Survey of Red Sea Urchin Populations in the Gulf Islands, Strait of Georgia, British Columbia, 1998 and 1999

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SURVEY OF RED SEA URCHIN POPULATIONS IN THE GULF ISLANDS, STRAIT OF GEORGIA, BRITISH COLUMBIA, 1998 AND 1999

by

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ABSTRACT

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Surveys of red sea urchin populations in the Gulf Islands and Sidney area, parts of Pacific Fishery Management (PFM) Areas 17 and 18, were conducted in June 1998 and September 1999. A total of 37 and 36 transects were surveyed by SCUBA divers in 1998 and 1999 respectively. Mean density, per PFM sub-area, ranged from 0.00 to 0.81 urchins per m^2 in 1998 and from 0.20 to 0.42 urchins per m^2 in 1999. Overall mean density for the survey, both years combined, was 0.30 urchins per m^2. Mean biomass, per PFM sub-area, ranged from 0.0 to 482.4g per m^2 in 1998 and from 109.4 to 282.5g per m^2 in 1999. Overall mean biomass for the survey, both years combined, was 199.1g per m^2. Overall, for both years combined, 3.1% of the total urchins measured were ≤50mm test diameter (TD) whereas 87.1% of urchins were of legal size (≥100mm TD) for the commercial fishery. Red sea urchin populations were found deeper in the Gulf Islands than in other areas of the east coast of Vancouver Island.

RÉSUMÉ

Bureau, D., A. Campbell, W. C. Hajas, and C. A. Ayers. 2000. Survey of red sea urchin populations in the Gulf Islands, Strait of Georgia, British Columbia, 1998 and 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2552: 29 p.

Des relevés des populations d'oursins rouges des îles Gulf et de la région de Sidney, qui font partie des secteurs d'exploitation 17 et 18, ont été réalisés en juin 1998 et en septembre 1999. Au total, des plongeurs ont observé respectivement 37 et 36 transects en 1998 et 1999. La densité moyenne par sous-secteur allait de 0,00 à 0,81 oursin au m^2 en 1998, et de 0,20 à 0,42 oursin au m^2 en 1999. La densité moyenne globale des relevés, pour les deux années combinées, était de 0,30 oursin au m^2. La biomasse moyenne par sous-secteur allait de 0,0 à 482,4 g au m^2 en 1998 et de 109,4 à 282,5 g au m^2 en 1999. La biomasse moyenne des relevés, pour les deux années combinées, était de 199,1 g au m^2. Dans l'ensemble, pour les deux années combinées, 3,1 % du total des oursins mesurés avaient un diamètre du test (DT) de ≤ 50 mm, tandis que 87,1 % des oursins étaient de taille légale (≥100 mm DT) pour la pêche commerciale. Les populations d'oursins rouges ont été observées à des profondeurs plus grandes dans les îles Gulf que dans les autres zones de la côte est de l'île de Vancouver.

INTRODUCTION

Red sea urchin (*Strongylocentrotus franciscanus*) distribution in North America ranges from the southern tip of Baja California to Alaska (Kato and Schroeter 1985). In British Columbia (BC) the red sea urchin is found in shallow rocky subtidal habitats throughout the coast (Bernard 1977). Red sea urchins are commercially harvested for their roe, which is sold in Japan. Coastal First Nations communities harvest sea urchins as a food fishery. The commercial red sea urchin fishery started in the early 1970's and total landed value in 1997/98 was $ 14 million (Campbell et al. 1999a), making the red sea urchin fishery one of the most valuable shellfish fisheries in BC.

The commercial red sea urchin fishery history and management are described in Campbell and Harbo (1991) and Campbell et al. (1999a). Current management approaches include a minimum harvest size of 100 mm test diameter (TD), a coast-wide quota, individual vessel 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.

Red sea urchin population surveys are a joint effort between the Pacific Urchin Harvesters Association (PUHA), First Nations and Fisheries and Oceans Canada (DFO). They have been conducted in BC since 1993 in an effort to better understand urchin abundance, distribution and biology along the BC coast. The results of 1993 and 1994 surveys have been published (Jamieson et al. 1998a; 1998b; 1998c; 1998d). Results from earlier red sea urchin population surveys, conducted during the 1970's and 1980's, were reported by Breen et al. (1976; 1978) and Sloan et al. (1987). Adkins et al. (1981) surveyed red sea urchin populations in the Gulf Islands area covered by the present survey.

Fishery managers requested that surveys be conducted in the South Coast of BC to update density and biomass estimates to help determine quotas. The Gulf Islands and Sidney area [parts of Pacific Fishery Management (PFM) Areas 17 and 18] was selected for survey through discussion between DFO, PUHA and the Cowichan Tribes (Figure 1 and Figure 2). Fishing for red sea urchins in PFMAs 17 and 18 has occurred since 1979 (Adkins et al. 1981). The objective of this survey was to estimate current red sea urchin biomass in the area to help determine fishery quotas. Since biomass estimates, used for quota determination, are calculated on a PFM sub-area basis for management purposes (Campbell et al. 1999b), the results are presented on a PFM sub-area basis. Detailed survey results are presented here. Biomass estimates and quota recommendations for each PFM sub-area surveyed were presented in Campbell et al. (1999b).

Biomass was estimated by three different methods. Overall biomass estimates for all transects of the survey (Method 1, M1), were compared to those obtained from transects falling in the "productive" areas of Adkins et al. (1981) (Method 2, M2) and to those from transects falling on red sea urchins beds (Method 3, M3). Red sea urchin beds were defined as the areas where commercial harvest was recorded by harvesters on the logbook harvest charts. Data analysed in M2 and M3 were subsets of the M1 data. Comparisons of current survey results with the 1980 survey were best done using M2 since Adkins et al. (1981) only used transects falling in "productive" areas to calculate their density estimates. M3 provided estimates of density and biomass on red sea urchin beds that have historically been harvested in the area.

Depth distribution of urchins found on the present survey was compared to that in other areas of the east coast of Vancouver Island since red sea urchins in the Gulf generally appeared to be found deeper than in other areas of BC.

METHODS

SURVEY AREA AND TRANSECT LAYOUT

Most survey efforts were concentrated in areas where urchins were reported present by harvesters, harvest records and a previous survey by Adkins et al. (1981). In addition, fifteen transect locations surveyed by Adkins et al. (1981) were surveyed again in 1998–1999 (Table 1). Fourteen of these transects were in areas reported unproductive by Adkins et al. (1981). Transect locations were selected and plotted on marine charts prior to the survey to avoid biases in the field. The "productive" areas, as reported by harvest logs, the 1980 survey (Adkins et al. 1981) and discussion with harvesters, were divided in two sections: shoreline and small islands. The number of transects assigned to each section was proportional to the ratio of the surface area of water between 0 and 10m below chart datum (BCD) of each section over the total surface area of water between 0 and 10m BCD. Surface area of water between 0 and 10m BCD was estimated using the Compugrid GIS system after digitising the survey areas.

Transect layout within "productive" sections of coastline was done by randomly placing transects along shore in the "productive" areas. For small islands within "productive" areas, transects were assigned by randomly choosing islands and then randomly assigning a transect compass bearing to determine the position and direction of the transect off the island. Sections of sandy substrate were excluded from the survey. "Unproductive" areas were not considered for the random transect placement, only the transects that Adkins et al. (1981) surveyed in "unproductive" areas were re-surveyed in 1998-1999.

SURVEY LOGISTICS

The survey was conducted in two trips. The first trip was conducted between June 2 and June 7, 1998, using the "Kilpahlas" as a live-aboard vessel and the "Minnow" as a dive skiff, both vessels belonging to the Cowichan Tribes. A break down on the "Kilpahlas" on June 7, 1998, forced the rest of the survey to be postponed. The second trip was conducted between August 31 and September 4, 1999, on the "Kuroshio", a commercial red sea urchin fishing vessel.

DIVE SURVEY METHODS

Leadline transects were laid perpendicular to shore from the boat. Transects were laid out from shallow water to a depth of 15m, and thus transect length was dependent on the slope of the substrate. A float was attached to the deep end of each transect. A 2-diver team surveyed each transect from deep to shallow, one diver measuring urchins while the other recorded data. A one meter squared ($1m^2$) quadrat was placed on the bottom beside the transect and the test

diameter (TD) of each urchin present was measured to the nearest mm with callipers. The depth, substrate type, types of algae and number of green sea urchins (*Strongylocentrotus droebachiensis*) present in the quadrat were also recorded. The quadrat was then moved 2m forward along the transect and the process repeated so that every second meter on the transect was surveyed. In cases where the substrate was sand or mud and no urchins were found at the deep end of transects, observations of depth, substrate and algae were recorded every 20m to minimize dive time. Skipped quadrats were assigned zero values for urchin counts before data were analysed. Once urchins were encountered, sampling was conducted every 2m until the intertidal zone or the surface was reached. On long transects with large numbers of urchins, measurements of test diameters were recorded in only a portion of the quadrats surveyed (usually half). The number of urchins measured on a transect could therefore be smaller than the number of urchins counted.

ESTIMATION OF DENSITY AND BIOMASS

Density and biomass were estimated for urchins of 2 size groups: a) all sizes and b) for urchins of legal size for the commercial fishery (≥100mm TD). Estimates of mean density and biomass were calculated for each PFM sub-area in the survey using the following equations.

Density estimates (d_{ts}) in numbers/m^2 for each transect (t) and size group (s) were calculated as:

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

where N_{ct} equals the total number of urchins counted on transect t, N_{mts} is the number of urchins measured in size group s on transect t, N_{mt} is the total number of urchins measured on transect t; and a_t is the surface area of 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 1m^2.

Overall mean density ($\overline{d}_s$) for a PFM sub-area for urchins of size group s was estimated as:

$$\overline{d}_s = \frac{\sum_t (d_{ts} * L_t)}{\sum_t L_t}$$

where L_t is the length of transect t (Campbell et al. 1999b).

The standard error (s_d) of estimated mean density was calculated as:

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

where n is the number of transects surveyed, T is the total possible number of transects that can be sampled in a surveyed PFM sub-area and mean transect length ($\overline{L}$) was calculated as:

$$\overline{L} = \frac{\sum_t L_t}{n}$$

from Campbell et al. (1999b). The expression $\sqrt{(1-(n/T))}$ was approximately equal to 1 since n was much smaller than T.

To calculate biomass, the weight of all urchins measured was calculated using the relationship between urchin weight (W) in grams and test diameter (TD) in millimetres (Campbell et al. 1999b; 2000).

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

Biomass density (b_{ts} in g/m^2) of urchins of size group s, on a transect t, was estimated using a simplified form of the formula used in previous papers (Campbell et al. 2000). The formula was modified by Campbell et al. (1999b) to simplify computations:

$$b_{ts} = \frac{N_{ct}}{N_{mt}} * \frac{\sum W_{ts}}{a_t}$$

where ΣW_{ts} is the sum of the weights of urchins measured in size group s on transect t and a_t is the surface area of quadrats surveyed on the transect t.

Overall estimated mean biomass per surface area ($\overline{b_s}$ in g/m^2) for a PFM sub-area was calculated as (Campbell et al. 1999b):

$$\overline{b_s} = \frac{\sum_t (b_{ts} * L_t)}{\sum_t L_t}$$

The standard error of estimated mean biomass was calculated using the same formula used for standard errors of density but where d_{ts} and $\overline{d}_s$ were substituted with b_{ts} and $\overline{b}_s$, respectively.

Density and biomass on "productive" (Adkins et al. 1981) areas (M2) and red sea urchin beds (M3) were estimated using the same formulas but using only the appropriate subset of transects in the analyses. Transects were sub-sampled by comparing location of transects on

the survey charts to the location of "productive" areas from Adkins et al. (1981) and the location of red sea urchin beds in the harvest database charts.

Recruitment estimates for the red sea urchin in BC have generally been expressed as the percent of total red sea urchins measured that were ≤50mm TD (Adkins et al. 1981; Breen et al. 1976; 1978; Jamieson et al. 1998b; 1998c; 1998d, Sloan et al. 1987). We used the same size for comparison purposes.

RESULTS

SURVEY LOGISTICS

A total of 37 transects were surveyed in 1998 (Figure 1 and Table 2) and 36 transects were surveyed in 1999 (Figure 2 and Table 3). All transects surveyed in 1999 were in PFM Area 18. After completion of the 24 scheduled transects in 1999 time allowed for an additional 12 transects to be surveyed in PFM sub-area 18-6.

High current prevented surveying of two of the three transects scheduled in Georgenson Pass, between Mayne and Samuel Islands. Divers went down on one of the transects and although no counts were made, urchin density was estimated to be >2 per m^2.

In 1998, total transect length surveyed was 2083m on 37 transects for a mean transect length of 56m; a total of 180 urchins were counted in 931 quadrats. In 1999, total transect length surveyed was 3742m on 36 transect for a mean transect length of 104m; a total of 695 urchins were counted on 1437 quadrats.

Only 3 transects were surveyed in PFM sub-area 17-2, furthermore, transects were close to one another and near the south-east corner of the PFM sub-area, the density and biomass estimates obtained may therefore not be representative of the whole PFM sub-area.

Over most of the survey area, the rocks and algae on the bottom were covered in a layer of silt. *Agarum sp.* was abundant at several locations. Visibility was generally poor in 1998, especially on the east coast of Saturna and Mayne Islands. The visibility was good in 1999.

As Adkins et al. (1981) noted, in the Gulf region, the largest red urchin populations found during the present survey were in areas of strong tidal flow whereas protected sites supported low numbers. The random transect selection process allocated only one transect in Active Pass (PFM sub-area 18-2), one of the preferred fishing areas in the region which also is an area of high current.

SIZE FREQUENCY DISTRIBUTIONS

Size frequency data for all PFM sub-areas were pooled for each year. In 1998, 139 red sea urchins were measured, the mean size was 124.3mm TD (Figure 3). The smallest urchin measured (on a PFM sub-area basis) ranged from 39 to 136mm TD and the largest ranged from 142 to 166mm TD (Table 4). The overall proportion of legal sized urchins (≥100mm TD) was 84.2% whereas the proportion of urchins ≤50mm TD was 1.4%. On a PFM sub-area basis, in 1998, the proportion of urchins ≤50mm TD ranged from 0.0% to 9.1% and the proportion of legal sized urchins ranged from 75.0% to 100.0% (Table 4, Figure 4).

In 1999, a total of 674 urchins were measured, the mean size was 126.7mm TD (Figure 5). On a PFM sub-area basis, the smallest urchin measured ranged from 16 to 30mm TD and the largest ranged from 155 to 183mm TD (Table 5). The overall proportion of legal sized urchins (≥100mm TD) was 87.7% whereas the proportion of urchins ≤50mm TD was 3.4%. On a PFM sub-area basis, in 1999, the proportion of urchins ≤50mm TD ranged from 2.9% to 8.5% and the proportion of legal sized urchins ranged from 80.9% to 92.2% (Table 5, Figure 6). For both years and all areas combined, 3.1% of red sea urchins measured were ≤50mm TD and 87.1% of urchins were ≥100mm TD.

DENSITY AND BIOMASS ESTIMATES

Transects that had no red sea urchins in 1980 were surveyed again in 1998 and 1999 to see if red sea urchins colonised those areas. Most transects where no urchins were found in 1980 also had no urchins in 1998-1999 (Table 1).

In 1998, the estimated mean density of urchins of all sizes, was 0.04 and 0.21 urchins per m^2 for PFM areas 17 and 18, respectively (Table 6). Densities of legal sized urchins were 0.04 and 0.17 urchins per m^2 for PFM areas 17 and 18, respectively. The estimated mean biomass of red sea urchins of all sizes was 27.4 and 129.9 g per m^2 for PFM areas 17 and 18 respectively (Table 7). Biomass of legal sized urchins was 27.4 and 122.3 g per m^2 for PFM areas 17 and 18, respectively.

In 1999, the estimated mean density of urchins of all sizes, for all sub-areas, was 0.37 urchins per m^2 and 0.32 urchins per m^2 for legal sized urchins (Table 8). The estimated mean biomass of red sea urchins of all sizes, for all sub-areas (in 1999), was 250.3 g per m^2 and 242.7 g per m^2 for legal sized urchins (Table 9).

Mean overall densities, for all areas and both survey years pooled, were 0.30 and 0.26 urchins per m^2 for urchins of all sizes and legal sized urchins, respectively. Mean overall biomass, for all areas and both survey years pooled, were 199.1 and 192.1g per m^2 for urchins of all sizes and legal sized urchins, respectively.

Transects were sub-sampled to compare overall biomass (M1) to biomass in "productive" areas (M2) and biomass on red sea urchin beds (M3). Data for 1998 and 1999 were pooled and the analyses were applied only to urchins ≥100mm TD. Analysis of the data by PFM-area (Table 10) showed that estimated mean biomass was higher on urchins beds (M3) than on all transects surveyed (M1). There was no clear trend in biomass estimates between

the "productive" areas (M2) and estimates from all transects (M1) or bed transects only (M3), when the data were analysed by PFM-area. When data were analysed by PFM-sub-area (Table 10) the biomass estimates generally increased from "all transects" (M1) to the "productive" areas (M2) to the beds (M3). Biomass estimates from transects lying only on red sea urchin beds (M3) were always higher than those for all transects surveyed (M1).

For the purpose of comparison between the 1980 survey and the current survey, transects that lay in the areas described as "productive" in 1980 (Adkins et al. 1981) were analysed separately (M2). Mean biomass of urchins ≥100mm TD, based on the 1998-1999 data, was 141.1g/m^2 and 154.5g/m^2 for PFM areas 17 and 18, respectively, and 153.8g per m^2 both years and all areas combined.

DEPTH DISTRIBUTION

Red sea urchins were distributed deeper in the Gulf Islands than in some other areas of the BC coast. Estimates of mean urchin densities by 2.5m depth strata increased with depth in the Gulf Islands whereas in other areas of the South Coast of BC (Comox, Hornby Island and Kelsey Bay regions, surveyed in 1999) density was highest between 0 and 2.5m and then steadily decreased (Table 11).

Out of 40 transects where urchins were found in 1998 and 1999 in the Gulf, urchins extended shallower than 5m on only 30.0% of transects. The shallowest urchin found was deeper than 5m on 70.0% of transects, deeper than 7.5m on 60.0% of transects and deeper than 10m on 23.3% of transects. By comparison, data from two surveys near Comox and Johnstone Strait in 1999 showed that urchins extended shallower than 5m on 88.2% of transects and shallower than 2.5m on 65.9% of transects (D. Bureau unpublished data). The shallowest urchin found was deeper than 5m on only 11.8% of transects, deeper than 7.5m on 2.4% of transects and deeper than 10m on 0.0% of transects (D. Bureau unpublished data).

DISCUSSION

Recruitment was defined as the percent of the total red sea urchin population that was ≤50mm TD. Red sea urchins often have low recruitment (Bernard 1977; Sloan et al. 1987). The present survey showed the lowest recruitment of all areas surveyed in 1998 and 1999 on the East Coast of Vancouver Island (Bureau et al. 2000a; 2000b). The overall proportion of urchins ≤50mm TD in the Gulf Islands was 3.1%, for both years combined, 8.1% in Johnstone Strait (Bureau et al. 2000b) and 22.2% in the Comox region (Bureau et al. 2000a). Only 5.5% of urchins were found to be ≤60mm TD in the Gulf Islands in 1980 (Adkins et al. 1981). The numbers of urchins ≤60mm TD in 1998 and 1999 were 2.2% and 4.0% respectively (3.7% both years combined), lower than those reported for 1980. However, Sloan et al. (1987) found that only 0.8% of urchins were ≤50mm TD in the Sidney area in 1985 and overall only 9.5% of urchins were ≤50mm TD at four locations on the east coast of Vancouver Island.

Red sea urchin recruitment reported for southern BC was variable and ranged from 0 to 27% (Adkins et al. 1981; Breen et al. 1976; 1978; Sloan et al. 1987; Jamieson et al. 1998d).

Proportions of urchins ≤50mm TD, for surveys conducted in Northern BC in 1994, were 12.8% in the north-west Queen Charlotte Islands (Jamieson et al. 1998b) and 8.5% south of Bella Bella, central coast (Jamieson et al. 1998c).

Overall percentage of legal sized urchins was 87.1% for both years combined, lower than in 1985 (Sloan et al. 1987) but still higher than in several areas of the southern BC coast. Sloan et al. (1987) reported 92.9% of urchins were of legal size in the Sidney area in 1985 and 76.0% overall for four areas in the Strait of Georgia. Surveys conducted in 1999 on the east coast of Vancouver Island reported 38.6% legal sized urchins in the Comox region (Bureau et al. 2000a), 65.3% in Johnstone Strait (Bureau et al. 2000b). Adkins et al. (1981) did not measure test diameters during their survey of urchin populations in the Gulf Islands.

In northern BC, percentages of urchins ≥100mm TD for surveys conducted in 1994 were 49.6% in the north-west Queen Charlotte Islands (Jamieson et al. 1998b), 27.3% south of Bella Bella, central coast (Jamieson et al. 1998c) and 52.7% for Queen Charlotte Strait and Broughton Strait, north-east Vancouver Island (Jamieson et al. 1998d). Proportions of urchins ≥100mm TD for surveys conducted in 1993 were 19.0% on the west side and 48.9% on the east side of the Queen Charlotte Islands, 26.3% in the southern portion of the central coast, 39.9% in the northern portion of the central coast and 50.4% for the Dundas Island region in the north coast (Jamieson et al. 1998a). The Gulf Islands and Sidney region therefore had the second highest recorded proportion of legal sized urchins on the BC coast, surpassed only by the 1985 survey in Sidney (Sloan et al. 1987).

Transects surveyed on both 1980 and 1998-1999 surveys showed little change in urchin abundance (Table 1) except for transect 43 (transect 128 in 1980), however, densities were calculated differently between surveys making comparisons difficult for transects where urchins were found.

Current overall mean density estimate was 0.30 urchins per m^2, much lower than the 3.18 urchins per m^2 average reported by Adkins et al. (1981). However, density estimates obtained in the current survey are difficult to compare with those of Adkins et al. (1981) since the methods used were different. Adkins et al. (1981) estimated mean density only from those transects that had more than 1 urchin per m^2, whereas in the present survey, all quadrats of all transects were used in the density estimates. Densities in the Gulf Islands in 1998-1999 were lower than in other areas of the east coast of Vancouver Island. Surveys conducted in 1999 using the same survey and analysis methods showed red sea urchin densities (overall mean per survey) of 0.59 and 1.27 urchins per m^2 in the Comox region and in Johnstone Strait, respectively (Bureau et al. 2000a; 2000b).

Overall mean biomass on the current survey was 199.1g per m^2. Surveys conducted in 1999 using the same survey and analysis methods showed red sea urchin biomass (overall mean per survey) of 165.4g per m^2 in the Comox region (Bureau et al. 2000a) and 524.4g per m^2 in Johnstone Strait (Bureau et al. 2000b). The relatively low biomass in the Comox region, despite higher densities than in the Gulf Islands, was probably due to high recruitment. The large numbers of small individuals found in the Comox region provided for a high density, but low biomass.

The 1980 abundance estimates were calculated from transects in productive areas only. Analysing data from only those transects in the "productive" areas of Adkins et al. (1981) (M2) provided more comparable results between the 1980 and the 1998-1999 surveys. M2 showed a decrease in estimated biomass of legal sized urchins from 681.8 (Campbell et al. 2000) to

153.8g per m^2 between the 1980 and the 1998-1999 surveys. However, the 1980 sampling was confined to 25m long transects (or shorter if the end of the urchins zone was encountered) whereas in the current survey, transects were sampled to a depth of 10m below chart datum whether urchins were present or not. The discrepancy in survey methods would translate in overestimates of biomass using the 1980 methods compared to the current ones. The large difference in biomass estimates between 1980 and 1998-1999 may in part be due to differences in sampling and analysis and/or possibly to a change in red sea urchin abundance and/or depth distribution.

The difference in density versus depth trends indicated that red sea urchin distribution was deeper in the Gulf Islands and Sidney area than in other areas of the East Coast of Vancouver Island. The reason urchins are distributed deeper in the Gulf Islands is unknown but could be related to environmental variables (such as fresh water run-off from the Fraser River, sedimentation), pollution or removal of shallow water urchins by the fishery.

Campbell et al. (1999a) examined logbook data and found that there was a significant increase in mean maximum depth fished, from 10 to 13m, on the east coast of Vancouver Island during the 1982 to 1998 period. They suggested the reasons for the increase in harvesting depth may be due to overexploitation of red sea urchins in shallow areas or to environmental factors causing urchins to move deeper. The Gulf Islands area has the longest history of commercial harvest of red sea urchins. More work is needed to compare logbook data in more detail for the Gulf Islands versus the rest of the east coast of Vancouver Island.

Survey transects were conducted to a gauge depth of 15m (not corrected for tide), consequently, any urchins located deeper than 15m were not included in quota estimates. If a significant proportion of the red sea urchin populations found in the Gulf Islands reside at depths greater than the depth to which transects were surveyed then the mean biomass density calculated would underestimate true urchin abundance. We recommend that, for future surveys in the Gulf Islands and Sidney area, transects should extend to a depth greater than 15m to sample the local populations more accurately. The exact depth to which future sampling is to be conducted will have to take into account the red sea urchins' depth distribution and the shorter dive times allowed at greater depth.

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Table 1. List of transect locations that were surveyed on both the 1980 and the 1998–1999 red sea urchin population surveys in the Gulf Islands. No counts were made in 1980 on transects where density was visually estimated to be less than 1 urchin per m^2.

1980 Survey*		1998-1999 Survey		
Transect	Density	Transect	Density	Year Surveyed
76	No Counts	60	0.00	1998
77	No Counts	61	0.00	1998
78	No Counts	63	0.00	1998
79	No Counts	62	0.00	1998
86	No Counts	59	0.09	1998
106	0.00	14	0.00	1998
109	0.00	31	0.39	1998
110	0.00	32	0.00	1999
111	No Counts	57	0.00	1999
112	0.00	56	0.00	1999
113	0.00	58	0.00	1999
124	0.00	76	0.00	1999
125	0.00	78	0.01	1999
126	0.00	72	0.00	1999
128	3.48	43	0.69	1999

* From Adkins et al. (1981)

Table 2. Position of transects surveyed during the 1998 red sea urchin (RSU) population survey in the Gulf Islands. Transect length in m, density in number/m^2 and biomass in g/m^2. Num = Number, PFM = Pacific Fishery Management.

Transect	PFM Sub-area	Latitude	Longitude	Transect Length	Number Quadrats	Num RSU Counted	RSU Density	RSU Biomass
1	18-03	48 47.30	123 22.74	89	45	0	0.00	0.0
2	18-03	48 47.65	123 23.24	45	23	0	0.00	0.0
3	18-02	48 50.60	123 25.17	65	33	0	0.00	0.0
4	17-01	48 51.64	123 26.38	49	25	0	0.00	0.0
5	17-01	48 52.15	123 27.37	59	30	0	0.00	0.0
6	17-01	48 52.80	123 27.37	95	48	0	0.00	0.0
7	17-02	48 54.38	123 27.16	61	31	2	0.06	56.6
8	17-01	48 53.68	123 25.78	29	15	7	0.47	318.8
9	17-02	48 53.80	123 25.29	101	1	0	0.00	0.0
10	17-02	48 53.84	123 25.00	69	15	0	0.00	0.0
11	18-02	48 51.20	123 20.50	35	18	22	1.22	669.1
12	18-02	48 51.12	123 20.17	41	21	6	0.29	203.8
13	18-02	48 51.22	123 18.90	87	44	6	0.14	104.7
14	18-01	48 52.50	123 17.30	105	53	0	0.00	0.0
15	18-01	48 52.35	123 16.95	105	53	6	0.11	90.6
16	18-01	48 51.79	123 15.67	53	27	19	0.70	358.4
17	18-01	48 51.60	123 15.88	43	22	0	0.00	0.0
18	18-02	48 50.94	123 23.79	41	21	0	0.00	0.0
19	18-02	48 50.45	123 22.15	37	19	5	0.26	166.9
20	18-02	48 49.85	123 21.15	33	17	2	0.12	106.9
21	18-02	48 49.82	123 21.10	17	9	0	0.00	0.0
22	18-09	48 49.60	123 21.09	45	23	0	0.00	0.0
23	18-03	48 49.00	123 23.14	75	38	0	0.00	0.0
24	18-03	48 49.06	123 23.29	35	18	0	0.00	0.0
25	18-03	48 49.41	123 23.74	47	24	8	0.33	346.7
26	18-03	48 49.68	123 24.01	45	23	7	0.30	197.5
30	18-01	48 49.72	123 12.73	37	19	0	0.00	0.0
31	18-01	48 49.35	123 10.92	23	12	9	0.75	384.7
38	18-11	48 47.69	123 06.52	35	18	2	0.11	92.0
39	18-11	48 47.31	123 05.32	43	22	10	0.45	254.0
40	18-11	48 47.42	123 03.50	45	23	36	1.57	937.4
41	18-11	48 47.97	123 05.09	53	27	25	0.93	539.3
59	18-03	48 48.87	123 25.51	93	47	8	0.17	132.5
60	18-03	48 50.20	123 27.08	61	31	0	0.00	0.0
61	18-03	48 50.55	123 27.35	119	1	0	0.00	0.0
62	18-03	48 50.57	123 25.76	33	17	0	0.00	0.0
63	18-03	48 50.48	123 25.40	35	18	0	0.00	0.0

Table 3. Position of transects surveyed during the 1999 red sea urchin (RSU) population survey in the Gulf Islands. Transect length in m, density in number/m^2 and biomass in g/m^2. Num = Number, PFM = Pacific Fishery Management.

Transect	PFM Sub-area	Latitude	Longitude	Transect Length	Number Quadrats	Num RSU Counted	RSU Density	RSU Biomass
29	18-05	48 49.956	123 14.322	151	76	35	0.46	230.2
32	18-05	48 48.374	123 12.500	45	6	0	0.00	0.0
33	18-04	48 44.266	123 13.858	61	31	4	0.13	112.4
34	18-04	48 44.497	123 13.312	61	5	0	0.00	0.0
35	18-04	48 44.434	123 13.164	45	23	2	0.09	102.0
36	18-04	48 43.994	123 12.080	135	68	8	0.12	87.3
37	18-05	48 44.629	123 10.222	81	41	12	0.29	192.0
42	18-04	48 42.586	123 17.570	17	9	3	0.33	281.3
43	18-04	48 42.954	123 17.508	61	31	42	1.35	999.9
44	18-04	48 43.265	123 17.973	87	44	18	0.41	377.0
45	18-06	48 44.078	123 21.812	291	146	11	0.08	49.5
46	18-06	48 44.212	123 22.553	111	56	14	0.25	242.1
47	18-06	48 43.730	123 22.849	103	7	0	0.00	0.0
48	18-06	48 43.340	123 23.151	251	126	80	0.63	504.6
49	18-06	48 42.059	123 23.317	201	101	34	0.34	267.3
50	18-06	48 42.610	123 25.931	71	36	45	1.25	658.1
51	18-06	48 41.847	123 25.682	95	48	24	0.50	339.3
52	18-06	48 41.348	123 23.133	67	5	0	0.00	0.0
53	18-06	48 40.727	123 23.176	39	20	32	1.60	840.3
54	18-06	48 41.580	123 20.148	185	93	198	2.13	1342.4
55	18-06	48 41.226	123 19.123	39	20	17	0.85	467.4
56	18-05	48 46.502	123 12.172	41	3	0	0.00	0.0
57	18-05	48 47.683	123 12.803	41	3	0	0.00	0.0
58	18-05	48 46.746	123 14.884	101	6	0	0.00	0.0
70	18-04	48 43.757	123 18.473	109	7	0	0.00	0.0
71	18-06	48 43.369	123 21.785	121	7	0	0.00	0.0
72	18-06	48 40.864	123 22.279	187	11	0	0.00	0.0
73	18-06	48 41.287	123 22.235	73	5	0	0.00	0.0
74	18-06	48 42.316	123 18.823	47	24	16	0.67	422.9
75	18-06	48 42.764	123 19.470	55	28	12	0.43	327.6
76	18-06	48 43.368	123 19.864	101	51	0	0.00	0.0
77	18-06	48 43.865	123 19.444	193	97	31	0.32	285.0
78	18-06	48 42.896	123 22.286	121	61	1	0.02	16.7
79	18-06	48 42.601	123 24.948	175	88	8	0.09	50.5
80	18-06	48 42.123	123 25.620	95	48	48	1.00	638.9
81	18-06	48 42.102	123 23.745	85	6	0	0.00	0.0

Table 4. Number of red sea urchins measured and percentages (in brackets) of urchins ≤50 mm TD and ≥100 mm TD for each Pacific Fishery Management (PFM) sub-area surveyed in the 1998 population survey in the Gulf Islands.

PFM	Size Measured (mm)			Numbers Measured		
Sub-area	Minimum	Maximum	Mean	Total	≤50mm TD	≥100mm TD
17-01	122	142	130.9	7	0 (0.0)	7 (100.0)
17-02	136	151	143.5	2	0 (0.0)	2 (100.0)
17 Total	122	151	133.7	9	0 (0.0)	9 (100.0)
18-01	59	149	115.9	20	0 (0.0)	15 (75.0)
18-02	68	157	124.6	41	0 (0.0)	37 (90.2)
18-03	39	166	133.9	22	2 (9.1)	19 (86.4)
18-09	-	-	-	0	0 (0.0)	0 (0.0)
18-11	63	156	121.4	47	0 (0.0)	37 (78.7)
18 Total	39	166	123.7	130	2 (1.5)	108 (83.1)

Table 5. Number of red sea urchins measured and percentages (in brackets) of urchins ≤50 mm TD and ≥100 mm TD for each Pacific Fishery Management (PFM) sub-area surveyed in the 1999 population survey in the Gulf Islands.

PFM	Size Measured (mm)			Numbers Measured		
Sub-area	Minimum	Maximum	Mean	Total	≤50mm TD	≥100mm TD
18-04	24	164	135.4	77	3 (3.9)	71 (92.2)
18-05	30	155	115.3	47	4 (8.5)	38 (80.9)
18-06	16	183	126.5	550	16 (2.9)	482 (87.6)
Total	16	183	126.7	674	23 (3.4)	591 (87.7)

Table 6. Estimates of density of red sea urchins (RSU), by Pacific Fishery Management (PFM) sub-area, for the 1998 survey in the Gulf Islands.

PFM Sub-Area	Number of Transects	Sum of Transect Lengths (m)	Est. Number of RSU on Transects		Mean Density Num RSU/m^2		Standard Error of Mean Density	
			All Sizes	≥100mm	All Sizes	≥100mm	All Sizes	≥100mm
17-01	4	232	14	14	0.06	0.06	-	-
17-02	3	231	4	4	0.02	0.02	-	-
17 Total	7	463	17	17	0.04	0.04	0.03	0.03
18-01	6	366	66	50	0.18	0.14	0.11	0.08
18-02	8	356	80	72	0.22	0.20	0.12	0.10
18-03	11	677	45	39	0.07	0.06	0.04	0.03
18-09	1	45	0	0	0.00	0.00	-	-
18-11	4	176	143	112	0.81	0.64	-	-
18 Total	30	1620	335	273	0.21	0.17	0.06	0.05

Table 7. Estimates of biomass per m^2 of red sea urchins (RSU), by Pacific Fishery Management (PFM) sub-area, for the 1998 survey in the Gulf Islands.

PFM Sub-Area	Number of Transects	Sum of Transect Lengths (m)	Est. Weight of RSU on Transects (kg)		Mean Biomass of RSU g/m^2		Standard Error of Mean Biomass	
			All Sizes	≥100mm	All Sizes	≥100mm	All Sizes	≥100mm
17-01	4	232	9.5	9.20	39.8	39.8	-	-
17-02	3	231	3.5	3.50	15.0	15.0	-	-
17 Total	7	463	13.0	12.70	27.4	27.4	23.0	23.0
18-01	6	366	37.4	33.60	102.1	91.7	58.1	49.9
18-02	8	356	50.6	49.20	142.1	138.1	66.1	62.3
18-03	11	677	37.5	37.10	55.4	54.8	30.7	30.5
18-09	1	45	0.0	0.00	0.0	0.0	-	-
18-11	4	176	84.9	78.20	482.4	444.5	-	-
18 Total	30	1620	210.4	198.10	129.9	122.3	37.2	34.3

Table 8. Estimates of density of red sea urchins (RSU), by Pacific Fishery Management (PFM) sub-area, for the 1999 survey in the Gulf Islands.

PFM Sub-Area	Number of Transects	Sum of Transect Lengths (m)	Est. Number of RSU on Transects		Mean Density Num RSU/m^2		Standard Error of Mean Density	
			All Sizes	≥100mm	All Sizes	≥100mm	All Sizes	≥100mm
18-04	8	576	152	140	0.26	0.24	0.15	0.13
18-05	6	460	93	75	0.20	0.16	0.11	0.09
18-06	22	2706	1132	994	0.42	0.37	0.14	0.13
18 Total	36	3742	1377	1209	0.37	0.32	0.11	0.10

Table 9. Estimates of biomass per m^2 of red sea urchins (RSU), by Pacific Fishery Management (PFM) sub-area, for the 1999 survey in the Gulf Islands and Sidney area.

PFM Sub-Area	Number of Transects	Sum of Transect Lengths (m)	Est. Weight of RSU on Transects (kg)		Mean Biomass of RSU g/m^2		Standard Error of Mean Biomass	
			All Sizes	≥100mm	All Sizes	≥100mm	All Sizes	≥100mm
18-04	8	576	121.8	120.5	211.5	209.3	110.8	108.7
18-05	6	460	50.3	47.3	109.4	102.8	56.6	52.9
18-06	22	2706	764.4	740.4	282.5	273.6	91.3	88.8
18 Total	36	3742	936.5	908.2	250.3	242.7	68.4	66.5

Table 10. Comparisons of legal sized (≥100mm TD) red sea urchin biomass on transects lying in urchin beds (M3), transects lying in "productive areas" (M2) (Adkins et al. 1981) and all transects surveyed (M1) in the Gulf Islands red sea urchin population surveys of 1998 and 1999. Data for 1998 and 1999 were pooled.

Area	Number of Transects Surveyed			Estimated Weight of RSU in Surveyed Transects (g)			Sum of Transect Lengths (m)			Estimated Mean Biomass of RSU (g/m^2)			Standars Error of Mean Biomass of RSU (g/m^2)		
	Bed M3	Productive M2	All M1	Bed M3	Productive M2	All M1	Bed M3	Productive M2	All M1	Bed M3	Productive M2	All M1	Bed M3	Productive M2	All M1
17-01	-	1	4	-	9,245	9,245	-	29	232	-	318.8	39.8	-	-	-
17-02	1	1	3	3,454	3,454	3,454	61	61	231	56.6	56.6	15.0	-	-	-
17 Total	1	2	7	3,454	12,698	12,698	61	90	463	56.6	141.1	27.4	-	-	23.0
18-01	1	-	6	8,253	-	33,575	23	-	366	358.8	-	91.7	-	-	49.9
18-02	4	7	8	36,514	49,154	49,154	178	315	356	205.1	156.0	138.1	-	69.4	62.3
18-03	1	6	11	16,293	24,853	37,122	47	336	677	346.7	74.0	58.4	-	54.9	30.5
18-04	5	4	8	109,082	97,301	120,530	409	274	576	266.7	355.1	209.3	159.7	-	108.7
18-05	-	-	6	-	-	47,305	-	-	460	-	-	102.8	-	-	52.9
18-06	8	7	22	404,424	81,412	740,398	1,070	711	2,706	378.0	114.5	273.6	204.6	63.8	88.8
18-09	-	-	1	-	-	0	-	-	45	-	-	0.0	-	-	-
18-11	1	-	4	27,147	-	78,225	53	-	176	512.2	-	444.5	-	-	-
18 Total	20	24	66	601,715	252,720	1,106,309	1,780	1,636	5,362	338.0	154.5	206.3	124.4	50.6	48.2

Table 11. Estimated mean density of red sea urchins per 2.5m depth strata on the 1998-1999 red sea urchin population surveys in the Gulf Islands (parts of PFM areas 17 and 18) compared to data from other surveys conducted in the South Coast (Other SC) of BC in 1999 in parts of PFM areas 12, 13 and 14. Gulf Island data for 1998 and 1999 were pooled.

Depth	Density (Urchins / m^2)		Number of Quadrats	
(m)	Gulf Islands	Other SC	Gulf Islands	Other SC
<0.0	0.07	0.67	45	285
0.0-2.5	0.22	1.76	143	549
2.5-5.0	0.82	1.65	177	1077
5.0-7.5	1.29	1.00	127	911
7.5-10.0	1.55	0.92	152	608
10.0-12.5	1.19	0.85	176	415
>12.5	2.49	0.57	35	127

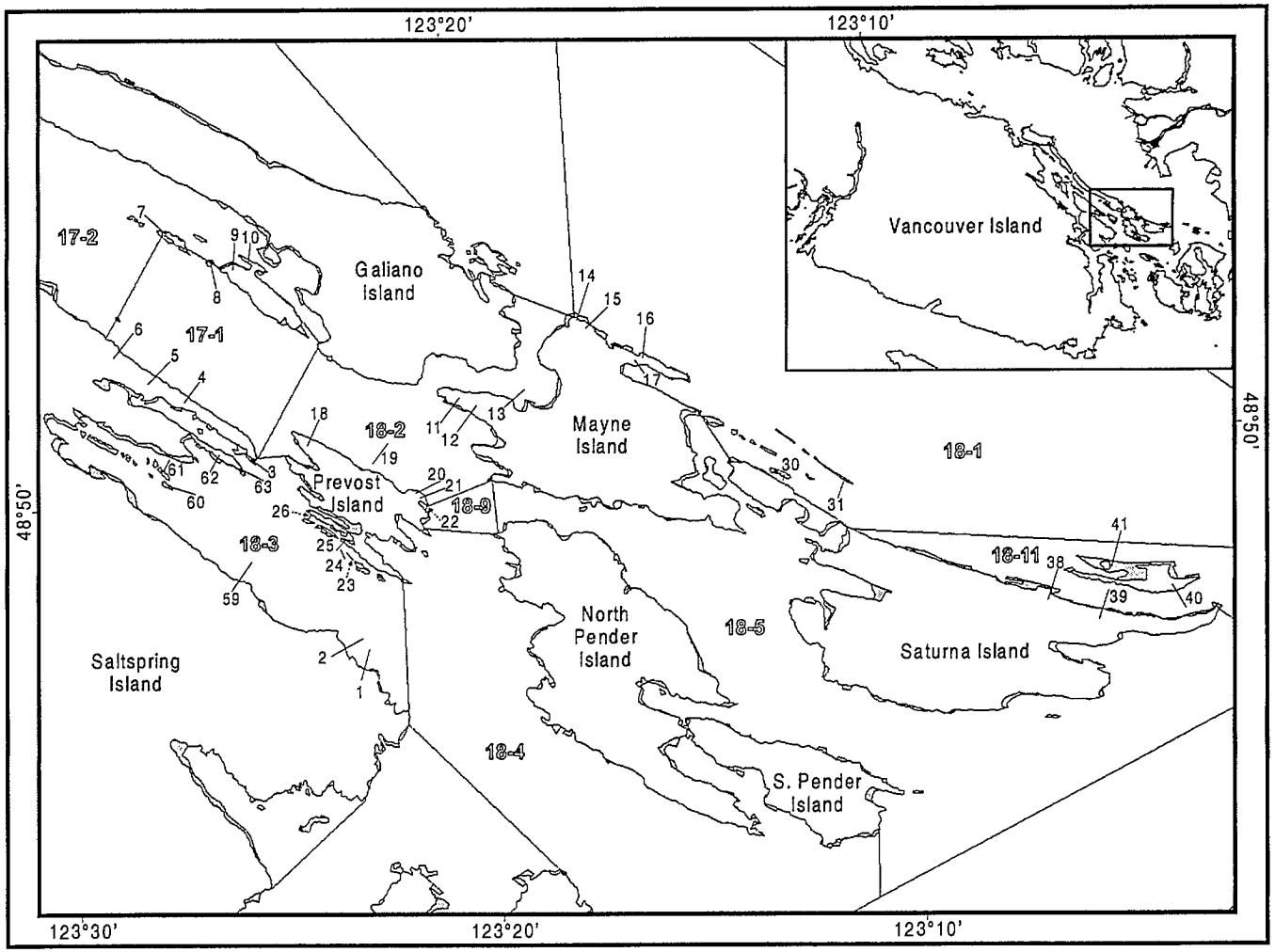

Figure 1. Map of survey area and location of transects surveyed on the 1998 red sea urchin population survey in the Gulf Islands. Outlined numbers indicate Pacific Fishery Management sub-areas and solid numbers identify transects. Light grey areas represent land and dark grey areas represent the intertidal zone.

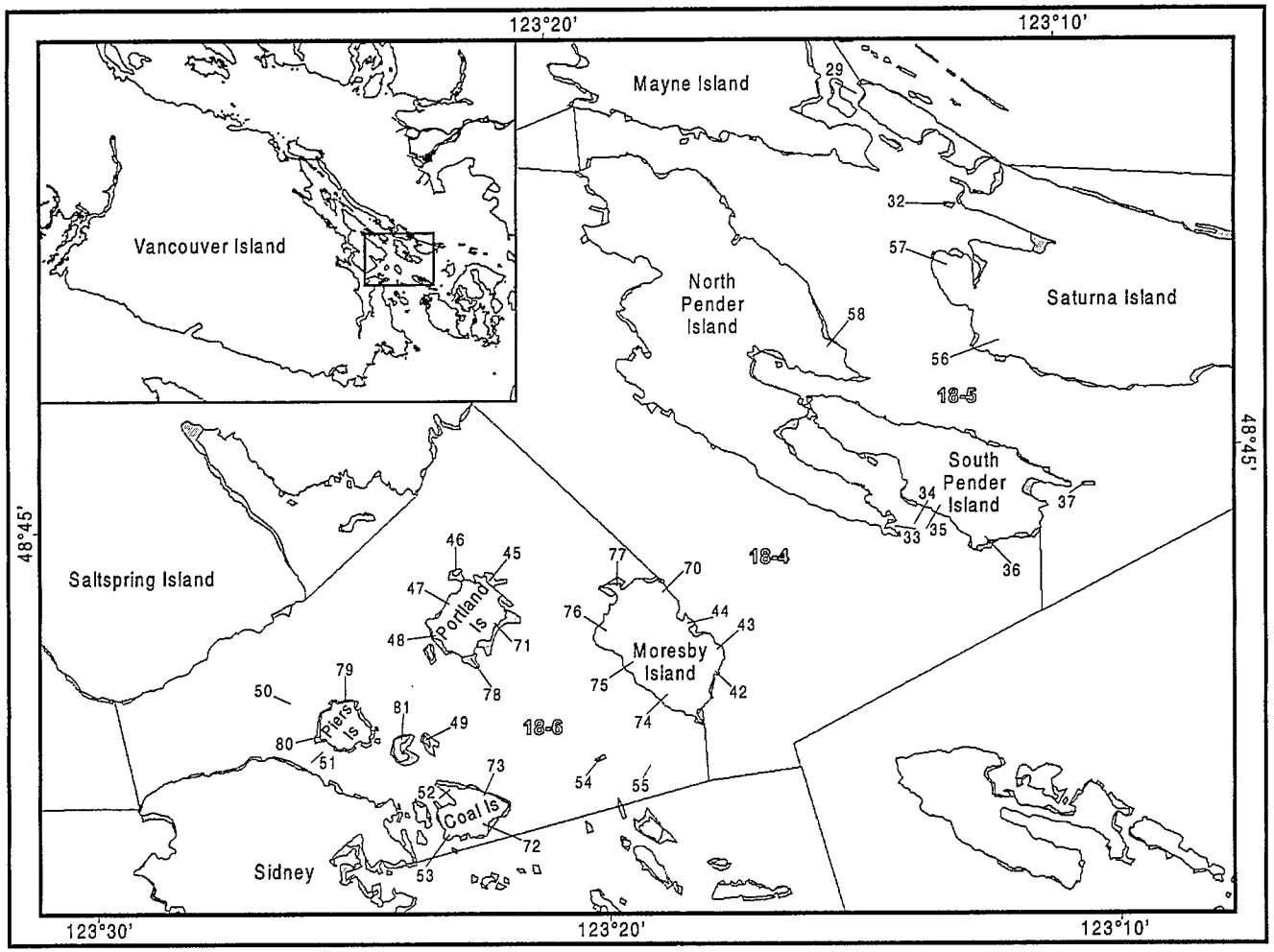

Figure 2. Map of survey area and location of transects surveyed on the 1999 red sea urchin population survey in the Gulf Islands. Outlined numbers indicate Pacific Fishery Management sub-areas and solid numbers identify transects. Light grey areas represent land and dark grey areas represent the intertidal zone.

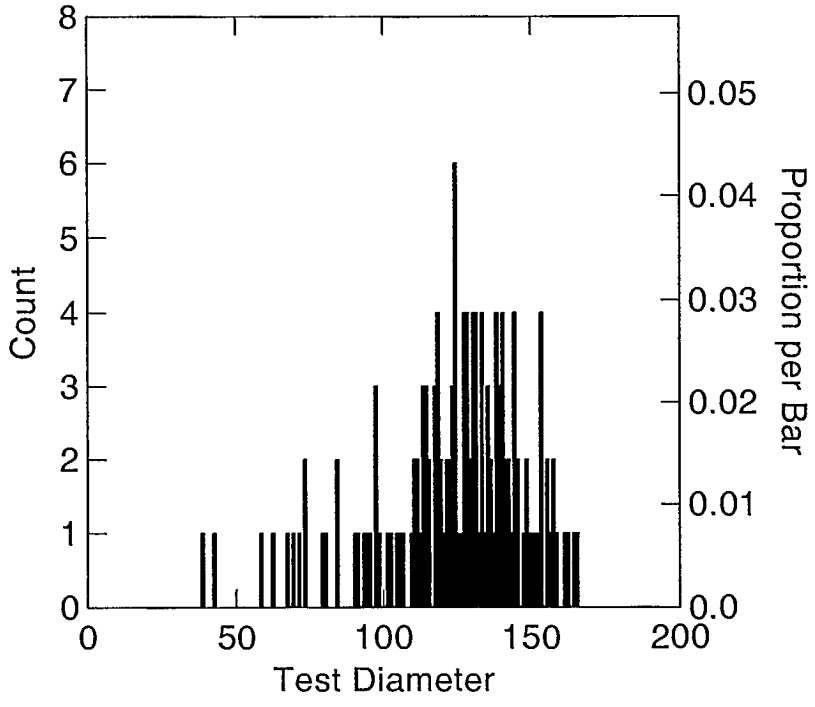

Figure 3. Size frequency distribution of red sea urchins measured on all transects during the 1998 population survey in the Gulf Islands. n = 139

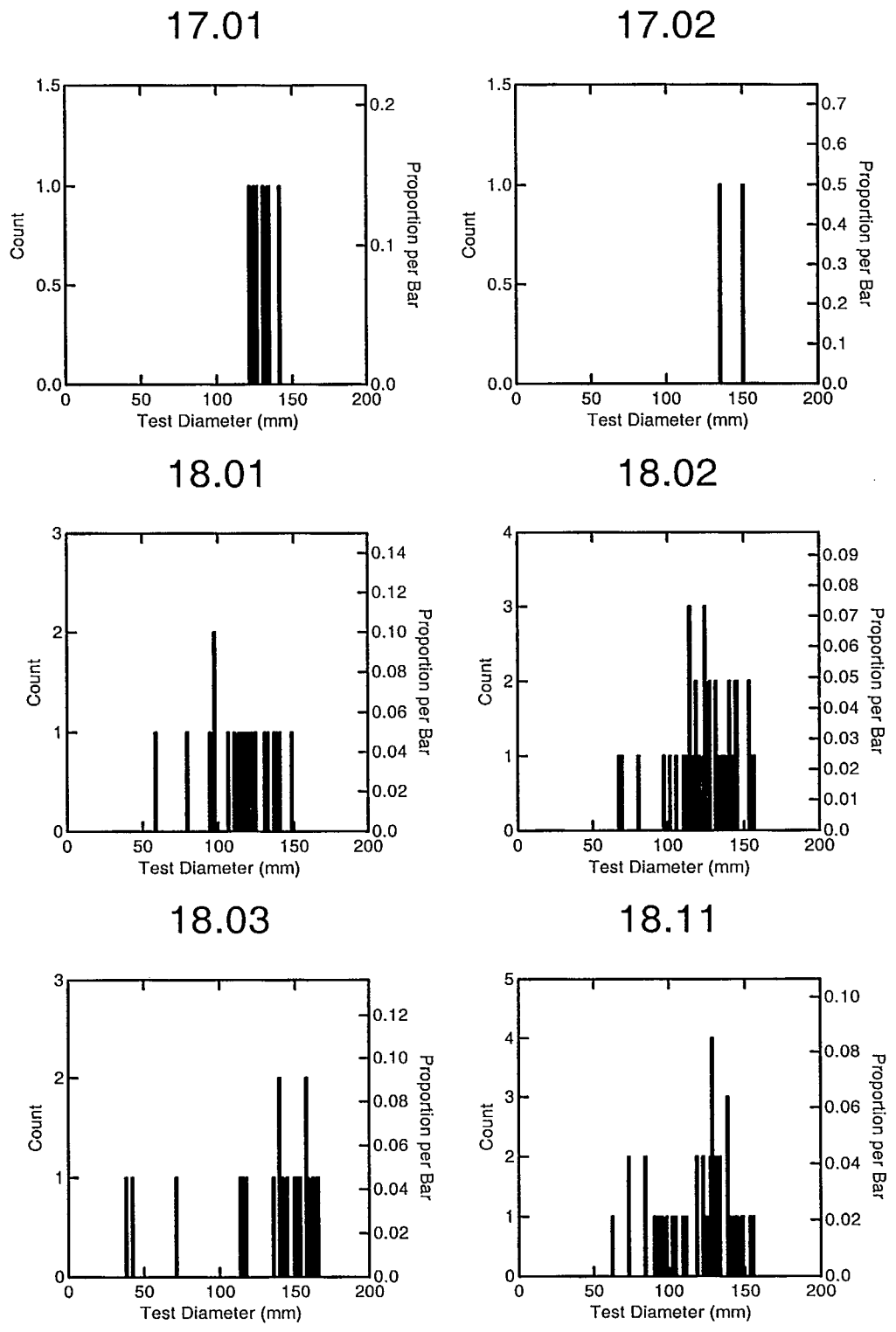

Figure 4. Size frequency distributions, per Pacific Fishery Management (PFM) sub-area, of red sea urchins measured during the 1998 population survey in the Gulf Islands. The numbers above the graphs are the PFM sub-area numbers. No urchins were measured in PFM sub-area 18.09.

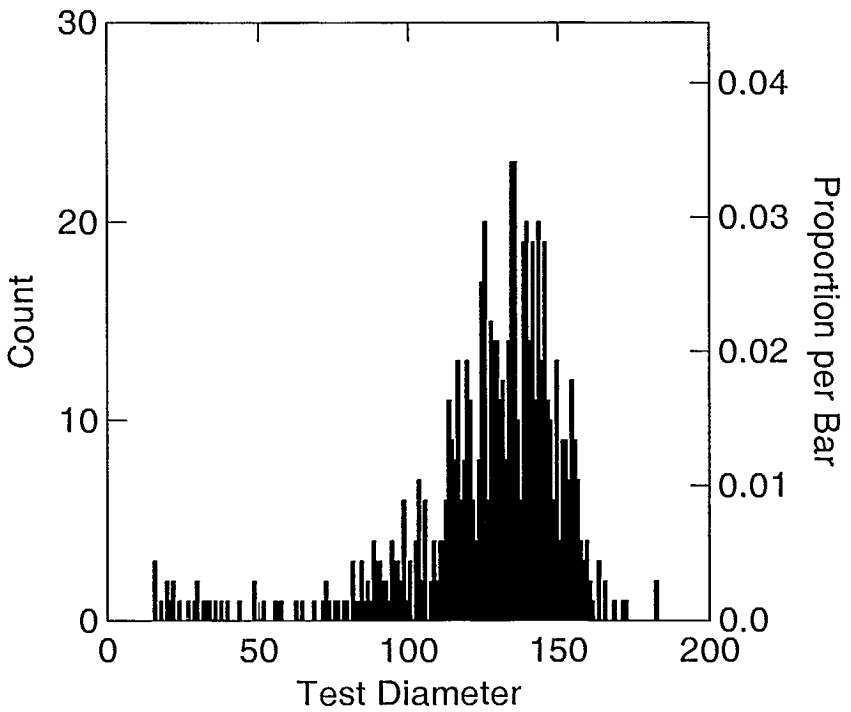

Figure 5. Size frequency distribution of red sea urchins measured on all transects during the 1999 population survey in the Gulf Islands. n = 674

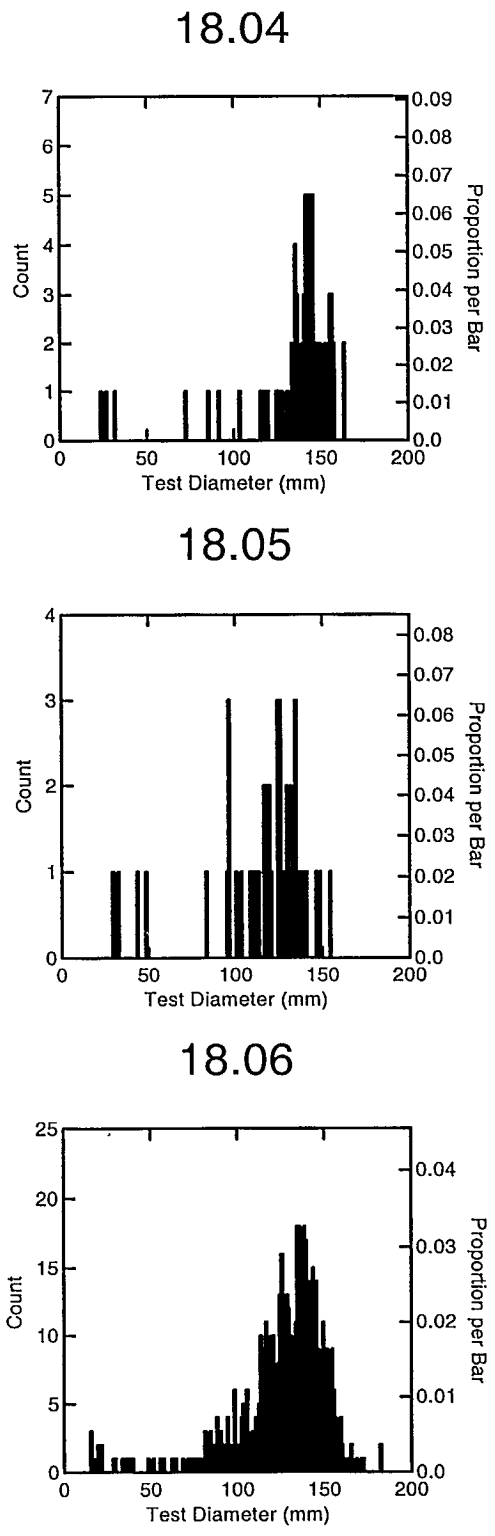

Figure 6. Size frequency distributions, per Pacific Fishery Management (PFM) sub-area, of red sea urchins measured during the 1999 population survey in the Gulf Islands. The numbers above the graphs are the PFM sub-area numbers.