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Quota options and recommendations for the 1999 and 2000 geoduck clam fisheries

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Abstract

Geoduck (*Panopea abrupta,* Conrad 1849) stocks were examined and quota options presented for the north coast, west coast of Vancouver Island, and waters inside Vancouver Island for 1999 and 2000. The assessment methodology is unchanged from previous assessments, where the area of geoduck habitat reported by fishers, estimates of geoduck densities from surveys and mean geoduck weights from market samples form the basis of biomass estimates, and a fixed sustainable harvest rate is applied to derive quota options. Changes in the estimates of biomass result from updated geoduck density estimates from survey data, updated estimates of mean geoduck weight from commercial market samples, and new estimates of geoduck harvest areas from recent harvest log data and from re-measurements of all pre-existing geoduck beds. The approach initiated in 1994 of reducing quotas where overharvesting had occurred, according to stock status relative to a 50-year cycle, was continued coastwide. A range of quota options are presented, based on the uncertainty around mean geoduck densities, around mean geoduck weights and around geoduck bed area.

For the 1999 fishery, recommended low, medium and high quota options are 2,260,000 lb, 4,241,000 lb and 6,886,000 lb. Quota options for the 2000 fishery are 1,865,000 lb, 3,679,000 lb and 6,127,000 lb.

Résumé

Les stocks de panope (*Panopea abrupta*, Conrad 1849) ont fait l'objet d'un examen et des options de quotas ont été présentées pour la partie nord de la côte ouest de l'île Vancouver et les eaux de l'île, pour l'an 1999 et l'an 2000. La méthodologie utilisée est la même que celle des évaluations antérieures, c'est-à-dire que la superficie d'habitat signalée par les pêcheurs, les densités estimées par relevés et le poids moyen des individus obtenu des échantillons commerciaux servent à estimer la biomasse. Un taux de récolte soutenue fixe est ensuite appliqué pour déterminer les quotas. Les modifications des estimations de biomasse résultent des mises à jour des densités déterminées par relevés et du poids moyen des panopes des échantillons commerciaux, des nouvelles estimations des zones de récolte tirées des données des registres de capture et des nouvelles déterminations de tous les fonds déjà mesurés. L'approche adoptée en 1994, qui consiste à réduire les quotas où il y a eu surexploitation, par rapport à l'état du stock fondé sur un cycle de 50 ans, a été maintenue à la grandeur de la côte. Une gamme d'options de quotas est présentée. Elle est fondée sur l'incertitude liée à la moyenne des densités de panopes, au poids moyen des individus et à la superficie des fonds peuplés.

Les options de quotas faibles, moyennes et élevées recommandées pour la pêche de 1999 sont, respectivement de 2 260 000, 4 241 000 et 6 886 000 livres. Pour celle de l'an 2000, ces options de quotas sont de 1 865 000, 3 679 000 et 6 127 000 livres.

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1. INTRODUCTION

The geoduck clam (*Panopea abrupta*, Conrad 1849) fishery began in 1976 in British Columbia and has grown to be the major invertebrate fishery in value, at $ 33,698 million dollars in 1997 (Table 1), and third in landings, next to shrimp, red sea urchins and crab. The fishery has been described by Cox (1979), Harbo and Peacock (1983), Harbo *et al.* (1986, 1992, 1993, 1994, 1995), Farlinger and Bates (1985) and Farlinger and Thomas (1988).

A fixed-exploitation rate strategy is currently used to manage the B.C. geoduck clam fishery. For each geoduck bed, the biomass is calculated from the estimated bed area, an estimated mean density and a mean weight per individual. The annual allowable harvest is calculated as the product of this biomass and a target harvest rate. Until the 1996 fishery, quota options had been calculated on a yearly basis. The Underwater Harvesters Association (UHA) requested quota projections for longer than one year to reassure the market concerns that stemmed from the downward trend in quotas since 1987. Equal quotas were implemented in the 1997 and 1998 management plans by reviewing the quota recommendations for each year and adjusting locations of fishing, or choosing within the range of options given. Quota recommendations for a longer period are not possible if assessments are to incorporate the most current fishery and survey data. The objectives of this assessment are to update the time-series of fishery information with data from the 1996 and 1997 seasons, present estimates of geoduck density from fishery-independent surveys and mean geoduck weight from market samples and provide quota options by Geoduck Management Area (GMA) for the 1999 and 2000 fishing rotations.

1.1 Geoduck Biology

Geoducks are distributed from Alaska to the Gulf of California (Quale 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 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 extended periods of time, juveniles are scarce and recruitment is low, although age-frequencies do show periodic peaks of abundance in juvenile settlement (unpublished data, Breen and Shields 1983, Goodwin and Shaul 1984). Laboratory experiments indicate that geoduck embryos have relatively narrow salinity and temperature tolerance limits (Goodwin 1973).

2. FISHERY BACKGROUND AND SUMMARY OF MANAGEMENT

The fishery began in Inside Waters of Vancouver Island in 1976, spread to Pacific Fishery Management (Statistical) Area 24 on the West Coast of Vancouver Island in 1979, and to the North Coast in 1980 (Figs. 1 and 2). Annual landings and value increased steadily from 1976 to 1987 when landings peaked at 5,735 t. Landed values continued to increase, despite a decrease in landings, and reached an all-time high of $42.5 M in 1995 (Fig. 2). Value has since decreased to $33.8 M in 1997. Cumulative landings to the end of 1997 are 63,743 tonnes. Summaries of landings by Statistical Area for the south and north coasts, are presented in Table 2 and Table 3, respectively. Overall, 24 % of landings have come from the Inside Waters of the South Coast, 44% from the west coast of Vancouver Island and 32 % from the North Coast.

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.

For the first three years of the fishery (1976-1978) there were no restrictions imposed on the fishery. A licence moratorium and regional quotas were introduced in 1979. A fleet reduction was implemented in 1980 and a separate quota was given for the west coast of Vancouver Island and Inside Waters. In 1981, minimum landing criteria further reduced the fleet size to 55 eligible licences and the North Coast quota was split into QCI (Queen Charlotte Islands), Prince Rupert, and the Central Coast. Harvest logbook data, mandatory since 1977, were first used in quota calculation in 1984. Quota options for 1991, 1992/1993, 1994, 1995, 1996 and 1997/1998 are presented in Harbo *et al.* (1992, 1993, 1994, 1995) and Hand *et al.* (1998b 1998c). Most quotas set were within the large ranges of potential stock and annual yield options. Some exploratory quotas were also set. Table 5 summarises the annual quotas for north and south coast districts from 1979 to 1998.

Individual Vessel Quotas (I.V.Q.'s) were introduced in 1989 and all landings since then have been monitored at designated landing ports by contracted port observers. Also in 1989, a three year rotational area fishery was implemented, where each of the three geographic regions of the coast (North Coast, West Coast and Inside Waters) were divided into three portions with roughly equal geoduck harvest area. Each of these subunits is fished at three times the annual exploitation rate, once every three years. The exception to rotational fisheries is Area 24, Clayoquot Sound, which is fished annually (Table 4). Rotational fisheries were implemented primarily for management reasons, to concentrate the fishing fleet to make it easier to monitor quotas and to reduce the annual number of landing ports for validation of quotas. The rotational fishery also allowed for a more thorough examination of fishery areas, since only one third of the coast needed to be processed.

In an effort to eliminate the redundancy in data collection that resulted from having two sources of harvest data (harvest logs and port validation) and improve data accuracy, since the data rarely agreed exactly, a pilot project was initiated in 1995 for Inside Waters where port monitors collected all harvest information from fishers at the time of landing. The industry-funded program proved successful and was expanded to the rest of the coast for the 1996 fishery. Harvest information is currently very accurate and is collected, keypunched and available for analysis within a short time period.

Although landing information is complete, the total fishing mortality could be higher by an unknown amount through the harvest and discarding of poor quality geoducks. The Asian market for live geoducks favours geoducks which are light in colour, free of blemishes, of good siphon length and unbroken. The market quality of geoducks varies from bed to bed and may be related to age or substrate characteristics (R. Harbo, DFO, pers. comm.). 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.

As the fishery developed, the number of Geoduck Management Areas was increased in order to spread out fishing effort, find new fishing grounds and to reduce the potential for local over-harvesting. For the 1989 to 1991 rotation, there were 75 GMA's defined, each with a separate quota. This increased to 170 GMA's for second rotation (1992 to 1994), to 233 for the third rotation (1995 to 1997) and 243 for the fourth rotation (1998-2000) (Table 4). Even though quotas are set by GMA in the North Coast, the on-grounds observer enables quota monitoring on a more precise bed-by-bed basis.

3. STOCK BIOMASS AND QUOTA CALCULATIONS

Calculations of virgin stock biomass use current estimates of the area of known geoduck-bearing habitat, estimates of virgin geoduck density and estimates of mean geoduck weight. Annual sustainable quotas are calculated at 1% of this biomass estimate. Associated with each of these components are various levels of uncertainty. These are discussed in detail in the following sections.

3.1 Geoduck Biomass

3.1.1 Area of Geoduck Habitat

Estimates of geoduck bed areas are obtained from the charts and harvest logs provided by fishers. Bed information is transcribed from the harvest charts to a set of reference nautical charts and assigned a unique (within Statistical Area and Subarea) ID number. Bed polygons are constrained to lie between either 10 and 60 feet or 5 and 20 metres depth, depending on the chart. Deeper stocks are not considered as part of the exploitable biomass because of the technical limitations of working at that depth and the lack of deep water survey data. Shallow stocks are restricted to protect eelgrass beds. The beds were initially measured planometrically on a computer-driven digitizing tablet with Gap1 software. Harbo *et al.* (1986) first published estimates of the area of beds that were harvested between 1978 and 1984. Estimates were revised each year as additional harvest beds were identified through the harvest log program. In 1995, all of the geoduck bed polygons that were reported to that date were re-digitized using COMPUGRID, a more powerful raster-based geo-spatial program. The resulting new area estimates were similar to, but often slightly higher than, the Gap1 estimate for beds that had not been extended through the discovery of new ground. As new beds were found in subsequent fisheries, they were similarly digitized and the information added to the database.

The method of determining area described above is likely to give a generous estimate of the size of the beds, since all of the area between the 60 ft (10 fathoms or 20 m, depending on the chart) and 10 ft depth contours within a harvest locale is included in the bed polygon. Surveys have shown that geoducks have a patchy distribution, largely related to the distribution of substrate types (Campbell *et al.* 1996a, 1998a; Hand *et al.* 1998a) and that not all of the measured area within a defined bed has harvestable geoduck densities.

Inaccuracies in the estimates of bed area can arise from several sources: from errors by fishers in recording the actual harvest location, in transcribing the fishers information onto the reference charts, from digitizing measurement error and from the condition, accuracy and scale of the reference nautical chart. In 1997, due to the tattered state of most of the paper charts, which could result in distorted digitized area measurements, all beds were redrawn onto new nautical charts. Some of the charts were new metric issues from the Canadian Hydrographic Service, however, many of the beds were simply transcribed onto a fresh copy of the same chart. When bed boundaries were modified, it was done using information from the north coast on-grounds observer, from geoduck surveys, from observer fisheries and from new harvest logs, as appropriate. Generally, a conservative approach was taken when transcribing the beds onto new charts. In situations where no additional information was available and where bed boundries were uncertain, decisions were directed by catch information and the density of geoducks removed from the bed. Often, logic would suggest that some bedcode changes were appropriate, such as grouping some beds together under a single code (if these beds had 'grown' together since originally being coded) or splitting other beds and assigning them different bed codes. The latter would also involve re-assigning the appropriate landing information to the new code.

As a result of this project, the estimate of area for every geoduck bed on the coast has changed. Minor differences resulted when beds polygons were simply transcribed onto a fresh copy of the same chart. Larger, and sometimes significant, differences resulted from a transfer from imperial to metric charts. Differences of varying amounts resulted when beds were redrawn to conform to depth restrictions or to exclude obvious rocky reefs, or when beds were modified with additional information from harvest logs, surveys or observer fishing. Large changes in areas for particular bedcodes often resulted from the logical amalgamation or splitting of beds, however these differences are merely artifacts of the process and do not affect the overall area and resulting biomass estimates.

The difference in bed area (ha and percent) resulting from the review is shown in Fig. 3, grouped by Statistical Area. The most dramatic difference occurred in Area 14, where there was an overall increase in area of over 800 ha, or 21% of the original area. In this case, the bed polygons had been transferred from imperial to metric charts. Some beds in Area 14 have been surveyed (described later in Section 3.1.2.1), and the surveyed area agreed closely with the new digitized area.

In some Areas, the individual bed area differences balance out so that the net difference is small. For example, Area 2 (Fig. 4) has bed area differences of as much as 29 ha but the overall difference is less than 4% of the original estimate. In other Areas, for example Area 6 (Fig. 4), some bed reductions were as large as 40 ha and there was an overall 17% reduction in area due to combinations of a change in the scale of the chart and redefinition of bed polygons with new information. Overall, the percent difference in bed area, relative to the original area, are -7% for North Coast beds, +10% for beds in Inside Waters and -2% for bed on the West Coast. The bed review has made progress in improving area estimates for many geoduck beds on the coast, however there are still a great many beds whose areas are suspected of being incorrectly estimated.

3.1.1.1 Bed Scaling

Overestimation of the measured area in some beds is suspected when fishery removals are less than would be expected, given the estimated biomass in that bed. For the 1992 and 1993 quotas (Harbo *et al.* 1993), arbitrary criteria were defined to decrease the area in suspiciously large beds which had not supported the expected production. 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 scaling factors were determined by finding the smallest-sized bed that produced the threshold cumulative reported landings. They were applied equally to all areas of the coast. Also, some beds were reduced in size based on the number of geoducks removed per square metre. Large-sized beds (>100 ha) with very low rates of removal were reduced by the ratio of the density removed in that bed to the overall density removed in its GMA. These approaches were used in assessments until the 1997 and 1998 fisheries, and ultimately resulted in a coastwide area reduction of 2,335 ha over 221 beds.

Methods for reducing the area in suspiciously large beds were modified for this assessment. Scaling factors for beds in the 1999 and 2000 rotations were applied on a more regional-specific basis, because we know that geoduck densities differ among regions. We considered that geoduck beds with less than 5,000 lb average annual landings (Fig. 5) were probably defined with insufficient data, because a vessel can harvest 5,000 lb in only 2 to 4 days, depending on the area. For many beds with less than 5,000 lb average annual landing, large areas were measured from only a few days fishing (Fig. 6).

Geoduck density estimates ($\#/m^2$) and mean individual geoduck weight, averaged over region, and the exploitation rate of 1% were used to calculated the expected bed area, given the average annual landings from that bed. For instance, beds in the Prince Rupert area have, on average, 4.9 lb/m^2 of geoducks (assuming an average density of $1.8/m^2$ from surveys and a mean weight of 2.6 lb from market samples). The area (A) that would expected for a bed that had produced an average of, say, 1000 lb per year of being harvested would be calculated by

$$A = \frac{1000}{4.9 \times 0.01} \qquad (1)$$

$$= 20{,}408 \text{ m}^2.$$

Bed area thresholds were calculated in 200 lb average landing intervals for each of 6 regions (Fig. 7). Beds with less than 5,000 lb average annual landing and with larger areas than the defined thresholds were reduced in size to the area calculated from equation (1) (Fig 7). The overall reduction in bed area that resulted from this process was 1,154 ha over 190 individual beds. This is about half of the reduction that resulted from the previous method described above (Harbo *et al.* 1993). By region, QCI area was reduced by 182 ha (16 %), Rupert area by 222 ha (19 %), Central Coast by 33 ha (3%), Statistical Area 12 by 105 ha (9%), Inside Waters by 404 ha (35%) and west coast of Vancouver Island. by 207 ha (18%).

Bed scaling is a temporary measure. Efforts are ongoing to resolve some of these 'problem' beds with bed verification programs using on-board observers and through geoduck surveys. Geoduck surveys have shown that geoduck bed areas can be both overestimated and underestimated and a preliminary examination of observer fishing to date has also indicated that the actual geoduck bed may be larger or smaller than recorded. Until a more quantitative examination of these data can be undertaken, an arbitrary error range of plus or minus 10% of the measured bed area is used to express the uncertainty in this parameter estimate.

New geoduck beds are still being discovered, particularly in the north coast where 214 new hectares (9 % increase) was added to the QCI database and 168 ha (10% increase) was added to the Rupert Area. Only 60 ha (0.8 %) and 91 ha (2 %) were found on the west coast and inside waters, respectively, in the 1996 and 1997 fisheries.

Deep water stocks of geoducks are known to exist through surveys, reports of fishers and the literature (Jamison *et al.* 1984). The technology exists to fish these stocks, however little is known of the densities, productivity or reproductive contribution of these stocks and they are currently not included as part of the fishable biomass.

Geoduck beds falling within a contaminated, temporary or permanent closure were excluded (Table 6). The majority of contaminated closures are in the South Coast Inside Waters.

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 fishers. 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 indicate higher densities ranging to 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 7).

Transect surveys were first conducted by DFO in 1992 and 1993 (Campbell *et al.* 1996a, 1996b), 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 members of the geoduck fishing industry (Underwater Harvesters Association), First Nations groups and the Department of Fisheries and Oceans, using a standardized survey design. Survey protocols and analyses followed the methodology described in Campbell *et al.* (1998b). To date, 22 surveys have been conducted coastwide, the results of 14 of which are used to calculate quotas for the 1999 and 2000 fisheries (Table 8).

As described in Section 3.1.1, beds are identified by fishers on their harvest logs and drawn by DFO personnel onto nautical charts. Surveys typically include a varying number of these bed polygons, and each are considered as strata in the stratified random sampling design used. Transects are randomly located within each bed. The sum of all geoducks counted in each bed or strata, divided by the sum of all transect areas is the mean survey density, in number of geoducks per square metre. These randomly placed transects often fall on unproductive areas, however, because bed perimeters are not abrupt and so-called beds often include ground that is unsuitable for geoducks. This results in data that are skewed, and confidence intervals around the mean geoduck density estimate are therefore determined by the bootstrap method. The lower and upper 95% confidence limits are used in computing the low range and high range options, respectively.

The previous practice in analyzing these survey data has been to back-calculate the virgin density (in beds where harvesting had occurred) by adding the density removed by the fishery to the survey density. The locations of surveys where virgin density was calculated include Burnaby Island and Hotspring Island in the Queen Charlotte Islands (Table 8), the McMullin Group in the Central Coast and Yellow Bank on the west coast of Vancouver Island, and these estimates were used to compute quotas for the 1997 and 1998 fisheries. A review of this practice has shown that this may produce inflated density estimates if recruitment to the surveyed bed had been large in the years between initial harvest and the survey. For example, the survey on Yellow and Elbow Banks, Area 24, in 1995 produced a survey density estimate of 1.8 geoducks/m^2. The density of geoducks removed by the fishery over the area surveyed was calculated to be 0.54 geoducks/m^2 while the density of geoducks that had recruited to the surveyed population since the fishery began was estimated to be 0.48 geoducks/m^2 (Hand and Dovey *in prep*). In this case, at least, the estimate of recruit density is approximately equal to the estimate of density removed. Our precautionary approach is to take current density estimates as surrogates for estimates of virgin density until recruitment frequency, intensity and response to harvest are understood.

As stated, surveys generally include a number of individual geoduck beds. Where density estimates are available for a specific bed, the quota for that bed is calculated from the survey results from that bed alone. For unsurveyed beds within the same Statistical Subarea as a survey, the overall density estimate for all surveyed beds combined (with bootstrapped confidence intervals) was used. Thus, for example, all beds in Areas 2-31, 2-18 or 2-19 were assumed to have a mean density of 1.15 geoducks/m^2 (Table 8). For unsurveyed beds in the same Statistical Area as a survey, the average density of all surveys conducted in that Area was used. For Statistical Areas where no surveys have been conducted, the density estimate for the nearest Statistical Area that did have a density estimate was used (Tables 7 and 8). These areas include Area 1 which was assumed to have the same density as Area 2, Areas 3 and 4 which were assumed to have the same density as Area 5 and Areas 8 and 9 which were assumed to have the same density as Area 7.

The accuracy of survey results for density estimation is affected by the behaviour of geoducks of regularly retracting their siphons, so as to be invisible at times (Goodwin 1977). While surveys attempt to correct for this with 'show factor plots', there is some likelihood that a complete census is not obtained and therefore densities may be underestimated.

3.1.2.1 Inside Waters

A mean density of 1 geoduck/m^2 was used to derive quotas for 1991 to 1993. In 1994, a value of 0.7/m^2 was used, based on 1992 survey data from Marina Island (Campbell *et al.* 1996a). For the 1995 fishery, additional 1993 survey data from Comox Bar (Campbell *et al.* 1996b) was used and densities were reduced to 0.45 geoducks/m^2 for beds larger than 75 ha. Area 12 was treated separately and higher densities of 1 and 2 geoducks/m^2, based on reports from fishers and the high level of removals from these beds, were assumed (Table 7).

A survey was conducted along the shore from Oyster River to Cape Lazo in Statistical Area 14 in 1995 and 1996. Densities were estimated to be only 0.17 geoducks/m^2 (1.3 - 0.23) over a large area of 1,265 ha (Table 8). There are no additional survey data available for southern Inside Waters. Densities estimated from the Marina Island and Comox Bar surveys still form the basis of quota calculations for southern Inside Waters except for the Oyster Bay area. A 75 ha threshold for a change in density from 0.45 and 0.7 geoducks/m^2 originated with the Marina Island survey, in that one bed in the study area was 74 ha and had a density of 0.73/m^2, while the other bed was of 310 ha and had a density of 0.48/m^2. The low density for large harvest areas was corroborated by the Comox Bar survey where the 433 ha bed had a density of 0.45/m^2. The large uncertainty in these results is in the cut-off point for the density change, ranging from 74 ha to 310 ha. For the assessment for the 1996 fishery, three threshold points for low, medium and high range quota options of 75 ha, 200 ha and 300 ha were used (Hand *et al.* 1998b). Specifically, for the low range quota option, quotas for beds less than 75 ha were calculated using a density of 0.7 geoduck/m^2 and for beds greater than 75 ha, a density of 0.45 geoduck/m^2 was used. For the medium estimate, beds less than 200 ha were assigned a density of 0.7/m^2 and beds greater than 200 ha were assigned a density of 0.45/m^2. For the high range option, the change in density occurred at 300 ha. Thus, if a bed was smaller than 200 ha, the medium and high range options would be equal. This approach was continued in the assessment for the 1997 and 1998 fisheries and again, here, for the 1999 and 2000 fisheries.

3.1.2.2 West Coast of Vancouver Island

An arbitrary density of 2 geoduck/m^2 was used to derive quotas for 1991 to 1993, based on the advice from fishers 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 7).

In 1995, a survey was conducted in the Elbow/Yellow Bank area, Pacific Fishery Management Area 24, and an estimated density of 1.8 geoducks/m^2 (1.5 - 2.2; 95% C.I.) was obtained (Hand and Dovey *in prep*). The density of geoducks removed by the fishery over the area surveyed 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 were calculated with a density of 1.4/m^2.

A survey was conducted on Ahousat Bank and along the shore of Catface Range, also in Area 24, in 1997. Results from this survey indicate a current density of 1.72 geoducks/m^2 (1.2 - 2.3). No attempt was made to back-calculate virgin density by adding the density of geoducks removed by the fishery.

For 1999-2000 quotas on the West Coast, surveyed bed densities were used, where available, to calculate biomass for those beds surveyed in 1995 and 1997. A mean of these two survey estimates was used for the remaining beds in Area 24. There are no other modern survey data from the west coast of Vancouver Island and we continue to use a single density estimate of 1.4/m^2 to calculate quotas for 1999 and 2000 for the remainder of the west coast areas (Table 7).

3.1.2.3 North Coast

Fishers 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 7). 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, five surveys have been conducted in the Rupert area of the North Coast (Table 8). Densities from those surveys range from 1.48/m^2 to 2.2/m^2. For 1999 quotas, the mean survey density for individual beds was used, where available, to calculate biomass. An average of the two surveys conducted in each of Area 5 and Area 6 were used for all unsurveyed beds in those Statistical Areas (Table 7). All beds in Statistical Areas 3 and 4 were assumed to have the same density as Area 5.

Four surveys have been conducted in the Queen Charlotte Islands since 1994 (Table 8). An average of the mean virgin density estimates from the two surveys conducted in 1994 and 1995 was used to calculate quotas for the 1997 fishery (Table 7). Surveys conducted in 1996 and 1997 produced survey (uncorrected) density estimates of 1.15 and 0.48 geoducks/m^2, respectively. For the 1997 survey in Cumshewa Inlet only, the density of geoducks removed by the fishery that occurred just prior to the survey (0.03 geoducks/m^2) was added to the survey density. In addition, the results for Cumshewa were not included in the overall Queen Charlotte Islands average because the on-grounds observer and fishers claim that the area is not typical. For unsurveyed beds in the same Subarea, the overall survey estimate was used (Table 8). The average density estimate from all surveys combined was used for remaining beds in Statistical Areas 1 and 2 where surveys have not been conducted (Table 8).

3.1.3. Average geoduck weight

Up to and including 1995, an average fresh weight of 1.065 kg (2.348 lb) was used for all areas of the coast, based on initial market 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 sampling in all three licence areas of the coast and spanning the period 1981 to 1995 (Burger *et al.* 1995). Different average weights for each region were used, based on the data collected from the areas where fishing occurred in 1996 (Hand *et al.* 1998b). For the 1997 and 1998 fisheries, additional new data was included and mean weights were calculated on a finer geographic scale. For the 1999 and 2000 fisheries, additional market sample data were included. Mean weights were applied to the specific bed that the market sample was collected, beds within the Subarea were assigned an average over that Subarea; beds within the Area were assigned an average of the Area (Appendix Table 1). Where data were not available from a Statistical Area, means of adjacent Areas were used (Table 9). Since no market weights were available from Statistical Area 3 or 4, the mean from Area 5 was used. The upper and lower 95% confidence limits were used to express the uncertainty in this parameter in computing the quota options.

An approximate 5% water loss occurs over the time between harvesting and processing (Archipelago Marine Research, unpublished data). Since many of the samples used for determining mean weights were collected at processing plants, these weights may be slightly underestimated.

3.2 Harvest Rates

As discussed in 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 fishers 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 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 are nearing completion that were designed to examine recruitment characteristics of geoduck populations and evaluate the sustainability of the harvest rate. Three study areas, one on the west coast and two in inside waters, have been set up to determine growth and mortality rates, to determine the rate of natural and enhanced recruitment and to monitor the effects of harvest on recruitment. These studies are in their fifth to sixth years and results should be available for use in stock assessments within a couple of years. Pending the results of these multi-year research projects, we continue to use the 1% harvest rate for calculating the 1999 and 2000 quota options.

In contrast, exploitation rates used for quota calculations in the Washington State are currently 2.7% of the surveyed biomass (Bob Sizemore, Washington Department of Fish and Wildlife, pers. comm.).

3.3 Quota Calculations

The original or unfished biomass, B_0 (lb) for each geoduck bed is calculated as

$$B_0 = AD_0\bar{W} \qquad 2$$

where A is the area (m^2) of the geoduck bed, D_0 is the estimated virgin density ($\#/m^2$), and W is the mean geoduck weight (lb). Upper and lower 95% confidence limits around the mean survey density and mean geoduck weight estimates and the upper and lower estimates of bed area ($\pm$10%) are used to multiplicatively calculate the upper and lower ranges of biomass estimates.

The 3-year rotational quota options (Q) are calculated as

$$Q = 3(.01B_0). \qquad 3$$

for each estimate of B_0.

Beginning in 1995, an amortization program was incorporated into quota calculations for South Coast areas, based on an arbitrary management goal of maintaining a population size of at least 50% B_0 (Harbo *et al.* 1995). As the estimates of geoduck biomass have improved through surveys, market sampling and observer fisheries, it became apparent that quotas for many beds had been set too high and overexploitation had occurred. This situation would also arise in quota areas where certain beds are closer to port, better known by fishers, more protected from exposure or of higher quality product. To compensate for this overage, calculated quotas by bed were reduced by the ratio of the number years of quota 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 that had greater than 50% of the estimated stock removed were closed, pending surveys and further evaluations. The practice was applied to South Coast fishing areas in 1995 and extended to North Coast areas for the 1996 fishery (Hand *et al.* 1998b). It is continued for the 1999 and 2000 quota calculations.

To produce the amortization factors for each bed, the following factors are used.

Factor	Definition
Y_F	Years of quota fished
L	Cumulative landings (lb)
Y_Q	Number of years of quota remaining in 50-year cycle
Y_R	Number of actual years remaining in 50-year cycle

The number of years of quota fished in a bed (Y_F) is calculated as

$$Y_F = \left(\frac{L}{0.01(B_0)} \right) \qquad 4$$

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*) for each bed is then calculated as

$$AF = \frac{Y_Q}{Y_R} \qquad 5$$

The distribution of amortization factors, by region, is shown if Figure 8. The percentage of the total bed area that is closed for conservation is 12% in the North Coast, 13% in Area 12, 4% in the Strait of Georgia and 8% on the west coast of Vancouver Island.

The reduced 3-year quota for each of the low, medium and high options is simply the calculated quota (Q) 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.

The estimated stock biomass, adjusted landings and recommended low, medium and high risk quota options, by Geoduck Management Area, are shown in Table 10 for the 1999 fishery and Table 11 for the 2000 fishery. These are summarized by region and compared to the quotas and geoduck areas from the last rotation for each region (Table 12).

4. 1999 AND 2000 QUOTA OPTIONS AND RECOMMENDATIONS

Recommended coastwide quotas for 1999 are:

Low Range - 2,260,000 lb
Medium Range - 4,241,000 lb
High Range - 6,886,000 lb

Recommended coastwide quotas for 2000 are:

Low Range -	1,865,000 lb
Medium Range -	3,679,000 lb
High Range -	6,127,000 lb

In comparison to the 1996 quota of 4,061,775 lb, the last time that the 1999 GMA'S were fished, the recommended low, medium and high risk quota options are 44% less, 4% greater and 70% greater, respectively. The 2000 quotas options are 52% less, 5% less and 58% greater than the 1997 quota of 3,879,927 lb.

5. DISCUSSION AND RECOMMENDATIONS

The quota calculation process described in this document makes use of all available data, applied in as fine a geographic scale as possible, using database software. Commercial landing information is currently accurate, complete and received in a timely fashion, and market sample data, observer data and survey data continue to be collected. The parameters used in the quota calculations are all associated with varying degrees of uncertainty. A discussion of each of these follows.

Estimates of average geoduck weight are probably the most precisely determined component in the process and it's variation has the least effect on the range of quotas. It is most likely, however, that they are underestimates of virgin weight, since most samples were collected from beds where harvests have occurred.

The database of geoduck density continues to grow through ongoing survey efforts, and measured densities are available for 56 individual beds in the 1999 and 2000 rotations. The consistent trend in survey results over most of the B.C. coast has been decreased densities from when estimates were somewhat arbitrary. Although there was a significant decrease in north coast geoduck densities in 1996 (Table 7), additional survey results after that year did not continue the downward trend.

While many fishers might feel that these density estimates are too low, it must be remembered that the survey data were often collected over non-productive terrain due to the contagious distribution of geoduck populations, the uncertainty of the exact location of harvest activities and the constraints of the survey design. Fishers would not be likely to fish in these areas, however the zero geoduck counts that usually resulted from these transect placements had to be included in the overall density estimate. On the other hand, the total area of the bed, including patches of unsuitable substrate, was used to calculate the biomass, and so the densities should be appropriate.

Another factor that may lead to the underestimation of density is the incomplete census of geoducks in show factor plots. Corrections to survey data from these plots are normally greater than 0.9 (i.e., corrections of less than 10%). Since show factor plots are usually only monitored over a 10-day period, it is likely that the show factors are underestimated and the corrections applied to the observed geoduck counts are low. Surveys conducted in Washington State do not include show factor plots, however a standard factor of 0.75 is applied to all survey data, based on the results from 12 show factor sites monitored over 10 years (Bob Sizemore, Washington Department of Fish and Wildlife).

An issue pointed out by fishers for some survey locations is the incomplete coverage of the surveys relative to the area of commercial fishing. The depth range of transect surveys usually does not extent to the same depths as the commercial fishery. Bed areas for quota calculations are measured to depths of 20m, or 66 ft, chart datum. Unless the survey transects are completed at zero or negative tides, the corrected depth to which survey divers go is usually no greater than 50 ft. Fishers have reported that in some areas, notably the Queen Charlotte Islands, geoducks tend to be found in greater abundance toward the deeper end of the range of depths accessible to harvest activity. It may be possible, then, that the transect surveys are underestimating densities by not measuring the same depth distribution that is available to harvesters.

The density of geoducks in beds that have not been surveyed is assumed to be equal to measured densities in the same Statistical Area or Subarea, or in some cases an adjacent Area. To be statistically valid in applying survey results to unsurveyed areas, a sufficient number of randomly selected beds from the total population of beds within a defined geographic area must be chosen. Each of these 'beds' would, in turn, require a sufficient number of transects to calculate a reasonable precise mean density. Potential beds for survey are not, however, selected at random because of the enormous amount of survey effort that would be required to satisfy these statistical requirements. Candidates for surveying must have enough ground in close enough proximity to be surveyed in approximately 10 days without an excess of travel time. Generally, candidate areas to be surveyed are selected by the UHA and, where available, Aboriginal groups. In the Queen Charlotte Islands and the Central Coast, surveys have mostly been completed with Aboriginal groups (the Haida, Kitasoo and Heiltsuk Fisheries Programs) and beds to be surveyed include input from these groups. In Statistical Areas where no survey data exist, the first chosen location would likely be a well known fishing area, with adequate ground within a relatively short distance of each other. Beds have sometimes been chosen because they have supported sustained fishing, and at other times, because they are relatively new. Repeat surveys of specific beds have been conducted (and more are contemplated) to measure the effect of fishing on density. As survey information accumulates, the factors and priorities which affect decisions on where to survey change.

Estimates of geoduck bed area are sensitive to human subjectivity, interpretation of fishers information and to variable imprecision of nautical charts. The systematic review and evaluation of all charted bed polygons conducted in 1997 has increased our confidence in many of the area estimates because of the additional information available from observers and surveys. Most geoduck bed area estimates are, however, still unverified. Arbitrary reductions in bed area based on landing history is used to deal with perceived overestimates on a gross level, however bed-verification observer fisheries provide a more satisfactory, although more costly, solution. Every year, several beds are fished with on-board observer and through time, more and more 'problem' beds are being resolved.

The recommended annual exploitation rate of 1% of virgin biomass is at the conservative end of the recommended range of 0.5% - 2%. Recommendations resulting from more recent modelling exercises are contradictory and do not provide a strong indication that the value should be a changed. Research on recruitment and productivity is nearing completion which will provide the data required to address this area of uncertainty. Examinations to date of the sustainable exploitation rate have used parameters taken from studies in Washington State and southern British Columbia. Since the north coast fishery now accounts for the majority of landings, efforts should be made to incorporate biological data from the northern regions. In particular, natural mortality rate has a major effect on productivity and emphasis should be placed on collecting biological data from unexploited areas in the north coast.

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Table 1. Number of licences issued, number of vessels fished, landings and landed values of geoduck clams in British Columbia, as reported on sales slips (1976 to 1988) and on validation logs (1989 to 1997).

Year	Licences Issued	Vessels with Landings	Total Landings (lb)	Total Landings (t)	Total Value[1] $10-3	Mean Price ($/lb)	Mean Price ($/kg)	Price Range[2] ($/lb)	Price Range[2] ($/kg)
1976	7	5	97,002	44	N/A	N/A	N/A	N/A	N/A
1977	30	14	540,898	245	89	0.17	0.37	N/A	N/A
1978	54	27	2,239,950	1,016	569	0.25	0.55	0.15 - 0.35	0.33 - 0.77
1979	101	72	5,429,886	2,463	1,669	0.31	0.68	0.13 - 0.40	0.29 - 0.88
1980	95	63	6,186,067	2,806	2,299	0.37	0.82	0.30 - 0.48	0.66 - 1.06
1981	52	49	5,961,405	2,704	2,162	0.36	0.79	0.32 - 0.70	0.71 - 1.54
1982	52	53	6,910,800	3,134	2,814	0.40	0.89	0.22 - 0.46	0.44 - 1.01
1983	54	53	5,810,913	2,636	1,804	0.31	0.68	0.00 - 0.60	0.00 - 1.32
1984	54	44	7,678,465	3,483	2,937	0.38	0.84	0.00 - 0.95	0.00 - 2.09
1985	55	52	11,838,624	5,370	4,599	0.40	0.89	0.00 - 1.00	0.00 - 2.20
1986	55	55	11,035,396	5,006	4,605	0.39	0.86	0.00 - 0.85	0.00 - 1.87
1987	55	56	12,643,298	5,735	6,184	0.49	1.08	0.00 - 1.05	0.00 - 2.31
1988	55	56	10,068,830	4,567	9,807	0.97	2.14	0.03 - 1.88	0.07 - 4.14
1989	55	47	8,784,247	3,985	12,571	1.43	3.15	0.25 - 1.75	0.55 - 3.85
1990	55	44	8,722,366	3,956	10,581	1.21	2.67	0.14 - 2.27	0.31 - 5.00
1991	55	44	7,346,864	3,333	9,659	1.29	2.84	0.58 - 2.55	1.27 - 5.62
1992	55	41	6,313,748	2,864	16,237	2.56	5.64	1.60 - 5.01	3.53 - 11.04
1993	55	44	5,365,420	2,434	26,994	4.99	11.00	1.00 - 9.38	2.20 - 20.68
1994	55	44	4,908,523	2,226	33,552	6.87	15.15	1.20 - 9.00	2.66 - 19.84
1995	55	45	4,624,330	2,098	42,518	9.36	20.63	3.50 - 15.00	7.72 - 33.07
1996	55	45	4,059,965	1,817	36,271	8.93	19.68	6.06 - 12.00	13.36 - 26.46
1997	55	42	3,960,083	1,796	33,698	8.51	18.76	2.50 - 11.00	5.51 - 24.25
Total:			133,616,280	60,608	258,805				

[1]Price taken from market reports and sales slips.

[2] Price paid to commercial fishermen

Table 2. Summary of geoduck landings (tonnes) by South Coast Management Area, as reported on sales slips (1976 to 1988) and on validation logs (1989 to 1997). A three year rotation of areas was initiated in 1989, with the exception of Area 24.

	East Coast Vancouver Island								West Coast Vancouver Island										Annual
Year	11	12	13	14	15	16	17	18	19	28	29	20	21	23	24	25	26	27	Total (t)
1976				10			8		26										44
1977			14	9	77		137	2						6					245
1978			8	261	321	3	24	19	136			1	3	2	236	2			1,016
1979		24	160	276	263	148	209	3	159					153	950	87	22	9	2,463
1980			97	215	17	301	225	34	91			5		288	841	321	303		2,738
1981			41	180	29	70	155	44	28			8		187	819	473	156	6	2,195
1982		83	14	144	33	103	17	1	14			14		174	1,218	366	726		2,907
1983		16	29	340	29	42	13	2	10					84	1,066	215	287	1	2,134
1984	8	302	150	285	54	129	128	1	118					219	628	442	443	2	2,909
1985	13	490	81	172	42	38	137	4	78			0		227	730	599	272	1,050	3,934
1986	21	212	148	200	137	117	136	13	124		11	96		231	803	450	226	388	3,313
1987		275	112	286	98	159	265	103	50		100	40		247	661	552	398	241	3,587
1988	62	290	51	191	59	95	110	2	116	1	17	49		192	633	187	206	279	2,541
1989	5	662	203											538	633			345	2,386
1990				605		258									540		614	343	2,360
1991					258		181	37	244		14	1			416	702	153		2,006
1992		256	78	291										255	479			306	1,665
1993				349		182									497		220	124	1,371
1994					181		134	20	64		10				232	496			1,137
1995	6	80	54	286										129	188			210	953
1996		96		193	43	102					2				239		129		804
1997			47		241	5									162	393			848
1976 to 1997	116	2,786	1,287	4,293	1,882	1,752	1,879	284	1,258	1	154	214	3	2,932	11,970	5,285	4,154	3,304	43,556
Inside Waters Total:						15,693			West Coast Total:			27,863							

Table 3. Summary of geoduck landings (tonnes) by North Coast Management Area, as reported on sales slips (1980 to 1988), and on validation logs (1989 to 1997). A three year rotation of areas was initiated in 1989.

	NORTH COAST MANAGEMENT AREA											Annual
Year	1	2E	2W	3	4	5	6	7	8	9	10	Total (t)
1980		31			4					28	5	68
1981		11				84	6	370	18		20	509
1982								227				227
1983								202	299			501
1984		4		3		214	8	109	183	54		575
1985		341	213			291	60	494	37			1,436
1986	7	254	325	120	125	323	24	392	2	103	17	1,692
1987	137	391	179	134	95	287	484	222	91	11	117	2,148
1988	119	462	45	77	150	191	423	309	250			2,026
1989							149	1,269	40		142	1,600
1990				77	356	441	721					1,596
1991	91	848	388									1,327
1992							202	853	83	23	39	1,199
1993				37	170	411	445					1,063
1994	48	684	359									1,091
1995							218	736	121	30	40	1,145
1996				78	159	399	402					1,038
1997	36	594	316									946
1976 to 1997	438	3,619	1,825	526	1,059	2,641	3,141	5,183	1,124	248	380	20,185

Table 4. Summary of Statistical Areas fished in each rotation, by Region, and the number of Management Area quotas for 1989 to 1998 and recommended for 1999 and 2000.

	Inside Waters		West Coast Van. Is.		North Coast	
Year	Areas	# GMA's	Areas	#	Areas	#
First Rotation (1989-90-91)						
1989	11.12.13	4	23. 24. 27A	5	lower 6. 7 to 10	7
1990	14.16	5	24. 26. 27H. I	8	3. 4. 5. upper 6	5
1991	15.17.18. 19. ptn 29	10	20. 24. 25. 26B1. B2. C	12	1. 2E. 2W	19
Second Rotation (1992-1993-1994)						
1992	all of 12	7	all of 23	5	ptn 6	8
	13	5	24	7	7	11
	14A. B. C	3	27A. B. D. E. F. G	8	8	2
					9	2
					10	1
1993	14D. E	2	24	6	3.4	7
	all of 16	5	26A. B2. D	3	5	9
			27H	1	6	11
1994	all of 15	7	all of 24	8	1	2
	17	2	25	3	2E	17
	18	2			2W	13
	19	3				
	29-4	1				
Third Rotation (1995-1996-1997)						
1995	12A. C. D. F. G	5	all of 23	5	lower 6	6
	13A. C. D. E	4	24	9	7	21
	14A. B. C	3	27	8	8. 9. 10	9
1996	12B	2	24	11	3	5
	14D. E	2	26A. C. D	4	4	10
	all of 16	6			5	13
					ptn 6	15
1997	13A. B. C. D	3	all of 24	12	1	2
	all of 15	10	25	4	2E	20
	18	2			2W	25
	19	1				
Fourth Rotation (1998-1999-2000)						
1998	all of 12	6	all of 23	5	ptn 6	8
	13E	1	24	12	7	32
	14A1. A2. B. C	4	27	5	8. 9. 10	9
	all of 17	4				
	ptn 29	1				
1999[1]	14D. E	2	all of 24	15	3	6
	all of 16	6	26	4	4	12
					5	11
					ptn 6. 106	15
2000[1]	13A. C. D. F	5	all of 24	14	1	2
	all of 15	10	25	4	2	45
	18	2				
	19	3				

[1] Proposed

Table 5. Summary of annual quotas (10^{-3} lb.) and the number of quota management areas (brackets) from 1979 to 1998 in the geoduck clam fishery.

	South Coast						North Coast								Coast	Total
Year	Inside Waters		West Coast V.I.		Subtotal		QCI		Prince Rupert		Central		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)	3,372.0	(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	959.2	(10)	811.6	(16)	1,770.8	(26)	closed		2,287.3	(43)	closed		2,287.3	(43)	4,058.2	(69)
1997	649.2	(17)	1,226.4	(15)	1,875.6	(32)	2,091.6	(47)	closed		closed		2,091.6	(47)	4,107.6	(79)
1998	647.8	(21)	1,080.0	(21)	1,727.8	(42)	closed		closed		2,232.0	(50)	2,232.0	(50)	3,959.8	(92)

Table 6. 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 (#/m²)	Estimated Biomass (lb)	Reason for Closure
North Coast							
2	1	1	SKIDIGATE MISSION	81	1.02	2,284,181	First Nations
2	13	3	N OF DOLOMITE NARROWS	2	1.14	75,679	Park
2	16	1	S OF DOLOMITE NARROWS	19	1.02	530,417	Park
Inside Waters							
12	16	3	HARDY BAY SE DUVAL IS	7	1.7	284,122	CONTAMINATED
12	16	11	BEAVER HBR	44	1.7	1,774,546	CONTAMINATED
12	16	13	E THOMAS PT - AIRPORT	4	1.7	162,356	FIRST NATIONS
13	3	1	GOWLAND HBR - MAY IS	4	0.7	54,820	MARINE PARK
13	3	2	S GOWLLAND IS	2	0.7	31,148	MARINE PARK
13	13	1	DREW HARBOUR	7	0.7	111,241	Contaminated
13	15	1	N MARINA IS	81	0.7	1,256,492	DFO Research
13	15	2	S MARINA IS	235	0.45	2,357,558	DFO Research
13	15	6	MANSONS LANDING	16	0.7	249,803	CONTAMINATED
14	8	1	DEEP BAY	12	0.7	191,390	CONTAMINATED
14	8	2	MUD BAY	9	0.7	134,474	CONTAMINATED
14	8	4	SHIPS PT	19	0.7	290,392	CONTAMINATED
14	11	2	UNION POINT	15	0.7	233,296	CONTAMINATED
14	11	4	GARTLEY POINT	19	0.7	290,392	CONTAMINATED
15	1	1	S WESTVIEW	52	0.7	806,549	CONTAMINATED
15	1	12	S OF POWELL RVR	7	0.7	109,944	CONTAMINATED
15	3	8	MITTLENATCH IS	9	0.7	102,336	MARINE PARK
17	17	7	E MUDGE IS	90	0.7	1,051,253	DFO Research
19	8	1	PATRICIA BAY	104	0.7	1,313,064	contaminated
19	8	2	COLES BAY	17	0.7	212,807	contaminated
29	5	4	CORDERO PT	3	0.7	41,822	Marine Protected Area
West Coast							
23	4	7	S FLEMMING	4	1.4	147,035	Bamfield Marine Station
23	5	2	MARBLE COVE	7	1.4	169,594	Bamfield Marine Station
23	5	13	SW FLEMING	8	1.4	207,282	Bamfield Marine Station
23	5	14	MID WEST SHORE FLEMING IS	8	1.4	194,389	Bamfield Marine Station
23	8	6	S BRABANT - N PEACOCK CH	6	1.4	195,597	Pacific Rim Park Reserve
23	8	7	NE CLARKE IS	6	1.4	217,180	Pacific Rim Park Reserve
23	8	8	E TURRET IS	3	1.4	109,265	Pacific Rim Park Reserve
24	1	2	HESQUIAT HBR	8	1.77	354,444	First Nations
24	6	6	WHITESAND COVE	42	1.77	1,822,794	MARINE PARK
24	6	18	AHOUS BAY	3	1.77	118,611	Whale Sanctuary
24	6	30	S OF ROBERT PT	8	1.77	332,513	DFO Research
24	6	31	DUNLAP IS	13	1.73	545,594	DFO Research
24	7	5	N RICHIE BAY	1	1.77	62,658	DFO Research
24	9	1	VAN NEYEL CHNL	38	1.77	1,251,411	contaminated
24	9	2	TOFINO	6	1.77	208,135	contaminated
26	7	1	N OF CHECKAKLIS IS BUNSBY'S	34	1.4	1,124,906	Sea Otter Reserve
26	7	2	BATTLE BAY - NW OF BUNSBY IS	6	1.4	212,675	Sea Otter Reserve
26	7	3	SW OF THEODORE PT	4	1.4	135,096	Sea Otter Reserve
26	7	4	ACOUS PENN - CUTTLE ISLAND	12	1.4	388,832	Sea Otter Reserve
26	7	5	WEST OF BATTLE BAY	3	1.4	109,682	Sea Otter Reserve

Table 7. Summary of geoduck densities (#/m²), by North Coast and South Coast regions, used to calculate quotas from 1991 to 2000.

NORTH COAST

Year	Queen Charlotte Is. Stat Areas	Queen Charlotte Is. low	Queen Charlotte Is. med.	Queen Charlotte Is. high	Prince Rupert Stat Areas	Prince Rupert low	Prince Rupert med.	Prince Rupert high	Central Coast Stat Areas	Central Coast low	Central Coast med.	Central Coast high
1991	All	-	3.5,5.0	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-	All	-	3.5, 5.0	-
1993	-	-	-	-	All	-	3.5	-	-	-	-	-
1994	All	-	1.0,3.0,3.5	-	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-	All	-	3.5	-
1996	-	-	-	-	All	1.3	1.8	2.5	-	-	-	-
1997	All	1.2	1.6	2.2	All	-	-	-	-	-	-	-
1998	-	-	-	-	All	-	-	-	All	1.2	1.7	2.3
1999	-	-	-	-	3,4,5	1.65	2.18	2.89	-	-	-	-
					6	1.14	1.57	2.05				
2000	All	0.69	1.0	1.46	-	-	-	-	-	-	-	-

SOUTH COAST

Year	West Coast Van. Is. Stat Areas	West Coast Van. Is. low	West Coast Van. Is. med.	West Coast Van. Is. high	Inside Waters Stat Areas	Inside Waters low	Inside Waters med.	Inside Waters high
1991	All	-	2.0	-	All	-	1.0	-
1992	All	-	2.0	-	All	-	1.0	-
1993	All	-	2.0	-	All	-	1.0	-
1994	All	-	1.4	-	All	-	0.7	-
1995	All	-	1.4	-	12	-	1.0,2.0	-
					13-19,29	-	0.45,0.7	-
1996	All	-	1.4	-	12	1.5	1.8	2.2
					13-19,29	-	0.45,0.7	-
1997	All	-	1.4	-	All	-	0.45,0.7	-
1998	Yellow Bank	2.1	2.4	2.8	ptn. 12	1.4	1.7	1.95
	Remainder	-	1.4	-	Remainder	-	0.45,0.7	-
1999	24	1.35	1.77	2.23	14-13	0.13	0.17	0.23
	26	-	1.4	-	rem. 14	-	0.45, 0.7	-
					16	-	0.45, 0.7	-
2000	24	1.35	1.77	2.23	13,15,19	-	0.45, 0.8	-
	25	-	1.4	-				

Table 8. Summary of mean geoduck density (#/m²), with sample size (number of transects, N) and 95% bootstrapped confidence limits, by individual bed, from geoduck surveys conducted in 1999 and 2000 rotation areas.

Location	Year Surveyed	Statistical Area	Bedcode	N	Density ((#/m²) Mean	L95%	U95%
Queen Charlotte Islands							
Burnaby Island	1994	2-12	1,2,3,6,7,9	39	1.14	**0.67**	1.85
Hotsprings Island	1995	2-11	11	5	2.69	1.20	4.69
		2-11	14	3	2.37	1.34	3.60
		2-11	6	7	1.51	0.48	2.39
		2-11	13	4	0.69	0.24	1.53
		2-11	7	6	1.14	0.42	2.27
		2-11	8	10	1.75	1.31	2.32
		2-11	10	7	0.73	0.25	1.31
			Combined	42	1.31	**0.93**	1.77
Houston Stewart	1996	2-31	8	4	0.29	0.11	0.69
		2-31	1,2	17	1.03	0.46	2.11
		2-31	3	4	2.79	0.99	5.70
		2-18	1	4	1.64	0.04	3.19
		2-18	10	4	3.07	1.93	5.67
		2-18	6	3	1.51	0.86	2.55
		2-18	3	3	0.43	0.16	0.89
		2-18	4	4	1.75	0.20	4.16
		2-19	1	9	0.48	0.25	0.70
		2-19	2	7	0.53	0.09	0.82
			Combined	59	1.15	**0.78**	1.58
Cumshewa Inlet[1]	1997	2-3	3	16	0.42	0.15	0.79
		2-3	2	37	0.34	0.18	0.54
		2-3	1	12	0.76	0.45	1.17
		2-3	9	3	0.16	0.09	0.22
		2-3	6	4	0.50	0.28	0.77
		2-3	5	7	0.73	0.19	1.47
		2-3	7	5	0.74	0.19	1.23
			Combined	84	0.48	**0.36**	0.62

Table 8, cont'd.

Location	Year Surveyed	Statistica Area	Bedcode	N	Density ((#/m²) Mean	L95%	U95%
Rupert							
Southwest Aristazabal	1995	6-17; 6-	1; 9,10	7	1.61	0.84	2.76
		6-13	8, 25, 26	8	0.98	0.74	1.36
		6-13	1	3	3.14	1.36	5.93
		6-13	4	11	1.46	0.66	2.74
Centralwest Aristazabal	1996	6-13	2, 3	12	0.83	0.55	1.21
		6-13	7	8	0.78	0.36	1.63
		6-13	6	4	0.54	0.28	0.79
		6-13	14	10	2.70	0.99	4.41
		6-13	13	10	1.39	0.21	3.35
		6-13	15	6	2.00	0.09	3.64
		6-13	11	8	1.71	0.32	3.63
			Combined	87	1.48	**1.12**	1.88
Griffith Harbour	1995	5-20	1	33	2.20	**1.60**	3.00
Otter Pass	1996	6-9	21	6	1.93	0.25	4.54
		6-9	5	16	0.87	0.25	1.99
		6-9	7	8	1.89	0.54	3.26
		6-9	1	5	1.62	1.22	2.10
		6-9	14	4	3.68	2.05	5.99
			Combined	39	1.65	**1.16**	2.22
Principe Channel	1997	5-13	4,6	24	2.62	1.87	3.52
		5-13	8	14	2.56	1.51	3.59
		5-13	10	6	0.51	0.23	0.75
		5-13	3	6	0.63	0.26	1.06
		5-13	1	7	2.48	1.35	3.76
		5-13	9	3	2.36	0	6.07
			Combined	60	2.16	**1.69**	2.78
W.C. Vancouver Island							
Yellow/Elbow Banks	1995	24-7	2	11	2.51	2.20	2.80
		24-6	32	16	1.51	0.92	2.12
		24-6	27	9	1.11	0.85	1.48
		24-6	26,31	8	1.73	1.31	2.18
			Combined	44	1.82	**1.49**	2.16
Ahousat	1997	24-6	2,7	28	1.72	**1.20**	2.30
Inside Waters							
Oyster R./ Cape Lazo	1995/96	14-13	1,5	55	0.17	**0.13**	0.23

[1] 1997 fishery removals added to survey density.

Table 9. Summary of mean individual geoduck weight (lb), 95% confidence limits and minimum estimate, where samples exist, from market samples, by Statistical Area and fishery year(s).

Stat Area	1995	1996	1997/98 Mean	1997/98 +/- 95%	1999/2000 Mean	1999/2000 +/- 95%	1999/2000 Min.
1	-	-	2.862	0.030	2.687	0.103	2.681
2	-	-	2.862	0.030	2.766	0.027	1.673
3[1]	-	2.765	-	-	2.685	0.039	-
4[1]	-	2.765	-	-	2.685	0.039	-
5	-	2.765	2.683	0.040	2.685	0.039	2.576
6	2.348	2.765	2.848	0.068	2.526	0.04	2.037
7	2.348	-	2.550	0.037	2.572	0.036	2.145
8[2]	2.348	-	2.550	0.037	2.572	0.036	-
9[2]	2.348	-	2.550	0.037	2.572	0.036	-
10[2]	2.348	-	2.550	0.037	2.572	0.036	-
11[2]	-	-	2.308	0.038	2.572	0.036	-
12[3]	2.348	2.396	2.308	0.038	2.308	0.038	-
13	2.348	-	2.233	0.027	2.225	0.082	2.225
14	2.348	2.227	2.233	0.027	2.234	0.028	1.582
15	-	-	2.200	0.043	2.199	0.027	1.533
16	-	2.227	-	-	2.075	0.029	1.811
17	-	-	1.664	0.065	1.664	0.065	1.664
18	-	-	1.797	0.065	1.797	0.065	1.797
19[4]	-	-	1.797	0.065	1.797	0.065	-
29[5]	-	-	1.797	0.065	2.075	0.029	-
23	2.348	-	2.409	0.052	2.409	0.052	1.771
24	2.348	2.474	2.424	0.041	2.392	0.036	1.481
25	-	-	2.569	0.077	2.325	0.064	2.011
26	-	2.474	-	-	2.389	0.043	2.249
27[6]	2.348	-	2.388	0.043	2.389	0.043	-

[1] Estimate in 1999/2000 from Area 5
[2] Estimate in 1999/2000 from Area 7
[3] Estimate in 1999/2000 from harvest logbook records where # pieces recorded
[4] Estimate in 1999/2000 from Area 18
[5] Estimate in 1999/2000 from Area 16
[6] Estimate in 1999/2000 from Area 26

Table 10. Estimates of geoduck bed area (ha), stock biomass('000 lb), landings (lb) and recommended low, medium and high quota options ('000 lb), by geoduck management area (GMA) for the 1999 geoduck fishery.

	Description	#	Bed	Estimated Stock Biomass('000 lb)			Total Adj.	Quota Options ('000 lb)		
GMA		Beds	Area (ha)	low	med	high	Landings (lb)	low	med	high
14D	Hornby Island	8	427	3,889.8	5,707.4	6,455.2	1,332,941	61.8	124.7	151.9
14E	Mapleguard Point-Northwest Bay	6	1,402	12,776.0	15,681.2	18,825.6	2,720,060	307.4	415.0	533.7
16A	West Texada excl. Crescent Bay	8	387	4,264.0	5,781.1	6,548.4	1,729,197	32.5	104.4	140.1
16B	Lasqueti Island	13	280	3,265.2	3,756.5	4,240.9	1,635,567	26.6	35.8	49.6
16C	E. Texada Island	3	26	321.2	371.3	414.3	587,546	2.8	3.6	4.3
16D	Thormanby Island, mainland	10	549	5,168.8	6,607.2	8,905.6	468,886	152.4	195.8	265.0
16E	Salmon-Sechelt Inlets, Porpoise B.	3	44	552.8	639.2	713.3	152,020	7.9	10.7	13.1
16F	Jervis Inlet	6	41	518.6	599.6	669.1	58,535	13.2	15.7	17.9
Total Inside		57	3,155	30,756.4	39,143.6	46,772.4	8,684,750	604.6	905.8	1,175.6
24A2a	Yorksis	1	139	3,690.8	5,879.7	8,271.7	1,751,708	3.0	38.3	76.9
24A2b	E. side Father Charles Channel	3	147	3,897.5	6,209.0	8,735.0	315,944	39.0	62.1	87.3
24A3	Tonquin/Echachis	3	97	2,572.5	4,098.2	5,765.4	337,371	25.6	40.9	57.6
24A4	Epper/Dunlap	9	222	5,554.6	8,328.0	11,873.5	1,396,435	36.5	66.3	109.3
24A5	Lemmens Inlet	3	111	2,281.9	3,601.1	5,374.3	897,645	6.0	23.9	49.6
24A6a	Yellow Bank	2	130	5,478.2	7,637.1	9,566.7	2,001,059	23.7	58.2	89.0
24A6b	E. Maurus Channel	3	106	2,196.9	3,937.0	6,156.3	2,747,536	4.1	8.2	11.6
24B1	Outside	10	711	21,675.1	32,418.6	46,095.7	7,800,646	124.2	268.5	439.2
24B2	West Coomes Bank	2	112	11,440.2	17,177.5	24,514.9	3,063,891	18.0	26.6	37.4
24B3	Ahousat	3	392	7,818.9	13,243.4	20,635.8	2,748,047	41.7	128.7	206.4
24B4	Russell Channel	3	289	8,420.2	12,454.6	17,521.4	1,534,992	74.7	124.5	175.2
24C1	Sydney Inlet	11	119	3,182.4	5,059.0	7,117.1	833,397	21.5	43.2	67.6
24C2	Exposed	3	38	1,047.5	1,623.3	2,283.6	92,600	10.4	18.3	27.5
24D1	Inlets	19	102	2,715.6	4,326.1	6,086.1	591,517	17.8	34.2	52.0
24D2	Indian Island	3	36	1,421.5	2,264.5	3,185.7	65,295	9.1	15.0	21.2
26A	North Inlets	13	89	2,557.6	2,979.0	3,335.4	930,994	50.4	62.2	72.2
26B	Mission Group	4	129	3,833.3	4,391.9	4,973.2	6,106,630	37.0	45.3	53.9
26C	Central Kyuquot Inlets	12	31	884.7	1,020.1	1,149.2	365,764	13.8	18.0	22.1
26D	South	15	171	4,994.0	5,716.7	6,445.4	1,483,842	89.9	107.4	126.2
Total WC		122	3,171	95,663.5	142,364.6	199,086.4	35,065,312	646.3	1,189.9	1,782.4

Table 10, cont'd.

GMA	Description	# Beds	Bed Area (ha)	Estimated Stock Biomass ('000 lb) low	med	high	Total Adj. Landings (lb)	Quota Options ('000 lb) low	med	high
PRA1	Duckers Island	1	29	764.8	1,169.1	1,705.7	237,877	10.6	25.4	45.0
PRA2	Surf Inlet	2	29	739.9	1,131.1	1,650.2	494,666	0.9	5.0	24.3
PRA3	Anderson Island	6	43	1,242.4	1,860.1	2,649.3	106,948	33.3	53.3	77.7
PRA4	Borrowman Bay	6	18	174.3	958.7	1,883.0	102,434	3.5	25.7	56.2
PRA5	Kettle Inlet	2	49	525.8	2,387.2	5,532.4		0.0	52.4	157.3
PRA6	Butler Shoal	3	56	369.3	888.1	1976.6		0.0	15.7	51.4
PRA7	Clifford Bay North	2	52	1,354.2	2,196.3	3,409.9		16.9	27.9	65.7
PRA8	Clifford Bay South	2	70	888.1	2,254.3	4,801.0		0	38.2	133.7
PRA9	Weeteeam Bay	8	75	1,855.1	3,904.6	7,491.0	795,154	23.1	88.8	198.3
PRA10	Moore Islands	7	47	1,207.3	1,877.0	2,738.3	55,010	33.6	54.0	80.4
PRB1	Calamity Bay	7	100	1,898.2	4,258.7	7,953.5	1,038,412	15.5	76.8	197.9
PRB2	Estevan Group	4	26	885.1	1,578.8	2,649.0	142,271	23.2	45.0	78.5
PRB3	Langley Pass	5	45	1,184.9	1,870.8	2,812.4	344,688	16.5	40.6	73.7
PRB4	Lotbiniere Bay	4	35	926.5	1,462.8	2,199.1	91,253	26.9	43.5	65.7
PRB5	Campania Island	3	14	372.2	569.0	830.2	28,688	9.7	15.8	23.8
PRC1	Wreck Island	2	55	2,116.2	3,198.6	4,733.5	446,329	42.8	81.3	134.9
PRC2	Waller Bay	1	27	1,048.8	1,585.2	2,346.0	187,105	23.5	42.2	68.8
PRC3	South Banks Island	2	7	284.5	430.1	636.5	19,367	8.4	12.8	19.1
PRD1	Freeman Pass	2	38	1,482.0	2,240.0	3,314.9	272,153	40.8	67.2	99.4
PRD10	Kingkown Inlet	1	63	2,355.6	3,548.9	5,307.7	992,996	16.3	69.0	146.5
PRD2	Shakes Islands	11	32	1,225.6	1,852.5	2,741.4	105,928	33.5	54.4	81.6
PRD3	Principe Channel North	10	128	4,799.7	7,671.7	11,472.4	50,300	142.4	229.0	343.4
PRD4	Principe Channel South	1	2	86.8	131.1	194.1	374	2.6	3.9	5.8
PRD5	Larson Harbour	1	42	1,610.5	2,505.5	3,825.7	180,958	48.3	75.2	114.8
PRD6,7,8	Borrowman Group	1	152	5,882.5	9,177.3	14,051.2	2,515,260	34.5	168.1	365.7
PRD9	Sneath Island	1	66	2,491.8	3,950.4	6,137.7	769,207	38.7	97.8	184.1
PRE1	Wales Island	4	4	135.8	201.1	295.8	4,766	3.9	6.0	8.9
PRE2	East Chatham Sound	3	13	475.5	704.0	1,035.4	126,797	9.1	14.4	25.2
PRE3	North Dundas Island	7	45	1,690.9	2,503.7	3,682.2	523,672	24.3	51.7	93.7
PRE4	Northwest Dundas Island	3	46	1,754.9	2,598.5	3,821.7	328,236	39.7	69.9	110.9
PRE5	Southwest Dundas Island	4	34	1,279.5	1,894.5	2,786.3	313,912	22.3	43.5	74.8
PRF1	Stephens Island	4	39	1,476.0	2,185.5	3,214.2	51,041	42.5	64.5	96.3
PRF2	North Porcher Island	9	42	1,606.0	2,377.9	3,497.3	373,548	36.6	56.9	86.1
PRF3	Oval Bay	1	15	569.6	843.5	1,240.5	67,489	17.1	25.3	37.2
PRG1	Connel Island	1	19	704.8	1,043.6	1,534.9	235,464	8.2	20.0	37.1
PRG2	Baron Island	8	29	1,088.9	1,612.3	2,371.3	195,473	23.6	41.5	67.4
PRG3	West Chatham Sound	9	21	806.1	1,193.6	1,755.5	44,308	22.0	33.8	51.0
PRG4	Melville/Dunira	2	60	2,278.6	3,373.8	4,962.0	505,940	42.7	79.5	132.9
PRG5	West Tree Nob Group	1	10	373.7	553.3	813.8	179,877	0.5	6.8	15.8
PRG6	East Tree Nob Group	2	65	2,460.9	3,643.7	5,358.9	363,663	63.3	101.3	156.4
PRG7	Archibald Island	1	19	726.1	1,075.1	1,581.2	278,931	6.5	19.9	39.4
Total NC		153	1,746	55,199.4	90,462.1	142,993.7	14,604,653	1,007.4	2,143.8	3,926.6

Table 11. Estimates of geoduck bed area (ha), stock biomass ('000 lb), landings (lb) and recommended low, medium and high quota options ('000 lb), by geoduck management area (GMA) for the 2000 geoduck fishery.

		#	Bed	Estimated Stock Biomass ('000 lb)			Total Adj.	Quota Options ('000 lb)		
GMA	Description	Beds	Area (ha)	low	med	high	Landings (lb)	low	med	high
13A	S.E. Quadra Island	7	128	1,726.7	1,991.9	2,271.8	267,584	48.5	56.8	65.3
13C	S.W. Cortes	6	109	1,240.0	1,697.5	1,935.9	718,781	16.3	23.5	33.9
13D	N.W. Cortes	9	82	1,112.7	1,283.5	1,463.9	179,125	30.1	36.3	42.9
13F	Hardwicke Island	1	6	80.5	92.8	105.9	13,094	1.7	2.0	2.4
15A	Savary Island North	1	130	775.3	1,397.1	1,599.8	488,888	0.0	21.0	31.1
15B	Savary Island South	1	425	2,716.1	3,126.7	3,559.0	358,924	81.5	93.8	106.8
15C1	W. Coast Hernando Island	1	11	112.3	129.1	146.8	253,718	0.0	0.0	0.0
15C2	E. Coast Hernando Island	1	62	634.6	729.5	829.3	495,383	0.0	0.0	0.0
15D	Balance of area 15	18	276	3,042.7	3,756.6	4,217.3	683,520	70.8	95.7	111.8
15E	Inlets	2	11	133.6	172.4	191.9	93,066	0.3	0.5	0.7
15F	Cortes/Redonda Islands	1	28	409.5	463.3	518.9	169,656	3.4	6.0	8.7
15G	Twin Islands	3	85	863.2	992.4	1,128.2	235,405	18.6	24.7	31.1
15H	W. Harwood Island	1	42	421.8	485.6	552.7	63,686	10.3	12.5	14.8
15I	E. Harwood Island	1	56	389.1	715.4	834.2	225,992	0.0	13.2	19.1
18A	Boatswains Bank	1	30	328.9	379.2	432.2	96,411	5.8	8.0	10.3
18B	Balance of area 18	10	90	982.9	1,133.1	1,291.4	232,652	19.4	24.1	29.2
19B	James Island	3	682	4,985.7	5,744.0	6,551.0	2,088,756	39.1	73.1	109.2
19C	Balance of area 19	8	307	2,990.5	3,860.2	4,402.6	653,691	61.0	92.6	112.3
Total Inside		75	2,561	22,946.0	28,150.4	32,032.7	7,318,333	406.7	583.8	729.5
24A2a	Yarksis	1	139	3,690.8	5,879.7	8,271.7	1,751,708	3.0	38.3	76.9
24A2b	E. side Father Charles Channel	3	147	3,897.5	6,209.0	8,735.0	315,944	39.0	62.1	87.3
24A3	Tonquin/Echachis	3	97	2,572.5	4,098.2	5,765.4	337,371	24.6	39.3	55.3
24A4	Epper/Dunlap	9	222	5,554.6	8,328.0	11,873.5	1,396,435	36.5	66.3	109.3
24A5	Lemmens Inlet	3	111	2,281.9	3,601.1	5,374.3	897,645	2.8	18.8	42.0
24A6a	Yellow Bank	2	130	5,478.2	7,637.1	9,566.7	2,001,059	23.7	58.2	89.0
24A6b	E. Maurus Channel	3	106	2,196.9	3,937.0	6,156.3	2,747,536	4.1	8.2	11.6
24B1	Outside	10	711	21,675.1	32,418.6	46,095.7	7,800,646	124.4	269.4	441.0
24B2	West Coomes Bank	2	112	3,352.3	4,999.8	7,090.0	3,063,891	80.9	165.6	245.1
24B3	Ahousat	3	392	7,818.9	13,243.4	20,635.8	2,748,047	39.9	126.5	203.1
24B4	Russell Channel	3	289	8,420.2	12,454.6	17,521.4	1,534,992	66.3	112.0	157.5
24C1	Sydney Inlet	11	119	3,182.4	5,059.0	7,117.1	837,644	21.4	39.1	67.3
24C2	Exposed	3	38	1,047.5	1,623.3	2,283.6	129,310	10.4	18.3	27.5
24D1	Inlets	19	102	2,715.6	4,326.1	6,086.1	591,517	17.2	33.0	50.4
24D2	Indian Island	3	36	1,421.5	2,264.5	3,185.7	65,295	14.1	22.6	31.9
25A	Esperanza	19	400	11,946.6	13,704.4	15,501.2	6,235,600	18.9	68.0	139.7
25B	Nuchatlitz	6	562	15,386.5	18,297.9	20,681.8	3,570,239	342.7	461.3	559.9
25C	Rosa Harbour	2	48	1,192.9	1,400.8	1,623.7	837,049	10.3	11.9	13.5
25D	Nootka	26	154	4,191.6	5,026.9	5,681.9	1,620,552	51.1	73.2	93.5
Total WC		131	3,915	108,023.6	154,509.2	209,246.8	38,482,479	931.4	1,692.3	2,502.1

Table 11 cont'd.

GMA	Description	# Beds	Bed Area (ha)	Estimated Stock Biomass ('000 lb) low	med	high	Total Adj. Landings (lb)	Quota Options ('000 lb) low	med	high
QCA1	Skidegate	3	68	1,237.2	2,223.2	3,556.7	115,656	30.3	58.7	93.9
QCA2	Cumshewa Inlet East	2	85	357.8	987.8	1,971.4	530,877	0.0	0.0	42.0
QCA3	Cumshewa Inlet West	6	260	2,607.3	5,191.9	9,110.6	568,955	58.4	150.7	273.1
QCA4	Skedans	3	34	544.5	909.0	1,440.9	97,933	12.4	25.2	43.1
QCA5	Limestone Islands	2	40	772.8	1,351.4	2,217.9	214,862	13.8	36.3	64.8
QCA6	Selwyn Inlet East	5	30	600.0	1,039.4	1,690.8	83,858	13.5	27.4	47.9
QCA7	Selwyn Inlet West	4	20	389.8	676.9	1,103.6	35,042	10.3	19.5	32.9
QCA8	Dana Inlet	2	18	366.1	635.7	1,036.3	42,059	9.2	18.0	31.0
QCA9	Tanu Island North	6	47	849.4	1,544.1	2,472.4	173,552	18.3	43.8	74.1
QCA10	Tanu Island South	11	47	896.9	1,630.4	2,610.6	280,074	15.8	37.0	68.1
QCB1	Collison Bay	3	27	486.4	884.3	1,415.8	97,361	11.0	24.0	41.0
QCB2	Carpenter Bay West	7	55	1,007.5	1,831.3	2,932.3	358,457	10.2	39.4	78.6
QCB3	Carpenter Bay East	3	53	966.0	1,739.9	2,777.8	181,951	22.4	51.9	83.1
QCB4	Upper East Houston-Stewart Ch.	5	47	654.5	1,792.0	3,730.2	424,603	9.6	32.6	101.8
QCB5	Lower East Houston-Stewart Ch.	5	33	321.1	1,439.3	3,482.2	547,833	3.4	19.5	98.8
QCB6	Keeweenah Bay	1	18	335.0	569.3	891.4	143,960	1.9	11.1	23.8
QCB7	Heater Harbour	5	35	667.8	1,134.8	1,776.8	108,791	15.0	30.5	52.0
QCB8	Inner Luxana Bay	2	60	588.5	1,207.4	1,965.3	136,483	11.9	35.4	58.5
QCB9	Outer Luxana Bay	2	29	158.7	636.8	1,083.4	156,693	0.8	10.9	26.2
QCB10	Howe Bay	1	55	1,330.9	2,253.6	3,516.8	199,056	37.8	67.6	105.5
QCC1	West Houston-Stewart (Moresby)	2	14	306.9	987.5	2,201.9	397,784	0.0	19.3	63.7
QCC2	West Houston-Stewart (Kunghit)	4	67	771.7	1,941.2	4,233.5	1,391,523	3.1	22.4	93.1
QCC3	Gordon Island	1	24	60.1	189.6	501.1	227,716	0.0	0.0	1.8
QCC4	Louscoone Inlet	5	47	856.5	1,525.5	2,364.5	317,313	9.7	33.6	63.6
QCC5	Flamingo Inlet	6	13	246.1	447.4	716.4	64,461	5.2	11.0	19.2
QCC6	Gowgaia Bay	8	32	581.2	1,056.4	1,691.5	122,944	11.6	25.6	45.5
QCD1	South Englefield Bay	10	34	615.0	1,117.9	1,790.0	104,019	13.1	28.5	49.5
QCD2	North Englefield Bay	2	11	200.1	363.8	582.5	174,169	0.0	0.8	7.6
QCD3	Buck Channel	2	10	179.6	326.6	523.3	24,941	4.7	9.4	15.6
QCD4	West Skidegate Channel	9	21	389.4	707.9	1,133.4	92,702	6.5	16.9	30.9
QCD5	Kano Inlet	3	40	757.6	1,358.9	2,255.3	189,295	13.2	34.8	67.0
QCD6	Shields Bay	3	47	850.7	1,546.3	2,475.9	73,495	25.0	46.2	74.2
QCD7	Rennel Sound	3	14	256.4	466.0	746.2	23,630	7.0	13.5	22.0
QCD8	Seal Inlet	2	28	375.8	656.8	1,077.4	95,905	6.5	16.6	31.2
QCD9	Hippa Island	7	78	1,038.2	1,830.2	3,006.4	823,329	1.0	8.9	51.3
QCD10	Port Chanal	6	57	1,042.8	1,895.5	3,035.0	221,300	23.1	52.7	89.4
QCD11	Port Louis	6	7	130.8	233.3	382.4	78,516	1.5	4.3	8.5
QCE1	Parry Pass	5	76	1,379.6	2,448.0	4,031.1	516,632	12.4	51.3	108.9
QCE2	Virago Sound	2	72	1,326.7	2,343.3	3,881.2	342,329	22.4	57.9	109.4
QCF1	Upper Juan Perez	8	51	1,083.8	2,669.6	4,451.8	296,374	18.2	69.3	126.9
QCF2	North Marco Island	9	89	1,534.9	3,240.4	5,770.7	602,827	23.1	76.6	160.8
QCF3	South Marco Island	10	26	426.9	1,059.9	1,036.1	184,072	5.5	22.3	23.1
QCF4	Werner Bay	4	12	182.5	371.7	669.9	76,446	3.4	10.3	19.5
QCF5	Lower Juan Perez	12	129	1,995.9	4,064.0	7,324.6	1,679,001	2.1	27.9	153.2
QCF6	Poole Inlet	6	84	1,531.2	2,783.3	4,456.5	231,901	35.6	78.3	132.5
QCF7	North Skincuttle Inlet	5	37	663.2	1,229.5	1,930.3	181,007	12.2	33.6	57.6
QCF8	South Skincuttle Inlet	3	25	403.9	829.8	1,175.6	546,105	0.0	2.5	4.0
Total QCI		221	2,206	34,335.7	67,369.0	114,227.6	13,577,793	571.7	1,513.5	3,070.4

Table 12. Summary of geoduck quota options for consideration in the 1999 and 2000 fisheries, compared to the quotas set for the same areas in the previous rotation.

		1996		1999			
Region	Stat Area	Quota	Area (ha)	low	med	high	Area (ha)
North Coast	3, 4, 5, ptn 6	2,291	1,283	1,008	2,144	3,927	1,746
West Coast	24, 26	812	2,952	646	1,190	1,782	3,171
Inside Waters	ptn 14, 16	959	2,426	606	907	1,177	3,155
Total		4,062	6,661	2,260	4,241	6,886	8,072

		1997		2000			
Region	Stat Area	Quota	Area (ha)	low	med	high	Area (ha)
North Coast	1,2	2,008	1,674	572	1,513	3,070	2,206
West Coast	24,25	1,224	3,632	886	1,582	2,327	3,915
Inside Waters	13,15,18,19	648	2,266	407	584	730	2,561
Total		3,880	7,572	1,865	3,679	6,127	8,682

		1988	
Region	Stat Area	Quota	Area (ha)
North Coast	6,7,8,9,10	2,232	1,619
West Coast	23,24,27	1,080	3,798
Inside Waters	12,14,17,29	648	3,032
Total		3,960	8,449

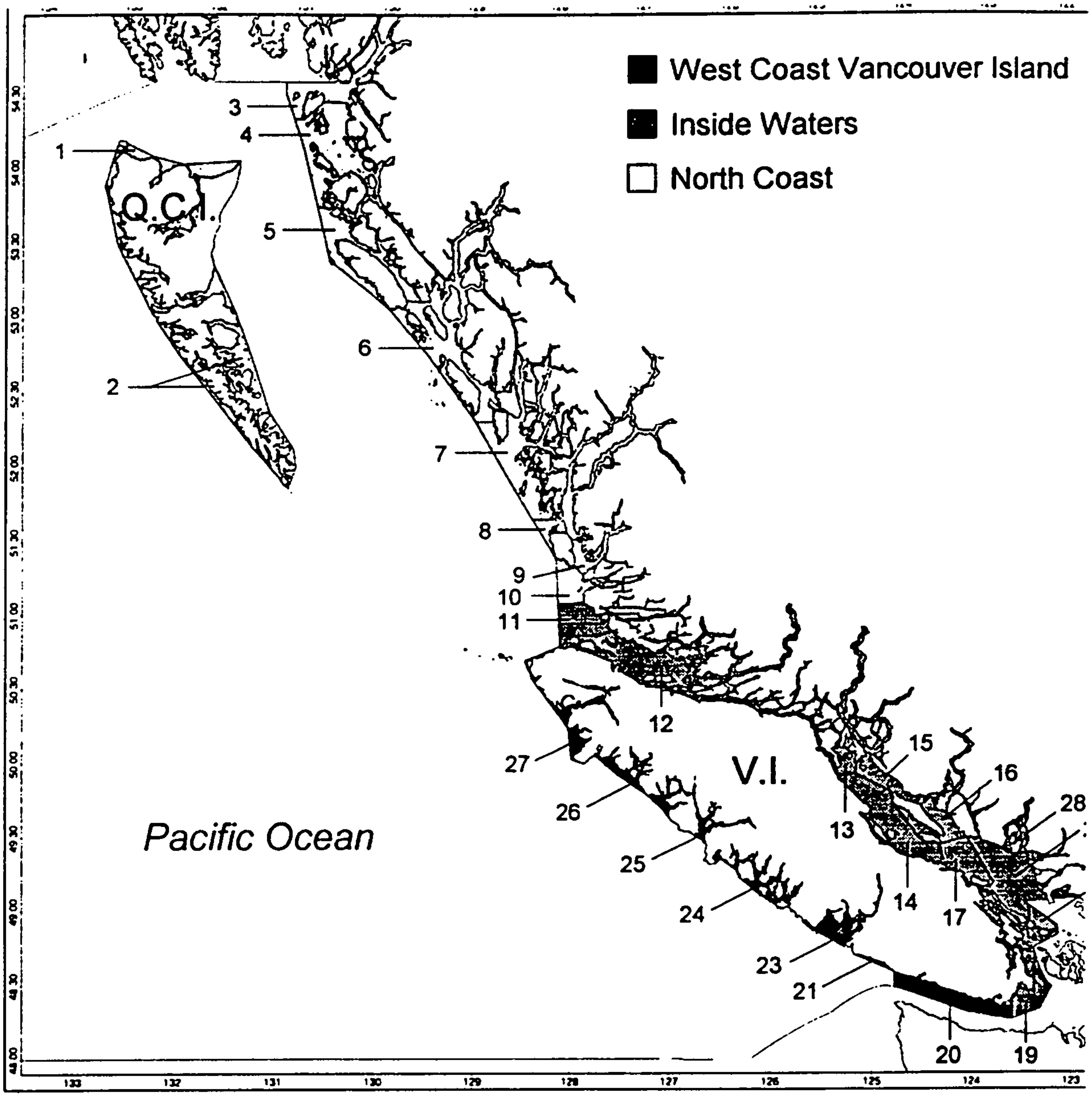


Figure 1. Regions of the British Columbia coast that are fished by the geoduck industry, with Pacific Fishery Management Statistical Area shown.

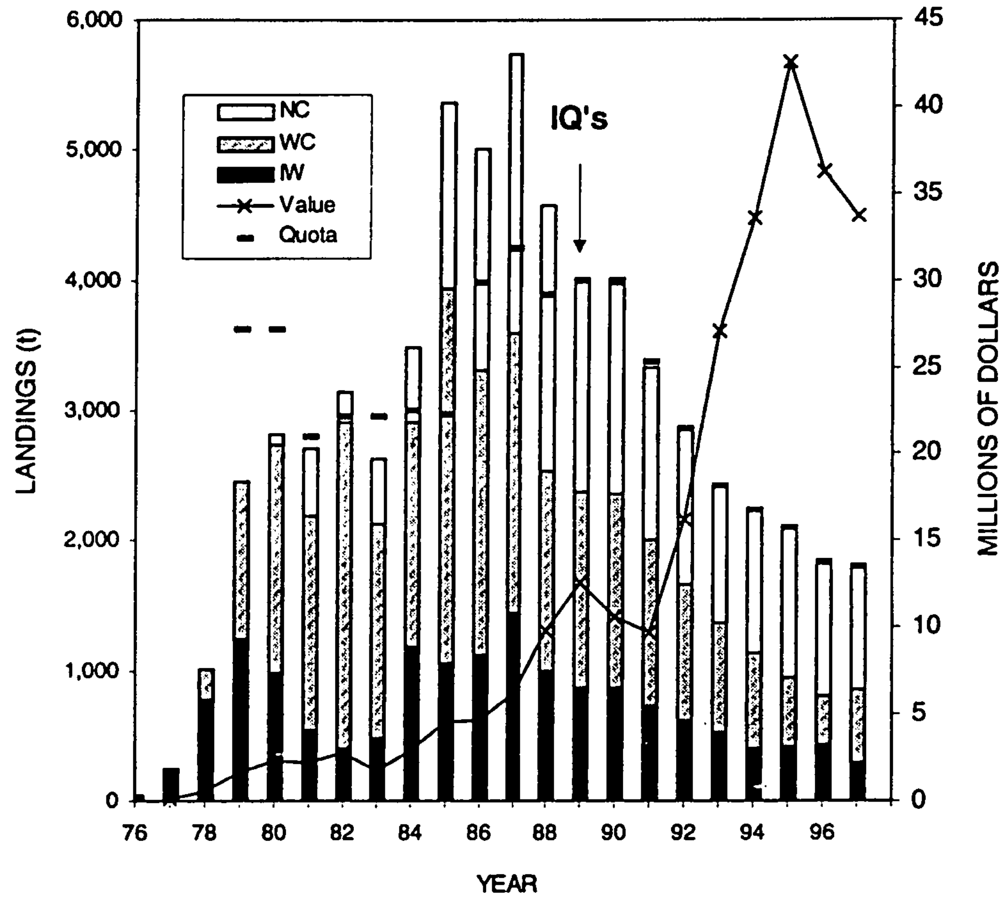


Figure 2. Geoduck quotas (t), landings (t) and value ($\$10^6$) by region and year. NC is the North Coast, WC is the west coast of Vancouver Island and IW is waters on the inside of Vancouver Island.

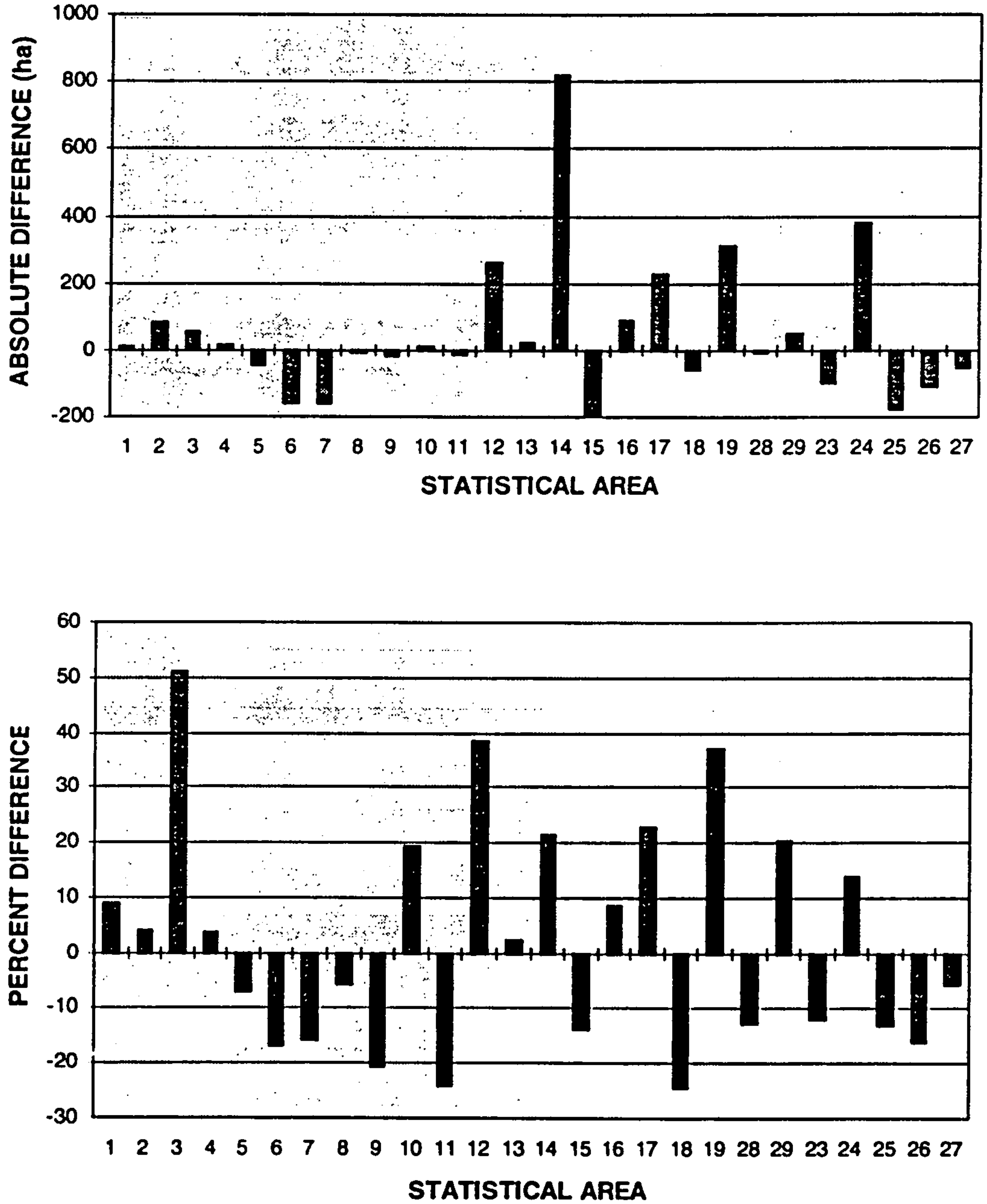
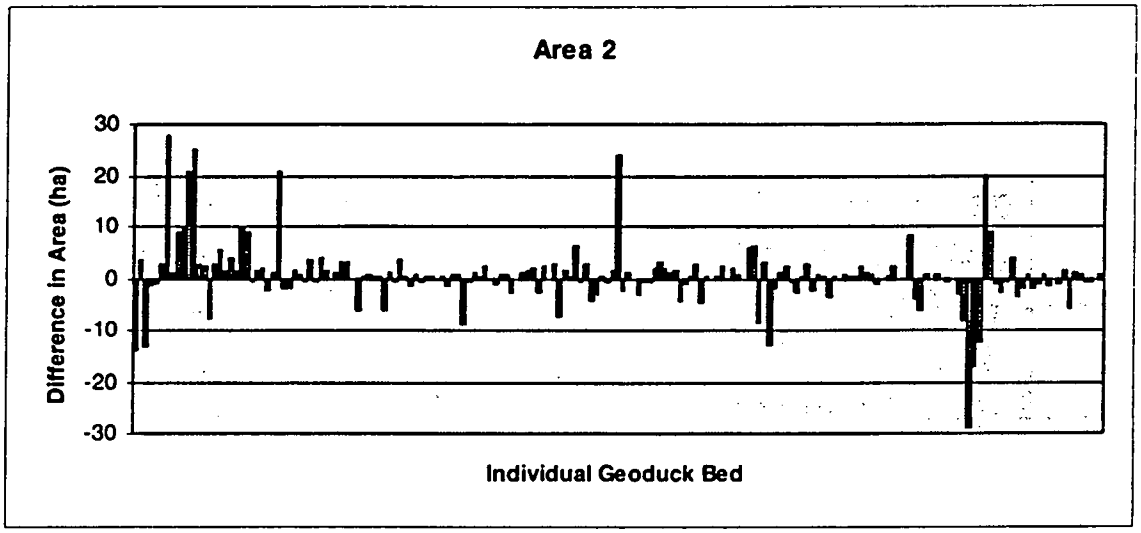


Figure 3. Absolute and percent difference in bed area estimates resulting from review and revisions to geoduck beds, by Statistical Area.



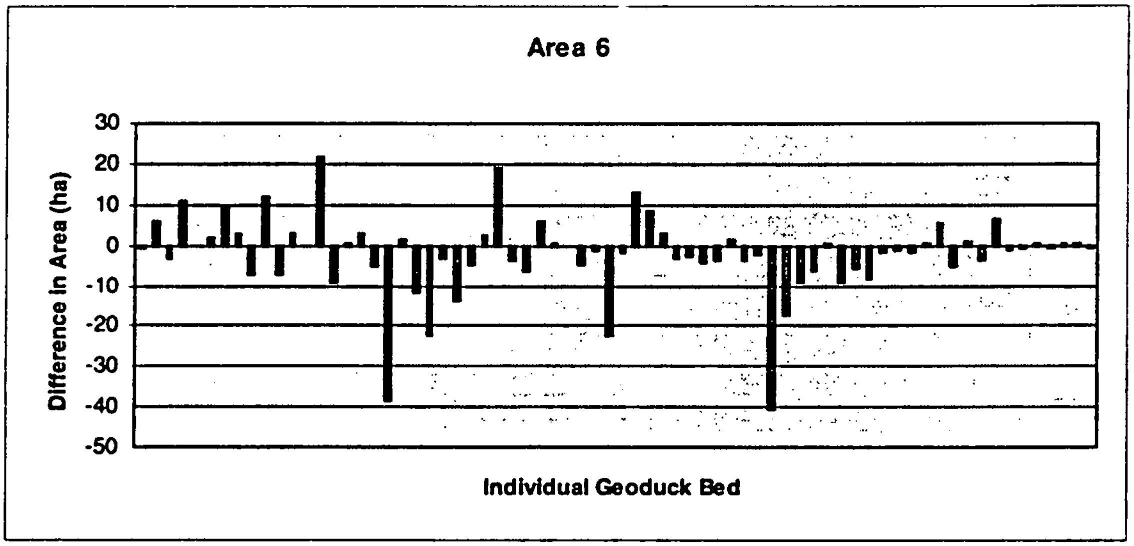


Figure 4. The absolute difference (ha) in estimates of bed area in that resulted from the review of geoduck harvest charts for Statistical Area 2 (top) and Statistical Area 6 (bottom). Each bar corresponds to an individual geoduck bed.

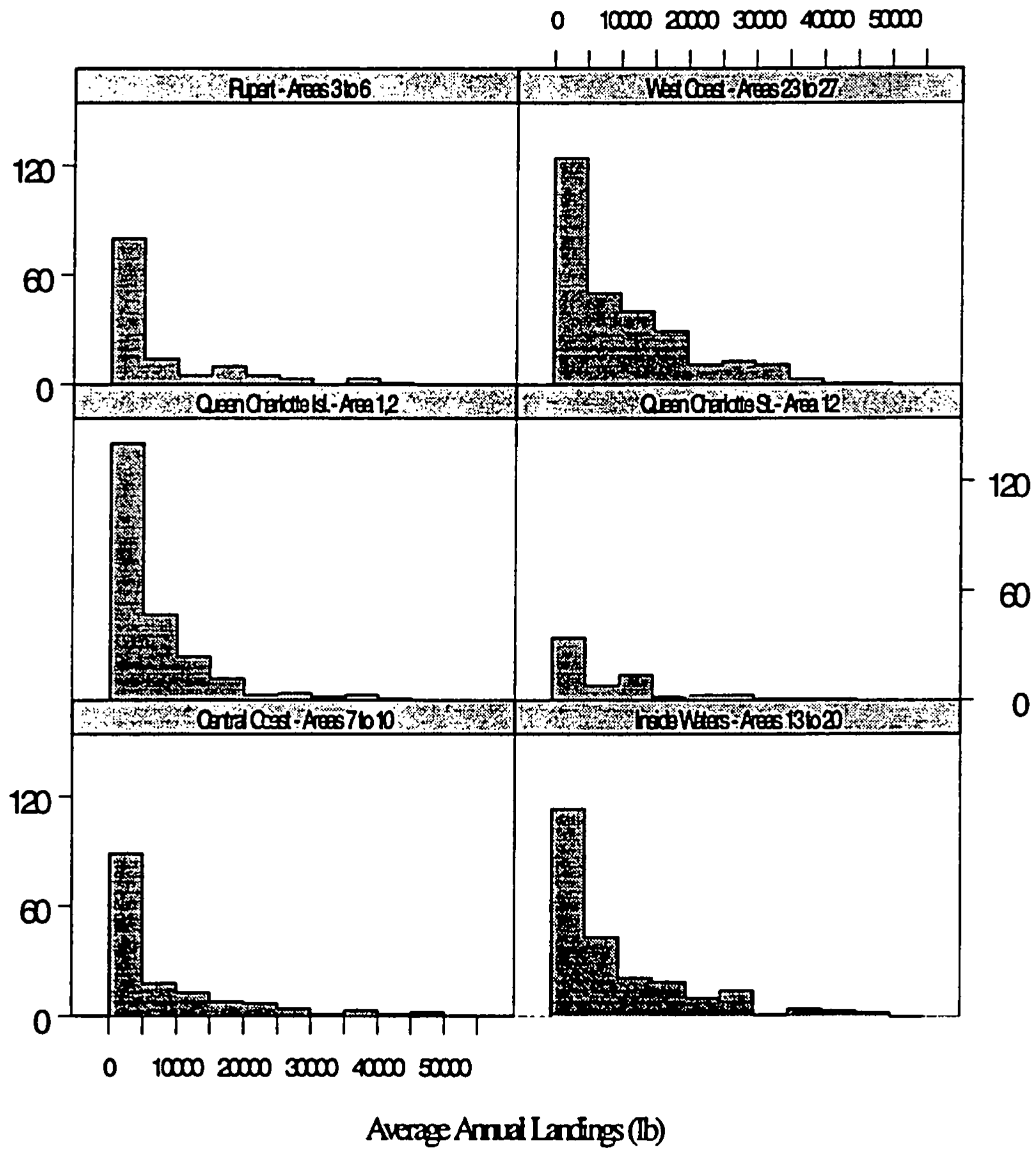


Figure 5. Distribution of average annual landings (lb), by bed and region.

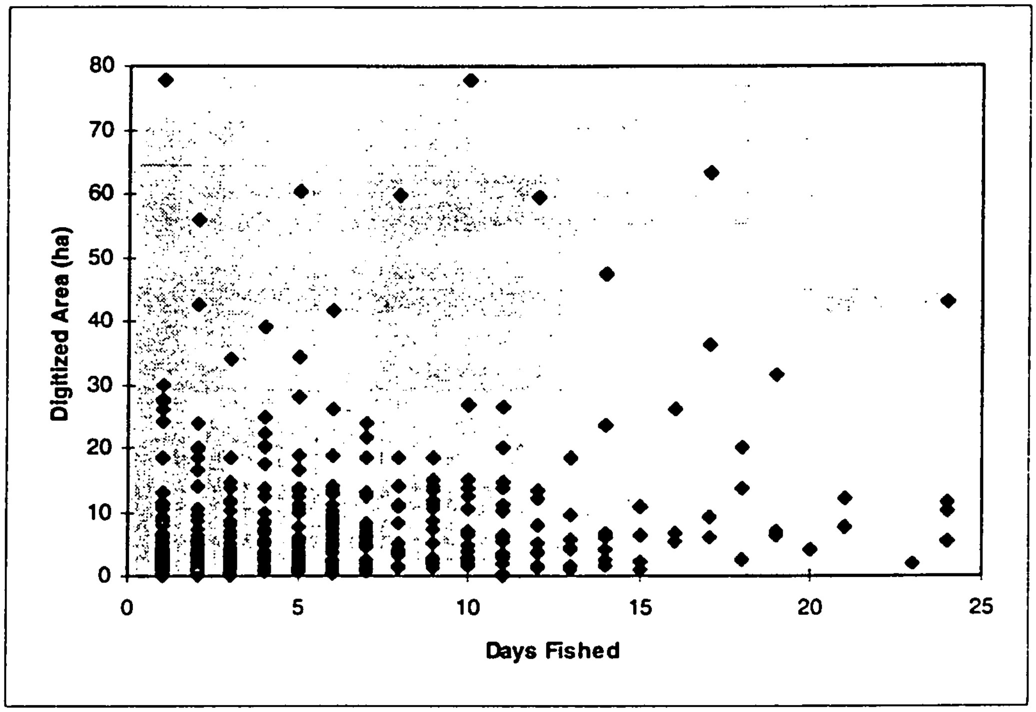


Figure 6. Plot of the digitized area measurement (ha) against the number of days fished for beds with less than 5,000 lb average annual landing.

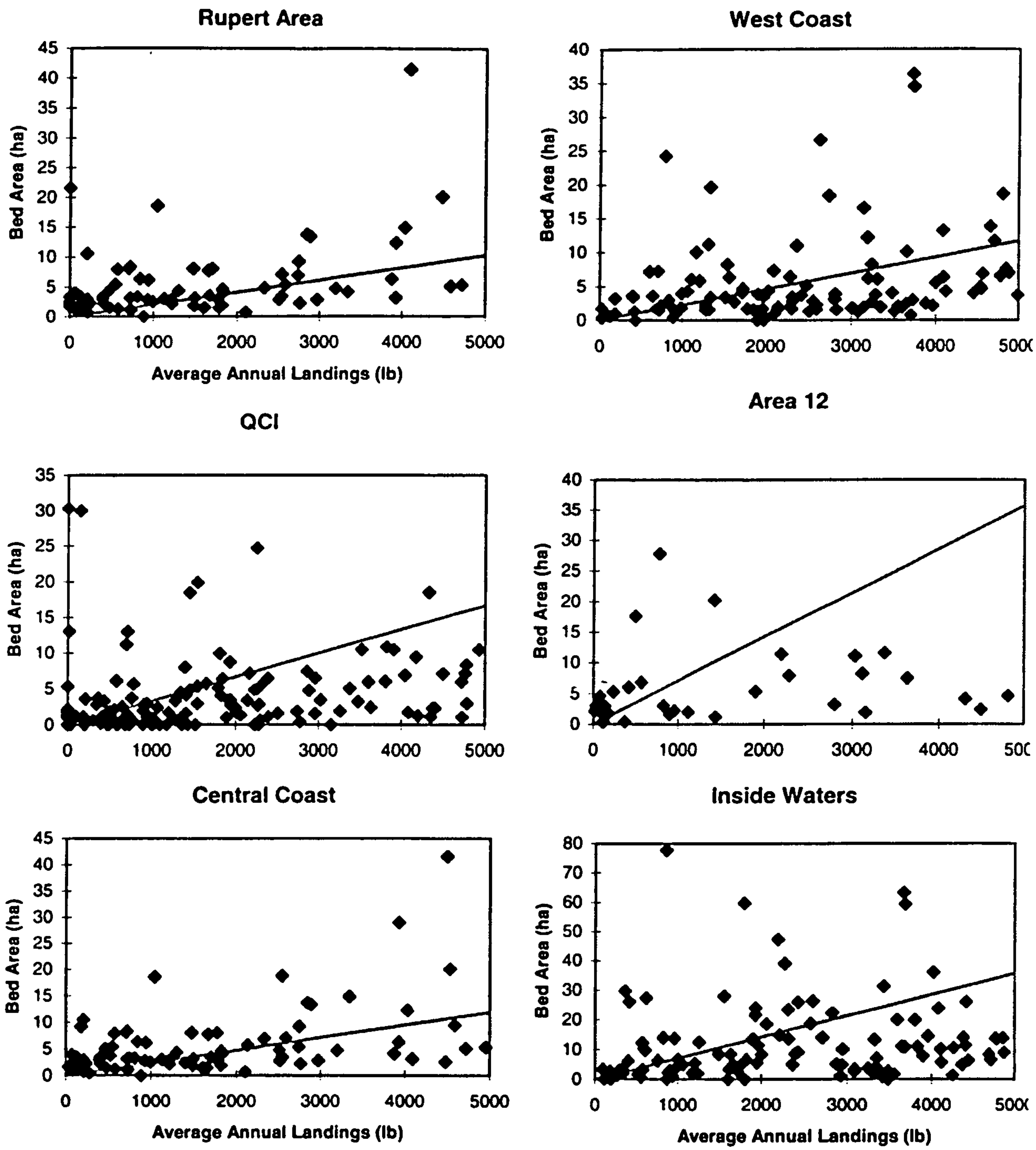


Figure 7. Plot of digitized bed area (ha) against average annual landing, by region. The defined area threshold for a given landing is shown; beds whose points lie above the line were reduced in area.

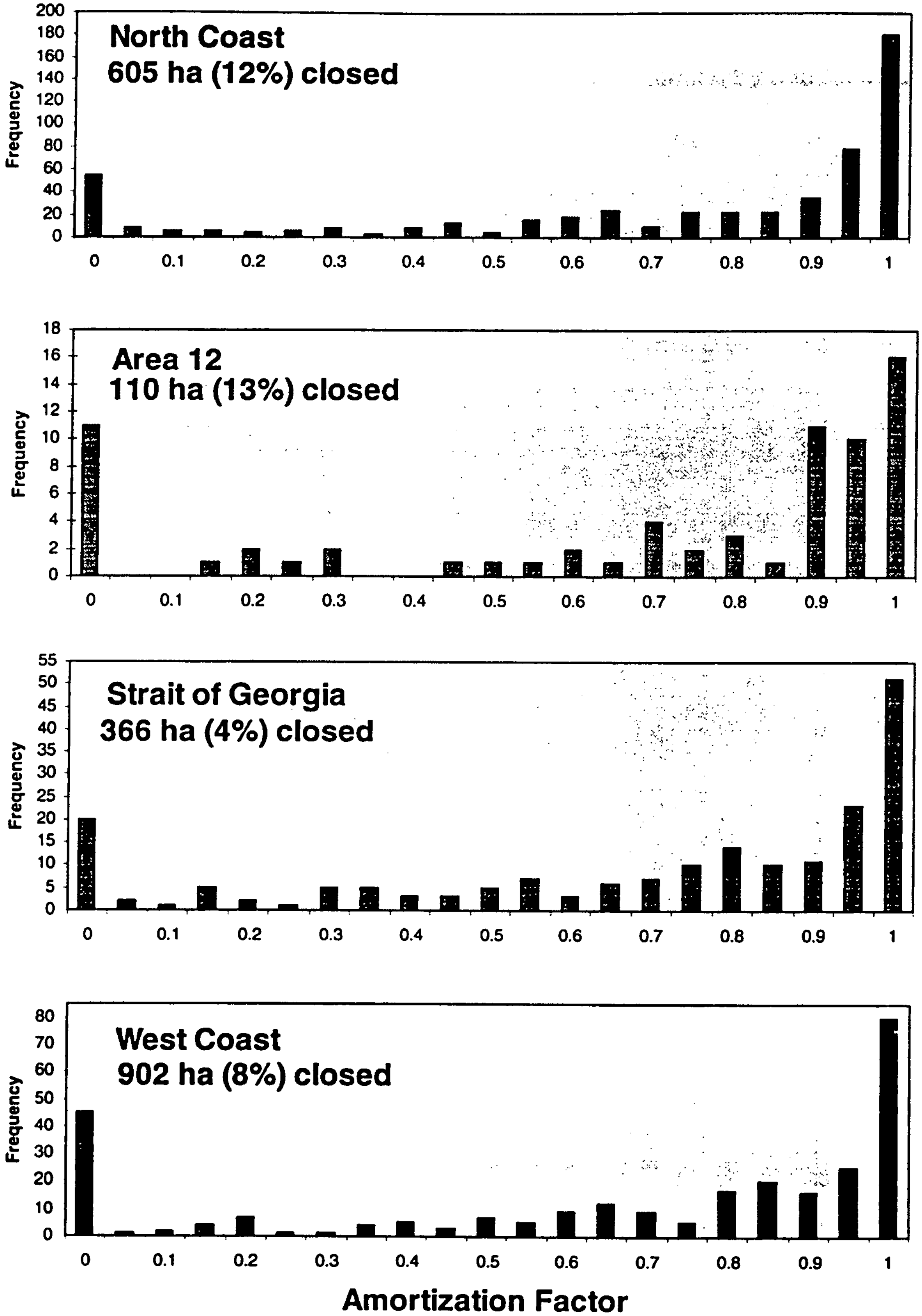


Figure 8. Distribution of geoduck bed amortization factors by region.

Appendix Table 1. Summary of mean individual geoduck weight (lb) with 95% confidence limits, by geoduck bed, from all market samples collected to date.

Stat Area	Sub Area	Old Code	New Code	Count	Mean Weight	LCL	UCL
1	3			200	2.680684	2.539554	2.821813
1	3	302	2	100	2.699687	2.57214	2.827234
			Subarea Totals	300	2.687018	2.583897	2.790139
			Area Totals	300	2.687	2.584	2.79
2	3	103	3	960	3.29768	3.220947	3.374413
			Subarea Totals	960	3.29768	3.220947	3.374413
2	6	0		192	2.854326	2.744011	2.96464
2	6	2203	1	240	2.911175	2.804854	3.017495
2	6	2207	4	240	3.257444	3.155363	3.359524
2	6	2209	6	240	2.516781	2.436638	2.596923
2	6	2210	7	240	3.000001	2.89151	3.108493
			Subarea Totals	1152	2.910179	2.862597	2.957761
2	7	2201	1	240	2.846818	2.747566	2.946071
			Subarea Totals	240	2.846818	2.747566	2.946071
2	11	2301	15	438	3.172057	3.104603	3.239511
			Subarea Totals	438	3.172057	3.104603	3.239511
2	18	703	4	250	2.781288	2.681174	2.881402
			Subarea Totals	250	2.781288	2.681174	2.881402
2	19	804	4	228	3.615264	3.471231	3.759296
2	19	901	5	250	3.550076	3.434437	3.665716
			Subarea Totals	478	3.58117	3.48969	3.67265
2	70			225	2.763412	2.659373	2.867452
2	70	1402	1	79	3.241683	3.039412	3.443954
			Subarea Totals	304	2.8877	2.791666	2.983734
2	71	1401	1	267	2.637676	2.535648	2.739704
			Subarea Totals	267	2.637676	2.535648	2.739704
2	82	1502	1	100	2.33218	2.21597	2.448391
2	82	1505	2	365	1.851894	1.797995	1.905794
			Subarea Totals	465	1.955182	1.902894	2.007469
2	87	1601	1	170	1.991895	1.903675	2.080115
2	87	1602	2	164	1.863707	1.784042	1.943373
2	87	1603	3	175	1.673102	1.601617	1.744588
2	87	1604	4	100	1.999528	1.904117	2.09494
2	87	1605	5	367	1.851654	1.797164	1.906144
			Subarea Totals	976	1.861243	1.827544	1.894941
2	93	9302	2	128	2.69087	2.56897	2.812769
			Subarea Totals	128	2.69087	2.56897	2.812769
			Area Totals	5658	2.766	2.739	2.793
5	20	302	1	502	2.735764	2.679078	2.79245
5	20	303	2	196	2.733052	2.635169	2.830935
			Subarea Totals	698	2.735002	2.685872	2.784133
5	21	301	1	317	2.575828	2.509857	2.6418
			Subarea Totals	317	2.575828	2.509857	2.6418
			Area Totals	1015	2.685	2.646	2.725
6	13	203	4	199	3.095458	2.997456	3.19346
6	13	204	5	199	3.095059	2.997405	3.192713
6	13	1303	13	200	2.60156	2.520293	2.682828
			Subarea Totals	598	2.930142	2.873564	2.986721
6	16	302	2	525	2.036832	1.983132	2.090532
			Subarea Totals	525	2.036832	1.983132	2.090532

Stat Area	Sub Area	Old Code	New Code	Count	Mean Weight	LCL	UCL
6	18	1107	1	105	2.72835	2.546803	2.909898
6	18	1107	6	105	2.72835	2.546803	2.909898
6	18	1112	2	209	2.273692	2.162395	2.384988
6	18	1114	3	105	3.178991	3.002691	3.355292
6	18	1120	5	105	2.115366	2.001238	2.229494
			Subarea Totals	629	2.550179	2.477864	2.622494
			Area Totals	1752	2.526	2.486	2.566
7	27	0	0	300	2.144731	2.090565	2.198896
7	27	101	1	250	2.378058	2.289273	2.466843
7	27	102	2	250	2.9677	2.878399	3.057002
7	27	107	7	750	2.5794	2.524954	2.633846
			Subarea Totals	1550	2.525425	2.488333	2.562517
7	32	301	1	80	3.021405	2.882458	3.160351
7	32	301	5	80	3.021405	2.882458	3.160351
			Subarea Totals	160	3.021405	2.882458	3.160351
			Area Totals	1710	2.572	2.536	2.607
13	15	701	4	316	2.224825	2.142916	2.306735
			Subarea Totals	316	2.224825	2.142916	2.306735
			Area Totals	316	2.225	2.143	2.307
14	5	5202	1	1032	2.065948	2.008125	2.12377
14	5	5205	2	729	2.516937	2.443564	2.590309
			Subarea Totals	1761	2.252643	2.205971	2.299316
14	7	101	1	369	1.581857	1.503429	1.660286
			Subarea Totals	369	1.581857	1.503429	1.660286
14	10	4601	1	934	2.144571	2.089365	2.199776
			Subarea Totals	934	2.144571	2.089365	2.199776
14	13	601	4	335	2.277418	2.200105	2.354731
14	13	602	5	636	2.463793	2.405091	2.522495
14	13	603	6	257	2.738714	2.610668	2.86676
			Subarea Totals	1228	2.470486	2.423976	2.516996
			Area Totals	4292	2.234	2.206	2.262
15	2	501	1	391	1.533432	1.470656	1.596208
15	2	702	7	198	1.834216	1.724077	1.944355
			Subarea Totals	589	1.634544	1.577672	1.691417
15	3	401	4	523	1.676537	1.620414	1.73266
			Subarea Totals	523	1.676537	1.620414	1.73266
15	5	201	1	1797	2.367377	2.324518	2.410237
15	5	201	2	1797	2.367377	2.324518	2.410237
			Subarea Totals	3594	2.367377	2.324518	2.410237
			Area Totals	4706	2.199	2.172	2.225
16	19	1202	2	333	1.81134	1.749699	1.872982
			Subarea Totals	333	1.81134	1.749699	1.872982
16	21	1301	1	352	2.124815	2.04231	2.20732
16	21	1302	2	669	2.138327	2.087959	2.188695
16	21	1501	5	331	2.226566	2.153982	2.29915
16	21	1502	6	308	2.005327	1.937955	2.072699
			Subarea Totals	1660	2.128379	2.095318	2.16144
			Area Totals	1993	2.075	2.046	2.105
17	0	0	0	250	1.664217	1.598899	1.729535
			Subarea Totals	250	1.664217	1.598899	1.729535
			Area Totals	250	1.664	1.599	1.73
18	11	7702	1	317	1.796909	1.73199	1.861828
			Subarea Totals	317	1.796909	1.73199	1.861828
			Area Totals	317	1.797	1.732	1.862
23	5	2104	4	349	1.771033	1.707966	1.8341
			Subarea Totals	349	1.771033	1.707966	1.8341
23	6	2701	10	341	2.11094	2.021132	2.200748
			Subarea Totals	341	2.11094	2.021132	2.200748
23	9	0	0	312	2.169871	2.095811	2.24393
23	9	1001	4	264	2.92173	2.809625	3.033835
			Subarea Totals	576	2.514473	2.442446	2.586499
23	10	0	0	275	3.366376	3.222442	3.51031
			Subarea Totals	275	3.366376	3.222442	3.51031

Stat Area	Sub Area	Old Code	New Code	Count	Mean Weight	LCL	UCL
			Area Totals	1541	2.409	2.357	2.461
24	6	601	2	307	2.10828	2.014399	2.202161
24	6	606	7	81	1.480648	1.281714	1.679581
24	6	701	9	131	2.617803	2.535049	2.700556
24	6	801	16	250	2.482662	2.417728	2.547596
24	6	802	17	334	2.738688	2.645179	2.832196
24	6	803	18	305	2.35958	2.260251	2.458909
24	6	901	22	358	2.641721	2.555943	2.727499
24	6	1204	32	223	2.373039	2.279408	2.466671
			Subarea Totals	1989	2.433429	2.396658	2.470199
24	9	1601	3	149	1.837349	1.696099	1.9786
			Subarea Totals	149	1.837349	1.696099	1.9786
			Area Totals	2138	2.392	2.356	2.428
25	13	101	1	311	2.010865	1.890386	2.131343
25	13	301	13	596	2.489593	2.418597	2.560589
			Subarea Totals	907	2.325443	2.261418	2.389467
			Area Totals	907	2.325	2.261	2.389
26	1	301	1	483	2.538239	2.473611	2.602867
26	1	302	2	317	2.248922	2.158186	2.339657
			Subarea Totals	800	2.423597	2.369665	2.477529
26	2	102	2	322	2.290757	2.215641	2.365874
26	2	106	6	83	2.429974	2.266589	2.593359
			Subarea Totals	405	2.319288	2.250694	2.387883
			Area Totals	1205	2.389	2.346	2.431