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Quota Options for the Geoduck Clam (*Panopea abrupta*) Fishery in British Columbia for 2001 and 2002

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ABSTRACT

Quota options for geoduck clams (*Panopea abrupta*, Conrad 1849) for the 2001 and 2002 fisheries were calculated using new parameter estimates, and presented by Geoduck Management Area for the North Coast Region, West Coast of Vancouver Island Region, and Inside Waters Region. The habitat-based approach was continued from previous assessments where, for each geoduck bed, virgin biomass is estimated as the product of the spatial area of geoduck beds, estimated virgin densities and mean geoduck weights. Error ranges in each parameter estimate were combined to provide a range of biomass estimates, and a harvest rate of 1% was applied to derive quota options. Past harvest levels were incorporated into the process of applying a $B_{50\%}$ limit reference point. The resulting reduction in quota was 23% and 14% of the total potential quota in 2001 and 2002 and the closing of 57 and 24 geoduck beds, respectively.

Biomass estimates and quota options are higher in each Region in 2001 and in 2002. Increases are primarily a result of generally higher estimates of geoduck bed area and, to a lesser degree, to higher estimates for mean geoduck weight and density. For 2001 and 2002, 315 ha and 374 ha of new geoduck bed were discovered. Additional increases in bed area resulted from modified bed-area scaling factors, the inclusion of beds not fished in the last rotation for logistical reasons, or the conversion from imperial to metric charts. For the 2001 fishery, recommended low, medium and high quota options are 947 t (2.1 million lb), 2406 t (5.3 million lb) and 4020 t (8.9 million lb), an average increase of 56% over the previous 1998 quotas in the same rotational area. Quota options for the 2002 fishery are 1245 t (2.7 million lb), 2875 t (6.3 million lb) and 4480 t (9.9 million lb), an increase of 49% over 1999 quotas. Given the uncertainty in parameter estimates, these quotas should be regarded as upper reference points. It is recommended that a large-scale bed verification and mapping program be initiated, that more extensive analysis of survey and fishery data be undertaken with spatial software, and that a rigorous assessment of the resource and management system be conducted.

RÉSUMÉ

Les choix de quota de panope (*Panopea abrupta*, Conrad 1849) pour les saisons de pêche 2001 et 2002, calculés d'après de nouvelles estimations des paramètres, sont présentés selon la zone de gestion de la panope des régions de la côte nord, de la côte ouest de l'île de Vancouver et des eaux intérieures. L'approche axée sur l'habitat appliquée dans les évaluations précédentes est encore utilisée; pour chaque gisement de panope, la biomasse vierge est considérée comme le produit de la superficie des gisements, des densités vierges estimées et du poids moyen de la panope. Les gammes d'erreur de chaque estimation de paramètre sont combinées pour obtenir une fourchette d'estimations de la biomasse et un taux de récolte de 1 % est utilisé pour calculer les choix de quotas. Les taux de récolte antérieurs sont inclus dans le calcul d'un point de référence limite de $B_{50\,\%}$. La réduction résultante du quota se chiffre à 23 % et 14 % du quota potentiel total pour 2001 et 2002, respectivement, et entraîne la fermeture de 57 et de 24 gisements de panope, respectivement.

Les estimations de la biomasse et les quotas calculés pour 2001 et 2002 sont plus élevés dans chaque région. Ces augmentations sont en grande partie le résultat d'estimations généralement plus élevées de la superficie des gisements de panope et, dans une moindre mesure, d'estimations plus élevées de la densité et du poids moyen de la panope. Pour 2001 et 2002, 315 ha et 374 ha de nouveaux gisements ont été identifiés. Des facteurs modifiés de mise à l'échelle de la superficie des gisements, l'inclusion de gisements non exploités lors du dernier cycle de récolte pour des raisons logistiques et l'utilisation de cartes métriques plutôt que de cartes impériales sont à l'origine d'autres augmentations de la superficie des gisements. Pour la saison de 2001, on recommande des quotas faibles, moyens et élevés de 947 t (2,1 millions lb), 2 406 t (5,3 millions lb) et 4 020 t (8,9 millions lb), soit une augmentation moyenne de 56 % par rapport aux quotas pour 1998 dans la même zone exploitée par rotation. Les choix de quota pour 2002 sont 1 245 t (2,7 millions lb), 2 875 t (6,3 millions lb) et 4 480 t (9,9 millions lb), soit une augmentation de 49 % par rapport aux quotas pour 1999. Étant donné l'incertitude entourant les estimations des paramètres, ces quotas devraient être considérés comme des points de référence maximaux. On recommande qu'un programme à grande échelle de vérification et de cartographie des gisements soit mis en oeuvre, qu'une analyse plus approfondie des données de relevés et de pêche soit menée à l'aide d'un logiciel d'analyse spatiale et qu'une évaluation rigoureuse de la ressource et du régime de gestion soit entreprise.

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1.0 INTRODUCTION

The geoduck clam (*Panopea abrupta,* Conrad 1849) fishery began in 1976 in British Columbia and has grown to be one of BC's most significant fisheries, valued at $ 33 million dollars in 1999. The fishery has been described by Cox (1979), Harbo and Peacock (1983), Farlinger and Bates (1985), Farlinger and Thomas (1988), Harbo *et al*. (1986, 1992, 1993, 1994, 1995) and Hand *et al.* (1998b, 1998c, 1998d).

Individual vessel quota management and licence limitation are the main strategies used to regulate the geoduck industry. Minimum size limits can not be applied to this fishery because, once removed, geoducks are not capable of re-burying into the substrate. Breen (1982) recommended target harvest rates to calculate quotas for the geoduck fishery, but stressed that these quotas would depend on accurate estimates of virgin biomass. Jamieson (1986) reviewed the geoduck management approach and the problems with invertebrate fishery management in general and Sloan (1985) discussed the feasibility of improving biomass estimation.

Until the 1996 fishery, quota options were calculated on a yearly basis. The Underwater Harvesters Association (UHA) requested longer-term quota projections to provide more stability and market confidence in the fishery. Balanced quotas were calculated and implemented over two-year periods for the 1997 and 1998 fisheries (Hand *et al.* 1998c) and the 1999 and 2000 fisheries (Hand *et al.* 1998d). Quota projections are not possible for longer than two years if the most current fishery and survey data are to be used.

Quotas options for each geoduck bed are calculated as the product of estimates of virgin biomass and a target harvest rate. Biomass is calculated from estimates of bed area, an estimated mean virgin density and a mean weight per individual. Quotas vary over time as new information is incorporated into calculations for virgin biomass. The objectives of this PSARC Working Paper are to update the time-series of fishery information with data from the 1998 and 1999 seasons, present new estimates of geoduck density from fishery-independent surveys and new estimates of mean geoduck weight from harvest log data, and to provide quota options by Geoduck Management Area (GMA) for the 2001 and 2002 fishing rotations (Appendix 1).

1.1 GEODUCK BIOLOGY

Geoducks are distributed from Alaska to the Gulf of California (Quayle 1970), however commercial fisheries exist only in northern Washington State, throughout British Columbia and in Alaska. Geoducks are large burrowing clams found between the intertidal and approximately 210 m (Jamison *et al.* 1984), with an average landed weight of approximately one kilogram. Individuals can be aged from growth rings using a validated procedure (Shaul and Goodwin 1982). They are among the longest-lived animals in the world, often reaching ages in excess of 100 years and with a maximum recorded age of 146 years (Breen and Shields 1983, Harbo *et al.* 1983). Geoducks grow rapidly in the initial 10 to 15 years, after which time the growth in shell length ceases while total weight increases at a slow rate through a thickening of the shell and an increase in meat weight (Harbo *et al.* 1983, Goodwin and Shaul 1984, Sloan and Robinson 1984). Estimates of natural mortality rate in British Columbia populations range from 0.01 to <0.05 (Breen and Shields 1983, Harbo *et al*. 1983, Sloan and Robinson 1984, Noakes and Campbell 1992). Geoducks begin to recruit to the fishery at age 4 and are fully recruited at 12 years (Harbo *et al*. 1983).

Adult geoducks have separate sexes. Ripe gonads are found in clams ranging from 7 to 107 years old, suggesting that individuals may be capable of reproducing over a century. Spawning occurs annually, mostly from June to July in association with increases in seawater temperature (Sloan and Robinson 1984). Larval stages have been described from hatchery programs. Females release from 7 to 10-million eggs which are fertilized and develop in the water column until settlement on the bottom within 40 to 50 days (Goodwin *et al.* 1979, Goodwin and Shaul 1984). The settled post-larvae are active crawlers and can travel along the bottom aided by a byssal thread parachute. At a shell length of approximately 2 mm, they begin to burrow into the substrate; the depth occupied is related to shell length and siphon length. At settlement and for the first two years, juvenile geoducks are vulnerable to a number of predators, including snails, sea stars, crabs (*Cancer spp*), shrimp and fishes (Goodwin and Pease 1989). Fast growing clams can bury to a refuge of 60 cm or more in two years. The end of the burrowing stage coincides with the beginning of annual reproductive activity at 7 to 8 years for males and females, respectively (Sloan and Robinson 1984).

Despite the large reproductive output of *P. abrupta* over a long life, juveniles are scarce and recruitment appears to be low. Age-frequencies do, however, show peaks of juvenile abundance (unpublished data, Breen and Shields 1983, Goodwin and Shaul 1984) which suggests that populations may be supported by recruitment pulses. Laboratory experiments indicate that geoduck embryos have relatively narrow salinity and temperature tolerance limits (Goodwin 1973).

2.0 DEVELOPMENT OF THE FISHERY AND SUMMARY OF MANAGEMENT

The fishery started in the Inside Waters of Vancouver Island in 1976, spread to the West Coast of Vancouver Island in 1979, and to the North Coast in 1980 (Figs. 1 and 2). There were initially no restrictions on the fishery and the number of licences grew quickly to 101 in 1979 when a licence moratorium was introduced. A fleet reduction was implemented between 1980 and 1981 which reduced the number of licences to 55. Annual landings and value increased steadily from 1976 to 1987 when landings peaked at 5,715 t (12.6 million lb). Cumulative landings to the end of 1999 are 67,291 t (147.9 million lb). Overall, 24 % of landings have come from Inside Waters, 43 % from the west coast of Vancouver Island and 33 % from the North Coast.

The coastwide fishing grounds have been partitioned into North Coast, West Coast and Inside Waters Regions since 1980. In 1989, each Region was subdivided into three sub-regions of approximately equal fishing area to be harvested over a three-year rotational period. The quota for sub-regions is three times the calculated annual quota. Rotational fisheries were implemented primarily for logistical reasons, for ease of monitoring of activities and harvests and concentration of assessment effort. The exception to rotational fisheries is Area 24, Clayoquot Sound, which is fished annually. Geoduck beds are logically grouped into Geoduck Management Areas (GMAs). These are opened sequentially and managed with a quota that is the sum of the quotas for the individual beds. As the fishery developed, fewer beds were grouped together into an increasing number of GMA's, in order to spread out fishing effort, find new fishing grounds and to reduce the potential for local over-harvesting (Table 1). Within GMAs, the spatial allocation of effort is determined by individual fishermen, although in the North Coast, the on-grounds observer encourages the fleet to move from a bed once its quota is taken.

Individual Vessel Quotas (I.V.Q.'s) were introduced in 1989, and landings since that time have been monitored at designated landing ports by contracted port observers. Under-reporting of fishing mortality through the discard of lower-valued dark geoducks has not been included in landing estimates. It is felt that highgrading is not as prevalent as it once was (J. Austin, president of UHA, pers. comm), however the groupings of beds into Geoduck Management Areas are arranged to reduce the market pressure to discard.

Quotas options have been calculated using fishery-independent survey data and harvest logbook data since 1994. Most quotas that have been set by fisheries managers were within the wide range of options provided for each GMA. Table 1 summarises annual quotas for the north and south coasts from 1979 to 2000.

3.0 CALCULATION OF GEODUCK QUOTAS

Three-year rotational geoduck quota options (*Q*) are calculated, on a bed-by-bed basis, as

$$Q = 3(.01B_0) \tag{1}$$

where B_0 is the virgin or unfished biomass. We continue to use an exploitation rate of 1%, at the conservative end of the range recommended by Breen (1982). This rate is applied to estimates of virgin biomass, which is consistent with the methods used in the original yield analysis.

3.1 GEODUCK BIOMASS

Virgin biomass is defined as the biomass of geoducks in a bed just prior to when it was first commercially fished, and is calculated as

$$B_0 = AD_0\,\bar{w}\,, \tag{2}$$

where A is the area (m^2) of the geoduck bed, D_0 is the estimated virgin density (#/m^2), and $\overline{w}$ is the mean geoduck weight (lb). Each of these variables has an associated level of uncertainty, which are discussed in detail in the following sections. Calculation of the uncertainty around biomass estimates follows methods in Taylor (1982) for products of variables where the uncertainties are random and independent among themselves. The coefficient of variation, or precision, of an estimate is the ratio of the error (in this case, the 95% confidence interval) of the estimate to the estimate itself. The coefficient of variation of B_0 (V_B) at the 95% level is calculated by

$$V_B = \sqrt{V_A^2 + V_D^2 + V_w^2} \tag{3}$$

where V_A, V_D and V_w are the coefficients of variation for estimates of bed area, virgin density and mean weight, respectively. The 95% confidence interval of virgin biomass for each bed is calculated as the product of V_B and B_0.

3.1.1 Geoduck Bed Area

Estimates of geoduck bed area are obtained from the charts and harvest logs provided by fishermen. The information is transcribed from the fishermen's harvest charts to a set of reference nautical charts in the form of a polygon, and assigned a unique identification number. Groupings of small geoduck beds in close proximity are frequently assigned the same identification number. As new areas are found each year, new chart polygons are drawn or existing ones extended, and the updated information is added to the database. Geoduck beds falling within contaminated waters, or in temporary or permanent closures (Table 2) were not included in quota calculations. The majority of contaminated closures are in the South Coast Inside Waters.

In the early years of the fishery, polygons were drawn to include the fishermen's marks on a chart indicating actual harvest locations, and were further extended to fit the chart depth contours of 5 m and 20 m (or 10 ft and 60 ft, depending on the chart units). Stocks deeper than 20 m or 60 ft are not included in estimates of exploitable biomass because of the technical limitations of working at that depth, while stocks shallower than 5 m or 10 ft are restricted to protect eelgrass beds. Bed mapping methods have evolved over time and polygons are no longer drawn to fit depth contours. Area estimates from more recently discovered beds are therefore more conservative. The area measurements of beds fished early in the fishery (predominantly in Inside Waters) have not been methodically reviewed and are suspected of being overestimates of the true area.

The precision of area estimates further depends on the accuracy of the information provided by fishermen, the accuracy and scale of the reference chart, and measurement error from digitizing. Interpretation of harvest logbook information by DFO personnel and the nature of the seabed itself also plays a significant role. Since bed polygons are generally drawn to contain all indicated locations of every vessel that ever fished in a bed, they may include areas of unsuitable geoduck habitat. Surveys have shown that geoducks have a patchy distribution, largely related to the distribution of substrate types (Campbell *et al*. 1996a,b; Hand *et al*. 1998a) and that, often, not all of the measured area within a defined bed contains harvestable geoduck densities. Conversely, the area of more recently discovered beds are likely to be underestimated because fishermen have not yet explored the full extent of these beds. Transect surveys and observer fishing have shown that geoduck bed areas can be both overestimated and underestimated (Hand, unpublished data).

Area estimates from individual beds have changed over time for reasons other than the growth of a bed or revision of bed boundaries. For instance, in 1997 the accumulated reference chart information was transcribed onto fresh nautical charts because the original paper charts had become tattered and distorted, and because in many cases new metric charts had become available from the Canadian Hydrographic Service. The act of re-drawing bed polygons onto fresh copies of the same chart led to minor changes in area estimates, while transcribing from imperial charts to metric versions resulted in sometimes significant differences in the area estimates. In addition, polygons have been digitized and areas calculated with a succession of GIS software over time, including Gap1, COMPUGRID, and currently ARCVIEW.

In 1992, area estimates were scaled down for beds where an overestimation of the measured area was suspected (Harbo *et al*. 1993). It was reasoned that large, lightly-harvested geoduck beds were probably poorly mapped, because it would have been physically impossible for a vessel to have explored the fill extent of the measured area. Beds with cumulative landings of 5,000 lb, 10,000 lb, 20,000 lb and 50,000 lb were reduced in size to 1 ha, 2 ha, 5 ha and 25 ha from the measured area. These coastwide thresholds were determined by finding the smallest-sized bed that produced the landing thresholds listed above. In addition, some large beds (>100 ha) were reduced by the ratio of the density removed in that bed to the overall density removed in the Management Area. By 1998, these procedures ultimately resulted in a coastwide area reduction of 2,335 ha over 221 beds.

Bed scaling methods were modified for the 1999 and 2000 fisheries (Hand *et al.* 1998d) and continued here for the 2001 and 2002 fisheries. Different scaling factors were applied to each of the Rupert, Central Coast, Queen Charolotte Strait, Inside Waters and West Coast Regions, to account for varying geoduck densities within BC (Table 3). An expected bed area (A), given an average annual landing threshold (L), is calculated from geoduck density estimates in lb/m^2 (D) and the assumed 1% exploitation rate as,

$$A = \frac{L}{D \times 0.01}. \quad (4)$$

For example, a bed in Inside Waters with an average harvest of 1000 lb per year, and with an estimated density of 1.58 lb/m^2 (0.7 geoducks/m^2 x 2.26 lb) would have an expected area of 6.32 hectares. A bed on the West Coast Region with similar production would have an expected area of only 2.47 ha because of the higher estimated density of 4.05 lb/m^2 (1.7 geoducks/m^2 x 2.38 lb).

The reduction in bed area resulting from this version of bed scaling was 166 ha (2% of total area) and 128 ha (2%) over 22 and 20 individual beds in 2001 and 2002, respectively. Application of scaling factors is a temporary solution to bed-area overestimation. Obvious mapping errors are being resolved through bed verification programs using on-board observers, and with interviews with fishermen. Use of new remote-sensing technology for substrate mapping of geoduck beds is being investigated. For all geoducks beds, an arbitrary error of plus or minus 10% of the measured (or scaled down) bed area is used to express uncertainty in this parameter estimate.

Geoduck beds are still being discovered, particularly in the north coast. In areas to be fished in the 2001 and 2002 rotations, 315 ha (3% of total area) and 374 ha (4%) were identified as beds fished for the first time in 1998 and 1999. The north coast accounted for over 60% of the new beds, in both rotations. This estimate of area for new beds is conservative, however, because new fishing locations as indicated on harvest charts are often given the same code as an existing bed if they are in close proximity. This has the unfortunate consequence of a loss of information specific to individual harvest locations, and is an aspect of the geoduck harvest database that requires attention.

3.1.2 Average Densities

Historically, estimates of geoduck density have been based on early exploratory surveys (published and unpublished data), and on information from fishermen. Early surveys are discussed by Harbo *et al*. (1986, 1992). Large-scale surveys in Washington State produced estimates of geoduck density of 0.86/m^2 over 13,678 ha (Goodwin 1978). Exploratory surveys by Cox and Charman (1980) suggested low densities of geoducks in British Columbia of 0.002 to 0.21 geoducks/m^2 over large areas (>100 ha). However, unpublished data from later surveys in 1980 and 1991 of areas on the west coast of Vancouver Island and the north coast indicated densities as high as 9.8 geoducks/m^2 . Assessments from 1991 to 1993 used average densities ranging from 1.0 to 5.0 geoducks/m^2, depending on the area (Table 3).

Transect surveys were first conducted by DFO in 1992 and 1993, the results of which were used to calculated biomass and quotas for Inside Waters in 1994 and 1995, respectively. Since then, joint surveys have been conducted by the geoduck Underwater Harvesters Association (UHA), First Nations groups and DFO, using a standardized survey design. To date, 35 surveys have been conducted in 33 locations coastwide. Survey protocols and analyses followed the methodology described in Campbell *et al*. (1998b). Quota options for the 2001 and 2002 fisheries are based on the results of 22 of these surveys (Table 4). Only a small proportion of surveys have been published, including Campbell *et al.* (1996a, 1996b, 1998a), Hand *et al.* (1998a) and Hand and Dovey (1999, 2000).

Surveys are designed to include one or more geoduck beds, as drawn on the DFO reference charts, and transects are randomly selected independently from each bed. The mean survey density (d_s) for a given bed is calculated as the ratio of sums for the number of geoducks counted (g) and the transect area (a) over all transects i, as

$$d_s = \frac{\sum_i g_i}{\sum_i a_i}. \tag{5}$$

The randomly-placed transects often fall on unproductive areas, either due to inaccurate bed mapping or because the bed truly includes patches of reef or other unsuitable substrate. The density data are consequently skewed, and non-parametric methods are used to calculate 95% confidence bounds on the mean density estimate, as described in Hand and Dovey (2000). This patchiness can result in a lower density estimate for a bed than is observed by fishermen, which can lead to skepticism on their part. However, since the bed areas used to calculate quotas include these low density patches, the overall densities derived from these surveys are appropriate for biomass calculation. Patchiness in geoduck distribution also results in wider confidence limits on the mean density estimates.

Virgin density (D_0) is calculated for each surveyed bed by adding the reduction in geoduck density as a result of harvest (hereafter referred to as 'density removed') to the survey density, as

$$D_0 = d_s + \frac{\sum_i B_i}{\overline{w}A} \tag{6}$$

where d_S is the density at the time of survey, $\sum B_i$ is the cumulative biomass removed from the bed by the fishery over the years prior to the survey ($i = 0$ *to* s), $\overline{w}$ is the mean weight of individual geoducks, and A is the best (most recent) estimate of the geoduck bed area. For cumulative biomass, landing records are not corrected for under-reporting, which is normally accomplished by applying the ratio of sales slip records to harvest log records on a Statistical Area basis. In this way, the estimate is considered conservative. Similarly, the mean weight estimate is likely conservative since it is based on the most current piece-count data from harvest logbooks. Campbell *et al.* (1998c) noted that, in an experimental plot, mean weight declined as geoduck density was reduced through fishing. The quantities B, $\overline{w}$ and A are here assumed to be calculated without error. Therefore, the upper and lower 95% confidence bounds on the mean virgin density estimate are the upper and lower bounds of d_s, plus the density removed. Errors in mean geoduck weight and bed area are later incorporated into the error of biomass estimates.

Because the 95% confidence limits around virgin density estimates are obtained by simply adding density removed to the limits for survey density, the magnitude of the difference between estimates of current biomass and reconstructed virgin biomass can be related directly to the magnitude of density removed for any given bed. Estimates of density removed range from trace amounts to as high as 400% of the surveyed density (Table 4, Figure 3). The highest estimates were from beds in PFMA 27 on the west coast of Vancouver Island and from PFMA 13 in Inside Waters. The 95% confidence intervals of survey density and virgin density will overlap, for a given bed, as long as the density removed is less than the 95% confidence interval of the mean survey density estimate. Beds where the intervals did not overlap, due to high estimates of density removed and/or very precise survey estimates, are indicated in Table 4.

Reconstructing virgin density by the method described above involves the assumption that natural mortality and recruitment are in balance. While this may be reasonable in an equilibrium situation in an unfished bed, the assumption may be invalid in a harvested bed. The impact of fishing on recruitment is not understood at this time. Violations of this assumption that would lead to overestimates of virgin density include the scenario where recruitment has been greater than natural mortality in a surveyed bed, and then estimated densities are extrapolated to unsurveyed beds where recruitment levels were not as high. The data are not available to comment on how likely this may be, however the consultative process with commercial fishermen ensures that inappropriately high quotas are not set. Assumption-violations where recruitment in a surveyed bed is exceptionally high may result in estimates of virgin density that are higher than the original density prior to harvest. These beds may be candidates for consideration of a higher exploitation rate than 1% (Campbell and Dorociez 1992).

To date, approximately 30% of the estimated area of geoduck bed, coastwide, has been surveyed. The proportion within each Region varies between 20% for west coast of Vancouver Island beds and 46% for the Queen Charlotte Islands. The rationale for the choice of survey location for surveys conducted in 1992 through to 1997 was directed by the desire to survey beds that had supported significant fisheries and were considered representative of other beds. Survey locations since 1998 have been selected by compiling candidate lists and choosing survey candidates at random. Surveys generally include more than one geoduck bed, and each one is sampled independently. Density estimates (with associated error) for individual beds (Table 4) were used to calculate biomass and quota for that bed. The overall density estimate for all beds in a survey (Table 4) was extrapolated to unsurveyed beds in the same PFMSubarea(s). For beds in Subareas where no surveys have been conducted, the density estimate from one or more surveys in the same PFMArea were averaged and extrapolated. For Statistical Areas where no surveys have been conducted, the regional mean density was used (Table 3).

The accuracy of survey results is affected by the behaviour of geoducks of retracting their siphons, so as to be undetectable at times (Goodwin 1977). While surveys attempt to correct for this with 'show factor plots' (eg. Hand and Dovey 2000), there is a high likelihood that a complete census is not obtained and therefore show factors and hence densities may be underestimated.

i) Inside Waters

A mean density of 1 geoduck/m^2 was used to derive quotas for 1991 to 1993 (Table 3). In 1994, density was reduced to 0.7/m^2, based on 1992 survey data from Marina Island (Campbell *et al*. 1996a). Survey data from Comox Bar in 1993 (Campbell *et al*. 1996b) led to a further reduction in density to 0.45 geoducks/m^2, for beds larger than 75 ha. Interestingly, a re-survey of Comox Bar five years later produced the same estimate of density (Hand, unpublished data). A survey conducted in 1995 along the shore from Oyster River to Cape Lazo in Statistical Area 14 produced density estimates of 0.17 geoducks/m^2 over a large area of 1,265 ha (Table 4). Densities of 0.16/m^2 and 0.65/m^2 were found in Area 16 at Thormanby Island in 1999. Area 12 was treated separately, with higher densities of 1 and 2 geoducks/m^2 assumed, based on reports from fishermen (Table 3).

Densities estimated from the Marina Island and Comox Bar surveys form the basis of quota calculations for southern Inside Waters except for the Oyster Bay and Thormanby areas. Beds larger than 200 ha were assumed to have a density of 0.45/m^2 and beds smaller than 200 ha were assumed to have a density of 0.7/m ^{2}. The threshold for the change in density was set to 75 ha for the low risk option and 300 ha for the high risk option (Hand *et al.* 1998c).

ii) West Coast of Vancouver Island

A mean density of 2 geoduck/m^2 was used to derive quotas for 1991 to 1993, based on the advice from fishermen that densities on the west coast were twice that or more than stocks in Inside Waters. In 1994 and 1995, the density was reduced to 1.4/m^2, double that of the new estimate of densities in Inside Waters (Table 3).

In 1995, a survey was conducted in the Elbow/Yellow Bank area, Statistical Area 24, and an estimated density of 1.8 geoducks/m^2 (1.5 - 2.2; 95% C.I.) was obtained (Hand and Dovey 1999). The number of geoducks removed by the fishery, expressed as density, was added to the survey density to estimate a virgin density of 2.4/m^2 (2.1 - 2.8). The lower 95% confidence limit of 2.1/m^2 was used to calculate quotas for 1997 and 1998 for only those beds surveyed, while quotas for all remaining areas on the west coast of Vancouver Island remained at 1.4/m^2. A survey conducted on Ahousat Bank and along the shore of Catface Range, also in Statistical Area 24, in 1997 resulted in a virgin density estimate of 1.96 geoducks/m^2 (1.44 - 2.53). Surveys in Kyuquot (Area 26) and Winter Harbour (Area 27) produced mean virgin density estimates of 1.99 (1.51 – 2.51) and 0.94 (0.78 – 1.15), respectively (Table 4). These densities were extrapolated to unsurveyed beds on the west coast in the manner described above.

iii) North Coast

Fishermen have reported the greatest densities of geoducks in the north coast (Harbo *et al.* 1986). For the 1991 fishery, some areas were assigned densities of 5 geoducks/m^2 (Table 3). Following preliminary surveys of known beds in the north coast in 1991 (Farlinger and Thomas 1991), there was concern that beds were not as large as indicated on charts and may have lower densities than previously thought. As a result, the highest densities used for quota calculations for 1992 to 1995 was 3.5 geoducks/m^2.

To date, 13 surveys have been conducted in the Central Coast and Rupert regions of the North Coast and 11 surveys in the Queen Charlotte Islands (Table 4). Virgin densities for the 2001 and 2002 fishing areas range from 1.72/m^2 to 4.30/m^2. The mean survey density for individual beds was used, where available, to calculate biomass. Averages of survey results within Subarea or Areas are extrapolated to unsurveyed beds sharing the same.

3.1.3. Average geoduck weight

Quota calculations to 1995 assumed a mean geoduck weight of 1.065 kg (2.348 lb) for all areas of the coast, based on limited sampling of geoducks collected from four sites on the West Coast, one site on the North coast and one site from Inside Waters in 1981/82 (Harbo *et al.* 1983). This estimate was revised for the 1996 fishery using data from additional and extensive market sampling in all three licence areas of the coast (Burger *et al*. 1995), and estimates varied by Statistical Area from 2.2 lb to 2.8 lb (Table 5). Mean weights for the 1997 and 1998 fisheries varied between 1.7 lb and 2.8 lb and were applied on a finer geographic scale using additional new sample data. For the 1999 and 2000 fisheries, yet more market sample data were included.

For quota calculations presented here, market sample data were abandoned as a source for calculating mean geoduck weight in favor of piece count information supplied by fishermen on harvest logs. This information has been recorded on harvest logs since 1997 and are more extensive than market sampling. Landed weight and the number of geoducks landed, by bed and validated landing, were extracted from the geoduck logbook database where true counts of the number of geoducks harvested were made (this is noted on harvest logs). Data were checked for outliers and errors and the mean and upper and lower 95% confidence intervals were calculated on a by-bed, by-subarea and by-area basis.

Confidence intervals around mean weight estimates were very wide for beds or Subareas where the sample size was small. The standard error (SE) stabilized for sample sizes greater than 10. For beds or Subareas where the sample size was less than 10, SE was estimated by using the standard error to mean ratio (SE/Mean) for cases where the sample size was greater than 25. On a by-bed basis, the SE/Mean was 0.021629 and on a by-Subarea basis the SE/Mean ratio was 0.022329. New SE's were estimated by multiplying the mean geoduck weight by the SE/Mean ratio appropriate for the spatial scale considered.

Mean weights from piece counts were not available for every geoduck bed. For those missing this information, the average weight over the Subarea or Area was assumed (Appendix 3).

3.2 HARVEST RATES

As discussed earlier, recruitment of geoduck clams is generally considered to be very low. The effect of fishing on recruitment is not known, although some evidence (Goodwin and Shaul, 1984) indicates that there may be a relationship between adult and juvenile abundance such that juveniles are less abundant in harvested areas. Conversely, there have been recent reports from commercial fishermen of high proportions of juveniles in some beds that have been heavily fished in the past. This is substantiated by some aged biological samples taken during surveys (unpublished data).

Breen (1982) estimated that quotas should be kept within 0.75 to 2.0% of the virgin biomass, depending on the stock-recruitment relationship, to achieve an equilibrium population of 50% B_0.

The negative recruitment effects of fishing noted by Goodwin and Shaul (1984) suggested using the lower end of the estimate. Results from a study in British Columbia in 1989 (Noakes and Campbell 1992) confirmed the low productivity and also suggested that the range was reasonable.

More recent PSARC working papers (Breen 1992, Campbell and Dorociez 1992) produced age-structured models and examined sustainable fishing patterns for geoduck populations in B.C. Breen (1992) suggested that the current 1% level was conservative while Campbell and Dorociez suggested that exploitation rates near 0.5% were more appropriate except where recruitment was shown to be higher, in which case 2% of the original biomass could be considered.

All of the available information indicates that geoduck productivity is low. Research projects on the west coast of Vancouver Island and Strait of Georgia, designed to examine recruitment characteristics of geoduck populations and to evaluate the sustainability of harvest, are close to maturity. Data from these projects and from biological samples collected during surveys will be analyzed to determine growth and mortality rates, rates of natural and enhanced recruitment and to monitor the effects of harvest on recruitment. Pending the results of these multi-year research projects, we continue to use the 1% harvest rate for calculating quota options.

3.3 QUOTA AMORTIZATION

In 1995, surveys began to show that biomass may have been previously overestimated, and a limit reference point or 'amortization' process was incorporated into quota calculations (Harbo *et al*. 1995. It was also recognized that overharvesting could have occurred in beds that were closer to port, better known by fishermen, more protected from exposure or of higher quality product. With the management goal of maintaining a population size of at least 50% B_0, and to compensate beds for previous overages, calculated quotas were reduced by the ratio of the number quota-years left in a 50-year cycle to the actual number of years left to fish in the 50 years since the fishery began in any given bed. Beds with greater than 50% of the estimated stock removed were closed, pending surveys and further evaluations. The process was initially applied to South Coast fishing areas in 1995 and extended to North Coast areas for the 1996 fishery (Hand *et al*. 1998b).

To produce the amortization factors for each bed, the years of quota fished (Y_F) is calculated as

$$Y_F = \left(\frac{L}{0.01(B_0)} \right) \tag{7}$$

where L is the cumulative landings (lb) by bed. The number of years of quota remaining in a 50-year cycle, Y_Q, is then $50-Y_F$. The number of actual years remaining in the 50-year cycle (Y_R) is 50 minus the number of years elapsed since the fishery began in any given bed. The amortization factor (AF) is then

$$AF = \frac{Y_Q}{Y_R} \tag{8}$$

The reduced 3-year quota for each of the low, medium and high options is simply the calculated quota (Q, from equation 1) times the amortization factor (AF).

Reported logbook landings have, especially in the early years of the fishery, been under-reported. To correct for this, reported landings by bed are factored by the ratio of fishslip landings (1976-1988) or validated landings (1989 - 1997) to logbook landings, summed over statistical area.

4.0 QUOTA OPTIONS for 2001 AND 2002

Amortization factors were applied to 330 beds and 190 beds, respectively, for the 2001 and 2002 fisheries. For the North Coast fishery in 2001, there was a reduction of quota amounting to roughly 800,000 lb, or a 28% reduction from total potential quota (Table 6). Percentage reduction for the West Coast and Inside Waters are 18% and 33% of potential, with the total for all regions of over 2 million lb or 23%. Reduction due the amortization process was less in 2002, at 1.6 million lb (14% of potential).

Quota options, by GMA, are presented in Table 7 for the 2001 fishery and Table 8 for the 2002 fishery. Also listed are the number of beds, bed area, mean density and geoduck weight, estimated virgin biomass and total adjusted landings. These are summarized by region and compared to the quotas and geoduck areas from the last rotation for each region (Table 9). Note that the comparison is made to the previously calculated quota, rather than to the final quota set by managers in the annual fishing plan.

For the fishery year 2001, suggested quota options are:

2001	Low	2,087,311 lb
	Medium	5,304,828 lb
	High	8,863,343 lb

The 2001 mid quota option is 57% greater than the recommended quota in 1998 of 3,387,548 lb. The difference is due partly to an increase in mean geoduck weight estimates for the Inside (2.4 lb compared to 2.1 lb), but primarily due to an increase in estimate of the spatial area of geoduck beds. Increases in bed area estimates stem from four issues: an increase of over 1000 ha in the estimate of GMA 14A2 as a result of surveying (accompanied by a decrease in density); less dramatic scaling factors (65 ha compared to 575 ha in 1998); persistent mapping error of geoduck bed locations, and the recent re-drawing and digitizing the bed polygons onto new metric charts from imperial charts. While the 1000 ha increase is entirely supportable, there are clearly substantial problems with estimates of geoduck bed areas in the Strait of Georgia.

The 70% increase in calculated medium quota for the West Coast is largely due to an increase in the overall mean density estimate from $1.4/m^2$ to $1.7/m^2$ from recent surveys. There were also a consistent increase in most estimates of bed area due to modified scaling criteria, results from bed-verification observer fishing, re-processing of reference charts, and from new or expanded beds. Increases in biomass estimates affects the amortization factor which, in turn, has an amplifying effect on the calculated quota.

Although the medium calculated quota for the North Coast in 2001 is 50% greater than calculated for 1998, it is actually a 10% drop from what was actually implemented in the management plan. The feedback from fishermen on those calculated quotas was clear, and managers chose a TAC towards the higher end of the range presented by stock assessment. The increase in mean density from $1.6/m^2$ to $2.05/m^2$ and small increases in bed area are responsible for the increase in medium quota estimate.

For the fishery year 2002, suggested quota options are:

2002	Low	2,744,247 lb
	Medium	6,339,453 lb
	High	9,876,049 lb

The medium quota option is 50% higher than that calculated for 1999. The majority of the increase came from the North Coast (Rupert) where geoduck bed area increased through the discovery of new or expanded beds and from descaling previous area estimates. Estimated densities on a bed-by-bed basis were also generally higher, leading to higher biomass estimates and lower amortization factors. West Coast quota estimates were higher, primarily due to an increase in estimated density from $1.4/m^2$ to $1.7/m^2$ and to 101 ha of new bed area. Inside Waters were higher due mainly to an increase in mean weight estimates and to minor increases in bed area through expansion of existing beds, new beds and de-scaling of some bed areas.

5.0 DISCUSSION

The quota calculations presented here include all available data, applied in as fine a geographic scale as possible, using database and geospatial software. Harvest information is accurate, complete and received in a timely fashion, and the information base on mean geoduck weight, density and spatial area continues to grow.

The present fishing pattern of the British Columbia geoduck fishery can be considered as conservative in a number of areas. Breen (1982) suggested that a harvest rate of 0.75-2.0% B_0 would result in a stabilised population at 50% B_0. The 1% harvest rate adopted in B.C. is towards the lower end of this range. In contrast, fisheries scientists in Washington State recommend a harvest rate of 2.7% of exploitable biomass, based on an $F_{40\%}$ fishing strategy (the estimate was actually modelled on B_0, but they use current biomass because of the difficulty of back-calculating B_0) (Bradbury and Tagart 2000). As a further measure, the fishery is managed over a 50-year time horizon wherein quotas are reduced to evenly spread the remainder of $0.5B_0$ through to the end of the 50-year period. Geoducks beds are closed when 50% of the virgin biomass has been harvested, and remain so until surveyed and evaluated. This 'amortization' resulted in quotas roughly 25% less than the potential quota.

Rather than allowing a fishing-down phase with higher than sustainable harvest rates until the population approaches the desired equilibrium level, the conservative harvest rate of 1% has been used since early days. Previous overestimates in biomass and consequently quotas, and the disproportionate allocation of fishing effort within large GMA's likely had the same effect as a fishing-down phase, and current biomass is expected to be lower than pre-fishery levels. One would therefore expect the present exploitation rate to be higher than 1%. Indeed, the pre-amortized quotas range from 1.04% to 4.00% of the current biomass, and average 1.3% over the 137 surveyed beds. The application of amortization factors, however, reduces the quotas to levels that are only 0.8% of the current biomass.

The estimation of virgin biomass is also conservative in a number of ways. Transect surveys are designed to measure densities within beds as they are identified on reference charts, but the data collected often include observations on unsuitable substrate. Since we can assume that many or most geoduck beds contain similar mixtures of habitat suitability, estimated densities that are extrapolated to unsurveyed beds are appropriate and not based on 'hot spot' measurements. The show factor data collected during surveys are probably underestimated, which would lead to a lower density estimate. The landing estimates used in the process of back-calculating virgin biomass are based on logbook records alone, and are conservative in that no corrections are made for under-reporting. When defining the boundaries for geoduck beds from fishers logbook charts, they are constrained by the 20m or 60ft depth contour, whereas geoducks are know to be distributed and fishable to greater depths. The conduct of the fishery, as well, is conservative in that efficiency is reduced both by geoduck show factors that are less than 100%, and by loss of visibility from sediment disruption.

Although these recommended quotas may be regarded as conservative, they are only as good as their component parts. With the collection of data from over 35 surveys coastwide, density estimates are beginning to stabilize within regions, particularly in the Prince Rupert and Central Coast regions. The low density estimates for most of the beds in the Strait of Georgia are extrapolated from surveys conducted in 1992 and 1993, however other surveys conducted in the Strait have consistently produced density estimates of less than $1.0/m^2$. Density estimates from the Queen Charlotte Islands (ranging from 0.6 to 3.1 geoducks/m^2) and the west coast of Vancouver Island (0.94 – 2.36) are more variable, and extrapolation to unsurveyed beds can be done with less confidence. Survey data have not yet been analysed to examine the relationship of density to habitat characteristics, and so extrapolations to unsurveyed beds are performed blindly, with the assumption that beds in closer proximity are more alike than ones further distant.

The estimates of geoduck bed area are the most problematic. Fishermen submit hard-copy markings on nautical charts showing the location of harvest activities, usually with an 'X'. The accumulation of these marks, along with some assumptions regarding the similarity of areas immediately adjacent, are used to define bed boundaries. Compounding the error inherent with that system is the imprecision of the nautical charts themselves. Ironically, the beds closest to home are the least well defined. Because the fishery first started in the Strait of Georgia and early logbook reports of bed locations were of lower quality than at present, we have a legacy of poorly defined bed locations for Inside Waters fishing areas. When the fishery expanded to the remote north coast, it was done so only on condition that an on-grounds observer, paid for by industry, be present to monitor activities. The on-grounds observer provides excellent information, and north coast geoduck beds are, in comparison, fairly well defined. In an effort to deal with over-estimated area and produce quota options that were more appropriate according to fishermen, arbitrary down-scaling was employed. The application of scaling factors, while preventing overharvest in poorly defined beds, effectively masks the issue of bad data. Until there is an improvement in the spatial mapping of beds, the problem will perisist.

Because of the substantial increase in calculated quotas and the uncertainty in some of the parameter estimates, the quota options presented in this paper should be regarded as upper reference points rather than targets. In particular, the medium option for Inside Waters for 2001 is over double the TAC that was set for 2000 and the three previous years. Total allowable catches (TACs) since 1996 have been steady at approximately 4 M lb (Table 1) and, in general, TAC's for the Inside Waters and West Coast have been lower than the medium option while the North Coast TAC has been set higher than the medium option. If the same regional TAC's are maintained in 2000, they will be lower than the low quota option South Coast regions and somewhere in the mid range for the North Coast. If higher quotas are requested by industry, quota recommendations for the north coast are considered reasonably accurate and indicate that there is room for expansion, especially the Rupert area. Managers may want to alter the boundary between Rupert and Central Coast sub-regions because of the large difference in quotas between rotation years 1 and 2.

6.0 RECOMMENDATIONS

Coastwide quota options recommended for the 2001 fishery are 2.1, 5.3 and 8.9 million lb (947, 2406 and 4020 t). Quota options recommended for the 2002 fishery are 2.7, 6.3 and 9.9 million lb (1245, 2875 and 4480 t). Given the uncertainty in parameter estimates, fishery managers should treat the quota options as upper reference points. For north coast fisheries, an adjustment in the boundary between the Rupert and Central Coast sub-regions is required in order to balance the quotas between years. An increase in north coast quotas seems supportable.

Recommendations for further research or analysis include:

1. Review and systematic mapping of geoduck beds, using remote sensing equipment and interviews with fishermen.
2. Spatial analysis of survey information to examine relationships with local-scale habitat characteristics and fishery history, and classification of beds by productivity.
3. A rigorous assessment of the resource and management system and an evaluation of the response of geoduck populations to fishing.

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Table 1. Summary of annual quotas (10^3 lb.) and the number of quota management areas (brackets) from 1979 to 1999 in the geoduck clam fishery, 1979 to 2000.

	South Coast						North Coast								Coast	Total
Year	Inside Waters		West Coast V.I.		Subtotal		QCI		Prince Rupert		Central Coast		Subtotal		Total (lb)	Quota Units
1979	-		-		4,500.0	(1)	-		-	-	-	-	3,500.0	(1)	8,000.0	(2)
1980	1,700.0	(5)	2,800.0	(3)	4,500.0	(8)	-		-	-	-	-	3,500.0	(1)	8,000.0	(9)
1981	876.0	(7)	3,125.0	(3)	4,001.0	(10)	600.0	(3)	575.0	(3)	950.0	(5)	2,175.0	(11)	6,176.0	(21)
1982					---------Coastwide quota set-------										6,500.0	(1)
1983	1,000.0	(1)	3,500.0	(1)	4,500.0	(2)	650.0	(1)	350.0	(1)	1,000.0	(1)	2,000.0	(3)	6,500.0	(5)
1984	1,500.0	(6)	3,100.0	(6)	4,600.0	(12)	650.0	(2)	350.0	(1)	1,000.0	(1)	2,000.0	(3)	6,600.0	(15)
1985	1,650.0	(10)	2,900.0	(9)	4,550.0	(19)	650.0	(3)	500.0	(1)	850.0	(1)	2,000.0	(4)	6,550.0	(23)
1986	2,025.0	(11)	3,500.0	(11)	5,525.0	(22)	1,350.0	(5)	850.0	(3)	1,050.0	(3)	3,250.0	(11)	8,775.0	(33)
1987	1,850.0	(13)	3,950.0	(14)	5,800.0	(27)	1,235.0	(6)	800.0	(3)	1,510.0	(7)	3,545.0	(16)	9,345.0	(43)
1988	1,750.0	(11)	3,350.0	(16)	5,100.0	(27)	950.0	(5)	800.0	(1)	1,725.0	(8)	3,475.0	(16)	8,575.0	(43)
1989	1,920.0	(4)	3,360.0	(5)	5,280.0	(9)	closed		closed		3,520.0	(7)	3,520.0	(7)	8,800.0	(16)
1990	1,920.0	(5)	3,360.0	(8)	5,280.0	(13)	closed		3,520.0	(5)	closed		3,520.0	(5)	8,800.0	(18)
1991	1,620.0	(10)	2,835.0	(12)	4,455.0	(22)	2,970.0	(19)	closed		closed		2,970.0		7,425.0	(41)
1992	1,377.0	(16)	2,295.0	(21)	3,672.0	(37)	closed		closed		2,639.3	(24)	2,639.3	(24)	6,311.3	(61)
1993	1,117.0	(7)	1,852.5	(13)	3,022.5	(20)	closed		2,340.0	(27)	closed		2,340.0	(27)	5,362.5	(47)
1994	900.0	(15)	1620.0	(15)	2,520.0	(30)	2,430.0	(32)	closed		closed		2,430.0	(32)	4,950.0	(62)
1995	924.3	(16)	1,176.0	(25)	2,100.8	(41)	closed		closed		2,520.9	(38)	2,520.9	(38)	4,621.7	(79)
1996	959.6	(10)	812.0	(16)	1,771.6	(26)	closed		2,288.4	(43)	closed		1,863.2	(43)	4,060,0	(69)
1997	648.0	(20)	1,224.0	(16)	1,872.0	(36)	2,088.0	(47)	closed		closed		2,088.0	(47)	3,960.1	(83)
1998	648.1	(23)	1,080.1	(22)	1,728.2	(45)	closed		closed		2,235.0	(49)	2,235.0	(49)	3,960.8	(94)
1999	648.0	(13)	1,080.2	(15)	1,728.2	(28)	closed		2,232.4	(52)	closed		2,232.4	(52)	3,960.6	(80)
2000	648.0	(18)	1,080.0	(15)	1,728.0	(33)	2,232.0	(64)	closed		closed		2,232.0	(64)	3,960.0	(97)

Table 2. Listing of geoduck beds that are closed due to contamination, marine parks, sea otter and whale reserves and First Nations.

Stat Area	Sub Area	Bed Code	Description	Bed Area (ha)	Estimated Density (#/m^2)	Estimated Biomass (lb)	Reason for Closure
North Coast							
1	2	3	DADENS	1.9	1.35	66,287	Contaminated
1	2	4	LANGARA/PARRY PASSAGE	0.7	1.35	25,416	Contaminated
1	2	5	CLOAK BAY	0.7	1.35	24,042	Contaminated
2	1	1	SKIDIGATE MISSION	81	1.35	3,027,288	First Nations
2	1	3	SHINGLE BAY	30	1.35	1,125,850	Contaminated
2	1	4	ROBBER ISLAND	1.6	1.35	59,000	Contaminated
2	1	5	TRANSIT ISLAND	3.8	1.35	125,095	Contaminated
2	1	6	ONWARD POINT	6.1	1.35	229,651	Contaminated
2	13	3	N OF DOLOMITE NARROWS	2.4	1.35	89,679	Park
2	16	1	S OF DOLOMITE NARROWS	19	1.35	697,169	Park
Inside Waters							
12	16	3	HARDY BAY SE DUVAL IS	76.8	1.35	244,279	Contaminated
12	16	11	BEAVER HBR	44	1.68	1,948,571	Contaminated
12	16	13	E THOMAS PT - AIRPORT	20	1.68	697,895	First Nations
13	3	1	GOWLAND HBR - MAY IS	3.5	0.7	64,672	Marine Park
13	3	2	S GOWLLAND IS	2.1	0.7	38,731	Marine Park
13	13	1	DREW HARBOUR	23	0.7	415,811	Contaminated
13	15	1	N MARINA IS	81	0.7	1,430,083	DFO Research
13	15	2	S MARINA IS	235	0.45	2,569,317	DFO Research
13	15	6	MANSONS LANDING	29	0.7	491,775	Contaminated
14	8	1	DEEP BAY	12	0.7	227,937	Contaminated
14	8	2	MUD BAY	8.5	0.7	158,589	Contaminated
14	8	4	SHIPS PT	16	0.7	305,466	Contaminated
14	11	2	UNION POINT	15	0.7	386,556	Contaminated
14	11	4	GARTLEY POINT	16	0.7	428,262	Contaminated
15	1	1	S WESTVIEW	53	0.7	870,391	Contaminated
15	3	8	MITTLENATCH IS	8.7	0.7	142,619	Marine Park
17	17	7	E MUDGE IS	90	0.7	1,128,104	DFO Research
19	8	1	PATRICIA BAY	104	0.7	1,313,171	Contaminated
19	8	2	COLES BAY	17	0.7	214,694	Contaminated
29	5	4	CORDERO PT	2.8	0.7	41,822	Marine Protected Area

Table 2, cont'd.

Stat Area	Sub Area	Bed Code	Description	Bed Area (ha)	Estimated Density (#/m^2)	Estimated Biomass (lb)	Reason for Closure
West Coast							
23	4	7	S FLEMMING	4.4	1.7	174,382	Bamfield Marine Stn
23	5	2	MARBLE COVE	6.7	1.7	245,651	Bamfield Marine Stn
23	5	13	SW FLEMING	8.3	1.7	303,688	Bamfield Marine Stn
23	5	14	MID W. SHORE FLEMING IS	7.8	1.7	286,167	Bamfield Marine Stn
23	8	6	S BRABANT - N PEACOCK CH	6.3	1.7	408,663	Bamfield Marine Stn
23	8	7	NE CLARKE IS	6.5	1.7	420,987	Bamfield Marine Stn
23	8	8	E TURRET IS	3.2	1.7	209,521	Bamfield Marine Stn
23	11	4	UCLUELET HBR ENTRANCE	0.6	1.7	18,739	Contaminated
24	1	2	HESQUIAT HBR	10	1.8	423,451	First Nations
24	6	6	WHITESAND COVE	13	2.16	748,300	Marine Park
24	6	18	AHOUS BAY	3.0	2.16	118,611	Whale Sanctuary
24	6	30	S OF ROBERT PT	7.9	2.16	430,068	DFO Research
24	6	31	DUNLAP IS	12	2.27	664,154	DFO Research
24	6	35	AHOUS BAY	1.6	2.16	87,545	Whale Sanctuary
24	7	5	N RICHIE BAY	1.3	2.16	70,361	DFO Research
24	9	1	VAN NEYEL CHNL	39	1.7	1,313,352	Contaminated
24	9	2	TOFINO	6.4	1.7	217,144	Contaminated
26	6	5	SOUTH WALTERS IS	3.9	1.99	184,143	Contaminated
26	6	9	INSIDE ROLSTON IS	2.7	1.99	111,899	Contaminated
26	7	1	N OF CHECKAKLIS IS	34	1.7	1,259,595	Sea Otter Reserve
26	7	2	BUNSBY'S BATTLE BAY - NW OF BUNSBY IS	6.2	1.7	233,584	Sea Otter Reserve
26	7	3	SW OF THEODORE PT	5.1	1.7	187,258	Sea Otter Reserve
26	7	4	ACOUS PENN - CUTTLE ISLAND	12	1.7	473,200	Sea Otter Reserve
26	7	5	WEST OF BATTLE BAY	3.4	1.7	126,760	Sea Otter Reserve
26	10	2	SW NASPARTI INLET	12	1.7	477,421	Sea Otter Reserve
26	10	3	NORTH OF CAMEL IS	14	1.7	561,052	Sea Otter Reserve
26	10	4	NASPARTI INLET WEST	8.9	1.7	377,719	Sea Otter Reserve
26	10	5	NASPARTI INLET EAST	18	1.7	717,779	Sea Otter Reserve
26	10	8	NW JACKOBSON PT	5.1	1.7	208,915	Sea Otter Reserve
26	10	9	ACOUS PENN NORTH	14	1.7	572,069	Sea Otter Reserve

Table 3. Summary of overall geoduck densities (#/m²), averaged by region, used to calculated quotas from 1991 to 2002 for beds without measured densities. Values in brackets are the number of individual surveys upon which the estimate is based.

	REGION					
YEAR	**INSIDE WATERS** **PFMA: 13 to 19, 28, 29**	**QUEEN CHARLOTTE STRAIT** **PFMA 12, (ptn.)**	**W. COAST VANCOUVER IS.** **PFMA: 23 to 27**	**PRINCE RUPERT** **PFMA: 3 to 6**	**CENTRAL COAST** **PFMA: 7 to 10**	**QUEEN CHARLOTTE ISLANDS** **PFMA: 1, 2**
1991	1.0	1.0	2.0	-	-	3.5, 5.0
1992	1.0	1.0	2.0	-	3.5, 5.0	-
1993	1.0	1.0	2.0	3.5	-	-
1994	0.7	0.7	1.4	-	-	1.0, 3.0, 3.5
1995	0.45, 0.7	1.0, 2.0	1.4	-	3.5	-
1996	0.45, 0.7	-	1.4	1.8	-	-
1997	0.45, 0.7	1.8 **(1)**	1.4	-	-	1.6
1998	0.45, 0.7	1.7 **(1)**	1.4 2.1 **(1)**	-	2.3 **(1)**	-
1999	0.45, 0.7	-	1.4 1.77 **(2)**	1.57 **(3)** 2.18 **(2)**	-	-
2000	0.45, 0.7	-	1.4 1.77 **(2)**	-	-	1.35 **(9)**
2001	0.45, 0.7	1.51 **(2)**	1.7 **(4)**	-	2.05 **(6)**	-
2002	0.45, 0.7	-	1.7 **(4)**	2.37 **(7)**	-	-

Table 4. Estimates of surveyed geoduck density with 95% confidence bounds, density removed (D_R) and re-constructed virgin density, by individual bed and for overall survey area. Geoduck management area (GMA) and number of transects surveyed in each bed (n) are shown. Survey results are provided for areas in the 2001 and 2002 fishery rotations only. An asterix indicates a bed where confidence intervals of survey and virgin density do not overlap.

Survey Area	Year	Area	Sub Area	Bed Code	GMA	n	Survey Density (#/m^2) Mean	Survey Density (#/m^2) 95%CB	D_R (#/m^2)	Virgin Density (#/m^2) Mean	Virgin Density (#/m^2) 95% CB
Dundas Islands	1998	3	1	1	PRE5	11	1.31	0.79 - 2.19	0.38	1.69	1.17 - 2.57
	1998	3	1	3	PRE4	19	2.27	1.47 - 3.11	0.38	2.65	1.85 - 3.49
	1998	3	1	4	PRE3	17	2.02	1.00 - 2.96	0.38	2.40	1.38 - 3.34
	1998	3	1	7	PRE5	4	3.44	2.51 - 4.57	0.38	3.82	2.89 - 4.95
	1998	3	1	8	PRE5		3.44	2.51 - 4.57	0.38	3.82	2.89 - 4.95
	1998	3	1	9	PRE6	5	0.94	0.56 - 1.35	0.38	1.32	0.94 - 1.73
	1998	3	1	11	PRE3	8	2.31	0.98 - 3.76	0.38	2.69	1.36 - 4.14
						64	**1.93**	**1.53 - 2.39**	**0.38**	**2.31**	**1.91 - 2.77**
Principe Channel	1997	5	13	1	PRD5	7	2.49	1.39 - 3.71	0.02	2.51	1.41 - 3.73
	1997	5	13	3	PRD5	6	0.63	0.26 - 1.06	0.02	0.65	0.28 - 1.08
	1997	5	13	4	PRD4	24	2.62	1.87 - 3.52	0.02	2.64	1.89 - 3.54
	1997	5	13	6	PRD4		2.62	1.87 - 3.52	0.02	2.64	1.89 - 3.54
	1997	5	13	8	PRD4	14	2.56	1.51 - 3.59	0.02	2.58	1.53 - 3.61
	1997	5	13	9	PRD4	3	2.36	0.00 - 6.07	0.02	2.38	0.02 - 6.09
	1997	5	13	10	PRD5	6	0.51	0.23 - 0.75	0.02	0.53	0.25 - 0.77
						60	**2.16**	**1.69 - 2.78**	**0.02**	**2.18**	**1.71 - 2.80**
Moore Islands	1998	106	2	1	PRA14	9	0.98	0.35 - 1.59	0.07	1.05	0.42 - 1.66
	1998	106	2	2	PRA14	15	4.58	2.51 - 6.82	0.07	4.65	2.58 - 6.89
	1998	106	2	3	PRA14	14	4.37	2.31 - 6.55	0.07	4.44	2.38 - 6.62
	1998	106	2	6	PRA14	3	10.20	5.09 - 16.17	0.07	10.27	5.16 - 16.24
						41	**4.23**	**3.05 - 5.60**	**0.07**	**4.30**	**3.12 - 5.67**
Griffith Harbour	1995	5	20	1	PRD8,9	**33**	**2.20**	**1.60 - 3.00**	**0.45**	**2.65**	**2.05 - 3.45**

Survey Area	Year	Area	Sub Area	Bed Code		GMA	n	Survey Density (#/m^2) Mean	Survey Density (#/m^2) 95%CB	D_R (#/m^2)	Virgin Density (#/m^2) Mean	Virgin Density (#/m^2) 95% CB
Otter Pass	1996	6	9	1		PRB1	5	1.62	1.22 - 2.10	0.39	2.01	1.61 - 2.49
	1996	6	9	5		PRB1	16	0.87	0.25 - 1.99	0.05	0.92	0.30 - 2.04
	1996	6	9	7		PRB1	8	1.98	0.54 - 3.26	0.31	2.29	0.85 - 3.57
	1996	6	9	14		PRB2	4	3.68	2.05 - 5.99	0.06	3.74	2.11 - 6.05
	1996	6	9	21		PRB1	6	1.93	0.25 - 4.54	0.06	1.99	0.31 - 4.60
							39	**1.65**	**1.16 - 2.22**	**0.19**	**1.84**	**1.35 - 2.41**
Rennison Island	1997	6	11	1		CCD1a	5	0.89	0.32 - 1.96	0.15	1.04	0.47 - 2.11
	1997	6	11	2		CCD1b	16	1.73	1.19 - 2.38	0.15	1.88	1.34 - 2.53
Anderson Islands	1997	6	13	12		PRA3	12	0.55	0.17 - 0.99	0.15	0.70	0.32 - 1.14
	1997	6	13	16		PRA4	3	1.71	0.70 - 2.92	0.15	1.86	0.85 - 3.07
	1997	6	13	17		PRA4	3	2.37	0.99 - 4.20	0.15	2.52	1.14 - 4.35
	1997	6	13	18		PRA4	9	1.52	0.66 - 2.62	0.15	1.67	0.81 - 2.77
	1997	6	13	23		PRA3	2	0.69	0.00 - 3.22	0.15	0.84	0.15 - 3.37
Laredo Channel	1997	6	14	1		CCD2	14	4.76	0.19 - 9.31	0.15	4.91	0.34 - 9.46
	1997	6	14	3		CCD1c	29	3.81	1.62 - 5.84	0.15	3.96	1.77 - 5.99
	1997	6	14	4		CCD2	5	2.26	0.36 - 5.02	0.15	2.41	0.51 - 5.17
							98	**1.88**	**1.41 - 2.46**	**0.15**	**2.03**	**1.56 - 2.61**
Weeteeam Bay	1995	6	13	1		PRA10	3	3.14	1.36 - 5.93	0.31	3.45	1.67 - 6.24
	1995	6	13	4		PRA9	11	1.46	0.65 - 2.75	0.43	1.89	1.08 - 3.18
	1995	6	13	8		PRA11	3	0.98	0.74 - 1.36	0.34	1.32	1.08 - 1.70
	1995	6	13	9		CCD7	4	1.61	0.84 - 2.76	0.5	2.11	1.34 - 3.26
	1995	6	13	10		PRA12	1	1.61	0.84 - 2.76	0.5	2.11	1.34 - 3.26
	1995	6	13	25	*	PRA11	1	0.98	0.74 - 1.36	0.34	1.32	1.08 - 1.70
	1995	6	13	26	*	PRA12	4	0.98	0.74 - 1.36	0.34	1.32	1.08 - 1.70
	1995	6	17	1		CCD7	2	1.61	0.84 - 2.76	0.5	2.11	1.34 - 3.26
Clifford Bay	1996	6	13	2	*	PRA8	5	0.83	0.55 - 1.21	0.41	1.24	0.96 - 1.62
	1996	6	13	3	*	PRA8	7	0.83	0.55 - 1.21	0.41	1.24	0.96 - 1.62
	1996	6	13	6		PRA7	4	0.54	0.28 - 0.79	0.15	0.69	0.43 - 0.94

Survey Area	Year	Area	Sub Area	Bed Code		GMA	n	Survey Density (#/m²) Mean	95%CB	D_R (#/m²)	Virgin Density (#/m²) Mean	95% CB
(Clifford Bay cont'd.)	1996	6	13	7		PRA8	8	0.78	0.36 - 1.63	0.17	0.95	0.53 - 1.80
	1996	6	13	11		PRA5	8	1.71	0.32 - 3.63	0.36	2.07	0.68 - 3.99
	1996	6	13	13		PRA6	10	1.38	0.2 - 3.35	0.16	1.54	0.36 - 3.51
	1996	6	13	14		PRA6	10	2.70	0.99 - 4.41	0.63	3.33	1.62 - 5.04
	1996	6	13	15		PRA5	6	2.00	0.09 - 3.64	0.2	2.20	0.29 - 3.84
							87	**1.48**	**1.12 - 1.88**	**0.34**	**1.82**	**1.46 - 2.22**
Kitasu Bay	1994	6	18	2		CCD4	4	3.47	2.5 - 4.45	0.01	3.48	2.51 - 4.46
	1994	6	18	3		CCD4	5	3.47	2.5 - 4.45	0.01	3.48	2.51 - 4.46
	1994	6	18	4		CCD4	3	0.78	0.17 - 1.17	0.00	0.78	0.17 - 1.17
	1994	6	18	5		CCD4	5	3.47	2.5 - 4.45	0.01	3.48	2.51 - 4.46
	1994	6	18	6		CCd4	4	3.47	2.5 - 4.45	0.01	3.48	2.51 - 4.46
Swindle Island	1994	6	16	1		CCD9	19	1.73	0.72 - 3.02	0.22	2.04	1.03 - 3.33
	1994	6	16	2		CCD5	7	1.73	0.72 - 3.02	0.22	2.04	1.03 - 3.33
W Price Is	1994	6	17	2	*	CCD8	3	1.44	1.1 - 1.78	0.56	2.00	1.66 - 2.34
	1994	7	31	1		CCD10	9	0.98	0.51 - 1.58	0.33	1.31	0.84 - 1.91
	1994	7	31	2		CCD11	10	1.76	1.1 - 2.39	0.75	2.51	1.85 - 3.14
							84	**1.69**	**1.02 - 2.40**	**0.31**	**2.00**	**1.33 - 2.71**
McMullin Group	1994	7	18	1-4,7		CCA1,2,3	25	1.27	0.77 - 1.88	0.42	1.69	1.19 - 2.30
Goose/Wurtele	1995	7	8,9,12	1		CCB3,4,5a	64	1.25	0.33 - 2.43	0.47	1.72	0.80 - 2.90
	1995	7	25	1,3,4		CCA9,10		1.25	0.33 - 2.43	0.47	1.72	0.80 - 2.90
	1995	7	32	1,5	*	CCB7,8		1.25	0.33 - 2.43	0.47	1.72	0.80 - 2.90
Bardswell/Prince	1996	7	18	5,9,11		CCA2,4	74	2.02	1.30 - 2.91	0.38	2.40	1.68 - 3.29
	1996	7	19,20	1		CCB9,11		2.02	1.30 - 2.91	0.38	2.40	1.68 - 3.29
	1996	7	23	2		CCB12		2.02	1.30 - 2.91	0.38	2.40	1.68 - 3.29
	1996	7	24	1		CCB12		2.02	1.30 - 2.91	0.38	2.40	1.68 - 3.29
	1996	7	25	17,18,21		CCA5,A6b		2.02	1.30 - 2.91	0.38	2.40	1.68 - 3.29
							163	**1.62**	**0.85 - 2.57**	**0.43**	**2.05**	**1.28 - 3.00**

Survey Area	Year	Area	Sub Area	Bed Code		GMA	n	Survey Density (#/m²) Mean	Survey Density 95%CB	D_R (#/m²)	Virgin Density (#/m²) Mean	Virgin Density 95% CB
Hakai Pass	1998	7	27	21,24		CCC2		1.65	1.24 - 2.13	0.4	2.05	1.64 - 2.53
	1998	8	1	1		CCC3		1.65	1.24 - 2.13	0.4	2.05	1.64 - 2.53
	1998	8	2	1-4,6,7		CCC1,3,4		1.65	1.24 - 2.13	0.4	2.05	1.64 - 2.53
	1998	8	4	1-4,7-9		CCC1		1.65	1.24 - 2.13	0.4	2.05	1.64 - 2.53
							104	**1.65**	**1.24 - 2.13**	**0.4**	**2.05**	**1.64 - 2.53**
Duncan Island	1995	12	11	1 - 14	*	**12A1**	**103**	**0.98**	**0.75 - 1.25**	**0.35**	**1.33**	**1.10 - 1.60**
Goletas Channel	1994	12	16	2		12B3	15	1.43	0.67 - 2.47	0.24	1.67	0.91 - 2.71
	1994	12	16	3		12B3	11	1.19	0.58 - 1.87	0.16	1.35	0.74 - 2.03
	1994	12	16	4	*	12B3	18	1.39	0.89 - 2.01	0.95	2.34	1.84 - 2.96
	1994	12	16	5		12B3	23	1.44	0.82 - 2.33	0.47	1.91	1.29 - 2.80
	1994	12	16	6		12B3	10	0.79	0.38 - 1.3	0.16	0.95	0.54 - 1.46
							77	**1.28**	**0.96 - 1.66**	**0.4**	**1.68**	**1.36 - 2.06**
Marina Island	1992	13	15	1	*	**13B**	**73**	**0.27**	**0.27 - 0.27**	**0.46**	**0.73**	**0.73 - 0.73**
Comox Bar	1998	14	10	1	*	**14B**	**17**	**0.31**	**0.22 - 0.40**	**0.14**	**0.45**	**0.36 - 0.54**
Oyster Bay	1995	14	13	1,5		**14A1,2**	**55**	**0.17**	**0.13 - 0.23**	**0.04**	**0.21**	**0.17 - 0.27**
Thormanby Island	1999	16	1	1		16D	9	0.16	0.12 - 0.20	0.02	0.18	0.14 - 0.22
	1999	16	2	1		16D	26	0.65	0.49 - 0.85	0.02	0.67	0.51 - 0.87
							35	**0.52**	**0.39 - 0.69**	**0.02**	**0.54**	**0.41 - 0.71**

Survey Area	Year	Area	Sub Area	Bed Code		GMA	n	Survey Density (#/m²) Mean	Survey Density 95%CB	D$_R$ (#/m²)	Virgin Density (#/m²) Mean	Virgin Density 95% CB
Ahousat	1997	24	6	2,7		**24B3,B4**	**28**	**1.72**	**1.20 - 2.29**	**0.24**	**1.96**	**1.44 - 2.53**
Elbow/Yellow Bank	1995	24	6	26	*	24A4	2	1.73	1.31 - 2.18	0.54	2.27	1.85 - 2.72
	1995	24	6	27	*	24A4	9	1.11	0.85 - 1.48	0.54	1.65	1.39 - 2.02
	1995	24	6	31	*	24A4	6	1.73	1.31 - 2.18	0.54	2.27	1.85 - 2.72
	1995	24	6	32		24A6c	16	1.51	0.92 - 2.12	0.54	2.05	1.46 - 2.66
	1995	24	7	2	*	24A6a	11	2.51	2.2 - 2.8	0.54	3.05	2.74 - 3.34
							44	**1.82**	**1.49 - 2.16**	**0.54**	**2.36**	**2.03 - 2.70**
Kyuquot	1998	26	1	1	*	26B	21	1.16	0.55 - 1.77	1.04	2.20	1.59 - 2.81
	1998	26	1	3		26B	6	0.28	0.05 - 0.71	0.04	0.32	0.13 - 0.65
	1998	26	6	13		26A	2	0.21	0.02 - 0.54	0.08	0.29	0.06 - 0.72
							29	**0.95**	**0.47 - 1.47**	**1.04**	**1.99**	**1.51 - 2.51**
Winter Harbour	1996	27	2	1	*	27D	10	0.09	0.01 - 0.15	0.13	0.22	0.14 - 0.28
	1996	27	2	3		27D	3	0.36	0.00 - 1.11	0.06	0.42	0.06 - 1.17
	1996	27	2	6		27B	2	0.05	0.02 - 0.12	0.03	0.08	0.05 - 0.15
	1996	27	3	2	*	27C	19	0.36	0.20 - 1.28	0.68	1.04	0.88 - 1.28
	1996	27	3	3	*	27C	11	0.42	0.17 - 0.70	0.35	0.77	0.52 - 1.05
	1996	27	3	4	*	27C	6	0.26	0.03 - 0.56	1.04	1.30	1.07 - 1.59
	1996	27	7	2		27A	12	1.02	0.37 - 1.63	0.13	1.15	0.50 - 1.76
	1996	27	7	3		27A	7	0.65	0.28 - 0.96	0.30	0.95	0.58 - 1.26
	1996	27	7	4		27A	6	1.42	0.18 - 2.68	0.40	1.82	0.58 - 3.08
	1996	27	7	5		27A	8	2.10	0.83 - 3.53	0.54	2.64	1.37 - 4.07
Overall							84	**0.57**	**0.41 - 0.78**	**0.37**	**0.94**	**0.78 - 1.15**

Table 5. Summary of mean individual geoduck weight (lb), averaged over Statistic Area, for fishery years 1995 to 2002.

Stat Area	1995	1996	1997/1998	1999/2000	2001/2002
3	-	2.765	-	2.685	2.256
4	-	2.765	-	2.685	2.613
5	-	2.765	2.683	2.685	2.455
6	2.348	2.765	2.848	2.526	2.443
7	2.348	-	2.55	2.572	2.533
8	2.348	-	2.55	2.572	2.738
9	2.348	-	2.55	2.572	2.378
10	2.348	-	2.55	2.572	2.090
12	2.348	2.396	2.308	2.308	2.552
13	2.348	-	2.233	2.225	2.763
14	2.348	2.227	2.233	2.234	2.704
15	-	-	2.2	2.199	2.355
16	-	2.227	-	2.075	2.082
17	-	-	1.664	1.664	2.201
23	2.348	-	2.409	2.409	2.538
24	2.348	2.474	2.424	2.392	2.401
26	-	2.474	-	2.389	2.208
27	2.348	-	2.388	2.389	2.226
29	-	-	-	2.075	2.059

Table 6. Reduction of geoduck quota (lb) resulting from the application of amortization factors or by the imposition of $B_{50\%}$ limit reference point, by fishing year and region.

Fishing Year	Region	Reduction of Quota (lb) Through Amortization	Through bed closure	Total	% of Potential Quota
2001	North Coast	684,180	114,107	798,287	28
2001	West Coast	729,847	334,343	1,064,190	18
2001	Inside Waters	339,145	155,270	494,415	33
	All	**1,753,172**	**603,720**	**2,356,892**	**23**
2002	North Coast	425,461	56,376	481,837	12
2002	West Coast	382,646	414,578	797,224	16
2002	Inside Waters	166,152	45,392	211,544	15
	All	**974,259**	**516,346**	**1,490,605**	**14**

Table 7. **The number of geoduck beds, estimated bed area (ha), range in density (#/m²) and weight (lb) estimates, estimated virgin biomass (lb), total adjusted landings (lb) and low, medium and high quota options, by geoduck management area (GMA), for the 2001 geoduck fishery. An asterix next to a GMA indicates that some or all of the geoduck beds therein have been surveyed.**

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m²)	Weight Range (lb)	Estimated Biomass (lb)	Total Landings (lb)	Quota Options (lb)		
								Low (lb)	Med (lb)	High (lb)
INSIDE WATERS										
12A1*	Balaclava	14	75	1.1 – 2.4	2.66 – 3.27	2,872,918	1,144,014	17,124	38,425	66,509
12A2	Walker Group	5	26	1.51	2.53	981,461	166,923	10,076	20,243	30,410
12B1a	East Bates Passage	3	40	1.51	2.53	1,526,590	21,805	29,873	45,277	60,677
12B1b	West Bates Passage	4	36	1.51	2.53	1,392,599	32,566	27,239	41,241	55,243
12B2	Northern Goletas Channel	5	60	1.51	2.53	2,283,587	537,546	15,213	41,749	68,285
12B3*	Southern Goletas Channel	4	46	0.95 – 2.34	2.65 – 3.37	2,338,360	1,662,800	0	4,225	40,651
12B4*	Masterman Island	4	23	1.68	2.65	1,039,268	424,216	7,979	16,392	25,570
12C	False Head	8	201	0.45 – 0.7	2.44 – 2.65	2,529,589	372,397	33,924	62,778	94,778
12D	Malcolm Island/Black Bluff	7	105	0.7	2.03 – 2.26	1,585,685	725,181	11,042	19,552	29,163
12E	Trinity Bay	2	17	0.7	2.53 – 2.66	304,040	383,987	426	732	1,038
12F	Malcolm Island east and south	4	37	0.7	2.35 – 2.63	635,240	35,329	11,084	18,730	26,376
12G	Mainland Inlets	12	56	0.7	2.53	989,953	17,213	17,359	28,967	40,571
13E	Remainder of 13 (Mittlenatch)	1	14	0.7	3.1	301,691	4,166	5,427	9,051	12,675
14A1*	Williams Beach Bluff to Cape Lazo	1	389	0.21	2.48	2,023,670	783,606	0	23,610	63,835
14A2*	Williams Beach Bluff to Shelter Pt.	1	1324	0.21	2.52	6,999,766	1,552,117	70,260	201,493	286,108
14B	Comox Bar	4(1)	944	0.45 – 0.7	2.25 – 2.73	10,295,339	3,481,367	22,179	162,490	357,883
14C1	North Baynes Sound	1	30	0.7	3.72	1,164,882	276,303	7,007	28,929	46,615
14C2	Mid Baynes Sound	1	28	0.7	2.37	632,081	106,303	6,060	17,478	27,184
14C3	South Baynes Sound	5	49	0.7	2.28 – 3.06	961,454	87,222	16,653	28,110	38,535
17A1	Icarus Point/Lantzville shore	2	74	0.7	2.11 – 2.42	1,225,162	208,153	10,176	36,755	54,275
17A2	Nanoose Bay to Blunden Pt.	1	59	0.7	2.24	931,736	216,355	6,075	25,812	39,399
17A3	Nanoose Bay	1	18	0.7	2.74	350,547	94,861	0	7,782	15,397
17B	Balance of area 17	3	18	0.7	2.26	291,177	515,195	929	2,015	3,101
17B1	North Gabriola	6	153	0.7	2.26 – 2.73	2,433,077	386,522	29,508	67,052	99,636
17B2	Pylades Channel	7	38	0.7	1.79 – 2.28	533,790	371,588	1,259	4,511	7,791
17B3	Ladysmith	6	101	0.7	1.55 – 2.28	1,400,387	1,068,148	1,564	7,650	27,886
17B4	Gulf Islands	18	91	0.7	1.55 – 2.28	1,315,977	274,573	13,938	27,218	42,211
29	Outside Valdes and Galiano Islands	1	20	0.7	2.06	281,060	121,497	0	1,190	4,835
Total Inside Waters		**131**	**4,072**	**0.21 – 2.4**	**1.55 – 3.72**	**49,228,537**	**14,957,380**	**372,122**	**982,246**	**1,652,469**

Table 7, cont'd.

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m^2)	Weight Range (lb)	Estimated Biomass (lb)	Total Landings (lb)	Quota Options (lb) low	mean	high
WEST COAST										
23A	Maggie River	7	183	1.7	1.73 – 2.62	6,579,550	2,457,439	5,792	82,840	205,937
23B	Toquart Bay/Pipestem Inlet	8	54	1.7	2.25 – 3.58	2,328,826	68,666	42,601	69,205	95,222
23C	Mayne Bay/Stopper Is.	10	130	1.7	2.07 – 3.49	5,486,762	1,408,793	37,811	106,518	194,195
23D	Pinkerton Islands	23	183	1.7	2.11 – 4.38	8,061,306	1,512,009	95,081	191,772	297,828
23E	Chain Group	15	99	1.7	1.66 – 2.86	3,728,359	1,370,811	25,642	53,166	89,367
24A2a	Yarksis	1	142	1.7	2.42	5,857,023	1,806,117	631	37,413	74,195
24A2b	E. Father Charles Channel	3	147	1.7	2.77 – 3.13	7,352,833	397,923	47,078	73,528	99,979
24A3	Tonquin/Echachis	3	97	1.7	2.77	4,576,310	337,371	29,221	45,646	62,069
24A4*	Epper/Dunlap	9 (3)	206	1.65 – 2.27	2.49 – 2.65	10,959,347	1,165,877	60,540	103,264	144,750
24A5	Lemmens Inlet	3	86	1.7	1.57 – 2.01	2,920,083	921,504	2,944	15,838	33,561
24A6a*	Yellow Bank	2 (1)	130	2.16 – 3.05	2.49	9,663,800	2,074,579	54,425	91,136	118,899
24A6b	E. Maurus Channel	1	17	2.16	2.31	830,684	135,944	4,510	8,307	11,189
24A6c*	Elbow Bank	2 (1)	90	2.05 – 2.16	2.53	4,683,355	2,625,633	1,541	2,413	18,757
24B1a	Outside – north	5	458	2.16	2.53 – 3.32	29,201,804	5,645,492	139,513	291,823	389,399
24B1b	Outside – south	6	274	2.16	1.45 – 2.54	14,037,442	1,424,631	86,161	137,485	188,810
24B2	Coomes Bank/Calmus Pass	3	215	2.16	2.53 – 2.87	13,001,926	3,437,995	24,287	87,948	154,491
24B3*	Ahousat	1	339	1.96	1.92	12,763,406	2,289,872	50,908	127,634	179,944
24B4	Russell Channel	4	331	1.96 - 2.16	2.31 – 3.17	17,081,255	2,331,518	97,958	165,667	228,051
24C1	Sydney Inlet	11	118	1.7	2.08 – 2.84	4,356,953	872,832	18,185	32,189	50,495
24C2	Exposed	3	40	1.7	2.49 – 3.49	2,111,540	126,884	19,980	33,001	45,940
24D1	Inlets	19	90	1.7	2.52	3,868,865	591,517	16,665	29,742	42,892
24D2	Indian Island	3	41	1.7	2.52	1,773,016	56,616	11,770	17,719	23,668
27A*	Quatsino Sound	7 (4)	103	0.94 – 2.64	1.64 – 3.07	3,029,104	790,093	2,842	57,599	135,346
27B*	Cliffe Point to Lawn Point	6 (1)	91	0.08 – 0.94	2.16 – 2.35	1,446,306	232,358	18,756	37,909	56,146
27C*	Forward Inlet	3 (3)	128	0.77 – 1.3	2.03 – 2.71	2,727,345	1,851,512	0	0	12,223
27D*	Kains Island	3 (2)	66	0.22 – 0.94	1.80 – 2.25	413,078	245,060	1,280	2,626	5,952
27E	San Josef Bay	1	128	1.7	2.22	4,829,539	403,381	84,566	143,671	194,534
27F	Sea Otter Cove	2	17	1.7	2.22	657,990	229,754	658	6,513	13,984
27H	Klaskino Inlet	10	225	1.7	2.06 – 2.90	9,164,497	2,054,813	89,291	193,038	305,249
27I	Klaskish Inlet	15	104	1.7	2.11 – 2.70	4,310,460	1,547,338	17,176	60,017	110,083
Total West Coast		**189**	**4,334**	**0.08 – 3.05**	**1.45 – 4.38**	**197,802,762**	**40,414,333**	**1,087,812**	**2,305,627**	**3,583,153**

Table 7, cont'd.

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m^2)	Weight Range (lb)	Estimated Biomass (lb)	Total Landings (lb)	Quota Options (lb) low	mean	high
CENTRAL COAST										
CCA1*	McMullin Group	2	39	1.69	2.19 – 2.50	1,493,121	592,690	5,137	14,216	38,742
CCA2*	Stryker Island	5 (3)	46	1.69 – 2.4	1.85 – 2.48	2,119,954	251,944	18,270	53,150	87,929
CCA3*	Tribal Group	4 (2)	37	1.69 – 2.05	2.34 – 3.46	1,683,170	396,505	5,287	32,441	62,811
CCA4*	Admiral Group	6 (1)	7	2.05 – 2.4	2.37 – 3.3	450,507	126,976	1,753	6,341	14,365
CCA5*	Prince Group	4 (2)	6	2.05 – 2.4	2.22 – 4.62	404,811	85,859	3,005	7,568	14,492
CCA6a	Latta Island	2	16	2.05	2.56 – 3.05	971,914	175,328	2,621	22,917	43,213
CCA6b*	Hunter Channel	3 (1)	13	2.05 – 2.4	2.54 – 3.27	807,284	100,525	6,597	21,054	35,511
CCA7a	N McNaughton Group	6	40	2.05	2.50 – 3.28	2,252,740	440,057	12,237	51,751	92,747
CCA7b	S McNaughton Group	2	32	2.05	2.56 – 2.58	1,674,531	185,134	14,238	50,022	78,295
CCA7c	Kinsman Inlet	1	7	2.05	2.95	393,394	65,290	1,351	8,570	15,789
CCA8	Simmonds Group	5	53	2.05	2.44 – 3.09	2,906,873	1,059,213	2,138	30,684	95,824
CCA9*	Goose Island North	2 (1)	16	1.72 – 2.05	2.20 – 2.87	719,552	51,162	6,412	21,079	34,589
CCA10*	Goose Island South	3 (2)	39	1.72 – 2.05	1.57 – 2.13	1,363,189	155,595	1,845	37,950	71,885
CCA11	Spider Island	5	31	2.05	2.10 – 3.17	1,689,130	763,485	2,292	10,941	32,944
CCA12a	Typhoon Is	2	23	3.5	2.252.50	1,819,958	711,198	0	18,284	50,397
CCA12b	S Edna Island	1	27	3.5	2.18	2,097,284	623,830	3,027	39,826	76,626
CCA12c	Triquet Island	2	40	3.5	2.42 – 2.57	3,531,132	1,115,172	740	58,584	118,316
CCA12d	Anne Islands	4	28	2.05	2.50 – 2.97	1,679,557	284,258	20,535	49,458	68,918
CCA13a	Ronald Island	2	43	2.05	2.28 – 2.81	2,100,483	1,192,947	0	2,825	30,779
CCA13b	S Manley Is	1	26	2.05	2.38	1,247,789	83,696	21,587	37,434	53,280
CCA14	Serpent Group	4	8	2.05	1.99 – 2.65	379,613	103,293	3,529	5,754	10,407
CCA15a	Kittyhawk Group	2	8	2.05	2.69 – 2.73	459,396	163,802	3,255	5,953	10,107
CCA15b	Kildidt Sound	7	13	2.05	2.44 – 3.16	779,040	37,746	8,422	22,265	36,107
CCB1	Mathieson Channel	3	11	2.05	2.04 – 2.28	485,112	43,462	3,941	12,908	21,845
CCB2	Moss Passage	3	29	2.05	2.06 – 2.45	1,376,462	117,445	13,979	39,601	64,097
CCB3*	Ivory Island	1	33	2.05	1.96	1,303,341	437,203	0	17,389	47,950
CCB4*	Berry Inlet	1	9	2.05	2.05	371,120	9,681	4,868	11,134	17,399
CCB5a*	West Seaforth Channel	4 (1)	23	2.05	2.04 – 2.22	1,031,974	238,682	5,214	18,550	38,589
CCB5b	East Seaforth Channel	8	15	2.05	2.04 – 2.85	710,980	56,472	6,588	19,771	32,604
CCB6	St. John Harbour	3	15	2.05	2.73 – 2.74	850,724	37,871	10,192	25,116	39,929
CCB7*	Cape Mark	1	18	5.00	2.98	2,702,069	1,051,302	0	28,100	71,577
CCB8*	Godfrey Rock	1	47	2.05	2.47	2,399,132	212,424	46,039	71,974	97,908
CCB9*	Princess Alice Island	2 (1)	10	2.05 – 2.4	2.98	672,527	90,032	5,711	16,999	28,286

Table 7, cont'd.

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m²)	Weight Range (lb)	Estimated Biomass ('000 lb)	Total Landings (lb)	Quota Options (lb) low	Quota Options (lb) mean	Quota Options (lb) high
CCB10	Thompson Bay	3	7	2.05	1.81 – 2.57	341,572	90,275	911	5,586	12,752
CCB11*	Houghton Islands	1	21	2.4	2.50	1,245,574	130,025	14,599	36,957	55,254
CCB12*	Joassa Ch./Raymond Pass	4 (2)	5	2.05 – 2.4	2.58 – 2.99	318,609	39,209	3,041	7,804	13,017
CCC1*	Nalau Passage	10 (8)	58	2.05	1.92 – 2.88	2,939,325	661,566	25,606	56,739	94,418
CCC2*	Sterling Island West	8 (2)	53	2.05	2.20 – 3.06	2,824,209	623,677	20,982	60,768	101,782
CCC3*	Choked Passage	4	89	2.05	2.85 – 4.44	5,736,782	938,026	71,985	163,008	235,894
CCC4*	South Hakai Passage	3 (2)	14	2.05	2.29 – 3.28	803,111	32,145	14,898	23,864	32,589
CCC5a	West Fitz Hugh Sound	2	4	2.05	2.44 – 2.63	235,169	11,613	2,502	6,555	10,609
CCC5b	East Fitz Hugh Sound	2	8	2.05	2.50	402,128	33,276	3,420	10,605	17,787
CCC6	Rivers Inlet	8	62	2.05	2.20 – 2.95	2,944,857	272,731	25,711	84,626	138,027
CCC7	Calvert Island North	2	5	2.05	2.10 – 2.59	261,345	10,768	3,096	7,823	12,253
CCC8	Calvert Island South	2	23	2.05	2.00 – 2.50	1,160,470	522,054	0	5,785	30,373
CCC9	Smith Inlet North	4	31	2.05	1.70 – 2.46	1,277,840	362,280	3,836	20,958	46,446
CCC10	Smith Inlet South	5	30	2.05	1.70 – 2.30	1,212,082	173,178	8,895	29,683	51,476
CCD1a*	Rennison Island	1	11	2.03	2.42	546,396	75,074	5,266	15,641	24,277
CCD1b*	North Aristazabal Is	1	23	1.88	2.33	998,104	262,488	0	18,676	37,967
CCD1c*	Mid Aristazabal Is	2 (1)	41	2.03 – 3.96	2.50 – 2.81	3,448,271	189,411	28,681	102,897	170,221
CCD2*	East Laredo Channel	4 (2)	24	2.03 – 4.91	2.00 – 3.00	1,898,687	120,925	7,763	54,873	109,173
CCD3	Laredo Inlet	12	59	1.87 – 2.37	1.58 – 2.95	2,848,636	724,213	28,191	59,018	94,135
CCD4*	Kitasu Bay	4 (3)	47	1.09 – 3.78	2.20 – 2.62	2,900,104	137,350	40,683	85,001	126,185
CCD5*	Larkin Point	1	27	2.04	2.45	1,381,054	533,807	0	12,814	53,279
CCD6	South Laredo Channel	7	45	1.87 – 2.37	1.87 – 2.75	2,253,155	134,927	33,292	62,956	93,327
CCD7*	Southwest Aristazabal Is.	2	20	2.11	2.35 – 2.54	1,045,481	366,764	0	11,125	34,047
CCD8*	Rudolf Bay	1	6	2.00	2.47	297,775	188,493	0	0	614
CCD9a	Outer Higgins Pass, north	1	15	2.04	2.45	759,580	293,594	0	7,047	29,304
CCD9b	Outer Higgins Pass, south	1	25	2.04	2.62	1,312,000	507,116	0	12,173	50,615
CCD10*	West Price Island South	1	29	2.07	2.41	1,468,449	272,068	11,397	34,662	57,926
CCD11*	West Price Island Middle	1	28	2.51	2.51	1,732,897	616,950	0	18,712	46,362
CCD12	Milbanke Sound South	1	23	2.05	2.19	1,018,288	79,359	10,645	30,549	48,033
CCD13a	Higgins Pass	1	15	2.05	2.29	706,322	7,223	9,265	21,190	33,115
CCD13b	South Swindle Is	1	48	2.05	2.65	2,608,382	176,958	15,904	78,251	132,208
Total Central Coast		**202**	**1,701**	**1.09 – 5.00**	**1.57 – 4.62**	**93,854,515**	**19,647,821**	**627,377**	**2,016,955**	**3,627,721**

Table 8. The number of geoduck beds, estimated bed area (ha), range in density (#/m^2) and weight (lb) estimates, estimated virgin biomass (lb), total adjusted landings (lb) and low, medium and high quota options, by geoduck management area (GMA), for the 2002 geoduck fishery. An asterix next to a GMA indicates that some or all of the geoduck beds therein have been surveyed.

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m^2)	Weight Range (lb)	Estimated Biomass ('000 lb)	Total Landings (lb)	Quota Options (lb) low	mean	high
INSIDE WATERS										
14D	Hornby Island	8	434	0.7	2.31 – 2.69	7,403,143	1,528,702	69,675	197,267	303,470
14E	Mapleguard Point-Northwest Bay	6	1504	0.45 – 0.7	2.34 – 2.72	18,443,024	2,971,834	238,018	517,638	762,616
16A	West Texada excl. Crescent Bay	8	391	0.7	2.14 – 2.47	6,419,252	1,851,347	26,183	138,553	252,719
16B	Lasqueti Island	13	283	0.7	2.06 – 2.49	4,583,984	1,673,119	15,861	62,694	127,722
16C	E. Texada Island	3	34	0.7	2.00	480,034	606,266	999	3,238	5,477
16D*	Thormanby Island, mainland	10 (2)	596	0.18 – 0.7	1.90 – 2.18	7,490,272	493,768	127,828	222,656	316,427
16E	Salmon-Sechelt Inlets, Porpoise Bay	3	52	0.7	1.75 – 1.83	655,280	165,024	3,303	12,363	22,162
16F	Jervis Inlet	8	42	0.7	1.80 – 2.37	624,348	67,055	9,029	16,945	24,580
Total Inside Waters		**59**	**3,336**	**0.18 – 0.7**	**1.75 – 2.72**	**46,099,338**	**9,357,113**	**490,896**	**1,171,353**	**1,815,174**

Table 8, cont'd.

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m^2)	Weight Range (lb)	Estimated Biomass ('000 lb)	Total Landings (lb)	Quota Options (lb) low	mean	high
WEST COAST										
24A2a	Yarksis	1	142	1.7	2.42	5,857,023	1,806,117	631	37,413	74,195
24A2b	E. Father Charles Channel	3	147	1.7	2.77 – 3.13	7,352,833	397,923	47,078	73,528	99,979
24A3	Tonquin/Echachis	3	97	1.7	2.77	4,576,310	337,371	29,221	45,646	62,069
24A4*	Epper/Dunlap	10	221	1.65 – 2.27	2.49 – 2.65	10,959,347	1,165,877	60,540	103,264	144,750
24A5	Lemmens Inlet	3	86	1.7	1.57 – 2.01	2,920,083	921,504	2,944	15,838	33,561
24A6a*	Yellow Bank	2	130	2.16 – 3.05	2.49	9,663,800	2,074,579	54,425	91,136	118,899
24A6b	E. Maurus Channel	3	107	2.16	2.31	830,684	135,944	4,510	8,307	11,189
24A6c*	Elbow Bank			2.05 – 2.16	2.53	4,683,355	2,625,633	1,541	2,413	18,757
24B1a	Outside - north	10	716	2.16	2.53 – 3.32	29,201,804	5,645,492	139,513	291,823	389,399
24B1b	Outside – south			2.16	1.45 – 2.54	14,037,442	1,424,631	86,161	137,485	188,810
24B2	West Coomes Bank	2	200	2.16	2.53 – 2.87	13,001,926	3,437,995	24,287	87,948	154,491
24B3*	Ahousat	2	369	1.96	1.92	12,763,406	2,289,872	50,908	127,634	179,944
24B4	Russell Channel	3	290	1.96 - 2.16	2.31 – 3.17	17,081,255	2,331,518	97,958	165,667	228,051
24C1	Sydney Inlet	12	129	1.7	2.08 – 2.08	4,356,953	872,832	18,185	32,189	50,495
24C2	Exposed	3	38	1.7	2.49 – 3.49	2,111,540	126,884	19,980	33,001	45,940
24D1	Inlets	19	90	1.7	2.52	3,868,865	591,517	16,665	29,742	42,892
24D2	Indian Island	3	41	1.7	2.52	1,773,016	56,616	11,770	17,719	23,668
26A*	North Inlets	15 (1)	79	0.29 – 1.7	1.73 – 2.95	2,828,128	217,030	44,036	79,886	114,852
26B*	Mission Group	4 (2)	229	0.32 – 2.2	1.86 – 2.21	9,063,072	6,164,442	29,615	52,013	74,495
26C	Central Kyuquot Inlets	14	52	1.7 – 1.99	1.86 – 2.23	2,072,312	1,196,944	21,503	44,888	68,436
26D	South	15	175	1.7 – 1.99	1.81 – 3.23	7,203,245	1,574,038	77,165	148,326	227,965
26E	Amai Inlet	2	6	1.7	2.20 – 2.27	239,021	18,116	3,546	6,208	8,870
Total West Coast		**129**	**3,364**	**0.29 – 3.05**	**1.45 – 3.49**	**166,445,419**	**35,412,875**	**842,181**	**1,632,073**	**2,361,707**

Table 8, cont'd.

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m^2)	Weight Range (lb)	Estimated Biomass ('000 lb)	Total Landings (lb)	Quota Options (lb) low	mean	high
PRINCE RUPERT										
PRA1	Duckers Island	1	33	2.37	2.27	1,799,790	284,686	16,936	48,569	78,035
PRA2	Surf Inlet	2	26	2.37	2.29	1,387,685	513,407	131	14,472	39,997
PRA3*	Anderson Island North	3 (2)	35	0.7 – 1.82	2.46 – 2.86	866,538	72,191	5,840	24,191	49,164
PRA4*	Anderson Island South	3	41	1.67 – 2.52	2.15 – 2.73	2,196,253	88,686	11,938	64,191	115,560
PRA5*	Borrowman Bay	6 (2)	22	1.82 – 2.2	2.32 – 2.82	1,142,177	121,981	7,202	31,312	58,923
PRA6*	Kettle Inlet	2	54	1.54 – 3.33	2.50 – 2.62	2,922,900	473,347	0	74,108	163,850
PRA7*	Butler Shoal	1	9	0.69	2.03	132,122	44,047	0	1,651	4,192
PRA8*	Clifford Bay North	5 (3)	72	0.95 – 1.82	2.56 – 4.29	2,454,099	1,005,054	6,867	26,794	63,351
PRA9*	Clifford Bay South	1	53	1.77	2.69	2,688,197	682,239	1,005	46,745	92,485
PRA10*	Arriaga Islands	1	21	3.45	2.58	1,849,116	253,165	0	55,473	100,408
PRA11*	Weeteeam Bay West	4 (2)	24	1.32 – 1.82	2.48 – 2.71	860,146	222,916	3,004	15,414	28,695
PRA12*	Weeteeam Bay Mid	2	20	1.32 – 2.11	2.66 – 2.74	940,170	223,148	6,976	19,235	32,256
PRA14*	Moore Islands	7 (4)	48	1.05 – 10.27	2.35 – 2.56	4,941,221	135,193	51,956	147,633	240,027
PRB1*	Calamity Bay	7 (4)	139	0.92 – 2.2	2.14 – 2.84	6,161,458	1,253,414	21,925	132,367	264,917
PRB2*	Estevan Group	3 (1)	35	1.84 – 3.74	2.21 – 2.87	2,289,081	110,784	25,731	60,904	94,044
PRB3	Langley Pass	6	58	1.84	2.45 – 3.12	3,088,331	385,327	33,707	81,303	128,899
PRB4	Lotbiniere Bay	5	47	1.84	2.37 – 2.72	2,108,837	136,682	31,073	62,727	92,968
PRB5	Campania Island, North	2	8	2.37	2.55 – 2.59	495,202	9,731	8,324	14,622	20,917
PRB6	Campania Island, South	2	24	2.37	2.74 – 2.91	1,616,168	43,165	26,415	48,485	70,304
PRC1	Wreck Island	2	63	2.37	2.53 – 2.78	4,073,870	526,112	44,781	114,186	173,515
PRC2	Waller Bay	1	30	2.37	2.43	1,729,278	211,797	19,381	48,963	75,544
PRC3	South Banks Island	3	24	2.37	2.42 – 2.78	1,552,016	24,484	27,211	46,502	65,793
PRD1	Freeman Pass	2	38	2.37	2.48	2,261,474	332,387	31,767	67,808	95,518
PRD2	Shakes Islands	6	27	2.37	2.18 – 2.73	1,553,738	105,255	23,472	46,382	66,696
PRD3	Spicer Islands	10	31	2.37	1.93 – 2.74	1,586,931	44,235	26,387	47,005	67,355
PRD4*	Principe Channel NW	13 (4)	131	2.16 – 2.62	2.08 – 3.00	7,834,767	240,826	119,301	231,046	341,039
PRD5*	Principe Channel NE	4 (3)	23	0.51 – 2.48	1.85 – 2.49	734,267	39,956	7,511	20,871	34,287
PRD6	Principe Channel South	1	7	2.37	2.85	494,369	2,776	8,701	14,831	20,961
PRD7	Larsen Harbour	1	44	2.65	2.41	2,807,223	241,490	48,653	84,217	119,780
PRD8,9*	Borrowman Group 1 & 2	1	156	2.65	2.29	9,458,159	2,791,284	10,096	170,982	331,868
PRD11	Sneath Island	1	181	2.65	2.55	12,244,501	843,260	212,439	367,335	522,231
PRD12	Kingkown Inlet	1	67	2.37	2.56	4,091,217	1,073,924	9,296	94,034	175,274

Table 8, cont'd.

GMA	DESCRIPTION	# Beds	Bed Area (ha)	Density Range (#/m^2)	Weight Range (lb)	Estimated Biomass ('000 lb)	Total Landings (lb)	Quota Options (lb) low	mean	high
PRE1	Wales Island	4	8	2.37	2.37	475,703	6,724	8,304	14,256	20,179
PRE2	East Chatham Sound	4	16	2.37	1.87 – 3.10	939,613	135,624	11,088	22,600	36,209
PRE3*	Northeast Dundas Island	7 (2)	51	2.31 – 2.69	1.89 – 2.14	2,547,520	581,681	17,411	50,534	99,460
PRE4*	North Dundas Island	1	39	2.65	2.12	2,185,273	252,191	26,535	65,558	96,880
PRE5*	Northwest Dundas Island	4 (3)	53	1.69 – 3.82	2.14 – 2.32	3,099,944	433,663	33,242	85,828	130,547
PRE6*	Southwest Dundas Island	2 (1)	53	1.32 – 2.37	2.14 – 2.46	1,842,935	59,614	30,499	54,784	78,841
PRF1	Stephens Island North	3	8	2.37	2.17 – 2.56	505,614	57,246	6,939	14,816	21,438
PRF2	Stephens Island South	6	18	2.37	2.17 – 2.95	1,029,811	28,254	17,212	30,130	43,039
PRF3	N. Porcher Island	9	48	2.37	2.08 – 2.75	2,851,723	423,525	38,238	71,021	102,293
PRF4	Oval Bay	1	149	2.37	2.82	9,938,093	87,744	160,736	298,143	435,549
PRG1	Connel Island	1	23	2.37	2.46	1,331,638	255,705	8,281	30,759	53,237
PRG2	Baron Island	9	55	2.37	2.16 – 2.72	3,238,461	249,579	47,041	92,321	135,990
PRG3	West Chatham Sound	9	39	2.37	2.15 – 3.66	2,827,409	58,156	44,787	83,487	122,029
PRG4	Melville/Dunira	2	73	2.37	2.63 – 2.71	4,567,073	582,214	54,705	127,599	193,412
PRG5	West Tree Nob Group	1	11	2.37	3.15	799,530	195,386	2,937	15,328	27,720
PRG6	East Tree Nob Group	3	70	2.37	2.35 – 2.73	4,044,254	460,953	49,687	114,083	175,971
PRG7	Archibald Island	2	23	2.37	2.48 – 2.54	1,351,080	307,773	6,219	29,719	53,218
Prince Rupert Total		**178**	**2,331**	**0.51 – 10.27**	**1.85 – 4.29**	**133,936,972**	**16,784,399**	**1,411,170**	**3,536,027**	**5,699,168**

Table 9. Summary of geoduck quota options (lb), with estimates of spatial area of geoduck beds (ha), for the 2001 and 2002 fisheries. The mean quota recommendation from the previous two rotations are presented for comparison.

ROTATION YEAR 1

	1995		1998		**2001**			
Region	Quota (lb)	Area (ha)	Quota (lb)	Area (ha)	**Quota (lb)**			**Area (ha)**
					low	**mid**	**high**	
N. Coast (CC)	2,520,900	1,079	1,348,810	1,619	**627,377**	**2,016,955**	**3,627,721**	**1,701**
West Coast	1,176,000	3,663	1,357,353	3,798	**1,087,812**	**2,305,627**	**3,583,153**	**4,334**
Inside Waters	924,300	3,278	681,385	3,032	**372,122**	**982,246**	**1,652,469**	**4,072**
Total	4,621,200	8,020	3,387,548	8,449	**2,087,311**	**5,304,828**	**8,863,343**	**10,107**

ROTATION YEAR 2

	1996		1999		**2002**			
Region	Quota (lb)	Area (ha)	Quota (lb)	Area (ha)	**Quota (lb)**			**Area (ha)**
					low	**mid**	**high**	
N. Coast (Rup.)	1,353,653	1,283	2,144,321	1,746	**1,411,170**	**3,536,027**	**5,699,168**	**2,331**
West Coast	781,135	2,952	1,189,889	3,171	**842,181**	**1,632,073**	**2,361,707**	**3,364**
Inside Waters	910,936	2,426	906,769	3,155	**490,896**	**1,171,353**	**1,815,174**	**3,336**
Total	3,045,724	6,661	4,240,979	8,072	**2,744,247**	**6,339,453**	**9,876,049**	**9,031**

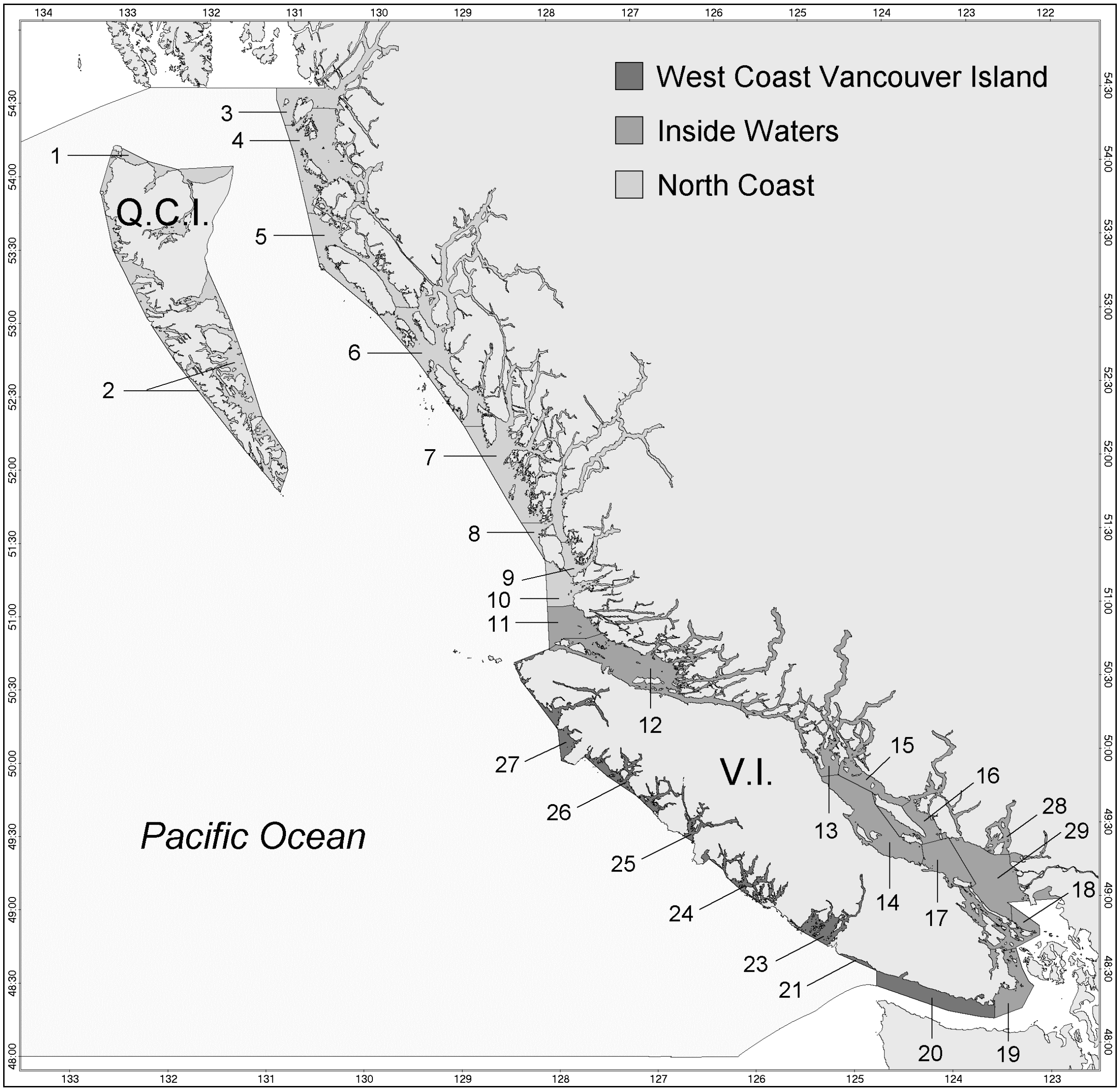

Figure 1. Regions of the British Columbia coast that are fished by the geoduck industry, with Pacific Fishery Management Statistical Areas (PFMA) shown.

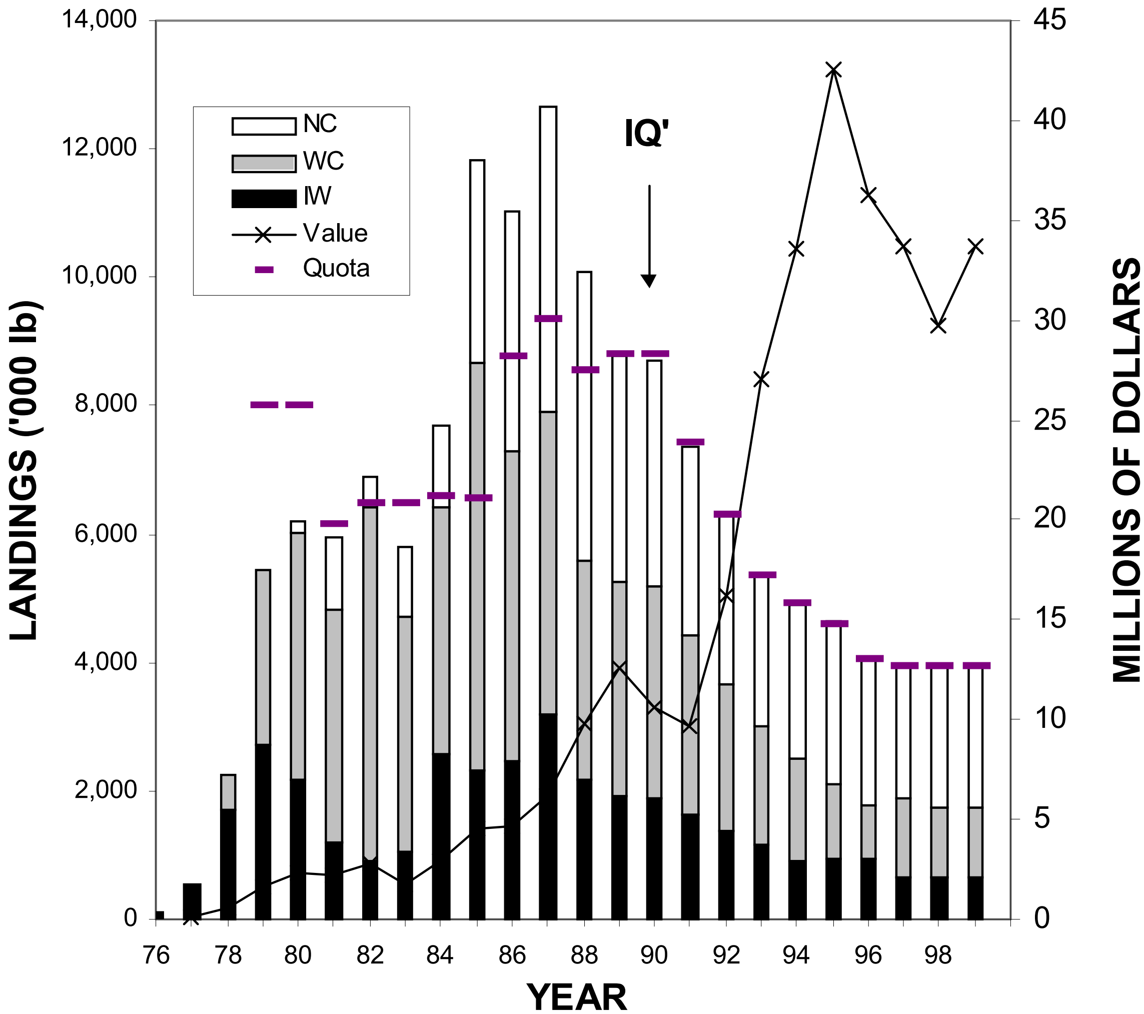

Figure 2. Geoduck quotas ('000 lb), landings ('000 lb) and value ($\$10^6$) by region and year. NC: North Coast; WC: west coast of Vancouver Island; IW: inside water.

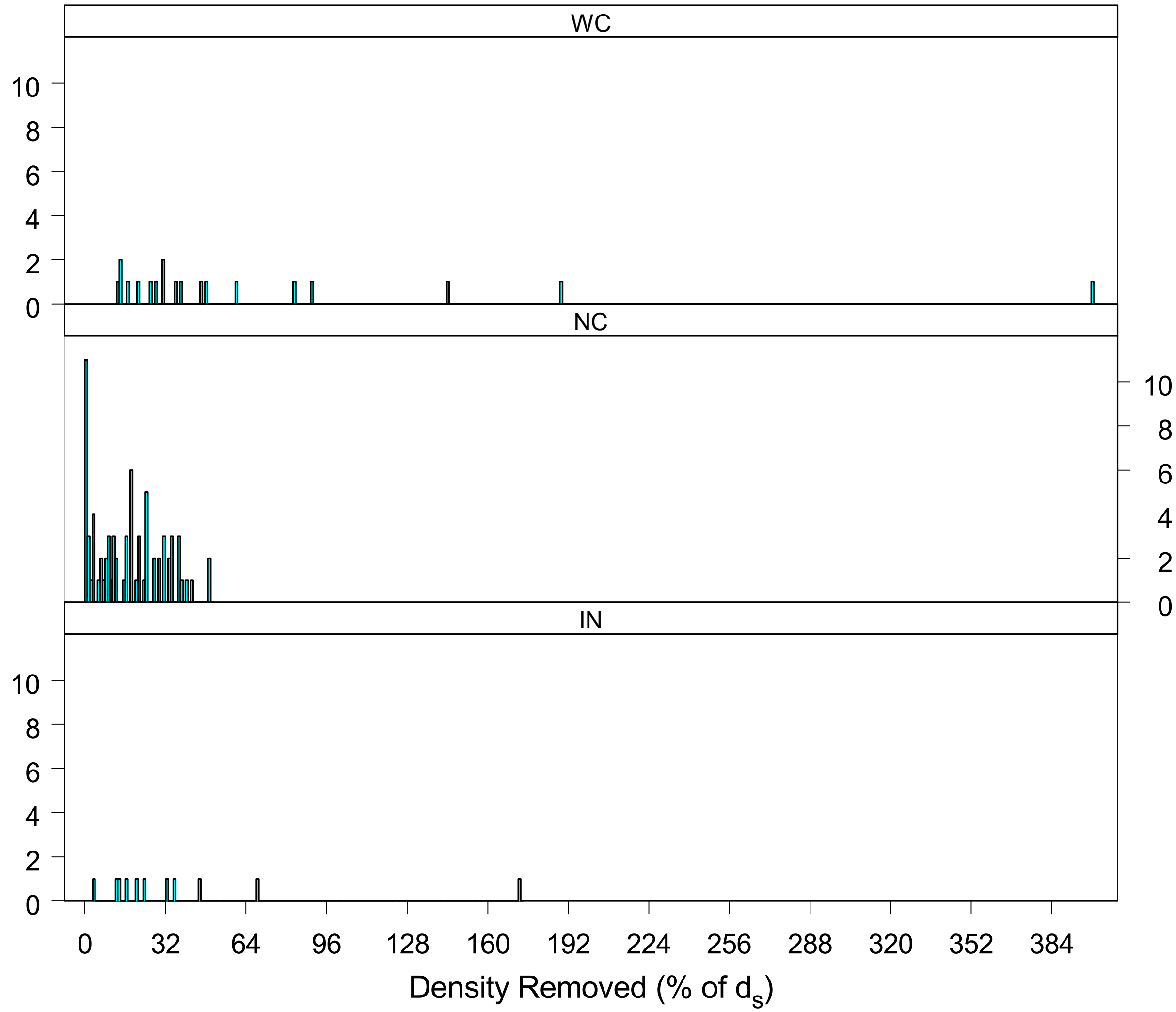

Figure 3. Plot of the density of geoduck removed (#/m^2) from individual surveyed beds, expressed as % of surveyed density, by coastal region.

Appendix 1. Request for Working Paper.

PSARC INVERTEBRATE SUBCOMMITTEE

Date Submitted: Jan 21, 2000

Individual or group requesting advice:

(Fisheries Manager/Biologist, Science, SWG, PSARC, Industry, Other stakeholder etc.)

Steve Heizer, Fisheries Management Biologist, South Coast Division, Juanita Rogers, R. Harbo

Proposed PSARC Presentation Date:

June, 2000

Subject of Paper (title if developed):

Quota Options for Geoducks – 2001-2002

Stock Assessment Lead Author:

Claudia Hand, Shellfish Stock Assessment Division

Fisheries Management Author/Reviewer:

Steve Heizer

Rationale for request:

(What is the issue, what will it address, importance, etc.)

Required for development of 2001-2002 fishing plans.

Question(s) to be addressed in the Working Paper:

(To be developed by initiator)

What should the GMA-by-GMA quotas be for the rotations fished in 2001 and 2002?
What modifications and/or changes have occurred in the assessment process (eg. survey protocols) ?
What new data (new or modified beds and other harvest log data, Observer data, surveys, biological samples) have been incorporated into the assessment?
What beds are closed in 2001/2002 due to estimated harvests greater than 50% of the original biomass?

Objective of Working Paper:

(To be developed by FM & StAD for internal papers)

Present quota options (low-medium-high) for each GMA opening in both 2001 and 2002, taking into account new surveys, new closures and new data available for determination of these quotas.

Stakeholders Affected:

"G" Licence holders, aboriginal groups, other potential harvesters

How Advice May Impact the Development of a Fishing Plan:

Essential in the development of fishing plan.

Timing Issues Related to When Advice is Necessary

Fishing plan development schedule requires that data be included in the plan for review at Shellfish Working Group in early September, then reviewed by the Sectoral Committee and returned to the Shellfish Working Group in October. Finalization of the plan will be in December for issuance of 2001 licenses.

Appendix 2. Summary of mean individual geoduck weight (lb) by Subarea with 95% confidence intervals, from piece-count data submitted by fishermen on harvest logs, for areas to be fished in 2001 and 2002.

Statistical Area	SubArea	Number of Landings	Mean Geoduck Weight (lb)		
			Mean	Low 95% CI	High 95% CI
3	1	73	2.139	2.062	2.215
3	3	2	2.370	2.264	2.476
3	4	2	2.259	2.158	2.359
4	1	94	2.524	2.443	2.605
4	2	48	2.579	2.468	2.691
4	3	13	2.819	2.563	3.075
4	4	11	2.463	2.361	2.564
4	5	13	3.105	2.760	3.450
4	9	1	2.170	2.073	2.267
4	13	35	2.630	2.473	2.788
5	10	33	2.315	2.185	2.445
5	12	31	2.478	2.384	2.573
5	13	103	2.275	2.207	2.343
5	17	26	2.577	2.455	2.700
5	20	167	2.362	2.312	2.413
5	21	46	2.564	2.416	2.713
5	22	37	2.613	2.470	2.756
6	9	105	2.527	2.439	2.616
6	10	38	2.549	2.394	2.705
6	11	36	2.365	2.213	2.516
6	12	13	2.288	2.092	2.484
6	13	230	2.648	2.593	2.702
6	14	51	2.485	2.351	2.619
6	15	7	2.429	2.321	2.538
6	16	52	2.502	2.412	2.591
6	17	15	2.400	2.291	2.509
6	18	31	2.513	2.345	2.681
6	19	32	2.171	2.021	2.320
7	1	6	2.205	2.106	2.303
7	3	45	2.384	2.199	2.569
7	8	1	2.053	1.961	2.144
7	9	25	2.043	1.946	2.140
7	12	13	2.184	2.118	2.250
7	17	1	2.928	2.797	3.059
7	18	83	2.501	2.410	2.593
7	19	5	2.224	2.124	2.323
7	20	2	2.979	2.846	3.112
7	21	2	2.568	2.453	2.682
7	22	1	2.855	2.727	2.982
7	23	5	2.802	2.677	2.928
7	24	2	2.746	2.623	2.868

Appendix 2, cont'd.

Statistical Area	SubArea	Number of Landings	Mean Geoduck Weight (lb)		
			Mean	Low 95% CI	High 95% CI
7	25	163	2.556	2.470	2.642
7	27	262	2.503	2.446	2.560
7	28	11	2.862	2.537	3.187
7	31	51	2.468	2.352	2.585
7	32	18	2.729	2.489	2.969
8	2	72	3.034	2.901	3.167
8	4	33	2.442	2.263	2.621
9	1	8	2.197	2.099	2.296
9	2	27	2.434	2.270	2.598
9	12	6	2.502	2.390	2.614
10	1	8	2.502	2.390	2.614
10	3	10	1.705	1.629	1.781
10	4	14	2.062	1.888	2.236
12	6	12	2.542	2.406	2.677
12	8	34	2.256	2.188	2.324
12	11	31	2.763	2.605	2.920
12	16	15	2.649	2.450	2.848
13	1	3	3.098	2.960	3.237
13	15	8	2.427	2.318	2.535
14	4	9	2.691	2.571	2.811
14	5	179	2.383	2.321	2.445
14	7	73	2.509	2.426	2.591
14	8	15	2.656	2.449	2.863
14	9	14	2.312	2.208	2.416
14	10	55	2.277	2.170	2.384
14	11	7	3.724	3.557	3.890
14	13	168	2.509	2.455	2.563
14	15	21	3.274	3.024	3.524
15	2	73	2.355	2.234	2.477
16	1	8	1.947	1.861	2.034
16	2	23	1.927	1.821	2.033
16	5	13	1.797	1.745	1.850
16	11	12	2.264	2.013	2.515
16	16	1	1.797	1.716	1.877
16	17	2	2.127	2.032	2.222
16	18	12	2.000	1.911	2.089
16	19	13	2.372	2.180	2.565
16	20	13	2.068	1.964	2.171
16	21	40	2.337	2.211	2.464
16	22	41	2.259	2.156	2.363
17	5	14	1.960	1.849	2.071
17	6	2	1.551	1.481	1.620
17	10	15	2.264	2.121	2.407
17	13	3	2.728	2.606	2.850

Appendix 2, cont'd.

Statistical Area	SubArea	Number of Landings	Mean Geoduck Weight (lb)		
			Mean	Low 95% CI	High 95% CI
17	17	2	1.786	1.706	1.866
17	18	23	2.338	2.093	2.582
17	19	18	2.243	2.126	2.361
17	20	11	2.740	2.447	3.032
23	5	9	2.147	2.051	2.243
23	6	37	2.312	2.224	2.400
23	8	3	3.816	3.645	3.986
23	9	10	2.642	2.524	2.760
23	10	35	2.250	2.129	2.372
23	11	3	2.062	1.970	2.154
24	2	57	2.225	2.174	2.276
24	6	519	2.533	2.489	2.577
24	7	35	2.487	2.419	2.555
24	8	83	2.770	2.666	2.875
24	9	20	1.990	1.872	2.107
26	1	32	1.869	1.790	1.948
26	2	100	2.196	2.110	2.282
26	3	12	2.236	2.152	2.319
26	6	22	2.234	2.030	2.439
26	7	21	2.213	2.102	2.323
26	8	39	2.298	2.125	2.471
26	9	2	2.218	2.118	2.317
26	10	24	2.400	2.301	2.499
27	2	57	2.251	2.133	2.368
27	3	49	2.294	2.163	2.426
27	5	75	2.153	2.081	2.226
27	6	72	2.465	2.384	2.547
27	7	69	1.967	1.851	2.083
29	1	1	2.059	1.967	2.151
106	2	37	2.482	2.390	2.574