeurs autonomes, qui ont mesuré 957 oursins rouges. Dans les sous-secteurs 12-3 et 12-21, la densité (nombre/m^2) des oursins rouges de toutes tailles était respectivement de 0,83/m^2 et 0,63/m^2, et, pour les oursins de taille réglementaire (≥90 mm de diamètre du test, DT), la densité était respectivement de 0,69/m^2 et 0,53/m^2. On n'a pas noté de différences significatives dans la densité moyenne estimée (nombre/m^2) ni dans la biomasse (g/m^2) entre les oursins rouges observés à l'intérieur (12 transects) et à l'extérieur (48 transects) de gisements auparavant exploités par la pêche commerciale. Dans l'ensemble, 5,0 % de tous les oursins rouges mesurés présentaient ≤50 mm DT, tandis que 83,9 % avaient la taille réglementaire 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 (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 traditional food, social and ceremonial fisheries. The commercial red sea urchin fishery began in British Columbia (BC) 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 were 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 sea urchin fishery.

Early red sea urchin population surveys were conducted during the 1970's and 1980's by Breen et al. (1976, 1978), Adkins et al. (1981) 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-d; Bureau et al. 2000a-d; Tzotzos et al. 2003a-d, 2006; Atkins et al. 2006a-g).

Fishery managers requested that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. An area off Robson Bight [Pacific Fishery Management (PFM) sub-areas 12-3 and 12-21] (Figure 1), was selected for survey through discussion between PUHA and DFO. The objective of this paper is to present detailed survey results and to estimate density and biomass of red sea urchins within and outside of commercially fished beds, for PFM sub-areas 12-3 and 12-21.

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in PFM sub-areas 12-3 and 12-21. Transect locations were selected and plotted on a marine chart prior to the survey to avoid bias in the field.

Transects were systematically placed along the shoreline with a random starting point. The ArcView GIS system was used to measure the shoreline length (SL) of the survey area, including islands. The position of the first transect was determined randomly, and subsequent transects were then spaced evenly along the shoreline. Areas of unsuitable red sea urchin habitat (eg. sand and mud substrates) were excluded from the survey area. Since variation in urchin density was unlikely to match the spacing of the transects, the systematic sample was treated as a random sample of transects (Jamieson and Schwarz 1998).

SURVEY LOGISTICS

The survey was conducted between August 1-8, 2001, on the "Monika", a commercial red sea urchin fishing vessel. A crew of five people, consisting of four divers, one of which was a biologist, and the others commercial red sea urchin harvesters, and the boat skipper, was used for the survey.

DIVE SURVEY METHODS

In the field, location of transects were determined from geographical references on the shoreline and GPS. Exposure to wave action/current was recorded, for each transect, as one of nine codes: 0 = extreme shelter, 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. Leadline transects were laid perpendicular to shore from the boat, with a float attached to the deep end of each transect. Transects were laid out from shallow water to a depth of 15m (not corrected for tide), so transect length was dependent on the slope of the substrate and tide height. 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, with callipers, to the nearest millimeter. If urchins could not be measured because they were inaccessible or broken/lost they were still counted, therefore the count of urchins in a quadrat may be higher than the number measured. The depth, substrate type, types of algae (and percent cover), shell length of abalone (*Haliotis kamtschatkana*), and TD of green (*S. droebachiensis*) and purple (*S. purpuratus*) sea urchins present in each 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 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.

DATA ANALYSIS

Habitat

Depth Categories

Gauge depths recorded by divers were corrected to depth below Chart Datum by subtracting tide height from the observed depths. Tide heights from the closest tide station were used to correct depths. The depth (m) for each quadrat was assigned to one of seven depth ranges: 1= <0.0m; 2= 0.0 - <2.5m; 3= 2.5 - <5.0m; 4= 5.0 - <7.5m; 5= 7.5 - <10.0m; 6= 10.0 -<12.5m; and 7= ≥12.5m.

Substrate

The divers record the dominant substrates (up to three) within each quadrat using one of nine generic codes: 1=smooth bedrock; 2=bedrock with crevices; 3=boulders, >30cm; 4=cobble, between 7.5cm and 30cm; 5=gravel, between 2cm and 7.5cm; 6=pea gravel, between 0.25-2cm; 7=sand; 8=shell; and 9=mud. For the analysis, the nine substrate codes were grouped into three main dominant categories: 1=rock (codes 1-5); 2=sand/shell (codes 6-8); and 3=mud (code 9). Each quadrat was assigned a dominant substrate code in order to determine the average percent of each dominant substrate.

Algae

Algal species were assigned to one of four categories based on growth characteristics: canopy (taller than 2m), understorey (30cm to 2m), turf (<30cm), and encrusting. The percent cover of algae in each category, for each quadrat, was calculated as the sum of the individual species' percent cover. Mean percent cover, by growth category, for each depth category was then calculated by averaging the quadrat percent covers over the depth category.

Estimation of Density and Biomass

Density and biomass estimates were calculated from transects that were located inside commercially harvested red sea urchin beds, for transects located outside of the harvested beds, and for all transects combined. Commercially harvested beds were defined as areas where commercial harvesting occurred between 1997 and 2000; therefore, areas defined as outside beds may have had fishing events prior to 1997 and/or after 2000. The process involved in defining the commercially harvested urchin beds was described by Campbell et al. (2001).

Densities and biomass were estimated for red urchins in three size groups: a) all sizes, b) small urchins <50 mm TD, and c) urchins of legal size for the commercial fishery (≥90 mm TD). Estimates of mean density and biomass were calculated using the equations below.

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

$$d_{ts} = \frac{N_{ct}}{a_t} * \frac{N_{mts}}{N_{mt}} \quad (1)$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mts} is the number of red urchins measured in size group s on transect t, N_{mt} is the total number of red 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 a weighted mean of transect densities:

$$\overline{d_s} = \frac{\sum_t (d_{ts} * L_t)}{\sum_t L_t} \quad (2)$$

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:

$$s_d = \sqrt{1 - \frac{n}{T}} * \sqrt{\frac{\sum_t (d_{ts} * L_t - \overline{d}_s * L_t)^2}{n * (n-1) * \overline{L}^2}} \quad (3)$$

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:

$$\overline{L} = \frac{\sum_t L_t}{n} \quad \text{(Campbell et al. 1999b)} \quad (4)$$

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

$$W = 0.0012659 * TD^{2.7068} \quad \text{n= 167, } r^2\text{=0.960} \quad (5)$$

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:

$$b_{ts} = \frac{N_{ct}}{N_{mt}} * \frac{\sum W_{ts}}{a_t} \quad (6)$$

where N_{ct} is the total number of red urchins counted on transect t, N_{mt} is the total number of red urchins measured on transect t, ΣW_{ts} is the sum of the weights of red 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 as a weighted mean of transect biomass:

$$\overline{b_s} = \frac{\sum_t (b_{ts} * L_t)}{\sum_t L_t} \qquad \text{(Campbell et al. 1999b)} \qquad (7)$$

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. The biomass estimate, for each PFM sub-area surveyed, was converted into quota recommendations for management purposes by Campbell et al. (2001).

A Kruskal Wallace Analysis (Systat 10) was used to compare red urchin densities between inside and outside of commercial beds overall and for each PFM sub-area.

Density and biomass estimates were also generated by depth.

Recruitment

Estimates of recruitment (R_T) of red sea urchin populations in BC have generally been expressed as a percentage 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). For comparison purposes, the same method was used here. Recruitment was also calculated as a percentage of the total number of sub-legal 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 may be reduced due to the harvest (Tegner and Dayton 1981).

RESULTS

SURVEY LOGISTICS

In total, 60 transects were surveyed during eight dive days (Table 1, Figure 1). A total of 964 red sea urchins were counted and 957 were measured for TD in 1189 quadrats along the 60 transects. By PFM sub-area, 857 red urchins were measured along 51 transects in area 12-3, and 107 red urchins were measured along 9 transects in area 12-21. The total transect length surveyed was 2318 m, for an average transect length of 39 m. Overall, 12 of the transects were located on commercial red sea urchin

beds recorded from 1997 to 2000, and the remaining 48 transects were located outside commercial bed areas (Table 1).

SUBSTRATE AND HABITAT

All transects were located in areas of moderate or high exposure, with the exception of three transects located in areas of minimal sea movement (Table 1). Of the total (1189) quadrats sampled, 60% had rock, 29% had sand/shell, and 11% had mud as the primary substrate. Of the 964 red sea urchins counted, 78% were observed between 0.0 m and 7.5 m depth.

Understorey, and encrusting algae were consistently encountered at all depths surveyed; canopy and turf species of algae decreased in abundance with increased depth (table 2).

SIZE FREQUENCY DISTRIBUTION

The overall mean size of red sea urchins measured was 117.8 mm TD (Table 3, Figure 2). The smallest and largest red urchins measured were 9 mm and 177 mm TD, respectively. By PFM sub-area, 12-3 and 12-21 had a mean size of 117.9 mm TD and 117.2 mm TD, respectively. The overall mean size of red urchins on and outside of commercial bed areas was 115.3 mm and 118.8 mm TD, respectively.

The overall percentage of legal-sized red urchins (≥90 mm TD) was 83.9%, whereas the overall percentage of red urchins ≤50 mm TD (R_T) was 5.0%. Of the sublegal urchins, the percentage that was ≤50 mm TD (R_S) was 31.2%. By PFM sub-area, the percentage of legal-sized red sea urchins in sub-areas 12-3 and 12-21 was 83.9% and 84.1%, the percentage of red urchins ≤50 mm TD (R_T) was 4.8% and 6.5%, and the percentage of sublegal red urchins ≤50 mm TD (R_S) was 29.9% and 41.2%, respectively (Table 3).

Eighty two percent (81.9%) of the red sea urchins sampled inside commercial bed areas (n=259) were of legal size, as were 84.7% of the urchins sampled outside commercial bed areas (n=698). In area 12-3, the percentage of the population surveyed inside and outside commercial bed areas that was of legal size was 82.3% and 84.3%, respectively. In area 12-21, the percentage of legal-sized red sea urchins found inside and outside commercial bed areas was 80.8% and 93.1%, respectively (Table 3).

DENSITY AND BIOMASS ESTIMATES

Overall, the estimated mean density and biomass for red sea urchins of all sizes was 0.80/m^2 and 468.69 g/m^2, respectively, and 0.67/m^2 and 453.72 g/m^2 for legal-sized red urchins (Table 4). Although differences in density and biomass between in and out

of commercial bed areas were observed over all size classes, the differences were not significant (Table 5).

Overall (PFM sub-areas combined), for transects lying within recorded red sea urchin beds, the estimated mean density of red urchins of all sizes was 1.24/m^2, and was 1.01/m^2 for legal-sized urchins (Table 4). For transects lying outside of commercial bed areas, the estimated mean density was 0.71/m^2 for red urchins of all sizes, and 0.60/m^2 for legal-sized urchins. Inside bed areas, the estimated mean biomass of red sea urchins of all sizes was 694.47 g/m^2, and was 670.97 g/m^2 for legal-sized urchins; outside bed areas the estimated mean biomass was 420.46 g/m^2 and 407.31 g/m^2, respectively (Table 4).

By PFM sub-area, the estimated mean density for all sizes in sub-area 12-3 was 0.83/m^2 and in sub-area 12-21 it was 0.63/m^2; the mean density of legal-sized urchins was 0.69/m^2 and 0.63/m^2, respectively (Table 4). When comparing densities by PFM sub-areas, densities were significantly higher inside than outside of commercial bed areas in sub-area 12-21 for all size groupings, but no significant differences were observed in sub-area 12-3 (Table 5).

The highest mean density and biomass of red sea urchins of any size category was observed in the 0.0–2.5 m depth range for both inside and outside of commercial bed areas (Tables 6 and 7), although no statistical tests were performed.

DISCUSSION

The mean TD of red sea urchins observed during this survey near Robson Bight (117.8 mm TD) was larger than all other broad brush surveys completed from 2000 to 2004, with the exception of a survey completed in 2001 in Becher Bay (118.1 mm TD) (Tzotzos et al. 2003d). Robson Bight and Becher Bay also have the lowest estimated mean densities of all broad brush surveys completed from 2000 to 2004 (Bureau et al. 2000a-d; Tzotzos et al. 2003a-d, 2006; Atkins et al. 2006a-g). The mean density of red sea urchins in Robson Bight was 0.80/m^2 overall, and 1.24/m^2 inside commercial bed areas. The large TD, coupled with low overall densities provides little incentive for commercial harvesters to fish this area.

Recruitment (R_T) estimates observed during this survey were also low. Recruitment was measured as the percent of the total population that was $\leq$50 mm TD. The overall recruitment was 5.4% within commercial bed areas, and 4.9% outside beds areas. In PFM sub-area 12-21 recruitment was zero outside bed areas, however the sample size was small (6 transects). Numerous factors could influence recruitment at any given area including physical and oceanographic influences, predation on larvae and juveniles, and interactions between juveniles and adults (Kalvass 1992; Sloan et al. 1987). High currents may play a major role in keeping local recruitment at a low level.

In both PFM sub-areas, inside and outside of commercial bed areas, the highest density estimates were found at the depth range between 0 and 2.5 m, which could

have been due to the depth where their food, algae and algal drift were most abundant. Overall, canopy, understorey and encrusting algae were most abundant at that depth range.

ACKNOWLEDGEMENTS

We thank Dominique Bureau, Janusz Pawlowski and Wacek Jarosz for conducting the dive survey; Marc Ulanowski for boat tending; the PUHA for providing financial and logistical support for the survey; Leslie Barton for preparing figure 1; and Dan Leus and Kim Davies for reviewing this paper.

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Table 1. Summary of transects surveyed during the Aug 1-8, 2001 red sea urchin (RSU) population survey near Robson Bight. Density in number per square meter and biomass in grams per square meter. PFM = Pacific Fishery Management [sub-area]. Depths have been corrected to chart datum. Exposure values: 1 = extreme shelter, 4 = moderate exposure, 8 = high exposure. Check marks (✓) indicate transect lying within a known commercial RSU bed.

Transect	PFM Sub-area	Latitude	Longitude	Depth (m)		Exposure	Time		Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
				Minimum	Maximum		Start	End							
1	12-3	50 34.234	126 46.771	-0.79	8.56	1	15:16	15:30	14	27	14	13	0.93	941.82	
2	12-3	50 33.970	126 46.654	-0.43	12.07	4	09:57	10:44	47	37	19	32	1.68	785.23	
3	12-3	50 33.811	126 46.331	-0.76	9.75	8	10:59	11:57	58	85	43	54	1.26	584.39	
4	12-3	50 33.656	126 45.508	-1.31	8.44	8	12:17	12:48	31	31	16	7	0.44	212.72	✓
5	12-3	50 33.480	126 44.531	-1.58	8.63	4	13:03	13:20	17	19	10	45	4.50	1952.58	✓
6	12-3	50 33.424	126 43.835	-0.15	11.34	8	14:05	14:44	39	49	25	36	1.44	1215.54	✓
7	12-3	50 33.342	126 42.835	-2.07	9.30	8	13:15	13:43	28	31	16	29	1.81	803.95	✓
8	12-3	50 33.510	126 41.948	-0.98	8.53	4	12:49	13:01	12	41	21	0	0.00	0.00	✓
9	12-3	50 32.778	126 39.756	-1.71	9.72	4	12:14	12:32	18	21	11	17	1.55	834.63	✓
10	12-21	50 32.564	126 38.975	2.50	9.05	4	11:46	12:04	18	25	12	20	1.67	895.93	✓
11	12-21	50 32.649	126 38.810	-1.22	10.27	4	10:53	11:10	17	39	20	25	1.25	754.72	✓
12	12-21	50 32.438	126 38.565	1.55	11.46	8	10:31	10:42	11	17	9	11	1.22	938.50	
13	12-21	50 32.626	126 37.852	-1.49	12.16	4	17:04	17:17	13	25	13	0	0.00	0.00	
14	12-21	50 32.456	126 36.908	-0.79	3.78	1	17:51	17:59	8	61	31	0	0.00	0.00	
15	12-21	50 32.436	126 37.227	-1.43	10.45	1	17:30	17:41	11	51	26	0	0.00	0.00	
16	12-21	50 32.042	126 37.897	-0.55	13.14	8	09:55	10:18	23	29	15	33	2.20	1281.79	✓
17	12-21	50 32.126	126 37.452	-1.62	10.12	4	16:24	16:49	25	41	21	18	0.86	419.71	
18	12-21	50 31.846	126 36.563	-1.58	9.27	4	15:52	16:07	15	43	22	0	0.00	0.00	
19	12-3	50 31.464	126 36.244	-0.30	11.19	8	09:57	10:21	24	37	19	13	0.68	474.66	
20	12-3	50 31.344	126 35.328	-0.79	10.85	8	10:32	10:59	27	37	19	33	1.74	809.92	
21	12-3	50 31.179	126 34.507	0.98	11.92	8	09:05	09:25	20	27	14	20	1.43	941.71	✓
22	12-3	50 31.407	126 33.688	1.58	6.80	4	09:47	10:11	24	65	33	0	0.00	0.00	
23	12-3	50 31.370	126 33.486	0.49	11.92	4	10:21	10:45	24	19	10	19	1.90	946.97	
24	12-3	50 31.493	126 32.961	0.64	10.64	8	11:11	11:35	24	57	29	12	0.41	200.54	
25	12-3	50 31.436	126 31.878	0.15	9.57	8	12:58	13:18	20	85	43	1	0.02	0.35	
26	12-3	50 31.252	126 31.004	-1.74	9.14	8	13:32	13:50	18	19	10	21	2.10	1409.51	
27	12-3	50 31.016	126 30.126	-1.40	8.78	8	14:03	14:17	14	19	10	8	0.80	655.15	
28	12-3	50 30.975	126 29.273	-2.62	7.92	8	14:32	14:56	24	41	21	16	0.76	603.26	
29	12-3	50 30.924	126 28.549	-2.19	8.29	8	15:05	15:35	30	55	28	26	0.93	591.30	
30	12-3	50 30.706	126 27.942	-1.65	8.14	8	15:45	16:01	16	21	11	4	0.36	353.01	
31	12-3	50 30.733	126 27.547	-1.95	7.25	8	15:55	16:30	35	67	34	64	1.88	1189.44	
32	12-3	50 30.846	126 26.616	-2.53	8.11	8	16:47	17:03	16	23	12	4	0.33	270.90	

continued next page

Table 1. continued

Transect	PFM Sub-area	Latitude	Longitude	Depth (m)		Exposure	Time		Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
				Minimum	Maximum		Start	End							
33	12-3	50 30.985	126 24.526	0.79	10.42	8	09:05	09:26	21	19	10	48	4.80	639.66	
34	12-3			1.28	5.00	4	11:04	11:16	12	81	41	0	0.00	0.00	
35	12-3	50 30.773	126 25.752	-0.67	10.03	8	08:23	08:51	28	49	25	34	1.36	808.32	
36	12-3	50 31.265	126 23.894	0.52	11.22	8	10:35	10:48	13	107	54	0	0.00	0.00	
37	12-3	50 31.614	126 23.243	0.88	10.33	8	10:16	10:22	6	69	35	0	0.00	0.00	
38	12-3	50 31.408	126 22.707	0.88	10.91	8	09:53	10:02	9	27	14	30	2.14	892.94	
39	12-3	50 31.238	126 21.885	1.43	9.63	8	09:24	09:39	15	35	18	19	1.06	698.08	
40	12-3	50 29.027	126 21.607	-0.76	10.18	8	12:36	12:58	22	17	9	16	1.78	521.80	
41	12-3	50 28.979	126 22.607	-0.15	9.81	8	13:05	13:20	15	17	9	28	3.11	572.61	
42	12-3	50 29.031	126 23.589	-1.46	8.87	8	13:30	13:51	21	29	15	17	1.13	440.53	
43	12-3	50 28.855	126 24.503	-1.65	11.46	4	13:15	13:37	22	37	19	20	1.05	489.62	
44	12-3	50 28.769	126 25.587	-0.09	10.88	4	12:51	13:00	9	61	31	0	0.00	0.00	
45	12-3	50 28.735	126 26.068	-1.22	8.78	4	14:02	14:15	13	81	41	0	0.00	0.00	
46	12-3			-0.73	11.09	4	14:35	14:45	10	47	24	0	0.00	0.00	
47	12-3	50 28.935	126 27.961	-1.55	8.56	8	14:21	14:27	6	21	11	0	0.00	0.00	
48	12-3	50 28.899	126 28.812	-1.83	8.38	8	14:38	14:58	20	23	12	38	3.17	385.97	
49	12-3	50 29.067	126 29.871	-2.01	8.44	8	15:08	15:22	14	21	12	15	1.25	540.89	
50	12-3	50 29.971	126 38.268	0.70	10.76	8	10:27	10:29	2	19	10	0	0.00	0.00	
51	12-3	50 30.208	126 38.747	0.40	11.06	8	10:47	10:54	7	41	21	0	0.00	0.00	
52	12-3	50 30.721	126 40.061	-0.58	11.03	8	11:06	11:15	9	31	16	0	0.00	0.00	
53	12-3	50 30.966	126 41.017	0.21	10.97	8	11:22	11:40	18	29	15	52	3.47	477.12	
54	12-3	50 31.164	126 41.678	-0.18	10.85	8	11:46	11:55	9	27	14	0	0.00	0.00	
55	12-3	50 31.431	126 42.656	0.61	10.73	8	12:02	12:09	7	27	14	0	0.00	0.00	
56	12-3	50 31.55	126 43.579	0.76	10.61	8	12:16	12:27	11	17	9	7	0.78	582.43	
57	12-3	50 31.895	126 44.359	-1.77	7.50	4	15:41	16:04	23	67	34	27	0.79	436.21	✓
58	12-3	50 32.132	126 45.440	-1.52	8.20	4	14:38	15:00	22	29	15	0	0.00	0.00	✓
59	12-3	50 32.295	126 46.295	-2.47	7.96	8	14:04	14:20	16	31	16	8	0.50	776.18	
60	12-3	50 32.641	126 46.858	-0.24	8.38	4	13:37	13:55	18	15	8	17	2.13	613.59	

Table 2. Mean number of red sea urchins (RSU), mean substrate type, and percent cover of algae for each depth category surveyed during the 2001 survey conducted near Robson Bight. Depths have been corrected to chart datum. Substrate categories: 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, crustose layer on rocks.

Depth	Number of RSU		Number	Mean Substrate	Mean Percent Cover by Algae			
Range (m)	Total	Mean per Quadrat	Of Quadrats	Category	Canopy	Understorey	Turf	Encrusting
PFM sub-area 12-3								
<0.0 m	52	0.5	101	1.02	33.7	45.1	34.6	52.1
0.0 - <2.5 m	268	1.6	172	1.24	51.3	52.3	11.0	58.9
2.5 - <5.0 m	238	0.9	252	1.52	17.8	44.9	5.8	49.9
5.0 - <7.5 m	161	0.6	267	1.64	2.0	39.5	3.8	44.3
7.5 - <10.0 m	106	0.6	176	1.63	3.6	38.5	4.3	44.9
10.0 - <12.5 m	32	0.6	52	1.54	0.3	26.5	1.1	31.9
≥12.5 m				None surveyed				
PFM sub-area 12-21								
<0.0 m	5	0.3	17	1.06	18.2	19.4	50.9	55.0
0.0 - <2.5 m	43	1.2	36	1.56	43.8	42.5	10.8	45.0
2.5 - <5.0 m	24	0.5	45	1.58	41.2	59.2	3.5	49.0
5.0 - <7.5 m	14	0.5	29	2.00	6.9	69.4	0	49.3
7.5 - <10.0 m	16	0.7	23	1.83	0	40.3	0	41.0
10.0 - <12.5 m	4	0.2	18	2.33	0	41.9	0	30.6
≥12.5 m	1	1.0	1	1.00	0	5.0	0	20.0
PFM sub-area 12-3 and 12-21 combined								
<0.0 m	57	0.5	118	1.03	31.1	40.9	37.3	52.6
0.0 - <2.5 m	311	1.5	208	1.30	50.0	50.6	11.0	56.5
2.5 - <5.0 m	262	0.9	297	1.53	21.3	46.9	5.5	49.8
5.0 - <7.5 m	175	0.6	296	1.67	2.5	42.1	3.4	44.7
7.5 - <10.0 m	122	0.6	199	1.65	3.0	38.7	3.7	44.4
10.0 - <12.5 m	36	0.5	70	1.74	0.2	29.3	0.8	31.7
≥12.5 m	1	1.0	1	1.00	0	5.0	0	20.0

Table 3. Number of red sea urchins measured and percentage of urchins ≤50 mm TD and ≥90 mm TD for Pacific Fishery Management (PFM) sub-areas 12-3 and 12-21, surveyed during the 2001 population survey near Robson Bight. R_T = percent of all red urchins that were ≤50 mm TD. R_S = percent of sublegal urchins that were ≤50 mm TD.

PFM Sub- Area	Transects Used	Test Diameter (mm)			Numbers Measured			% Total Measured		% Sublegal
		Mean	Minimum	Maximum	Total	≤50 mm TD	≥90 mm TD	≤50 mm (R_T)	≥90 mm	≤50 mm (R_S)
12-3	Within Beds	115.1	22	177	181	7	149	3.9	82.3	21.9
	Outside Beds	118.7	9	172	669	34	564	5.1	84.3	32.4
	All	117.9	9	177	850	41	713	4.8	83.9	29.9
12-21	Within Beds	115.7	31	171	78	7	63	9.0	80.8	46.7
	Outside Beds	121.2	65	157	29	0	27	0.0	93.1	0.0
	All	117.2	31	171	107	7	90	6.5	84.1	41.2
Survey Total	Within Beds	115.3	22	177	259	14	212	5.4	81.9	29.8
	Outside Beds	118.8	9	172	698	34	591	4.9	84.7	31.8
	All	117.8	9	177	957	48	803	5.0	83.9	31.2

Table 4. Mean density and biomass estimates of red sea urchins by size (test diameter, TD), within and outside of commercial beds, by Pacific Fishery Management sub-area, for the 2001 survey near Robson Bight. Estimates are for transects within red sea urchin beds recorded between 1997-2000, for transects outside the beds, and for all transects combined. Values in brackets are standard errors.

PFM Sub-Area	Transects Used	Number of Transects	Sum of Transect Lengths (m)	Mean Density (no./m^2) by TD			Mean Biomass (g/m^2) by TD		
				≤50 mm	≥90 mm	All Sizes	≤50 mm	≥90 mm	All Sizes
12-3	Within Beds	9	315	0.04 (0.02)	0.92 (0.25)	1.11 (0.32)	0.95 (0.53)	594.12 (179.50)	616.95 (186.91)
	Outside Beds	42	1672	0.04 (0.01)	0.65 (0.13)	0.77 (0.15)	0.72 (0.23)	445.76 (87.41)	460.48 (89.85)
	All	51	1987	0.04 (0.01)	0.69 (0.12)	0.83 (0.14)	0.76 (0.21)	469.28 (79.28)	485.28 (81.63)
12-21	Within Beds	3	93	0.15	1.34	1.66	4.75	931.28	957.04
	Outside Beds	6	238	0.00 (0.00)	0.22 (0.16)	0.23 (0.17)	0.00 (0.00)	137.15 (100.06)	139.34 (101.62)
	All	9	331	0.04 (0.03)	0.53 (0.22)	0.63 (0.27)	1.33 (0.87)	360.28 (153.19)	369.08 (156.87)
Survey Total	Within Beds	12	408	0.07 (0.02)	1.01 (0.21)	1.24 (0.26)	1.81 (0.74)	670.97 (147.84)	694.47 (153.43)
	Outside Beds	48	1910	0.03 (0.01)	0.60 (0.11)	0.71 (0.13)	0.63 (0.20)	407.31 (77.79)	420.46 (79.98)
	All	60	2318	0.04 (0.01)	0.67 (0.10)	0.80 (0.12)	0.84 (0.22)	453.72 (70.95)	468.69 (73.02)

Table 5. Kruskal-Wallace test results comparing mean densities of red sea urchins by size groups between inside and outside commercial bed areas by PFM sub-area for the 2001 survey near Robson Bight.

PFM Sub-area	P-values		
	≤50 mm	≥90 mm	All Sizes
12-3	0.705	0.474	0.515
12-21	**0.006**	**0.031**	**0.015**
12-3 and 12-21	0.093	0.123	0.121

Table 6. Mean density estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2001 survey conducted near Robson Bight. Values in brackets are ± S.E.

Depth Range (m)	Transect Count	Mean Density (number/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 12-3										
<0.0 m	35	0.04 (0.04)	0.05 (0.04)	0.05 (0.03)	0.49 (0.39)	0.23 (0.16)	0.29 (0.15)	0.66 (0.55)	0.33 (0.23)	0.41 (0.21)
0.0 – <2.5 m	51	0.07 (0.04)	0.08 (0.03)	0.08 (0.03)	1.54 (0.45)	1.28 (0.39)	1.32 (0.34)	1.87 (0.57)	1.52 (0.46)	1.58 (0.39)
2.5 – <5.0 m	51	0.04 (0.02)	0.03 (0.01)	0.03 (0.01)	1.11 (0.36)	0.82 (0.22)	0.87 (0.20)	1.32 (0.42)	0.94 (0.25)	1.00 (0.22)
5.0 – <7.5 m	50	0.05 (0.03)	0.02 (0.01)	0.02 (0.01)	0.78 (0.19)	0.50 (0.13)	0.55 (0.11)	0.93 (0.23)	0.59 (0.15)	0.65 (0.13)
7.5 – <10.0 m	47	0.02 (0.02)	0.03 (0.01)	0.03 (0.01)	0.64 (0.29)	0.45 (0.13)	0.48 (0.12)	0.78 (0.37)	0.52 (0.15)	0.56 (0.14)
10.0 – <12.5 m	23	0.00	0.02 (0.01)	0.02 (0.01)	0.16	0.40 (0.14)	0.38 (0.13)	0.18	0.47 (0.17)	0.45 (0.15)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PFM sub-area 12-21										
<0.0 m	7	0.06	0.00	0.02 (0.02)	0.87	0.00	0.21 (0.22)	1.07	0.00	0.25 (0.26)
0.0 – <2.5 m	9	0.28	0.00	0.08 (0.05)	3.50	0.37 (0.31)	1.25 (0.65)	4.34	0.39 (0.33)	1.50 (0.79)
2.5 – <5.0 m	8	0.05	0.00	0.02 (0.01)	0.67	0.32 (0.24)	0.43 (0.21)	0.83	0.34 (0.27)	0.50 (0.25)
5.0 – <7.5 m	8	0.21	0.00	0.07 (0.07)	1.15	0.00	0.40 (0.34)	1.44	0.00	0.50 (0.42)
7.5 – <10.0 m	7	0.11	0.00	0.05 (0.03)	0.76	0.43	0.57 (0.19)	0.95	0.46	0.67 (0.22)
10.0 – <12.5 m	6	0.04	0.00	0.01 (0.01)	0.52	0.12	0.25 (0.20)	0.64	0.13	0.30 (0.24)
≥12.5 m	1	0.06	0.00	0.06	0.82	0.00	0.82	1.00	0.00	1.00
PFM sub-area 12-3 and 12-21 combined										
<0.0 m	42	0.04 (0.03)	0.04 (0.03)	0.04 (0.03)	0.56 (0.35)	0.19 (0.13)	0.27 (0.13)	0.73 (0.48)	0.27 (0.19)	0.38 (0.18)
0.0 – <2.5 m	60	0.12 (0.04)	0.07 (0.03)	0.08 (0.02)	1.99 (0.52)	1.17 (0.34)	1.31 (0.30)	2.43 (0.65)	1.38 (0.40)	1.56 (0.35)
2.5 – <5.0 m	59	0.04 (0.02)	0.03 (0.01)	0.03 (0.01)	0.04 (0.02)	0.77 (0.20)	0.82 (0.17)	1.21 (0.34)	0.88 (0.23)	0.94 (0.20)
5.0 – <7.5 m	58	0.08 (0.05)	0.02 (0.01)	0.03 (0.01)	0.86 (0.22)	0.45 (0.11)	0.53 (0.10)	1.04 (0.27)	0.53 (0.13)	0.63 (0.12)
7.5 – <10.0 m	54	0.05 (0.02)	0.03 (0.01)	0.03 (0.01)	0.67 (0.22)	0.45 (0.12)	0.49 (0.11)	0.83 (0.27)	0.52 (0.14)	0.57 (0.12)
10.0 – <12.5 m	29	0.02	0.01 (0.01)	0.01 (0.01)	0.33	0.36 (0.12)	0.35 (0.11)	0.40	0.42 (0.14)	0.42 (0.13)
≥12.5 m	1	0.06	0.00	0.06	0.82	0.00	0.82	1.00	0.00	1.00

Table 7. Biomass estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, and total urchins surveyed, during the 2001 survey conducted near Robson Bight. Values in brackets are ± S.E.

Depth Range (m)	Transect Count	Mean Biomass (g/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 12-3										
<0.0 m	35	0.89 (0.93)	0.89 (0.64)	0.89 (0.53)	266.75 (222.52)	135.98 (93.67)	165.80 (86.54)	286.31 (240.69)	144.37 (99.44)	176.74 (92.41)
0.0 – <2.5 m	51	1.45 (0.86)	1.97 (0.86)	1.89 (0.73)	1030.45 (355.65)	933.59 (291.65)	948.95 (251.04)	1068.46 (367.70)	962.01 (299.61)	978.88 (257.99)
2.5 – <5.0 m	51	0.98 (0.53)	0.48 (0.20)	0.56 (0.18)	703.14 (226.94)	567.41 (153.15)	588.93 (133.79)	728.76 (234.91)	582.34 (156.18)	605.55 (136.62)
5.0 – <7.5 m	50	1.28 (1.00)	0.38 (0.15)	0.53 (0.21)	518.12 (153.50)	331.09 (78.54)	362.00 (71.15)	534.11 (157.51)	343.80 (81.51)	375.25 (73.67)
7.5 – <10.0 m	47	0.51 (0.49)	0.39 (0.18)	0.41 (0.16)	385.51 (164.88)	333.37 (105.40)	340.94 (92.81)	402.78 (173.50)	340.61 (106.78)	349.64 (94.27)
10.0 – <12.5 m	23	0.00	0.22 (0.13)	0.20 (0.12)	114.23	238.34 (86.06)	227.70 (78.92)	117.09	248.70 (89.64)	237.42 (82.19)
≥12.5 m		none surveyed								
PFM sub-area 12-21										
<0.0 m	7	2.18	0.00	0.51 (0.54)	608.87	0.00	143.26 (151.06)	621.19	0.00	146.16 (154.12)
0.0 – <2.5 m	9	8.14	0.00	2.29 (1.31)	2353.95	207.86 (163.03)	810.84 (423.66)	2438.76	211.50 (166.06)	837.29 (440.10)
2.5 – <5.0 m	8	1.33	0.00	0.44 (0.35)	449.76	224.10 (189.89)	299.05 (155.91)	465.20	227.30 (192.32)	306.31 (159.18)
5.0 – <7.5 m	8	7.09	0.00	2.44 (2.34)	838.19	0.00	288.71 (251.85)	855.92	0.00	294.82 (256.17)
7.5 – <10.0 m	7	3.48	0.00	1.48 (1.15)	537.22	258.65	376.95 (124.03)	551.84	262.93	385.62 (126.46)
10.0 – <12.5 m	6	1.31	0.00	0.44 (0.46)	365.32	96.24	186.82 (143.08)	372.71	97.42	190.09 (145.72)
≥12.5 m	1	2.05	0.00	2.05	571.07	0.00	571.07	582.63	0.00	582.63

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Table 7. continued.

Depth Range (m)	Transect Count	Mean Biomass (g/m^2) by test diameter								
		≤50 mm			≥90 mm			All Sizes		
		In	Out	Total	In	Out	Total	In	Out	Total
PFM sub-area 12-3 and 12-21 combined										
<0.0 m	42	1.14 (0.85)	0.72 (0.52)	0.82 (0.44)	332.10 (209.86)	110.85 (76.37)	161.60 (75.03)	350.28 (223.20)	117.70 (81.07)	171.04 (79.68)
1.0 – <2.5 m	60	2.98 (1.12)	1.73 (0.75)	1.95 (0.65)	1332.13 (371.10)	843.16 (256.91)	929.23 (222.54)	1380.81 (385.57)	868.49 (263.93)	958.67 (228.87)
2.5 – <5.0 m	59	1.06 (0.45)	0.43 (0.18)	0.54 (0.17)	645.39 (182.33)	532.87 (138.61)	553.12 (118.36)	668.68 (188.61)	546.62 (141.35)	568.59 (120.87)
5.0 – <7.5 m	58	2.60 (1.65)	0.34 (0.14)	0.76 (0.34)	591.08 (173.92)	297.95 (71.54)	352.91 (68.80)	607.47 (177.24)	309.38 (74.28)	365.27 (71.02)
7.5 – <10.0 m	54	1.32 (0.80)	0.36 (0.16)	0.53 (0.20)	426.89 (126.46)	327.43 (97.53)	345.04 (83.29)	443.43 (132.28)	334.43 (98.81)	353.73 (84.59)
10.0 – <12.5 m	29	0.62	0.19 (0.11)	0.24 (0.12)	232.80	218.19 (74.89)	220.12 (68.44)	237.80	227.25 (77.93)	228.64 (71.06)
≥12.5 m	1	2.05	0.00	2.05	571.07	0.00	571.07	582.63	0.00	582.63

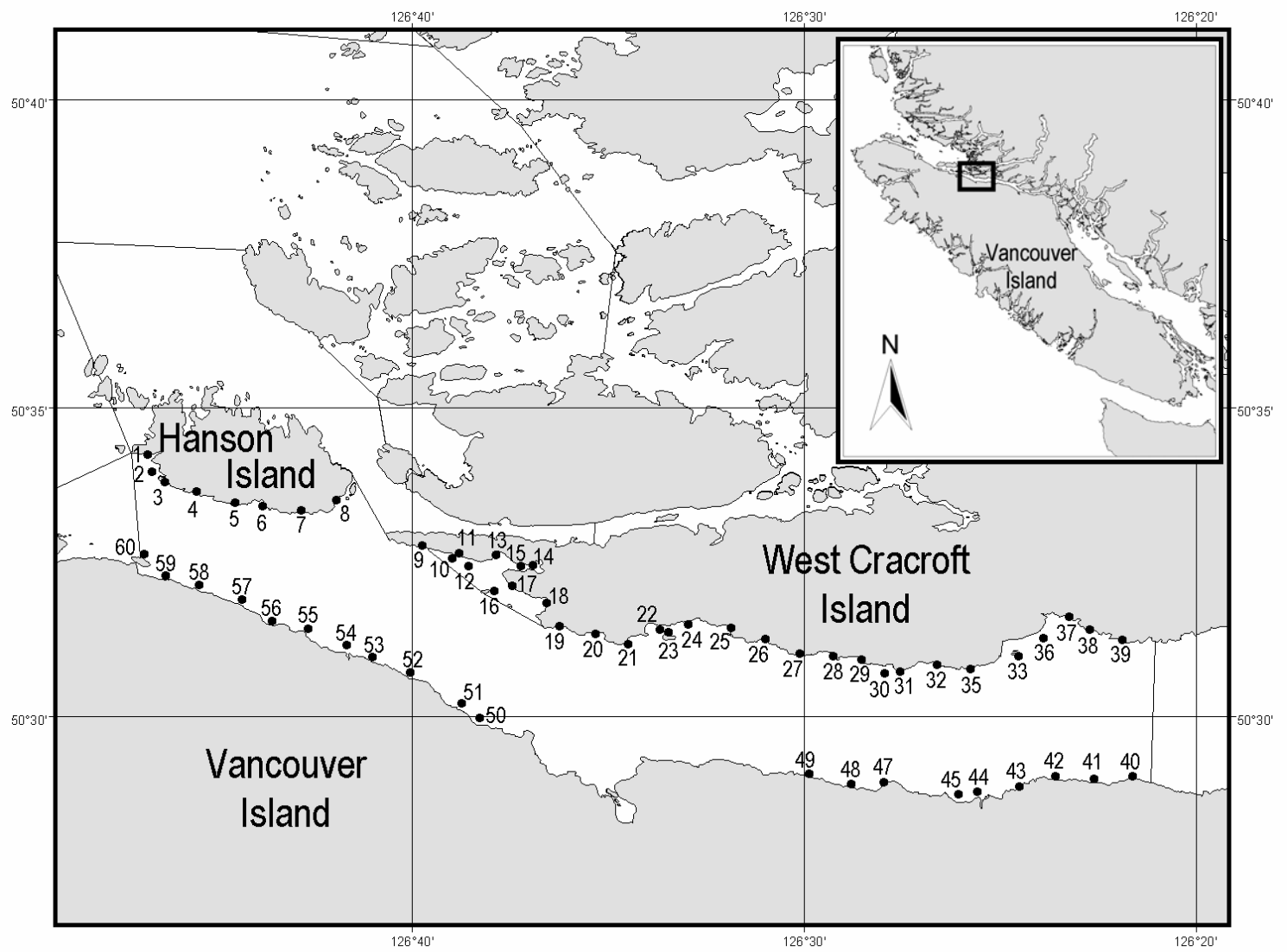

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted near Robson Bight, 2001. Hyphenated numbers indicate Pacific Fisheries Management sub-areas and other numbers indicate transects. Inset map indicates survey location.

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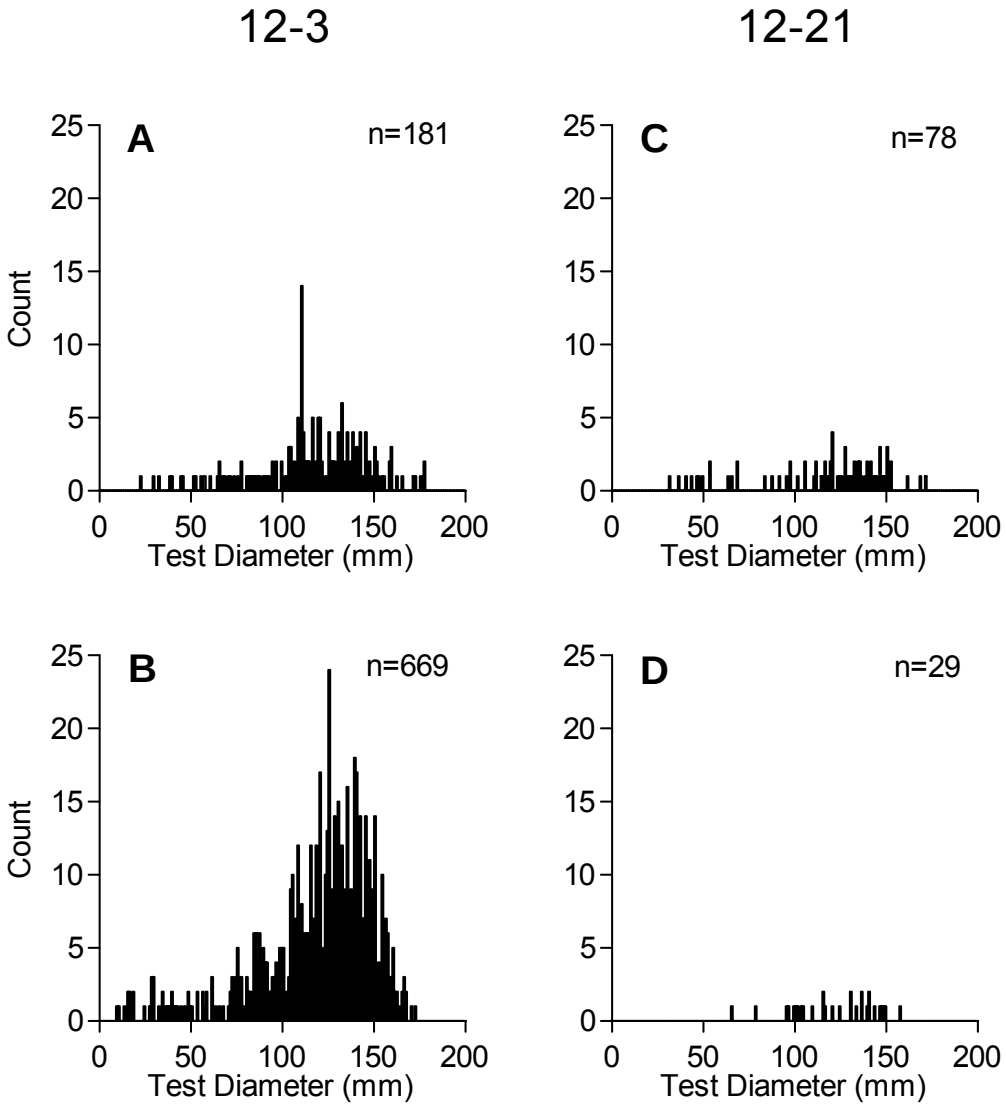

Figure 2. Size frequency distribution of red sea urchins measured along transects inside (A, C) and outside (B, D) of commercial bed areas during the 2001 survey at Robson Bight. Pacific Fisheries Management sub-areas are indicated above the figures. n= number of red sea urchins measured for test diameter.