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Discussion on a Precautionary Approach for Management of the Red Sea Urchin Fishery in British Columbia

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1. ABSTRACT

The red sea urchin has been fished commercially in British Columbia (B.C.) since 1971. The total landed value has generally increased throughout the red sea urchin fishery to nearly Can. $11.3 million by 1996. There were 109 licensed vessels with a coastwide annual quota of 6625 t, 19.1 % allocated to the South Coast and 80.9 % allocated to the North Coast of B.C. in 1996. Currently the main management tools of the red sea urchin fishery include (1) a minimum size limit of 100 mm TD (test diameter, mm) to allow about three spawning years for red sea urchin prior to harvest, (2) a quota system to provide a conservative fixed exploitation rate, (3) limited licence entry, and (4) an Individual Quota (IQ) program.

Commercial fishermen and fish processors have been requesting reductions in the minimum legal size limit to better meet market demands for the best quality gonad (roe) product which is extracted from red sea urchins. Fisheries Managers have requested that a long term strategy be developed that incorporates adaptive management methods for optimal harvest of red sea urchins while maintaining a precautionary approach to the management of this valuable resource. The objectives of this paper are to review the history of the commercial fishery, data collection programs, the biological features of red sea urchins, and discuss fishery management goals, the problems and concerns, and discuss a precautionary approach to future strategies.

Taking into account the biological characteristics of red sea urchins (which are slow growth, long life, and sporadic recruitment) and the uncertainty of biomass and natural mortality estimates, the following are some of the management strategies that are suggested for consideration. Reductions in the minimum size limit such as to 90 mm test diameter (TD) should be accompanied by reductions of exploitation rate to ensure sufficient brood stock reproduction. Large experimental management areas could be used to test the efficacy of the present management system and address issues as they relate to the appropriateness of different exploitation rates, change in size limit to 90 mm TD or limit thresholds. Monitoring programs would be needed to obtain changes in size composition and gonad quality of commercially harvested populations and fishery independent abundance/biomass indices.

1.2 RÉSUMÉ

L'oursin rouge fait l'objet d'une pêche commerciale depuis 1971 en Colombie-Britannique. De façon générale, la valeur totale des débarquements a augmenté tout au long de la pêche pour atteindre près de 11,3 millions de dollars (can.) en 1996. Au cours de cette année, on comptait 109 bateaux avec permis de pêche pour un quota annuel total à l'échelle de la côte de 6625 t réparti à raison de 19,1 % pour la côte Sud et de 80,9 % pour la côte Nord. Actuellement, les principaux outils de gestion de cette pêche sont : 1) une limite de taille minimale de 100 mm DT (diamètre test) afin de permettre environ trois années de reproduction avant la récolte, 2) un régime de quotas assurant un taux d'exploitation fixe et conservateur, 3) la limitation du nombre de permis et 4) un programme de quotas individuels (QI).

Les pêcheurs commerciaux et les transformateurs ont demandé des réductions de la taille légale afin de mieux satisfaire à la demande du marché pour des gonades (corail) de meilleure qualité, qui sont le produit tiré de l'oursin rouge. Les gestionnaires des pêches ont demandé que l'on élabore une stratégie à long terme incorporant des méthodes de gestion adaptative afin d'optimiser la récolte tout en maintenant une démarche prudente à la gestion de cette ressource de valeur.Le présent document a pour objectifs de présenter un examen de l'historique de la pêche commerciale, des programmes de collecte de données et des caractéristiques biologiques de l'oursin rouge, de traiter des objectifs de gestion, des problèmes et des préoccupations de la pêche et de discuter de l'application d'une démarche prudente aux stratégies futures.

En tenant compte des caractéristiques biologiques de l'oursin rouge (croissance lente, longue vie et recrutement sporadique) et de l'incertitude liée aux estimations de la biomasse et de la mortalité naturelle, les stratégies de gestion ci-après sont proposées pour considération. Ainsi, une réduction de la taille limite minimale, par exemple à un DT de 90 mm, devrait s'accompagner d'une baisse du taux d'exploitation afin de garantir une reproduction suffisante du stock de géniteurs. Des zones de gestion expérimentale de grande superficie pourraient être utilisées pour vérifier l'efficacité du régime de gestion actuel et régler les questions relatives à la pertinence de taux d'exploitation différents, d'une réduction de la taille limite à 90 mm de DT ou de l'utilisation de limites seuils. Il faudrait disposer de programmes de contrôle pour connaître les variations de la composition par taille et de la qualité des gonades des populations exploitées commercialement, et pour obtenir des indices de l'abondance et de la biomasse indépendants de la pêche.

2. INTRODUCTION

As custodian of marine invertebrate resources, the role of Fisheries and Oceans Canada (DFO) is to ensure that these resources and their habitats are conserved in an ecologically sustainable way and that the harvesting of invertebrates is conducted in a precautionary manner, while yielding reasonable returns to the community. Periodically there is a need to evaluate the management of a specific fishery, where for a variety of reasons (e.g., changes in stock status or economic markets) new or improved strategies are required to manage the resource. Such an evaluation has been requested by Fisheries Managers and Industry for the red sea urchin (*Strongylocentrotus franciscanus*; phylum Echinodermata) commercial dive fishery which has been conducted in British Columbia (B.C.) since 1971. Commercial fishermen and fish processors have been requesting reductions in the minimum legal size limit to better meet market demands for the best quality gonad (roe) product which is extracted from red sea urchins. Fisheries Managers have requested that a long term strategy be developed that incorporates adaptive management methods for optimal harvest of red sea urchins while maintaining a precautionary approach to the management of this valuable resource.

The most recent management plans and assessment of the red sea urchin fishery in B.C. are described by Campbell *et al*. (2000), Anon (1998) and Rogers and Neifer (1999).

The objectives of this paper are to review the history of the commercial fishery, data collection programs, the biological features of red sea urchins, and discuss fishery management goals, the problems and concerns and possible future strategies.

3.0 DESCRIPTION OF FISHERY

3.1 Fishery Definition

The red sea urchin (*S. franciscanus*) is one of three sea urchin species historically fished in B.C. waters (Sloan 1986; Campbell and Harbo 1991). Red and green sea urchins (*S. droebachiensis*) are fished under authority of a limited Z licence, category “ZC” for reds and category ZA for “greens”. Purple sea urchins (*S. purpuratus*) were fished under scientific permit from 1990 to 1992.

Sea urchins are harvested for their roe (gonad) which is extracted at processing plants for fresh shipment to markets. Red sea urchins are removed from the ocean floor by divers using short handled rakes. Packer vessels and trucks deliver the product fresh to plants for processing. The gonads are extracted, processed and sold almost exclusively in Japan. A smaller market is developing in other Asian communities and domestic North America, where the product is sold as ‘uni’. The yield of roe from a whole animal ranges from 5 to 15% of total body weight.

Commercial licences are defined as “North Coast” (Pacific Fishery Management (PFM) areas 1 to 10, inclusive, and 101, 105 and 106) or “South Coast” (PFM areas 11 to 29 inclusive, and 111, 123, 124 and 125) (Fig. 1). PFMA areas and subareas, as described in the *Pacific Fishery Management Area Regulations*, are referenced in describing Quota Areas. For the purpose of setting quotas, each Quota Area, which can include a combination of PFM subareas, has a name, e.g., RU01 Upper West QCI, and is assigned a maximum allowable catch in pounds.

Other regulations referenced for this fishery include the *Fishery (General) Regulations* (i.e., Conditions of Licence) and the *Pacific Fishery Regulations, 1993* (i.e., open times and size limits).

3.2. **Fishery Management**

Currently the main management tools of the red sea urchin fishery include (1) a minimum size limit of 100 mm TD (test diameter, mm) to allow about three spawning years for red sea urchin prior to harvest (Breen 1984), (2) a quota system to provide a conservative fixed exploitation rate, (3) limited licence entry, and (4) an Individual Quota (IQ) program (Table 1, 2).

The red sea urchin fishery began on the South Coast of B.C. in 1971 and expanded to the North Coast in 1984. The DFO implemented a limited entry licensing scheme in October 1991 and 102 licences were issued, a reduction of approximately 46% from the previous year (Table 1, 2). This action was taken to curtail the tremendous uncontrolled growth observed in the fishery. By 1994, licence appeals had increased the number of licences to 110 and this level of participation has remained constant through to the 1998/99 fishery.

The Pacific Urchin Harvesters Association (PUHA) voluntarily implemented an individual Quota (IQ) program in 1994 and 1995. The DFO sanctioned the program as a pilot in 1996.

Under the pilot IQ program, 2 % of the estimated coastwide Total Allowable Catch (TAC) is reserved for First Nations food, social and ceremonial purposes and each commercial licence is allocated 1/110 of the remaining TAC. The fishery is considered data limited and, as such, is managed under a precautionary regime. The industry association is responsible for developing and implementing a third party catch monitoring and validation program to ensure that area quotas and IQs are not exceeded. Further components of this program include an On-Grounds Monitor (OGM) for the fishery in areas north of Cape Caution, and biological sampling and survey programs.

Fishery timing and area openings are critical to maintaining optimum value for sea urchin roe and Canada's economic position in the Japanese market. Harvest schedules are determined in consultation with PUHA and sea urchin processors. The South Coast fishery is prosecuted primarily during the period of traditional peak market demand, avoiding mid-year months. The North Coast fishery is scheduled to provide a continuous year-round supply of high quality product. Initial area quotas were largely arbitrary and precautionary. Since 1995, the quotas for most areas have been based on survey information and catch data from mandatory harvest logs.

In 1997, an 18-month management plan was developed to permit a licensing change from a calendar year to a market-driven year from 1 July of one year through 30 June of the next year. The new fishing season, also allowed sufficient time for licence renewals to be made during a low fishing activity period.

The coast wide TAC for 1998/99 was reduced by approximately 12% from that of the 1997/98 management plan. This was the result of new information with respect to the biology of red sea urchins, survey results from new areas, improved estimates of harvest areas from harvest logs, and additional information provided by fishermen. Scientific research and joint Industry, First Nations, and Fisheries And Oceans Canada stock assessment surveys are of vital importance to this fishery as it moves from a precautionary management regime to a biologically based fishery.

During 1998/99 the fishery was managed under a block system in an attempt to increase harvesting flexibility and ensure the provision of the best quality roe to the market (Fig. 2). Harvesters worked under a fishing protocol which required that a minimum of 20% of the area quota be harvested; this enabled harvesters to consider both weather and product quality upon entering an area. A vote to move was conducted if one or both issues were a concern.

3.3. **Enforcement Concerns**

Harvest of undersize urchins remains the largest enforcement concern in this fishery. The roe found in smaller urchins has a higher value due to market demands.

There appears to be very little illegal harvest of other species by the red sea urchin industry. When the IQ program was implemented, PUHA hired an On-grounds Monitor for the northern fleet. This patrol vessel follows the fleet for eight months of the year and ensures that regulations and data requirements are adhered to on the grounds.

3.4 **Fishery Value**

The total landed value has generally increased throughout the red sea urchin fishery to nearly Can. $14 million for the 18-month fishery in 1997/98, except for 1993 when landings were lowered due to quota introduction in the North Coast (Table 2, Fig. 3). The unit value increased to Can. $1.97/kg in 1996, but decreased to $1.66/kg in 1997/98 due reduced market values (Table 2, Fig. 3).

Implementation of the IQ program increased the unit value of the product by guaranteeing fishermen a fixed portion of the overall quota, more freedom to schedule to fish different areas, respond to market requirements, provided industry control over volume, product quality, and increase international competitiveness (Harbo 1998).

3.4.1 Cost Recovery

PUHA fund services for research (including the salary for a biologist) and management through fees to association members. PUHA contract most programs (e.g., Harvest Port Validators, independent charter vessel and on ground monitor to record fishing vessel activity and beds fished), although there have been agreements for personnel support with DFO in collaborative research projects. The provincial B.C. government has contributed grants (e.g., partners in progress) to encourage collaborative research between PUHA, First Nations and DFO.

3.5 Stock Assessment and Research

3.5.1 Fishery Dependent Data

Catch and effort data were obtained from sales slips and from harvest logbooks that fishermen completed each day of fishing. Information from sales slips included total weight (pounds) and value (dollars) landed, CFV number, PFM subarea, date and days fished. Information from the harvest logbooks included location of bed (with diagram), date, landed weight and minutes of diving. The harvest logbooks were not completed by each vessel so the data were used as a sample of catch per unit of effort (CPUE, kilograms per minute) only where both total catch (kg) and effort (minutes) per region were reported per diver for each area per day. Average daily vessel CPUE were calculated as the mean CPUE values per diver per day per vessel per area. Average annual CPUE (and standard errors) per PFM area were calculated from the average daily vessel CPUE values per PFM area. The PFM areas were grouped for each general region as follows: North Coast (PFM areas 1 to 10, 102, 105, 106) and South Coast (PFM areas 11 to 29 inclusive, and 111, 123, 124 and 125) (Fig. 1). Further subdivision groupings were Queen Charlotte Island (PFM areas 1 and 2), Central Coast (PFM areas 3 to 10, 105, 106), East Coast of Vancouver Island (ECVI or inside waters included PFM areas 11 to19 and 28 and 29, excluding 12-14) and West Coast of Vancouver Island (WCVI included PFM areas 20 to 27 and 12-14, 111, 123, 124, 125) (Fig. 1). Average annual CPUE per region were calculated from mean daily vessel CPUE values per region.

3.5.1.1 Catch and Effort

The number of fishing vessels peaked at 116 in 1990 (Table 2). Coastwide landings peaked in 1992 (Tables 2, 3, and 4, Fig. 3, 4). Quotas have generally restricted landings in the South Coast since 1985 and in North Coast since 1993 (Table 2, Fig. 3, 4). Higher landings come from the North Coast than the South Coast (Tables 3, 4, Fig. 4).

CPUE (kilograms per diver minute) from harvest logbooks was variable between years and PFM area (Appendix 1) and region (Fig. 5). There were no distinct general trends in CPUE at the general region level and PFM area level between 1982-1994 (Fig. 5, Appendix Figs. 1) nor generally at the bed level (e.g., Fig. 6).

The lack in CPUE trends suggests that CPUE data for red sea urchins, at present, can not be used to indicate fishery trends in B.C. and may include the following factors. Fishermen may be maintaining high CPUE values through serial depletion, by moving to unexploited areas or increased depths within some PFM subareas, suggesting that CPUE would not decline until most of the suitable commercial sized sea urchins were removed from a PFM area. This may have occurred where fishermen have requested closure of a few PFM subareas which they consider have been over fished. Fishermen have increased search time for high quality urchins in response to recent changes in market demands and the implementation of an IQ scheme. Market demands may influence CPUE through buyers having control over the fishing operation and harvest rates of some vessels since the IQ program began (i.e., fishermen may fish to fill a specific buyer's request). Also fishermen may selected harvest areas where only urchins with the best quality roe are found allowing residual stocks to move from nearby poor feed areas to replace fished urchins in good feed areas. Fishermen claim that groomed urchin beds produce better quality urchins suggesting urchin densities and food supply are optimal, whereas new unexploited areas generally may produce urchins with poor quality roe due to high densities and or poor food supply.

There is a need to re-examine the distribution of effort and variability of CPUE data on a smaller spatial scale (e.g., by bed and depth) than the PFM area level to determine whether CPUE is an appropriate index of red sea urchin abundance after further examination of bed sizes have changed over the years (see following two sections).

3.5.1.2 Depth fished

The large variation in depths fished for red sea urchins is influenced by local conditions such as substrate topography, exposure, and slope and tide. Mean depths of beds fished were 9.9, 10.8 and 11.3 m (not adjusted to datum) for the North Coast, ECVI and WCVI regions, respectively. Mean minimum depths significantly ($p<0.001$) declined to < 4 m in the North

Coast and < 5 m in WCVI during 1990-1997/98 (Fig. 7A, 7C). This may be due to fishermen learning to harvest red sea urchins more frequently at the "feed line" in shallow waters where the quality roe could be improved due to accumulation of suitable food such as drift algae. There were no differences in changes of mean min depths for ECVI and mean max depths for the North Coast and WCVI over the years analysed (Fig. 7B, 7C).

There was a significant ($p<0.001$) increase in mean max depths fished from 10 to about 13 m in ECVI during 1982-97/98 (Fig. 7B). The reasons for the increase in harvesting deeper may be due to overexploitation of red sea urchins in the shallow areas or unknown environmental factors causing urchins to move to deeper waters. This area has the longest history of commercial harvesting of red sea urchins in B.C. Kalvas and Hendrix (1997) found similar trends in California where the red sea urchin landings declined in recent years. Kalvas and Hendrix (1997) suggested there may have been a reduced sea urchin abundance at shallower water depths or some divers suggested that changes in urchin abundance occurred in response to rougher sea conditions in shallow waters compared to previous years.

Clearly, for red sea urchins in B.C., further analyses of the logbook data are required to better understand changes in depth ranges fished in specific PFM subareas and beds.

3.5.1.3 Bed Characteristics

Red sea urchins are generally found in shallow rocky subtidal communities from the low intertidal to about 20m throughout the coast of B.C. Commercial bed areas of red sea urchins were indicated on charts or diagrams provided by fishermen with their harvest logbooks throughout B.C. during 1982-1996. The detailed bed areas were outlined on hydrographic charts according to the logbooks data and were digitized and areas estimated. The digitized bed areas used in the analyses for this paper are those indicated as harvested during 1982-1996. Estimation of these red urchin bed areas must be treated with caution since the beds were not measured empirically in the field, and the proportion of the substrate types are unknown and may differ from one area to another. Red sea urchin areas are difficult to categorize by bed. Some fishermen may check many areas with red sea urchins before actually finding urchins with good quality roe to harvest; these bed areas, referred to as "food traps", could be shallow at the edge of a kelp forest or deeper where algal drift accumulates (M. Featherstone personal communication)

The number of different beds harvested per year (identified in the logbooks) increased and generally levelled off for each region at different times: 1990 for the South Coast and 1994-96 for the Central Coast and QCI (Fig. 8). Estimated bed areas differed for each PFM subarea and increased by an average 21 % between 1994 and 1996 (Table 5, Appendix 2). However, the total estimated bed area for the North Coast as of 1996 was 50,205.2 ha which was similar to the 50,977.8 ha estimated by Heritage and Campbell (1993) from all potential bed areas estimated by fishermen. The average size of bed per PFM subarea in the North Coast was larger than that in the South Coast during 1996 (Table 5).

Using charts to estimate bed areas is crude, especially as each location may have different substrate surface areas. The harvest logbooks provide an historical cumulative estimate of fishable sea urchin areas but may include a few areas that no longer have viable red sea urchin populations. There may be areas still unexplored, especially in the North Coast, that may contain substantial unfished "virgin" populations that have not been included in the bed area estimates. Bed area estimates probably provide the most uncertainty of all the estimates used to calculate red sea urchin biomass. The most recent bed area estimates for the 1997-99 logbooks have yet to be digitized and calculated.

The records of log book bed area entries should be made on an annual basis rather than a cumulative basis on charts. Clear identification of beds in relation to the amount of red sea urchins removed from each bed needs to recorded carefully by fishermen and on grounds observers to allow detailed stock analyses on a bed by bed and/or PFM subarea basis in both the North and South Coasts. To date there have not been any on grounds observers for the South Coast.

3.5.1.4 Port Sampling

There is no program to monitor area, seasonal or annual changes in size frequency and gonad quality of commercially harvested red sea urchins in B.C. Although the processors note gonad quality, they have different systems of grading for different markets which would make collecting this information challenging. Monitoring harvested red sea urchins at ports and or in processing plants would provide valuable information in time and area changes of urchin size frequencies, mean weights and gonad quality.

3.5.2 Fishery Independent Surveys

A few surveys to estimate standing stock of red sea urchins in B.C. during 1976-94 have been published (Breen *et al*. 1976, 1978; Adkins *et al*. 1981; Sloan *et al.* 1987; Jamieson *et al*. 1998a, 1998b, 1998c, 1998d). The results of these surveys and additional surveys conducted during 1995-97, were summarized in Campbell (1998) and Campbell *et al*. (2000). The majority of “broadbrush” surveys to estimate red sea urchin abundance in B.C. were conducted during the 1990’s. The number of transects per PFM subarea surveyed during the 1990’s is listed in Appendix 2. The North Coast has been surveyed more frequently than the South Coast during the 1990’s (Table 5). To date, about 78.6 % and 36.4 % of the PFM subareas in the South Coast and North Coast, respectively, have not been surveyed (Table 5). The mean number of transects per PFM subarea was 8.4 and 2.2 for the North Coast and South Coast, respectively (Table 5). Clearly there is a need to survey PFM subareas with more beds and those that have not been surveyed for more than 10 years (e.g., WCVI and southern ECVI, Fig. 1).

Annual “intensive” surveys at local study sites (near Tofino, Price Island, eastern QCI), that were closed to commercial fishing, have been conducted during 1994-98, for long term study of the productivity parameters (e.g., density, size frequency, age, growth, reproduction and mortality) of red sea urchin populations. These studies are on going and some of the data are in the preliminary stages of analysis.

3.5.3 Biological Features

A number of papers review various aspects of red sea urchin biology (Bernard and Miller 1973; Kato and Schroeter 1985; Mottet 1976; Bernard 1977; Breen 1980; Sloan *et al*. 1987; Tegner 1989; Campbell and Harbo 1991; Botsford *et al*. 1993, 1994; Lai and Bradbury 1998; Ebert 1998). We review only biological factors of red sea urchins that may be important in the development of sustainable harvest strategies (e.g., gonad size and maturity, spawning success, and rate of growth, recruitment and mortality).

3.5.3.3 Reproduction

In B.C., wild red sea urchins first reproduce at about 50 mm TD (Test Diameter in mm) (Bernard and Miller 1973) with 100 % of the population reaching maturity at about 70 mm TD (A. Campbell unpublished data).

Mature males and females are mass spawners broadcasting their gametes. Reproduction occurs annually with the timing of the spawning season varying within March to September depending on local environmental conditions such as food availability and temperature (Bernard 1977). Gonads increase in size usually from September to January (Kramer and Nordin 1975).

The effect of food quality and availability to support growth and reproduction are important factors in limiting urchin stocks. Although red sea urchins are omnivorous grazers, kelps, such as *Nereocystis leutkeana*, provide optimal growth and gonad quality (Vadas 1977; Bureau *et al*. 1997; Morris and Campbell 1996). In areas of low abundance or poor food quality urchins may relocate nutrients causing poor quality gonads and reduce their reproduction potential.

Fertilization success of gametes (sperm/ova) is highest in closely spaced individuals with low water movement, but decreases as urchin densities decrease or with increased currents (Levitan 1991; Levitan *et al*. 1992). Levitan and Sewell (1998) point out that managers should keep in mind the effect of densities on fertilization success when considering decisions concerning restrictions in catch and body size for sea urchin fisheries.

The free swimming larval period may take 1 – 4 months depending on temperature prior to settling to the benthic stage (Strathmann 1978). Substrate requirements for sea urchin settlement are poorly understood although substrates with algae may increase settlement rates (Cameron and Schroeter 1980; Rowley 1989). However, suitable substrates for settlement of sea urchin larvae are probably not limiting in the wild (Tegner 1989).

3.5.3.2 Recruitment

Recruitment in juvenile red sea urchin populations, estimated as the percent of population ≤ 50 mm TD, was found to be highly variable between areas in North America ranging from 5.5 % to 16.0 % (review by Kalvass 1992). Sloan *et al*. (1987) estimated recruitment to average about 9.5% in red sea urchin populations in southern B.C. Little has been published about recruitment (in the fishery management sense) to the fishable legal size. Lack of suitable shelter under the spine canopy of large red sea urchins has been attributed to low survival of juveniles and subsequently poor recruitment to fishable sizes (Tegner and Dayton 1977, 1981). Little is known about spawner recruit relationships and physical characteristics affecting larval settlement and recruitment patterns in red sea urchins (Ebert *et al*. 1994; Wing *et al*. 1995; Miller and Emlet 1997). The physical and biological factors influencing the local and broad spatial and temporal variation of recruitment of red sea urchins in B.C. require study.

3.5.3.3 Growth

Growth is fastest in the juveniles and slows considerably as adults age. Growth rates of juvenile and adult red sea urchins can be site specific depending on local conditions such as food abundance and quality (Vadas 1977; Morris and Campbell 1996). Various authors (e.g., Bernard and Miller 1973; Breen 1984; Kato and Schroeter 1985; Lai and Bradbury 1989) considered growth rates of red sea urchins to be faster (e.g., 4 - 8 yr to reach 100 mm TD) than that reported by Ebert (1998) who found tagged sea urchins from Washington and Oregon to take about 10 yr to reach 100 mm TD and 50 yr to reach 140 mm TD. Preliminary analyses of tagging and ageing studies throughout B.C. indicate red sea urchins take about 6-8 years to reach 90 mm TD and 8-11 years to reach 100 mm TD depending on location sampled (Campbell *et al*. unpublished data.).

3.5.3.4 Mortality

Theoretically, in stable populations that have not been fished, recruitment and growth balances natural mortality. Instantaneous natural mortality (M) is considered a general index of population replacement and has been estimated by various methods. Breen (1984) estimated M to range from 0.016 to 0.22 for red urchins from 3 sites in southern B.C. and considered a value between 0.1-0.2 to be acceptable. There are no published estimates of instantaneous natural mortality rate (M) for red sea urchins from northern B.C. Woodby (1992) estimated M = 0.16 for red sea urchins from the Sitka, Alaska area. Botsford *et al*. (1993) estimated M = 0.14 for a population of red sea urchins in California. Lai and Bradbury (1998) estimated M to be about 0.16 for red sea urchins from Washington. Based on published values Campbell (1998) assumed M to be 0.15 in calculating quotas for the 1995 red sea urchin fishery in B.C. Ebert (1998) calculated the mean instantaneous total mortality rate ($Z\ yr^{-1}$) of red sea urchins, from a total of twelve samples collected from six locations in Oregon and Washington, to be 0.052 (min. 0.016, max 0.133, lower 95% confidence interval (CI) 0.028, upper CI 0.076); equivalent to a mean annual survival rate of 0.949 (e^{-Z}). The average mortality values reported by Ebert (1998) are generally below those previously reported in the literature. Clearly M will vary between areas and between size classes for red sea urchins in B.C. Although a similar tagging program on red sea urchins in B.C. has been conducted mortality data from this program have yet to be analysed and therefore are not available for this paper. For the purposes of this paper, a range of M values from 0.052 to 0.150 can be considered reasonable for red sea urchins in B.C.

3.5.4 Biomass and Quota Estimation

Campbell *et al*. (2000) estimated mean biomass per square metre (g / m^2), for each size group h, as

$$b_h = d\ P_h\ W_h \tag{1}$$

Total current biomass of red sea urchins, for each size group and PFM area was calculated as

$$B_c = A\ d\ P_h\ W_h \tag{2}$$

where B_c = current mean biomass (g) converted to tonnes (10^6 g) and summed for each PFM subarea; A = commercial urchin bed area (m^2) estimated from digitized charts, subsequently converted to hectares (10,000 m^2 per ha); d = estimated mean density (number per m^2) of red sea urchins of all sizes; P_h = proportion of urchins in size group h; W_h = estimated mean weight (g) of commercial-sized red sea urchins in size group h (e.g., TD $\geq$ 100 mm or 100 - 140 mm TD).

To estimate quotas (Q), Campbell *et al.* (2000) used a conservative management approach for the red sea urchin fishery in B.C. similar to that proposed by Woodby (1992) for the red sea urchin fishery in Alaska. A modified surplus production model was used to estimate a maximum sustainable yield (MSY) from a stock that is in the early stages of exploitation (Schaefer 1954; Gulland 1971). The model assumes that the MSY occurs when the maximum sustainable fishing mortality is equal to M.

$$Q = X\ M\ B_c \tag{3}$$

where B_c is the current biomass, M is the instantaneous natural mortality rate and X = a correction factor to insure that a sustainable fishing mortality rate is well below the calculated MSY. The value of X = 0.20 was used in this paper and considered a reasonably conservative safeguard to account for errors in estimating the lower current biomass values (Caddy 1986; Garcia *et al*. 1989). The correction factor should provide for a conservative harvest per year (of about 2 %, assuming M=0.10) in a developing fishery where little is known about the productivity of the population. Since equation 3 is derived from a Graham-Schaefer production model, recruitment is assumed to be unaltered by these low fishing levels. Although this approximation was developed for an unexploited virgin stock (B_o) we assumed that $B_c = B_o$ which would make the quota estimation theoretically more conservative since B_c should be less than B_o in an on going fishery.

Caution is required in the interpretation of these calculations for the quota because there are so many assumptions in the parameters used in the oversimplified model. Also there is considerable error in measuring densities and bed areas which would yield large confidence limits around the current biomass estimates. Campbell *et al*. (2000) only used the estimated mean biomass B_c whereas Woodby (1992) chose to be more conservative by using the lower bound of a 90% confidence interval estimate of the virgin population size.

4.0 FISHERY MANAGEMENT GOALS AND STRATEGIES

Many biological goals, concerns, suggested strategies and recommendations for the red sea urchin fishery in B.C. are made in this section. Although there are a number of other general subjects, such as those related to Economic and Social goals, the scope of this paper allows only detailed discussion related to biological goals.

4.1 Biological goals

The goals are to use precautionary management strategies in a red sea urchin fishery, such as controlling size limits and exploitation rates, to provide optimal product quality and long term sustainable population levels.

4.1.1 Concerns

To achieve these goals there are two critical factors to be addressed in the assessment and management of the fishery:

1) The red sea urchin fishery is proceeding in a conservative manner that will not subject stocks to overfishing; and
2) The management and assessment frameworks are designed so that scientific defensible data can be collected and that the full potential of the fishery can be realised.

To insure that the fishery is being managed in a sufficiently precautionary manner there will be an initial under-utilisation of the stocks to provide the necessary protection for these data limited stocks. Are we achieving this presently with the system we have in place? To answer affirmatively there are a number of concerns or questions that must be addressed. Also, there are a number of input and output management controls that can be used to achieve these goals. The red sea urchin fishery has progressed through a number of management options starting with a size limit and generally proceeding to a fixed exploitation rate through a quota system (Table 1). The difficulty is to continue to develop a system that can address the following concerns and questions.

4.1.1.1 Recruitment Overfishing

4.1.1.1.1 Variability in Stock Recruitment Relations

The management system must recognise the variability associated with spawner recruit relationships. The number of fertilised eggs in an area will not necessarily produce the same number of recruits in the same area each year. A number of abiotic and biotic factors may contribute to this variation in mortality, and the source of spawners will likely be in a different area compared to the location (sink) were the progeny ultimately settle and recruit. Little is known about spawner recruit relationships and the physical factors affecting larval settlement and recruitment patterns in red sea urchins (Ebert *et al*. 1994; Wing *et al*. 1995; Miller and Emlet 1997). The important aspect is to understand the range in variability and insure that the population does not fall below a level where the likelihood of replacement is compromised. At the present, the management system is based on a conservative fixed exploitation rate (Campbell *et al*. 2000) and a minimum size limit (Breen 1984). The fixed exploitation rate is applied to a set of biomass estimates extrapolated from a series of surveys.

Problems associated with the present quota system are the uncertainty of natural mortality (M) rates and the biomass estimates and the resulting exploitation rates in some areas. Breen (1984) recognised a range of values for M for different areas of the coast which were probably due to age/size differential mortality. Managers have selected a range of exploitation rates varying from 2-5% over the period of quotas (Harbo and Sloan 1987; Harbo and Thomas 1992; Campbell *et al*. 2000). Biomass estimates are calculated from bed-areas outlined in fishmen logbooks which incorporate the shoreline and the depth ranged fished. Densities from surveys are used to estimate the biomass of the bed areas at the PFM subarea level. When this is not possible then the mean density at the area level is used to calculate the density for non-surveyed PFM subareas. This procedure does not take into account the relative fishing success for surveyed and non-surveyed PFM areas. The biomass estimate used only takes into account the fishable portion of the stock at the time of the survey. There is no way of accounting for variable settlement/recruitment coming into the area. Without consistently frequent surveys there is no way fishery management can be responsive enough to take advantage of strong year classes and avoidance of weak year classes.

Breen (1984) goes through two arguments that could be used to justify using a minimum size limit when addressing recruitment overfishing. The first is that a size limit could be used to protect sufficient reproductive potential to attempt to insure that recruitment does not fall below replacement. The second special argument that can be made for red sea urchins is that adult urchins provide a spine cover for juveniles that is necessary for good survival (Tegner and Dayton 1977). In this case, minimum and maximun size limits would leave enough large adults to protect the settlement of juveniles, such as used in Washington State (Lai and Bradbury 1998). Breen (1984) concluded that using a size limit as the only control mechanism to prevent recruitment overfishing would not be achieved with the 100mm size limit that is presently used. If we were to use a size limit solely to prevent recruitment overfishing it would be larger than the industry's upper limit for market quality. Breen (1984) recommended that a better way of preventing recruitment overfishing is "controlling effort or catch in such a way as to protect local stocks from over harvesting".

Lai and Bradbury (1998) developed simulation models to examine the relative merits of harvest rates, size limits and periodic harvesting on red sea urchin populations in Washington.

They found that there was approximately twice the risk of stock collapse without a minimum size limit than with a size limit at different fishing rates. They also found that the probability of sustainability of red sea urchin populations would increase substantially by restricting effort or catch and by increasing the period between harvests (e.g., from 1 to 5 year rotations).

4.1.1.1.2 Density Dependent effects

There are a number of complex density dependent compensatory and depensatory mechanisms that this animal may elicit in growth, mortality, increased survival of juveniles due to protection by adult spine canopies, spawning success, roe quality and egg viability.

The present quota management system does not take advantage of compensatory mechanisms that the animals may elicit, such as increased growth, and improved roe production, which could result in loss of fishery production opportunities. However, more importantly the present management system does not have a mechanism to protect the stock at low density levels that may impact the population negatively, e.g., "the Allee affect" (Allee 1931), when the density of animals becomes so low that it impacts on the reproductive success of the animal. This is particularly important in organisms that are broadcast spawners. Levitan *et al*. (1992) found that fertilization success was a function of the number of animals, distance apart, position in the cluster, flow direction and velocity of the current etc. For animals that show this type of fertilization this is a critical factor that must be included in the management system in providing various forms of harvest refugia (e.g., size restrictions, catch limits through quotas or rotating spatial harvests and spatial closures) (Botsford *et al*. 1993; Quinn *et al*. 1993; Pfister and Bradbury 1996; Levitan and Sewell 1998).

In contrast, Ebert (1998) found potentially little Allee effects on growth of red sea urchins in Oregon and Washington using simulation techniques. He recommended not to assume Allee effects are important without incorporating sensitivity analyses in dynamic modelling methods.

4.1.1.2 Appropriate Size Limits

The utility of the present size limit (100 mm TD) is to prevent growth overfishing (i.e., preventing harvest of individuals at a small average size) when a greater yield per recruit could be taken from the same individuals at a larger size. The yield per recruit is maximized when the individuals are harvested close to the "critical size" (Breen 1984) where growth balances natural mortality. There is a special case to be made for red sea urchins in that what we are trying to achieve is not maximum weight of any roe, as one would in a normal yield per recruit relationship, but optimal production of quality roe. Quality is defined by size, shape, colour, etc. and the highest quality roe. Industry indicates that high quality roe is not obtained from the largest animals but from animals in the range of 90-120 mm TD (M. Featherstone personal communication). Critical in trying to achieve this goal of maximizing quality roe is the need to understand the factors (e.g., urchin age and size, food quality and supply) that go into the production of good quality roe, while insuring sufficient animals reproduce and reducing the risk of recruitment overfishing.

The present size limit appears to be limiting the quality of the product that is available to industry. Due to poor quality concerns a number of areas with high densities of red sea urchins are not fished by fishermen (M. Featherstone, personal communication). Fishermen believe that a management objective should be to balance such factors as roe quality with a sustainable harvest for maximum economic yield. The question has to be, what is the management objective for this fishery, to produce maximum quantity of low or mixed quality product or a very much reduced quantity of a high quality product? Unfortunately we do not have the economic information that managers and fishermen can use to understand the tradeoffs of this kind of decision. The industry believes that maximum quality product can be obtained by fishing to a minimum size limit of 90 mm TD (Mike Featherstone personal communication). If the fishery does become selective for a mid-sized product the management and assessment system must be designed to protect and sustain that size of animal. If we are not careful we could subject an excessive harvest rate on a mid size range (e.g., 90-120 mm TD) of animals that the fishery could soon remove and create a hole in the population that would continually expand as larger, older animals grew out of the population and younger animals were continually cropped. Consequently the population could ultimately collapse.

4.1.1.3 Managing at the Appropriate Spatial Scale

Are we managing at an appropriate spatial scale for the definition of a stock? At present there is insufficient data to indicate what scale would be most appropriate. There are a number of indicators that may provide clues to spatial separation: indicators may include genetic differences, morphological differences, biological markers such as parasites, variations in growth rates, variations in population structure. Boutillier and Bond (1999) discussed this issue with respect to the prawn fishery where they found differences in growth rates and parasite loads over quite small spatial scales. Generally, Boutillier and Bond (1999) felt that, if at all uncertain, it is more conservative to manage on as minimal a spatial scale as is feasible. For red sea urchins this would be at the bed level. There are some clues that indicate that a small spatial scale may be appropriate such as variations in growth sizes and variations in recruitment patterns over small spatial scales. The level of concern is proportional to the extent of exchange of larvae at the metapopulation level. If the exchange is low it can lead to sequential depletion of the stocks and large scale overfishing. Red sea urchin larvae are in the water for 1-4 months and there is a good chance in most areas that there is quite a large exchange of larvae. If however the success of larval settlement and survival depends on the presence of an adult spine canopy then once overfished an area may take a long time to recover. The population structure and growth rate differences between different areas in close proximity may indicate that there is probably little or no exchange of animals post settlement.

4.1.1.4 Appropriate Exploitation Levels

Are the exploitation levels truly conservative? The levels of exploitation vary from approximately 2-3% over very broad areas and are probably conservative for an animal that lives to about 50 years of age. However, the discrepancy appears in that there is a 3 fold range in uncertainty with respect to the natural mortality of these animals. Campbell *et al*. (2000) gave a range of quotas with four estimates of M that ranged from 0.05 to 0.15. With uncertainties in biomass estimates in some PFM sub areas, especially where actual biomass may be lower than estimated, assigned quotas may increase exploitation rates well above 3%. A lower exploitation rate (e.g., <2 %) probably would be required for a change in minimum size limit from 100 mm to 90 mm TD.

There are indications in a few PFM subareas of the fishery that the exploitation levels may not be sustainable. A few areas have been closed to fishing, after fishermen requested some PFM subareas be closed or quota reduced, because urchin population levels were considered too low. To reopen closed areas, a survey would be required and new quota set. There has been a continuous expansion of the fishery into new areas while the quotas have been decreasing. There was a 20% increase in bed area over the two years from 1994 to 1996 in most areas of the coast (Table 5). This may be an indication that the previously fished areas had not sufficiently recovered to sustain the fishery, and/or the urchin management areas were too large and sequential localized overfishing has been occurring. This scenario is similar to the one described by Boutillier *et al*. (1998) in the sea cucumber fishery. Expansion into new areas seems counter productive if we believe the premise that was stated earlier that lower densities reduce competition for food and results in improved roe yields in the remaining animals.

4.1.1.5 Adequate Measures of Biomass

Do we have adequate measures of the biomass? At this time we rely on surveys in a few small areas that are then used to estimate quotas over the entire coast. As the bed areas increase so does the overall quota of the area. There is no discounting of the quota system to account for the excess removals of animals from specific beds nor is there expansion of quotas to reflect local recruitment of some year classes. The first factor would be reflected in a system similar to the geoduck quota calculations (Campbell *et al*. 1998; Hand *et al*. 1998) and the second would be addressed by repeat surveys.

Calculating biomass and quotas only by PFM area has created a problem to managers when allocating quota by RU's (Red Urchin management areas) which are groupings by PFM subareas and accurate quotas at this level were not available. These RU groupings of PFM areas can change slightly between years (and occasionally within a fishing year) depending on the managers' consultations with fishermen, on-grounds monitor and processors. To overcome this problem managers assumed average biomass (g/m^2) calculated for each PFM area could be applied to each PFM subarea, even ones that had not been surveyed. This method could present problems by inflating quota estimates especially when relying on density estimates from surveys that are >4 years old and where many of the PFM subareas in the South Coast and North Coast have not been surveyed even within the last 10 years (Table 5). Providing reasonably accurate biomass and quota estimates by PFM subarea or even a finer scale (e.g., by bed) may require a different precautionary approach than has been conducted in the past.

4.1.1.6 Closed Area Refugia

Closed areas can be used for a number of purposes, such as small or large scale experimental tests of various management options, or for social reasons. Rogers-Bennett *et al*. (1995) and Rogers-Bennett (1997) have advocated permanently closed areas (e.g., marine protected areas, MPAs) as a management tool to provide additional protection to red sea urchin populations that can contribute as effective "source" reproduction areas for California's red sea urchin fishery. Experimental adaptive management for the sea cucumber fishery is currently using 50% of the coastline of B.C. as refuge areas, 25% to test a variety of exploitation rates, and 25% is open to an IQ fishery (Boutillier *et al*. 1998).

4.1.1.7 Reference Points

Caddy and Mahon (1995) indicated that reference points, which start as conceptual criteria defining general management goals, should be converted into technical reference points which quantify the important biological or economic characteristics of a fishery.

Biological reference points can be considered as indicators of stock status which could be a useful management index [e.g., changes in CPUE, changes in size composition of fished urchins, changes in abundance of recruits (legal sized urchins), pre-recruits, or spawners ($\geq$ 70 mm TD), or fishing mortality, in different regions (North, South) or PFM areas].

Limit reference points are levels at or below which long term damage to a stock may occur resulting in reduced resource productivity.

Only limited data are available for most red sea urchin populations in B.C. However, some general reference points need to be set. As better information is collected from commercial catch sampling and fishery independent surveys, more robust biological and limit reference points can be established.

What is missing from the present management system for the red sea urchins, that is present in the geoduck fishery in B.C., is a limit threshold that defines a level below which fishing would be prohibited in an area. In geoducks this is set at a relative level of 50% of the original biomass (Campbell *et al*. 1998; Hand *et al*. 1998). A limit threshold could be defined as an absolute measure such as an estimated particular mean density of red sea urchins per square meter. This could be a 50% approximation of the densities in well-established populations that have not been fished. The importance of having a critical density of animals was previously discussed in the context of research by Levitan *et al.* (1992) which showed that spawning success was controlled by the number of animals, the distance apart, the position within the cluster and the direction and velocity of the current. A limit threshold could eliminate marginal populations from the fishery and will hopefully not compromise the spawning success of populations. The problem is to define a spatial scale over which such criteria are appropriate and which need to be measured and evaluated.

4.2 Considerations for Biological Strategies

The following are a number of recommended strategies that could be used to achieve the goals and address the concerns stated in the previous sections.

1) Conduct further research to estimate suitable size limits and exploitation rates to achieve a sustainable red sea urchin fishery that produces optimal gonad quality product for the industry.
2) Continue collecting fishery independent abundance/biomass indices of harvestable, prerecruit and juvenile sized urchins from surveys in harvested and unharvested areas, at a PFM subarea and/or bed level. Maintain a time series of stock abundance data on unfished, moderately fished and potentially overfished areas to better understand the influence of varying exploitation rates on the resilience of local populations. Some surveys should investigate the reason why red sea urchins are being fished at greater depths in ECVI than in other regions.
3) Use a conservative estimate of density (e.g., the lower 90% confidence level of estimated mean densities of whole PFM area) from the surveys to extrapolate into PFM subareas that have not been surveyed previously or have been unsurveyed for greater than 10 years.
4) Establish quotas based on the fraction of stock in the preferred fishery size range. If there is a size limit reduction to 90 mm TD, biomass and quota estimates should be based on estimates of the density of the preferred size range (e.g., 90-120 mm TD) of red sea urchins from surveys.
5) Develop a monitoring program of commercially harvested populations, at port and processing locations, to monitor changes in size composition and gonad quality of harvested

urchins. This would be especially important if there is a reduction in the size limit to 90 mm TD to monitor (a) the effect of the preferred fishery size range on quota, and (b) the efficacy of the size in relation to roe quality as defined by the processing.

6) Bed area estimates need to be updated on an annual basis.
7) Establish large experimental management areas (EMA) which could be used to test the efficacy of the present management system. Testing in the EMA could address issues as they relate to the appropriateness of different exploitation rates and changes in size limit.
8) Continue collecting basic biological information and preparing reports in support of management of red sea urchins (e.g., Examine (i) spatial and temporal variation in growth, natural and fishing mortality and size at maturity, (ii) effects of density and adult size on gonad quality, egg quality, senescence and larval survival, (iii) genetic diversity by area for better definition of stock boundaries, and (iv) larval settlement patterns in time and space through deployment of larval collectors and examination of water current patterns).
9) Attempt to work toward quantifying commercial fishery mortalities on red sea urchins (e.g., loss underwater through testing of quality prior to harvest, dumping of undersize product, and breakage during sorting on deck and during transport).

4.3 Habitat goals and strategies

Minimise impacts of red sea urchin fishing on the environment by promoting harvesting techniques, work with various groups in monitoring ecosystems in relation to changing sea urchin abundance in fished and in closed fishing areas (including experimental and proposed marine protected areas).

Monitor the development of red sea urchin aquaculture and enhancement areas to avoid any deleterious impacts on red sea urchin fishery and habitat.

Monitor sea otter population growth and sea otter impacts on red sea urchin populations.

4.4 Economic goals and strategies

Optimise fishery yield and manage the fishery for equitable and fair economic returns to fishermen. Industry needs to ensure sufficient fees are collected from licence holders to pay for appropriate compliance, research, and monitoring costs. Strategies could include (1) making improvements to the IQ program to address: distribution of fishing effort; quality-oriented harvest; continuous market supply; and maintaining competitive access to the Japanese market. (2) an economic study to collect regular economic data, capital, operating/fishing, and management costs and market information (unit values & gonad quality), to evaluate benefits/costs of IVQ system, and appropriate size limits to optimise fishery yield and value. (3) Develop methods to assist C&P for efficient monitoring of fishery for compliance of regulations. (4) Develop economic reference points – performance indicators?

4.5 Social goals and strategies

(1) Address and evaluate the impacts of commercial red sea urchin fisheries on the ability of First Nations to harvest for food, social and ceremonial purposes. (2) Maintain flexibility in management plan development to incorporate new initiatives into the fishery. For example, with Fisheries and Oceans Canada approval, PUHA implemented a voting system to try and improve the fishing pattern and control the harvest rate. Unfortunately, all fishermen did not adhere to the voting system, and there remains the need for a harvesting protocol that will satisfy both Fisheries And Oceans Canada and the industry's requirements.

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Table 1. History of management actions in the commercial red sea urchin fishery, 1971 - 1999.

YEAR	KEY POINTS	SUMMARY
1971-77	**Coastwide**:	First reported landings. Participation very low. All landings in South Coast
Prior to 1982	**Coastwide**:	Category “Z-C” licence required.
1982 to 1985	**Coastwide**:	Category “Z-C” licence required. Steady increase in effort and landings.
1986	**Coastwide**:	Category “Z-C” licence required. Minor landings in North Coast
1987	**Coastwide**:	Category “Z-C” licence required. Minimum size limit 100mm coastwide. Harvest logs and sales slips required. Voluntary compliance closures for First Nations use.
	North Coast:	Fishery open year-round, no area quotas. Fishery focused in Central Coast due to proximity to South Coast plants.
	South Coast:	Time and area quota restrictions (based on historical effort and 1981 and 1984 surveys).
1988	**Coastwide**:	Category “Z-C” licence required. Minimum size limit 100 mm coastwide. Harvest logs and sales slips required. Research requested in support of lowering the size limit.
	North Coast:	Maximum size limit 140 mm. No area restrictions or quotas. Experimental management, with the intention of introducing rotational fishing. Fishery open year-round. First Nations allocation closure in Burnaby Narrows (SA 2-13).
	South Coast:	TAC 3,600,000 lb. plus exploratory fishing. Time and area quota restrictions. Weekly processor reports required.
1989	**Coastwide**:	Category “Z-C” licence required. Minimum size limit 100 mm. Fishing notification and catch reporting required. Research requested in support of lowering the size limit.
	North Coast:	Maximum size limit 140 mm. Experimental management continued. Fishing restricted to PFM areas 1, 2E, 2W, PFM areas 6 to 10, and PFM areas 3 to 4.
	South Coast:	TAC 3,625,000 lb. Time and area quota restrictions.

1990	**Coastwide**: **North Coast**: **South Coast**:	Category "Z-C" licence required. Minimum size limit 100 mm. Hail and catch reporting required. Harvest log sheets mandatory. Fish slip requirements defined in plan. WCB certification required. Maximum size limit 140 mm. North Coast fishery open year-round. Area restrictions and first year of 3 year rotational fishery set in PFM subareas 2-1 to 2-10, 2-42 to 2-67, 3, 4, 5 and 7. TAC 3,675,000 lb. South Coast area quotas mostly arbitrary. Area quotas set to limit expansion until stock and biological information is collected and evaluated. Time and area quota restrictions.
1991	**Coastwide**: **North Coast**: **South Coast**:	Category "Z-C" licence required. Minimum size limit 100 mm. Fishing notification, Harvest Logbooks and harvest charts required. Licences limited to 102 (October 21/91). Weekly processor reports required. Fish slips required. WCB certification required. Maximum size limit 140 mm. Second year of rotational fishery (January 7 to December 31) in PFM subareas 2-1 to 2-10, 2-63 to 2-84, 3, 4, 5, 6-18 to 6-20, 6-24, 6-25, 7-25 to 7-28, 8, 9, 10. North Coast effort and landings increased significantly. TAC 3,400,000 lb. Time and area quota restrictions.
1992	**Coastwide**: **North Coast**: **South Coast**:	Schedule II with a "Z-C" licence required. Minimum size limit 100 mm. Licence limitation – 102 licences. Notification and catch reporting requirements. Weekly processor reports required. WCB certification required. Maximum size limit 140 mm. North Coast closures considered for First Nation allocation. Open PFM subareas 2-1 to 2-10, 2-63 to 2-84, 5-13 to 5-22, 6-9, 6-13, 6-16, 6-11, 6-14, 6-15, 6-17, 7-31, 7-18, 8, 9. Some time restrictions implemented. TAC 3,425,000 lb. South Coast openings built around markets. Most openings for 4 d/week. Additional exploratory areas implemented for WCVI. New closures in PFM areas 14, 15, 16.

1993	**Coastwide**: **North Coast**: **South Coast**:	Category "Z-C" licence required. Minimum size limit 100 mm. Notification and catch reporting requirements. Catch monitored at first point of landing. Weekly processor reports required. WCB certification required. Pacific Urchin Harvesters Association (PUHA) steering committee established. Maximum size limit removed. New TAC 12 million lb applied in NC. Harvesting during three time periods (January to May, June to August, October to December) in rotating areas. TAC 3,089,000 lb. South Coast area, openings and quota changes. Time and area quota restrictions. Quota lowered due to overages in the 1992 season.
1994	**Coastwide**: **North Coast**: **South Coast**: **Other:**	Category "Z-C" licence required. Minimum size limit 100 mm. Area licencing – North and South Coast divided at Cape Caution. One year licence area selection. Notification and catch reporting requirements. New logbook requirements. Voluntary Individual Quota (IQ) program instituted by industry (IQ xxx lb). Service bureau hired by PUHA to validate landings. Weekly processor reports required. WCB certification required. Export requirements. TAC 12 million lb. plus 1 million lb. for exploratory fishing. Time and area quota restrictions. TAC 2.901 million lb. plus 500,000 lb. for exploratory fishing. Time and area quota restrictions. New closures in PFM area 28 and new study areas in PFM subarea 2-3 and PFM area 24.
1995	**Coastwide**: **North Coast**: • TAC: • Management strategy: **South Coast**: • TAC: • Management strategy:	Category "Z-C" licence required. Minimum size limit 100 mm. Area licencing. Voluntary IQ program continued. Notification and catch reporting requirements. Notification and catch reporting program established with D&D Pacific Consulting. WCB certification required. Export requirements. PUHA research fund established. New closures in PFM subareas 2-31 and 2-70. 12 million lb. Schedule of openings established to disperse the fishery throughout most of the year to meet market demands. Charter patrolman hired by for on-grounds monitoring from January to April and October to December. 3,051,000 lb. (reduction due to overage in 1994). Time and area quota restrictions.

1996:	**Coastwide**:	Category "Z-C" licence required. Minimum size limit 100 mm. Area licencing. Two year pilot of Individual Quotas (IQs). IQ 132,763 lb. Industry-funded catch monitoring and validation program developed collaboratively between PUHA, D&D Pacific Fisheries Ltd. and Fisheries And Oceans Canada (fishing notification, product offloading, catch validation, quota overage, transfer and relinquishment restrictions). WCB certification required. Export requirements.
	North Coast: • TAC/IQ: • Management strategy:	11,815,907 lb. Monthly schedule of openings. Industry-funded charter patrolman on grounds for 8 months.
	South Coast: • TAC/IQ: • Management strategy:	2,788,023 lb. Minimum 4 vessels fishing before an area opened. Time and area quota restrictions.
	Other:	Licence stacking. Licence transferability. Vessel length restrictions waived for the duration of the pilot. New research area closures in PFM area 26.
1997/98	**Coastwide**:	Category "Z-C" licence required. Minimum size limit 100 mm. Area licencing. 18 month fishery January 1, 1997 to June 30, 1998 to facilitate a change to licence year. IQ pilot continued. IQ 197,439 lb. Catch monitoring and validation program. Harvest log and Validation log amalgamated. Fishermen required to submit harvest information with every validated delivery. Harvest chart records required within 28 days of the previous month's fishing. WCB certification required. Export requirements.
	North Coast: • TAC/IQ: • Management strategy:	17,966,949 lb.; 91 licences (18 month quota). Schedule of openings, based on market demand. Industry-funded charter patrolman on grounds for 8 months.
	South Coast: • TAC/IQ • Management strategy:	3,751,341 lb.; 19 licences (18 month quota). Time and area restrictions.
	Other:	Licence stacking. Licence transferability. Vessel length restrictions waived for the duration of the pilot. New closures in PFM areas 5, 17, 18, 24. Up to 200 lb. quota overage permitted. Program to carry-over quota overages implemented as a disincentive for excessive overages. Quota overage to be deducted from the licence tab quota in 1998/99. Tagging requirements for all containers used for red sea urchins.

1998/99	**Coastwide**:	Category "Z-C" licence required. Minimum size limit 100 mm. Area licencing. 12 month plan July 1 to June 30. IQ pilot continued. IQ 112,265 lb. Catch monitoring and validation program. WCB certification required. Export requirements.
	North Coast:	
	• TAC/IQ:	10,215,165 lb.; 91 licences (12 month quota).
	• Management strategy:	Block system – Quota Areas assigned maximum allowable catch and opening sequence. Fishing protocol built by PUHA. Minimum 20% landing requirement for each Quota Area. Industry-funded charter patrolman on grounds for 8 months.
	South Coast:	
	• TAC/IQ	2,133,035 lb.; 19 licences (12 month quota).
	• Management strategy:	Time and area restrictions.
	Other:	Licence stacking. Licence transferability. Vessel length restrictions waived for the duration of the pilot. Quota overage disincentive program removed. Up to 500 lb. quota overage permitted. Tagging requirements for all containers. Offload product prior to fishing new Quota Area.

Table 2. Annual red sea urchin landings (tonnes), value and effort for British Columbia, 1978 to June 1998, as reported on sales slips and harvest logs.

					SALES SLIP DATA					HARVEST LOG DATA		
Year	Licences Issued	Vessels with Landings	South Coast Quota[1] (t)	North Coast Quota (t)	Coastwide Landings (t)	Landed Value ($ '000)	Total Vessel Fishing Days	Whole Landed Value ($/t)	CPUE (t/vessel day)	Coastwide Landings (t)	Total Diver Hours[3]	CPUE (kg/diver hr)
1978	C	4			75	16	54	213	1.4	-	-	-
1979	C	29			317	76	298	240	1.1	-	-	-
1980	C	18			333	84	331	252	1.0	-	-	-
1981	C	18	136		116	34	127	293	0.9	-	-	-
1982	C	21			160	56	195	350	0.8	45	76	-
1983	Z 64	36			982	358	757	364	1.3	720	1,428	504
1984	Z 85	47			1,764	712	1,058	404	1.7	1,377	3,782	364
1985	Z 86	46	1,803		1,815	763	1,126	421	1.6	1,204	2,882	418
1986	Z 103	67	1,500		2,067	1,011	1,534	489	1.3	1,582	3,397	466
1987	Z 184	97	1,633		2,223	1,276	1,737	574	1.3	1,436	3,429	419
1988	Z 184	84	1,678		2,115	1,238	1,239	585	1.7	1,764	5,057	349
1989	Z 240	109	1,644		2,658	1,631	1,542	614	1.7	2,005	5,409	371
1990	Z 188	116	1,668		3,158	1,953	2,651	618	1.2	2,440	7,479	326
1991	Z 102	89	1,531		6,945	4,187	3,862	603	1.8	6,427	16,356	393
1992	Z 108	110[2]	1,554		12,982	8,662	6,222	667	2.1	12,480	31,170	400
1993	Z 107	103	1,401	5,443	6,388	5,373	3,364	841	1.9	6,106	17,202	355
1994	Z 110	98	1,543	5,897	5,829	8,066	3,978	1,384	1.5	5,960	18,942	315
1995	Z 108	108	1,387	5,455	6,585	11,350	4,167	1,724	1.6	6,807	21,398	318
1996	Z 109	109	1,265	5,360	5,753	11,358	3,536	1,974	1.6	6,410	18,046	355
1997/98 [3]	Z 110	109	1,702	8,150	8,448	13,994	5,305	1,656	1.6	8,738	30,223	289

[1]South coast quota includes exploratory areas; North Coast quota new in 1993.

[2]Larger than the number of licences issued due to licence transfers.

[3]Change in licencing from calender year to market-driven year. 1997/98 season ran January 1/97 to June 30/98.

Table 3. Summary of red sea urchin landings (tonnes) by South Coast Management Area 1971 to June 1998, as reported on sales slips and harvest logs. Catch corrected by using Validation & Harvest logs for 1994-98 only.

	SOUTH COAST PFM AREAS																				
	East Coast Vancouver Island												West Coast Vancouver Island								Total Annual
Year	11	12	13	14	15	16	17	18	19	28	29	Total	20	21	23	24	25	26	27	Total	Landings
1971-73[1]									110.0			110.0				254.0				254.0	474.0
1974-77[1]		1.4		*	*	1.4			66.0			68.8	*		1.3					1.3	138.9
1978			*						46.0			46.0	29.0							29.0	121.0
1979			*	78.0			57.0	133.0	45.0			313.0	1.8	0.9	2.5					5.2	631.2
1980				18.0			162.0	54.0	97.0			331.0	1.8							1.8	663.8
1981			20.0	4.0	*		5.3	47.0	22.0			98.3				17.0				17.0	213.6
1982		2.5		46.0			0.8	11.0	94.0			153.5				5.0				5.0	312.0
1983[2]	7.8	99.0	264.0	260.0	*	*	59.0	38.0	112.0			839.8	24.0		22.0	38.0		62.0		146.0	1,825.6
1984	0.3	437.0	777.3	172.0			33.0	67.4	76.3		5.7	1,569.0	69.1		17.3	103.0		3.9		193.3	3,331.3
1985		354.0	492.0	167.0	106.0	5.9	29.0	48.0	77.0		47.0	1,325.9	30.0		96.0	158.0	145.0	15.0	45.0	489.0	3,140.8
1986	27.0	548.0	376.0	178.0	56.0	4.4	57.0	129.0	105.0		2.0	1,482.4	40.0		154.0	285.0		2.5	91.0	572.5	3,537.3
1987[3]	6.9	420.0	491.0	193.0	32.4		71.0	71.0	123.0	17.0	7.8	1,433.1	17.0		63.0	199.0	95.0	8.3	12.0	394.3	3,260.5
1988	2.6	534.0	480.0	78.0	21.0	2.3	*	22.0	78.0			1,217.9	74.0		13.0	250.0	66.0		58.0	461.0	2,896.8
1989		569.0	493.0	122.0	6.7		9.0	64.0	57.0		1.6	1,322.3	15.0			223.0	39.0		86.0	363.0	3,007.6
1990	84.8	437.6	428.4	56.6	1.2	0.6	43.0	46.5	58.6	0.3	1.8	1,159.4	7.9		59.7	215.1	56.8		68.1	407.6	2,726.4
1991	36.4	358.7	370.7		8.6		26.6	94.8	27.2		14.1	937.1	31.2	2.7	58.4	185.1	115.8		121.1	514.3	2,388.5
1992	8.0	531.0	320.0				103.0	36.0	86.0		4.0	1,088.0	56.0	9.0	31.0	200.0	10.0		65.0	371.0	2,547.0
1993	55.5	329.0	184.0				21.0	104.7	17.3			711.5	14.5		40.4	92.0	7.0	2.0	50.0	205.9	1,628.9
1994	17.0	348.0	168.0				4.0	59.0	14.0		1.0	611.0	3.0		54.0	111.0	50.0		49.0	267.0	1,489.0
1995	34.0	364.0	175.0				28.0	69.0	15.0		9.0	694.0	20.0		57.0	199.0			98.0	374.0	1,762.0
1996	38.0	344.0	238.0				25.0	112.0	7.0		10.0	774.0	33.0		46.0	122.0			70.0	271.0	1,819.0
1997/98	61.0	594.0	426.0		2.3		26.0	67.0	40.0		16.0	1,232.3	32.0		54.0	132.0			85.0	303.0	2,767.6
1971 to June '98	379.3	6,271.2	5,703.4	1,372.6	234.2	14.6	758.9	1,273.4	1,373.4	17.3	120.0	17,518.3	499.3	12.6	769.6	2,788.2	584.6	93.7	898.2	5,646.2	40,682.8

* Less than 500 kg.

¹ Data for each year cannot be published separately.

² Mandatory log book under Z licence started in 1983.

³ Sales slips combined for red and green sea urchins in 1987, were later separated by price criteria, but 320 t remained missing in area table. See Table 1.

Table 4. Summary of red sea urchin landings (tonnes) by North Coast Management Area 1984 to June 1998, from sales slips and harvest logs. Catch corrected by using Validation & Harvest logs for 1994-98 only.

	NORTH COAST PFM AREAS											
Year	1	2E	2W	3	4	5	6	7	8	9	10	Annual Landings
1984	2.2											2.2
1986											12.0	12.0
1987					23.0			179.0	91.0			293.0
1988					73.0	11.0	7.3	314.0	32.0			437.3
1989	0.2	223.0		1.6	116.0	1.3	168.0	217.0	65.0		180.0	972.1
1990		26.6	10.7	24.5	156.8	265.3	67.1	1,040.1				1,591.1
1991		333.1	2.7	143.3	1,026.7	2,577.3	77.7	774.7	114.6	24.5	304.9	5,379.5
1992		1,111.0		1.0		3,294.0	4,063.0	2,763.0	140.0	114.0	38.0	11,524.0
1993	97.0	189.0	88.9	127.2	1,008.0	463.0	2,103.0	1,012.0	43.4		215.3	5,346.8
1994	221.0	402.2	167.4	173.0	687.0	1,056.0	1,244.0	861.0	57.0	46.0	164.0	5,078.6
1995[1]	258.0	440.2	256.3	48.0	940.0	1,280.0	1,053.0	1,076.0	111.0	49.0	224.0	5,735.5
1996	259.0	365.0	241.8	66.0	851.0	1,156.0	1,213.0	833.0	122.0	10.0	248.0	5,364.8
1997/98	582.0	718.7	311.1	62.0	1,076.0	1,107.0	2,175.0	870.0	112.0	41.0	152.0	7,206.8
1984 to June '98	1,419.4	3,808.8	1,078.9	646.6	5,957.5	11,210.9	12,171.1	9,939.8	888.0	284.5	1,538.2	48,943.7

[1] Area 106 = 115.3 t

Table 5. Summary of red sea urchin bed areas (hectares) and number of transects surveyed per PFM subarea during 1993-97 in British Columbia. See Appendix 2 for more details.

Description	North Coast	South Coast
Number of PFM subareas with beds 1994	94	100
Number of PFM subareas with beds 1996	110	112
Total bed area (ha) 1994	39,709.4	7,573.7
Total bed area (ha) 1996	50,205.2	9,669.2
Percent Change in bed area 1994-96	20.91	21.67
Mean bed hectares per PFM subarea 1996	448.3	86.3
Percent of PFM subareas with transects 1996	63.64	21.43
Percent of PFM subareas without transects 1996	36.36	78.57
Mean number of transects per PFM subarea 1996	8.4	2.2

Fig. 1. Location of PFM areas and general coastal regions where red sea urchins are fished. QCI = Queen Charlotte Island (PFM areas 1 – 2), North Coast (PFM areas 1 – 10), Central Coast (PFM areas 3 – 10), South Coast is divided into ECVI = East coast of Vancouver Island (PFM areas 11 – 19, 28, 29) and WCVI = West Coast of Vancouver Island (PFM areas 20 – 27).

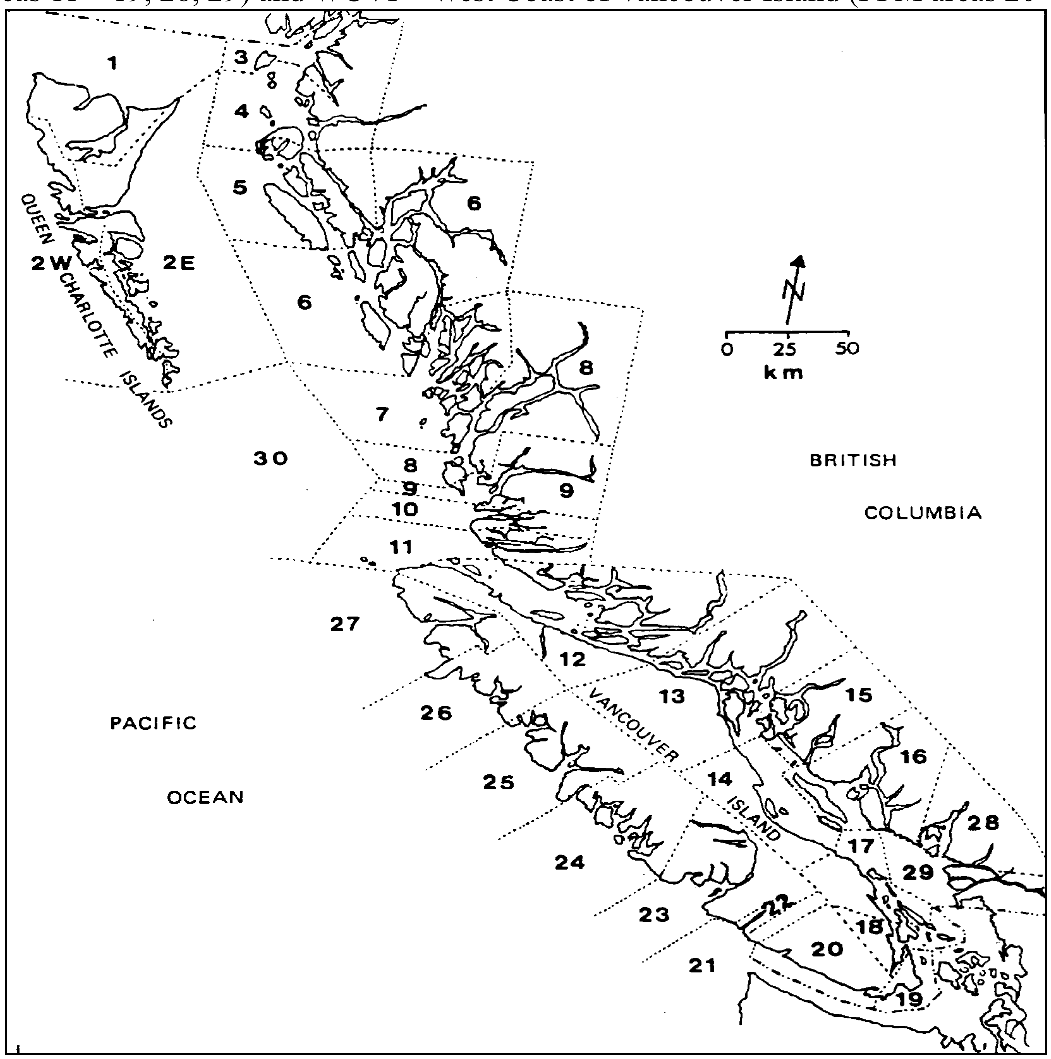
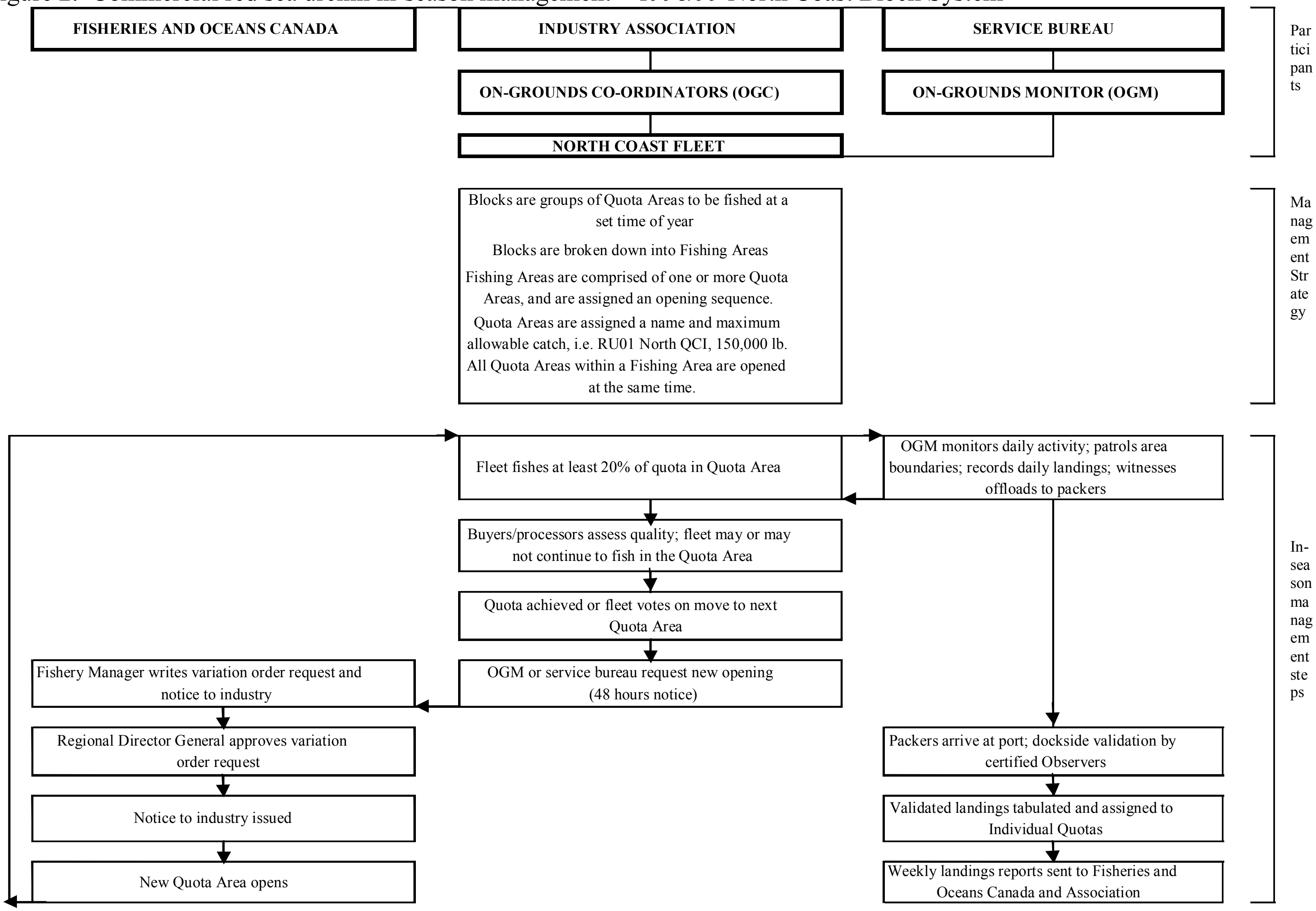


Figure 2. Commercial red sea urchin in-season management – 1998/99 North Coast Block System



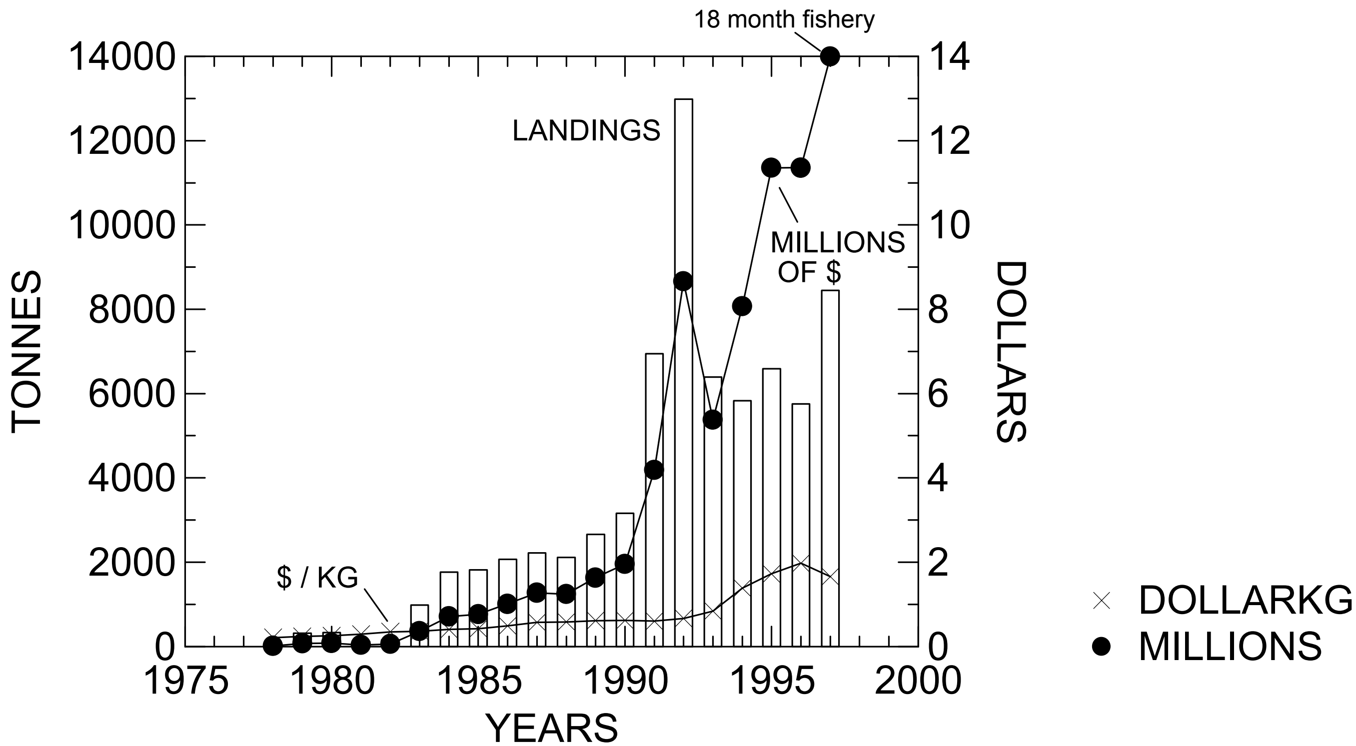


Fig. 3. Annual yield and value for the red sea urchin fishery in British Columbia, 1978 – 98.

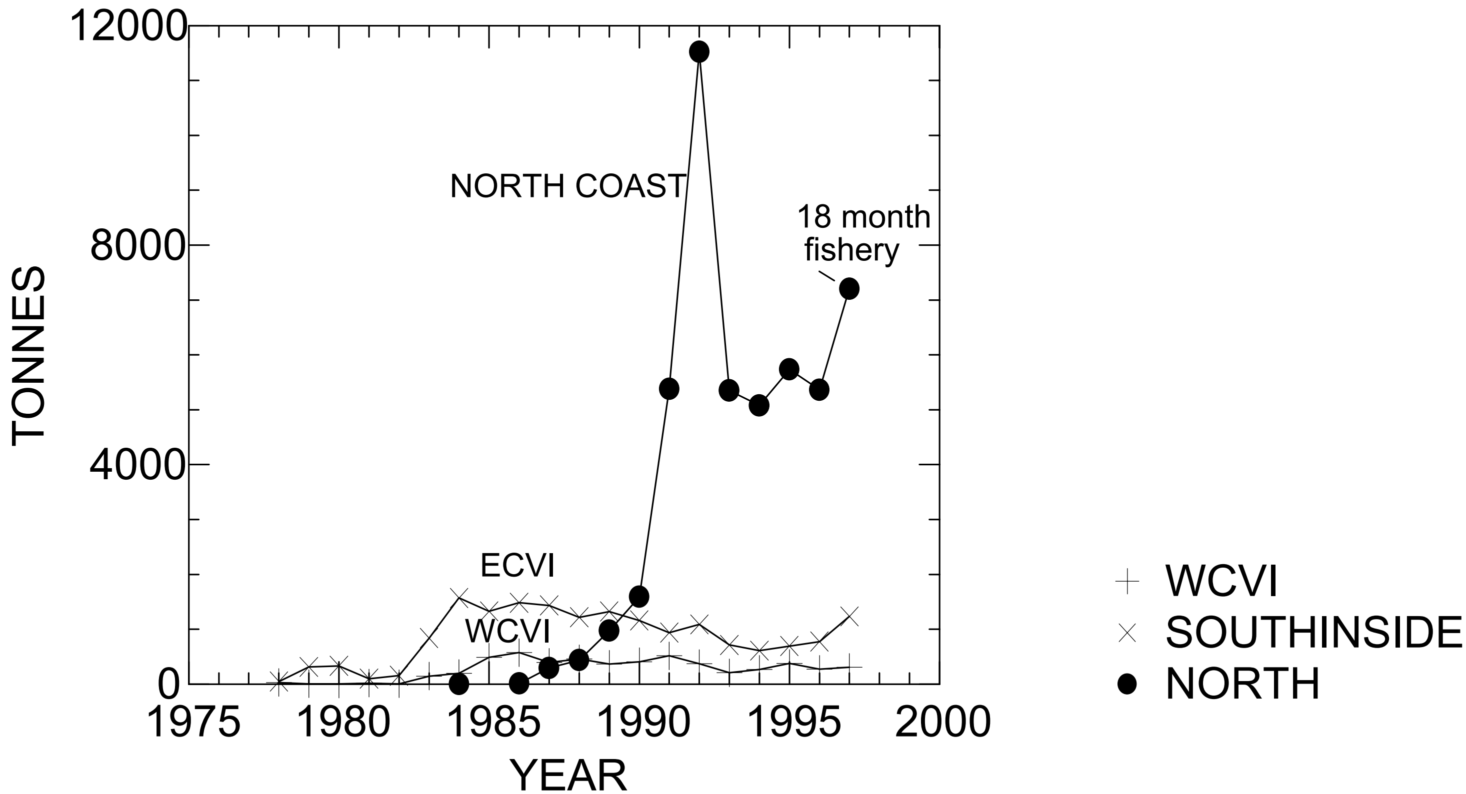


Fig. 4. Annual landings (t) for the North Coast, South Coast – East Coast Vancouver Island (ECVI) and West Coast of Vancouver Island (WCVI) from sales slips, 1978 – 98.

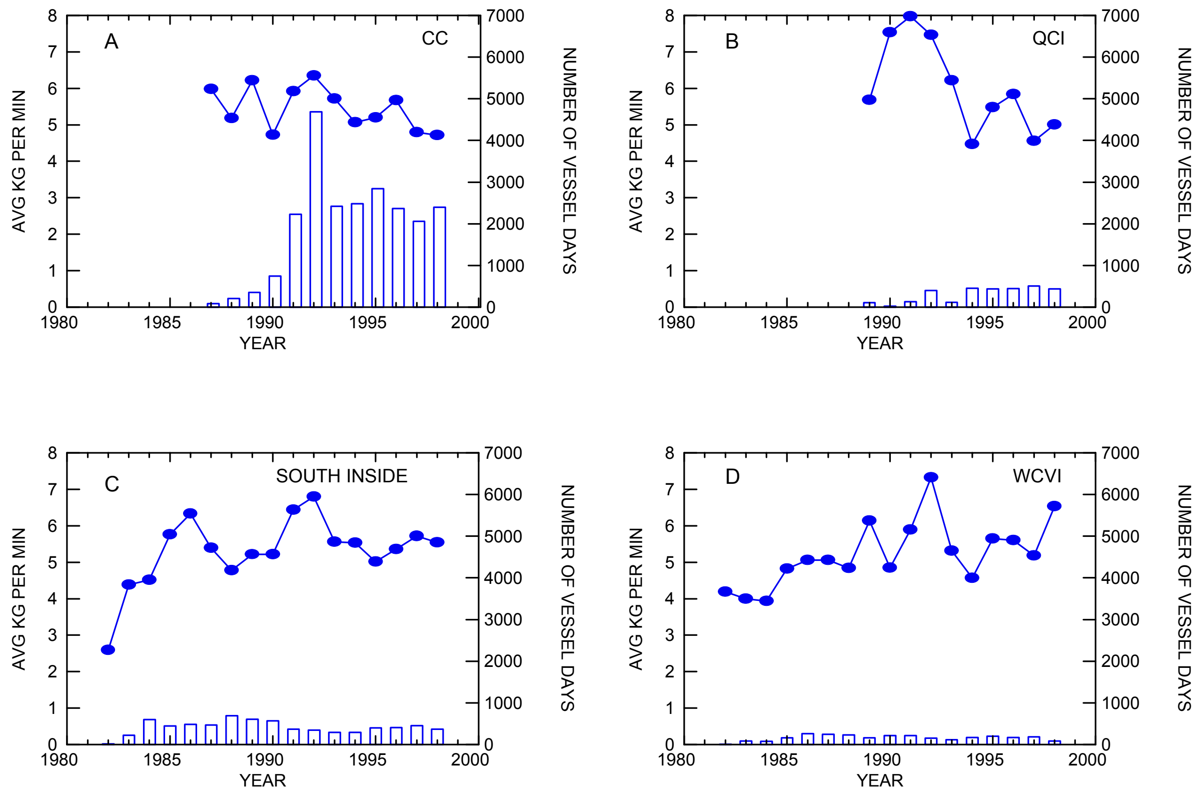


Fig. 5. Annual mean catch per unit effort (dots, kg/minute) and total effort expressed as number of vessel days (columns) per region (A) Central Coast (CC), (B) Queen Charlotte Islands (QCI), (C) South Inside waters, and (D) west coast Vancouver Island (WCVI) for the Red Sea Urchin Fishery in British Columbia. Although the 1998 data are part of the 18-month 1997/98 fishery they are shown separately in these graphs as data collected from1 January to 30 June, 1998.

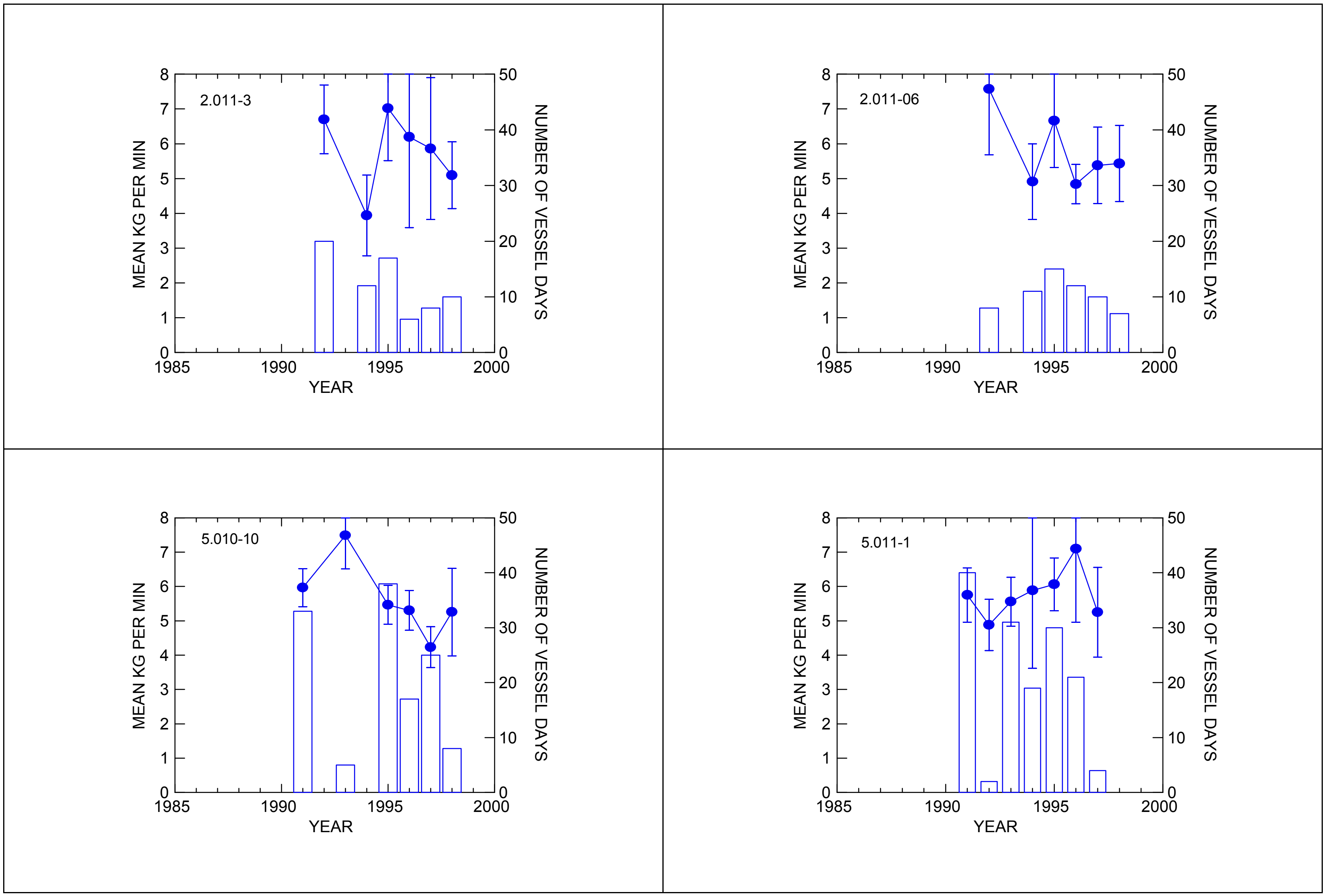


Fig. 6. Annual mean catch per unit effort (dots, kg/minute, vertical lines are ± 2S.E.) and total effort expressed as number of vessel days (columns) per bed (top left number indicates PFM area. subarea – bed number).

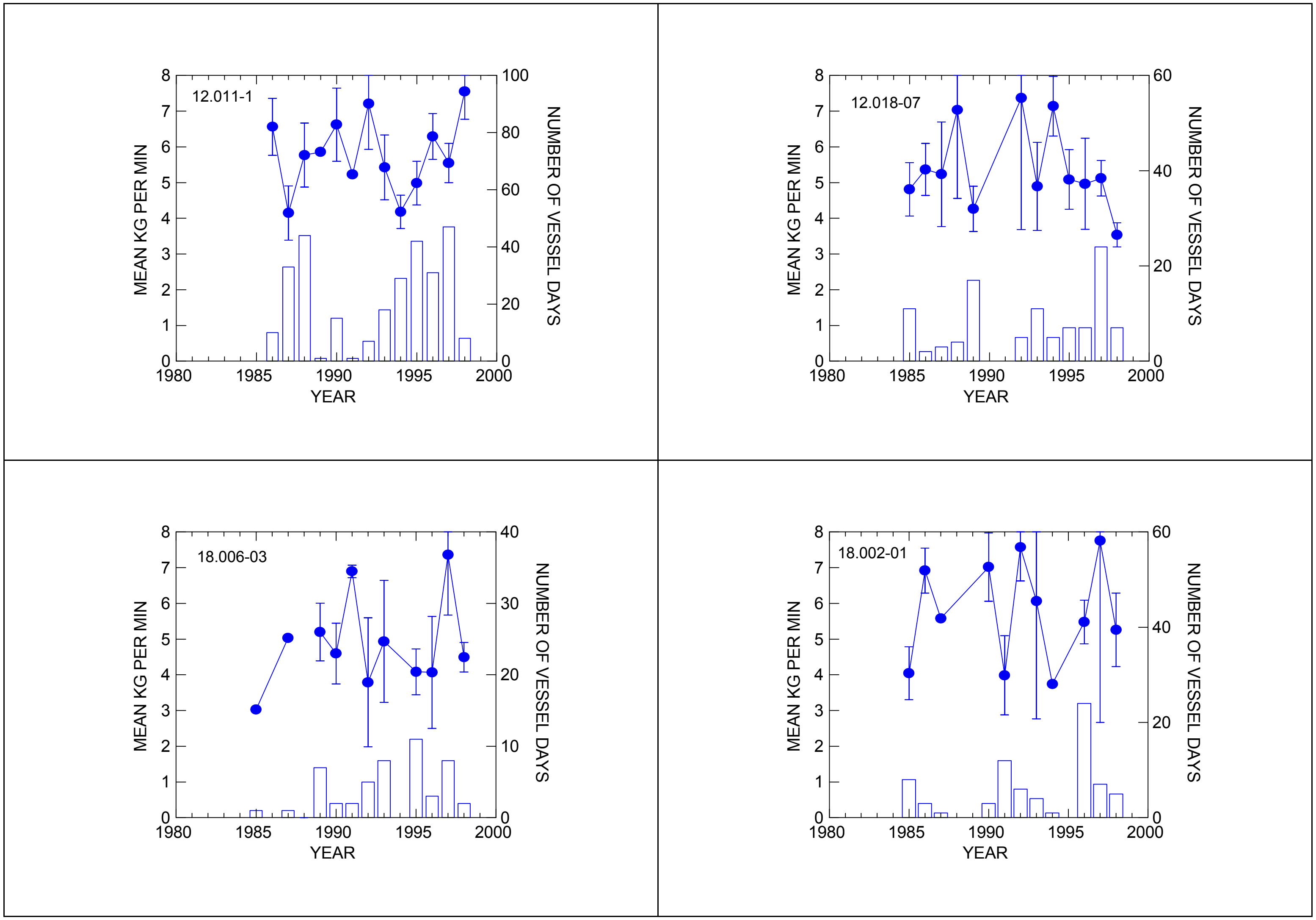


Fig. 6 cont'd. Annual mean catch per unit effort (dots, kg/minute, vertical lines are ± 2S.E.) and total effort expressed as number of vessel days (columns) per bed (top left number indicates PFM area. subarea – bed number).

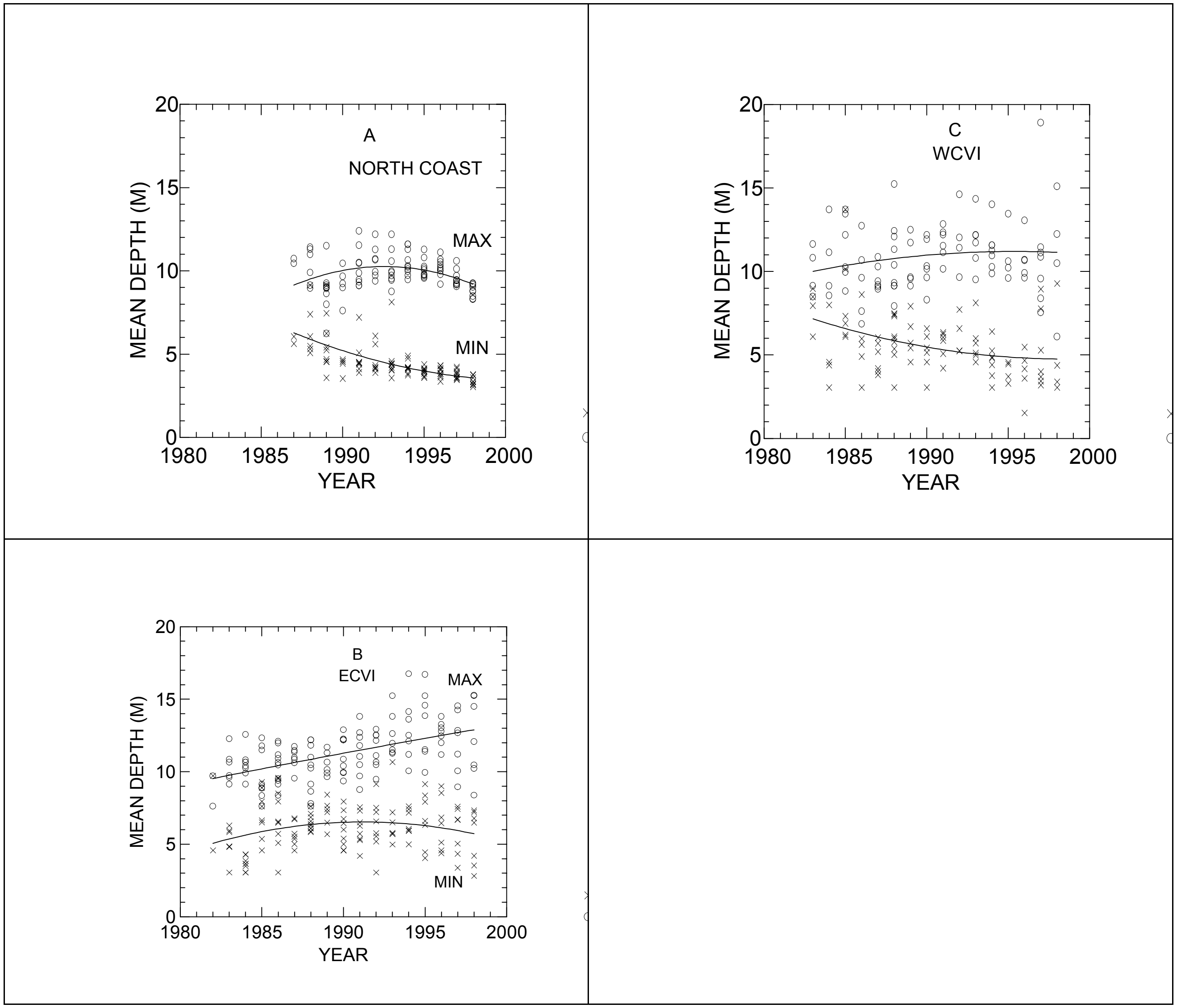


Fig. 7. Mean annual minimum and maximum depth (not adjusted for depth at datum) for PFM area from daily log books of red sea urchin fishermen for regions (A) North Coast, (B) East Coast Vancouver Island, and (C) West Coast Vancouver Island. Lines are fitted with quadratic equations to show general trends.

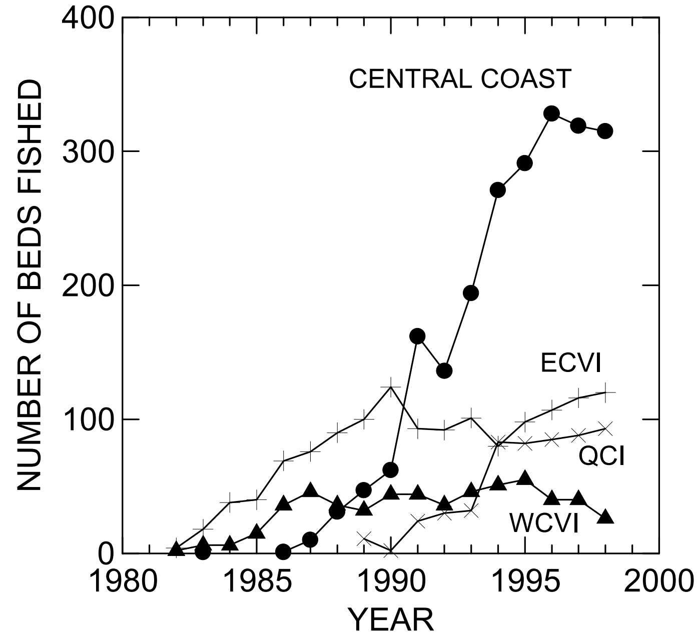
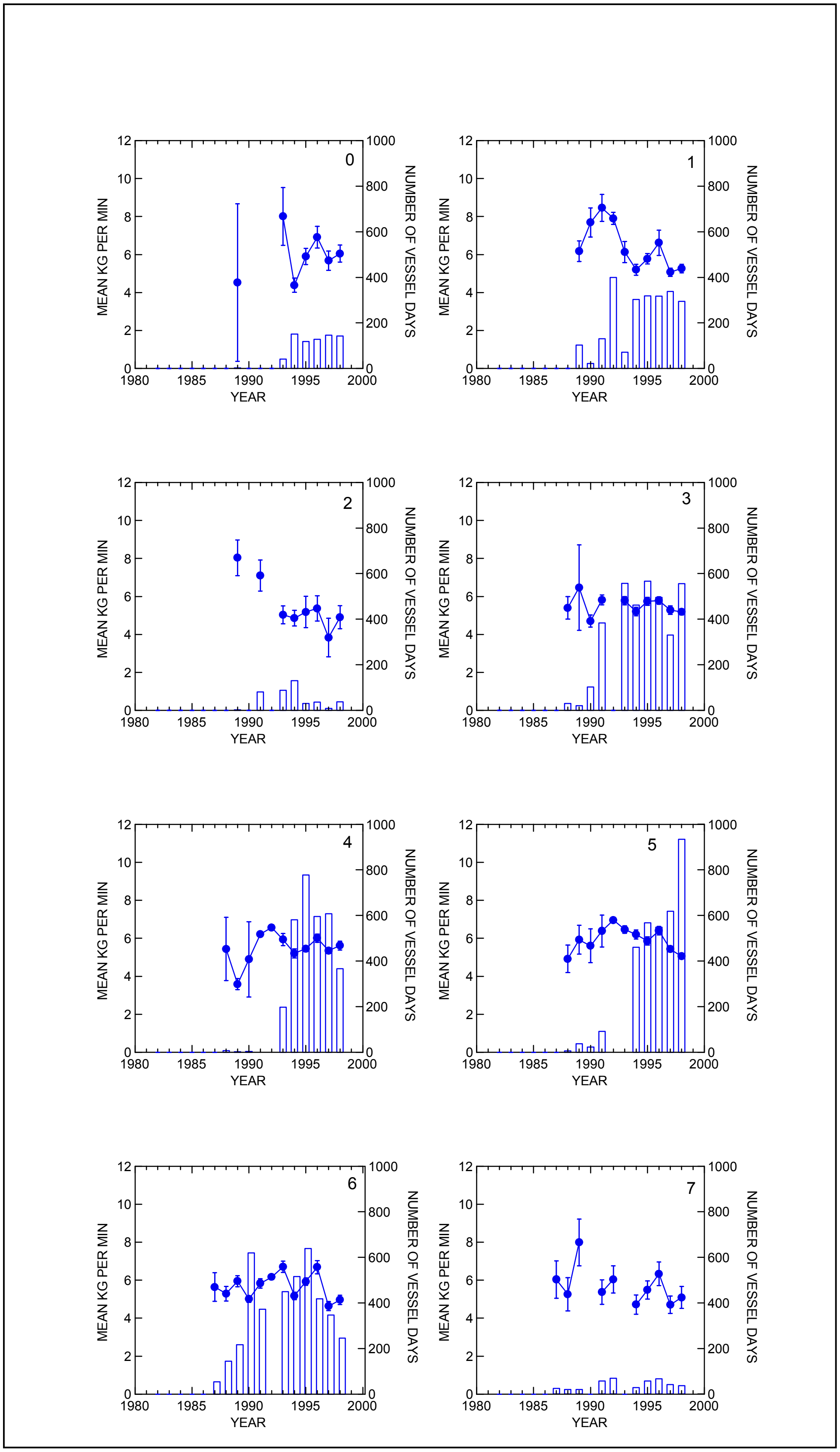
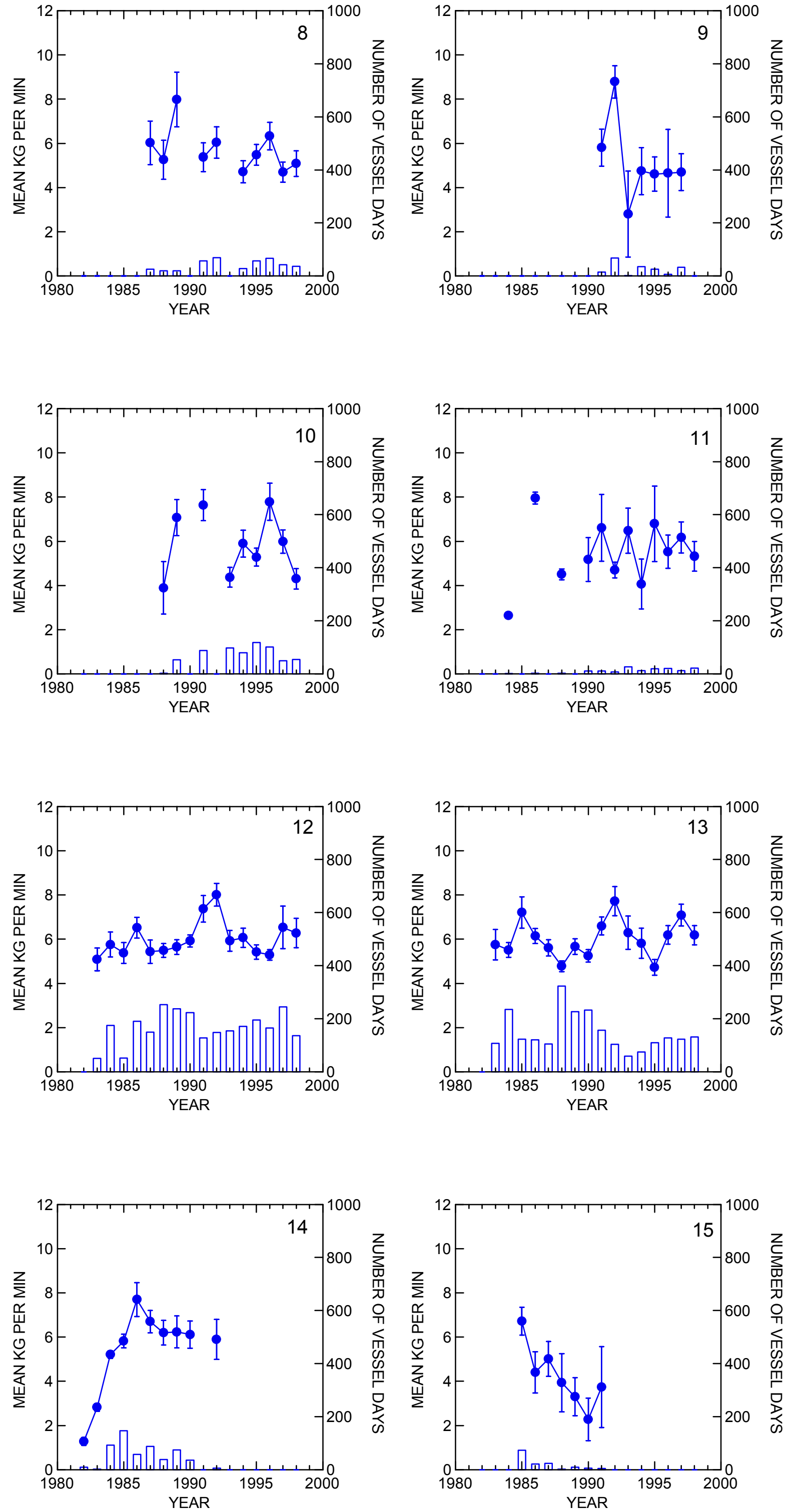


Fig. 8. The total number of red sea urchin beds recorded on fishermen log books as of 1996 for different regions: CC = central coast; QCI = Queen Charlotte Islands; ECVI = East Coast of Vancouver Island or South coast inside; WCVI = West Coast Vancouver Island.

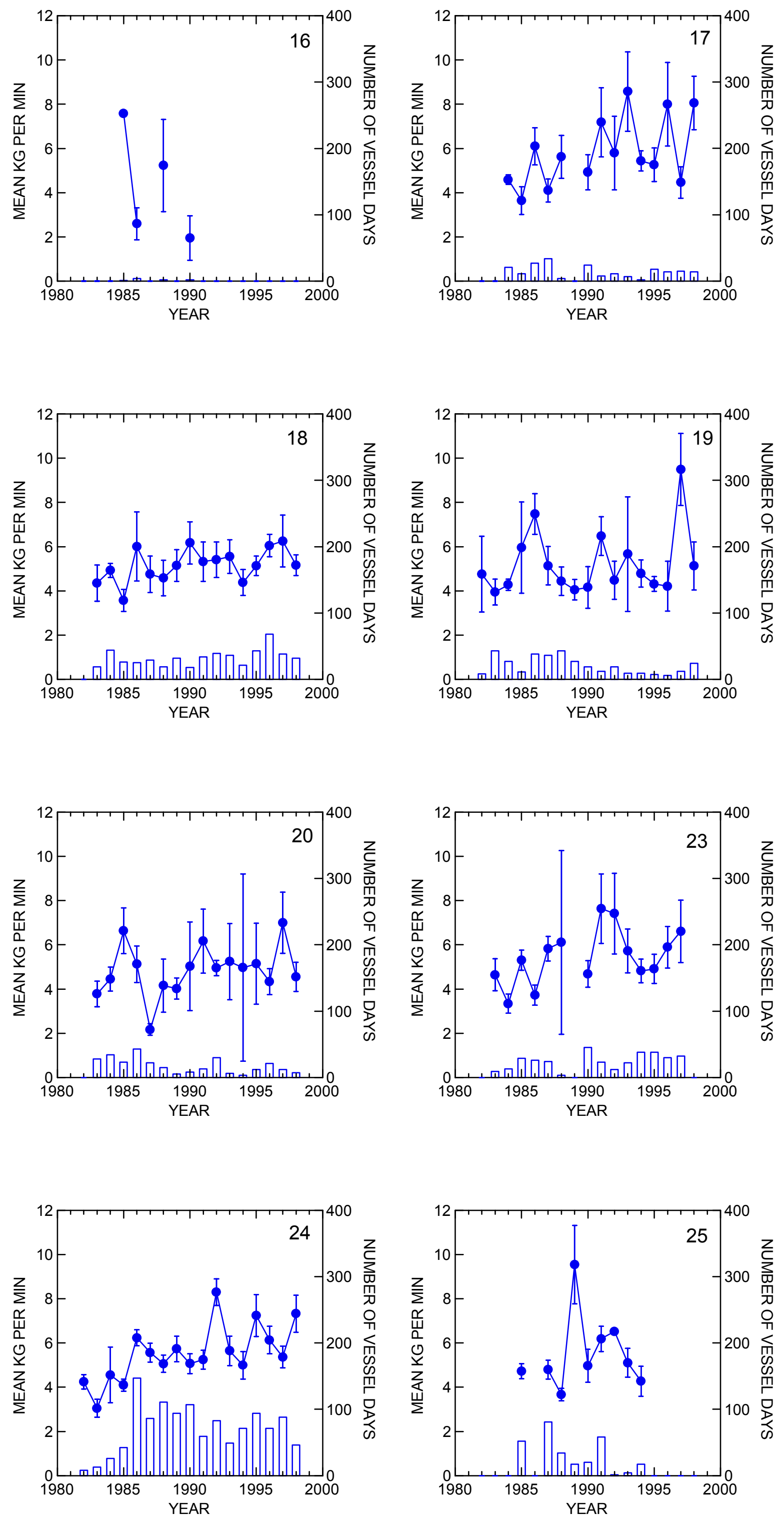
Appendix 1. Mean annual CPUE (dots, kilograms per diver minute) per vessel per day (vertical lines are ± 2 SE) and total number of vessel days (indication of sample size) for each PFM area. Data are from harvest logbooks. Data for PFM area 0 are from unassigned locations in log books.



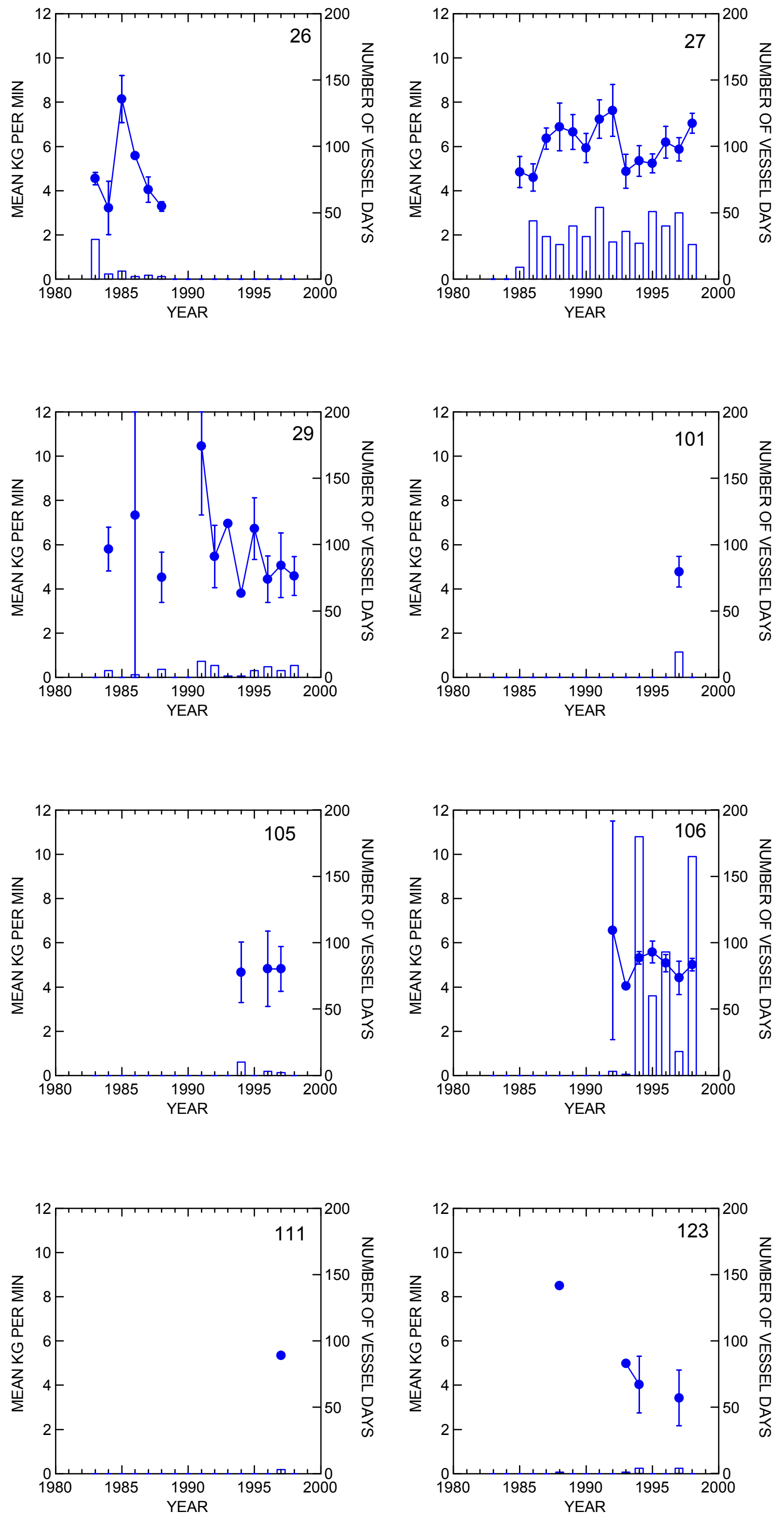
Appendix 1. Mean annual CPUE (dots, kilograms per diver minute) per vessel per day (vertical lines are $\pm$ 2 SE) and total number of vessel days (indication of sample size) for each PFM area. Data are from harvest logbooks. Data for PFM area 0 are from unassigned locations in log books.



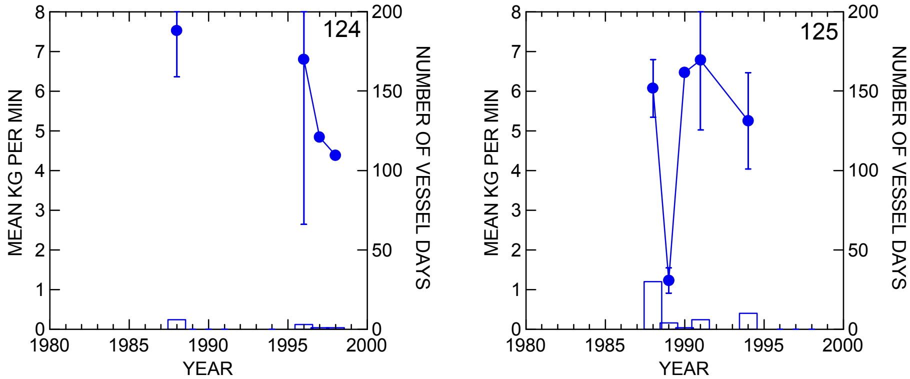
Appendix 1. Mean annual CPUE (dots, kilograms per diver minute) per vessel per day (vertical lines are $\pm$ 2 SE) and total number of vessel days (indication of sample size) for each PFM area. Data are from harvest logbooks. Data for PFM area 0 are from unassigned locations in log books.



Appendix 1. Mean annual CPUE (dots, kilograms per diver minute) per vessel per day (vertical lines are ± 2 SE) and total number of vessel days (indication of sample size) for each PFM area. Data are from harvest logbooks. Data for PFM area 0 are from unassigned locations in log books.



Appendix 1. Mean annual CPUE (dots, kilograms per diver minute) per vessel per day (vertical lines are $\pm$ 2 SE) and total number of vessel days (indication of sample size) for each PFM area. Data are from harvest logbooks. Data for PFM area 0 are from unassigned locations in log books.



Appendix 2. Number of transects and years surveys for red sea urchins were conducted during 1993-97, and bed areas estimated from log books to 1994 and 1996, with percent change, by PFM subarea. Only PFM subareas with data are shown.

Surveys Conducted						Bed Area
PFM subarea	Years	Area	Number of transects	Bed Area (ha) 1994	1996	Percent Change
North Coast						
1.001	94	NQCI	5	3369.8	4837.6	30.34
1.002	94	NQCI	15	331.0	405.0	18.28
1.003	94	NQCI	16	1903.0	2024.2	5.99
1.005				454.7	454.7	0.00
1.007	94	NQCI	9	947.7	1360.4	30.34
2.003	93	EQCI	5	339.3	339.3	0.00
2.006				274.6	298.0	7.87
2.007	93	EQCI	6	458.2	469.4	2.37
2.008	93	EQCI	7	275.8	331.9	16.90
2.010	93	EQCI	4		2.2	100.00
2.011	93	EQCI	8	936.4	973.4	3.81
2.012	93	EQCI	6	210.8	212.8	0.96
2.013				26.2	26.2	0.00
2.014	93	EQCI	9	260.5	284.5	8.44
2.015	93	EQCI	6	118.3	128.7	8.08
2.017	93	EQCI	11	234.0	341.8	31.55
2.018	95	EQCI	11	136.6	291.1	53.06
2.019	95	EQCI	5		34.4	100.00
2.031	95	WQCI	5	191.8	419.6	54.29
2.033	95	WQCI	4			
2.036	95	WQCI	5		95.2	100.00
2.037					29.0	100.00
2.049	93	WQCI	2		193.4	100.00
2.050	93	WQCI	2		146.2	100.00
2.051					27.2	100.00
2.053	93	WQCI	1			
2.055	93	WQCI	1			
2.059	93	WQCI	5			
2.060	93	WQCI	3			
2.063	93	WQCI	6			
2.064	93	WQCI	2	29.4	29.4	0.00
2.065				18.9	27.0	30.18
2.066	93	WQCI	5	5.8	5.8	0.00
2.067	93	WQCI	3	61.8	61.8	0.00
2.068	95	WQCI	4	456.8	561.9	18.70
2.069	95	WQCI	1			
2.071	95	WQCI	2			
2.074	95	WQCI	1			
2.075	95	WQCI	4			
2.078	95	WQCI	2			
2.079	95	WQCI	2			
2.080	95	WQCI	1			
2.087					32.6	100.00
2.088				49.3	61.9	20.30
2.094				47.6	47.6	0.00
2.095				68.8	68.8	0.00
2.096				94.1	96.6	2.57
2.098				38.2	98.8	61.35
2.100					11.8	100.00
3.001	93	Tsimshian	29	706.5	724.2	2.44
3.002	93	Tsimshian	6	33.0	33.0	0.00
3.003	93			73.7	73.7	0.00
3.004	93			24.4	24.4	0.00
4.001	93	Tsimshian	34	905.8	1074.0	15.66
4.002	93-95	StephensIs	41	702.8	848.8	17.20
4.003				819.0	875.2	6.42
4.004				66.2	55.0	-20.28
4.005				12.3	85.5	85.63
4.009	95	StephensIs	23	526.1	659.4	20.21
4.013	93	Tsimshian	3	633.4	738.2	14.19
5.009				393.1	342.5	-14.79
5.010				1058.6	1506.4	29.72
5.011	94	BanksIs	6	428.2	557.0	23.12
5.012				326.6	395.3	17.37
5.013	94	BanksIs	3	795.0	835.6	4.86
5.014				101.6	114.6	11.28
5.016				525.8	525.8	0.00
5.017				383.6	996.2	61.50
5.019					3.7	100.00
5.020	94	BanksIs	26	1887.8	2174.2	13.18
5.021	97	BanksIs	22	660.4	667.1	1.00
5.022				1664.2	2169.9	23.31
6.005				65.7	65.7	0.00
6.009				2919.8	3230.7	9.62

Appendix 2. Number of transects and years surveys for red sea urchins were conducted during 1993-97, and bed areas estimated from log books to 1994 and 1996, with percent change, by PFM subarea. Only PFM subareas with data are shown.

Surveys Conducted						Bed Area
PFM	Years	Area	Number	Bed Area (ha)		Percent
subarea			of transects	1994	1996	Change
6.010	94	CampaniaIs	30	1257.6	1671.7	24.77
6.011				74.2	99.7	25.60
6.012	94	CampaniaIs	7	217.6	203.5	-6.92
6.013	93	Kitasoo	32	2097.3	2545.4	17.61
6.014	93	Kitasoo	11	234.1	299.9	21.94
6.015	93	Kitasoo	8	302.3	520.1	41.87
6.016	93-95	PriceIs	38	434.0	903.8	51.98
6.017	93-95	PriceIs	18	422.7	510.3	17.17
6.018	93	Kitasoo	3	115.4	115.4	0.00
6.019	93	Kitasoo	6	22.0	109.3	79.88
6.020				29.8	29.8	0.00
6.025				28.8	28.8	0.00
7.001	97	Goose	15	55.2	55.2	0.00
7.002	93	Kitasoo	4			
7.003	93	Kitasoo	14	388.2	439.2	11.62
7.004	93	Kitasoo	4	160.4	208.7	23.17
7.005				56.5	56.5	0.00
7.006				142.4	142.4	0.00
7.008	93	Heiltsuk	5			
7.009				527.9	713.1	25.98
7.012				40.8	148.8	72.56
7.017					3.5	100.00
7.018	93-4-5-6-7	Heiltsuk	156	1011.7	1294.3	21.83
7.019				74.1	94.6	21.65
7.020	93	Heiltsuk	4	51.8	51.8	0.00
7.021				27.1	40.1	32.44
7.023	94	Heiltsuk	1	27.2	51.6	47.25
7.024					2.6	100.00
7.025	93-4-5-7	Heiltsuk	94	596.2	796.0	25.10
7.026	95-97	Heiltsuk	13	52.2	52.2	0.00
7.027	93	Heiltsuk	8	154.8	204.1	24.15
7.028					19.4	100.00
7.031	93-95	kitasoo	42	883.3	1107.1	20.21
7.032	93	Heiltsuk	4	99.9	308.2	67.58
8.001				14.4	27.1	46.68
8.002				34.2	87.5	60.95
8.003				5.5	5.5	0.00
8.004				100.3	156.2	35.80
8.016				48.2	64.6	25.37
9.001				132.8	138.6	4.18
9.002				212.0	232.2	8.72
9.010				26.3	26.3	0.00
9.011					5.6	100.00
9.012				103.1	103.1	0.00
10.001	93	Heiltsuk	5	239.0	266.1	10.19
10.002				368.0	485.8	24.24
10.003				177.8	214.8	17.24
10.004				54.7	74.0	26.09
105.001					50.3	100.00
105.002					6.6	100.00
106.002	94	CampaniaIs	28	1554.8	1827.9	14.94
South Coast						
11.001	96		31	135.9	135.9	0.00
11.002	96	QCStrait	31	82.8	142.6	41.98
12.001				55.2	61.6	10.45
12.002				96.5	96.5	0.00
12.003	94	QCStrait	9	159.4	180.6	11.76
12.004	94	QCStrait	1		2.3	100.00
12.005	94	QCStrait	9	153.4	143.2	-7.15
12.006	94	QCStrait	14	131.3	146.1	10.13
12.007	95	QCStrait	6	69.0	73.5	6.10
12.008	94	QCStrait	3	93.0	93.0	0.00
12.011	94	QCStrait	15	200.2	239.4	16.39
12.012	94	QCStrait	2	155.7	172.6	9.78
12.013	95-96	QCStrait	31	117.3	117.3	0.00
12.014	96	CapeSutil	6		425.3	100.00
12.015	94	QCStrait	2	19.8	27.6	28.01
12.016	94	QCStrait	18	215.1	303.7	29.17
12.017	94	QCStrait	2	39.1	39.1	0.00
12.018	94	QCStrait	18	311.4	350.0	11.05
12.019	94	QCStrait	3	65.7	65.7	0.00
12.020	94	QCStrait	1	1.4	1.4	0.00
12.021	94	QCStrait	2	17.6	17.6	0.00
12.026	94	QCStrait	1		4.0	100.00

Appendix 2. Number of transects and years surveys for red sea urchins were conducted during 1993-97, and bed areas estimated from log books to 1994 and 1996, with percent change, by PFM subarea. Only PFM subareas with data are shown.

Surveys Conducted						Bed Area
PFM subarea	Years	Area	Number of transects	Bed Area (ha) 1994	Bed Area (ha) 1996	Percent Change
12.036	94	QCStrait	1			
12.039	94-95	QCStrait	24	55.8	59.8	6.75
12.041	95	QCStrait	7	62.7	86.8	27.75
12.042				10.8	18.0	40.00
13.001				170.2	170.2	0.00
13.002				74.7	74.7	0.00
13.003				40.7	40.7	0.00
13.006				4.8	60.8	92.11
13.007					51.1	100.00
13.008					8.4	100.00
13.009				12.3	19.3	36.44
13.010				72.3	72.3	0.00
13.011				28.8	28.8	0.00
13.012				142.1	142.1	0.00
13.016				14.9	14.9	0.00
13.017					8.9	100.00
13.023				32.2	66.1	51.30
13.025				69.4	107.6	35.46
13.026				13.1	30.5	56.96
13.027				31.0	31.0	0.00
13.028				106.2	152.1	30.14
13.029				11.2	17.6	36.22
13.030				13.1	84.1	84.45
13.031				29.1	29.1	0.00
13.032				165.0	165.0	0.00
13.033				53.2	53.2	0.00
13.035				69.0	71.9	4.12
13.036				7.3	46.1	84.20
13.039				62.6	62.6	0.00
13.040				3.4	23.3	85.25
13.041				18.7	18.7	0.00
14.007				79.9	79.9	0.00
14.008				22.0	22.0	0.00
14.009				205.4	205.4	0.00
14.010				226.0	226.0	0.00
14.011				75.9	75.9	0.00
14.012				55.8	55.8	0.00
14.013				182.3	182.3	0.00
15.001				6.7	6.7	0.00
15.002				25.8	25.8	0.00
15.004				4.4	4.4	0.00
17.001				1.2	1.2	0.00
17.002				65.8	65.8	0.00
17.003				42.7	69.7	38.78
17.008				30.1	30.1	0.00
17.010				30.4	40.0	23.98
17.012				4.0	4.0	0.00
17.017				8.1	8.1	0.00
18.001				85.6	89.8	4.76
18.002				82.1	131.6	37.60
18.003				30.2	53.8	43.98
18.004				25.2	66.8	62.24
18.005				67.5	67.5	0.00
18.006				129.2	181.3	28.75
18.007				11.4	19.4	41.12
18.009					4.2	100.00
18.011				8.4	54.9	84.78
19.004				29.5	29.5	0.00
19.005				203.5	215.9	5.76
20.003				294.2	294.2	0.00
20.005				132.3	172.5	23.30
20.006				32.5	32.5	0.00
23.005				40.2	52.9	23.90
23.007				34.8	64.2	45.83
23.009				6.9	6.9	0.00
23.011				103.8	132.6	21.75
24.002				55.6	88.4	37.10
24.006				357.9	452.5	20.90
24.007				26.6	97.5	72.68
24.008				102.8	153.9	33.19
24.009				7.0	7.0	0.00
25.006				69.3	70.3	1.42
25.007				193.4	193.4	0.00
25.013				297.4	297.4	0.00
25.015				41.4	41.4	0.00

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	Surveys Conducted					Bed Area
PFM	Years	Area	Number	Bed Area (ha)		Percent
subarea			of transects	1994	1996	Change
26.001				12.1	12.1	0.00
26.006				25.7	25.7	0.00
27.001				29.4	29.4	0.00
27.002				194.8	268.4	27.43
27.003				42.1	42.1	0.00
27.005				21.8	21.8	0.00
27.007				46.2	46.2	0.00
27.009				59.1	59.1	0.00
28.001					6.5	100.00
29.002					1.1	100.00
29.003					3.8	100.00
29.004				22.4	23.8	5.88
29.005				35.5	35.5	0.00
111.000	96	Cox Isl.	6		205.4	100.00
124.003					2.8	100.00
125.001				54.9	54.9	0.00