Survey of Red Sea Urchin Populations In Beaver Pass and Freeman Pass, British Columbia, 2002

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SURVEY OF RED SEA URCHIN POPULATIONS IN BEAVER PASS AND FREEMAN PASS, BRITISH COLUMBIA, 2002

by

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ABSTRACT

Atkins, M., Campbell, A., Hajas, W.C., and Tzotzos, D. 2006. Survey of red sea urchin populations in Beaver Pass and Freeman Pass, British Columbia, 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2754: iii + 25 p.

A survey of red sea urchin populations was conducted in Beaver Pass and Freeman Pass (Pacific Fisheries Management sub-areas 5-10 and 5-12, respectively) during May, 2002. A total of 60 transects were surveyed by SCUBA divers, and 1243 red sea urchins were measured. Estimated mean densities (number/m^2) and biomass (g/m^2) were compared for red sea urchins found inside (18 transects) and outside (34 transects) previously fished commercial bed areas, and in research bed areas (8 transects). Densities were also compared by depth. In PFM sub-area 5-10 and 5-12 the density for red sea urchins of all sizes was 1.44/m^2 and 0.72/m^2, and for legal-sized red urchins (≥90 mm test diameter, TD) the density was 0.87/m^2 and 0.40/m^2, respectively. Overall, 23.3% of all red urchins measured were ≤50 mm TD whereas 59.1% 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 in Beaver Pass and Freeman Pass, British Columbia, 2002. Can. Manuscr. Rep. Fish. Aquat. Sci. 2754: iii + 25 p.

Un relevé des populations d'oursins rouges a été réalisé en mai 2002 dans le passage Beaver et le passage Freeman (sous-secteurs 5-10 et 5-12 de gestion des pêches du Pacifique, respectivement). Au total, 60 transects ont été couverts par des plongeurs autonomes, qui ont mesuré 1243 oursins rouges. On a comparé la densité moyenne estimée (nombre/m^2) et la biomasse (g/m^2) chez les oursins rouges observés à l'intérieur (18 transects) et à l'extérieur (34 transects) de gisements auparavant exploités par la pêche commerciale, ainsi que dans des gisements faisant l'objet de recherches (8 transects). On a également comparé les densités selon la profondeur. Dans les sous-secteurs 5-10 et 5-12, la densité des oursins rouges de toutes tailles était respectivement de 1,44/m^2 et 0,72/m^2, et, pour les oursins de taille réglementaire (≥90 mm de diamètre du test, DT), la densité était respectivement de 0,87/m^2 et de 0,40/m^2. Dans l'ensemble, 23,3 % de tous les oursins rouges mesurés présentaient ≤50 mm DT, tandis que 59,1 % 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). 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. Areas in Beaver Pass and Freeman Pass [Pacific Fishery Management (PFM) sub-areas 5-10 and 5-12] (Figure 1), were 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 5-10 and 5-12.

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in PFM sub-areas 5-10 and 5-12. 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).

In sub-area 5-10, the designation of research bed included an area that was selected as a potential abalone research area; this red sea urchin survey was a preliminary survey of the habitat and community within. The area of the research beds were not closed to commercial harvest at the time of this survey.

SURVEY LOGISTICS

The survey was conducted from May 10-14, 2002, on the "King Clam", 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 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 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 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, for transect located in designated research 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:

$$d_{ts} = \frac{N_{ct}}{a_t} * \frac{N_{mts}}{N_{mt}} \tag{1}$$

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:

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

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:

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

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:

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

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).

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

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:

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

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 and in research 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 five dive days (Table 1, Figure 1). A total of 1274 red sea urchins were counted, 1243 of which were measured, in 777 quadrats along the 60 transects. Total transect length surveyed was 2242m, for an average transect length of 37m. Eighteen (18) transects were located in the commercial red sea urchin beds recorded from 1997 to 2000, and eight (8) were located in designated research beds.

SUBSTRATE AND HABITAT

The majority of transects surveyed were located in areas of moderate or high exposure although one transect was located in a well sheltered area (Table 1). Of the 777 quadrats sampled, 74% had rock, 15% had sand/shell, and 11% had mud as the primary substrate. Of the 1243 red sea urchins counted, 85% were observed between 0.0 m and 7.5 m depth.

Understorey and turf algae were found at the highest density in the shallowest water (<0 m chart datum), and canopy algae were found at the highest density in depth category 2 (0.0 – <2.5 m). Understorey, turf and encrusting algae were consistently encountered at all depths surveyed.

SIZE FREQUENCY DISTRIBUTIONS

The mean size of all red sea urchins measured was 92.6 mm TD (Table 3, Fig. 2). The smallest and largest red urchins measured were 7 mm and 178 mm TD, respectively. By PFM, sub-areas 5-10 and 5-12 had a mean size of 94.5 mm TD and 88.6 mm TD, respectively. Overall, the mean size of red urchins found inside and outside of commercial bed areas and in research bed areas was 89.0 mm, 96.7 mm, and 93.5 mm TD, respectively (Table 3).

The overall percentage of legal-sized red urchins (≥90 mm TD) was 59.1%, whereas the percent of red urchins ≤50 mm TD (R_T) was 23.3% (Table 3). Of the total sublegal urchins, the percentage that was ≤50 mm TD (R_S) was 56.8%. By PFM sub-area, the percentage of legal-sized red sea urchins in sub-areas 5-10 and 5-12 was 60.8% and 55.3%, and the percentage of red urchins ≤50 mm TD (R_T) was 22.8% and 24.1%, respectively (Table 3).

Fifty eight percent (57.8%) of the red sea urchins sampled inside commercial bed areas (n=521) were of legal size, as were 60.7% of the red urchins sampled outside bed areas (n=382), and 59.1% of the urchins sampled within research beds (n=340) (Table 3). In area 5-10, the percentage of the legal-sized red sea urchins inside and outside of commercial bed areas and in research bed areas was 66.4%, 57.8% and 59.1%, respectively. In area 5-12, the percentage of legal-sized red sea urchins found inside and outside commercial bed areas was 50.0% and 66.9%, respectively (Table 3).

DENSITY AND BIOMASS ESTIMATES

For all transects combined, the estimated mean density and biomass for red sea urchins of all sizes was 1.10/m^2 and 423.87 g/m^2, respectively, and 0.65/m^2 and 392.36 g/m^2 for legal-sized urchins (Table 4). For transects lying within recorded red sea urchin beds, the estimated mean density of red urchins of all sizes was 1.26/m^2, and was 0.73/m^2 for legal-sized urchins. For transects lying outside of commercial bed areas, the estimated mean density was 0.62/m^2 for red urchins of all sizes, and 0.38/m^2 for legal-sized urchins. Inside bed areas, the estimated mean biomass of red sea urchins of all sizes was 447.12 g/m^2, and was 413.99 g/m^2 for legal-sized urchins; outside bed areas the estimated mean biomass was 257.46 g/m^2 and 236.31 g/m^2, respectively (Table 4).

By PFM sub-area, the estimated mean density inside and outside commercial beds, and in research beds for red urchins of all sizes in area 5-10 was 0.95/m^2, 1.12/m^2 and 3.68/m^2, respectively. In sub-area 5-12 there were no transects within research beds, however the mean density inside and outside of commercial beds was 1.78/m^2, and 0.31/m^2, respectively. The mean density of legal-sized red urchins was 0.63/m^2, 0.65/m^2 and 2.17/m^2, respectively for sub-area 5-10, and 0.89/m^2 and 0.21/m^2, respectively for sub-area 5-12 (Table 4). When comparing densities by PFM sub-area between inside and outside of commercial bed areas no statistical differences were observed for any size grouping; however, densities were significantly higher in research beds for all but the smallest (≤50 mm TD) red urchins (Table 5).

The highest mean density and biomass estimates of red sea urchins of any size category were observed at depths between 0.0 and 5.0 m (Tables 6 and 7), although no statistical tests were performed.

DISCUSSION

The mean size of red sea urchins found in PFM sub-area 5-10 was similar between in and out of commercial bed areas and in research bed areas, however, in sub-area 5-12 the mean size of red urchins inside commercial bed areas was lower (82.8 mm TD) than outside bed areas (101.5 mm TD). This may be an indication of higher fishing pressure in sub-area 5-12 than in 5-10, increased recruitment inside commercial bed areas, or may simply be an artefact of a small sample size.

The density of recruits (≤50 mm TD) observed during this survey (0.25/m^2) was similar to the density observed off Campbell River (0.21/m^2) (Atkins et al. 2006e); but was lower than the densities off Campania Island (0.38/m^2), in Fitz Hugh Sound (0.46/m^2), and in Queen Charlotte Strait (0.83/m^2) (Atkins et al. 2006b,f,g). The density of recruits off Campbell River was, however, higher than the densities observed in Barkley Sound (0.13/m^2), the Dundas Group (0.07/m^2), and near Robson Bight (0.04/m^2) (Atkins et al. 2006a,c,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).

When comparing estimated mean densities between bed areas, the highest density of red sea urchins was found inside the areas set aside as potential abalone research areas, close to the First Nations community of Kitkatla. This was an initial survey of the potential research beds which were not developed into long term study sites and remained open to the commercial fishery at all times, however, for reasons of unsuitable fishing conditions or poor roe quality it appeared that the fishing here was limited or non-existent. The commercial harvest may be concentrated in areas of lower urchin density due to the search for high roe quality. In areas of high urchin density, roe quality could be diminished due to intra-specific competition for food.

The overall density of red sea urchins observed during this survey (1.10/m^2) was similar to surveys in Laredo Channel in 2000 (1.09/m^2) (Tzotzos et al. 2003a) and in the Dundas Group in 2003 (1.32/m^2) (Atkins et al. 2006c); and was lower than all but two surveys from 2001 to 2004: Robson Bight in 2001 (0.80/m^2) (Atkins et al. 2006d), and Becher Bay in 2001 (0.29/m^2) (Tzotzos et al. 2003d). The density estimates for Banks Island (1997), and Campania Island (2004) (Atkins et al. 2006b), other recent surveys along the north coast, were higher at 2.23/m^2 and 3.08/m^2, respectively.

The maximum density of red sea urchins was found between 0-5 m depth, which was also observed in surveys in Laredo Channel (Tzotzos et al. 2003a), the Deserters Group (Tzotzos et al. 2003c), the Dundas Group (Atkins et al. 2006c), and Queen Charlotte Strait (Atkins et al. 2006g). This may have been due to the depth where food, algae and algal drift were most abundant, combined with being the shallowest depths generally tolerated by red sea urchins.

A large number of transects sampled during this survey were located in areas of moderate exposure, and one was located in a well sheltered area. Coupled with reduced water flow, sheltered areas typically have softer substrates such as gravel, sand, and mud. In these locations we would expect to see a reduction in red sea urchin density as urchins are typically found in areas of high exposure on rocky substrate.

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Table 1. Summary of transects surveyed during the May 10-14, 2002 red sea urchin (RSU) population survey in Beaver Pass and Freeman Pass. Density in number per meter squared and biomass in grams per meter squared. PFM = Pacific Fishery Management [sub-area]. Depths have been corrected to chart datum. Exposure: 2 = well sheltered, 4 = moderate exposure, 8 = high exposure. Check marks (✓) indicate transect lying within a known commercial RSU harvest area; (®) indicate transect lying within a research bed.

Transect	PFM Sub-area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Exposure	Time Start	Time End	Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
1	5-10	53 41.355	130 24.664	0.06	10.67	8	10:05	10:36	31	51	26	24	0.92	442.68	✓
2	5-10	53 41.758	130 24.021	-1.37	9.78	8	10:53	11:02	9	31	16	7	0.44	89.56	✓
3	5-10	53 42.495	130 23.861	-2.01	7.35	8	11:22	11:32	10	27	4	0	0.00	0.00	✓
4	5-10	53 42.936	130 22.679	-3.54	8.08	8	12:16	12:34	18	41	21	18	0.86	511.69	✓
5	5-10	53 43.172	130 22.293	-1.86	8.05	8	11:46	11:54	8	81	5	0	0.00	0.00	✓
6	5-10	53 43.942	130 21.044	0.24	9.60	4	11:46	11:57	11	15	8	10	1.25	612.59	✓
7	5-10	53 44.036	130 20.547	0.06	10.82	4	11:13	11:36	23	39	20	20	1.00	262.45	✓
8	5-10	53 44.249	130 20.075	1.52	11.13	4	10:51	11:02	11	39	20	9	0.45	312.96	✓
9	5-10	53 44.479	130 19.676	0.91	11.06	4	10:30	10:40	10	41	3	0	0.00	0.00	
10	5-10	53 45.094	130 18.224	1.43	10.12	4	09:41	10:17	36	33	17	77	4.53	2129.34	®
11	5-10	53 45.272	130 18.020	0.67	8.05	4	08:40	09:27	47	125	63	95	1.51	547.90	✓
12	5-10	53 46.075	130 18.631	-0.34	10.94	4	08:03	08:27	24	21	11	44	4.00	1905.12	®
13	5-10	53 46.262	130 20.037	-1.37	9.69	4	11:34	12:08	34	31	16	104	6.50	1876.22	®
14	5-10	53 45.990	130 19.565	-0.06	10.24	4	11:08	11:20	12	31	16	23	1.44	524.26	
15	5-10	53 45.665	130 19.310	0.70	10.73	4	10:40	10:57	17	41	21	16	0.76	649.23	
16	5-10	53 45.358	130 19.713	-0.67	10.70	4	10:23	10:30	7	41	3	0	0.00	0.00	
17	5-10	53 44.905	130 20.416	0.21	10.67	4	09:24	09:38	14	23	12	24	2.00	503.60	
18	5-10	53 44.594	130 20.933	1.25	10.70	4	09:05	09:15	10	15	8	11	1.38	713.53	®
19	5-10	53 44.353	130 21.671	1.19	10.09	4	08:48	08:56	8	21	3	0	0.00	0.00	✓
20	5-10	53 44.208	130 22.218	0.30	11.46	4	08:15	08:38	23	25	13	43	3.31	1545.04	®
21	5-10	53 44.135	130 22.572	0.37	10.24	4	07:46	08:03	17	23	12	10	0.83	620.92	
22	5-10	53 43.090	130 24.801	-2.44	7.53	4	12:48	13:02	14	19	10	36	3.60	1102.14	✓
23	5-10	53 43.740	130 25.264	-2.71	6.86	8	13:14	13:27	13	35	18	25	1.39	445.36	
24	5-10	53 43.962	130 24.925	-2.01	6.95	8	13:38	13:54	16	21	11	34	3.09	819.17	®
25	5-10	53 44.280	130 24.375	-2.71	6.46	8	14:08	14:24	16	19	10	30	3.00	1493.77	✓
26	5-10	53 45.011	130 22.142	-0.30	8.08	2	17:47	17:57	10	71	5	0	0.00	0.00	
27	5-10	53 44.915	130 23.035	-1.40	8.05	4	17:25	17:36	11	23	7	0	0.00	0.00	
28	5-10	53 44.951	130 23.386	-2.99	6.43	4	14:37	14:48	11	17	9	13	1.44	1087.69	®
29	5-10	53 45.109	130 23.894	-2.90	6.49	4	14:58	15:10	12	15	8	15	1.88	778.75	®
30	5-10	53 45.718	130 23.248	-1.25	7.71	4	17:03	17:15	12	13	7	5	0.71	261.32	

continued next page

Table 1. continued

Transect	PFM Sub-area	Latitude	Longitude	Depth (m) Minimum	Depth (m) Maximum	Exposure	Time Start	Time End	Total Time (minutes)	Transect Length(m)	Number Quadrats	Number RSU Counted	RSU Density	RSU Biomass	In Bed
31	5-10	53 46.007	130 23.487	-1.19	7.07	4	16:37	16:57	20	13	7	36	5.14	1808.42	
32	5-10	53 46.539	130 23.203	-1.77	8.35	4	12:38	12:57	19	17	9	39	4.33	1719.75	
33	5-10	53 46.847	130 23.044	-1.71	7.74	4	16:31	16:53	22	75	38	20	0.53	243.02	
34	5-10	53 46.236	130 24.118	-2.23	6.64	4	15:53	16:17	24	15	8	57	7.13	1586.93	
35	5-10	53 45.564	130 24.696	-1.98	6.98	4	15:24	15:44	20	21	11	29	2.64	919.35	
36	5-12	53 49.030	130 38.414	2.90	2.90	8	10:12	10:22	10	1	1	0	0.00	0.00	✓
37	5-12	53 49.617	130 37.482	-3.05	8.11	8	11:06	11:17	11	105	8	0	0.00	0.00	
38	5-12	53 49.707	130 37.064	-2.90	8.93	4	11:32	11:49	17	105	8	0	0.00	0.00	✓
39	5-12	53 50.400	130 35.561	-2.26	10.12	4	12:06	12:18	12	19	10	26	2.60	1054.83	
40	5-12	53 50.747	130 34.947	-1.46	6.31	4	14:42	15:02	20	15	8	28	3.50	1659.50	
41	5-12	53 49.918	130 37.478	-3.02	8.41	4	12:13	12:30	17	27	14	27	1.93	774.20	
42	5-12	53 50.020	130 37.537	-2.87	6.98	4	12:39	12:56	17	19	10	13	1.30	359.59	
43	5-12	53 50.259	130 37.019	-1.98	9.33	4	13:04	13:20	16	33	17	33	1.94	872.65	✓
44	5-12	53 50.533	130 36.542	-1.92	6.25	4	13:41	13:56	15	39	20	1	0.05	36.96	
45	5-12	53 50.346	130 36.087	-1.22	8.75	4	11:06	11:18	12	19	10	1	0.10	64.00	
46	5-12	53 50.501	130 36.179	-1.68	9.57	4	10:26	10:32	6	41	3	0	0.00	0.00	
47	5-12	53 50.440	130 35.719	-3.69	7.35	4	12:28	13:04	36	37	19	139	7.32	1624.50	✓
48	5-12	53 50.720	130 35.545	-3.29	5.64	4	13:23	13:47	24	79	40	63	1.58	547.07	✓
49	5-12	53 50.828	130 35.540	-1.16	6.46	4	13:57	14:06	9	33	4	0	0.00	0.00	
50	5-12	53 50.603	130 36.932	-2.68	5.91	4	14:28	14:53	25	39	20	26	1.30	525.12	
51	5-12	53 51.300	130 35.015	-1.80	6.34	4	15:20	15:27	7	41	3	0	0.00	0.00	
52	5-12	53 51.326	130 35.404	-2.10	6.89	4	15:40	15:51	11	61	4	0	0.00	0.00	
53	5-12	53 51.278	130 35.737	-2.77	7.53	4	16:04	16:10	6	31	3	0	0.00	0.00	
54	5-12	53 51.306	130 35.258	-2.90	7.25	4	16:28	16:41	13	81	5	0	0.00	0.00	
55	5-12	53 51.377	130 36.405	-0.70	8.60	4	16:54	17:05	11	81	41	3	0.07	64.48	
56	5-12	53 50.820	130 36.627	-1.01	9.17	4	10:45	10:52	7	31	3	0	0.00	0.00	
57	5-12	53 50.677	130 36.350	-3.60	7.28	4	14:06	14:18	12	17	9	1	0.11	3.26	
58	5-12	53 50.558	130 37.509	-2.74	7.28	4	15:11	15:36	25	45	23	39	1.70	716.45	✓
59	5-12	53 50.632	130 38.020	0.21	10.15	4	09:54	10:05	11	47	4	0	0.00	0.00	
60	5-12	53 50.400	130 38.209	-0.18	9.57	4	09:11	09:33	22	27	14	0	0.00	0.00	

Table 2. Mean percent cover of algae, substrate type, and number of red sea urchins (RSU) for each depth category surveyed during the 2002 survey conducted in Beaver Pass and Freeman Pass. Depth ranges have been corrected to chart datum. Substrate categories: 1 = rock; 2 = sand/shell; 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 5-10								
<0.0 m	5	0.1	52	1.06	8.7	63.9	31.9	49.6
0.0 - <2.5 m	273	3.5	77	1.09	29.0	43.9	13.2	77.7
2.5 - <5.0 m	282	2.2	130	1.18	9.5	17.0	33.2	57.1
5.0 - <7.5 m	222	1.6	137	1.29	1.3	27.7	17.2	44.8
7.5 - <10.0 m	70	1.2	57	1.32	0	17.4	25.4	48.4
10.0 - <12.5 m	22	1.0	23	1.30	0	10.9	27.0	48.3
≥12.5 m				None Surveyed				
PFM sub-area 5-12								
<0.0 m	87	1.2	72	1.10	1.9	48.4	31.9	71.6
0.0 - <2.5 m	155	2.7	57	1.53	8.5	24.7	22.3	46.3
2.5 - <5.0 m	110	1.3	86	1.81	1.1	28.8	12.7	37.1
5.0 - <7.5 m	36	0.6	62	1.52	1.2	16.0	18.5	30.5
7.5 - <10.0 m	9	0.4	22	1.55	0	3.2	13.2	27.7
10.0 - <12.5 m	1	0.5	2	2.00	0	0	0	45.0
≥12.5 m				None Surveyed				
PFM sub-areas 5-10 and 5-12 combined								
<0.0 m	92	0.7	124	1.08	4.8	54.9	31.9	62.4
0.0 - <2.5 m	428	3.2	134	1.28	20.3	35.7	17.1	64.3
2.5 - <5.0 m	392	1.8	216	1.44	6.1	21.7	25.1	49.2
5.0 - <7.5 m	260	1.3	199	1.52	1.3	24.1	17.6	40.4
7.5 - <10.0 m	79	1.0	79	1.38	0	13.4	22.0	42.7
10.0 - <12.5 m	23	0.9	25	1.36	0	10.0	24.8	48.0
≥12.5 m				None Surveyed				

Table 3. Number and mean size of red sea urchins measured, and percent of urchins ≤50mm TD and ≥90mm TD for each Pacific Fishery Management (PFM) sub-area surveyed during the 2002 population survey in Beaver Pass and Freeman Pass. R_T = percent of all red urchins that were ≤50mm TD. R_S = percent of sublegal urchins that were ≤50mm TD.

PFM	Transects	Test Diameter (mm)			Numbers Measured			% Total Measured		% Sublegal
Sub-area	Used	Mean	Minimum	Maximum	Total	≤50 mm TD	≥90 mm TD	≤50 mm (R_T)	≥90 mm	≤50 mm (R_S)
5-10	Within Beds	95.9	7	169	247	48	164	19.4	66.4	57.8
	Outside Beds	94.3	7	178	258	59	149	22.9	57.8	54.1
	Research Beds	93.5	9	174	340	86	201	25.3	59.1	61.9
	All	94.5	7	178	845	193	514	22.8	60.8	58.3
5-12	Within Beds	82.8	7	175	274	83	137	30.3	50.0	60.6
	Outside Beds	101.5	26	157	124	13	83	10.5	66.9	31.7
	All	88.6	7	175	398	96	220	24.1	55.3	53.9
Survey Total	Within Beds	89.0	7	175	521	131	301	25.1	57.8	59.5
	Outside Beds	96.7	7	178	382	72	232	18.8	60.7	48.0
	Research Beds	93.5	9	174	340	86	201	25.3	59.1	61.9
	All	92.6	7	178	1243	289	734	23.3	59.1	56.8

Table 4. Mean density and biomass estimates of red sea urchins by size (test diameter, TD), by bed area, and by Pacific Fishery Management sub-area, for the 2002 survey in Beaver Pass and Freeman Pass. Estimates are for transects within red sea urchin beds recorded between 1997 and 2000, for transects outside the beds, for transects in research 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 /m^2			Mean Biomass (g/m^2)		
				≤50 mm	≥90 mm	All Sizes	≤50 mm	≥90 mm	All Sizes
5-10	Within Beds	12	508	0.19 (0.08)	0.63 (0.17)	0.95 (0.26)	3.48 (1.43)	367.73 (94.53)	387.62 (99.50)
	Outside Beds	15	483	0.23 (0.09)	0.65 (0.21)	1.12 (0.36)	4.27 (1.65)	419.54 (128.57)	457.66 (141.23)
	Research Beds	8	178	0.94 (0.32)	2.17 (0.24)	3.68 (0.66)	17.45 (5.48)	1395.25 (196.35)	1492.49 (203.13)
	All	35	1169	0.32 (0.08)	0.87 (0.15)	1.44 (0.28)	5.93 (1.51)	545.59 (98.54)	584.79 (105.69)
5-12	Within Beds	6	300	0.54 (0.42)	0.89 (0.42)	1.78 (1.02)	10.80 (8.95)	492.32 (227.16)	547.88 (259.97)
	Outside Beds	19	773	0.03 (0.02)	0.21 (0.10)	0.31 (0.14)	0.83 (0.41)	121.83 (54.10)	132.38 (59.21)
	All	25	1073	0.18 (0.11)	0.40 (0.14)	0.72 (0.30)	3.62 (2.40)	225.41 (75.21)	248.55 (84.65)
5-10 and 5-12	Within Beds	18	808	0.32 (0.15)	0.73 (0.17)	1.26 (0.38)	6.20 (3.17)	413.99 (95.76)	447.12 (106.27)
Combined	Outside Beds	34	1256	0.11 (0.04)	0.38 (0.10)	0.62 (0.17)	2.15 (0.70)	236.31 (62.35)	257.46 (68.30)
	Research Beds	8	178	0.94 (0.32)	2.17 (0.24)	3.68 (0.66)	17.45 (5.48)	1395.25 (196.35)	1492.49 (203.13)
	All	60	2242	0.25 (0.07)	0.65 (0.11)	1.10 (0.21)	4.82 (1.39)	392.36 (66.03)	423.87 (71.72)

Table 5. Kruskal-Wallace test results for comparing mean densities between inside and outside commercial bed areas and in research beds, by PFM sub-area and size category, for red sea urchins surveyed in the 2002 population survey in Beaver Pass and Freeman Pass.

PFM Sub-areas	P-values		
	≤50 mm	≥90 mm	All Sizes
5-10			
In vs. Out	0.613	0.961	0.623
In vs. Research	0.083	**0.003**	**0.003**
Out vs. Research	0.210	**0.020**	**0.045**
5-12			
In vs. Out	0.144	0.150	0.157
5-10 and 5-12 combined			
In vs. Out	0.325	0.181	0.296
In vs. Research	0.086	**0.003**	**0.009**
Out vs. Research	**0.015**	**0.001**	**0.002**

Table 6. Mean density estimates of red sea urchins by depth range for all urchins surveyed inside commercial beds, outside commercials beds, in research beds, and total urchins surveyed, during the 2002 survey conducted in Beaver Pass and Freeman Pass. 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	Res.	Total	In	Out	Res.	Total	In	Out	Res.	Total
PFM sub-area 5-10													
<0.0 m	22	0.01 (0.01)	0.00	0.08 (0.08)	0.02 (0.01)	0.03 (0.03)	0.00	0.42 (0.43)	0.07 (0.07)	0.04 (0.05)	0.00	0.60 (0.61)	0.11 (0.10)
0.0– <2.5 m	32	0.92 (0.47)	0.44 (0.28)	1.66 (1.24)	0.88 (0.33)	2.24 (0.95)	1.23 (0.61)	2.82 (1.33)	2.00 (0.58)	3.66 (1.60)	2.04 (1.03)	5.61 (3.28)	3.45 (1.05)
2.5 – <5.0 m	32	0.23 (0.10)	0.44 (0.20)	1.39 (0.78)	0.51 (0.17)	0.97 (0.31)	1.31 (0.46)	3.46 (1.00)	1.52 (0.31)	1.38 (0.41)	2.32 (0.91)	5.92 (2.04)	2.52 (0.59)
5.0 – <7.5 m	34	0.10 (0.08)	0.32 (0.20)	1.07 (0.54)	0.34 (0.14)	0.35 (0.21)	0.77 (0.37)	2.68 (1.08)	0.88 (0.29)	0.53 (0.35)	1.38 (0.68)	4.26 (1.66)	1.45 (0.48)
7.5 – <10.0 m	23	0.03 (0.02)	0.29 (0.13)	1.23 (0.43)	0.29 (0.12)	0.06 (0.06)	0.93 (0.54)	2.85 (0.85)	0.77 (0.31)	0.12 (0.10)	1.51 (0.78)	4.67 (1.19)	1.26 (0.48)
10.0 – <12.5 m	14	0.07	0.03 (0.02)	1.35	0.32 (0.28)	0.10	0.13 (0.09)	2.92	0.71 (0.56)	0.26	0.22 (0.14)	4.55	1.15 (0.88)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PFM sub-area 5-12													
<0.0 m	23	0.60 (0.66)	0.01 (0.01)	0.00	0.18 (0.17)	0.95 (0.70)	0.01 (0.01)	0.00	0.29 (0.18)	2.03 (1.65)	0.03 (0.03)	0.00	0.61 (0.44)
0.0– <2.5 m	19	1.49 (1.14)	0.12 (0.08)	0.00	0.59 (0.38)	2.11 (1.10)	0.55 (0.29)	0.00	1.09 (0.43)	4.41 (2.74)	0.88 (0.49)	0.00	2.10 (0.97)
2.5 – <5.0 m	24	0.39 (0.23)	0.04 (0.02)	0.00	0.14 (0.07)	0.81 (0.41)	0.26 (0.16)	0.00	0.42 (0.17)	1.43 (0.70)	0.39 (0.25)	0.00	0.69 (0.28)
5.0 – <7.5 m	19	0.23	0.04 (0.02)	0.00	0.08 (0.04)	0.40	0.35 (0.21)	0.00	0.36 (0.16)	0.75	0.51 (0.30)	0.00	0.56 (0.24)
7.5 – <10.0 m	11	0.00	0.01 (0.01)	0.00	0.01 (0.01)	0.00	0.17 (0.12)	0.00	0.12 (0.09)	0.00	0.22 (0.17)	0.00	0.16 (0.13)
10.0 – <12.5 m	2	0.00	0.02	0.00	0.02	0.00	0.19	0.00	0.19	0.00	0.29	0.00	0.29
≥12.5 m	0	0.00	0.00	0.00	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	Res.	Total	In	Out	Res.	Total	In	Out	Res.	Total
PFM sub-areas 5-10 and 5-12 combined													
<0.0 m	45	0.35 (0.35)	0.01 (0.01)	0.08 (0.08)	0.12 (0.10)	0.56 (0.37)	0.01 (0.01)	0.42 (0.43)	0.20 (0.11)	1.19 (0.88)	0.02 (0.02)	0.60 (0.61)	0.41 (0.26)
0.0– <2.5 m	51	1.13 (0.47)	0.24 (0.12)	1.66 (1.24)	0.75 (0.25)	2.19 (0.71)	0.81 (0.29)	2.82 (1.33)	1.58 (0.39)	3.94 (1.34)	1.32 (0.49)	5.61 (3.28)	2.83 (0.74)
2.5 – <5.0 m	56	0.50 (0.15)	0.19 (0.08)	1.39 (0.78)	0.33 (0.10)	0.91 (0.24)	0.65 (0.22)	3.46 (1.00)	0.98 (0.19)	1.40 (0.36)	1.11 (0.40)	5.92 (2.04)	1.62 (0.35)
5.0 – <7.5 m	53	0.14 (0.06)	0.15 (0.09)	1.07 (0.54)	0.23 (0.08)	0.36 (0.16)	0.52 (0.20)	2.68 (1.08)	0.66 (0.18)	0.59 (0.26)	0.87 (0.33)	4.26 (1.66)	1.08 (0.30)
7.5 – <10.0 m	34	0.02 (0.02)	0.14 (0.07)	1.23 (0.43)	0.19 (0.08)	0.05 (0.04)	0.51 (0.29)	2.85 (0.85)	0.53 (0.20)	0.09 (0.08)	0.81 (0.42)	4.67 (1.19)	0.85 (0.31)
10.0 – <12.5 m	16	0.07	0.02 (0.02)	1.35	0.28 (0.24)	0.10	0.15 (0.08)	2.92	0.64 (0.49)	0.26	0.23 (0.13)	4.55	1.04 (0.77)
≥12.5 m	0	0.00	0.00	0.00	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, in research beds, and total urchins surveyed, during the 2002 survey conducted in Beaver Pass and Freeman Pass. 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	Res.	Total	In	Out	Res.	Total	In	Out	Res.	Total
PFM sub-area 5-10													
<0.0 m	22	0.15 (0.17)	0.00	1.29 (1.30)	0.25 (0.21)	12.28 (13.79)	0.00	269.64 (271.95)	45.71 (42.99)	13.34 (14.97)	0.00	285.77 (288.22)	48.55 (45.58)
0.0– <2.5 m	32	18.69 (9.34)	7.55 (4.52)	30.66 (22.10)	17.00 (6.29)	1267.99 (544.09)	762.40 (360.85)	1673.78 (810.76)	1167.69 (331.81)	1346.59 (578.01)	827.43 (396.16)	1859.72 (926.95)	1260.20 (358.29)
2.5 – <5.0 m	32	4.16 (1.97)	11.00 (6.57)	28.27 (13.88)	10.93 (3.83)	573.89 (186.56)	864.14 (277.74)	2085.56 (587.83)	941.82 (190.80)	599.79 (191.25)	961.27 (321.15)	2254.10 (641.72)	1020.38 (211.17)
5.0 – <7.5 m	34	1.71 (1.20)	4.57 (2.51)	18.99 (8.29)	5.56 (2.08)	191.09 (108.40)	497.99 (224.57)	1840.55 (783.87)	571.63 (193.11)	201.68 (115.68)	541.91 (242.26)	1932.30 (802.74)	608.09 (202.15)
7.5 – <10.0 m	23	0.48 (0.38)	5.50 (2.34)	22.07 (6.15)	5.34 (2.01)	31.42 (27.92)	591.56 (332.85)	1963.69 (632.35)	506.05 (205.55)	34.98 (30.60)	641.44 (357.04)	2065.94 (636.34)	540.21 (216.76)
10.0 – <12.5 m	14	1.61	0.80 (0.82)	20.95	5.34 (4.18)	62.94	109.07 (83.05)	2078.36	510.40 (402.36)	75.82	116.30 (84.25)	2146.11	532.36 (414.15)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PFM sub-area 5-12													
<0.0 m	23	12.93 (14.02)	0.18 (0.18)	0.00	3.90 (3.73)	532.46 (388.51)	8.23 (8.57)	0.00	161.15 (102.18)	601.21 (442.04)	8.56 (8.91)	0.00	181.44 (116.29)
0.0– <2.5 m	19	29.34 (24.24)	2.87 (1.86)	0.00	12.02 (7.96)	1148.34 (592.23)	328.70 (179.17)	0.00	612.02 (237.20)	1285.82 (680.42)	359.16 (197.53)	0.00	679.47 (268.25)
2.5 – <5.0 m	24	6.90 (4.00)	0.97 (0.59)	0.00	2.68 (1.27)	443.83 (220.25)	144.78 (90.47)	0.00	230.88 (93.48)	482.62 (236.84)	158.68 (99.48)	0.00	251.94 (101.58)
5.0 – <7.5 m	19	4.03	1.04 (0.60)	0.00	1.75 (0.78)	215.18	197.11 (117.40)	0.00	201.40 (90.81)	236.15	215.17 (128.25)	0.00	220.15 (99.17)
7.5 – <10.0 m	11	0.00	0.35 (0.38)	0.00	0.25 (0.27)	0.00	116.20 (76.88)	0.00	85.30 (58.86)	0.00	123.14 (82.22)	0.00	90.40 (62.71)
10.0 – <12.5 m	2	0.00	0.66	0.00	0.66	0.00	103.43	0.00	103.43	0.00	116.79	0.00	116.79
≥12.5 m	0	0.00	0.00	0.00	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	Res.	Total	In	Out	Res.	Total	In	Out	Res.	Total
PFM sub-areas 5-10 and 5-12 combined													
<0.0 m	45	7.54	0.12	1.29	2.44	313.12	5.53	269.64	115.19	353.33	5.75	285.77	128.53
		(7.54)	(0.12)	(1.30)	(2.22)	(205.82)	(5.66)	(271.95)	(63.10)	(234.30)	(5.89)	(288.22)	(71.48)
0.0– <2.5 m	51	22.63	4.65	30.66	14.73	1223.66	493.83	1673.78	914.58	1324.08	537.45	1859.72	995.68
		(9.83)	(2.05)	(22.10)	(5.00)	(399.07)	(176.62)	(810.76)	(221.56)	(430.30)	(194.01)	(926.95)	(241.27)
2.5 – <5.0 m	56	5.24	4.72	28.27	6.88	522.55	413.33	2085.56	592.72	553.54	458.29	2254.10	643.04
		(1.84)	(2.57)	(13.88)	(2.10)	(139.52)	(133.15)	(587.83)	(115.04)	(145.28)	(150.99)	(641.72)	(126.49)
5.0 – <7.5 m	53	2.36	2.50	18.99	3.96	197.75	321.98	1840.55	416.12	211.20	350.77	1932.30	445.13
		(1.08)	(1.10)	(8.29)	(1.25)	(80.43)	(117.39)	(783.87)	(119.22)	(86.06)	(127.13)	(802.74)	(125.34)
7.5 – <10.0 m	34	0.37	2.69	22.07	3.46	23.93	332.08	1963.69	350.30	26.64	358.53	2065.94	373.70
		(0.29)	(1.29)	(6.15)	(1.31)	(20.95)	(175.07)	(632.35)	(134.27)	(22.96)	(188.44)	(636.34)	(141.84)
10.0 – <12.5 m	16	1.61	0.76	20.95	4.73	62.94	107.67	2078.36	457.74	75.82	116.42	2146.11	478.58
			(0.63)		(3.65)		(67.07)		(351.30)		(69.24)		(361.66)
≥12.5 m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

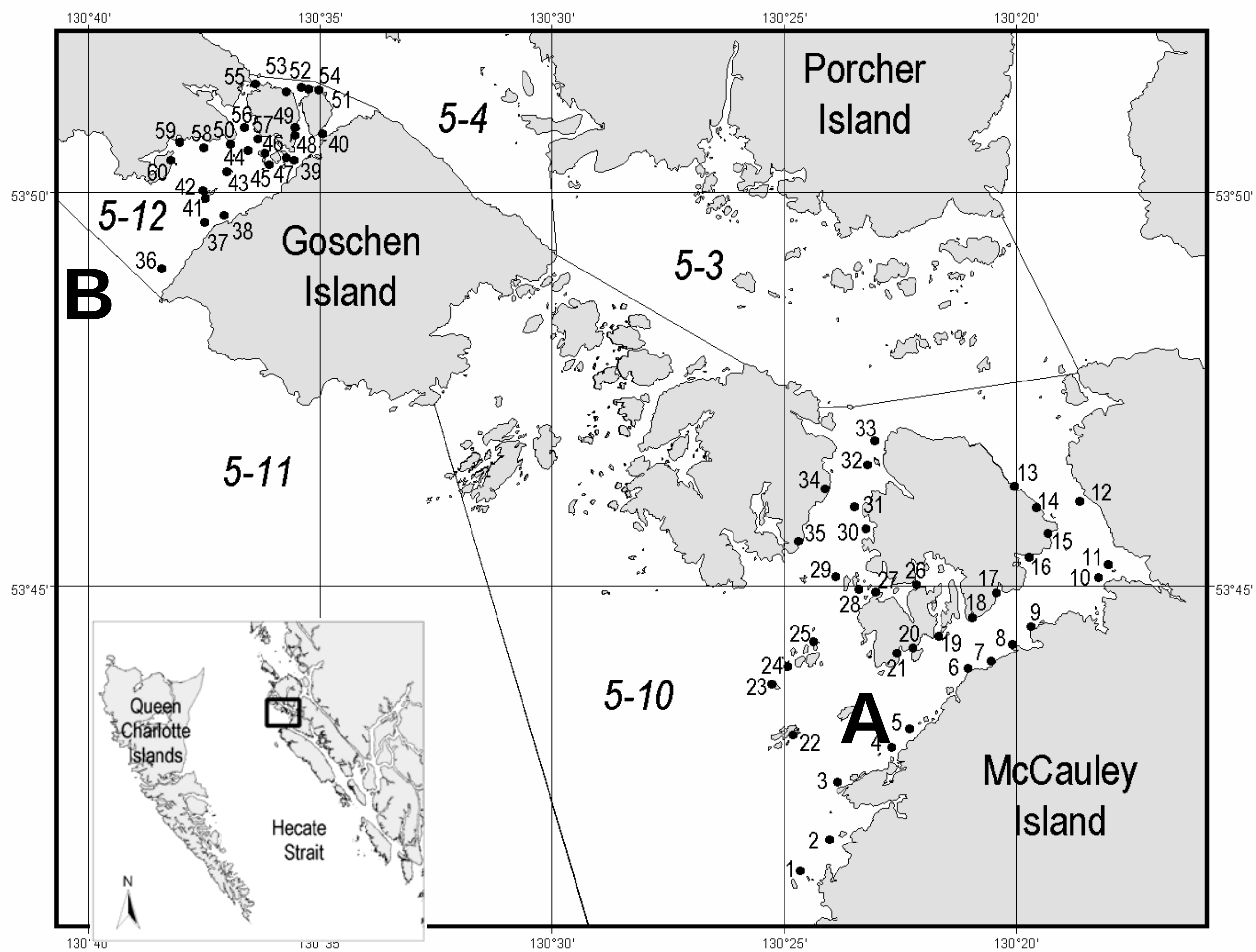

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted in Beaver Pass (A) and Freeman Pass (B), 2002. Hyphenated numbers indicate Pacific Fishery Management sub-areas, and smaller numbers identify transect locations. Inset figure denotes survey location.

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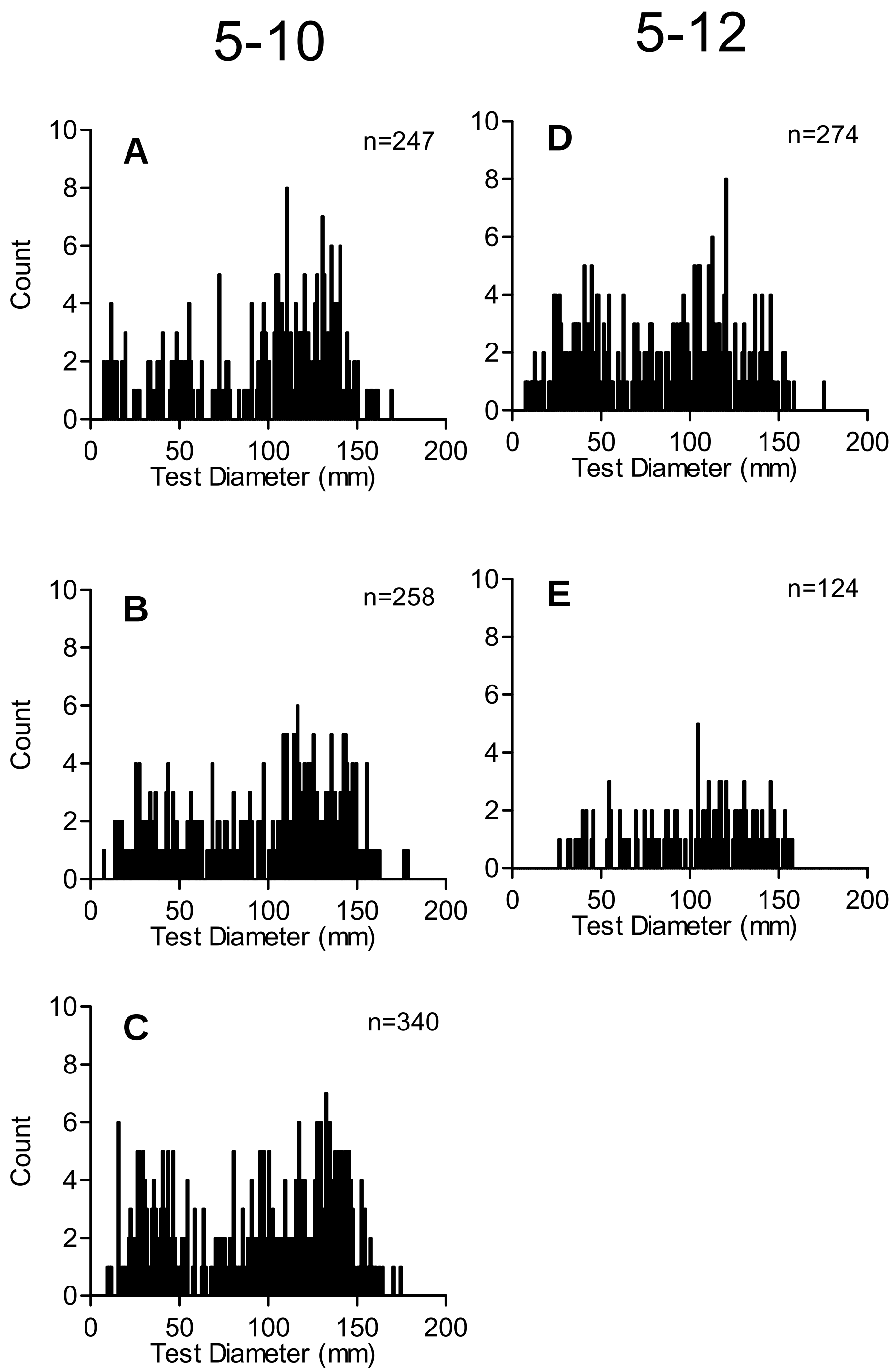

Figure 2. Size frequency distribution of red sea urchins measured along transects inside (A, D) and outside (B, E) of commercial bed areas, and in research bed areas (C), in PFM sub-areas 5-10 and 5-12 during the 2002 survey at Beaver Pass and Freeman Pass. PFM sub-areas are indicated above the figures. n= number of red sea urchins measured for test diameter.