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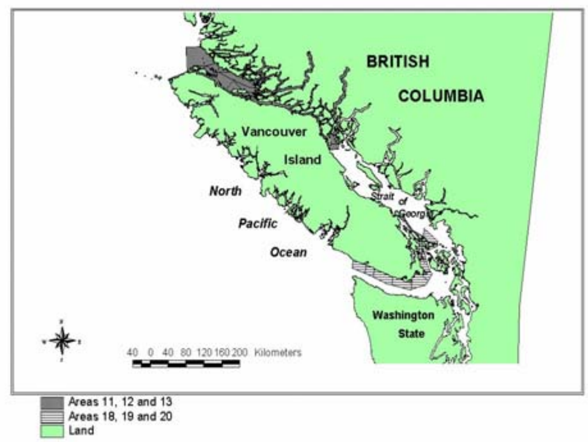
Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2005/064

STOCK ASSESSMENT AND QUOTA OPTIONS FOR THE GREEN SEA URCHIN *Strongylocentrotus droebachiensis* FISHERY IN BRITISH COLUMBIA, 2006-2009

Juvenile to adult stages of the green sea urchi (Strongylocentrotus droebachiensis*) from British Columbia. Wolf Carolsfeld, photo.*



showing areas open to fishing in 2003 and 2004 for the green sea urchin Strongylocentrotus droebachiensis*. PFMAs (Areas) 11-13 are Queen Charlotte Strait; PFMAs 18-20 are Gulf Islands.*

Context

The green sea urchin Strongylocentrotus droebachiensis *fishery is a small but important component of British Columbia's dive fisheries. Integrated Fishery Management Plans (IFMP) for this fishery are prepared for three year periods. Stock assessments which analyse fishery-dependent and fishery-independent data are required to provide the scientific advice for these management plans. A new three year IFMP (2006-2009) will be developed following advice from this paper. The objective of this paper is to provide quota options for the green urchin fishery in the major harvest locations in British Columbia (Pacific Fisheries Management Areas (PFMA) 11, 12, 13, 18, 19, 20). Questions to be addressed include: 1.What are the ranges of sustainable harvest rates for the major commercial harvest areas on the coast (PFMAs 11-13, and 18-20)? 2. What are the risks or uncertainties associated with the range of quota options? 3. Do the current annual surveys at the index locations need to be continued to provide reliable data on a longer time series? 4. Are there additional areas of stock assessment work suggested from the latest analysis?*

SUMMARY

- Green sea urchins remain a small but important part of the British Columbia dive fisheries.
- Overall, green urchin populations in their two major fishing regions of British Columbia (Queen Charlotte Strait; Gulf Islands) appear to be under low fishing pressure (catch per unit of effort is now at similar levels to that at the beginning of the fishery in the late 1980s).

- Total landings were 168 t with a landed value of $731,000 in 2003 but fell to 83 t with a value of $315,000 in 2004 (preliminary data).
- The decrease in 2004 appears to be due to the lowest level of effort recorded since the start of the fishery in the late 1980s. Such low effort appears to be largely a result of poor market prices in Japan.
- Three versions of the biomass dynamic model were used to estimate population status; the Bayesian model was selected as being the most conservative and for its superior and explicit handling of data and model uncertainties.
- A series of quota options (target reference points expressed as reductions from the maximum sustainable yield (MSY) limit reference point) are provided for each fishery management area, along with the associated levels of probability that they are equal to or greater than the true MSY.
- Quotas established at their 2004 levels (159.5 t in Queen Charlotte Strait; 26.5 t in Gulf Islands) would represent very low probabilities of being equal to or greater than the true MSY (1.7% in Queen Charlotte Strait; 0.2% in Gulf Islands).

DESCRIPTION OF THE ISSUE

Commercial harvesting for green sea urchins, *Strongylocentrotus droebachiensis*, in British Columbia began in 1987. The fishery was managed with few restrictions until 1991, when licence limitation was introduced to control record high effort and catches, followed by quota limitations in 1994 and an individual quota system with dockside validation in 1995. Previous stock assessments were conducted by Harbo and Hobbs (1996), Perry *et al*. (1998, 2001, 2003), and Perry and Waddell (1998, 1999). Overview and methodological papers in the primary literature were published in 2002 (Perry *et al*. 2002) and 2005 (Zhang and Perry 2005). These publications document the rationale and methods for this assessment (see in particular Perry et al. 2002, 2003; and Zhang and Perry 2005). Consequently, the detailed background and methods of this assessment will not be described in this present report. The purpose of the present paper is to update these previously published methods using the most recently available information from the 2003 and 2004 fishing seasons and to provide quota options for the green urchin fishery in the major harvest locations in British Columbia Pacific Fisheries Management Areas (PFMAs) 11, 12, 13, 18, 19, and 20.

Biology

Green sea urchins occur in cool temperate waters in both the Pacific and Atlantic Oceans. They are circumpolar in the Pacific, occurring from northern Washington State through the Aleutian Islands and west to Hokkaido (Japan) and Korea. Green urchins occur inter-tidally and to depths of >140 m, generally on rocky, gravel or shell substrates. Sexes are separate, with sizes at maturity of about 25 mm in southern B.C. (Waddell and Perry 2005a). In B.C., the spawning period generally occurs during February and March. Larvae are pelagic for 9-10 weeks depending on temperature. In Alaska it takes about 4 years (Munk 1992) for a green urchin to reach a test diameter of 55 mm (the minimum legal size in B.C.).

Fisheries

The principal areas now open to fishing for green sea urchins are the Queen Charlotte Strait (PFMA 11-13) and the Gulf Islands (PFMA 18-20) (Fig. 1). Area 20 is not formally part of the Gulf Islands, but for convenience here is included under “Gulf Islands”. The fishery in B.C. developed rapidly, with landings reaching a peak of 1042 t and a landed value of 4.4 million dollars in 1992, followed by a sharp decline (Fig. 2). It is principally a roe fishery whose product is shipped live to the Japanese market. The fishery for green sea urchins is currently conducted during winter (November 1 to March 1), with the highest market prices occurring around Christmas. It is managed with a 55 mm test diameter size limit, licence limitations, area quotas, individual quotas, and area closures. The licence year is defined from 1 June to 31 May of each year, accordingly the analyses presented in this report were conducted on a “fishing season” basis, i.e. from the fall of one year to the spring of the following year. The fishery is conducted by hand-picking by SCUBA divers using small vessels.

ASSESSMENT

The Fishery

This analysis updates information from the green sea urchin fishery and fishery-independent surveys in fishing seasons 2003 and 2004. Landings since the 1994 fishing season have been limited by quotas. Total landings in 2003 showed a slight increase over those in 2001 and 2002 (Fig. 2), although in 2004 they fell to their lowest level since the beginning of the fishery in 1987. This does not appear to signal an inability to achieve quotas due to a lack of product, however. It appears to be a result of low prices in Japan because of over-supply of green urchins coming from Russia (see later section on Additional Stakeholder Perspectives). Total effort in 2003 remained similar to that in 2001 and 2002, although it fell in 2004 to the lowest since the beginning of the fishery (Fig. 2). The overall Catch per Unit of Effort (CPUE) reached its highest value in 2003, but fell in 2004 for the first time since 1998. Landed values were up in 2003 ($731,000) but fell in 2004 ($315,000) to their lowest level since the start of the fishery. Unit price in 2004 (Cdn$3.18/kg) was the lowest in over a decade.

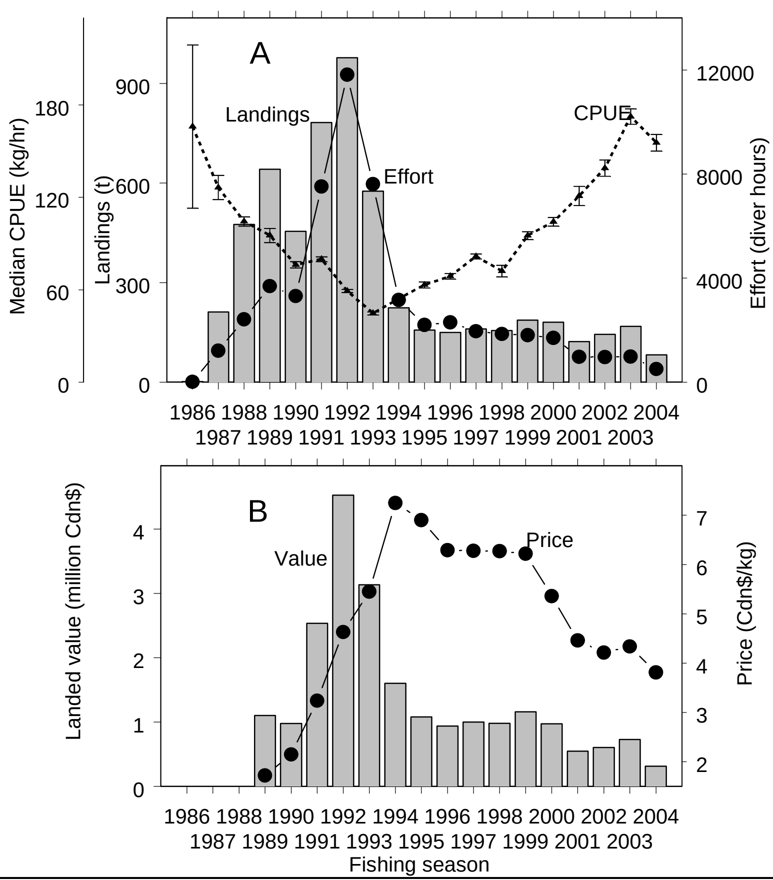


Figure 2. A) Landings (from fish slip data up to 1995, then from harvest and validation logs), effort, and catch per unit of effort (CPUE); and (B) landed value and unit price for the green sea urchin fishery in B.C. Data are presented on the basis of a fishing season (October of year i to March of year i+1).

The median catch per unit of effort by major fishing region shows declining trends with fishing season until 1992 in the Gulf Islands region (PFMA 17-20,28) and until 1993 in the Queen Charlotte Strait region (PFMA 11-13), and increases in both regions since 1994 (Fig. 3). Note that PFMA 17 and 28 were closed to fishing in 1999 because of low catches, therefore subsequent statistics in the Gulf Islands are for PFMA 18-20 only. This increase was sustained until 2003, but CPUE in both regions (PFMA 11-13 and 18-20) declined in 2004. The standard errors about the medians are small, but have become wider since 2002 indicating greater variability of CPUE. Trajectories of median CPUE versus effort for both the Gulf Islands (PFMA 18-20) and Queen Charlotte Strait (PFMA 11-13) regions indicate that catch per unit of effort remains as good recently as it was during the early days of the fishery.

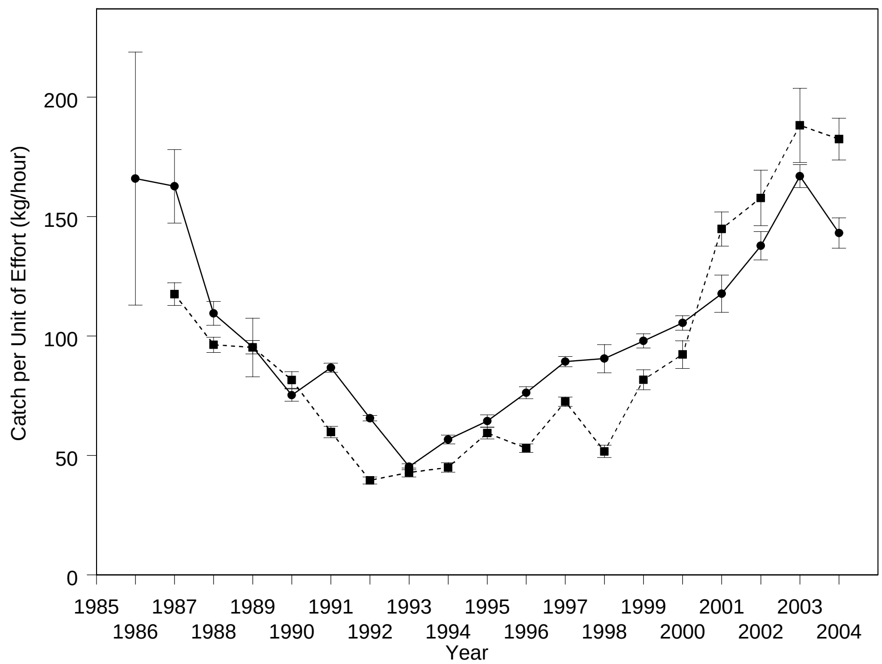


Figure 3. Median catch per unit of effort ± 1 standard error (kg/diver hour) on a fishing season basis for the green urchin fishery in B.C. Solid line: Queen Charlotte Strait region (PFMA 11, 12, 13); dashed line: Gulf Islands region (PFMA 17-20,28 up to 1999, PFMA 18-20 subsequently).

Biomass Dynamic Models

Three versions of the biomass dynamic model were used in the previous assessment (Perry et al. 2003) and primary publications (Perry et al. 2002; Zhang and Perry 2005) to estimate management reference points. These are the "Schnute" and "time series fitting" versions, and a "Bayesian" model.

Schnute version:

The maximum sustainable yield (MSY) from the Schnute version of the surplus production model (MSY ± 95% confidence interval) for the Queen Charlotte Strait region (PFMA 11-13) was 265 ± 50 t, with a model R^2 of 0.50 and a P-value of 0.008 (Table 1). The maximum sustainable yield calculated for the Gulf Islands region (PFMA 18-20) was 105 ± 30 t with a model R^2 of 0.39 and a P-value of 0.03 (Table 1).

Time series version:
The time series fitting method produced a maximum likelihood (approximated by the median of 1000 model runs) estimate of MSY of 321 t with two standard deviations (approximating the 95% confidence interval) of 51 t for the Queen Charlotte Strait region, and an estimate of 91 ± 12 t for the Gulf Islands region. The “true” MSY estimated from this time series fitting approach for the Queen Charlotte Strait region (PFMA 11-13) has a 50% probability of being between 306 and 338 t (i.e. between the first and third quartiles), and between 88 and 95 t in the Gulf Islands region (PFMA 18-20).

Bayesian model version:
The Bayesian model which is described in Perry et al. (2003) and Zhang and Perry (2005) is now implemented in WinBUGS, an interactive Windows software program for Bayesian analysis of complex statistical models (Spiegelhalter et al. 2003). Results show a greater range (i.e. greater uncertainty) of possible MSY values than is produced by the time series model. The most likely (approximated by the median) estimate of MSY is similar for both types of analysis for PFMA 11-13, however 2 standard deviation ranges are much larger for the Bayesian analysis (Bayesian estimate of 318 ± 194 t; time series estimate of 321 ± 51 t). In the Bayesian analysis, the “true” MSY for PFMA 11-13 has a 50% probability of being between 269 and 378 t (i.e. between the first and third quartiles of MSY calculated from 10000 model runs). In addition, the 1% probability estimate of MSY is 142 t in the Bayesian analysis, whereas it is 274 t in the time series fitting method. The larger range of potential MSY estimates in the Bayesian model are to be expected considering this model includes uncertainties in both observations and model structure (see below regarding Sources of Uncertainty). A similar comparison between the Bayesian analysis and the time series fitting method for the Gulf Islands provides the following results: for the Bayesian analysis the median estimate of MSY ± 2 standard deviations is 93 ± 75 t, and 91 ± 12 t for the time series method. The inter-quartile range (50% of the values occur between the 1st and 3rd quartiles) for the Bayesian analysis is 77 – 114 t and 88 – 95 t for the time series method.

Interpretation of biomass dynamic model results:
All three versions of the biomass dynamic model produced similar results for each region (Table 1). The Schnute version produced the lowest estimate of MSY for the Queen Charlotte Strait region but the highest estimate for the Gulf Islands region. The 95% confidence intervals about the maximum likelihood estimate of MSY from the time series fitting model overlapped with the 95% confidence interval estimates of MSY from the Schnute model. Maximum likelihood estimates from the Bayesian model for both regions were very similar to MSY estimates from the time series fitting model, and the 95% confidence intervals included the MSY estimates from the time series and Schnute model versions. The Bayesian model was therefore chosen as the preferred model, because of its consistency with the other two models, the larger (and therefore more conservative) confidence intervals, and how it handles data and model uncertainties (see later section).

Table 1. Summary of maximum sustainable yield (MSY) estimates from the three versions of the biomass dynamic model.

Model	Queen Charlotte Strait (PFMA 11-13)		Gulf Islands (PFMA 18-20)	
	MSY (t)	95% Confidence Interval (+/- t)	MSY (t)	95% Confidence Interval (+/- t)
Schnute	265	50	105	30
Time Series	321	51	91	12
Bayesian	318	194	93	75

Fishery-independent Surveys

Ten surveys have been conducted during the fall (just prior to the opening of each season's fishery) since October/November 1995 in the Stephenson Islets area of eastern Queen Charlotte Strait (PFMA 12). The highest biomass of legal-sized urchins (≥55 mm test diameter) occurred in the autumn of 2003; however the next year (2004), the surveyed legal-sized biomass had fallen by approximately 40%. This decrease in 2004 is not unexpected, considering that the biomass of sublegal-sized urchins in the autumn of 2003 was lower than that in 2002. The increase of sublegal-sized urchins in 2004 suggests that the biomass of legal-sized urchins in 2005 should also be expected to increase. Reports on the recent surveys have been published by Waddell and Perry (2005, 2006). A fishery-independent survey was conducted in Active Pass in September 2003, however it has been difficult to establish an index survey site in this region to provide on-going time-series data because of particular physical and oceanographic conditions. Regular surveys at an index site or sites in this region would be extremely useful to provide fishery-independent assessment of trends in green urchin abundance.

Quota Options

Traditionally, MSY values have been considered as targets which management actions should try to achieve. However, many of the assumptions of surplus production models (such as no change in gear efficiency, constant catchability (in time, space, and across ages), a linear relationship between CPUE and effort, and equal availability of the fish to the fishery) are not likely to be true during the development of a fishery such as for green sea urchins. Therefore, as with the previous assessments for green sea urchins, the MSY values calculated in this assessment are defined as limit reference points which management actions should ensure are not exceeded. The target reference points, to which management actions should aim, should be set sufficiently far from the limit reference point so that there is a low probability that the target reference point is larger than or equal to the true MSY.

The maximum likelihood estimates of MSY (i.e. the median MSY's from 10000 saved samples from model runs) for the Queen Charlotte Strait (PFMA 11-13) and Gulf Islands (PFMA 18-20) regions from the Bayesian model were chosen as the limit reference points. Table 2 provides the MSY limit reference points for each region, and the target reference points that are equivalent to various reductions from the MSY values. For each of these target reference points, the probabilities that the target reference points are larger than or equal to the true MSY are also provided, based on the Bayesian model results. For each target reference point, the allocations of quota to each of the PFMAs are also provided based on the proportion that area contributed to aggregate landings (on a fishing season basis) from 1995 to 2004. This dependence on using the pattern of previous landings to set the current quotas carries a risk that some management areas may become more exploited than intended if the conditions that determine green urchin distributions and abundance change among areas over time. Fishery-independent surveys, and monitoring the sizes of urchins landed and the spatial pattern of fishing, are being used to guard against this possibility. Quotas assigned during previous years have had a very low probability (low risk) that they were equal to or greater than the true MSY. Quotas similar to the previous three years (159.5 t in Queen Charlotte Islands, PFMA 11-13; 26.5 t in the Gulf Islands, PFMA 18-20) have a 1.7 % probability in Queen Charlotte Strait and a 0.2% probability in the Gulf Islands of being equal to or greater than the true MSY.

Sources of uncertainties:

The major sources of uncertainties in this assessment relate to the fishery-dependent data. These data form the core of the assessment. They are derived principally from fishery logbooks completed by the fishers. Landing data are measured at dockside by Port Validators as part of the Individual Quota system for this fishery. However, effort data, the number of hours spent by each diver underwater to obtain the product that is landed, can have wide uncertainty, due both to the way the logbooks are completed and to the method of fishing underwater (e.g. "surveying" versus harvesting). These uncertainties have been dealt with in this assessment in two ways: (1) by use of the median CPUE, which is more

Table 2a. Target reference points (as reductions from MSY), the probability the target reference point is equal to or greater than the true MSY, and allocation of the total quota to PFMA 11-13 (Queen Charlotte Strait) based on the proportion that area contributed to aggregate landings (on a fishing season basis) from 1995 to 2004. Limit reference point (median MSY) and probabilities (risk) that the target reference point is equal to or greater than the true MSY are derived from the Bayesian model.

	Target Reference Point (Total for PFMA 11-13; t)	Probability that the target reference point is equal to or greater than the true MSY (%)	Target Reference Point for PFMA 11 (t)	Target Reference Point for PFMA 12 (t)	Target Reference Point for PFMA 13 (t)
Proportion caught (1995-2004 fishing seasons)			0.009	0.632	0.359
Limit reference point (median MSY)	318	50	3	201	114
0.9*median MSY	287	33.4	3	181	103
0.8* median MSY	254	18.8	2	161	91
0.7* median MSY	223	9.3	2	141	80
0.6* median MSY	191	4.1	2	121	68
0.5* median MSY	158	1.6	1	100	57
0.4* median MSY	127	0.5	1	80	46
0.3* median MSY	95	0.1	1	60	34
0.2* median MSY	64	<0.1	1	40	23
0.1* median MSY	31	<0.1	0	20	11

Table 2b. Target reference points (as reductions from the median MSY), the probability the target reference point is equal to or greater than the true MSY, and allocation of the total quota to PFMA 18-20 (Gulf Islands) based on the proportion that area contributed to aggregate landings (on a fishing season basis) from 1995 to 2004. Limit reference point (median MSY) and probabilities (risk) that the target reference point is equal to or greater than the true MSY are derived from the Bayesian model.

	Target Reference Point (Total for PFMA 18-20; t)	Probability that the target reference point is equal to or greater than the true MSY (%)	Target Reference Point for PFMA 18 (t)	Target Reference Point for PFMA 19 (t)	Target Reference Point for PFMA 20 (t)
Proportion caught (1995-2004 fishing seasons)			0.431	0.452	0.117
Limit reference point (median MSY)	93	50	40	42	11
0.9* median MSY	84	35.4	36	38	10
0.8* median MSY	75	22.6	32	34	9
0.7* median MSY	65	12.6	28	29	8
0.6* median MSY	56	7.2	24	25	7
0.5* median MSY	46	3.2	20	21	5
0.4* median MSY	37	1.2	16	17	4
0.3* median MSY	28	0.3	12	13	3
0.2* median MSY	18	<0.1	8	8	2
0.1* median MSY	9	<0.1	4	4	1

robust to outliers in the effort data than other measures of central tendency such as the mean; and (2) by use of the Bayesian model to estimate MSY and its potential range. The Bayesian model structure explicitly includes uncertainties in the fishery logbook data, in the data from the earliest 9 years of the fishery (the “gold-rush” period), and in the fishery-independent survey data.

ADDITIONAL STAKEHOLDER PERSPECTIVES

Low fishing effort and harvest levels, particularly in 2004, reflect low prices in Japan. These low prices are due principally to very large harvests from the Russian Far East and their importation into Japan. Visits to Japan have been conducted by members of the West Coast Green Urchin Association to try and increase the market base and to underline the high quality of the product from B.C. Reports from Japan also suggest that more stringent controls on the Russian harvest of sea urchins may be forthcoming, but it is unknown how effective these may be at increasing the market price of green urchins harvested in British Columbia.

CONCLUSIONS AND ADVICE

Green sea urchins remain a small but important part of the British Columbia dive fisheries. Overall, green urchin populations in their two major fishing regions of British Columbia appear to be healthy (catch per unit of effort now is at similar levels to that at the beginning of the fishery in the late 1980s) with relatively low fishing pressure. Landings, landed value, and catch per unit of effort (CPUE) increased in 2003 from the previous two years, but all declined in 2004. Low landings (and therefore low total landed value) appear to be due to low effort in 2004 (lowest recorded since the beginning of the fishery in 1986). This was largely due to low product unit price resulting from oversupply in the Japanese market with urchins harvested in Russia.

Declines of legal-sized biomass measured from fishery-independent surveys in autumn 2004 in PFMA 12 (eastern Queen Charlotte Strait) does recommend continued observation, although increases in sublegal-sized biomass in 2004 suggest that legal-sized biomass may also have increased in 2005.

Advice in response to the questions posed by Fishery Managers (and listed in the Context box of this present report) is:

1) Quota options developed using a Bayesian biomass dynamic model and interpreting maximum sustainable yield as a limit reference point, target reference points set as reductions from the median MSY, and their associated probabilities that the target reference point is equal to or greater than the true MSY, are provided in Table 2 for both Queen Charlotte Strait (PFMA 11-13) and the Gulf Islands (PFMA 18-20) regions.
2) Quotas established at their 2004 levels (159.5 t in Queen Charlotte Strait; 26.5 t in Gulf Islands) would represent very low probabilities that the target reference point is equal to or greater than the true MSY (1.7% in Queen Charlotte Strait; 0.2% in the Gulf Islands).
3) Annual fishery-independent surveys (currently conducted in PFMA 12) should be continued to provide a time series independent of the fishery for assessment of green urchin population trends. A time series survey in the Gulf Islands should also be developed, although this has been difficult to establish due to particular conditions of topography, weather and ocean conditions.
4) Laboratory experiments are nearing completion regarding the age and growth of green sea urchins in British Columbia, for development of a reliable ageing technique. Such a technique would be valuable for assessing the actual age of urchins rather than using the present technique of size-mode analysis.

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Internet address: www.dfo-mpo.gc.ca/csas

ISSN 1480-4913 (Printed)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

Perry, R.I., Zhang, Z. and Waddell, B. 2006. Stock Assessment and Quota Options for the Green Sea Urchin *Strongylocentrotus droebachiensis* fishery in British Columbia, 2006-2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/064.