



2019 STOCK STATUS UPDATE OF BRITISH COLUMBIA WILD GEODUCK

Context

Pacific Geoduck (*Panopea generosa*) populations occur in discrete beds of soft substrate, distributed throughout the coast of British Columbia (BC). Geoducks are clams, live buried up to 1 m below the sediment surface, and are therefore sedentary. Individual Geoduck beds are connected by means of planktonic larvae, thereby forming meta-populations. Based on current knowledge, Geoduck populations form a single genetic stock along the BC coast (Miller et al. 2006).

A commercial dive fishery in BC for wild Geoducks began in 1976. The BC Geoduck fishery is managed with a total allowable catch (TAC), individual vessel quotas, scheduled openings and area quotas. The fishery operates on a three year spatial rotation in the North Coast and Inside Waters quota areas (Figure 1), while the West Coast of Vancouver Island (WCVI) area is fished annually.

Stock assessment and management of the fishery are conducted on the spatial scale of individual Geoduck sub-beds. In 2019, there were 2,907 documented Geoduck beds on the BC coast made up of 5,227 sub-beds ranging in size from 0.03 hectares (ha) to 451.01 ha. Sub-beds are discrete patches of Geoduck habitat on the sea floor that were initially assigned a common bed code (Bureau 2017).

The stock is assessed following methods described in the stock assessment framework (Bureau et al. 2012). The framework was updated (DFO 2014, Bureau 2017, DFO 2017) as requested by Fisheries and Oceans Canada's (DFO's) Fisheries Management branch. Biomass estimates are updated annually with new data on population densities, mean Geoduck weights and bed areas.

The Limit Reference Point (LRP) for the BC Geoduck fishery is defined as current biomass (B_c) being equal to 40% of estimated unfished biomass (B') and is applied on a by-sub-bed basis (Bureau 2017, DFO 2017). The stock index for a Geoduck sub-bed is defined as the ratio of current biomass to unfished biomass (B_c/B').

This report provides estimates of BC Geoduck stock biomass and stock index, updated in 2019, and summarizes the Science Advice provided to fishery managers for setting quotas for the 2020-2021 Geoduck fishing season.

This Science Response Report results from the Science Response Process of December 1, 2020 on the 2019 Stock Status update of British Columbia wild Geoduck.

Background

Description of the Fishery

The BC commercial Geoduck fishery began in 1976 and has since grown to be one of the highest valued fisheries in BC at CAD \$44.7 million for 2016-17 fishing season. Geoducks are hand-picked by divers using surface-supply gear. Individual Geoducks are extracted from the sea bed using a hand held water jet, pumped from the surface. Divers typically harvest Geoducks between 3 m and 20 m in depth.

The management and stock assessment history for the BC Geoduck fishery were described in detail in Hand and Bureau (2012) and Bureau et al. (2012). Details of current management measures are provided in the Geoduck and Horse Clam Integrated Fisheries Management Plan (DFO 2019). The fishery originally developed in the Inside Waters, followed by the WCVI in 1978 and expansion to the North Coast in 1980 (Figures 1 and 2). The majority of landings have come from the North Coast since 1995.

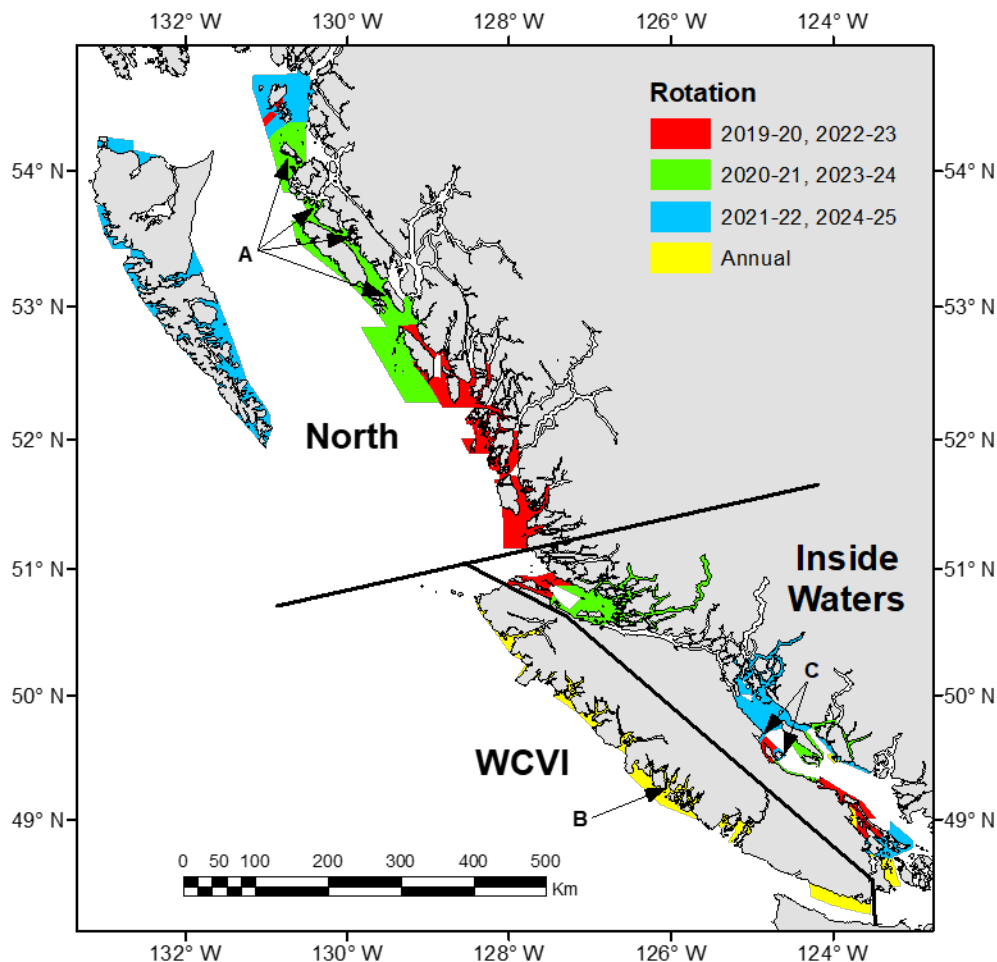


Figure 1: Map of British Columbia coast showing Geoduck “Quota Areas” (North, WCVI = West Coast of Vancouver Island, and Inside Waters, separated by solid lines) and “Rotational Areas” (different colors). Location of 2018 Geoduck density surveys indicated by letters: A = Deer Point to Langley Pass, Campania Island, Freeman Pass to Spicer Island, Anger Island, Stephens Island and Prescott Island, North Coast, B = Millar Channel, WCVI, and C= Comox Bar and Hornby Island, Inside Waters.

Pacific Region

Total Allowable Catch (TAC), in the context of this report, refers to the annual commercial catch allocation, established by fishery managers, for the BC wild Geoduck fishery. The TAC was relatively stable around 1,800 t between 1996 and 2004, but then was decreased to 1,559 t between 2005 and 2011. From 2012 to 2015, the TAC was 1,497 t. The TAC was decreased to 1,397 t for the 2016-2017 fishing season (Figure 2). There has been 100% dock side validation of commercial landings by a third-party service provider since 1989.

In 2012, each of the 55 Geoduck commercial licenses were divided into 10 quota blocks with the option to transfer quota blocks between licenses. The fishery operated on the calendar year until 2015. The fishery operated for fourteen months for the 2016-2017 season to change the season start date to March 1st, starting with the 2017-2018 fishing season.

Since 2007, harvest options have been based on estimates of current biomass (B_c) and regional annual exploitation rates of 1.2 – 1.8% and the LRP has been set to 40% of unfished biomass (B') (Zhang and Hand 2006, 2007). Harvest options for portions of the coast under three year rotation are three times the annual rate once every three years.

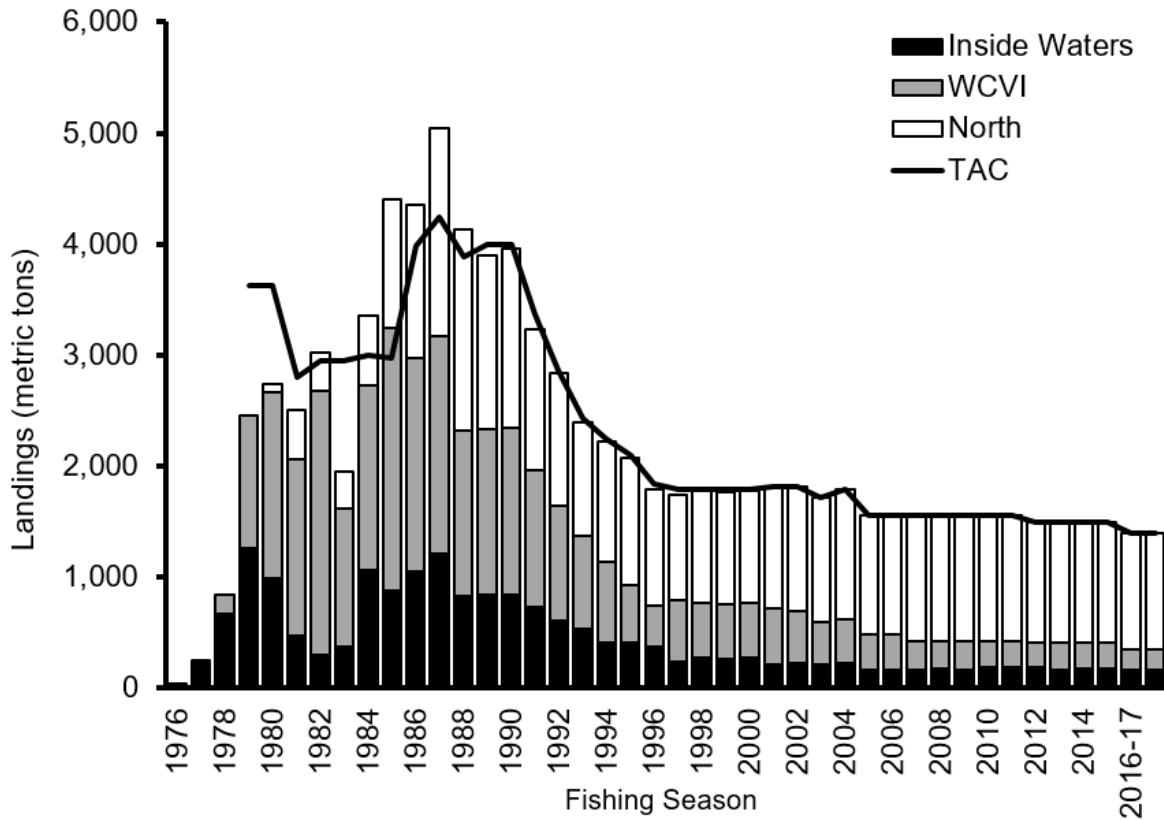


Figure 2: History of landings (metric tons) for the BC Geoduck fishery.

Not all documented Geoduck beds on the BC coast can be harvested. Some beds are closed to harvest for a number of reasons including: contamination closures, research closures, parks or other protected areas, areas that cannot be harvested due to logistical issues, or areas where water quality has not been classified by Environment Canada (known as unclassified waters). Geoduck beds in some areas are not harvested due to the impact of Sea Otter (*Enhydra lutris*) predation on Geoduck stocks. Beds in areas where Sea Otters are reported to have had an

impact are assumed to not be harvestable. In addition, Geoducks also occur outside documented beds (e.g. deeper or shallower than harvestable depths, beds not yet discovered).

Analysis and Response

Stock Status and Stock Index

Stock Status

This stock status update follows the methods presented in the Geoduck stock assessment framework (Bureau et al. 2012) and later modifications (DFO 2014, Bureau 2017, DFO 2017) for estimating Geoduck stock biomass. Geoduck biomass is estimated on a by-Geoduck-sub-bed basis as the product of Geoduck density, mean weight and sub-bed area. Although the assessment methods are only updated when required, Geoduck biomass is re-estimated annually to include the latest available dive survey density data as well as new data on Geoduck mean weights, bed areas and harvest.

Geoduck surveys occur in different portions of the BC coast each year and only a portion of the beds are surveyed each year. On average 1,014 ha are surveyed each year and 1,071 ha were surveyed in 2018. Therefore, each year, density estimates are updated for some beds. Also, each year, estimates of sub-bed area and mean weights are updated for some sub-beds. Although harvest is accounted for in biomass estimations, changes in biomass from year to year also reflect increased or updated knowledge for portions of the stock and may therefore not be reflective of stock trends over time.

This 2019 stock status update incorporates new data from Geoduck fishery-independent density dive surveys conducted in 2018 as well as revisions to mean weight and bed area estimates based on the 2017 fishing season harvest events. Bed area and biomass were not reported for Pacific Fishery Management Areas (PFMA) 11, 28, 102 and 111 in the 2018 Geoduck stock status report (DFO 2020a) because those PFMAs are not open to harvest. Bed area and biomass for these four PFMAs are reported here.

Bed Area

The main source of data used to delineate the extent of Geoduck beds is harvest events. Estimates of Geoduck bed area are updated yearly to incorporate newly available data. Each year, harvest events from two seasons prior are reviewed to refine bed areas (Bureau et al. 2012). Any new beds discovered or extensions to existing beds are then documented. Results from density dive surveys and hydro-acoustic substrate-mapping surveys are also used to refine the area of beds surveyed the previous year. In 2018, hydro-acoustic substrate classification (single-beam) was replaced by multi-beam surveys of the target beds prior to the dive surveys. Comments from harvesters or on-ground monitors at annual meetings are also used to refine bed area boundaries. Because of the fishery-dependent nature of the data used to delineate beds, only areas where Geoducks are found in commercially harvestable quantities are documented. Geoduck beds therefore do not represent a full inventory of locations where Geoducks occur on the BC coast.

The total area of documented Geoduck beds in BC was estimated to be 22,326 ha, of which 15,758 ha were open to harvest for the 2020-2021 season (Table 1). Beds that were not available to the fishery, represented 6,568 ha of bed area. The amount of Geoduck bed area not available to the fishery has increased from 2018 to 2019 due to the closure of several beds within the Gwaii Haanas National Marine Conservation Area in PFMA 2.

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Table 1: Amount of Geoduck bed area (hectares) under various categories, by Pacific Fishery Management Area (PFMA) and coastwide. "Closures" refers to beds in parks, reserves, research closures, contamination closures, unclassified waters, or tenured for aquaculture. "Otters" refers to beds that have been impacted by Sea Otter predation. "Below LRP" are beds with a stock index <0.4. "Open" are beds for which harvest options are estimated.

PFMA	Bed Area (ha)				
	Total	Closures	Otters	Below LRP	Open
1	199	4	0	1	194
2	2,302	405	0	38	1,860
102	10	10	0	0	0
3	190	3	0	1	186
4	658	4	0	2	652
5	796	1	32	28	735
6	1,351	4	50	55	1,242
106	96	0	0	1	94
7	1,222	3	536	76	608
8	151	0	0	0	151
9	103	0	7	0	96
10	107	0	13	1	92
11	21	21	0	0	0
111	43	43	0	0	0
12	692	76	95	32	490
13	725	68	0	101	556
14	3,764	22	0	79	3,663
15	1,377	366	0	93	917
16	722	13	0	34	674
17	686	168	0	8	510
18	135	6	0	0	129
19	587	68	0	0	520
28	30	30	0	0	0
29	164	3	0	0	162
20	299	0	0	0	299
23	1,285	814	0	9	462
24	2,273	129	535	186	1,423
124	14	0	0	0	14
25	1,039	1	1,033	2	3
26	608	140	389	54	24
27	678	0	670	8	0
Coastwide	22,326	2,398	3,359	811	15,758

Pacific Region

Density

In 2018, density dive surveys were conducted on a portion of the Geoduck beds in the following areas of the BC coast (Figure 1):

- Deer Point to Langley Pass, Campania Island, Freeman Pass to Spicer Island, Anger Island, Stephens Island and Prescott Island; North Coast
- Millar Channel; WCVI
- Comox Bar and Hornby Island; Inside Waters

The 2018 Geoduck density surveys covered 125 beds representing 1,071 ha of area. To date, 1,533 beds have been dive surveyed, representing 15,875 ha of bed area (71% of total) (Table 2). Of the surveyed beds, 436 have been surveyed more than once, representing 8,350 ha (37% of total). The average of mean current density estimates from all surveyed beds was 1.89 Geoducks/m². Average density was higher in the North Coast than in the South Coast (Inside Waters and WCVI). Density of Geoducks was below 1.0 Geoduck/m² for 67% of the surveyed bed area (Table 3).

Table 2: 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)		Bed Area Surveyed (ha)
		Mean	Range	
Haida Gwaii	316	1.56	(0.00 - 5.28)	1,928
Prince Rupert	416	2.53	(0.14 - 9.06)	2,323
Central Coast	509	2.18	(0.09 - 12.04)	1,660
North - All	1,241	2.14	(0.00 - 12.04)	5,911
Area 12	45	1.03	(0.09 - 2.69)	468
Strait of Georgia	95	0.31	(0.04 - 1.74)	5,970
Inside Waters - All	140	0.54	(0.04 - 2.69)	6,438
Area 24	41	1.10	(0.05 - 3.04)	2,038
Area 23	38	0.75	(0.23 - 1.86)	380
Area 23 Closures	49	1.75	(0.35 - 4.06)	447
Rest of WCVI	24	0.41	(0.00 - 1.28)	661
WCVI - All	152	1.11	(0.00 - 4.06)	3,525
Coastwide	1,533	1.89	(0.00 - 12.04)	15,875

Table 3: Number and percentage of surveyed Geoduck beds and bed area within different mean current density categories, coastwide.

Mean Current Density Geoducks/m ²	Surveyed Beds		Cumulative % Number	Bed Area		Cumulative % Area
	Number	%		Hectares	%	
0 to <1	574	37.4	37.4	10,604	66.8	66.8
1 to <2	416	27.1	64.6	2,824	17.8	84.6
2 to <3	253	16.5	81.1	988	6.2	90.8
3 to <4	127	8.3	89.4	641	4.0	94.9
4 to <6	105	6.8	96.2	521	3.3	98.1
6 to <8	34	2.2	98.4	231	1.5	99.6
≥8	24	1.6	100.0	66	0.4	100.0

Pacific Region

Mean Weight

Since 2001, Geoduck mean weights have been estimated from commercial fishery landings data (Bureau et al. 2012, DFO 2014). Mean weights are updated annually after adding the latest year of available commercial landings data to the dataset. For Geoduck beds where insufficient data are available to estimate mean weight, the mean weight is extrapolated from nearby beds (Bureau et al. 2012).

For beds where bed-specific estimates of mean weight are available, the average of mean Geoduck weight estimates was 1.10 kg coastwide (n=908), 1.12 kg in the North Coast (n=669), 0.98 kg on the WCVI (n=126) and 1.10 kg in the Inside Waters (n=113). Mean weight estimates ranged from 0.57 to 1.83 kg. Mean Geoduck weight was between 1.0 and 1.5 kg for 72% of the beds while 26% of beds had a mean weight between 0.5 and 1.0 kg (Table 4).

Table 4: Number and percentage of Geoduck beds and bed area within different mean weight ranges (for beds where bed-specific mean weight data are available).

Mean Geoduck Weight (kg)	Beds		Cumulative % Number	Bed Area		Cumulative % Area
	Number	%		Hectares	%	
< 0.5	0	0.0	0.0	0	0.0	0.0
0.5 to <1.0	236	26.0	26.0	3,480	21.2	21.2
1.0 to <1.5	656	72.2	98.2	12,763	77.9	99.1
1.5 to <2.0	16	1.8	100.0	142	0.9	100.0
≥2	0	0.0	100.0	0	0.0	100.0

Geoduck Biomass

Geoduck biomass is estimated only for the exploitable portion of the population (Bureau 2017). The biomass of Geoducks outside of documented Geoduck beds, including the portion of the population that exists deeper than harvestable depths, is unknown. Only Geoducks large enough to be counted by survey divers (approximately 5 years and older) are included in the density estimates and therefore biomass estimates do not include juvenile Geoducks.

Geoduck biomass is reported by Pacific Fishery Management Area (PFMA), for several categories of sub-beds (Table 5). Total biomass includes all documented beds on the coast. Open biomass refers to biomass on beds for which harvest options are estimated. Few surveys have been conducted in areas impacted by Sea Otters. Consequently, there is greater uncertainty in the biomass estimates in these areas and it is likely that biomass is overestimated for areas impacted by Sea Otters.

The Geoduck stock biomass for all open sub-beds in BC was estimated at 173,850 t (95% CB: 95,045 – 308,513 t, Table 5). The Geoduck stock biomass for all documented sub-beds coastwide was estimated at 229,795 t (95% CB: 117,900 – 430,461 t, Table 5). Although the total Geoduck biomass presented here is similar to that estimated last year (228,797 t, DFO 2020a), the biomass open to harvest has dropped mostly due to beds that have now been closed to harvest within the Gwaii Haanas National Marine Conservation Area and because of a larger number of beds impacted by Sea Otters.

**Science Response: 2019 BC Geoduck
Stock Status Update**

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Table 5: Estimated Geoduck biomass (metric tons), by Pacific Fishery Management Area (PFMA) and coastwide, for sub-beds that are open to harvest, below the LRP (< LRP), impacted by Sea Otter predation, located in closures and total. 95% CBs are low and high 95% confidence bounds.

PFMA	Open		< LRP Median	Otters Median	Closures Median	Total	
	Median	95% CBs				Median	95% CBs
1	1,131	290 - 3,617	3	0	45	1,179	296 - 3,808
2	28,877	14,390 - 52,129	236	0	7,027	36,139	17,469 - 67,069
102	0	0 - 0	0	0	127	127	16 - 512
3	3,550	1,709 - 6,213	4	0	9	3,563	1,715 - 6,236
4	22,607	13,236 - 36,666	12	0	94	22,713	13,277 - 36,893
5	22,361	14,188 - 33,423	208	548	13	23,131	14,650 - 34,597
6	32,489	16,084 - 58,433	554	719	95	33,857	16,836 - 60,742
106	4,862	3,181 - 7,766	2	0	0	4,864	3,182 - 7,769
7	12,930	5,579 - 26,963	405	11,295	49	24,678	10,741 - 52,979
8	3,970	1,931 - 7,285	0	0	0	3,970	1,931 - 7,285
9	922	366 - 2,989	0	100	0	1,021	385 - 3,466
10	1,002	391 - 2,022	4	125	0	1,131	427 - 2,622
11	0	0 - 0	0	0	227	227	24 - 605
111	0	0 - 0	0	0	147	147	0 - 608
12	4,637	2,137 - 8,501	110	1,353	805	6,904	3,165 - 13,182
13	926	543 - 1,912	188	0	164	1,278	750 - 2,844
14	6,242	4,481 - 8,821	63	0	67	6,372	4,552 - 9,065
15	1,358	515 - 5,003	70	0	577	2,006	794 - 7,560
16	2,523	1,581 - 5,089	68	0	21	2,613	1,641 - 5,311
17	1,316	750 - 3,548	48	0	306	1,670	839 - 5,660
18	782	507 - 1,338	0	0	8	790	510 - 1,378
19	933	242 - 4,976	0	0	155	1,088	278 - 6,002
28	0	0 - 0	0	0	52	52	12 - 341
29	365	164 - 1,229	0	0	4	369	165 - 1,253
20	746	0 - 2,850	0	0	0	746	0 - 2,850
23	3,764	2,086 - 5,837	37	0	16,803	20,605	8,846 - 35,068
24	15,219	10,592 - 21,139	427	3,998	1,001	20,645	13,908 - 29,534
124	182	15 - 497	0	0	0	182	15 - 497
25	38	14 - 57	5	3,223	2	3,268	312 - 11,596
26	119	71 - 209	183	1,793	418	2,513	899 - 6,648
27	0	0 - 0	30	1,918	0	1,948	269 - 6,481
Coastwide	173,850	95,045 - 308,513	2,656	25,072	28,217	229,795	117,900 - 430,461

Stock Index

The stock index for the BC Geoduck fishery is defined as the ratio of current biomass to unfished biomass (B_c/B') and is estimated on a by-sub-bed basis. Sub-beds where the stock index is below 0.4 are not open to harvest. The stock index is re-estimated yearly for each sub-bed when biomass estimates are updated.

Pacific Region

The stock index was above 0.4 for 95% of the bed area and 99% of the biomass in potentially fishable areas (sub-beds open + below LRP, i.e., outside closures and not impacted by Sea Otters, Table 6).

The overall stock index based on total documented coastwide Geoduck biomass was estimated at 83% (ratio of the sum of current biomass to the sum of unfished biomass, for all beds). The overall stock index of Geoduck biomass within open beds was estimated at 89% (ratio of the sum of current biomass to the sum of unfished biomass, for open beds). The value of the Limit Reference Point for the BC Geoduck stock in 2019 was estimated at 111,073 t (95% CB: 60,068 – 211,798 t).

An additional margin of safety for Geoduck conservation exists because portions of the Geoduck stock are sheltered from harvest. Some Geoduck beds are located in areas that fall under a variety of closure types (contamination closures, parks, research closures, etc.), some Geoducks exist in areas that are un-harvestable due to substrate characteristics and many beds extend to shallower and/or greater depths than where harvest takes place. The Geoduck biomass in these *de-facto* reserves has, however, not been quantified. Since Geoduck beds are defined primarily through harvesting events, the inventory of Geoduck populations in BC is not complete.

Table 6: Number of Geoduck sub-beds, amount of area and percent of biomass within various ranges of stock index, for sub-beds outside closures and not impacted by Sea Otters, i.e., sub-beds open + below LRP.

Stock Index	Sub-Beds		Area		Biomass %
	Number	%	Hectares	%	
All potentially fishable beds	3,777	100.0	16,569	100.0	100.0
≥0.40	3,611	95.6	15,758	95.1	98.5
<0.4 (below LRP)	166	4.4	811	4.9	1.5

Conclusions

Geoduck biomass on open sub-beds on the BC coast was estimated at 173,850 t (95% CB: 95,045 – 308,513 t, Table 5). Total coastwide biomass for all documented sub-beds was estimated at 229,795 t (95% CB: 117,900 – 430,461 t, Table 5), well above the LRP of 111,073 t (95% CB: 60,068 – 211,798 t).

For all open Geoduck sub-beds in BC, the sum of the lower 95% confidence bounds of annual harvest options was 1,631 t. The TAC for the BC commercial Geoduck fishery for the 2020-2021 fishing season was set at 1,372 t by fishery managers (DFO 2020b) and was therefore below the lower 95% confidence bound of harvest options.

For the Geoduck fishery, Zhang and Hand (2006, 2007) recommended regional annual harvest rates ranging from 1.2 to 1.8% of current Geoduck biomass. The removal reference (maximum allowable harvest rate for the stock as a whole) for the BC Geoduck fishery can therefore be defined as 1.8% of the coastwide current Geoduck biomass estimate.

Although regional annual harvest rates of 1.2 to 1.8% are used in estimating harvest options for each Geoduck sub-bed, the actual harvest rate, defined as the TAC divided by biomass, for the BC Geoduck fishery as a whole is lower. The actual Geoduck annual harvest rate for the 2020-2021 fishing season was 0.6% of the estimated median total documented biomass and 1.2% of

the estimated lower 95% confidence bound of total documented biomass (i.e. biomass on all documented sub-beds); well below the 1.8% removal reference.

Based on biomass estimated for the 2020-2021 Geoduck harvesting season, the coastwide Geoduck stock index was 83% and 89% for all documented sub-beds on the coast and for open sub-beds only, respectively, well above the 40% limit reference point.

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