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STATUS UPDATE OF WILD BRITISH COLUMBIA GEODUCK STOCKS, 2011

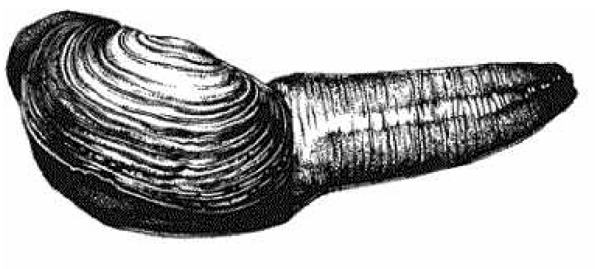

Figure 1: Geoduck clam, Panopea generosa.

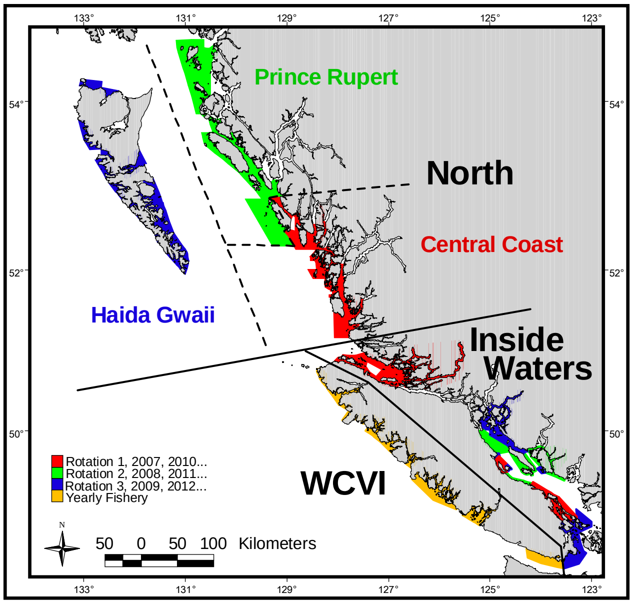

Figure 2: Map of British Columbia coast showing geoduck "Licence Areas" (black letters, separated by solid lines) and "Rotational Areas" (different colors and dashed lines). WCVI = West Coast of Vancouver Island.

Context :

Geoduck clam (Panopea generosa) populations occur in discrete beds of soft substrate, distributed throughout the coast of British Columbia (BC). The individual beds are connected by means of planktonic larvae, thereby forming meta-populations.

The BC geoduck fishery is managed with a Total Allowable Catch (TAC), individual vessel quotas (IVQs), scheduled openings and area quotas. The fisheries in the North and Inside Waters regions are on a three-year rotation, while the West Coast of Vancouver Island (WCVI) is fished annually. All landings are validated at designated ports by a third-party service provider.

Stock assessment and management of the fishery are conducted on the spatial scale of individual geoduck beds. A Limit Reference Point (LRP) of 40% of estimated virgin biomass (B_0) is established and implemented by individual geoduck bed. The assessment framework was described in 2002 (Hand and Bureau 2012) and updated in 2008 (Bureau et al. 2012). Assessment frameworks are modified as warranted by new information or analytical approaches, or as requested by DFO's Fisheries Management branch. Biomass estimates are updated annually with new data on population densities, mean geoduck weights and bed area.

This report provides updated estimates of geoduck stock biomass in BC and estimates of Stock Index relative to the LRP.

SUMMARY

- The area of harvestable geoduck beds in British Columbia (BC) is estimated to be 18,068 ha. The overall mean estimated current density of all surveyed beds is 1.7 geoducks/m^2 while mean geoduck weight in all beds is estimated to be 1.11 kg.
- Current geoduck biomass, in 2011, in harvestable beds on the BC coast is estimated to be 178,352 metric tonnes (t) (95% confidence bounds: 92,668 t – 339,582 t).
- For all harvestable beds in BC, the sums of the low 95% and low 90% annual harvest options are 1,427 t and 1,590 t, respectively, while the sum of maximum harvest options, according to the management decision rules, is 2,986 t.
- An alternative to the current Limit Reference Point (LRP), based on the proportion of current to virgin biomass, is required due to the uncertainties associated with estimating virgin biomass and because of violations of many of the inherent assumptions of the current LRP.
- The expansion of sea otter (*Enhydra lutris*) populations (size and range) in BC will continue to impact the geoduck fishery, leading to further reductions in geoduck populations and harvest options in the future.
- Reallocation of existing geoduck beds to subtidal geoduck aquaculture has resulted in a decrease of 215 ha in bed area available to the wild fishery within the Strait of Georgia. Recent aquaculture tenure applications would impact another 193 ha of bed area within the Strait of Georgia. With increased interest in geoduck subtidal aquaculture, further allocation of wild beds to subtidal geoduck aquaculture will lead to decreased bed area available to the fishery and decreased harvest options.
- More research is planned to investigate the effects of biological sample handling practices on mean weight estimates.

INTRODUCTION

Species Biology

The geoduck clam (*Panopea generosa* Gould, 1850) (Figure 1) is an infaunal bivalve with a geographic range from Alaska to Baja California. Populations exist in almost all sedimentary substrates, but are generally only harvestable in soft sand, mud and small aggregate sediments.

Geoducks are among the longest-lived animals in the world, often reaching ages over 100 years and with a maximum recorded age of 168 years (Bureau et al. 2002). Geoducks grow rapidly in the initial 10 to 15 years and generally reach maximum size by age 20 (Bureau et al. 2002). Growth rate and maximum size are spatially variable. Sexual maturity can occur as early as 2 years of age (Campbell and Ming 2003). Geoducks begin to recruit to the fishery at age 4 and are fully recruited by age 6 to 12 (Harbo et al. 1983).

Geoducks are broadcast spawners with separate sexes. Spawning typically occurs from June to July with females releasing from 7 to 10 million eggs which are fertilized externally. Larvae develop in the water column until settlement on the bottom within 40 to 50 days (Goodwin et al. 1979). The long pelagic larval period potentially results in distribution over large distances from the spawning area and thus a poor relationship between spawning stock in a given bed and subsequent recruitment. Recruitment is highly episodic (Black et al. 2008) and also appears to be related to long-term regime cycles (Zhang and Hand 2007). Recruitment was at a coastwide high around 1950, declined until the mid 1980s, followed by an increase in recruitment rate in recent years (Zhang and Hand 2007).

Fishery

A commercial fishery for geoducks began in British Columbia (BC) in 1976 and has since grown to be one of the highest valued fisheries in BC at CAD $40 million in 2010. The fishery originally developed in the Inside Waters (IW), followed by the West Coast of Vancouver Island (WCVI) in 1978 and expansion to the North Coast (NC) in 1980 (Figure 2). The fishery was initially open-access and competitive and was assessed with sparse information on population abundance and dynamics. Arbitrary quotas were introduced in 1979, after which quota reductions were implemented due to uncertainty about stock size. The number of licences was limited to 55 in 1981. Landings peaked in 1987 at 5,735 metric tonnes (t) and decreased through management action to 1,817 t in 1996. Quotas were first based on estimates of bed area from logbook data in 1988. Total Allowable Catch (TAC), in the context of this report, refers to the annual catch ceiling, established by fishery managers, for the BC wild geoduck fishery. The Individual Vessel Quota (IVQ) program, where the geoduck TAC was divided equally among the 55 geoduck licences, was established in 1989 when dockside validation, area licensing and a three-year fishery rotation were also implemented. In 1994, a 50% virgin biomass (B_0) Limit Reference Point (LRP) was introduced wherein geoduck beds where biomass was estimated to be less than 50% of B_0 were closed to harvest. The TAC was stable between 1996 and 2004, but then was dropped to 1,559 t between 2005 and 2011. The majority of landings have come from the NC since 1995 (Figure 3). Since 2007, harvest options are based on estimates of current biomass (B_c) and regional exploitation rates of 1.2 – 1.8% and the LRP has been set to 40% B_0 (Zhang and Hand 2007).

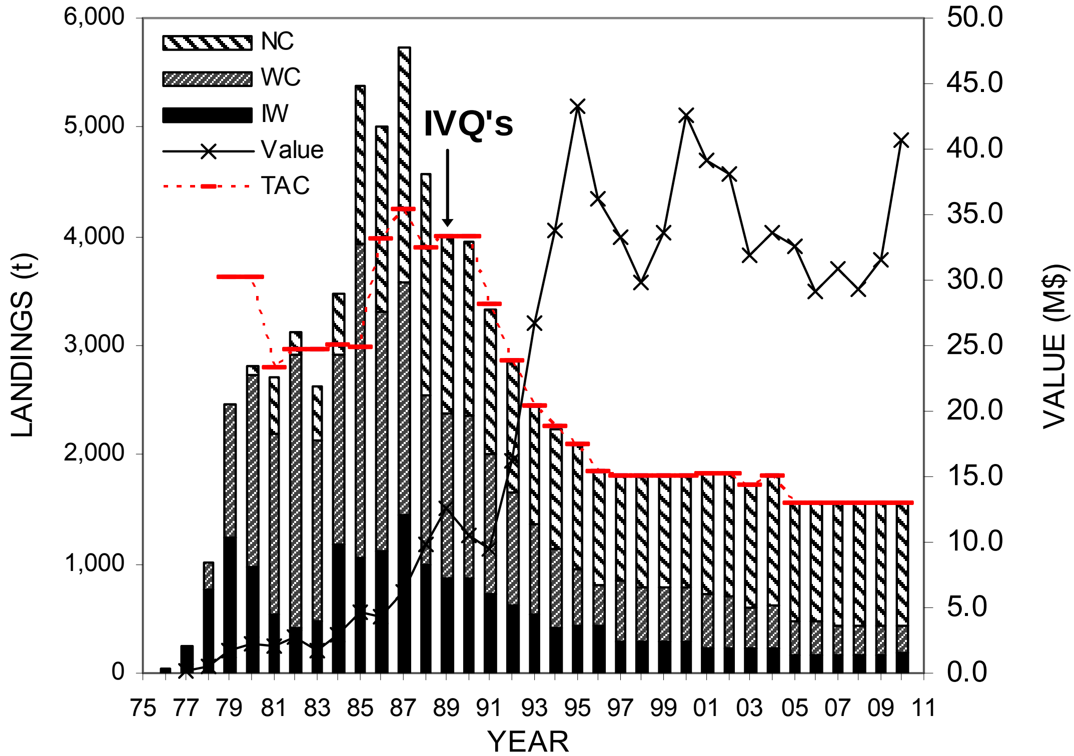

Figure 3: History of landings, TAC (metric tonnes) and value (million CAD) for the British Columbia geoduck fishery. NC=North Coast, WC=West Coast of Vancouver Island and IW=Inside Waters.

Trends in overall catch per unit effort (CPUE) in the BC geoduck fishery show an increase in the early years of the fishery, peaking in 1989 at 3.6 kg/min with a subsequent decrease to approximately 2.8 kg/min in 1998 (Figure 4). CPUE is higher in the NC due to higher geoduck densities and consequent reduced search time. Overall CPUE has increased slightly since 1998 as progressively more of the fishery has taken place in the North.

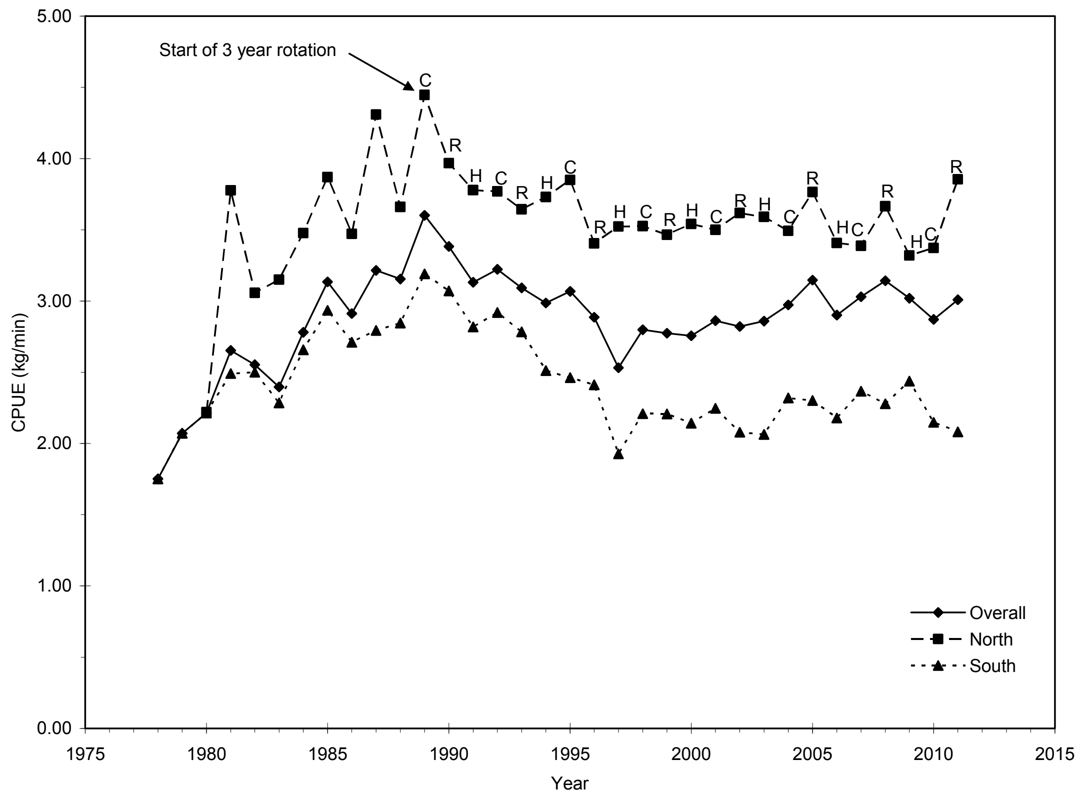

Figure 4: Catch per unit effort (CPUE, kg of geoducks harvested per dive minute) over time for the entire BC coast (Overall) and South and NCs separately. For NC, rotations are indicated by the letters C= Central Coast, R= Prince Rupert and H= Haida Gwaii.

Variations in CPUE between years are partially due to the rotational nature of the fishery, since different areas are fished in different years. This is illustrated by the trend between 2003 and 2011 in the NC, where CPUE has been consistently higher in the Prince Rupert rotation than in the Haida Gwaii and Central Coast rotations. Biomass estimates are higher in the Prince Rupert rotation, giving harvesters more flexibility in choosing locations to harvest that optimize CPUE. The imbalance in estimated biomass between NC rotations will be addressed in 2012 with a review and re-assignment of Geoduck Management Areas (GMAs).

Current management measures include TAC, IVQs, area quotas and scheduled openings. In-season, timing of openings is conditional on water and shellfish quality testing (*i.e.,* bacterial loads in the water and paralytic shellfish poisoning in the shellfish). The fishery is assessed and managed on the spatial scale of individual geoduck beds. In the NC and WCVI, an On-Grounds Monitor (OGM) is present during harvesting operations to monitor and direct fleet activities and collect anecdotal information. All landings are validated at dock-side by a third-party service provider. Costs associated with OGMs and dock-side validation are covered by the industry.

Geoducks are hand picked by divers using surface-supply gear. Individual geoducks are extracted from the sea bed using a water jet, pumped from the surface. The only non-target catch is horse clams (*Tresus capax* and *T. nuttallii*), which are allowed to be retained under the conditions of geoduck licence. Discarding is not allowed and the practice of high-grading (*i.e.,* discarding lower quality geoducks on the seabed) is discouraged within the industry and by OGM oversight. For many years, harvesters have insisted that no quality grading take place at time of purchase and therefore all geoduck in each landing fetch the same price, regardless of quality, so that there is less incentive to high-grade. The extent to which high-grading takes place is, however, unquantified.

On the vessel, the geoducks are banded to keep the shells from gaping and packed into small totes, with the layers separated by liners. In the NC, totes are transferred from the fishing vessels to a packer vessel that transports the product to the nearest port. The catch from each vessel is validated at the dock before being transported by truck to licensed processing plants in Vancouver for packaging before being flown to live markets in China. The geoduck fishery is market-driven and is spread throughout the year to provide stable market conditions and better price. Competition from the Alaska and Washington geoduck fisheries impacts the timing of harvest in BC.

ASSESSMENT

In this report, advice provided by DFO Science branch to DFO Fisheries Management branch is referred to as “Harvest Options”, while “Quota” refers to a portion of the TAC, *i.e.,* IVQ, area quota or bed quota, as assigned by fishery managers, so that the sum of quotas is equal to the TAC. The stock assessment framework used to estimate population biomass and harvest options for the BC fishery from 1988 to 2006 was described in Hand and Bureau (2012). During that period, geoduck harvest options were calculated, on a by-bed basis, from estimates of virgin (pre-fishery) geoduck biomass (B_0) and a 1% exploitation rate. Due to inherent problems with calculating virgin biomass, the approach changed in 2006 to one based on estimates of current biomass (B_c), along with revised exploitation rate estimates and a new LRP set at 40% B_0 (Zhang and Hand 2007). The revised assessment framework is described in Bureau et al. (2012). The geoduck biomass estimation process was further refined by including density-categorization for unsurveyed beds for which density information from fishery questionnaires and OGMs were available.

Approximately 2,400 geoduck beds have been identified along the BC coast. Some beds are comprised of more than one polygon in the Geographic Information System (GIS) bed maps; each individual polygon being defined as a sub-bed, which number around 4,800. The number of geoduck beds and sub-beds change every year as new beds are discovered or multiple sub-beds merge if the fishing area expands between them.

Harvest options for the geoduck fishery are calculated on a by-bed basis. Starting with the 2007 fishing season, geoduck harvest options have been calculated using a fixed regional exploitation rate applied to estimates of current biomass, following recommendations of Zhang and Hand (2007):

$$Harvest\_Option_b = A_b \times \overline{W_b} \times dc_b \times ER_r \qquad \text{Equation 1}$$

where the subscript *b* represents a geoduck bed, A_b is the area of bed *b* (m^2), $\overline{W_b}$ is the mean geoduck weight in bed *b*, dc_b is the current density of geoducks in bed *b* (geoducks/m^2) and ER_r is the exploitation rate set for region *r*, where *r* represents either Haida Gwaii, Prince Rupert, Central Coast, WCVI or IW. Bed harvest options are then apportioned into sub-bed harvest options, based on area.

A range of harvest options are provided to fishery managers for each geoduck bed, based on the uncertainty in each of the parameter estimates. The following four sections describe how each parameter used in calculations of harvest options is estimated.

Bed Area

The area of geoduck beds is determined from four sources of information: (1) harvest locations, provided on harvest logbooks, are imported into a GIS to map the locations of harvest and define bed areas; (2) substrate mapping is performed using remote sensing hydro-acoustic (QTC View) backscatter analysis; (3) substrate and depth information recorded on geoduck dive surveys; and (4) comments and feedback on bed locations and sizes from OGMs and harvesters at regularly-held meetings and from logbook comments.

The total area of geoduck beds in BC is estimated to be 21,539 hectares (ha), of which 18,068 ha is considered to be harvestable (Table 1). Beds that are not harvestable (not available to the fishery) include those in parks, contamination closures, research closures, beds affected by sea otters and beds lost to aquaculture; which represent 3,471 ha. A further 1,201 ha are closed due to conservation concerns, *i.e.,* beds below the LRP (see “Stock Index and Limit Reference Point” section), so that the area open for harvest is 16,867 ha. To date, 9,792 ha of bed, or 45.5% of the bed area on the coast has been substrate mapped.

Table 1: Amount of geoduck bed area (hectares) under various statuses, by Licence Area and coastwide. Closed beds are closed due to contamination, parks, research or aquaculture. “Otters” refers to beds that have been impacted by sea otters. “Harvestable” represents beds where harvest options are calculated. “Below LRP” are beds which are closed because they are below the Limit Reference Point.

	Bed Area (ha)					
Licence Area	Total	Closed	Otters	Harvestable	Below LRP	Open
North	7,184	111	598	6,475	115	6,360
Inside Waters	8,898	638	0	8,260	527	7,733
WCVI	5,457	321	1,803	3,333	559	2,774
Total	21,539	1,070	2,401	18,068	1,201	16,867

Sea otters (*Enhydra lutris*) are a natural predator of geoducks and are impacting geoduck populations as the range and population of sea otters expand in the Central Coast, WCVI and recently in the northeast of Vancouver Island. Sea otter predation on geoducks has led to the closure of most geoduck beds on the WCVI north of Estevan Point. Geoduck beds impacted by sea otters are identified using feedback from OGMs and harvesters, through logbook questionnaires and at meetings. Coastwide to date, sea otters have impacted 2,401 ha of geoduck bed area (11% of total bed area), 1,803 ha on WCVI (33% of WCVI area) and 598 ha in the Central Coast (28% of Central Coast area). The geoduck quota for WCVI has decreased by 56% between 2001 and 2012 from 497 t (1,095,000 lbs) to 217 t (480,000 lbs), with an accompanying decrease in the number of licences fished from 15 to 8. As the range and population size of sea otters grow, there will be increasing impact on geoduck populations which will inevitably lead to further reductions in the recommended harvest options. Currently, harvest options are not calculated for beds that have been impacted by sea otters.

Geoduck aquaculture in BC started in the 1990’s and has been limited to the Strait of Georgia (Hand and Marcus 2004). To date, 411 ha have been tenured for subtidal geoduck aquaculture between 17 sites, of which 215 ha (3% of IW) fall on existing geoduck beds. There is considerable interest from the aquaculture industry to expand intertidal and subtidal geoduck aquaculture in BC. Aquaculture tenure applications have been received for an additional 361 ha, of which 193 ha overlap existing geoduck beds. Furthermore, applications have been made to include geoducks on existing licenses, representing approximately 100 ha of seabed.

Mean Weight

Since 2001, mean weights of geoducks have been estimated from commercial fishery landings data. Landed weight and the number of geoducks landed (available since 1997), by bed, for each validated landing in the logbook database, are used to estimate mean weight with 95% confidence bounds (CB). Mean weights are calculated on a by-bed, by-GMA, by-Pacific Fishery Management Sub-area and by-Pacific Fishery Management Area (PFMA) basis. For beds where a bed-specific mean weight estimate is not available, the average weight over the GMA, PFM Sub-area or PFMA is used. Since 2010, regional correction factors are applied to mean weight estimates for the Haida Gwaii (-10%) and Prince Rupert (-8%) regions (Bureau et al. 2012), because mean weight estimates from biological samples from those regions were significantly lower than mean weights estimated from harvested product. Observed differences in mean weight estimates might be caused by different handling practices, and associated water loss, that biological samples are subjected to vs. the commercial catch. The effect of handling practices on mean weight estimates has not yet been investigated and research is planned for 2012.

Table 2: Number and percentage of geoduck beds and bed area within different mean weight ranges (where bed-specific data are available).

Mean Geoduck	Beds		Cumulative	Bed Area		Cumulative
Weight (kg)	Number	%	% Number	Hectares	%	% Area
< 0.5	1	0.0	0.0	1	0.0	0.0
0.5 to <1.0	614	28.7	28.7	5,328	26.1	26.1
1.0 to <1.5	1,407	65.7	94.4	14,743	72.2	98.3
1.5 to <2.0	119	5.6	100.0	343	1.7	100.0
≥2	1	0.0	100.0	1	0.0	100.0

Mean geoduck weight is estimated at 1.11 kg for all BC beds, 1.14 kg in the NC, 1.00 kg on the WCVI and 1.09 kg in the IW. Mean weight estimates range between 0.41 kg to 2.13 kg over the 2,400 beds. The average coefficient of variation of mean weight, where a bed-specific estimate is available, is 0.13. Mean geoduck weight is between 1.0 and 1.5 kg for 66% of the beds while 29% of beds have a mean weight between 0.5 and 1.0 kg (Table 2).

Density

Geoduck density is estimated from dive surveys. Surveys use a stratified random design where geoduck beds are defined as strata and transects are randomly located within each strata. Transects are laid perpendicular to shore from 3 to 18 m chart depth and are marked every 5 m. A team of two divers swim each transect, each diver surveying within 1 m of their side of the line. Data are recorded in 5 m sections, including counts of geoducks and horse clams, depth, substrate types and dominant algae present. Transects are grouped into survey sites for analysis purposes and confidence bounds of estimated mean density are calculated using bootstrap methods. The mean coefficient of variation of survey site density estimates for 2003 to 2010 surveys is 0.390, where coefficient of variation = (mean – low 95% CB) / mean.

The survey density is used to estimate biomass on surveyed beds. To date, 871 beds have been dive surveyed, which encompassed 12,697 ha of bed area (59% of total) (Table 3). Of the surveyed beds, 161 have been surveyed more than once, representing 4,561 ha (21% of total). Mean current density over all surveyed beds is 1.7 geoducks/m^2. Of the beds that have been surveyed, a greater proportion of area than of number of beds is below 1 geoduck/m^2 (Table 4). South Coast beds are typically larger and lower density than NC beds, and more area has been surveyed in the South (IW 5,025 ha + WCVI 2,861 ha = 7,886 ha South) than in the North (4,811 ha).

Table 3: Current geoduck density (mean and range) on surveyed beds, number of beds and bed area surveyed, by region.

Region	Number of Surveyed Beds	Density (geoducks/m^2) Mean	Density (geoducks/m^2) Range	Bed Area Surveyed (ha)
Central Coast	276	2.06	(0.12 - 9.45)	1,329
Prince Rupert	206	2.28	(0.12 - 9.85)	1,853
Haida Gwaii	218	1.45	(0.00 - 5.60)	1,629
North Coast	**700**	**1.94**	**(0.00 - 9.85)**	**4,811**
PFMAs 23 & 24	69	0.86	(0.12 - 4.29)	2,159
Rest WCVI	24	0.54	(0.00 - 2.02)	702
WCVI	**93**	**0.78**	**(0.00 - 4.29)**	**2,861**
PFMA 12	27	1.33	(0.16 - 2.69)	294
Strait of Georgia	51	0.34	(0.03 - 1.86)	4,731
Inside Waters	**78**	**0.68**	**(0.03 - 2.69)**	**5,025**
Entire Coast	**871**	**1.70**	**(0.00 - 9.85)**	**12,697**

Table 4: Number and percentage of surveyed geoduck beds in different mean current density categories.

Mean Current Density	Surveyed Beds		Cumulative	Bed Area		Cumulative
Geoducks/m^2	Number	%	% Number	Hectares	%	% Area
0 to <1	351	40.3	40.3	8,373	66.0	66.0
1 to <2	250	28.7	69.0	2,250	17.7	83.7
2 to <3	125	14.4	83.4	1,142	9.0	92.7
3 to <4	71	8.2	91.5	345	2.7	95.4
4 to <6	57	6.5	98.0	504	4.0	99.4
6 to <8	11	1.3	99.3	43	0.3	99.7
≥8	6	0.7	100.0	37	0.3	100.0

Density dive surveys follow established DFO survey protocols and data are analyzed and archived by DFO. The majority of density surveys are conducted from geoduck harvest boats chartered by the Underwater Harvester's Association (UHA) with an experienced, lead contract biologist. Divers on each survey crew include the UHA contract biologist, geoduck harvesters with a minimum three years' experience in the industry and one of the following: DFO scientists/divers, experienced First Nation surveyors or independent third party divers. This protocol ensures there is local knowledge on the survey as well as independent surveyors. The geoduck fishery has now, through time and the active involvement and financial contribution by the UHA, become one of the more data-rich fisheries in BC.

For unsurveyed beds, biomass is estimated using discretization methods where densities from surveyed beds are extrapolated (Bureau et al. 2012). Density categorization was implemented to create an improved model for density extrapolation over the simple assumption that beds in close proximity to one another are more similar than are more distant beds. For example, an unsurveyed bed classified as 'high density', based on OGM and harvesters logbook comments, would be assigned a density estimate derived from only the surveyed beds within the same region that are also classified as high density.

Exploitation Rates

Zhang and Hand (2007) recommended regional annual exploitation rates of: 1.6% for Haida Gwaii, 1.8% for Prince Rupert, Central Coast and IW, and 1.2% for WCVI, to be applied to estimates of current density. The annual exploitation rates are multiplied by three for regions harvested under three year rotation, so that the average exploitation rate over a rotation period is equal to the annual harvest rate.

Stock Index and Limit Reference Point

The Stock Index, defined as the ratio of current biomass to virgin biomass (B_c/B_0), is calculated yearly to establish the stock status for each geoduck bed relative to the LRP. The average Stock Index of all beds is 0.78 (based on regional mean biomass estimates). In other words, it is estimated that current mean geoduck biomass on the BC coast is 78% of estimated virgin biomass. Stock Index is above the LRP of 0.4 for 93% of harvestable bed area and 98% of the harvestable biomass, while Stock Index is above 0.8 for 31% of harvestable area and 51% of harvestable biomass (Table 5).

Table 5: Number of beds, amount of area and percent of biomass that falls within various ranges of Stock Index, calculated using harvestable beds only and using regional mean estimates of biomass.

Stock	Beds		Area		Biomass
Index	Number	%	Hectares	%	%
All Beds	1,956	100.0	18,050	100.0	100.0
≥0.80	1,199	61.3	5,675	31.4	51.4
≥0.5 to <0.8	597	30.5	8,394	46.5	39.9
≥0.4 to <0.5	80	4.1	2,782	15.4	6.4
<0.4 (below LRP)	80	4.1	1,201	6.7	2.3

The LRP currently in use for the BC geoduck fishery consists of closing a bed once the Stock Index falls below 0.40. For harvestable beds, 1,201 ha (6.7% of harvestable area) fall under the LRP (527 ha in the IW, 559 ha on WCVI and 115 ha in the NC). The higher amount of area under the LRP in the South Coast is due to the longer fishing history in the South, coupled with fewer harvest controls in the early years of the fishery when it operated mostly in the South. Currently, beds that are approaching the LRP, *i.e.,* where the Stock Index is between 0.4 and 0.5, represent 15% of harvestable bed area or 6% of harvestable biomass.

An additional margin of safety for geoduck conservation exists because portions of the geoduck population are sheltered from harvest. Some geoduck beds are located in areas that fall under a variety of closure types (contamination closures, parks, research closures), some geoducks exist in areas that are unharvestable due to substrate characteristics and many beds extend to depths greater than where harvest takes place. The geoduck biomass in these *de-facto* reserves has, however, not been quantified. Relative geoduck abundance data, collected on sea cucumber and sea urchin surveys, may help identify undocumented areas where geoducks are present. Since geoduck bed areas get defined primarily through harvesting events, the inventory of geoduck populations in BC is incomplete. Geoduck harvesters continue to discover new beds every year.

Estimated Geoduck Biomass in BC

Current geoduck biomass, in harvestable beds on the BC coast, is estimated at 178,352 t (95% CB: 92,668 t – 339,582 t) or 393,195,796 lbs (95% CB: 204,296,971 lbs – 748,641,430 lbs). For all harvestable beds in BC, the sums of the low 95% and low 90% annual harvest options are

1,427 t (3,146,847 lbs) and 1,590 t (3,505,706 lbs), respectively, while the sum of maximum harvest options, according to the management decision rules, is 2,986 t (6,583,713 lbs). The TAC for the BC geoduck fishery between 2005 and 2011 was set at 1,559 t (3,437,500 lbs) and will drop to 1,497 t (3,300,000 lbs) for 2012. The BC geoduck fishery is therefore, overall, managed between the 95% and 90% confidence levels.

Sources of Uncertainties

The uncertainties in the parameter estimates used to estimate geoduck biomass (bed area, mean weight and density) were described in detail in Bureau et al. (2012) and are incorporated into the biomass calculations and expressed in the range of harvest options provided to fishery managers. For every geoduck bed, an estimated mean biomass is provided along with 95%, 90% and 75% confidence bounds.

Gaps in knowledge that affect the accuracy of advice provided to fishery managers include: factors that affect recruitment and natural mortality; the show factor (variable proportion of population visible to survey divers and harvesters); and the ultimate impact of sea otter predation and whether sea otters and the commercial fishery can co-exist.

Perhaps the most important source of uncertainty in the geoduck stock assessment process lies in the back-calculation of virgin biomass. Virgin biomass is estimated by adding historical landings for a given geoduck bed to its estimated current biomass. The calculation of virgin biomass assumes that recruitment and natural mortality are in balance. Recruitment of geoducks is sporadic and unpredictable, so the assumption is probably not valid on the spatial scale of a bed or at a reasonable temporal scale. Geoducks that have recruited to beds after the start of the fishery are not accounted for, nor is natural mortality. The problems associated with the calculation of virgin biomass were discussed in detail in Bureau et al. (2012). An alternative to a biomass-based LRP is therefore desirable.

Ecosystem Considerations

Studies of the potential environmental impacts of geoduck harvesting have shown that harvest impacts on the marine environment are minor and limited in both duration and scale (Goodwin 1978; Breen and Shields 1983; C. Pearce, DFO, personal communication). Geoduck harvest does not appear to have significant, long-term impacts on the benthic environment and infaunal communities, especially in relation to the scale of natural variation. Larger-scale studies on environmental impacts are currently ongoing (C. Pearce, DFO, personal communication).

CONCLUSIONS

The geoduck fishery is data-rich, as a result of the considerable effort that has been spent over the last 20 years to conduct geoduck density and bed mapping surveys. The fishery is assessed and managed on a fine spatial scale, *i.e.,* by geoduck bed. A LRP is in place to ensure conservation. The average bed Stock Index is 0.78. The current TAC is set below the overall lower 90% confidence bounds of harvest options. An unquantified portion of the geoduck population exists in natural refugia (deep water and “chunky” ground) or are protected from harvest because they fall within the boundaries of parks, research closures or contamination closures, while other beds are not targeted because of low market quality. The geoduck fishery is therefore considered to be assessed and managed conservatively.

The following summarizes the conclusions and recommendations arising from this assessment:

- The area of harvestable geoduck beds in BC is estimated to be 18,068 ha. The overall mean estimated current density of all surveyed beds is 1.7 geoducks/m^2 while mean geoduck weight in all beds is estimated to be 1.11 kg.
- Geoduck biomass in harvestable beds on the BC coast is estimated at 178,352 t (95% CB: 92,668 t – 339,582 t).
- For all harvestable beds in BC, the sums of the low 95% and low 90% annual harvest options are 1,427 t and 1,590 t, respectively, while the sum of maximum harvest options, according to the management decision rules, is 2,986 t.
- The decrease in TAC for 2012 can mostly be attributed to predation by sea otters and the associated loss of harvest opportunities, and to the reallocation of beds to geoduck subtidal aquaculture.
- More research is planned for 2012 to investigate the effects of biological sample handling practices on mean weight estimates.
- A provisional LRP is established for the geoduck fishery, however, it has not been evaluated nor is there an Upper Stock Reference (USR) (DFO 2009) in place. In addition, because of the issues associated with back-calculating original biomass (B_0) and the difficulty in monitoring recovery of closed beds, the development of an alternative LRP and USR that are compliant with DFO's Precautionary Approach is desired.

OTHER CONSIDERATIONS

The UHA has been conducting geoduck enhancement in the Strait of Georgia since 1995. Since then, enhancement of geoducks has been conducted on approximately 33 ha. Starting in 2007, as much as 17.9 t (39,469 lbs) of enhanced product has been harvested yearly as part of the TAC. For 2012, the planned harvest from enhancement plots is 27.2 t (60,000 lbs) as part of the TAC. It is expected that geoducks from enhancement activities will continue to be harvested as part of the TAC in future years.

Aquaculture harvest is not subject to the same monitoring and validation procedures as the commercial fishery. There is thus a potential for unreported harvest of geoducks from wild beds to occur.

It is expected that the expansion of the sea otter population and range in BC will continue to impact the geoduck fishery, leading to further reductions in geoduck biomass and harvest options. Similarly, further allocations of geoduck beds to subtidal geoduck aquaculture will lead to reductions in geoduck bed area available to the wild fishery and reduced harvest options.

SOURCES OF INFORMATION

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