



## 2018 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 that live buried up to 1m 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 dive fishery for Geoducks began in BC in 1976. The 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 regions (Figure 1), while the West Coast of Vancouver Island (WCVI) is fished annually.

Stock assessment and management of the fishery are conducted on the spatial scale of individual Geoduck sub-beds. In 2018, there were 2,888 documented Geoduck beds on the BC coast made up of 5,216 sub-beds ranging in size from 0.03 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) which was updated (DFO 2014, Bureau 2017, DFO 2017a) as warranted by new information, analytical approaches, or as requested by Fisheries and Oceans Canada (DFO's) Fisheries Management branch. Biomass estimates are updated annually with new data on population densities, mean Geoduck weights and bed area.

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 2017a). The stock index for a Geoduck sub-bed is defined as the ratio of current biomass to unfished biomass. Updates to unfished biomass and stock index estimation methods presented in Bureau (2017) were first implemented at the time of estimating Geoduck biomass for the 2019-2020 season.

This report provides estimates of BC Geoduck stock biomass and stock index, updated in 2018, and summarizes the Science Advice provided to fishery managers for setting quotas for the 2019-2020 Geoduck fishing season.

This Science Response Report results from the Science Response Process of September 15, 2020 on the 2018 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 3m and 20m 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 2018). 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.

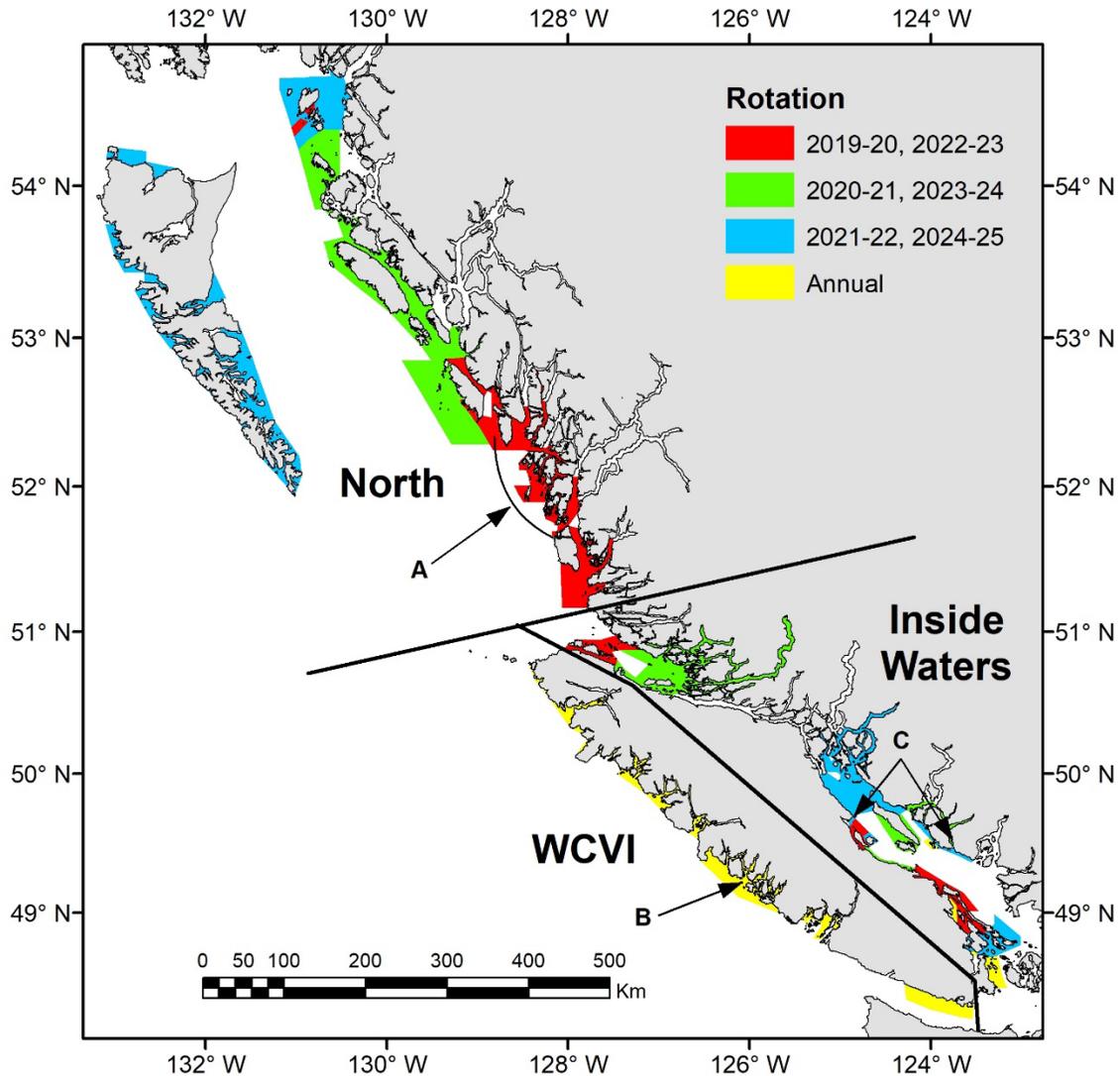


Figure 1: Map of British Columbia coast showing Geoduck “Quota Areas” (black letters, separated by solid lines) and “Rotational Areas” (different colors). WCVI = West Coast of Vancouver Island. Location of 2017 Geoduck density surveys indicated by letters: A = Stirling Island to Price Island, Central Coast, B = Coomes Bank and Millar Channel, WCVI and C = Comox Bar and Sechelt Inlets, Inside Waters.

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 was 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 1<sup>st</sup>, starting with the 2017-2018 fishing season (DFO 2017b).

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.

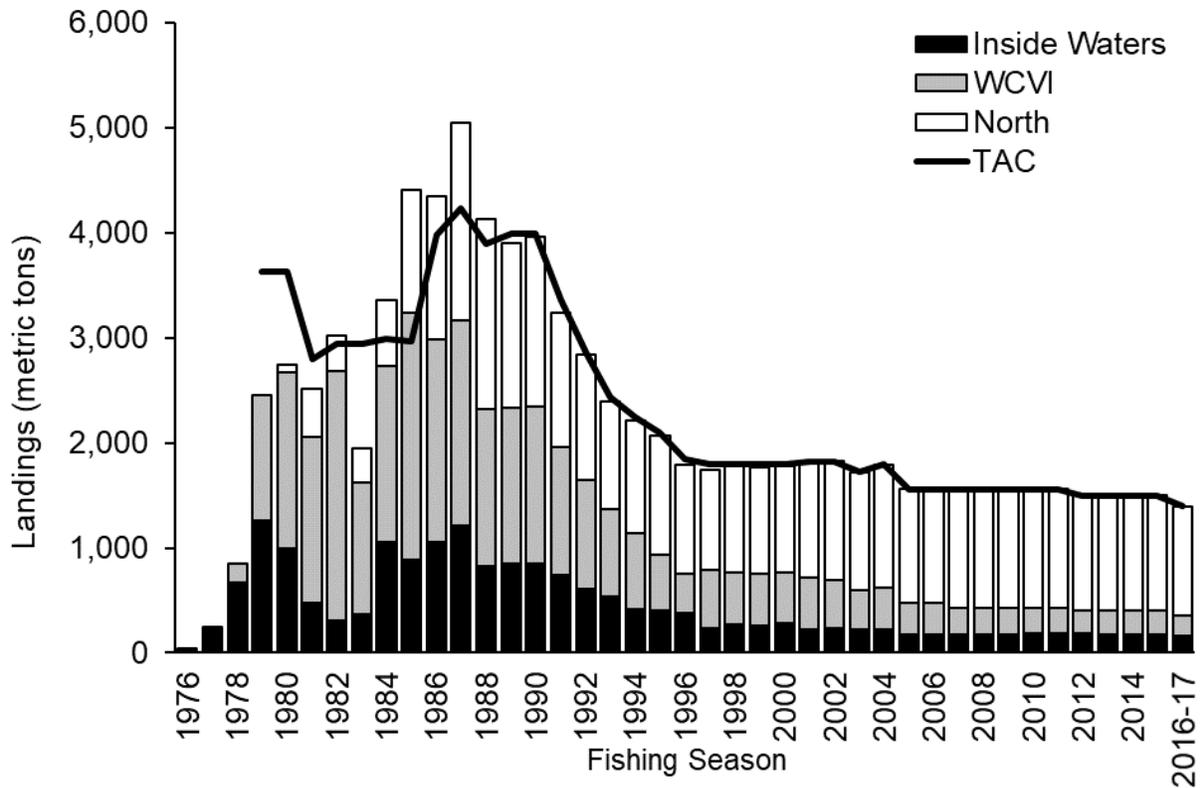


Figure 2: History of landings (metric tons) for the BC Geoduck fishery.

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 cannot be 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, Geoduck also occur outside documented beds, e.g., deeper or shallower than harvestable depths, beds not yet discovered, etc.

## Analysis and Response

### Stock Status and Stock Index

#### Stock Status

The stock status update presented here follows the methods presented in the Geoduck stock assessment framework (Bureau et al. 2012) and later modifications (DFO 2014, Bureau 2017, DFO 2017a) 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 and bed areas.

Geoduck surveys occur in different portions of the BC coast each year and only a portion of the beds are surveyed each year. 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. Changes in biomass from year to year thus reflect increased or updated knowledge for portions of the stock and may therefore not be reflective of stock trends over time.

The 2018 stock status update incorporates new data from Geoduck fishery-independent density dive surveys conducted in 2017 as well as revisions to mean weight and bed area estimates based on the 2016 fishing season harvest events.

#### *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. 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 is estimated to be 21,975 hectares (ha), of which 16,848 ha are open to harvest for the 2019-2020 season (Table 1). Beds that are not available to the fishery represent 5,127 ha of bed area.

#### *Density*

In 2017, density dive surveys were conducted on a portion of the Geoduck beds in the following areas of the BC coast (Figure 1):

- Kittyhawk Group, Spider Anchorage, Stirling Island, Superstition Point and Price Island; Central Coast
- Coomes Bank and Millar Channel; WCVI
- Comox Bar and Sechelt Inlet; Inside Waters

The 2017 Geoduck density surveys covered 109 beds representing 1,598 ha of area. To date, 1,483 beds have been dive surveyed, representing 15,777 ha of bed area (72% of total) (Table 2). Of the surveyed beds, 366 have been surveyed more than once, representing 7,609 ha (35% of total). The average of mean current density estimates from all surveyed beds is 1.87

Geoducks/m<sup>2</sup>. Average density is higher in the North Coast than in the South Coast (Inside Waters and WCVI). Density of Geoducks is below 1.0 Geoduck/m<sup>2</sup> for 67% of the surveyed bed area (Table 3).

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	198	3	0	1	194
2	2,283	75	0	20	2,188
3	190	3	0	1	186
4	632	2	0	2	628
5	794	1	0	19	774
6	1,361	6	0	65	1,290
106	95	0	0	1	93
7	1,222	3	488	80	650
8	151	0	0	0	151
9	103	4	5	0	95
10	107	0	11	1	94
12	689	72	0	51	567
13	712	55	0	101	556
14	3,745	22	0	0	3,723
15	1,258	247	0	93	917
16	713	12	0	34	667
17	686	168	0	8	510
18	135	6	0	0	129
19	553	34	0	0	520
29	164	3	0	0	162
20	299	0	0	0	299
23	1,277	813	0	9	455
24	2,268	128	3	179	1,958
124	14	0	0	0	14
25	1,039	1	829	204	4
26	608	140	244	199	24
27	678	0	670	8	0
Coastwide	21,975	1,797	2,251	1,079	16,848

### 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 is 1.10 kg coastwide (n=883), 1.12 kg in the North Coast (n=649), 0.98 kg on the WCVI (n=125) and 1.10 kg in the Inside Waters (n=109). Mean weight estimates range between 0.57 kg to 1.83 kg. Mean Geoduck weight is between 1.0 and 1.5 kg for 72% of the beds while 27% of beds have a mean weight between 0.5 and 1.0 kg (Table 4).

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 <sup>2</sup> )		Bed Area Surveyed (ha)
		Mean	Range	
Haida Gwaii	316	1.59	(0.00 - 5.45)	1,928
Prince Rupert	367	2.51	(0.07 - 9.05)	2,267
Central Coast	509	2.18	(0.09 - 12.04)	1,659
<b>North - All</b>	<b>1192</b>	<b>2.13</b>	<b>(0.00 - 12.04)</b>	<b>5,854</b>
Area 12	45	1.03	(0.09 - 2.69)	466
Strait of Georgia	94	0.31	(0.04 - 1.74)	5,937
<b>Inside Waters - All</b>	<b>139</b>	<b>0.54</b>	<b>(0.04 - 2.69)</b>	<b>6,403</b>
Area 24	41	1.11	(0.05 - 3.07)	2,034
Area 23	38	0.75	(0.23 - 1.86)	378
Area 23 Closures	49	1.75	(0.35 - 4.06)	447
Rest of WCVI	24	0.41	(0.00 - 1.28)	661
<b>WCVI - All</b>	<b>152</b>	<b>1.12</b>	<b>(0.00 - 4.06)</b>	<b>3,519</b>
<b>Coastwide</b>	<b>1483</b>	<b>1.87</b>	<b>(0.00 - 12.04)</b>	<b>15,777</b>

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

Mean Current Density Geoducks/m <sup>2</sup>	Surveyed Beds		Cumulative % Number	Bed Area		Cumulative % Area
	Number	%		Hectares	%	
0 to <1	572	38.6	38.6	10,549	66.9	66.9
1 to <2	402	27.1	65.7	2,761	17.5	84.4
2 to <3	230	15.5	81.2	1,067	6.8	91.1
3 to <4	116	7.8	89.0	589	3.7	94.9
4 to <6	105	7.1	96.1	518	3.3	98.1
6 to <8	34	2.3	98.4	230	1.5	99.6
≥8	24	1.6	100.0	63	0.4	100.0

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	234	26.5	26.5	3,544	21.8	21.8
1.0 to <1.5	633	71.7	98.2	12,557	77.3	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.

*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, impacted by Sea Otter predation, located in closures and total. 95% CBs are low and high 95% confidence bounds.*

PFMA	Open		Below LRP Median	Otters Median	Closures Median	Total	
	Median	95% CBs				Median	95% CBs
1	1,151	288 – 3,656	3	0	31	1,185	292 – 3,793
2	35,795	18,037 – 63,970	143	0	821	36,759	18,246 – 67,359
3	3,530	1,693 - 6,278	4	0	9	3,543	1,698 - 6,301
4	22,153	13,058 – 35,869	12	0	74	22,240	13,094 - 36,015
5	22,690	13,911 – 35,103	127	0	12	22,829	13,995 - 35,330
6	32,255	16,070 – 58,659	621	0	89	32,964	16,491 – 59,725
106	4,823	3,153 – 7,718	2	0	0	4,825	3,154 7,722
7	13,512	5,815 – 28,201	439	10,653	49	24,653	10,723 - 52,939
8	3,970	1,931 – 7,284	0	0	0	3,970	1,931 – 7,284
9	912	362 – 2,923	0	76	33	1,021	385 , 3,463
10	1,023	399 – 2,063	4	104	0	1,131	427 – 2,620
12	5,866	2,890 – 10,571	207	0	758	6,831	3,149 – 12,999
13	942	557 – 1,933	188	0	141	1,272	759 – 2,707
14	6,585	4,486 – 9,632	0	0	67	6,652	4,528 - 9,792
15	1,418	530 – 5,052	70	0	391	1,879	763 – 6,439
16	2,525	1,576 – 5,027	68	0	21	2,614	1,636 - 5,247
17	1,346	750 – 3,588	48	0	314	1,708	839 - 5731
18	785	511 – 1,337	0	0	8	793	513 – 1,376
19	950	246 – 5,120	0	0	79	1,029	264 - 5,641
29	370	165 – 1,226	0	0	4	374	166 – 1,249
20	746	0 – 2,850	0	0	0	746	0 – 2,850
23	3,725	2,076 – 5,736	38	0	16,872	20,636	8,861 - 35,089
24	19,802	14,087 – 26,952	411	16	997	21,226	14,516 - 30,058
124	182	15 - 499	0	0	0	182	15 - 499
25	51	19 - 76	275	2,942	2	3,269	312 - 11,596
26	119	71 - 209	1,299	681	418	2,518	904 – 6,653
27	0	-	30	1,918	0	1,948	269 - 6,479
<b>Total</b>	<b>187,226</b>	<b>102,697 - 331,531</b>	<b>3,988</b>	<b>16,391</b>	<b>21,193</b>	<b>228,797</b>	<b>117,930 - 426,953</b>

The Geoduck stock biomass for all open sub-beds in BC is estimated at 187,226 t (95% CB: 102,697 t – 331,531 t, Table 5). The Geoduck stock biomass for all documented sub-beds coastwide is estimated at 228,797 t (95% CB: 117,930 – 426,953 t, Table 5).

### 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.

Updates to Geoduck unfished biomass ( $B'$ ) and stock index estimation methods published in 2017 (Bureau 2017, DFO 2017a) were incorporated in biomass and stock index estimations for the 2019-2020 Geoduck harvest season.

The stock index is above 0.4 for 94% of the bed area and 98% of the biomass in potentially fishable areas (sub-beds open + below LRP, i.e., outside closures and not impacted by Sea Otters, Table 6).

*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	3,988	100.0	17,927	100.0	100.0
≥0.40	3,811	95.6	16,848	94.0	97.9
<0.4 (below LRP)	177	4.4	1,079	6.0	2.1

The overall stock index based on total documented coastwide Geoduck biomass is 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 is estimated at 89% (ratio of the sum of current biomass to the sum of unfished biomass, for open beds).

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.

## Conclusions

Geoduck biomass on open sub-beds on the BC coast is estimated at 187,226 t (95% CB: 102,697 t – 331,531 t, Table 5). Total coastwide biomass for all documented sub-beds is estimated at 228,797 t (95% CB: 117,930 – 426,953 t, Table 5).

For all open Geoduck sub-beds in BC, the sum of the lower 95% confidence bounds of annual harvest options is 1,677 t. The TAC for the BC commercial Geoduck fishery for the 2019-2020 fishing season was set at 1,397 t by fishery managers (DFO 2019) and is 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 Geoduck stock as a whole is lower. The actual Geoduck annual harvest rate for the 2019-2020 fishing season is 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 2019-2020 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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