Survey of Red Sea Urchin Populations In Barkley Sound, British Columbia, 2003

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SURVEY OF RED SEA URCHIN POPULATIONS IN BARKLEY SOUND, BRITISH COLUMBIA, 2003

by

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ABSTRACT

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations in Barkley Sound, British Columbia, 2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2752: iii + 33 p.

A survey of red sea urchin populations was conducted in Barkley Sound (Pacific Fisheries Management sub-areas 23-5, 23-6, 23-7, 23-8, 23-9, 23-10, 23-11, 123-3 and 123-5) during July, 2003. A total of 71 transects were surveyed by SCUBA divers, and 3946 red sea urchins were measured. The overall mean density (number/m^2) of red sea urchins of all sizes was 2.53/m^2, and for legal-sized red urchins (≥90 mm test diameter, TD) the density was 1.47/m^2. The estimated mean density of red sea urchins found inside (45 transects) was higher compared to outside (26 transects) previously fished commercial bed areas. Overall, 5.1% of all red urchins measured were ≤50 mm TD whereas 58.0% were of legal size for the commercial fishery.

RÉSUMÉ

Atkins, M., A. Campbell, W. C. Hajas, and D. Tzotzos. 2006. Survey of red sea urchin populations in Barkley Sound, British Columbia, 2003. Can. Manuscr. Rep. Fish. Aquat. Sci. 2752: iii + 33 p.

Un relevé des populations d'oursins rouges a été réalisé en juillet 2003 dans la baie Barkley (sous-secteurs 23-5, 23-6, 23-7, 23-8, 23-9, 23-10, 23-11, 123-3 et 123-5 de gestion des pêches du Pacifique). Au total, 71 transects ont été couverts par des plongeurs autonomes, qui ont mesuré 3946 oursins rouges. La densité moyenne totale (nombre/m^2) des oursins rouges de toutes tailles était de 2,53/m^2 et, pour les oursins de taille réglementaire (≥90 mm de diamètre du test, DT), la densité était de 1,47/m^2. La densité moyenne estimée était plus élevée chez les oursins rouges observés à l'intérieur (45 transects) qu'à l'extérieur (26 transects) de gisements auparavant exploités par la pêche commerciale. Dans l'ensemble, 5,1 % de tous les oursins rouges mesurés présentaient ≤50 mm DT, tandis que 58,0 % 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). Red sea urchins are found throughout shallow rocky subtidal habitats of British Columbia (Bernard 1977; Campbell and Harbo 1991). 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 2003-2004 season was $7.7 million (Juanita Rogers, pers. comm.), making the harvest of red sea urchins a valuable shellfish fishery 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. Barkley Sound [Pacific Fishery Management (PFM) Area 23, sub-areas 5-11 and Area 123, sub-areas 3 and 5] (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 23-5, 23-6, 23-7, 23-8, 23-9, 23-10, 23-11, 123-3 and 123-5.

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in PFM sub-areas 23-5, 23-6, 23-7, 23-8, 23-9, 23-10, 23-11, 123-3 and 123-5. 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 from July 21-27, 2003, on the "Monika" a commercial red sea urchin fishing vessel. A crew of four people, consisting of three divers, one of which was a biologist, and the other two commercial red sea urchin harvesters, and a boat tender, 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 the 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 located at Ucluelet were used to correct depths. The depth (m) for each quadrat was assigned to one of seven depth ranges: 1= <0.0 m; 2= 0.0 - <2.5 m; 3= 2.5 - <5.0 m; 4= 5.0 - <7.5 m; 5= 7.5 - <10.0 m; 6= 10.0 -<12.5 m; and 7= ≥12.5 m.

Substrate

The divers recorded 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 2 m), understorey (30 cm to 2 m), turf (<30 cm), 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).

Density 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).

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

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, 71 transects were surveyed during seven dive days (Table 1, Figure 1). A total of 3955 red sea urchins were counted, 3946 of which were measured for TD, in 1344 quadrats on the 71 transects. Total transect length surveyed was 3059 m, for an average transect length of 43 m. Forty-five (45) transects were located in the commercial red sea urchin beds recorded from 1997 to 2000.

SUBSTRATE AND HABITAT

All transects surveyed had a moderate or high exposure (Table 1). Of the 1344 quadrats sampled, 87% had rock, 11% had sand/shell, and 2% had mud as the primary substrate. Of the 3946 red sea urchins counted, 84% were observed between 0.0 m and 7.5 m depth.

Canopy, understorey, and turf algae were found at highest densities in less than 2.5 m of water (chart datum) (Table 2), and in most cases their abundance decreased with increased depth. Encrusting algae was consistently encountered at all depths surveyed.

SIZE FREQUENCY DISTRIBUTIONS

The mean size of all red sea urchins measured was 92.1 mm TD (Table 3). The smallest and largest red urchins measured were 11 mm and 193 mm TD, respectively. By PFM sub-areas, mean sizes ranged from 73.9 mm TD to 99.1 mm TD. Overall, the mean size of red urchins inside and outside of commercial bed areas was 90.7 mm and 95.2 mm TD, respectively.

The overall percentage of legal-sized red sea urchins (≥90 mm TD) was 58.0%, whereas the overall percentage of urchins ≤50 mm TD (R_T) was 5.1%. Of the sublegal red urchins, 12.2% were ≤50 mm TD (R_S).

Fifty six percent (56.2%) of the red sea urchins sampled inside commercial bed areas (n=2771) were of legal size, as were 62.5% of the red urchins sampled outside bed areas (n=1175).

DENSITY AND BIOMASS ESTIMATES

For all transects combined, the estimated mean density and biomass for red sea urchins of all sizes was 2.53/m^2 and 756.91 g/m^2, respectively, and 1.47/m^2 and 603.48 g/m^2 for legal-sized red urchins (Table 4). Significant differences in density between inside and outside commercial bed areas were observed for red urchins of all sizes, for legal-sized urchins, and for urchins ≤50 mm TD (Table 5) when data from all sub-areas were combined.

Overall (PFM sub-areas combined), for transects lying on red sea urchin beds, the estimated mean density of red urchins of all sizes was 2.81/m^2, and was 1.57/m^2 for legal-sized red urchins. For transects lying outside of commercial bed areas, the estimated mean density was 2.04/m^2 for urchins of all sizes, and 1.28/m^2 for legal-sized urchins. Inside bed areas, the estimated mean biomass of red sea urchins of all sizes was 814.87 g/m^2, and was 639.16 g/m^2 for legal-sized urchins; outside bed areas the estimated mean biomass was 657.12 g/m^2 and 542.05 g/m^2, respectively (Table 4).

When comparing densities by PFM sub-area between inside and outside of commercial beds the only statistical differences were found in sub-area 23-7 for red urchins of all sizes and legal-sized urchins; densities in and out of commercial bed areas in all other PFM sub-areas were not significantly different (Table 5).

Most commonly, in Barkley Sound the highest mean densities and biomass estimates of red sea urchins of any size category were observed at depths between 2.5 and 5.0 m (Tables 6 and 7), however no significance testing was performed.

DISCUSSION

Due to the broad nature of this survey, and the small sample of transects surveyed in many of the PFM sub-areas, it is difficult to make any comparisons on a per sub-area basis. For this reason discussions will be made for the survey as a whole.

The mean TD of red sea urchins observed on commercial bed areas was slightly lower than those observed outside of beds; this coupled with a higher percentage of red urchins ≤50 mm TD (R_T) inside than outside of beds suggests that either 1) harvesting may be removing adults from the population, and/or 2) there may be higher recruitment inside the commercial bed areas. Table 4 shows there was a higher density of recruits and of legal-sized urchins (≥90 mm TD) in beds than outside; this supports the second hypothesis and also suggests that non-bed areas may have less-favourable habitat for recruitment and/or survival of small urchins.

Recruitment (R_T) in Barkley Sound (5.1%) is the third lowest observed in ten surveys since 2001, the lowest being in Becher Bay, 2001 (1.4%) (Tzotzos et al. 2003d) followed by Robson Bight, 2001 (5.0%) (Atkins et al. 2006d). The density of recruits in Barkley Sound (0.13/m^2) is also low; lower than all surveys since 2001 (excluding Becher Bay), with the exceptions of the Dundas Group, 2003 (0.07/m^2) and Robson Bight, 2001 (0.04/m^2) (Atkins et al. 2006c,d). 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 and heavy seas may play a major role in keeping local recruitment at a low level. The low recruitment levels observed may also be as a result of removing the breeding adults through harvesting.

Densities inside commercial bed areas were significantly higher compared to those outside beds. The higher density could be caused by the following possible factors: (1) physical or biological factors favour urchin survival and recruitment in these areas; or, (2) the commercial harvest was concentrated in areas of greater urchin density. For commercial interest, density in the bed areas must not however be too high; in areas of high urchin density, roe quality diminishes due to competition for food.

Compared with other recent population surveys around Vancouver Island, the total estimated mean density of red sea urchins in Barkley Sound (2.53/m^2) was similar

to Tofino, 2000 (2.35/m^2) (Tzotzos et al. 2003b) and Queen Charlotte Strait, 2004 (3.25/m^2) (Atkins et al. 2006g), but was higher than Campbell River, 2002 (1.13/m^2) (Atkins et al. 2006e), Robson Bight, 2001 (0.80/m^2) (Atkins et al. 2006d), and Becher Bay, 2001 (0.29/m^2) (Tzotzos et al. 2003d).

The maximum density of red sea urchins in Barkley Sound was found between 0-7.5m depth. The majority of survey observations describe the highest densities between 0-5m as in Laredo Channel (Tzotzos et al. 2003a), the Deserters Group (Tzotzos et al. 2003c), Beaver Pass and Freeman Pass (Atkins et al. 2006a), the Dundas Group (Atkins et al. 2006c), and Queen Charlotte Strait (Atkins et al. 2006g). This may be the depth where food, algae and algal drift were most abundant, combined with being the shallowest depths generally tolerated by red sea urchins.

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Table 1. Summary of transects surveyed during the July 21-27, 2003 red sea urchin (RSU) population survey in Barkley Sound. Density in number per meter squared and biomass in grams per meter squared. PFM = Pacific Fishery Management. Depths have been corrected to chart datum. Exposure: 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	23-11	48 55.230	125 32.141	1.65	10.09	8	14:47	15:15	28	57	29	99	3.41	793.50	✓
2	23-11	48 55.289	125 31.656	-0.61	8.63	8	09:32	09:58	26	61	31	73	2.35	774.11	✓
3	23-11	48 55.282	125 31.261	-0.21	7.99	8	11:47	12:23	36	51	26	79	3.04	1030.83	✓
4	23-11	48 55.527	125 31.487	0.49	3.23	8	10:24	10:34	10	61	4	0	0.00	0.00	✓
5	23-11	48 55.431	125 30.783	0.37	10.49	8	10:50	11:28	38	49	25	121	4.84	1230.96	✓
6	23-11	48 55.263	125 30.430	-0.12	6.22	8	12:37	13:07	30	53	27	78	2.89	978.02	✓
7	23-11	48 55.207	125 30.331	1.77	8.08	8	14:25	15:00	35	59	30	91	3.03	935.00	✓
8	23-11	48 55.171	125 30.165	0.34	4.54	8	13:37	13:55	18	53	27	36	1.33	441.44	✓
9	23-11	48 55.172	125 30.103	1.92	4.05	8	14:03	14:15	12	43	22	14	0.64	374.71	✓
10	23-11	48 54.986	125 30.008	0.37	10.39	8	15:33	15:53	20	31	16	48	3.00	755.04	✓
11	23-11	48 54.950	125 30.122	-0.30	8.81	8	15:14	15:27	13	15	8	23	2.88	821.35	✓
12	23-11	48 54.502	125 30.479	1.92	7.41	8	17:09	17:42	33	57	29	72	2.48	678.79	✓
13	23-11	48 54.805	125 31.089	1.92	10.42	8	16:24	16:55	31	29	15	83	5.53	1591.23	✓
14	123-3	48 54.516	125 31.088	1.52	10.64	8	15:51	16:10	19	17	9	33	3.67	925.32	✓
15	123-3	48 54.114	125 30.668	-0.49	9.91	8	09:19	10:01	42	63	32	135	4.22	1398.28	✓
16	123-3	48 54.092	125 30.106	-0.09	10.36	8	10:15	11:11	56	43	22	229	10.41	2378.65	✓
17	23-11	48 54.460	125 30.040	1.19	9.48	8	16:23	16:53	30	23	12	106	8.83	2880.97	✓
18	23-11	48 54.443	125 28.419	2.19	11.67	8	15:33	16:03	30	31	16	77	4.81	1461.99	✓
19	23-11	48 54.554	125 28.146	1.31	11.34	8	14:42	15:20	38	45	23	124	5.39	1597.20	✓
20	23-7	48 49.153	125 13.905	2.07	10.85	8	16:10	16:27	17	27	14	40	2.86	761.31	✓
21	23-7	48 48.235	125 13.113	0.18	11.70	8	11:32	12:09	37	73	37	120	3.24	770.35	✓
22	23-7	48 49.404	125 12.842	0.00	7.56	8	10:39	11:14	35	67	34	92	2.71	630.07	✓
23	23-7	48 49.635	125 12.538	0.79	9.05	8	12:28	12:57	29	41	21	84	4.00	948.28	✓
24	23-7	48 49.659	125 12.235	0.46	9.94	8	13:05	13:32	27	53	27	87	3.22	847.82	✓
25	23-7	48 49.814	125 12.106	0.18	5.52	8	15:06	15:38	32	61	31	43	1.39	815.09	✓
26	23-7	48 50.045	125 12.247	0.76	2.32	4	17:23	17:32	9	23	12	0	0.00	0.00	✓
27	23-7	48 50.131	125 12.293	0.43	4.72	8	18:13	18:37	24	59	30	52	1.73	814.03	✓
28	23-7	48 50.297	125 12.562	0.03	10.45	8	18:52	19:09	17	17	9	49	5.44	1626.76	✓
29	23-7	48 50.428	125 12.604	1.07	10.03	8	19:19	19:49	30	33	17	99	5.82	1608.50	✓

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							
30	23-7	48 50.103	125 12.659	-0.34	8.41	4	16:26	17:07	41	43	22	107	4.86	1360.79	✓
31	23-7	48 49.897	125 13.153	1.07	10.49	8	17:18	17:54	36	47	24	117	4.88	1451.15	✓
32	23-5	48 55.005	125 08.086	0.27	6.25	8	10:17	10:56	39	59	30	122	4.07	789.11	✓
33	23-5	48 55.436	125 06.718	0.40	7.99	8	11:12	11:33	21	51	26	49	1.88	529.93	✓
34	23-5	48 55.652	125 06.642	0.76	9.60	8	11:44	11:54	10	39	20	7	0.35	159.11	✓
35	23-5	48 55.788	125 06.638	-0.98	9.39	8	14:23	14:30	7	37	3	0	0.00	0.00	✓
36	23-5	48 55.794	125 06.770	-0.70	9.97	8	12:05	12:17	12	37	19	11	0.58	473.05	✓
37	23-5	48 55.845	125 06.887	-0.94	9.39	8	12:26	12:39	13	41	21	15	0.71	274.33	✓
38	23-5	48 55.897	125 06.726	-0.03	10.64	8	14:07	14:14	7	31	3	0	0.00	0.00	✓
39	23-5	48 55.982	125 06.419	0.82	10.58	8	14:39	14:46	7	31	3	0	0.00	0.00	✓
40	23-5	48 56.064	125 06.295	0.15	3.20	8	14:57	15:05	8	31	3	0	0.00	0.00	✓
41	23-5	48 56.122	125 06.588	-1.04	8.66	8	11:36	11:50	14	37	19	21	1.11	358.40	✓
42	23-5	48 55.979	125 07.003	0.70	10.15	8	11:14	11:29	15	27	14	24	1.71	581.81	✓
43	23-5	48 55.901	125 07.117	-0.24	9.17	8	10:52	11:08	16	29	15	24	1.60	441.87	✓
44	23-5	48 56.573	125 05.870	-0.30	10.21	8	16:06	16:42	36	59	30	64	2.13	576.52	✓
45	23-5	48 57.422	125 05.240	-0.94	10.30	8	12:16	12:30	14	41	21	32	1.52	432.06	✓
46	123-5	48 58.428	125 37.141	1.92	11.09	8	10:59	11:16	17	85	43	12	0.28	153.35	
47	123-5	48 56.877	125 35.125	0.34	4.27	8	11:44	13:37	113	59	30	513	17.10	5903.70	
48	123-5	48 56.097	125 33.443	3.51	6.92	8	14:07	14:27	20	49	25	21	0.84	282.03	
49	123-5	48 53.004	125 29.092	0.37	3.44	8	11:29	14:41	192	41	21	4	0.19	59.09	
50	23-11	48 55.653	125 27.326	0.94	3.63	8	14:00	14:28	28	49	25	58	2.32	592.90	
51	23-9	48 56.975	125 24.326	0.46	10.15	8	12:57	13:20	23	61	31	57	1.84	347.25	
52	23-10	48 58.000	125 23.380	-1.46	7.65	8	12:30	12:43	13	61	31	12	0.39	166.93	
53	23-10	48 58.394	125 22.100	-0.34	4.21	8	11:53	12:12	19	71	36	24	0.67	220.65	
54	23-8	48 57.440	125 14.222	-0.12	9.94	8	11:01	11:14	13	41	5	0	0.00	0.00	
55	23-8	48 56.733	125 14.719	-1.37	9.91	8	10:33	10:41	8	35	4	0	0.00	0.00	
56	23-6	48 57.683	125 11.444	0.70	10.82	8	17:48	17:58	10	39	20	12	0.60	78.00	
57	23-6	48 59.364	125 11.713	1.25	10.42	8	15:48	15:55	7	17	3	0	0.00	0.00	
58	23-6	48 59.366	125 11.200	-0.09	10.58	8	16:25	16:35	10	61	4	0	0.00	0.00	
59	23-6	48 59.797	125 10.958	2.41	11.28	8	16:08	16:13	5	21	3	0	0.00	0.00	
60	23-6	48 59.403	125 09.661	0.09	10.49	8	15:25	15:31	6	17	3	0	0.00	0.00	
61	23-6	48 58.310	125 09.676	-0.03	10.45	8	16:56	17:28	32	55	28	72	2.57	712.72	

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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							
62	23-6	48 59.200	125 07.626	0.73	5.30	8	13:34	13:42	8	63	5	0	0.00	0.00	
63	23-6	48 58.435	125 05.461	-0.21	9.78	8	12:45	13:10	25	57	29	42	1.45	389.51	
64	23-5	48 56.984	125 04.144	-0.85	9.81	8	17:23	17:28	5	21	2	0	0.00	0.00	
65	23-5	48 56.998	125 05.182	1.07	8.41	8	17:02	17:09	7	41	3	0	0.00	0.00	
66	23-5	48 56.196	125 05.879	1.77	10.36	8	15:36	15:56	20	49	25	14	0.56	244.02	
67	23-5	48 55.854	125 06.038	1.31	10.45	8	15:15	15:22	7	21	3	0	0.00	0.00	
68	23-7	48 49.623	125 14.586	1.89	10.39	8	16:43	17:01	18	21	11	64	5.82	1263.23	
69	23-7	48 48.628	125 11.062	2.19	11.28	8	15:30	15:46	16	11	6	41	6.83	2106.73	
70	23-7	48 47.871	125 12.378	1.37	6.13	8	14:25	14:55	30	41	21	101	4.81	1886.86	
71	23-7	48 47.370	125 13.012	1.77	10.55	8	13:25	14:08	43	37	19	128	6.74	2201.80	

Table 2. Mean number of red sea urchins (RSU), mean substrate type, and percent cover of algae for each depth range surveyed during the 2003 survey conducted in Barkley Sound. 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 23-5								
<0.0 m	0	0	13	1.00	6.9	56.5	37.5	52.3
0.0 - <2.5 m	73	1.4	54	1.01	8.6	19.8	19.8	75.4
2.5 - <5.0 m	186	3.0	63	1.06	0.1	2.4	1.3	74.4
5.0 - <7.5 m	74	1.3	55	1.29	1.5	4.0	0.2	40.2
7.5 - <10.0 m	47	0.7	66	1.62	0	3.9	1.2	18.0
10.0 - <12.5 m	3	0.3	9	1.78	0	0	0	6.7
PFMA 23-6								
<0.0 m	0	0	3	1.00	0	80	83.3	33.3
0.0 - <2.5 m	6	0.3	18	1.00	23.9	26.4	33.9	66.1
2.5 - <5.0 m	53	2.1	25	1.12	4.0	15.6	10.4	42.0
5.0 - <7.5 m	45	2.0	22	1.18	0	7.7	6.4	39.1
7.5 - <10.0 m	17	1.0	17	1.00	0	9.4	9.4	50.0
10.0 - <12.5 m	5	0.5	10	1.20	0	27.0	14.0	25.0
PFM sub-area 23-7								
<0.0 m	0	0	1	1.00	101	100	0	70
0.0 - <2.5 m	268	4.1	66	1.17	21.4	22.3	20.1	43.5
2.5 - <5.0 m	405	4.3	94	1.12	12.8	10.2	11.1	56.9
5.0 - <7.5 m	375	3.4	110	1.05	0	0.4	1.0	70.1
7.5 - <10.0 m	140	2.8	50	1.12	0.1	0	0	70.0
10.0 - <12.5 m	36	2.6	14	1.00	0	0	0	78.6
PFM sub-area 23-8								
<0.0 m	0	0	2	2.00	0	50	0	20
0.0 - <2.5 m	0	0	3	1.67	0	36.7	13.3	20
2.5 - <5.0 m	0	0	1	1.00	0	60.0	0	30.0
5.0 - <7.5 m	0	0	1	1.00	0	101	20.0	30.0
7.5 - <10.0 m	0	0	2	1.50	0	50.0	0	30.0
10.0 - <12.5 m	0	0	0	0	0	0	0	0

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Table 2. continued.

Depth Range (m)	Number of RSU		Number Of Quadrats	Mean Substrate Category	Mean Percent Cover by Algae			
	Total	Mean per Quadrat			Canopy	Understorey	Turf	Encrusting
PFM sub-area 23-9								
<0.0 m	0	0	0	0	0	0	0	0
0.0 - <2.5 m	10	1.4	7	1.00	0	60.0	27.1	77.1
2.5 - <5.0 m	21	3.5	6	1.00	0	0	3.3	100
5.0 - <7.5 m	8	0.9	9	1.00	0	0	6.7	80.0
7.5 - <10.0 m	11	1.2	9	1.11	0	0	0	73.3
10.0 - <12.5 m	7	2.3	3	1.00	0	0	0	80.0
PFM sub-area 23-10								
<0.0 m	0	0	5	1.00	0	0	60.0	33.3
0.0 - <2.5 m	11	0.8	14	1.00	0	0.1	3.6	77.1
2.5 - <5.0 m	24	0.8	30	1.00	0	0	22.7	68.0
5.0 - <7.5 m	1	0.1	15	2.87	0	0	0	1.3
7.5 - <10.0 m	0	0	3	3.00	0	0	0	0
10.0 - <12.5 m	0	0	0	0	0	0	0	0
PFM sub-area 23-11								
<0.0 m	0	0	4	1.00	75.0	100	55.0	37.5
0.0 - <2.5 m	151	3.4	45	1.00	28.7	38.0	31.2	46.7
2.5 - <5.0 m	404	3.8	105	1.36	7.0	8.6	10.1	41.1
5.0 - <7.5 m	398	3.7	107	1.00	8.6	0.9	2.6	58.8
7.5 - <10.0 m	197	2.2	90	1.08	16.7	8.8	1.6	56.2
10.0 - <12.5 m	32	2.3	14	1.14	25.7	8.6	0	50.7
PFM sub-area 123-3								
<0.0 m	7	3.5	2	1.00	50.0	60.5	70.0	50.0
0.0 - <2.5 m	90	5.3	17	1.00	34.1	73.0	45.3	49.4
2.5 - <5.0 m	121	5.8	21	1.00	9.5	19.0	40.0	53.3
5.0 - <7.5 m	71	7.9	9	1.00	0	0	8.9	73.3
7.5 - <10.0 m	100	3.2	31	1.00	0	0	0	49.4
10.0 - <12.5 m	12	3.0	4	1.00	0	0	0	80.0

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Table 2. continued.

Depth Range (m)	Number of RSU		Number Of Quadrats	Mean Substrate Category	Mean Percent Cover by Algae			
	Total	Mean per Quadrat			Canopy	Understorey	Turf	Encrusting
PFM sub-area 123-5								
<0.0 m	0	0	0	0	0	0	0	0
0.0 - <2.5 m	311	15.6	20	1.00	0.5	30.0	35.3	72.0
2.5 - <5.0 m	207	8.0	26	1.04	7.3	23.1	46.9	45.0
5.0 - <7.5 m	16	0.8	20	1.00	80.3	44.0	13.5	60.0
7.5 - <10.0 m	0	0	10	1.00	0	0	5.0	0
10.0 - <12.5 m	12	0.5	22	1.00	0	0	18.2	18.2
PFM sub-areas combined								
<0.0 m	7	0.2	30	1.07	21.1	60.6	45.6	44.3
0.0 - <2.5 m	920	3.8	244	1.06	17.2	29.1	25.3	58.2
2.5 - <5.0 m	1421	3.8	371	1.15	6.6	9.3	14.0	54.9
5.0 - <7.5 m	988	2.9	345	1.16	7.6	4.4	2.8	56.4
7.5 - <10.0 m	512	1.8	278	1.22	5.4	4.7	1.6	46.2
10.0 - <12.5 m	107	1.4	76	1.14	4.7	5.1	7.1	40.5
≥12.5 m	None Surveyed							

Table 3. Number and mean size of red sea urchins measured and percentage of urchins ≤50mm TD and ≥90mm TD for each Pacific Fishery Management (PFM) sub-area surveyed during the 2003 population survey in Barkley Sound. R_T = percent of all red urchins that were ≤50mm TD. R_S = percent of sublegal urchins that were ≤50mm TD.

PFM Sub- Area	Transects Used	Test Diameter (mm)			Numbers Measured			% Total Measured		% Sublegal
		Mean	Minimum	Maximum	Total	≥90 mm TD	≤50 mm TD	≥90 mm	≤50 mm (R_T)	≤50 mm (R_S)
23-5	Within Beds	88.8	11	170	369	188	27	50.9	7.3	14.9
	Outside Beds	108.9	72	134	14	13	0	92.9	0.0	0.0
	All	89.6	11	170	383	201	27	52.5	7.0	14.8
23-6	Within Beds	0	0	0	0	0	0	0	0	0
	Outside Beds	88.6	28	123	126	65	5	51.6	4.0	8.2
	All	88.6	28	123	126	65	5	51.6	4.0	8.2
23-7	Within Beds	92.2	14	193	886	504	29	56.9	3.3	7.6
	Outside Beds	96.1	30	143	334	220	4	65.9	1.2	3.5
	All	93.3	14	193	1220	724	33	59.3	2.7	6.7
23-8	Within Beds	0	0	0	0	0	0	0	0	0
	Outside Beds	0	0	0	0	0	0	0	0	0
	All	0	0	0	0	0	0	0	0	0
23-9	Within Beds	0	0	0	0	0	0	0	0	0
	Outside Beds	73.9	24	135	57	20	9	35.1	15.8	24.3
	All	73.9	24	135	57	20	9	35.1	15.8	24.3
23-10	Within Beds	0	0	0	0	0	0	0	0	0
	Outside Beds	99.1	15	130	36	27	2	75.0	5.6	22.2
	All	99.1	15	130	36	27	2	75.0	5.6	22.2
23-11	Within Beds	91.0	16	154	1124	669	95	59.5	8.5	20.9
	Outside Beds	86.8	28	120	58	35	3	60.3	5.2	13.0
	All	90.8	16	154	1182	704	98	59.6	8.3	20.5

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Table 3. continued.

PFM Sub- Area	Transects Used	Test Diameter (mm) Mean	Minimum	Maximum	Numbers Measured Total	≥90 mm TD	≤50 mm TD	% Total Measured ≥90 mm	≤50 mm (R_T)	% Sublegals ≤50 mm (R_S)
123-3	Within Beds	88.3	25	139	392	195	23	49.7	5.9	11.7
	Outside Beds	96.8	83	112	4	2	0	50.0	0.0	0.0
	All	88.4	25	139	396	197	23	49.7	5.8	11.6
123-5	Within Beds	0	0	0	0	0	0	0	0	0
	Outside Beds	98.7	25	151	546	352	5	64.5	0.9	2.6
	All	98.7	25	151	546	352	5	64.5	0.9	2.6
Total	Within Beds	90.7	11	193	2771	1556	174	56.2	6.3	14.3
	Outside Beds	95.2	15	151	1175	734	28	62.5	2.4	6.3
	All	92.1	11	193	3946	2290	202	58.0	5.1	12.2

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 2003 survey in Barkley Sound. Estimates are for transects within red sea urchin beds recorded between 1997 and 2000, for transects outside the beds, and for all transects combined. Values in brackets are ± S.E..

PFM Sub-area	Transects Surveyed	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
23-5	Within Beds	14	550	0.10 (0.05)	0.67 (0.13)	1.31 (0.38)	1.20 (0.64)	270.83 (46.64)	367.37 (74.41)
	Outside Beds	4	132	0.00	0.19	0.21	0.00	88.58	90.58
	All	18	682	0.08 (0.04)	0.58 (0.12)	1.10 (0.33)	0.97 (0.54)	235.55 (43.17)	313.80 (67.43)
23-6	Within Beds	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Outside Beds	8	330	0.03 (0.01)	0.39 (0.24)	0.75 (0.42)	0.64 (0.36)	139.49 (87.66)	195.28 (116.15)
	All	8	330	0.03 (0.01)	0.39 (0.24)	0.75 (0.42)	0.64 (0.36)	139.49 (87.66)	195.28 (116.15)
23-7	Within Beds	12	544	0.10 (0.04)	1.82 (0.24)	3.20 (0.42)	1.71 (0.49)	709.56 (86.71)	937.39 (98.99)
	Outside Beds	4	110	0.07	3.86	5.85	1.82	1580.92	1895.73
	All	16	654	0.10 (0.03)	2.16 (0.29)	3.64 (0.43)	1.73 (0.42)	856.12 (117.77)	1098.58 (128.01)
23-8	Within Beds	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Outside Beds	2	76	0.00	0.00	0.00	0.00	0.00	0.00
	All	2	76	0.00	0.00	0.00	0.00	0.00	0.00
23-9	Within Beds	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Outside Beds	1	61	0.29	065	1.84	9.94	254.76	347.25
	All	1	61	0.29	065	1.84	9.94	254.76	347.25
23-10	Within Beds	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Outside Beds	2	132	0.03	0.40	0.54	0.47	180.87	195.82
	All	2	132	0.03	0.40	0.54	0.47	180.87	195.82

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Table 4. continued.

PFM Sub-area	Transects Surveyed	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
23-11	Within Beds	16	718	0.26 (0.07)	1.82 (0.29)	3.06 (0.46)	8.23 (2.13)	761.60 (113.58)	913.47 (133.03)
	Outside Beds	1	49	0.12	1.40	2.32	3.32	498.74	592.90
	All	17	767	0.25 (0.07)	1.79 (0.27)	3.01 (0.43)	7.92 (2.01)	744.80 (106.78)	892.99 (125.15)
123-3	Within Beds	3	123	0.37	3.14	6.31	10.74	1260.10	1698.48
	Outside Beds	1	41	0.00	0.10	0.19	0.00	38.61	59.09
	All	4	164	0.28	2.38	4.78	8.05	954.73	1288.63
123-5	Within Beds	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Outside Beds	3	193	0.05	3.59	5.56	1.26	1617.65	1943.90
	All	3	193	0.05	3.59	5.56	1.26	1617.65	1943.90
Total	Within Beds	45	1935	0.18 (0.03)	1.57 (0.16)	2.81 (0.30)	4.56 (1.01)	639.16 (62.56)	814.87 (78.07)
	Outside Beds	26	1124	0.05 (0.02)	1.28 (0.57)	2.04 (0.89)	1.32 (0.54)	542.05 (254.08)	657.12 (306.77)
	All	71	3059	0.13 (0.02)	1.47 (0.23)	2.53 (0.38)	3.37 (0.70)	603.48 (100.40)	756.91 (122.04)

Table 5. Kruskal-Wallace test results for comparing mean densities of red sea urchins by size groups between inside and outside commercial bed areas by PFM sub-area for the 2003 survey in Barkley Sound.

PFM sub-area	P-values		
	≤50 mm	≥90 mm	All Sizes
23-5	0.129	0.080	0.063
23-6	n/a	n/a	n/a
23-7	0.855	**0.021**	**0.021**
23-8	n/a	n/a	n/a
23-9	n/a	n/a	n/a
23-10	n/a	n/a	n/a
23-11	0.838	0.540	0.307
123-3	0.180	0.180	0.180
123-5	n/a	n/a	n/a
PFM sub-areas combined	**0.011**	**0.006**	**0.007**

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 2003 population survey conducted in Barkley Sound. Values in brackets area ± 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 23-5										
<0.0 m	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	15	0.10 (0.05)	0.00	0.08 (0.04)	0.56 (0.17)	0.00	0.45 (0.15)	1.15 (0.42)	0.00	0.93 (0.37)
2.5 – <5.0 m	14	0.20 (0.07)	0.00	0.18 (0.07)	1.80 (0.42)	0.66	1.70 (0.40)	3.08 (0.68)	0.71	2.88 (0.65)
5.0 – <7.5 m	14	0.10 (0.05)	0.00	0.08 (0.04)	0.92 (0.21)	0.15	0.77 (0.19)	1.81 (0.45)	0.16	1.48 (0.41)
7.5 – <10.0 m	13	0.03 (0.02)	0.00	0.02 (0.02)	0.46 (0.16)	0.61	0.50 (0.16)	0.78 (0.28)	0.66	0.76 (0.24)
10.0 – <12.5 m	7	0.02 (0.02)	0.00	0.02 (0.02)	0.28 (0.16)	0.65	0.38 (0.16)	0.46 (0.26)	0.70	0.52 (0.21)
≥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 23-6										
<0.0 m	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	6	0.00	0.01 (0.01)	0.01 (0.01)	0.00	0.08 (0.06)	0.08 (0.06)	0.00	0.19 (0.12)	0.19 (0.12)
2.5 – <5.0 m	7	0.00	0.08 (0.06)	0.08 (0.06)	0.00	0.60 (0.36)	0.60 (0.36)	0.00	1.36 (0.66)	1.36 (0.66)
5.0 – <7.5 m	5	0.00	0.05 (0.02)	0.05 (0.02)	0.00	0.74 (0.41)	0.74 (0.41)	0.00	1.38 (0.70)	1.38 (0.70)
7.5 – <10.0 m	3	0.00	0.02	0.02	0.00	0.52	0.52	0.00	0.92	0.92
10.0 – <12.5 m	6	0.00	0.01 (0.01)	0.01 (0.01)	0.00	0.25 (0.23)	0.25 (0.23)	0.00	0.44 (0.40)	0.44 (0.40)
≥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 23-7										
<0.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	16	0.18 (0.07)	0.00	0.15 (0.06)	2.89 (0.47)	0.00	2.41 (0.48)	5.01 (0.78)	0.00	4.17 (0.81)
2.5 – <5.0 m	15	0.15 (0.06)	0.10	0.15 (0.05)	2.23 (0.27)	4.58	2.64 (0.33)	4.06 (0.60)	7.32	4.62 (0.61)
5.0 – <7.5 m	14	0.10 (0.03)	0.09	0.10 (0.03)	1.60 (0.32)	5.30	2.31 (0.53)	3.03 (0.56)	7.76	3.94 (0.71)
7.5 – <10.0 m	11	0.06 (0.03)	0.07	0.06 (0.02)	1.03 (0.36)	4.36	1.54 (0.57)	1.94 (0.64)	6.85	2.69 (0.86)
10.0 – <12.5 m	8	0.05 (0.01)	0.05	0.05 (0.01)	1.14 (0.37)	2.56	1.51 (0.44)	2.12 (0.65)	4.07	2.62 (0.65)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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Table 6. continued.

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 23-8										
<0.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 – <5.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0 – <7.5 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5 – <10.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0 – <12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
≥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 23-9										
<0.0 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	1	0.00	0.23	0.23	0.00	0.50	0.50	0.00	1.43	1.43
2.5 – <5.0 m	1	0.00	0.55	0.55	0.00	1.23	1.23	0.00	3.50	3.50
5.0 – <7.5 m	1	0.00	0.21	0.21	0.00	0.47	0.47	0.00	1.33	1.33
7.5 – <10.0 m	1	0.00	0.19	0.19	0.00	0.43	0.43	0.00	1.22	1.22
10.0 – <12.5 m	1	0.00	0.37	0.37	0.00	0.82	0.82	0.00	2.33	2.33
≥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 23-10										
<0.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	2	0.00	0.08	0.08	0.00	0.77	0.77	0.00	1.02	1.02
2.5 – <5.0 m	2	0.00	0.04	0.04	0.00	0.57	0.57	0.00	0.76	0.76
5.0 – <7.5 m	1	0.00	0.01	0.01	0.00	0.05	0.05	0.00	0.07	0.07
7.5 – <10.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0 – <12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
≥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 23-11										
<0.0 m	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	16	0.19 (0.07)	0.11	0.19 (0.07)	2.10 (0.57)	1.31	2.05 (0.53)	3.36 (0.87)	2.18	3.29 (0.81)
2.5 – <5.0 m	16	0.45 (0.14)	0.14	0.43 (0.13)	3.56 (0.80)	1.58	3.43 (0.76)	5.80 (1.29)	2.36	5.59 (1.21)
5.0 – <7.5 m	13	0.40 (0.11)	0.00	0.40 (0.11)	2.53 (0.37)	0.00	2.53 (0.37)	4.39 (0.64)	0.00	4.39 (0.64)
7.5 – <10.0 m	11	0.25 (0.07)	0.00	0.25 (0.07)	1.27 (0.24)	0.00	1.27 (0.24)	2.32 (0.49)	0.00	2.32 (0.49)
10.0 – <12.5 m	6	0.21 (0.11)	0.00	0.21 (0.11)	1.55 (0.61)	0.00	1.55 (0.61)	2.67 (1.00)	0.00	2.67 (1.00)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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Table 6. continued.

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 123-3										
<0.0 m	2	0.18	0.00	0.18	2.84	0.00	2.84	4.16	0.00	4.16
0.0– <2.5 m	4	0.91	0.00	0.68	7.89	0.00	5.91	15.47	0.00	11.60
2.5 – <5.0 m	4	0.69	0.00	0.51	5.24	0.20	3.98	11.08	0.40	8.41
5.0 – <7.5 m	3	0.40	0.00	0.40	3.59	0.00	3.59	7.10	0.00	7.10
7.5 – <10.0 m	3	0.20	0.00	0.20	1.88	0.00	1.88	3.63	0.00	3.63
10.0 – <12.5 m	2	0.18	0.00	0.18	1.28	0.00	1.28	3.00	0.00	3.00
≥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 123-5										
<0.0 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	2	0.00	0.05	0.05	0.00	4.26	4.26	0.00	6.71	6.71
2.5 – <5.0 m	3	0.00	0.06	0.06	0.00	3.76	3.76	0.00	5.87	5.87
5.0 – <7.5 m	1	0.00	0.04	0.04	0.00	0.61	0.61	0.00	0.80	0.80
7.5 – <10.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0 – <12.5 m	1	0.00	0.00	0.00	0.00	0.45	0.45	0.00	0.55	0.55
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
All PFM sub-areas combined										
<0.0 m	23	0.03 (0.03)	0.00	0.02 (0.02)	0.47 (0.45)	0.00	0.29 (0.28)	0.69 (0.67)	0.00	0.42 (0.42)
0.0– <2.5 m	64	0.21 (0.05)	0.04 (0.02)	0.16 (0.04)	2.32 (0.40)	0.88 (0.64)	1.83 (0.35)	4.07 (0.74)	1.42 (1.00)	3.18 (0.62)
2.5 – <5.0 m	63	0.31 (0.07)	0.10 (0.04)	0.24 (0.05)	2.81 (0.37)	1.71 (0.70)	2.43 (0.35)	4.90 (0.69)	2.89 (1.10)	4.20 (0.60)
5.0 – <7.5 m	53	0.23 (0.05)	0.05 (0.02)	0.17 (0.04)	1.89 (0.22)	1.25 (0.49)	1.70 (0.21)	3.48 (0.40)	1.98 (0.68)	3.04 (0.36)
7.5 – <10.0 m	46	0.13 (0.03)	0.03 (0.02)	0.10 (0.02)	1.02 (0.15)	0.77 (0.40)	0.94 (0.16)	1.88 (0.29)	1.24 (0.59)	1.68 (0.27)
10.0 – <12.5 m	31	0.11 (0.04)	0.06 (0.04)	0.09 (0.03)	1.06 (0.25)	0.73 (0.26)	0.92 (0.18)	1.93 (0.43)	1.23 (0.42)	1.64 (0.31)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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 2003 survey conducted in Barkley Sound. Values in brackets area ± 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 23-5										
<0.0 m	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	15	1.25 (0.66)	0.00	1.02 (0.56)	205.93 (57.19)	0.00	167.38 (52.46)	293.85 (88.76)	0.00	238.85 (80.41)
2.5 – <5.0 m	14	2.06 (0.87)	0.00	1.89 (0.82)	781.85 (172.87)	304.37	740.66 (162.93)	972.84 (195.10)	311.25	915.76 (187.39)
5.0 – <7.5 m	14	1.09 (0.64)	0.00	0.88 (0.54)	354.80 (74.71)	67.18	298.00 (67.35)	492.78 (105.08)	68.70	409.02 (96.38)
7.5 – <10.0 m	13	0.66 (0.58)	0.00	0.52 (0.46)	179.79 (57.15)	282.16	202.11 (64.98)	230.86 (74.94)	288.54	243.43 (74.47)
10.0 – <12.5 m	7	0.65 (0.56)	0.00	0.47 (0.43)	105.07 (58.99)	298.28	157.29 (71.46)	132.85 (74.92)	305.03	179.38 (76.37)
≥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 23-6										
<0.0 m	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0 – <2.5 m	6	0.00	0.29 (0.25)	0.29 (0.25)	0.00	27.29 (22.69)	27.29 (22.69)	0.00	43.71 (30.84)	43.71 (30.84)
2.5 – <5.0 m	7	0.00	1.94 (1.44)	1.94 (1.44)	0.00	216.36 (131.77)	216.36 (131.77)	0.00	323.87 (173.62)	323.87 (173.62)
5.0 – <7.5 m	5	0.00	0.97 (0.47)	0.97 (0.47)	0.00	264.64 (148.76)	264.64 (148.76)	0.00	366.87 (197.43)	366.87 (197.43)
7.5 – <10.0 m	3	0.00	0.45	0.45	0.00	186.63	186.63	0.00	252.95	252.95
10.0 – <12.5 m	6	0.00	0.28 (0.25)	0.28 (0.25)	0.00	91.07 (82.68)	91.07 (82.68)	0.00	120.99 (109.83)	120.99 (109.83)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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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 23-7										
<0.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	16	3.09 (0.90)	0.00	2.57 (0.79)	1196.35 (254.80)	0.00	995.13 (239.93)	1541.54 (256.17)	0.00	1282.26 (259.31)
2.5 – <5.0 m	15	2.38 (0.73)	3.06	2.50 (0.67)	892.29 (119.45)	1816.55	1053.42 (133.37)	1190.25 (140.57)	2240.68	1373.37 (154.15)
5.0 – <7.5 m	14	1.47 (0.42)	2.22	1.62 (0.38)	578.16 (112.60)	2232.61	896.33 (233.84)	815.10 (151.71)	2621.86	1162.55 (259.12)
7.5 – <10.0 m	11	0.94 (0.37)	1.97	1.09 (0.34)	369.64 (128.53)	1679.10	569.09 (219.57)	521.10 (177.13)	2080.53	758.63 (267.84)
10.0 – <12.5 m	8	0.69 (0.23)	1.35	0.86 (0.23)	406.96 (136.83)	980.54	555.74 (175.89)	567.79 (185.68)	1221.97	737.49 (208.97)
≥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 23-8										
<0.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0 – <2.5 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5 – <5.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.0 – <7.5 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.5 – <10.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0 – <12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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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 23-9										
<0.0 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	1	7.73	0.00	7.73	197.93	0.00	197.93	269.79	0.00	269.79
2.5 – <5.0 m	1	18.93	0.00	18.93	484.93	0.00	484.93	660.98	0.00	660.98
5.0 – <7.5 m	1	7.21	0.00	7.21	184.74	0.00	184.74	251.80	0.00	251.80
7.5 – <10.0 m	1	6.61	0.00	6.61	169.34	0.00	169.34	230.82	0.00	230.82
10.0 – <12.5 m	1	12.62	0.00	12.62	323.29	0.00	323.29	440.66	0.00	440.66
≥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 23-10										
<0.0 m	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0 – <2.5 m	2	0.00	2.00	2.00	0.00	389.89	389.89	0.00	419.96	419.96
2.5 – <5.0 m	2	0.00	0.79	0.79	0.00	259.97	259.97	0.00	281.21	281.21
5.0 – <7.5 m	1	0.00	0.16	0.16	0.00	26.74	26.74	0.00	28.75	28.75
7.5 – <10.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0 – <12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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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 23-11										
<0.0 m	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	16	6.46 (2.35)	3.11	6.24 (2.20)	896.33 (239.71)	467.89	868.41 (225.25)	1058.55 (278.54)	556.22	1025.82 (261.74)
2.5 – <5.0 m	16	13.96 (4.08)	3.75	13.28 (3.85)	1512.70 (337.77)	564.31	1449.56 (319.89)	1788.30 (397.83)	670.85	1713.90 (376.76)
5.0 – <7.5 m	13	12.97 (3.32)	0.00	12.97 (3.32)	1036.97 (149.81)	0.00	1036.97 (149.81)	1266.02 (178.70)	0.00	1266.02 (178.70)
7.5 – <10.0 m	11	8.12 (2.40)	0.00	8.12 (2.40)	509.77 (90.85)	0.00	509.77 (90.85)	636.07 (119.74)	0.00	636.07 (119.74)
10.0 – <12.5 m	6	6.46 (3.21)	0.00	6.46 (3.21)	591.30 (221.27)	0.00	591.30 (221.27)	743.50 (282.38)	0.00	743.50 (282.38)
≥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 123-3										
<0.0 m	2	4.45	0.00	4.45	1199.94	0.00	1199.94	1378.93	0.00	1378.93
0.0 – <2.5 m	4	25.91	0.00	19.43	3175.32	0.00	2381.49	4214.27	0.00	3160.70
2.5 – <5.0 m	4	20.04	0.00	15.03	2074.57	81.07	1576.20	2873.37	124.10	2186.05
5.0 – <7.5 m	3	11.77	0.00	11.77	1447.23	0.00	1447.23	1939.36	0.00	1939.36
7.5 – <10.0 m	3	5.84	0.00	5.84	758.82	0.00	758.82	1007.59	0.00	1007.59
10.0 – <12.5 m	2	5.72	0.00	5.72	497.21	0.00	497.21	744.12	0.00	744.12
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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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 123-5										
<0.0 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.0– <2.5 m	2	0.00	1.06	1.06	0.00	1911.87	1911.87	0.00	2315.39	2315.39
2.5 – <5.0 m	3	0.00	1.40	1.40	0.00	1677.04	1677.04	0.00	2023.37	2023.37
5.0 – <7.5 m	1	0.00	1.62	1.62	0.00	241.66	241.66	0.00	268.60	268.60
7.5 – <10.0 m	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0 – <12.5 m	1	0.00	0.00	0.00	0.00	279.57	279.57	0.00	299.73	299.73
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
All PFM sub-areas combined										
<0.0 m	23	0.74 (0.71)	0.00	0.45 (0.45)	198.43 (192.23)	0.00	121.95 (120.05)	228.03 (220.90)	0.00	140.14 (137.95)
0.0 – <2.5 m	64	5.41 (1.53)	1.18 (0.55)	3.98 (1.06)	956.13 (171.16)	391.91 (286.25)	766.44 (152.09)	1210.99 (209.31)	471.13 (346.15)	962.25 (186.00)
2.5 – <5.0 m	63	7.76 (1.98)	2.69 (1.20)	6.00 (1.39)	1170.30 (153.20)	710.79 (309.48)	1010.65 (148.92)	1463.25 (187.94)	880.92 (374.65)	1260.92 (181.89)
5.0 – <7.5 m	53	6.20 (1.57)	1.50 (0.63)	4.81 (1.16)	743.19 (87.56)	508.95 (216.85)	674.11 (89.66)	969.07 (107.75)	617.54 (246.18)	865.39 (107.25)
7.5 – <10.0 m	46	3.69 (1.05)	0.99 (0.63)	2.85 (0.77)	395.82 (56.66)	302.42 (160.73)	366.71 (63.08)	518.28 (75.07)	371.11 (190.78)	472.41 (78.73)
10.0 – <12.5 m	31	3.15 (1.29)	1.86 (1.47)	2.61 (0.96)	396.74 (91.58)	305.35 (100.04)	358.50 (66.80)	525.49 (118.39)	370.57 (120.20)	460.67 (84.70)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

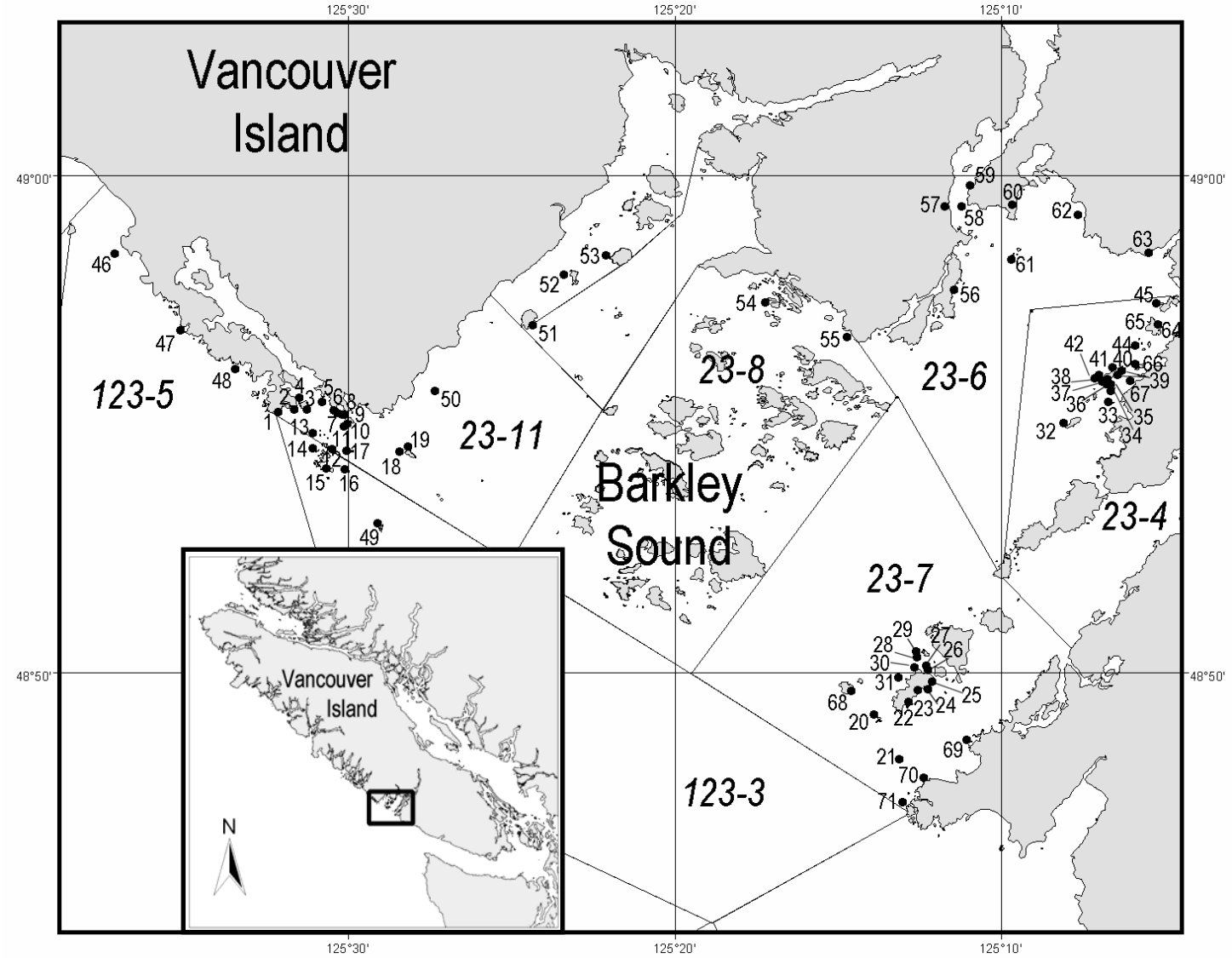

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted in Barkley Sound, 2003. Hyphenated numbers indicate Pacific Fishery Management sub-areas, and smaller numbers identify transect locations. Inset figure denotes survey location.

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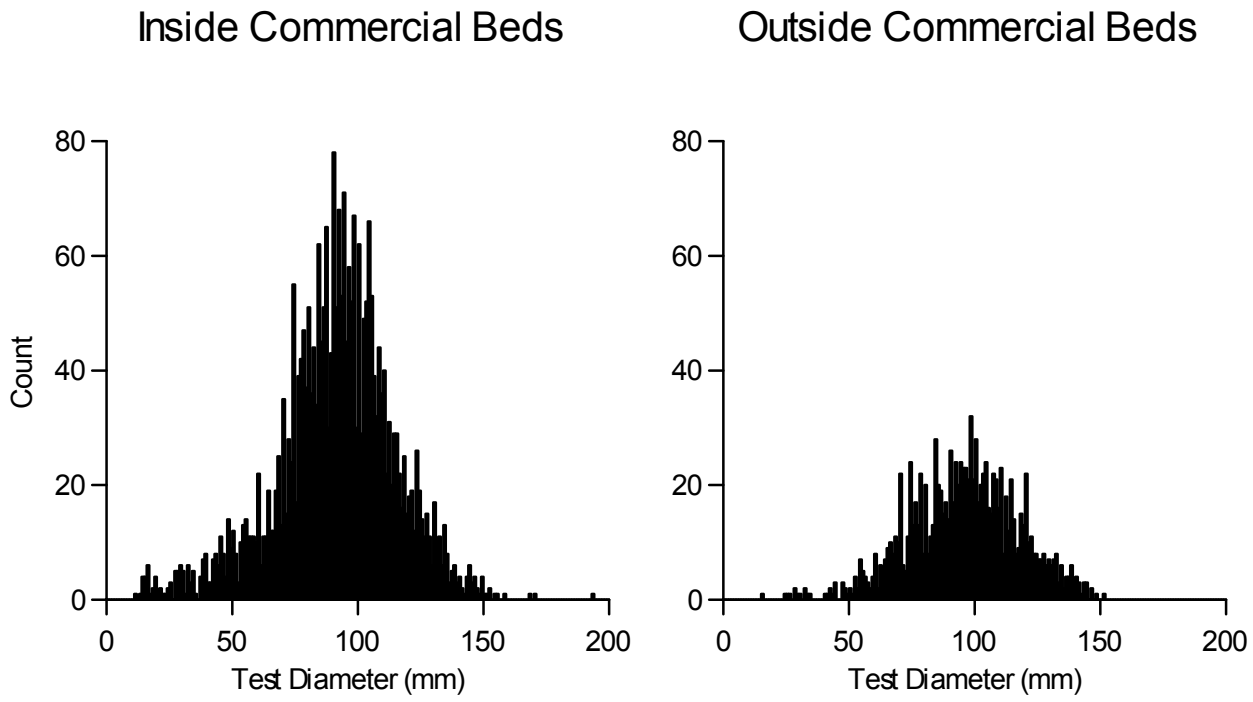

Figure 2. Size frequency distribution of red sea urchins measured along transects inside (n=2771) and outside (n=1175) of commercial bed areas during the 2003 survey in Barkley Sound.