Survey of Red Sea Urchin Populations At Price Island, British Columbia, 2001

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SURVEY OF RED SEA URCHIN POPULATIONS AT PRICE ISLAND, BRITISH COLUMBIA, 2001

by

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ABSTRACT

Tzotzos, D., Atkins, M., and Campbell, A. 2006. Survey of red sea urchin populations at Price Island, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2757: iii + 21 p.

A survey of red sea urchin populations was conducted at Price Island (Pacific Fishery Management, PFM sub-area 7-1, 7-2, 7-3, and 7-31), during September, 2001. A total of 35 randomly placed transects were surveyed by SCUBA divers, and 3583 red sea urchins were measured. There were no significant differences in estimated mean densities (number/m^2) and biomass (g/m^2) between red sea urchins found inside and outside previously fished commercial beds in PFM sub-area 7-3. No commercial beds were surveyed in the other PFM sub-areas. The total estimated mean density was 6.98 urchins per m^2, and the estimated mean biomass was 1696.5g per m^2. Overall, 12.6% of the total number of urchins measured were ≤50 mm test diameter (TD), whereas 46.6% were of legal size (≥ 90 mm TD) for the commercial fishery.

RÉSUMÉ

Tzotzos, D., Atkins, M., and Campbell, A. 2006. Survey of red sea urchin populations at Price Island, British Columbia, 2001. Can. Manuscr. Rep. Fish. Aquat. Sci. 2757: iii + 21 p.

Un relevé des populations d'oursins rouges a été réalisé en septembre 2001 à l'île Price (sous-secteurs 7-1, 7-2, 7-3 et 7-31 de gestion des pêches du Pacifique). Au total, 35 transects établis au hasard ont été couverts par des plongeurs autonomes, qui ont mesuré 3583 oursins rouges. On n'a pas noté de différences significatives dans la densité moyenne estimée (nombre/m^2) ni dans la biomasse (g/m^2) entre les oursins rouges observés à l'intérieur et à l'extérieur de gisements auparavant exploités par la pêche commerciale dans le sous-secteur 7-3. Aucun gisement exploité commercialement n'a été examiné dans les autres sous-secteurs. La densité moyenne totale estimée était de 6,98 oursins par m^2, et la biomasse moyenne a été estimée à 1696,5 g par m^2. Dans l'ensemble, 12,6 % de tous les oursins rouges mesurés présentaient ≤50 mm DT, tandis que 46,6% avaient la taille réglementaire (≥ 90 mm TD) 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). Red sea urchins are commercially harvested for their gonads (roe), which are sold mainly in Japan. Coastal First Nations communities harvest sea urchins as part of their food, social, and ceremonial fisheries. The commercial red sea urchin fishery started in British Columbia (BC) in the early 1970's and the total landed value for the 2000-2001 season was $8.4 million (Campbell et al. 2001), making the red sea urchin fishery one of the most valuable shellfish fisheries in BC.

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

Early red sea urchin population surveys were conducted during the 1970's and 1980's by Adkins et al. (1981), Breen et al. (1976, 1978) and Sloan et al. (1987). Since 1993, red sea urchin population surveys have been conducted as a joint effort between the Pacific Urchin Harvesters Association (PUHA), First Nations, and Fisheries and Oceans Canada (DFO) (Jamieson et al. 1998a-d; Bureau et al. 2000a-d; Tzotzos et al. 2003a-d, 2006; Atkins et al. 2006a-h).

Fishery managers request that red sea urchin surveys be conducted to update density and biomass estimates to help determine quotas. The Price Island area [parts of Pacific Fishery Management (PFM) sub-areas 7-1, 7-2, 7-3, and 7-31] (Figure 1), was selected for survey through discussion between PUHA and DFO. The objective of this paper was to present detailed survey results and to estimate red sea urchin density and biomass for PFM sub-areas 7-1, 7-2, 7-3, and 7-31.

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Survey efforts were concentrated in PFM sub-areas 7-1, 7-2, 7-3, and 7-31 (Figure 1). 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. Mean distance between transects was estimated as SL/n where n is the number of transects along the shoreline. Since variation in urchin density was unlikely to match the spacing of the transects, the systematic sample was treated as a random sample of transects (Jamieson and Schwarz 1998).

SURVEY LOGISTICS

The survey was conducted between September 6-10, 2001. The PUHA provided the "Westport I", a commercial red sea urchin fishing vessel, with a crew of three people consisting of two divers, one of which was a biologist and the other a commercial red sea urchin harvester. The PUHA also retained the services of a third party commercial diver.

DIVE SURVEY METHODS

In the field, locations 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 the 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, 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).

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

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

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

where N_{ct} is the total number of red urchins counted on transect t, N_{mt} is the total number of red urchins measured on transect t, ΣW_{ts} is the sum of the weights of red urchins measured in size group s on transect t and a_t is the surface area of quadrats surveyed on the transect t.

Overall estimated mean biomass ($\bar{b}_s$) 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 $\bar{d}_s$ were substituted for b_{ts} and $\bar{b}_s$, 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, 35 transects were surveyed during five dive days (Table 1, Figure 1). A total of 3583 red sea urchins were measured in 514 quadrats on the 35 transects. Total transect length surveyed was 991m, for an average transect length of 28m. Eight transects were located in the commercial red sea urchin beds recorded from 1997 to 2000. Surveyed transects were spread throughout PFM sub-areas 7-1, 7-2, 7-3, and 7-

31. At the time of the survey, PFM sub-area 7-31 was closed to commercial harvesting for research purposes.

SUBSTRATE AND HABITAT

Generally, the survey area was characterised by steep slopes, accounting for the relatively short transects. Bedrock (smooth and creviced) was the primary substrate in 387 (75.3%) quadrats. Boulders and cobble were the primary substrate in 119 (23.2%) quadrats, while shell was the primary substrate type in 8 (1.5%) quadrats.

Of 3583 red sea urchins measured, 81% were observed between 0.0m and 7.5m (Table 2). All surveyed transects had exposure values of 8: high exposure (Table 1).

SIZE FREQUENCY DISTRIBUTIONS

The mean size of all red sea urchins measured was 83.2 mm TD (Table 3, Figure 2). The smallest and largest red urchins measured were 5 mm and 158 mm TD, respectively. Overall, the mean size of red urchins found within and outside of commercial bed areas was 85.0 mm and 82.7 mm TD, respectively

The overall percentage of legal-sized red urchins (≥90 mm TD) was 46.6%, whereas the percentage of urchins ≤50 mm TD (R_T) was 12.6%. Of the total sublegal red urchins, 23.5% were ≤50 mm TD (R_S). Inside and outside commercial beds areas, the percentage of legal-sized red urchins was 52.5% and 45.0%, the percentage of red urchins ≤50 mm TD (R_T) was 14.6% and 12.0%, and the percentage of sublegal red urchins ≤50 mm TD (R_S) was 30.7% and 21.9%, respectively.

DENSITY AND BIOMASS ESTIMATES

For all transects combined, the estimated mean density and biomass for red sea urchins of all sizes was 6.98/m^2 and 1696.5 g/m^2, respectively, and 3.25/m^2 and 1227.6 g/m^2 for legal-sized urchins (Table 4). Although differences in density and biomass between in and out of bed areas were observed for all size groupings, the differences were not significant (Table 5). Overall (PFM sub-areas combined), for transects lying within recorded red sea urchin beds, the estimated mean density of red urchins of all sizes was 6.30/m^2, and was 3.31/m^2 for legal-sized urchins. For transects lying outside of commercial bed areas, the estimated mean density was 7.18/m^2 for red urchins of all sizes, and 3.23/m^2 for legal-sized urchins. Inside bed areas, the estimated mean biomass of red sea urchins of all sizes was 1684.2 g/m^2, and was 1349.0 g/m^2 for legal-sized urchins; outside bed areas the estimated mean biomass was 1700.0 g/m^2 and 1192.2 g/m^2, respectively (Table 4).

DISCUSSION

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

The overall density and biomass estimates of 6.98 urchins/m^2 and 1696.5g/m^2 from this survey were much higher than the values observed during surveys conducted in other areas of the central coast. The Fitz Hugh Sound survey conducted in 2001 showed overall red sea urchin densities of 1.12 urchins per m^2, and an overall biomass estimate of 274.6g/m^2 (Atkins et al. 2005h). The Laredo Channel survey conducted in 2000 showed overall red sea urchin density and biomass estimates of 1.09 urchins per m^2 and 255.9g/m^2 (Tzotzos et al. 2003a).

Overall, no significant differences were observed when densities inside and outside of know commercial beds were compared. This, coupled with high estimated densities suggested that population growth (recruitment) was not being limited through over-fishing.

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Table 1. Summary of transects surveyed during the September 6-10, 2001 red sea urchin (RSU) population survey at Price Island. Density in number per meter squared and biomass in grams per meter squared. PFM = Pacific Fishery Management. Depths have been corrected to chart datum. Check marks (✓) indicate transect lying within a known commercial RSU harvest area. Exposure value of 8 = high exposure.

	PFM			Depth (m)		Time		Total Time	Exposure	Transect	Number	Number RSU	RSU	RSU	In
Transect	Sub-Area	Latitude	Longitude	Minimum	Maximum	Start	End	(minutes)	Value	Length(m)	Quadrats	Counted	Density	Biomass	Bed
1	7-31	52 16.048	128 42.344	-1.25	7.99	16:23	16:58	35	8	27	14	134	9.57	2607.60	
2	7-31	52 16.307	128 42.184	-0.76	9.85	9:51	10:01	10	8	23	12	25	2.08	543.01	
3	7-31	52 16.383	128 41.488	-0.06	5.76	15:24	15:41	17	8	17	9	62	6.89	854.84	
4	7-31			-0.88	8.02	14:57	15:12	15	8	17	9	42	4.67	1071.26	
5	7-31	52 16.363	128 41.18	-0.46	7.68	14:23	14:50	27	8	41	22	50	2.27	524.24	
6	7-31	52 16.463	128 40.829	0.88	9.42	8:51	9:32	41	8	51	26	202	7.77	1959.76	
7	7-2	52 15.943	128 41.69	1.25	7.89	17:10	17:33	23	8	23	12	88	7.33	1822.32	
8	7-2	52 15.698	128 43.068	0.40	8.93	11:10	12:01	51	8	71	36	303	8.42	1722.55	
9	7-31	52 15.702	128 43.122	0.34	7.68	12:06	12:20	14	8	15	8	58	7.25	1992.49	
10	7-31	52 15.787	128 43.003	0.06	9.69	10:20	10:55	35	8	39	20	203	10.15	2026.26	
11	7-1	52 15.398	128 42.064	5.70	9.97	12:26	13:17	51	8	47	24	139	5.79	1383.45	
12	7-2	52 15.502	128 42.624	1.31	9.02	15:02	15:34	32	8	37	19	143	7.53	1616.40	
13	7-1	52 15.238	128 43.055	2.68	10.06	12:32	12:45	13	8	13	7	43	6.14	1536.89	
14	7-1	52 15.185	128 42.807	2.16	10.00	11:50	12:13	23	8	13	7	69	9.86	2534.94	
15	7-1	52 14.95	128 42.682	4.88	10.64	9:53	10:20	27	8	21	11	53	4.82	1122.19	
16	7-2	52 15.243	128 42.569	2.47	10.30	11:01	11:40	39	8	21	11	198	18.00	5216.28	
17	7-1	52 15.069	128 42.439	5.46	10.67	10:27	10:50	23	8	25	13	54	4.15	1268.89	
18	7-2	52 15.601	128 42.51	0.37	8.11	17:37	18:03	26	8	21	11	132	12.00	3245.93	
19	7-2	52 15.642	128 42.67	0.55	7.89	15:54	16:24	30	8	23	12	145	12.08	2604.03	
20	7-2	52 15.783	128 42.429	0.73	6.40	17:04	17:30	26	8	21	11	116	10.55	2485.49	
21	7-2			3.66	7.77	18:11	18:26	15	8	17	9	74	8.22	2214.25	
22	7-2	52 16.364	128 40.178	-1.31	8.05	17:53	18:11	18	8	13	7	50	7.14	1305.89	
23	7-31	52 16.691	128 40.105	-1.19	8.53	18:26	19:07	41	8	63	32	115	3.59	885.20	
24	7-3	52 17.823	128 38.984	-0.03	7.50	17:06	17:18	12	8	19	10	21	2.10	587.89	✓
25	7-3	52 17.817	128 38.804	0.43	7.04	17:24	17:36	12	8	9	5	26	5.20	1321.82	✓
26	7-3	52 17.976	128 38.906	-1.25	5.67	18:08	18:42	34	8	43	22	89	4.05	1139.36	✓
27	7-3	52 17.891	128 38.689	3.41	7.83	17:44	17:58	14	8	15	8	47	5.88	1557.24	✓
28	7-3	52 18.74	128 37.611	0.88	8.78	12:38	13:38	60	8	51	26	328	12.62	3398.99	✓
29	7-3	52 19.239	128 37.241	0.37	10.33	11:41	12:22	41	8	47	24	175	7.29	1537.24	
30	7-31	52 16.269	128 40.618	2.07	9.36	8:40	8:44	4	8	13	7	20	2.86	675.99	
31	7-3	52 20.339	128 37.193	-0.24	6.68	10:07	10:36	29	8	41	21	109	5.19	1220.62	✓
32	7-3	52 19.81	128 37.028	1.55	10.12	10:57	11:25	28	8	37	19	137	7.21	1823.07	
33	7-3	52 18.318	128 37.043	0.79	8.56	14:58	15:15	17	8	19	10	25	2.50	917.97	✓
34	7-3	52 17.568	128 39.479	-0.52	6.68	16:28	16:50	22	8	27	14	82	5.86	1518.90	✓
35	7-3	52 17.181	128 35.598	-0.67	7.96	15:35	15:49	14	8	11	6	26	4.33	1090.90	

Table 2. Mean percent cover by algae, substrate type, and number of red sea urchins (RSU) for each depth category surveyed during the 2001 survey conducted at Price Island. Depths have been corrected to chart datum. Substrate values: 1 = rock; 2 = sand; 3 = mud. Canopy = tall, shading, surface-reaching algae. Understorey = 30cm to 2m in height. Turf = 5cm to 30cm in height. Encrusting = species forming a thin, 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 7-1								
<0.0 m				none surveyed				
0.0 - <2.5 m	0	0.00	1	1.00	40.00	50.00	0.00	100.00
2.5 - <5.0 m	46	9.20	5	1.00	2.00	18.00	0.00	100.00
5.0 - <7.5 m	160	5.00	32	1.00	0.63	19.84	3.75	100.00
7.5 - <10.0 m	121	6.05	20	1.00	0.10	4.00	0.00	100.00
10.0 - <12.5 m	31	7.75	4	1.00	0.00	3.75	0.00	100.00
≥12.5 m				none surveyed				
PFM sub-area 7-2								
<0.0 m	0	0.00	1	1.00	0.00	60.00	70.00	100.00
0.0 - <2.5 m	379	18.05	21	1.00	4.29	7.62	2.14	99.05
2.5 - <5.0 m	309	8.58	36	1.00	1.67	0.83	0.28	100.00
5.0 - <7.5 m	341	7.26	47	1.00	0.00	0.00	0.00	98.51
7.5 - <10.0 m	201	9.14	22	1.00	0.00	0.00	0.00	100.00
10.0 - <12.5 m	19	19.00	1	1.00	0.00	0.00	0.00	100.00
≥12.5 m				none surveyed				
PFM sub-area 7-3								
<0.0 m	75	8.33	9	1.00	26.67	37.22	16.67	88.89
0.0 - <2.5 m	376	12.97	29	1.00	10.34	18.45	2.76	94.31
2.5 - <5.0 m	300	5.66	53	1.02	0.75	1.23	1.17	85.19
5.0 - <7.5 m	253	4.87	52	1.00	0.00	0.58	0.90	90.10
7.5 - <10.0 m	60	3.00	20	1.00	0.00	0.00	0.00	92.75
10.0 - <12.5 m	1	0.50	2	1.00	0.00	0.00	0.00	100.00
≥12.5 m				none surveyed				

Continued next page

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 7-31								
<0.0 m	48	6.00	8	1.00	24.38	58.13	23.13	66.25
0.0 - <2.5 m	347	10.52	33	1.00	8.48	10.15	5.30	92.42
2.5 - <5.0 m	212	4.24	50	1.10	3.90	5.50	1.90	80.80
5.0 - <7.5 m	187	4.79	39	1.03	1.28	1.28	0.13	96.03
7.5 - <10.0 m	117	4.03	29	1.03	0.00	0.00	0.00	85.34
10.0 - <12.5 m				none surveyed				
≥12.5 m				none surveyed				
PFM sub-areas Combined								
<0.0 m	123	6.83	18	1.00	24.17	47.78	22.50	79.44
0.0 - <2.5 m	1102	13.12	84	1.00	8.45	12.86	3.57	94.82
2.5 - <5.0 m	867	6.02	144	1.04	2.11	3.19	1.16	87.88
5.0 - <7.5 m	941	5.54	170	1.01	0.41	4.21	1.01	95.65
7.5 - <10.0 m	499	5.48	91	1.01	0.02	0.88	0.00	93.74
10.0 - <12.5 m	51	7.29	7	1.00	0.00	2.14	0.00	100.00
≥12.5 m				none surveyed				

Table 3. Number of red sea urchins measured and percent of urchins ≤50mm TD and ≥90mm TD for each Pacific Fishery Management (PFM) sub-area surveyed in the 2001 population survey at Price Island. R_T = percent of all 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			Percent of Total Urchins Measured		
								≤50 mm TD		≥90 mm TD
		Mean	Minimum	Maximum	Total	≤50 mm TD	≥90 mm TD	R_T	R_S	
7-1	Within Beds					none surveyed				
	Outside Beds	86.3	12	146	358	26	172	7.3	14.0	48.0
	All	86.3	12	146	358	26	172	7.3	14.0	48.0
7-2	Within Beds					none surveyed				
	Outside Beds	82.9	10	155	1249	140	559	11.2	20.3	44.8
	All	82.9	10	155	1249	140	559	11.2	20.3	44.8
7-3	Within Beds	85.0	5	158	727	106	382	14.6	30.7	52.5
	Outside Beds	76.9	6	140	338	77	147	22.8	40.3	43.5
	All	82.4	5	158	1065	183	529	17.2	34.1	49.7
7-31	Within Beds					none surveyed				
	Outside Beds	83.2	12	135	911	101	408	11.1	20.1	44.8
	All	83.2	12	135	911	101	408	11.1	20.1	44.8
Survey Total	Within Beds	85.0	5	158	727	106	382	14.6	30.7	52.5
	Outside Beds	82.7	6	155	2856	344	1286	12.0	21.9	45.0
	All	83.2	5	158	3583	450	1668	12.6	23.5	46.6

Table 4. Estimates of density and biomass of red sea urchins (RSU), by Pacific Fishery Management sub-area, for the 2001 survey at Price Island. Estimates are for transects within red sea urchin beds recorded between 1997-2000, for transects outside the beds, and for all transects combined.

PFM Sub-Area	Transects Used	Number of Transects	Sum of Transect Lengths (m)	Mean Density RSU/m^2		Standard Error of Mean Density		Mean Biomass of RSU g/m^2		Standard Error of Mean Biomass	
				All Sizes	≥90mm	All Sizes	≥90mm	All Sizes	≥90mm	All Sizes	≥90mm
7-1	Within Beds	0	0	--	--	--	--	--	--	--	--
	Outside Beds	5	119	5.76	2.77	0.66	0.28	1455.8	1022.8	157.33	131.97
	All	5	119	5.76	2.77	0.66	0.28	1455.8	1022.8	157.33	131.97
7-2	Within Beds	0	0	--	--	--	--	--	--	--	--
	Outside Beds	9	247	9.74	4.36	1.02	0.66	2301.4	1615.9	354.8	293.7
	All	9	247	9.74	4.36	1.02	0.66	2301.4	1615.9	354.8	293.7
7-3	Within Beds	8	224	6.30	3.31	1.70	0.85	1684.2	1349.0	458.7	352.9
	Outside Beds	3	95	6.92	3.01	--	--	1596.9	1217.7	--	--
	All	11	319	6.48	3.22	1.17	0.60	1658.2	1309.9	319.6	247.4
7-31	Within Beds	0	0	--	--	--	--	--	--	--	--
	Outside Beds	10	306	5.75	2.58	1.09	0.48	1341.66	908.11	253.66	175.36
	All	10	306	5.75	2.58	1.09	0.48	1341.66	908.11	253.66	175.36
7 Total	Within Beds	8	224	6.30	3.31	1.70	0.85	1684.2	1349.0	458.7	352.9
	Outside Beds	27	767	7.18	3.23	0.64	0.30	1700.0	1192.2	163.7	122.5
	All	35	991	6.98	3.25	0.61	0.30	1696.5	1227.6	159.8	123.8

Table 5. Kruskal-Wallace test results for comparing mean densities between inside and outside commercial bed areas by PFM sub-area and test diameter for red sea urchins surveyed in the 2001 population survey at Price Island.

PFM Sub-area	P-values		
	≤50 mm	≥90 mm	All Sizes
7-1	n/a	n/a	n/a
7-2	n/a	n/a	n/a
7-3	0.683	0.683	0.307
7-31	n/a	n/a	n/a
Sub-areas combined	0.467	0.421	0.107

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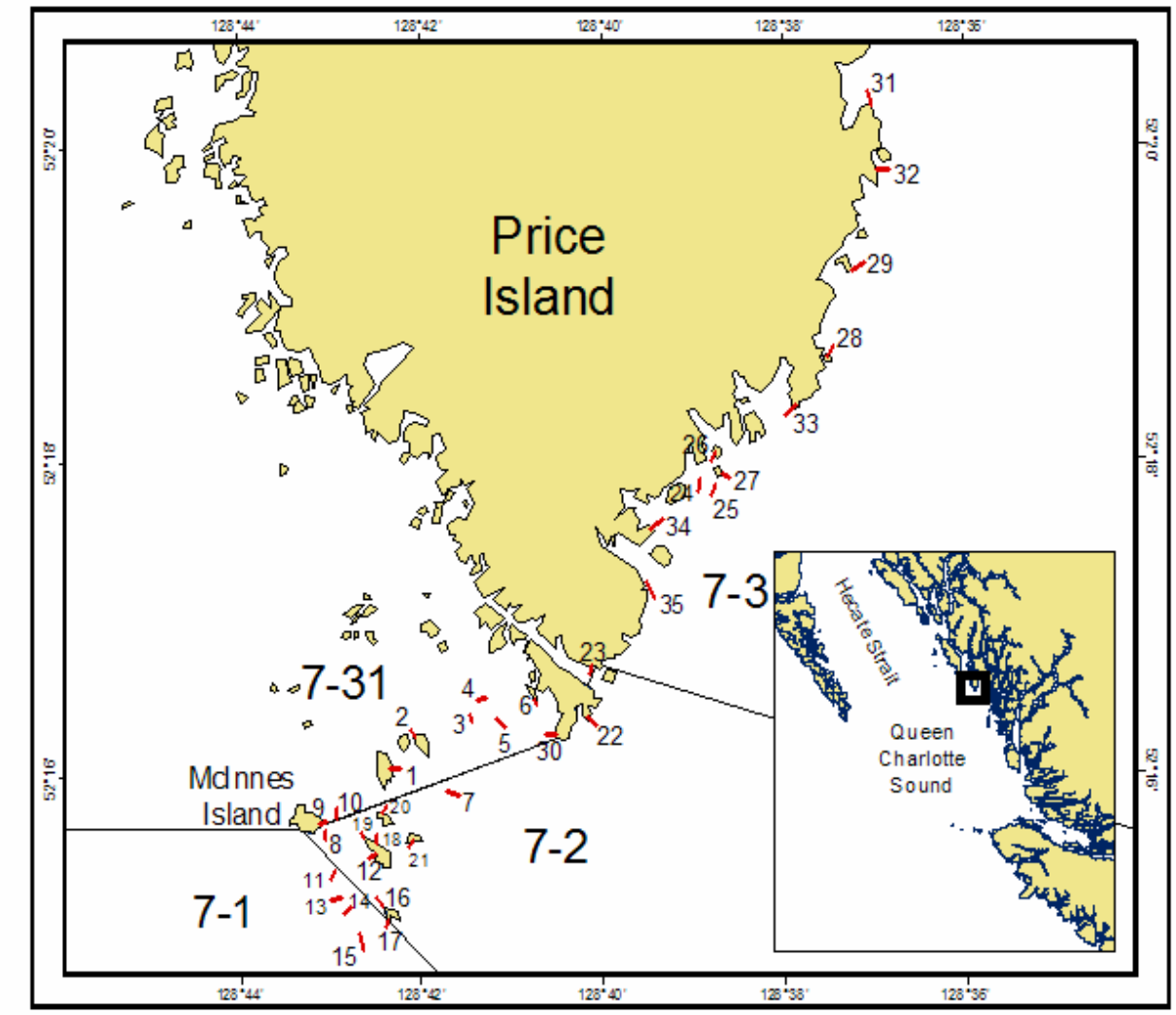

Figure 1. Map of survey area and transect locations for the red sea urchin population survey conducted at Price Island, 2001. Hyphenated numbers indicate Pacific Fishery Management sub-areas, and smaller numbers identify transect locations. Inset figure denotes survey location.

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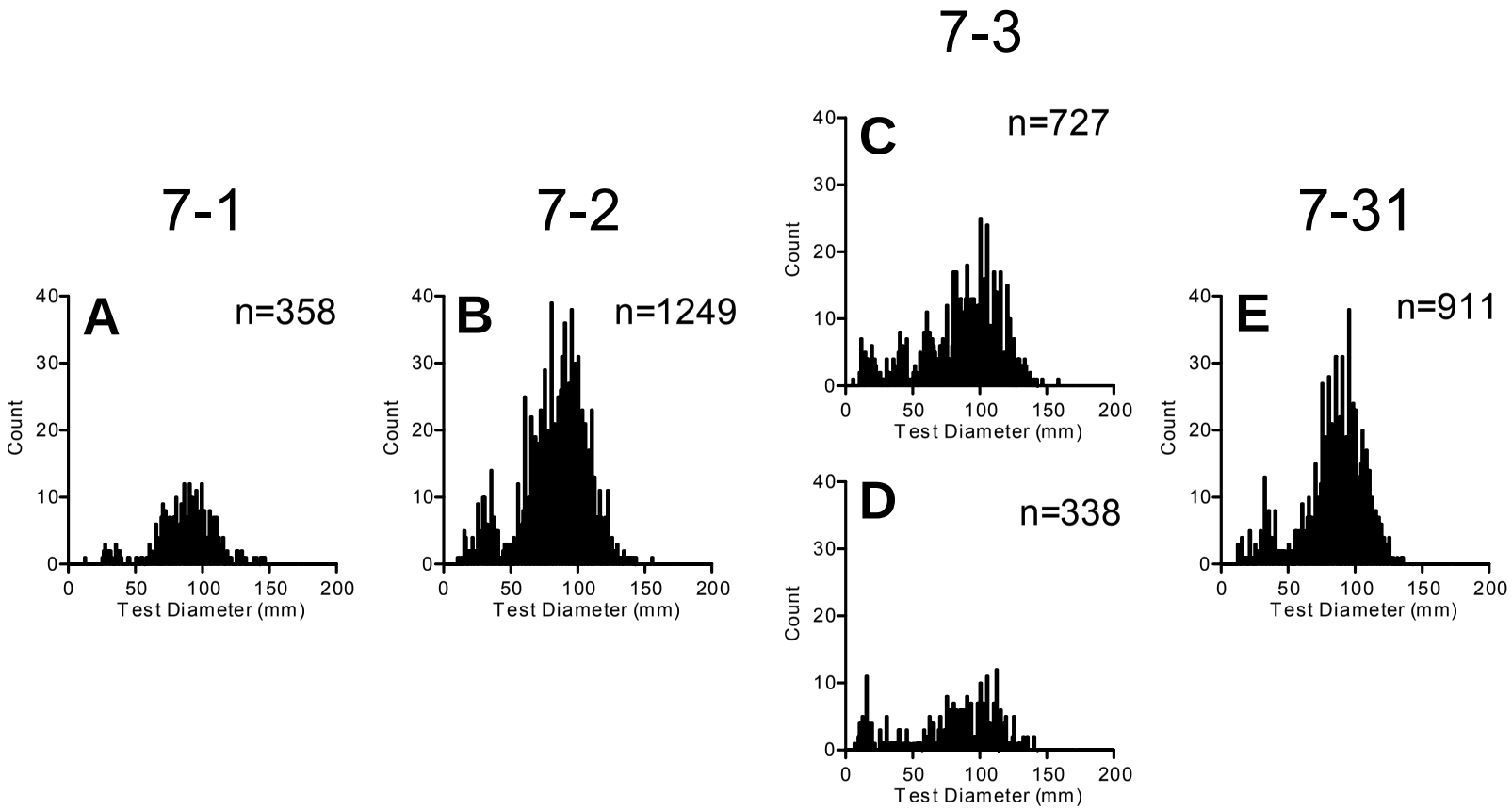

Figure 2. Size frequency distribution of red sea urchins measured along transects inside (C) and outside (A, B, D, E) of commercial bed areas during the 2001 survey at Price Island. Pacific Fisheries Management sub-area are indicated above the graphs. n= number of red sea urchins measured for test diameter.