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Baseline Density Estimates From Sea Cucumber (*Parastichopus Californicus*) Surveys Conducted in British Columbia, Canada

Estimations de la densité de référence d'après les relevés de concombres de mer (*Parastichopus californicus*) effectués en Colombie-Britannique (Canada)

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ABSTRACT

The sea cucumber (*Parastichopus californicus*) fishery in British Columbia (BC) is managed by restricting harvest to 25% of the coast and basing quotas on conservative estimates of biomass and exploitation rate. In the absence of survey data from BC, biomass estimates have been calculated with estimates of density derived from Alaska surveys. Since 1998, seven dive transect surveys have been conducted in six locations within the open fishery areas in BC, comprising over 30% of open shoreline. This report presents the results of these surveys and makes recommendation for a new baseline density estimate to be applied to un-surveyed coastline. Estimates of mean sea cucumber weight and shoreline length are also reviewed.

The lowest estimate of all lower 90% confidence intervals from BC surveys, 5.08 sea cucumbers per metre of shoreline (c/m-sh), is recommended for use in un-surveyed coastline of BC where conditions are favourable for sea cucumbers. This is approximately double the previous estimate, of 2.54 c/m-sh. For areas where the habitat is marginal, including extreme exposure to ocean surf or complete lack of tidal current, the original baseline density estimate is recommended. The total recommended quota over all open area in BC is 50% higher using new density, mean weight and shoreline length estimates, from 424 t to 624 t.

RÉSUMÉ

La pêche du concombre de mer (*Parastichopus californicus*) en Colombie-Britannique n'est permise que sur 25 % des côtes, et les quotas sont fondés sur des estimations prudentes de la biomasse et du taux d'exploitation. En l'absence de données de relevés, les estimations de la biomasse ont été calculées à partir d'estimations de la densité dérivées de relevés effectués en Alaska. Depuis 1998, sept relevés ont été effectués par des plongeurs à six sites dans les zones de pêche ouvertes, ces sites comprenant plus de 30 % de celles-ci. Ce rapport présente les résultats de ces relevés ainsi que des recommandations relatives à une nouvelle estimation de la densité de référence à utiliser pour les parties du littoral qui n'ont pas fait l'objet de relevés. Les estimations du poids moyen des concombres de mer et de la longueur moyenne du rivage sont également examinées.

Il est recommandé d'utiliser l'estimation la plus basse de toutes les limites inférieures de confiance à 90 % des relevés effectués en C.-B., soit 5,08 concombres de mer par mètre de rivage, pour les parties du littoral qui n'ont pas fait l'objet de relevés et où les conditions sont favorables pour les concombres de mer. Cette estimation est environ le double de l'estimation précédente (2,54 concombres de mer par mètre de rivage). L'estimation initiale de la densité de référence est recommandée pour les zones où l'habitat est marginal, y compris les zones très exposées au déferlement des vagues ou celles sans courant de marée. Le quota total recommandé pour l'ensemble des zones ouvertes en C.-B. est 50 % plus élevé (passant de 424 à 624 tonnes) s'il est établi en fonction des nouvelles estimations de la densité, du poids moyen et de la longueur du rivage.

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Introduction

The commercial fishery for giant red sea cucumbers (*Parastichopus californicus*) has existed in British Columbia (BC) for over 20 years, with 85 licence holders and a 2002 ex-vessel value of $1.8M. Sea cucumbers are handpicked by SCUBA divers and sold to an Asian market as trepang (brined and dehydrated skin) and frozen meat.

Commercial landings of sea cucumbers were first recorded in 1971, however the fishery was first regulated under a commercial licence, on an experimental basis, in 1980. The fishery expanded rapidly, with annual landings exceeding 1,900 tonnes round weight (700 tonnes split weight) in 1988. Area closures and arbitrary regional quotas were first implemented in 1986, but this did little to limit the fishery. Landings and the number of licences issued continued to increase and quotas were commonly exceeded. The expansion of the fishery and concerns stemming from declining catch per unit effort (CPUE) in some areas, led to arbitrary quota reductions in 1989, the implementation of licence limitation in 1991 and further quota reductions in 1993. From 1993 to 1996, three-year rotation was introduced in the south coast to allow for a two-year period of recovery between harvests. A pilot Individual Quota (IQ) program was introduced in 1995, and all landings have been validated since that time. The rotational fishery was discontinued in 1997 following recommendations made by Phillips and Boutillier (1998) to return to the collection of an annual time-series of fisheries data for use in biomass dynamic models.

Despite it's over 20-year history, the BC sea cucumber fishery is still considered data-limited. It has been managed under a precautionary regime since 1997 and is following the Phased Approach for new and developing fisheries (Perry *et al.* 1999). A review of existing information and a stock assessment with quota options based on logbook data was presented in Phillips and Boutillier (1998). Recommendations for the collection of new information were made by Boutillier *et al.* (1998) in order to move towards the formulation of defensible assessments of the fishery. A key recommendation in this paper was the limitation of the expansion of the fishery until the necessary data had been collected for BC waters. The fishery was restricted to 25% of the coast in non-contiguous static areas, while 25% of the coast was set aside for research activities where experimental fisheries or other studies could be conducted (Hand and Rogers 1999). The remaining 50% of the coast was closed to harvest until a biologically-based management plan could be implemented (Rice *et al*. 1997).

Since the beginning of the precautionary regime in 1997, quotas in the sea cucumber fishery have been calculated from estimates of biomass, against which a conservative harvest rate is applied (Boutillier *et al*. 1998). In the absence of survey data from BC waters, biomass estimates have been based on estimates of density derived from surveys in Alaska (Larson *et al*. 1995). The minimum of all lower 90% confidence interval (CI) estimates from eleven dive surveys conducted in S.E. Alaska (2.54 cucumbers per metre of shoreline (c/m-sh)) was adopted as the baseline density estimate for use in BC. This estimate was considered to be the most risk averse of options available at the time (Boutillier *et al.* 1998). Estimates of the shoreline length were calculated from a seamless base map of the BC coastline digitized in 1994 (Boutillier *et al*. 1998) and mean sea cucumber weight estimates were based on landing data from the 1995 BC fishery (Rome and Clarke, unpublished data). An exploitation rate of 4.2%, calculated with a Schaefer biomass dynamic model from Washington State survey and fishery data (A. Bradbury, Washington Department of Fish and Wildlife, unpublished results), was adopted for BC. This rate was the lowest option of the range of choices available from Washington and Alaska studies, and hence is considered conservative.

The management plan allows for increases in quota in areas where the biomass estimate is based on dive transect survey results. By convention, density estimates from surveys conducted in open fishery areas, referred to as 'open surveys', are applied only to the area surveyed, and areas must be resurveyed every four years. During the last five years, approximately 30% of the open shoreline has been surveyed in seven surveys over six separate areas (one area has been surveyed twice).

This report was produced at the request of resource managers (Appendix 1). The goal is to present the results of all open surveys conducted to date, and provide new baseline density estimates to replace the estimates currently used for unsurveyed areas. Also included is a review of the other parameter estimates used in calculating sea cucumber biomass, specifically shoreline length and mean weight. Recommendations are made for further analysis and future research. Exploitation rate estimates are not addressed here.

Methods

Description of Survey Areas

The open surveys presented in this paper (Fig. 1) were conducted in several different geographical areas and habitat types, to span the distribution of sea cucumber on the BC coast (Table 1). Surveys were conducted in April (Tofino), May (Area 7, Gil/Gribbell and Trutch) and June (Area 12 and Fitz Hugh), and repeat surveys are conducted in the same month as the original survey. Typically, a survey included approximately 400 km of shoreline length, which corresponded to the area that can be surveyed by two teams of three or four divers each, in a ten-day period. The survey areas were defined by the overall perimeter of several PFMA Subareas (hereafter referred to as Subareas) grouped together (Figs. 2 to 4). Although PFMAs have no logical application to sea cucumber stocks, they were convenient to use because they have geo-referenced boundaries and known shoreline measurements.

Gil and Gribbell Islands, 1999

The area is located in the North Coast of BC and consists of channels, islands and inlets (Fig. 5). The topography is mainly of moderate to steep slope and hard substrate. Tidal current regimes ranged from low to very strong flow, while exposure to ocean swells ranged from nil to moderate. The percent cover of algae was relatively high (approximately 40%) and, in current-swept areas, of a diverse species composition. The most common substrates were shell, boulder and bedrock.

<u>Trutch, 2001</u>

The area included the Estevan group, a small archipelago located in the North Coast (Fig. 6). Both the exposure to wave action and the current regimes ranged widely from very low to very high. The algae cover was approximately 50% and consisted predominantly of *Agarum, Nereocystis* and *Macrocystis*. The most common substrates were sand, boulder and bedrock. The Estevan Group had a few uncharted passages which were not included in the survey area.

<u>Area 7, 1998 and 2002</u>

The area is located in the Central Coast of BC and encompasses channels, inlets and islets (Fig. 7). The topography was quite varied within the survey area, with slope ranging from vertical to gentle and substrate ranging from vertical bedrock to muddy bays. The exposure varied from nil to low, while the current regime was diverse ranging from nil to strong. Algal coverage was fairly high (30%), consisting mainly of *Agarum sp*. Conditions were typical of channels and inlets: moderate slopes of boulders with sand, shell and cobble.

<u>Fitz Hugh, 2002</u>

The area is located in the Central Coast and consists of large passages, inlets and islands (Fig. 8). The exposure and current regimes ranged from low to moderate. Slope ranged from vertical to flat, and the most common substrates were sand and bedrock.

<u>Area 12 Inlets, 2000</u>

The area is located in the Broughton Islands Group on the mainland shore of Queen Charlotte Strait (Fig. 9) and consists of numerous shallow inlets and passages. The slope was moderate to gentle, the current was nil to extreme and the exposure to wave action was low. The algal coverage was moderate (37%), consisting mainly of Agarum, while the substrate was primarily sand, shell or silt. Some areas had abundant filamentous green and brown algae.

<u>Tofino, 2001</u>

The area is located on the west coast of Vancouver Island and consists of inlets, bays, passages and open coastline (Fig. 10). The exposure ranged from low to extreme, while the current ranged from low to very strong. Exposed areas were characterised by sandy substrate against a rocky shoreline and gentle slopes below 20 to 40 feet. The portion of the area near the town of Tofino, with strong tidal current and heavy boat traffic, was excluded from the survey area because it was considered unfishable for safety reasons. The conservation area, Grice Bay, was also excluded.

Sea Cucumber Density Estimation

The density of sea cucumbers was estimated by a random sampling design first developed by Cripps and Campbell (2000). Dive surveys were collaborative efforts between the Department of Fisheries and Oceans (DFO), industry stakeholders (Pacific Sea Cucumber Harvesters Association, (PSCHA)), and First Nations (FN), where FN fisheries programs exist. Six locations have been surveyed since 1998, with one location (Area 7) surveyed twice (Table 1, Fig. 1).

Transect Survey Design

Approximately 200 transects were allocated within each survey area, with the goal of achieving a target precision for mean density estimates of ± 85% at the $\alpha = 0.10$ confidence level. In other words, the 90% confidence limit must lie within ± 15% of the estimated mean density. The sample size of 200 transects was derived from results of early surveys (Cripps and Campbell 2000).

The survey design was either simple random or stratified random (Table 1). Strata definition varied between surveys as, over time, more was understood of the factors that affect sea cucumber distribution and because each location presented different challenges. For the Area 7 and Gil/Gribbell surveys, transects were randomly assigned within the entire survey area. For the Area 12 and Fitz Hugh surveys, the area was stratified by Subarea to provide quota options on a finer geographic scale for management purposes. Due to a low sample size, PFMA 8-3 in Fitz Hugh was pooled with 8-4 as they have similar shoreline characteristics. For the Tofino and Trutch surveys, the survey area was stratified by habitat, with two strata in Tofino (exposed open coast and protected channels and inlets) and three strata in Trutch (exposed, protected and unknown). The unknown stratum in Trutch included shallow passages and bays within the Estevan Group which were of uncertain navigability. The sample size in each stratum, whether by Subarea or habitat, was proportional to the respective shoreline length.

Methods for determining the random location of transects within the survey areas have evolved over the years with the advent of new software and techniques. Initially, a digital curvi-meter was used to assign randomly selected transect positions on a chart for the 1998 survey in Area 7, which progressed to a random allocation using CompuGrid, a GIS software, for Gil/Gribbell and Area 12 surveys. A random selection of shoreline cells using a grid in ArcView was used for Tofino and Trutch, which further evolved to using an ArcView script that randomly assigned transects along the shoreline, used for the Fitz Hugh survey. Transects positions were transferred to hardcopy marine charts for use in the field by matching topographical features. The latitude and longitude of transects in the 1998 Area 7 survey was obtained from the marine chart. Otherwise, transect coordinates were obtained from GPS equipment onboard the survey vessel or Nobeltec, a navigational software.

Field Methods

Field locations of transects were determined by matching the topography, bathymetry and landscape with chart features. Transects were placed by orienting a leadline, marked at 5m intervals, perpendicular to the shore from 0 to 60 ft gauge depth (60 feet below chart datum for the Area 7 survey 1998). In narrow bays or channels, transects extended half-way between the shorelines.

A minimum of one DFO diving biologist was present on all surveys and attempts were made on his/her part to dive with a different survey diver each day to enable an examination of potential diver bias. Transects were surveyed by two divers, each holding a 2m wide bar on either side of the leadline and counting all sea cucumbers under the bar in each 5m section. Macrophytes were removed by hand to ensure that all sea cucumbers were visible, but rocks and boulders were not overturned to look for juveniles. Sea cucumbers less than 14 cm (the length of the diver's underwater pencil) were recorded separately as juveniles; these were likely underestimated and, consequently, were not included in the density estimates. All sea cucumbers were removed from the transect after enumeration and the diver on the left counted those on or under the lead line.

At the end of each 5m section, the divers stopped to separately record the number of sea cucumbers observed in each $10m^2$ quadrat, the depth, the two most prevalent substrate types, the two most abundant algae genera and percent cover of algae (not including encrusting algae). Sea cucumbers seen deeper than the deep extent of the transect were noted in the comments.

The survey data were checked, verified and entered at the end of each day. The gauge depth of only one diver in the team was used as the record of quadrat depth, while substrate information was pooled from both divers. Quadrat depths were determined as the average of the depth at the beginning and the end of each 5m section. Gauge depths were converted to chart datum using the tide height from the closest harmonic tide station using the computer program Tides and Currents Ltd.

Survey Data Analysis

The parametric estimate of mean sea cucumber density (d_j), in number of animals per metre of shoreline (c/m-sh), for each Subarea or stratum, *j,* was calculated as the sum of the sea cucumbers counted for all transects, divided by the total width of all transects

$$d_j = \frac{\sum_{i=1}^{n} c_i}{4n} \qquad \text{Equation (1)}$$

where c_i is the number of sea cucumbers in transect *i* and *n* is the total number of transects sampled, multiplied by 4, the width (m) of a transect.

Since the distribution of sea cucumber counts by transect were skewed in all of the data sets, non-parametric confidence intervals for the mean sea cucumber density were calculated using bootstrap techniques (Efron and Tibshirani 1993). The procedure randomly sampled *n* transects with replacement from the *n* surveyed transects. The number of sea cucumbers counted in the *n* resampled transects were added, as were the corresponding shoreline lengths (4*n*) for the resampled transects, and the mean density d_j^* calculated as in Equation (1). The process was repeated 1000 times to obtain 1000 estimated mean densities: $d^*_1, d^*_2, ..., d^*_{1000}$. The value of the 0.05 and 0.95 quantiles of the 1000 bootstrap means were used as the bounds of the 90% confidence interval.

The percent precision of the mean was calculated as

$$precision = \frac{(Mean - Lower\,90\%CI)}{Mean} * 100 .$$

Shoreline Length Estimation

Shoreline length estimates were initially calculated in 1997, using GIS software and employing a raster spatial data model (Boutillier *et al.* 1998). The model was applied to a basemap that had been digitized in 1994 from nautical charts. Since that time, new GIS software that uses a vector spatial data model and an alternate basemap (considered to contain greater detail than the original one used for shoreline length estimates) have become available. Shoreline length estimates derived from the vector spatial model applied to the original basemap were approximately 10% higher than the original estimate, while a 16% increase over the original resulted from use of the alternate basemap. The new methods are still not operational and, until such time that Departmental decisions on use of spatial data model and basemaps are finalized, quota calculations continue to be based on the more conservative 1997 measurements.

The greater detail contained in the alternate basemap was, however, utilized for two purposes: to aid in designing survey protocols and to estimate shoreline lengths where obvious adjustments were required. Adjustments to shoreline lengths were undertaken in surveyed areas to remove sections that are not harvestable, such as closures defined in the management plan, intertidal lagoons and rivers, uncharted areas, areas of heavy boat traffic, shallow channels or conservation areas. For consistency, the re-calculated shoreline estimates were scaled down with reference to original 1997 estimates.

Mean Weight Estimation

Mean weight data were collected from market samples of the commercial sea cucumber fishery between 1997 and 2001, obtained during dockside validation activities. Landings of product by vessel, Subarea, and fishing trip (one or two days of harvest) are given a unique identification number (ID). After weighing the load from one vessel, dockside validators extract approximately 25 animals per sample, place them in a bucket and obtain the weight to the nearest 50 g and count the number of animals. The number of samples collected per validation ID depends on how busy the dockside validator is at the time of unloading. Samples are collected from harvest containers (totes or cages) or from draining belts. To avoid bias, observers were instructed to take the sample from different locations within a container or along the belt. When sampling animals from containers, however, they reach only as deep as 20 cm (length of glove the observers are wearing). The product form was recorded as split (sliced longitudinally) or poked (body wall perforated). Poked market samples (2.4% of samples) were omitted from the analysis since the animals may contain more water than the split ones and mean weight would likely be biased.

The market sample data were grouped by Subarea and examined for trends of mean weight over time prior to pooling data for multiple years. For Subareas with a significant decrease in mean weight (ANOVA, $p < 0.05$), harvest records were examined to investigate whether the decrease was related to high levels of harvest. Since not all PFMAs are harvested every year, data from all years were pooled and averaged by PFMA, where appropriate.

Mean weight estimates are also available from biological samples collected during the dive surveys. After each of three randomly-selected transects from each survey area were completed, divers descended with a harvest bag and collected the first 50 animals encountered. These animals were split and individually weighed.

Mean weight estimates from market samples and biological samples were compared and tested to determine whether significant differences existed between them. Subareas with at least two biological samples and two market samples were used. A weighted mean difference and standard deviation between market samples and biological samples was calculated and tested against the null hypothesis that the difference was not significantly different from zero.

Quota calculations

The quota (Q_i) in metric tonnes for each Subarea *i* was calculated as

$$Q_i = \frac{E * D_i * S_i * W_i}{1000} \qquad \text{Equation (2)}$$

where E is the selected exploitation rate (4.2%), D_i is the low 90% confidence interval on estimated mean density (c/m-sh) in Subarea *i*, S_i is the shoreline length (m) and W_i is the mean weight (kg).

Results

Distribution of sea cucumbers

Findings from BC surveys have shown that areas devoid of sea cucumbers were characterized by either extreme wave exposure associated with shallow water and low relief substrate or bays of fine mud with little water movement. When sea cucumbers were found in areas of high wave exposure, they remained deeper. Deep channels with moderate to strong water current and complex substrates were noted to have the highest densities. This preference was expected, since sea cucumbers are deposit feeders and such underwater topography is favourable to the deposition of organic sediments. Sea cucumbers are often associated with the macrophyte *Agarum spp.*, which also flourishes in areas with moderate current and exposure. Harvesters also report finding higher densities along shores of forest clearcuts, possibly because organic sediments from runoff contribute to primary production.

Average sea cucumber body size was highly variable across spatial scales and could vary between sites that were as close as a few hundred meters, e.g. Jervis Inlet (Campagna and Hand 1999). Areas with strong tidal currents and/or vertical walls seemed to support small sea cucumbers, while large sea cucumbers favour quiet bays with soft substrates (K. Ridgway, President, Pacific Sea Cucumber Harvesters Association (PSCHA), pers. comm.). Areas with low density were often associated with large sea cucumbers, while areas of high densities are usually associated with animals of a smaller size (Campagna and Hand 1999). Areas of mixed sand and boulders support large cucumbers, which may also be associated with high densities. Size of animals was not necessarily related to harvest pressure, as small sea cucumbers were observed in some unharvested areas, such as northern Fitz Hugh Sound and Jervis Inlet prior to the experimental harvest (S. Campagna, pers. obs.).

Very few juvenile sea cucumbers were observed in the surveys: only 144 transects (8%) were noted to have juveniles. Juveniles prefer different habitats, are hidden from divers or are very scarce. Commercial sea cucumber harvesters and oyster growers have reported that sea cucumbers settle at high densities on oyster raft longlines.

Density

During the last five years, seven open surveys have been completed in six different areas of BC (Fig. 1). The low 90% CI on estimated mean density was higher than the baseline density estimate of 2.5 c/m-sh in 11 of the 15 separate survey strata. Only the 'exposed' stratum in Tofino (0.22 c/m-sh), 'exposed' (2.54 c/m-sh) and 'unknown' (2.48 c/m-sh) strata in Trutch, and PFMA 8-3 in Fitz Hugh (1.28 c/m-sh) had lower estimates (Table 1). Only nine transects could be completed in the exposed stratum at Tofino because most sites were accessible only on very calm days (Fig. 10) and the precision of the mean density estimate was low; the entire stratum was excluded from overall density estimates. Data collected in PFMA 24-09 were also excluded (and shoreline length removed) because it was considered poor habitat for sea cucumbers and therefore not appropriate for harvest. The northwest section of the exposed stratum in Trutch (Fig. 6) was subject to extreme wave exposure and its shoreline and associated transects were excluded from further analysis. The ‘unknown’ stratum of Trutch survey had a small sample size and wide confidence bounds (n = 13, Table 1). Because of the similarities in habitat, noted once in the field, the prior stratification was considered inappropriate and all strata were pooled. The low density estimate from PFMA 8-3 in the Fitz Hugh survey (Fig. 8, Table 1) was also a result of low sample size (n=8) and highly variable data; these data were pooled with data from PFMA 8-4 because of the similarity in shoreline exposures.

Survey data were either lumped (all strata of Trutch survey, two strata of Fitz Hugh survey) or in fact split (Area 7) and re-analyzed for use by resource managers in establishing fishing quotas. Transects in Area 7 were post-stratified Subarea in order to provide more spatially explicit results for management purposes. The low 90% CI of estimated mean density ranged from 5.08 to 21.46 c/m-sh (Table 2). By grouping Subareas with small sample sizes and where habitat similarities permitted, the precision of density estimates improved somewhat; however the target of 15% precision was only met in three in fifteen cases.

To facilitate the extrapolation of density estimates from surveyed areas to unsurveyed areas, two broad categories were established. The first category includes unsurveyed Subareas with relatively protected shoreline and no history of over-harvest (Fig. 11). These Subareas are assigned a new baseline density estimate of 5.08 c/m-sh, the minimum of all low 90% confidence intervals of open surveys in BC, following the convention of Boutillier *et al.* (1998).   The results from exposed sections of the Trutch and Tofino survey areas suggest that those habitats have very low densities of sea cucumbers; hence Subareas that have exposed shoreline were placed in a second category that maintains the current baseline density of 2.5 c/m-sh. Additionally, if a Subarea was considered to be poor (as relayed by commercial fishermen) or to have been over-harvested (as determined from harvest logbook data analysis), it was also placed in the third category.

The new baseline density estimate of 5.08 c/m-sh was higher than the respective surveyed Subarea density in only two situations; PFMA 24-10 and 24-9. The estimated density from PFMA 24-10 was 2.10 c/m-sh (n=33). This Subarea consisted of a channel with low exposure and convoluted shoreline (Fig. 10) and, based on other observations of sea cucumber distribution, moderate to high densities were expected. However, a shallow muddy bay occupied a large part of this Subarea and a significant number of transects, with low densities, were located there. Densities from PFMA 24-09, an inlet with little water exchange, gentle slope and soft substrates, were also low and ultimately were, as mentioned, not used in quota calculations.

Shoreline Length

Shoreline lengths used for calculating quotas were reduced in most surveyed areas with the discovery of unsuitable habitat, un-navigable waters or unsafe conditions for harvest. Shoreline reductions ranged from 0% to 45 % for the surveyed areas (Table 3). Shoreline adjustments were made prior to surveying in three surveys; Area 12, Trutch and Tofino. Additional shoreline reduction was completed after surveying for Area 12, Tofino, Trutch, Area 7 and Fitz Hugh. The Tofino area shoreline length was reduced by 45% after the removal of the area of excessive exposure and the muddy lagoon of PFMA 24-9. The Trutch area shoreline was reduced by 14% which included a large portion of uncharted area and a portion of shoreline subjected to extreme exposure. The remaining surveyed areas underwent minor or no shoreline reduction.

Unsurveyed Subareas underwent shoreline reductions in three obvious situations: PFMA 5-23 was reduced by 53% due to the management closure of the three inlets located there and PFMA's 7-13 and 13-16 were reduced by less that 10% to exclude un-navigable waters.

Mean Weight

A total of 2,422 samples of harvested (split) sea cucumbers have been collected over 1,148 commercial landing validations during the last five years. In contrast, the mean weight estimates used to calculate the original quota of 233 t were based on 160 samples of harvested sea cucumbers, collected during the 1995 fishery (Rome and Clarke, unpublished data).

Mean weight from market samples were compared to the mean weight obtained from biosamples (Table 4). Analysis did not reveal a significant difference between them (*t-test*, p=0.39), and so the market sample data were utilized solely, since they provided a wider geographic coverage.

There are anecdotal reports from fishermen that sea cucumber weight is decreasing over time in some areas (Don Christian, D&D Pacific Fisheries, pers. comm.). Market sample data were examined for trends in mean weight, by Subarea. Twenty Subareas had a significant change of mean weight over time ANOVA (p< =0.05). Nine Subareas had a positive slope, i.e. an increase in mean weight, while eleven had a negative slope. Of these eleven, eight Subareas experienced from one to four years of harvest that was over the recommended quota. Attempts to correlate decreasing weight with specific popular harvest locations were not conclusive. Since there was no consistent trend in the mean weight data, all data were pooled over years and mean weight calculated by Subarea.

Estimates of mean weight increased in 59 of the 98 Subareas open to commercial harvest and decreased in 22 Subareas, while the original estimate was retained in 17 Subareas because no fishing had occurred there during the last five years (Table 5).

Quotas

The effect of the new baseline density estimate on recommended quotas was a 50% increase over the current quota of 424.1 t, to 623.9 t (Table 5). Quotas were higher for most Subareas, despite the fact that some of the areas were significantly reduced in shoreline length. Some quotas increased up to nine-fold (PFMA 8-6 of Fitz Hugh). Most

Subareas in PFMA 13 decreased in quota due to lower estimated mean weights. A few Subareas retained the original density and mean estimates.

Discussion

Density

The new baseline density estimate recommended for use in un-surveyed areas is the minimum of all low 90% confidence intervals from open surveys conducted in BC. There is a low probability that the biomass estimated using this density estimate will exceed actual population biomass in any given Subarea.

The segments of the surveyed coast that were considered un-fishable, whether because of high exposure, unsafe conditions or un-navigable waters, were removed from the commercial fishery area for quota calculation purposes. To safeguard against overestimating biomass in unsurveyed areas that are similarly un-fishable, it is recommended that the original baseline density estimate of 2.5 c/m-sh be used or, more cautiously, omit the shoreline length altogether from quota calculations. Researchers in Alaska have recently adopted the policy of a lower density threshold of 1 kg per metre of shoreline (which equates to a little over 2.5 c/m-sh), below which a fishery is prohibited (D. Woodby, Alaska Department of Fish and Game, pers. comm.). Subareas that have been significantly over-harvested may also be placed in that category. An example of this might be PFMA 13, which was reported to have been heavily harvested many years ago and not yet recovered (K. Ridgway, PSCHA, pers. comm.).

Sea cucumbers are reputed to undergo seasonal vertical migrations, although there has been no data recorded on this phenomenon. If true, timing of surveys could therefore have an effect on the estimated density, such that survey results from one season may not be representative of the population available for harvest in a different season. This may impact the ability of fishermen to achieve the allocated quota or, conversely, result in underestimation of stock available for harvest. Data collected from EFAs should be examined to determine whether sea cucumber depth distribution varies between years. Index sites could also be established and monitored over several seasons to determine whether there is a seasonal component to change in sea cucumber depth distribution.

The precision of density estimates generally falls short of the objective of 90% confidence bounds within 15% of the mean. Survey results show that precision is largely related to sample size. The wide confidence bounds result in low lower 90% CI on the mean density estimates, and hence more conservative estimates for use in quota calculations. Nonetheless, there are sufficient survey data to enable a re-examination of the stratified random survey design, perhaps through simulations, to explore whether another design is more suited to the distribution of sea cucumbers.

Alternative calculations of density (i.e. true density, in sea cucumber per m^2), along with estimates of area, would permit an alternate calculation of cucumber biomass. A comparison of estimates of biomass from both sources would be useful to examine the influence of varying shoreline slope on density estimates. In addition, the use of mean sea cucumber density per square metre might be used as a threshold for commercial harvest.

Geographic Distribution

Results of surveys conducted to date have shown that a strong relationship exists between sea cucumber abundance and physical oceanographic features. An attempt was made to take advantage of this relationship in order to calculate more spatially-explicit baseline density estimates. Subareas were grossly categorized into 'exposed', 'moderate' and 'protected' by examining hydrographic charts, and the mean density with confidence intervals were calculated for each grouping. The low 90% CI of these density estimates were 4.84 c/m-sh, 9.85 c/m-sh and 14.2 c/m-sh for the exposed, moderate and protected categories, respectively. However when these estimates were compared to the estimate for each respective Subarea, 13 Subareas out of 25 had low 90% CI less than the low 90% CI for the corresponding category. This is because the exposure-category estimates have larger sample sizes and therefore tighter confidence intervals, which translates into higher low 90% CI. Use of these categorical density estimates would be less risk-averse and is not recommended at this time. The use of physical and oceanographic features to categorize the coastline into units relevant to sea cucumber productivity does, however, have potential as a means to move towards more spatially-explicit stock assessment and management and should be persued.

Mean Weight

The size distribution of sea cucumber populations is highly variable over the BC coast. Given that mean weight is a significant component of biomass estimation, small geographic-scale variation in mean weight, combined with the limited spatial resolution of estimates from market sampling could result overestimation of biomass. The magnitude of potential overharvest due to poor estimates of mean weight is difficult to estimate, however it is assumed that samples collected from harvested animals are representative of the population with an acceptable amount of variation among years. Further work should be conducted on the potential bias that may exist in sampling sea cucumbers from landed catch as a result of size-related sorting during transport and prior to sample selection. An annual review of the mean weight per Subarea may detect trends that are indicative of depletion.

Shoreline Length

Exposed, un-fishable shoreline has been removed from the biomass calculation process in surveyed areas, however shoreline in unsurveyed sections of the coast that may be similarly exposed are still included in shoreline length estimates. Quotas calculated for these exposed shorelines would likely be taken from other areas within the Cucumber Management Area, leading to localized over-harvest. Work should be undertaken to identify these areas and exclude the shoreline length from data used to calculate quotas. Lists of candidate areas could be identified using GIS software, followed by a review of geo-referenced harvest data and interviews with experienced harvesters for confirmation.

Shoreline lengths should also be re-measured from the most accurate basemap available. Consideration should also be given to qualifying the estimates by shoreline slope, since there would logically be more habitat available for sea cucumbers on gradual slopes.

Exploitation Rate

Although not discussed in this paper, exploitation rate may be the largest contribution to the overall uncertainty of the quota calculation. Our assumed harvest rate of 4.2% is derived from a biomass dynamic model using limited survey and catch data from Washington State. The adopted rate of 4.2% is considerably lower, however, than results of modelling of more recent and extensive data from Washington State, where estimates of maximum sustainable yield ranged from 12% to 35% (Bradbury *et al.* 1998). Given that no method has yet been found to age sea cucumbers, these production models may be one of the few tools available to estimate management parameters. Efforts should be made to utilize data available from BC, or collect new data, for use in biomass dynamic modelling.

Recommendations

1. Apply the new baseline density estimate of 5.08 c/m-sh to unsurveyed areas, except for areas of high exposure or areas of concern.

2. Continue to use the original estimate of 2.5 c/m-sh for areas of high exposure or those suspected of being over-harvested. Alternatively, those areas could be closed.

3. Use the low 90% CI of survey density for surveyed areas only.

4. Work towards improving estimates of shoreline length for harvest areas by utilizing the most recent digitised CHS charts and reviewing and removing sections where harvest is not possible.

5. Review annual estimates of mean weight by Subarea.

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Table 1. Mean density with 90% confidence intervals (CI) from all sea cucumber open surveys conducted to date in BC, with number of transects and precision of density estimate. Survey designs were either simple random sampling (SRS) or stratified random sampling (STR). Stratified surveys were stratified by Subarea or by habitat, where: (1) is exposed, (2) is protected and (3) is unknown.

Survey	Year	Subareas	Original Shoreline Length (m)	Survey Design	Number of Transects	Precision (%)	Densities (c/m-sh)		
							Mean	90%CI	Range
Gil/Gribbell	1999	6-(3, 5, 6, 7, 27, 28)	490,240	SRS	236	90	19.82	17.86 - 21.95	0 - 143
Trutch	2001	6-9 ptns	141,000	STR (1)	66	69	3.67	2.54 - 4.95	0 - 26.5
Trutch	2001	6-9 ptns	165,000	STR (2)	74	77	9.56	7.34 - 12.08	0 - 53.75
Trutch	2001	6-9 ptns	61,000	STR (3)	13	54	4.56	2.48 - 6.85	0 - 16.5
Area 7	1998	7-(15, 17, 30)	392,448	SRS	202	87	13.28	11.58 - 15.12	0 - 93.0
Area 7	2002	7-(15, 17, 30)	392,448	SRS	190	88	12.86	11.33 - 14.43	0 - 72.5
Fitz Hugh	2002	8-3	19,740	STR	8	18	7.00	1.28 - 16.81	0 - 43.25
Fitz Hugh	2002	8-4	221,071	STR	114	86	17.15	14.76 - 19.44	0 - 82.25
Fitz Hugh	2002	8-5	43,176	STR	23	80	15.27	12.28 - 18.50	1.75 - 35.75
Fitz Hugh	2002	8-6	21,958	STR	12	55	38.21	21.10 - 59.17	5.5 - 144.75
Fitz Hugh	2002	8-16	71,753	STR	37	79	13.59	10.76 - 16.62	0.5 - 49.75
Area 12	2000	12-40	132,031	STR	57	78	8.09	6.33 - 9.98	0 - 37.5
Area 12	2000	12-41	251,177	STR	115	79	6.82	5.42 - 8.35	0 - 38.5
Tofino	2001	24-(ptns 6, 8)	131,000	STR (1)	9	10	2.17	0.22-5.00	0 - 13.5
Tofino	2001	24-(4-10, 14, ptns 6, 8)	379,000	STR (2)	146	78	6.35	4.96-8.26	0 - 132.5
Combined[1]			2,520,594		1,100	94	12.39	11.65-13.16	0-144.75

[1] The combined results do not include data from the 1998 Area 7 survey.

Table 2. Sea cucumber quotas in surveyed areas that were recommended to managers compared to the original estimate, by survey strata, with quota management area (QMA) shoreline length, number of transects, low 90% confidence interval on mean density estimate, precision of the mean density estimate and mean sea cucumber weight. Transects associated with unsuitable shoreline were excluded from the analysis.

Survey	Year	QMA	PFMA	Revised Shoreline Length (m)	Number of Transects	Precision (%)	90% LCB Density (c/m-sh)	Mean Weight (g)	Quota (t)	
									Original	New
Gil/Gribbell	1999	6A,B	6-(3, 5, 6, 7, 27, 28)	490,240	236	90	17.85	263	13.54	96.66
Trutch	2001	6C	6-9	314,000	137	81	5.76	297	10.13	22.56
Area 7	1998	7A	7-15	136,080	66	79	6.72	263	3.76	10.10
Area 7	1998	7C	7-17	219,038	113	84	13.42	263	6.05	32.47
Area 7	1998	7C	7-30	37,330	18	65	11.76	263	1.03	4.85
Area 7	2002	7A	7-15	134,531	67	81	8.84	342	12.75	17.08
Area 7	2002	7C	7-17	205,719	105	85	11.66	298	32.47	30.02
Area 7	2002	7C	7-30	37,330	18	64	10.25	322	4.85	5.17
Fitz Hugh	2002	8A	8-3, 8-4	229,067	122	87	14.25	280	6.60	38.39
Fitz Hugh	2002	7C	8-5	43,167	23	80	12.29	258	1.20	5.75
Fitz Hugh	2002	7C	8-6	21,958	12	57	21.46	276	0.60	5.46
Fitz Hugh	2002	8A	8-16	70,442	37	77	10.54	331	1.98	10.32
Area 12	2000	12B	12-40	124,807	57	80	6.43	318	4.41	10.72
Area 12	2000	12B	12-41	229,085	115	79	5.08	318	8.39	15.54
Tofino	2001	24A,B	24-(4,5,7,10,14)	279,000	126	77	5.45	357	17.03	22.80
	Total			2,179,346	1,055		10.85			

Table 3. Summary of shoreline adjustments made in areas where open surveys were conducted.

Survey	Year	Shoreline Length (m) Original[1]	Post-survey	Percent Reduction
Gil/Gribbell	1999	490,240	490,240	0.0
Trutch	2001	367,366	314,000	14.5
Area 7	1998	392,448	392,448	0.0
Area 7	2002	392,448	377,580	3.8
Fitz Hugh	2002	377,698	364,634	3.5
Area 12	2000	383,208	353,892	7.7
Tofino	2001	510,000	279,000	45.3
Total[2]		2,520,960	2,179,346	13.6

[1] Original shoreline lengths from Boutillier *et al*. (1998).

[2] Total shoreline does not include estimates from the 1998 Area 7 survey.

Table 4. Comparison of the mean drained weights from biological samples collected during surveys and market samples collected from the sea cucumber fishery between 1997 and 2001.

	Pacific Fishery		Biosamples		Market Samples	
	Area	Subarea	n	mean wt	n	mean wt
*	6	3	3	256	50	255
*	6	5	4	270	77	244
*	6	6	2	204	26	225
	6	7	1	196	25	234
*	6	9	3	403	30	319
*	7	15	6	332	28	355
*	7	17	6	353	139	310
*	7	30	6	260	9	313
*	8	4	3	311	52	285
*	8	5	2	154	18	258
	8	16	1	311	19	340
*	12	40	3	332	7	405
*	12	41	3	267	29	314
	24	5	1	464	6	489
	24	6	1	191	17	313
	24	7	1	413	43	346
	Total	Average	46	295	575	313

*samples used to test for significant difference

Table 5. Revised quota estimates for Subareas open to sea cucumber harvest, with original and revised estimates for shoreline lengths and mean sea cucumber weight, revised densit estimates, original and revised quota estimates, quota difference (revised estimate minus original estimate), and PFMA category, where 1=surveyed, 2=unsurveyed good habitat and 3=unsurveyed poor habitat or area of concern.

Statistical		Shoreline Length (m)		Weight(g)		Density	Quota (t)		Difference	PFMA
Area	Subarea	Original	Revised	Original	Revised	c/m-sh	Original	Revised	(t)	Category
4	3	30,811	30,811	263	263	2.50	0.9	0.9	0.0	3
5	1	38,338	38,338	263	327	5.08	1.1	2.7	1.6	2
5	2	48,317	48,317	263	348	5.08	1.3	3.6	2.3	2
5	4	56,750	56,750	263	343	5.08	1.6	4.2	2.6	2
5	5	13,339	13,339	263	399	5.08	0.4	1.1	0.8	2
5	7	19,690	19,690	263	263	5.08	0.5	1.1	0.6	2
5	11	25,334	25,334	263	284	2.50	0.7	0.8	0.1	3
5	12	43,579	43,579	263	320	2.50	1.2	1.5	0.3	3
5	13	116,105	116,105	263	367	5.08	3.2	9.1	5.9	2
5	14	89,880	89,880	263	347	5.08	2.5	6.7	4.2	2
5	15	21,907	21,907	263	314	5.08	0.6	1.5	0.9	2
5	16	199,080	199,080	263	326	5.08	5.5	13.8	8.3	2
5	17	173,645	173,645	263	308	5.08	4.8	11.4	6.6	2
5	18	25,838	25,838	263	263	5.08	0.7	1.4	0.7	2
5	19	58,279	58,279	263	298	5.08	1.6	3.7	2.1	2
5	20	129,797	129,797	263	388	2.50	3.6	5.3	1.7	3
5	21	72,895	72,895	263	285	5.08	2.0	4.4	2.4	2
5	22	139,171	139,171	263	330	2.50	3.8	4.8	1.0	3
*5	23	188,278	88,565	263	278	5.08	5.2	5.3	0.1	2
5	24	114,946	114,946	263	213	5.08	3.2	5.2	2.0	2
6	2	130,822	130,822	263	242	5.08	3.6	6.8	3.1	2
6	3	141,540	141,540	263	255	17.85	3.9	27.1	23.2	1
6	5	203,683	203,683	263	244	17.85	5.6	37.2	31.6	1
6	6	86,906	86,906	263	225	17.85	2.4	14.7	12.3	1
6	7	28,829	28,829	263	234	17.85	0.8	5.1	4.3	1
6	8	43,210	43,210	263	227	5.08	1.2	2.1	0.9	2
6	9	367,366	314,000	263	319	5.76	10.1	28.4	18.2	1
6	10	192,662	192,662	263	308	5.08	5.3	12.7	7.3	2
6	11	11,206	11,206	263	263	5.08	0.3	0.6	0.3	2
6	12	106,882	106,882	263	322	5.08	3.0	7.3	4.4	2
6	14	60,413	60,413	263	332	5.08	1.7	4.3	2.6	2
6	15	39,866	39,866	263	355	5.08	1.1	3.0	1.9	2
6	16	110,225	110,225	263	357	5.08	3.0	8.4	5.4	2
6	26	16,212	16,212	263	268	5.08	0.4	0.9	0.5	2
6	27	6,871	6,871	263	258	17.85	0.2	1.3	1.1	1
6	28	22,411	22,411	263	218	17.85	0.6	3.7	3.0	1
7	2	6,518	6,518	263	263	2.50	0.2	0.2	0.0	3
7	3	122,270	122,270	263	305	5.08	3.4	8.0	4.6	2
7	12	83,194	83,194	263	301	5.08	2.3	5.3	3.0	2
*7	13	62,899	61,233	263	316	5.08	1.7	4.1	2.4	2
7	14	208,790	208,790	263	304	5.08	5.8	13.5	7.8	2
7	15	136,080	134,531	263	355	8.84	3.8	17.7	14.0	1

Statistical		Shoreline Length (m)		Weight(g)		Density	Quota (t)		Difference	PFMA
Area	Subarea	Original	Revised	Original	Revised	c/m-sh	Original	Revised	(t)	Category
7	16	85,260	85,260	263	263	5.08	2.4	4.8	2.4	2
7	17	219,038	205,719	263	310	11.66	6.0	31.2	25.2	1
7	18	197,450	197,450	263	289	2.50	5.5	6.0	0.5	3
7	19	32,978	32,978	263	263	2.50	0.9	0.9	0.0	3
7	20	28,997	28,997	263	408	2.50	0.8	1.2	0.4	3
7	21	67,721	67,721	263	323	5.08	1.9	4.7	2.8	2
7	22	12,818	12,818	263	296	5.08	0.4	0.8	0.5	2
7	23	192,461	192,461	263	317	5.08	5.3	13.0	7.7	2
7	24	40,858	40,858	263	297	5.08	1.1	2.6	1.5	2
7	25	279,082	279,082	263	372	2.50	7.7	10.9	3.2	3
7	26	17,825	17,825	263	263	2.50	0.5	0.5	0.0	3
7	27	201,113	201,113	263	263	2.50	5.6	5.6	0.0	3
7	28	109,570	109,570	263	301	5.08	3.0	7.0	4.0	2
7	30	37,330	37,330	263	313	10.25	1.0	5.0	4.0	1
7	31	75,180	75,180	263	263	2.50	2.1	2.1	0.0	3
7	32	76,289	76,289	263	358	2.50	2.1	2.9	0.8	3
8	2	90,821	90,821	263	364	2.50	2.5	3.5	1.0	3
8	3	19,740	7,996	263	236	14.25	0.5	2.8	2.2	1
8	4	221,071	221,071	263	285	14.25	6.1	37.7	31.6	1
8	5	43,176	43,176	263	258	12.29	1.2	5.7	4.6	1
8	6	21,958	21,958	263	252	21.46	0.6	5.0	4.4	1
8	7	193,973	193,973	263	263	5.08	5.4	10.9	5.5	2
8	13	102,934	102,934	263	284	5.08	2.8	6.2	3.4	2
8	14	70,056	70,056	263	263	5.08	1.9	3.9	2.0	2
8	16	71,753	70,442	263	340	10.54	2.0	10.8	8.8	1
9	1	59,590	59,590	263	263	2.50	1.6	1.6	0.0	3
9	2	198,979	198,979	263	342	5.08	5.5	14.5	9.0	2
9	12	188,177	188,177	263	351	5.08	5.2	14.1	8.9	2
12	7	65,201	65,201	318	374	5.08	2.2	5.2	3.0	2
12	8	16,649	16,649	318	330	5.08	0.6	1.2	0.6	2
12	9	1,915	1,915	318	366	5.08	0.1	0.1	0.1	2
12	10	924	924	318	318	5.08	0.0	0.1	0.0	2
12	11	103,454	103,454	318	378	5.08	3.5	8.3	4.9	2
*12	13	195,754	185,393	318	394	5.08	6.5	15.6	9.0	2
12	16	84,017	84,017	318	415	5.08	2.8	7.4	4.6	2
12	17	13,961	13,961	318	371	5.08	0.5	1.1	0.6	2
12	40	132,031	124,807	318	405	6.43	4.4	13.6	9.2	1
12	41	251,177	229,085	318	314	5.08	8.4	15.3	7.0	1
13	12	107,587	107,587	318	274	2.50	3.6	3.1	-0.5	3
13	13	31,433	31,433	318	271	2.50	1.0	0.9	-0.2	3
13	14	16,666	16,666	318	258	2.50	0.6	0.5	-0.1	3
13	15	52,466	52,466	318	318	2.50	1.8	1.8	0.0	3
*13	16	65,688	60,754	318	230	2.50	2.2	1.5	-0.7	3
13	17	64,126	64,126	318	257	2.50	2.1	1.7	-0.4	3
13	18	37,649	37,649	318	242	2.50	1.3	1.0	-0.3	3
13	19	42,118	42,118	318	168	2.50	1.4	0.7	-0.7	3
13	20	26,393	26,393	318	318	2.50	0.9	0.9	0.0	3

Statistical		Shoreline Length (m)		Weight(g)		Density	Quota (t)		Difference	PFMA
Area	Subarea	Original	Revised	Original	Revised	c/m-sh	Original	Revised	(t)	Category
13	23	70,930	70,930	318	301	2.50	2.4	2.2	-0.1	3
24	4	53,441	39,000	322	377	5.45	1.8	3.4	1.6	1
24	5	55,978	54,000	322	489	5.45	1.9	6.0	4.2	1
24	6	100,716	30,000	322	313	5.45	3.4	2.1	-1.3	1
24	7	75,029	74,000	322	346	5.45	2.5	5.9	3.3	1
24	8	49,459	0	322	322	-	1.7	Closed	-1.7	1
24	9	93,509	0	322	400	-	3.2	Closed	-3.2	1
24	10	53,441	53,000	322	419	5.45	1.8	5.1	3.3	1
24	14	29,215	29,000	322	373	5.45	1.0	2.5	1.5	1
Total		8,641,959	8,249,313				249.8	623.9	374.1	

* Unsurveyed PFMAs that were adjusted for shoreline length.

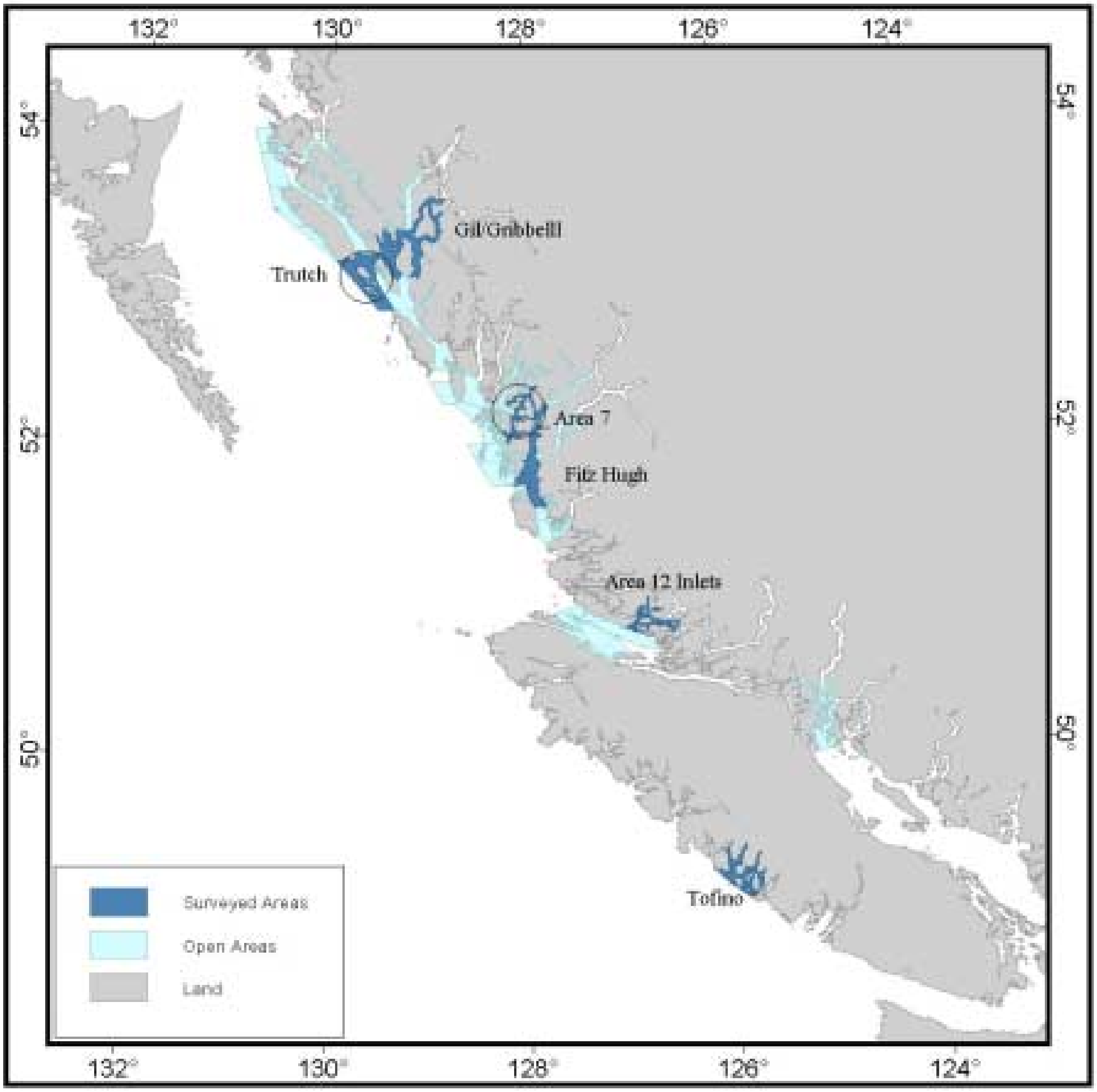

Figure 1. Map of the BC coast showing the areas open to sea cucumber harvest and the open areas that have been surveyed.

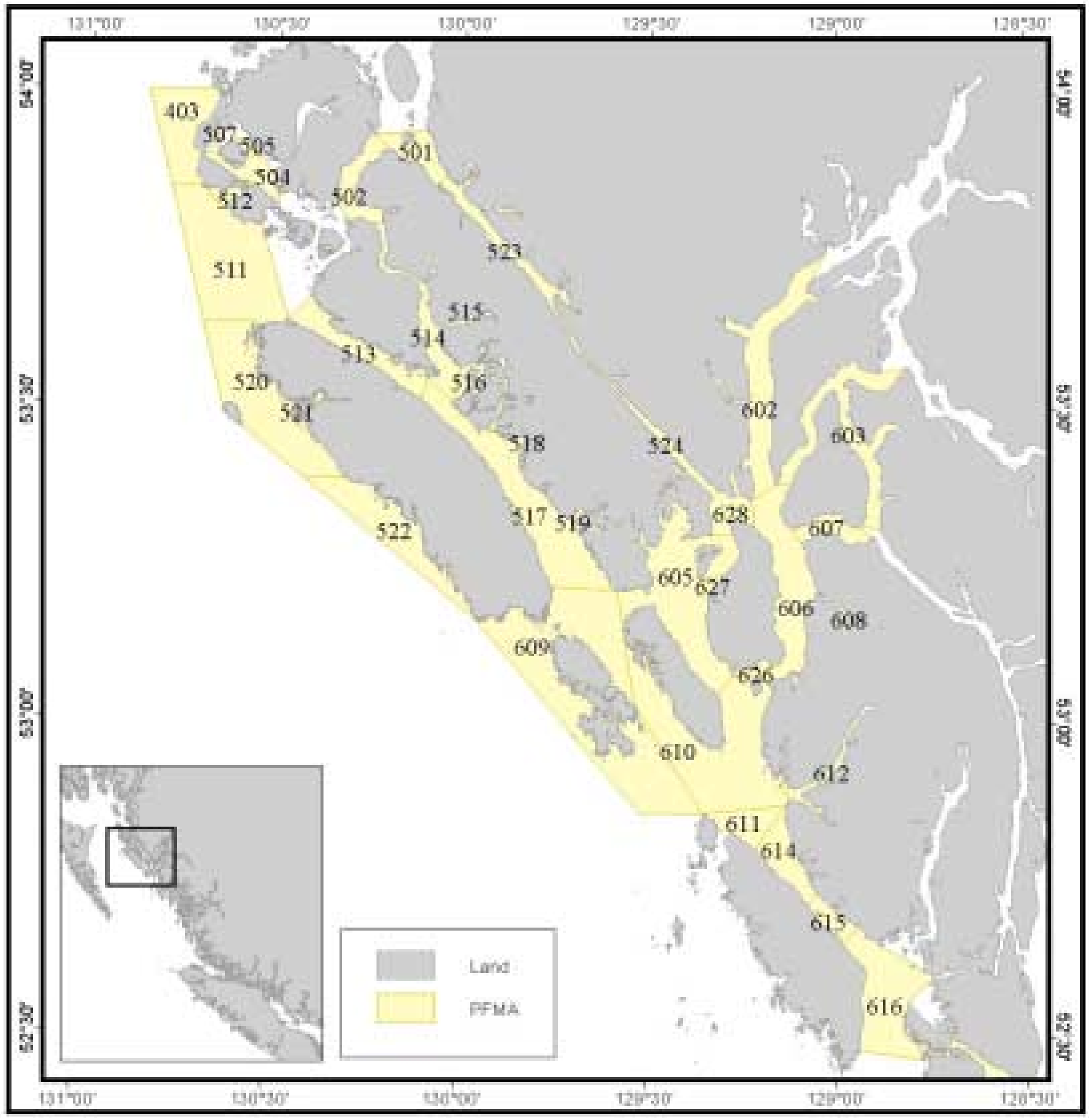

Figure 2. North Coast of BC showing the labelled Subareas open to sea cucumber harvest.

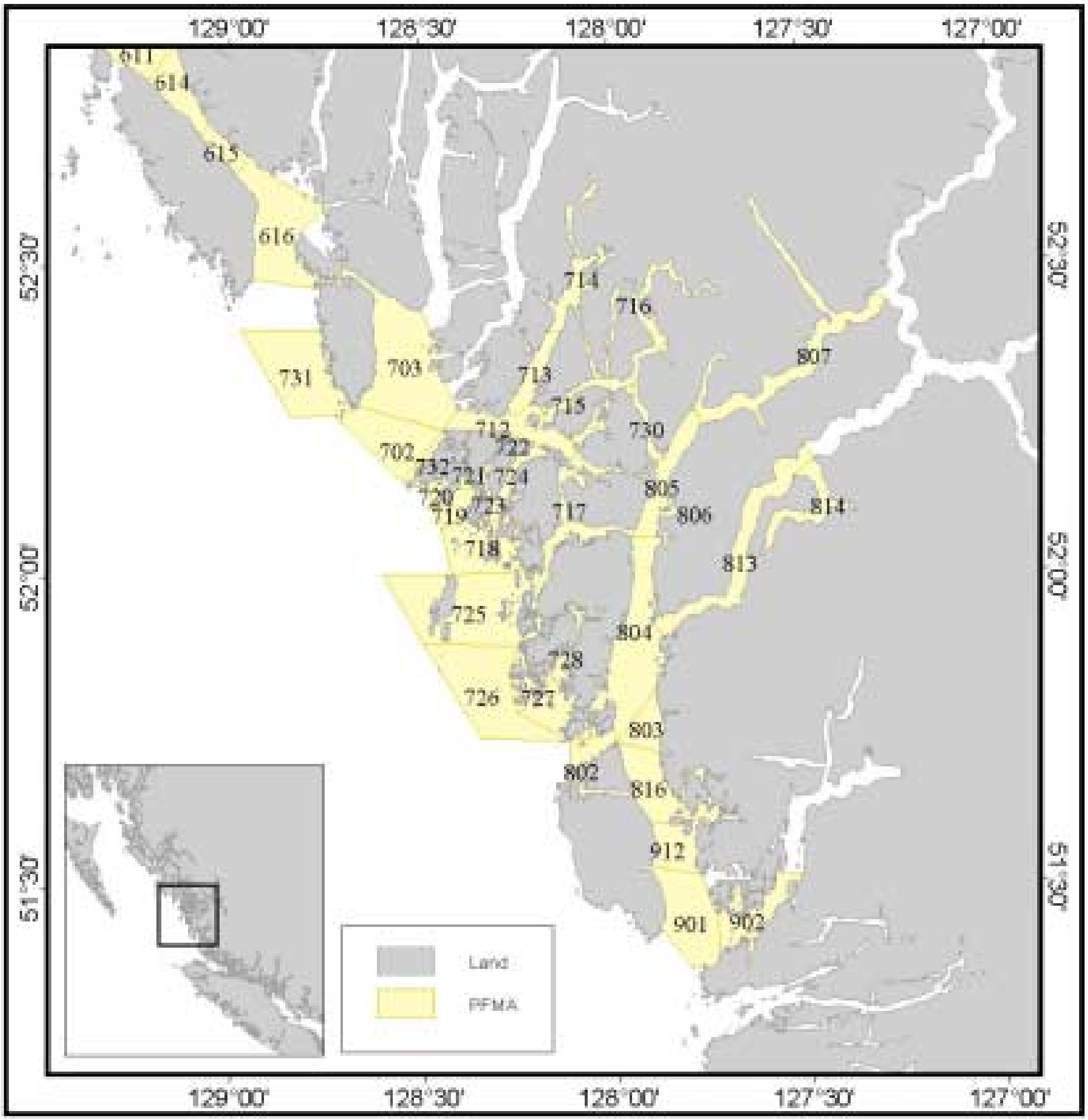

Figure 3. Central Coast of BC showing the labelled Subareas open to sea cucumber harvest.

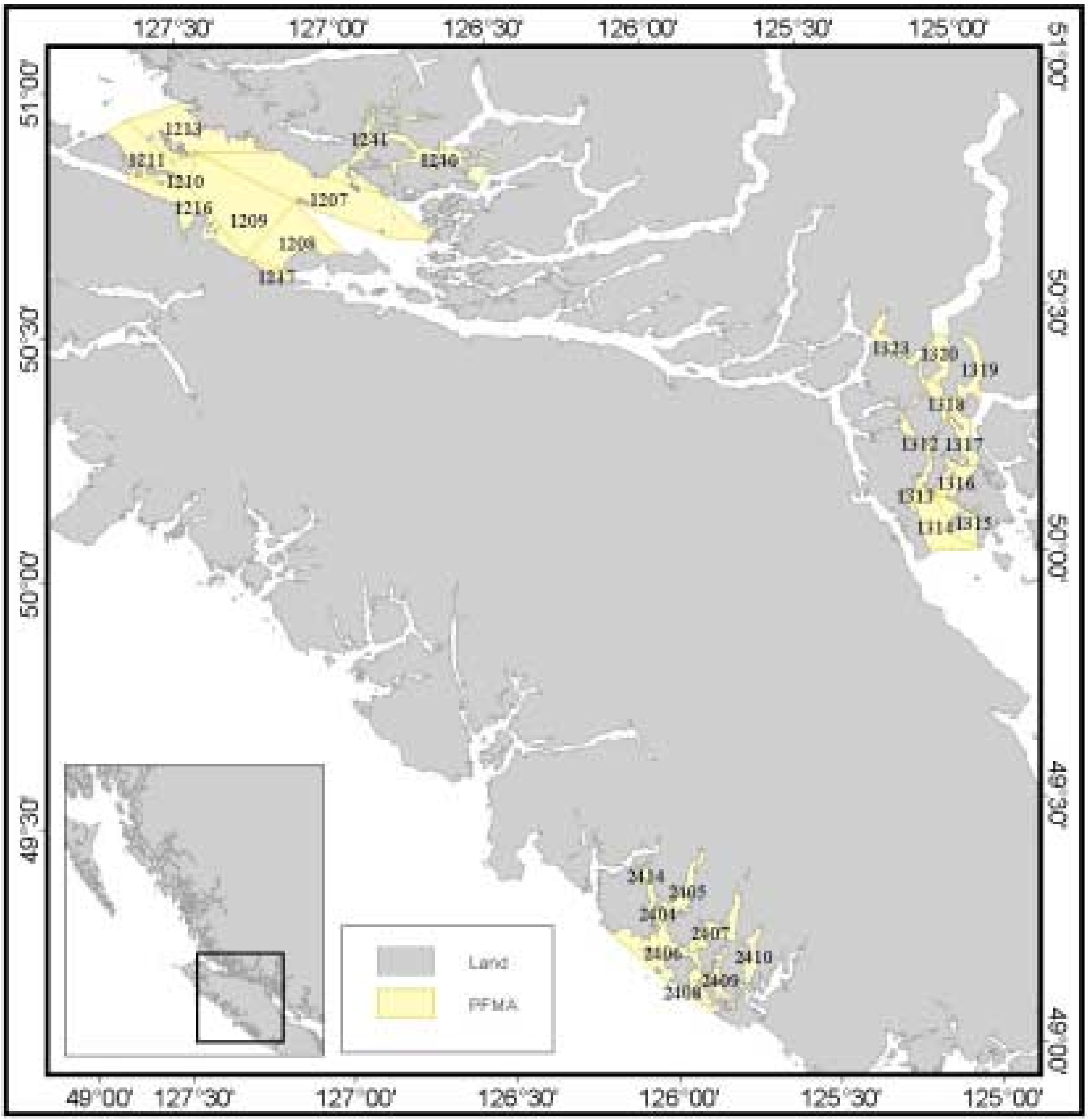

Figure 4. South Coast of BC showing the labelled Subareas open to sea cucumber harvest.

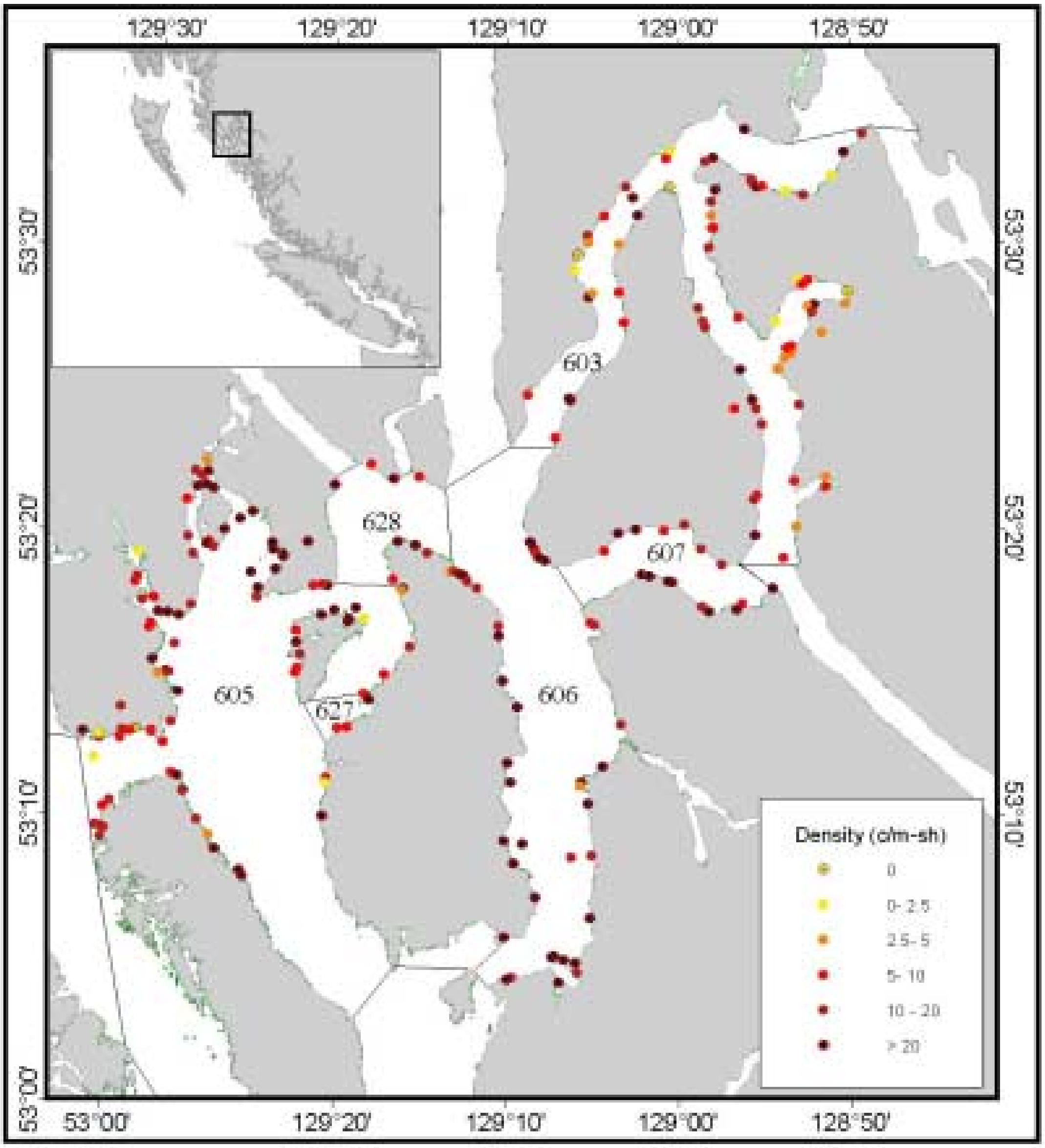

Figure 5. Transect locations and associated sea cucumber densities (c/m-sh) of the Gil-Gribbell survey, 1999.

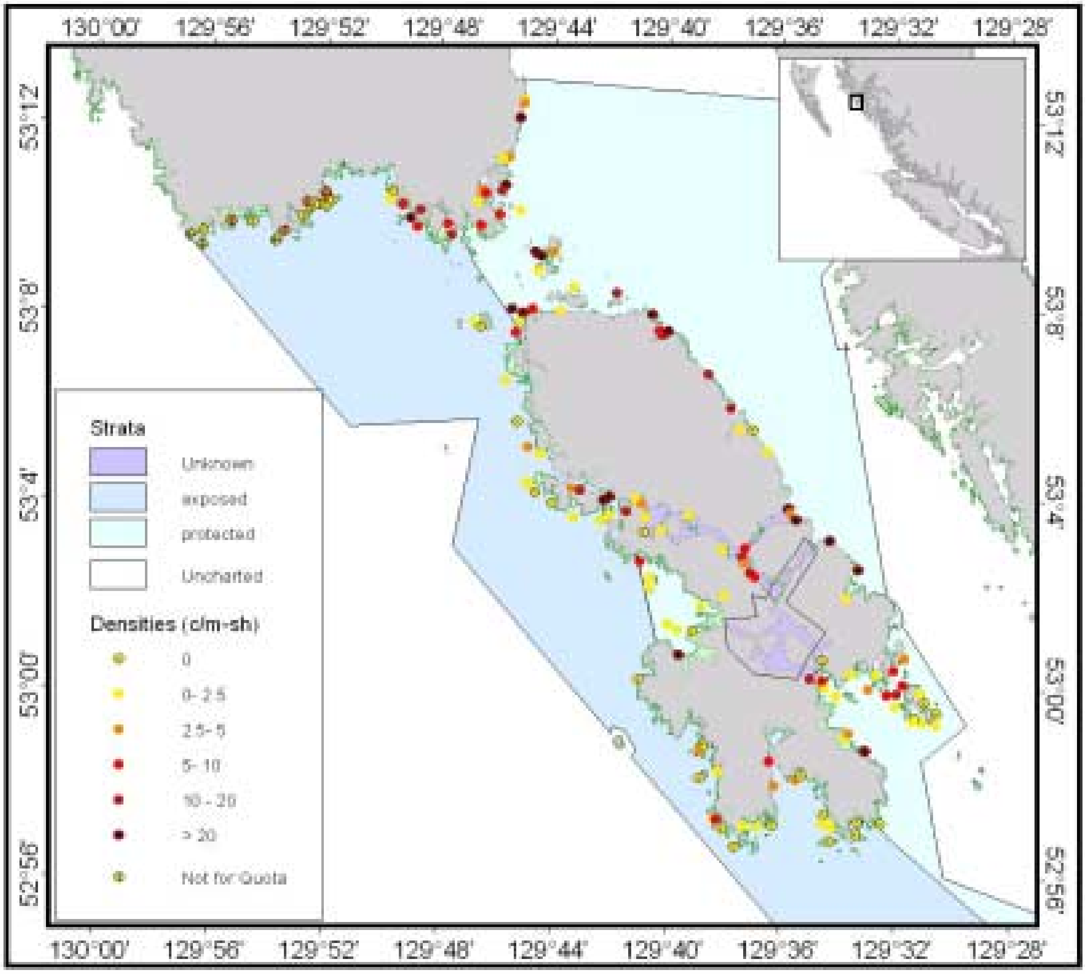

Figure 6. Transect locations, survey strata and associated sea cucumber densities (c/m-sh) of the Trutch Island survey, 2001. The uncharted area (marked as 'unknown) was not included in the survey. Transects marked with a line or a cross (0 c/m-sh) were not included in further calculations.

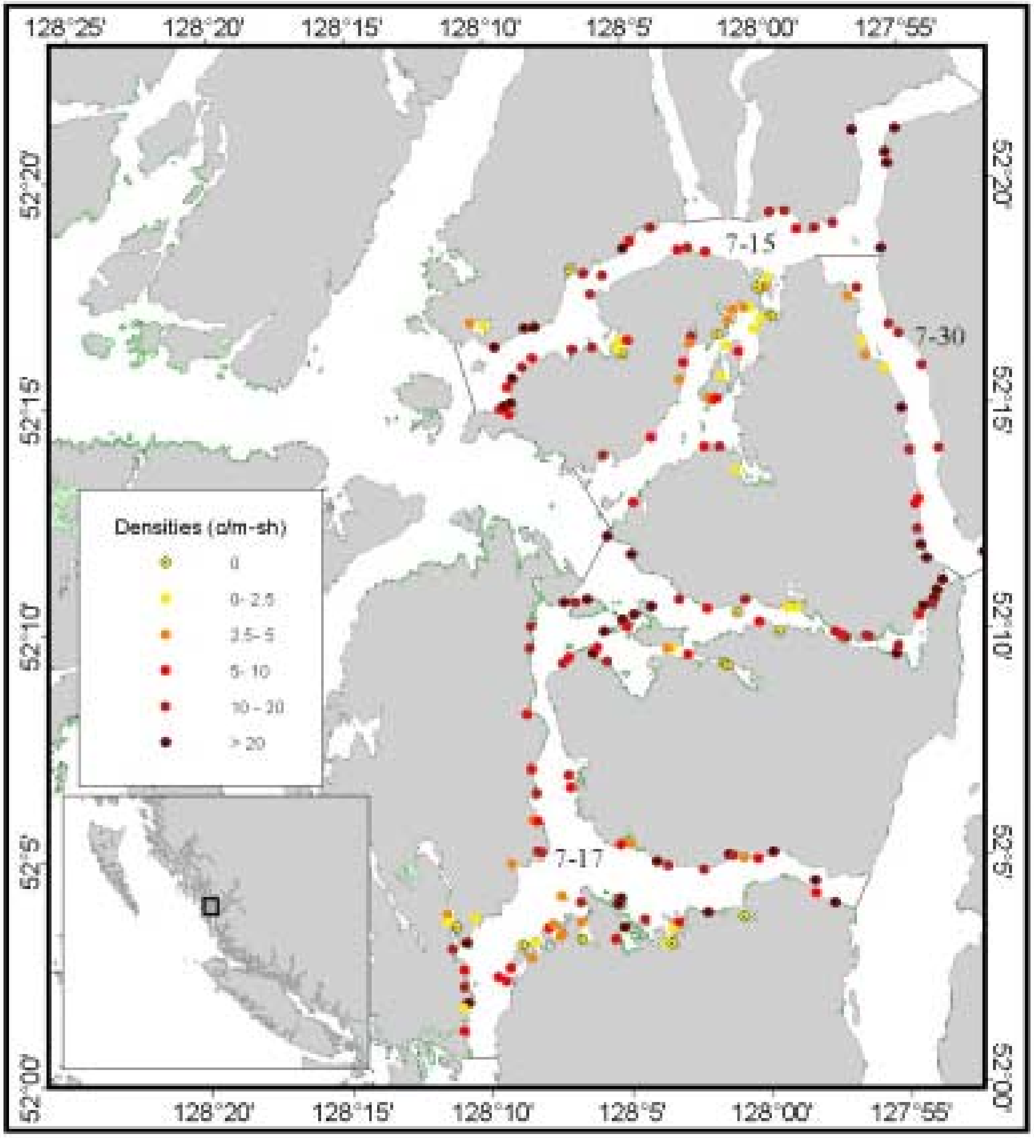

Figure 7. Transect locations and associated sea cucumber densities (c/m-sh) of the Area 7 survey, 1998 and 2002. Densities are from the 2002 survey.

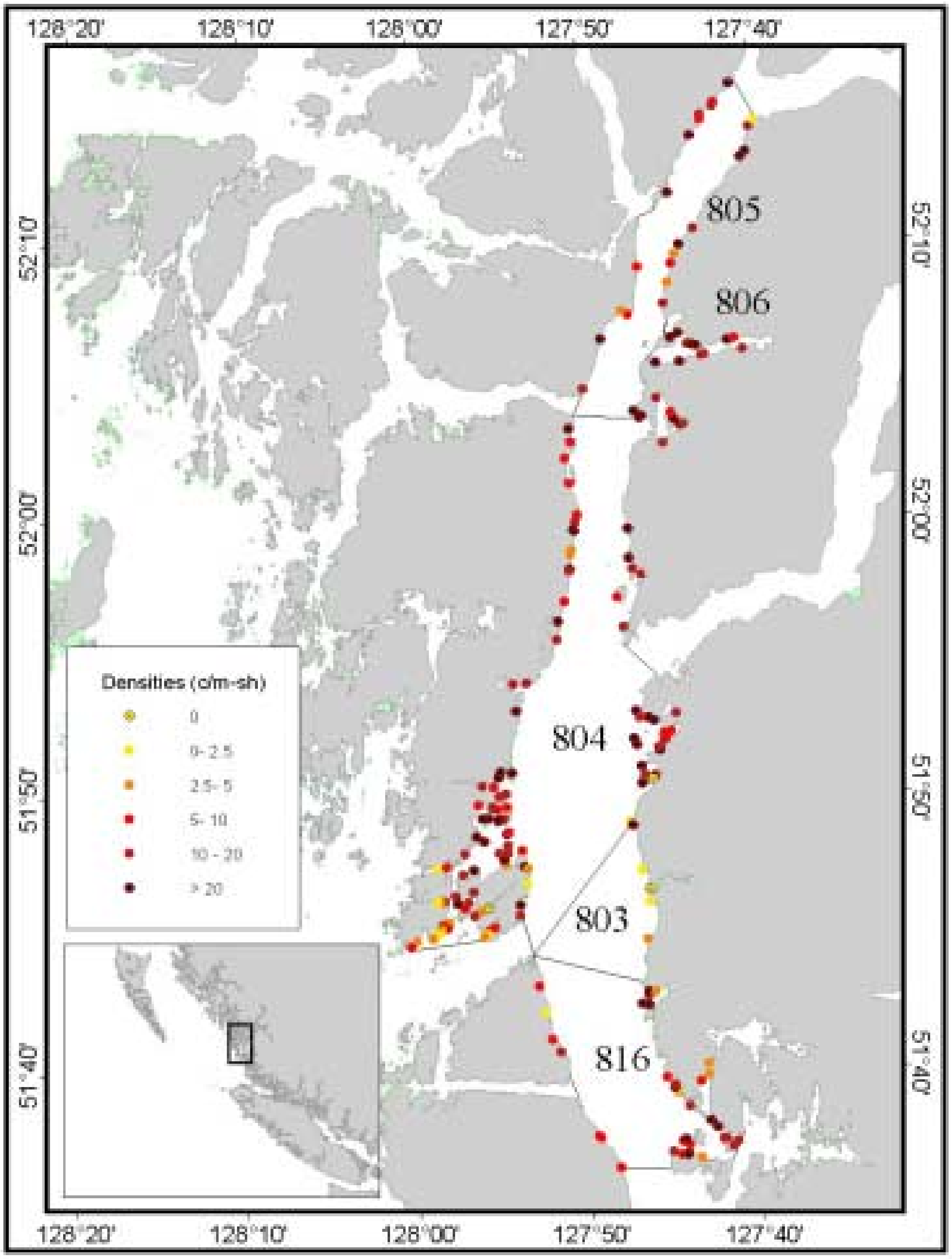

Figure 8. Transect locations, survey strata (Subareas) and associated sea cucumber densities (c/m-sh) of the Fitz Hugh Sound survey, 2002.

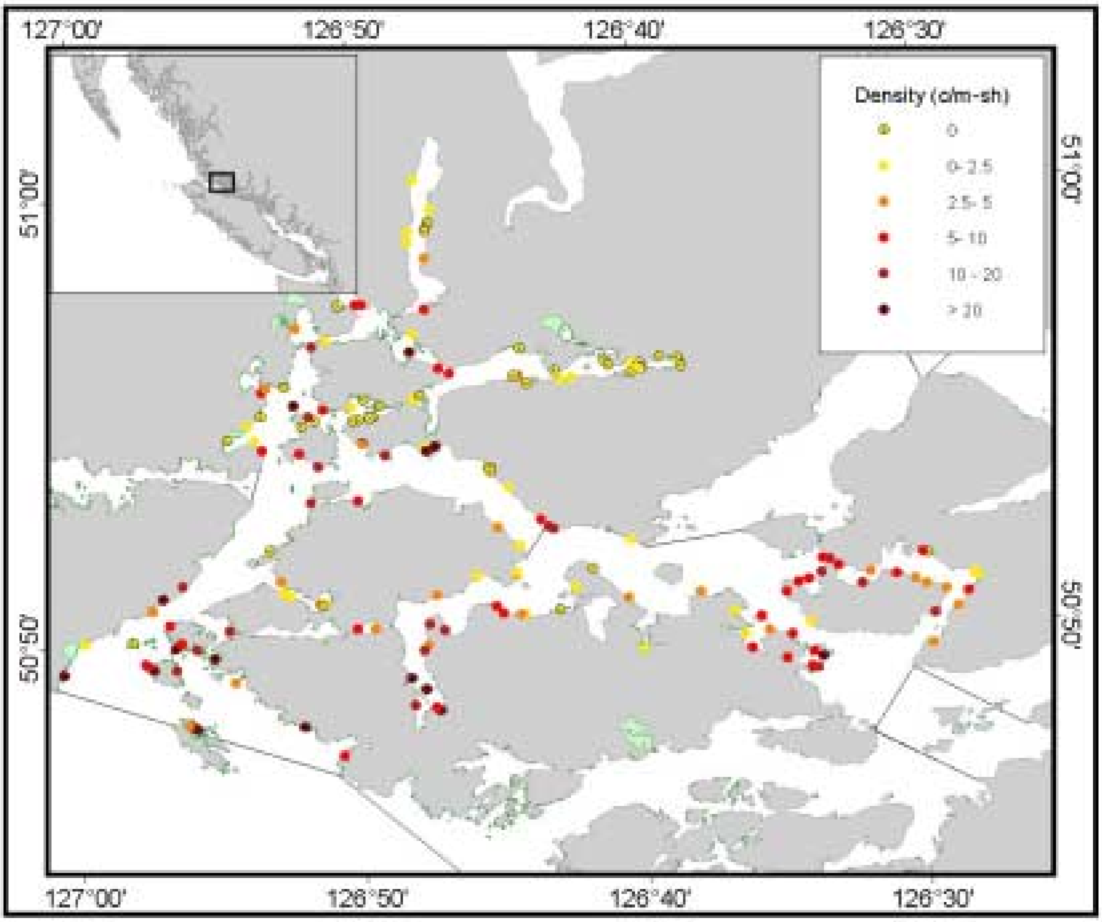

Figure 9. Transect locations and associated sea cucumber densities (c/m-sh) of the Area 12 survey, 2000.

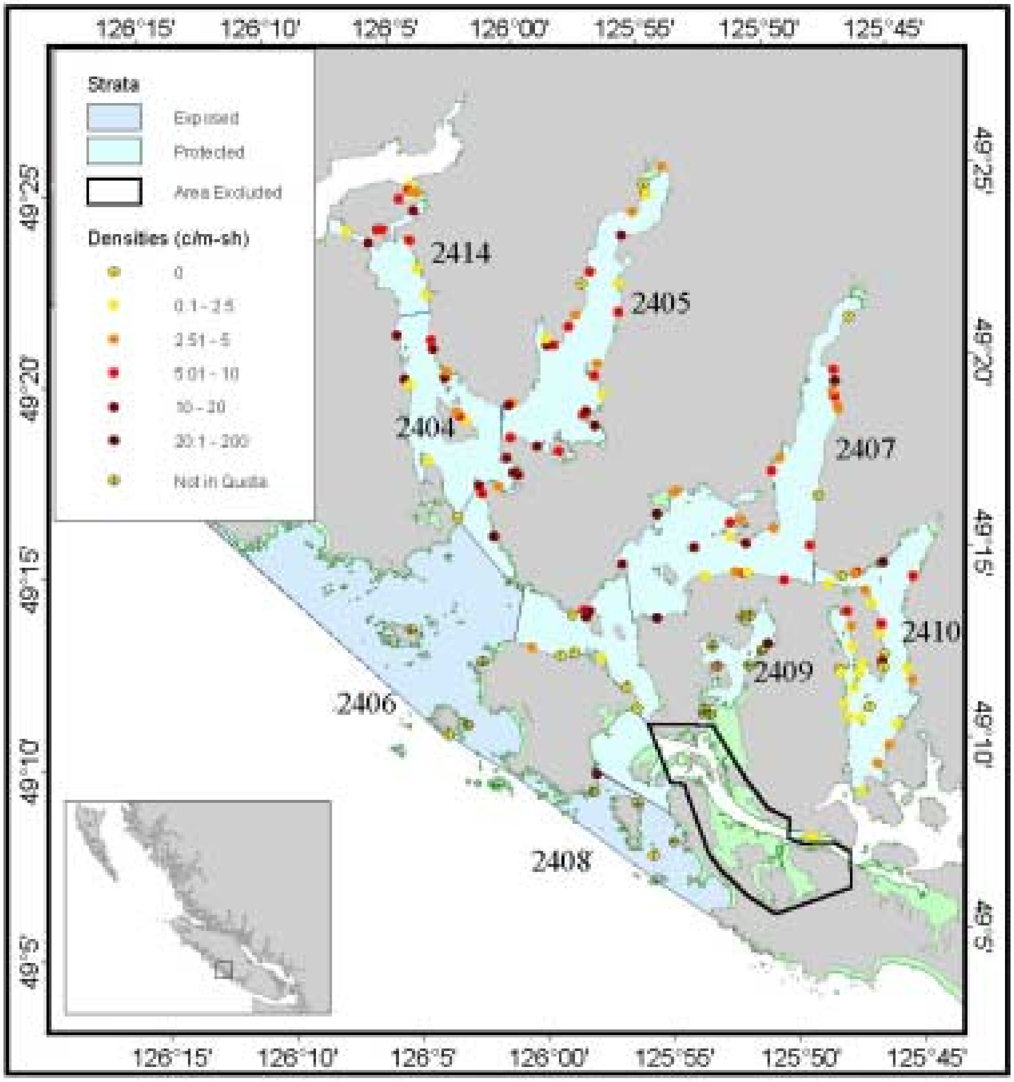

Figure 10. Transect locations, survey strata, area excluded and associated sea cucumber densities (c/m-sh) of the Tofino survey, 2001. Transect locations marked with a line or a cross (0 c/m-sh) were not included in further calculations.

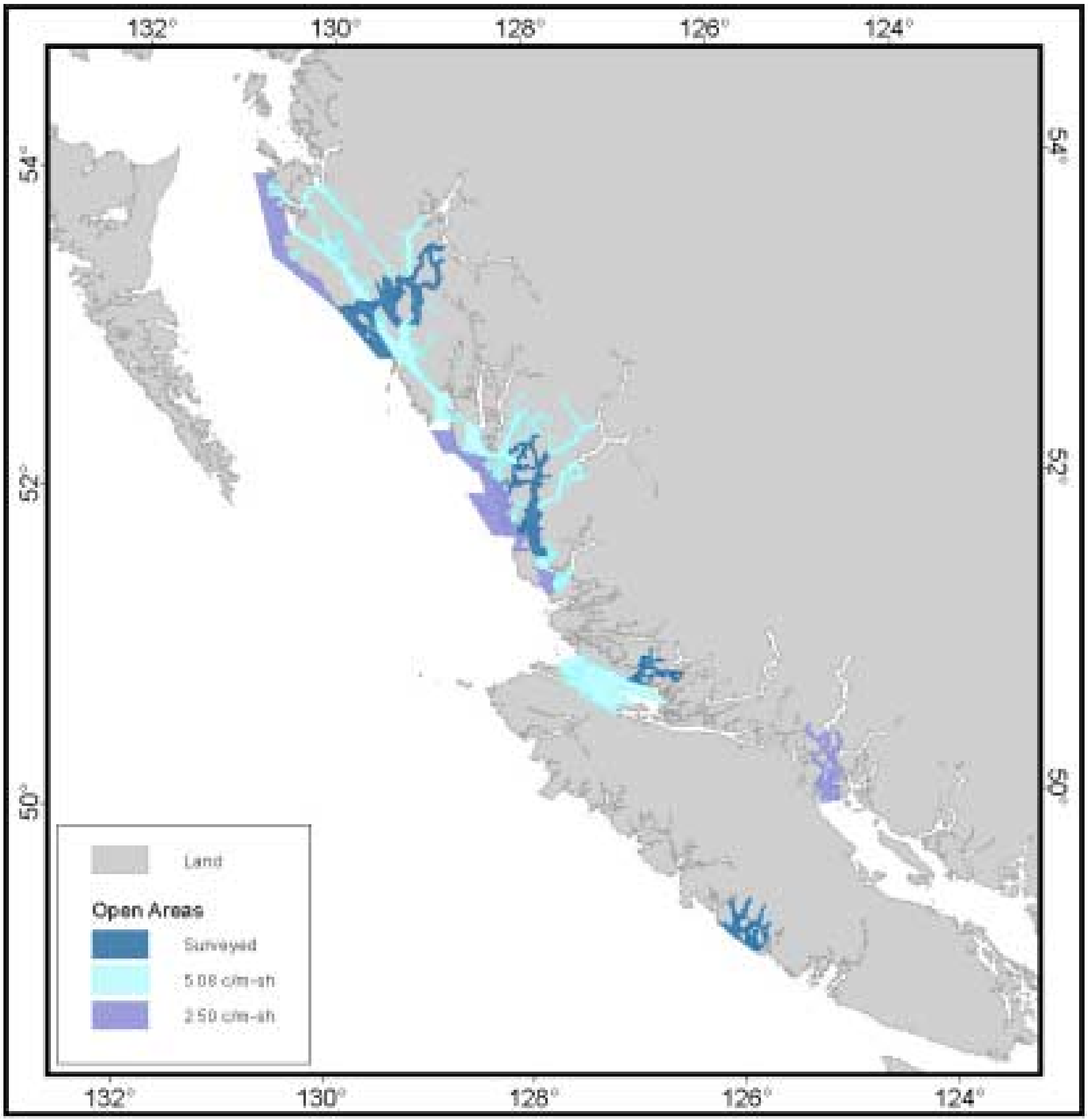

Figure 11. Recommended densities for three categories of Subarea within areas open to sea cucumber harvest. Subareas categories include surveyed, good habitat (5.08 c/m-sh) and poor habitat or area of concern (2.5 c/m-sh).

Appendix 1. Request for working paper.

Date Submitted: June 18, 2002
Individual or group requesting advice:
Juanita Rogers, DFO Shellfish Management Biologist
Proposed PSARC Presentation Date:
December 2002
Subject of Paper (title if developed):
Sea Cucumber quotas based on British Columbia survey data.
Stock Assessment Lead Author:
Claudia Hand, Shellfish Stock Assessment Division
Fisheries Management Author/Reviewer:
Juanita Rogers

Rationale for request:
Quotas in the sea cucumber fishery are based on conservative estimates of density from surveys conducted in Alaska. Since 1998, six surveys have been conducted in the open fishery areas of BC over 2,500 km of shoreline, or 30% of the area that is designated as commercial. A further 200 km of shoreline has been surveyed as part of experimental fisheries. Sufficient data exists to calculate quotas for the commercial fishery from BC surveys.

Question(s) to be addressed in the Working Paper:
What are estimates of sea cucumber density in surveyed commercial fishery areas?
What are estimate(s) of density, derived from these survey data sets that can be extrapolated to un-surveyed open fishery areas?
What are quotas for the sea cucumber fishery, based on these new estimates of density?

Objective of Working Paper:
To provide quotas for the sea cucumber fishery based on the best available data.
To provide the documentation of the parameters and procedures employed in the calculation of the quota.

Stakeholders Affected:
Sea cucumber license holders, buyers, harvesters (non-license holders) and crews, sport and FN users.

How Advice May Impact the Development of a Fishing Plan:
Required for the development of Fishing Plan.

Timing *Issues Related to When Advice is Necessary*
Required in time to write the 2003 fishing plan.