



STOCK STATUS UPDATE OF WILD GEODUCKS IN BRITISH COLUMBIA FOR 2021

Context

Pacific Geoduck (*Panopea generosa*) populations occur in discrete beds of soft substrate, distributed throughout the coast of British Columbia (BC). Geoducks are sedentary clams that live buried up to 1 m below the sediment surface. 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 for wild Geoducks began in BC 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 portions of the Inside Waters quota areas (Figure 1). 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 2021, there were 2,935 documented Geoduck beds on the BC coast made up of 5,242 sub-beds ranging in size from 0.03 hectares (ha) to 450.44 ha. Some beds are made up of multiple sub-beds, which 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 stock is defined as total coastwide current biomass (B_c) being equal to 40% of the total coastwide estimated unfished documented biomass (B') (Bureau 2017, DFO 2017). The Upper Stock Reference (USR) for the BC Geoduck stock is defined as total coastwide current biomass being equal to 50% of total coastwide estimated unfished documented biomass (DFO 2021a). The stock index is defined as the ratio of total coastwide current biomass to total coastwide unfished biomass (B_c/B'). The LRP and USR are applied on a coastwide basis for the purpose of determining Geoduck stock status (DFO 2021a).

This report provides estimates of BC Geoduck stock biomass and stock index, updated in 2021, and summarizes the Science Advice provided to fishery managers for setting quotas for the 2022-2023 Geoduck fishing season.

This Science Response Report results from the Regional Science Response Process of March 1, 2022 on the Stock Status Update of wild Geoducks in British Columbia for 2021.

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 \$43.8 million for 2020-2021 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 2022). 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.

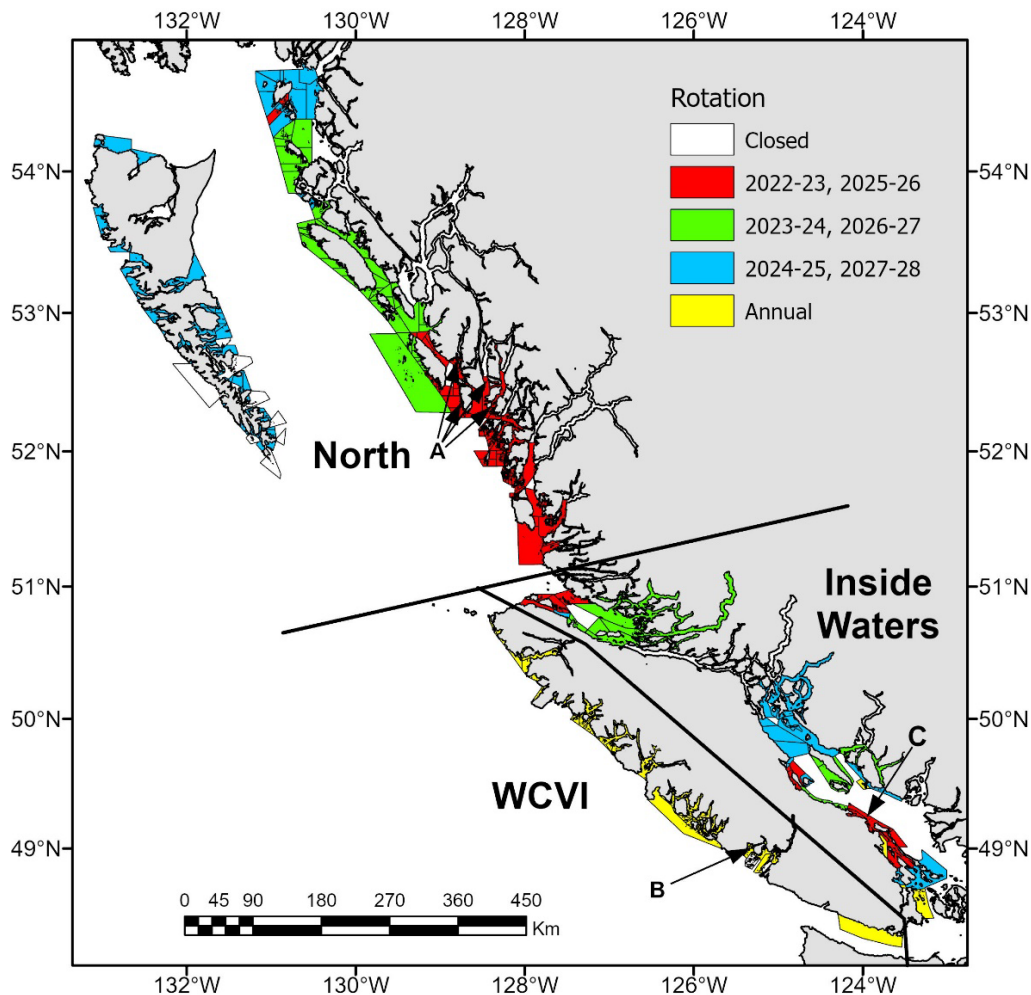


Figure 1: Map of British Columbia coast showing Geoduck “Quota Areas” (North, WCVI = West Coast of Vancouver Island, and Inside Waters, separated by solid lines) and “Rotational Areas” (different colors). Location of 2020 Geoduck density surveys indicated by letters: A = Laredo Inlet, West Price Island, Nowish, Moss Pass, and Berry Inlet; Central Coast, B = Bryant Islands to Stopper Islands, Barkley Sound; WCVI, and C = Nanoose to Gabriola Island; Inside Waters.

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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 and was 1,497 t from 2012 to 2015. The TAC was decreased to 1,397 t for the 2016-2017 to 2019-2020 fishing seasons (Figure 2). The TAC was decreased to 1,372 t and then to 1,297 t for the 2020-2021 and 2021-2022 fishing seasons, respectively (Figure 2), due to the implementation of closures in the Gwaii Haanas National Marine Conservation Area Reserve and expected impacts of Sea Otter predation (DFO 2021b). The TAC for the 2022-2023 season decreased to 1,272 t (DFO 2022). There has been 100% dock side validation of commercial landings by a third-party service provider since 1989.

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. The 2019-2020 season was scheduled from March 1, 2019 to February 28, 2020 but was extended until May 15, 2020 due to impacts of the COVID-19 pandemic. The 2020-2021 and 2021-2022 seasons ran from May 16, 2020 until April 30, 2021, and from May 1, 2021 until April 30, 2022, respectively. The 2022-2023 season will run from May 1, 2022 to April 15, 2023.

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 estimated unfished documented 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.

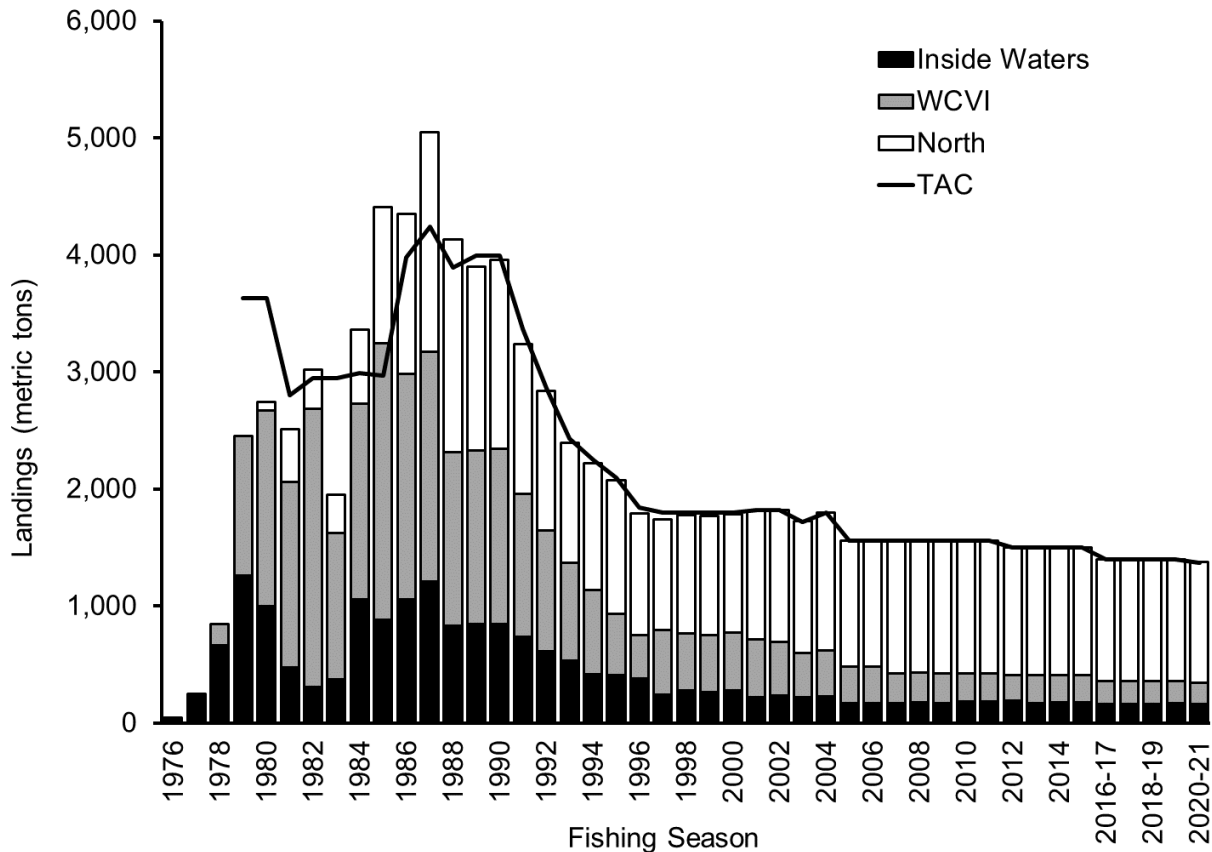


Figure 2: History of landings (metric tons) for the BC Geoduck fishery.

Analysis and Response

Biomass Estimation

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 993 ha are surveyed annually and 659 ha were surveyed in 2020. 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 2021 stock status update incorporates new data from Geoduck fishery-independent density dive surveys conducted in 2020 as well as revisions to mean weight and bed area estimates based on the 2019-2020 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. 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.

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 may or may not have quota assigned to them. In this report the term “available” beds refers to beds not impacted by closures and not reported to be impacted by Sea Otters.

The total area of documented Geoduck beds in BC was estimated to be 22,356 ha, of which 15,459 ha are potentially available to harvest over three rotations (Table 1). Beds that were impacted by closures represented 3,529 ha (16%) of the bed area on the BC coast. Beds reported to be impacted by Sea Otter predation represented 3,368 ha (15%) of the bed area on the BC coast.

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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, management closures, or tenured for aquaculture. "Otters" refers to beds that have been impacted by Sea Otter predation. "Available" refers to beds not impacted by closures and not reported to be impacted by Sea Otters.

PFMA	Bed Area (ha)			
	Total	Closures	Otters	Available
1	199	5	0	194
2	2,299	419	0	1,880
102	10	10	0	0
3	190	5	0	185
4	672	6	0	666
5	796	29	32	735
6	1,293	22	46	1,225
106	95	1	0	94
7	1,247	103	539	605
8	155	0	0	155
9	104	0	7	97
10	108	1	13	94
11	21	21	0	0
111	43	43	0	0
12	698	108	95	495
13	746	148	0	598
14	3,761	101	0	3,660
15	1,421	532	0	889
16	721	59	0	662
17	691	173	0	518
18	137	6	0	131
19	585	75	0	510
28	30	30	0	0
29	164	6	0	158
20	299	0	0	299
23	1,259	863	0	396
24	2,274	565	536	1,174
124	14	0	0	14
25	1,039	3	1,033	3
26	608	195	389	24
27	679	0	679	0
Coastwide	22,356	3,529	3,368	15,459

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Density

In 2020, density dive surveys were conducted on a portion of the Geoduck beds in the following areas of the BC coast (Figure 1):

- Laredo Inlet, West Price Island, Nowish, Moss Pass, and Berry Inlet; Central Coast
- Bryant Islands to Stopper Islands, Barkley Sound; WCVI
- Nanoose to Gabriola Island; Inside Waters

The 2020 Geoduck density surveys covered 98 beds representing 659 ha of area. To date, 1,579 beds have been dive surveyed, representing 15,961 ha of bed area (71% of total) (Table 2). Of the surveyed beds, 504 have been surveyed more than once, representing 9,170 ha (41% of total). The average of mean current density estimates from all surveyed beds was 1.93 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 65% 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	333	1.64	(0.00-5.27)	1,979
Prince Rupert	421	2.55	(0.14-9.06)	2,313
Central Coast	529	2.23	(0.09-12.04)	1,671
North - All	1283	2.18	(0.00-12.04)	5,962
Area 12	45	1.02	(0.09-2.69)	471
Strait of Georgia	95	0.30	(0.04-1.67)	6,019
Inside Waters - All	140	0.53	(0.04-2.69)	6,490
Area 24	41	1.10	(0.05-3.04)	2,036
Area 23	42	0.84	(0.24-1.84)	365
Area 23 Closures	49	1.75	(0.35-4.06)	447
Rest of WCVI	24	0.41	(0.00-1.28)	661
WCVI - All	156	1.13	(0.00-4.06)	3,509
Coastwide	1579	1.93	(0.00-12.04)	15,961

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	572	36.2	36.2	10,425	65.3	65.3
1 to <2	428	27.1	63.3	2,987	18.7	84.0
2 to <3	266	16.8	80.2	1,047	6.6	90.6
3 to <4	141	8.9	89.1	678	4.2	94.8
4 to <6	113	7.2	96.3	522	3.3	98.1
6 to <8	34	2.2	98.4	229	1.4	99.5
≥8	25	1.6	100.0	74	0.5	100.0

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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=949), 1.13 kg in the North Coast (n=701), 0.99 kg on the WCVI (n=128) and 1.09 kg in the Inside Waters (n=120). 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	247	26.0	26.0	3,793	22.8	22.8
1.0 to <1.5	686	72.3	98.3	12,667	76.3	99.1
1.5 to <2.0	16	1.7	100.0	143	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. Available biomass refers to biomass on beds not impacted by closures and not reported to be impacted by Sea Otter predation. 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 available sub-beds in BC was estimated at 178,000 t (95% CB: 97,901 – 311,068 t, Table 5). The Geoduck stock biomass for all documented sub-beds coastwide was estimated at 235,153 t (95% CB: 120,910 – 434,937 t, Table 5). Consequently, 13% of the Geoduck biomass on the BC coast is impacted by closures and 11% is reported to be impacted by Sea Otter predation.

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Table 5: Estimated Geoduck biomass (metric tons), by Pacific Fishery Management Area (PFMA) and coastwide, for sub-beds that are available, impacted by Sea Otter predation, impacted by closures and total. 95% CBs are low and high 95% confidence bounds.

PFMA	Available		Otters Median	Closures Median	Total	
	Median	95% CBs			Median	95% CBs
1	1,166	294 – 3,561	0	50	1,216	300 – 3,755
2	33,120	17,560 – 56,999	0	7,099	40,218	20,413 – 71,626
102	0	0 - 0	0	133	133	17 - 520
3	3,549	1,706 – 6,202	0	15	3,564	1,713 – 6,228
4	23,140	13,452 – 37,901	0	106	23,246	13,493 – 38,126
5	22,382	14,218 – 33,464	549	221	23,151	14,680 – 34,639
6	32,388	16,221 – 56,424	830	334	33,551	16,663 – 58,751
106	4,870	3,222 – 7,689	0	2	4,872	3,223 – 7,692
7	13,369	5,674 – 27,688	11,792	881	26,042	11,196 – 54,539
8	4,029	1,887 – 7,452	0	0	4,029	1,887 – 7,452
9	941	348 – 2,887	115	0	1,057	367 – 3,326
10	1,020	391 – 2,059	128	4	1,152	422 – 2,647
11	0	0 - 0	0	228	228	24 - 614
111	0	0 - 0	0	150	150	0 - 621
12	4,684	2,168 – 8,652	1,360	913	6,958	3,192 – 13,810
13	1,028	618 – 1,986	0	283	1,311	770 – 2,885
14	6,184	4,426 – 8,750	0	127	6,311	4,495 – 8,991
15	1,344	510 – 4,705	0	667	2,011	801 – 7,014
16	2,455	1,535 – 4,913	0	144	2,599	1,622 – 5,235
17	1,302	744 – 3,390	0	353	1,655	832 – 5,507
18	805	524 – 1,371	0	8	813	526 – 1,411
19	911	236 – 4,897	0	172	1,083	276 – 6,042
28	0	0 - 0	0	51	51	12 - 339
29	349	155 – 1,160	0	10	359	157 – 1,221
20	744	0 – 2,842	0	0	744	0 – 2,842
23	3,488	1,857 – 5,468	0	17,073	20,561	8,723 – 35,131
24	14,393	10,057 – 19,843	3,896	1,886	20,175	13,612 – 28,738
124	182	15 - 497	0	0	182	15 - 497
25	38	14 - 57	3,225	7	3,270	312 – 11,603
26	119	71 - 209	1,791	601	2,511	898 – 6,647
27	0	0 - 0	1,949	0	1,949	269 – 6,485
Coastwide	178,000	97,901 – 311,068	25,636	31,516	235,153	120,910 – 434,937

Stock Index and Stock Status

The stock index for the BC Geoduck fishery is defined as the ratio of total coastwide current biomass to total coastwide unfished biomass (B_c/B') and is estimated for the stock as a whole. The coastwide stock index is re-estimated yearly when biomass estimates are updated.

The stock index based on total documented coastwide Geoduck biomass was estimated at 84% (for all beds). The stock index of Geoduck biomass within available beds was estimated at 91%.

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The LRP for BC Geoducks is defined as current biomass (B_c) being equal to 40% of the estimated unfished documented biomass (B') (Zhang and Hand 2007). The value of the Limit Reference Point for the BC Geoduck stock in 2021 was estimated at 111,862 t (95% CB: 60,635– 212,071 t).

The primary role of the USR is to serve as a threshold to progressive reduction of the fishing mortality rate to avoid stock status reaching the LRP (DFO 2021c). The USR for the Geoduck stock is defined as total coastwide current biomass being equal to 50% of total coastwide estimated unfished documented biomass (DFO 2021a). The value of the USR for the BC Geoduck stock in 2021 was estimated at 139,828 t (95% CB: 75,794 – 265,088 t). The total coastwide current biomass was estimated at 253,153 t in 2021, placing the stock in the Healthy Zone.

Although the LRP and USR are applied on a coastwide spatial scale and stock status is determined coastwide, the management of the fishery occurs at a smaller spatial scale to ensure the sustainability of the fishery.

The LRP recommended by Zhang and Hand (2007) may not meet the definition of LRP under the Precautionary Approach Framework (DFO 2009), i.e., “the point below which serious harm is occurring to the stock”. Because of the absence of Sea Otters from the BC coast for nearly a century, it is believed that Geoduck abundance at the beginning of the fishery may have been at a historical high. It is therefore possible that the point below which serious harm is occurring to the stock is actually lower than the LRP currently in use for the Geoduck stock. In the future, DFO intends to review the LRP for Geoduck to align more fully with the intent of the Precautionary Approach Framework (DFO 2009) as the point below which serious harm occurs to the stock.

An additional margin of safety for Geoduck conservation exists because portions of the Geoduck stock are sheltered from harvest. Not all documented Geoduck beds can be harvested, some are located in areas that fall under a variety of closure types (contamination closures, parks, research closures, management closures, etc.) or areas where water quality has not been classified by Environment and Climate Change Canada (known as unclassified waters). 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

Based on biomass estimated in 2021 for the 2022-2023 Geoduck harvesting season, the coastwide Geoduck stock index was 84% and 91%, for all documented sub-beds on the coast and for available sub-beds only, respectively; well above the 50% USR. Geoduck biomass on available sub-beds on the BC coast in 2021 was estimated at 178,000 t (95% CB: 97,901 – 311,068 t, Table 5). Total coastwide biomass for all documented sub-beds was estimated at 235,153 t (95% CB: 120,910 – 434,937 t, Table 5), well above the LRP of 111,862 t (95% CB: 60,635– 212,071 t) and the USR of 139,828 t (95% CB: 75,794 – 265,088 t). Therefore, the Geoduck stock is in the Healthy Zone.

For all available Geoduck sub-beds in BC, the sum of the lower 95% confidence bounds of annual harvest options was 1,677 t. The TAC for the BC commercial Geoduck fishery for the 2022-2023 fishing season was set at 1,272 t by fishery managers (DFO 2022); below the lower 95% confidence bound of harvest options.

The removal reference (maximum allowable harvest rate for the stock as a whole) for the BC Geoduck stock was defined as 1.8% of the coastwide current Geoduck biomass estimate (DFO 2020). Although regional annual harvest rates of 1.2 to 1.8% are used in estimating harvest options (Zhang and Hand 2007) for each Geoduck sub-bed, the actual harvest rate, defined as the TAC divided by biomass, for the BC Geoduck stock as a whole is lower. The actual Geoduck annual harvest rate for the 2022-2023 fishing season was estimated at 0.5% of the estimated median total documented biomass and 1.1% 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.

Contributors

Contributor	Affiliation
Dominique Bureau	DFO Science, Pacific Region
Erin Porszt	DFO Science, Pacific Region (Lead author)
Pauline Ridings	DFO Fisheries Management, Pacific Region
Erin Wylie	DFO Fisheries Management, Pacific Region

Approved by

Andrew Thomson
Regional Director
Science Branch, Pacific Region
Fisheries and Oceans Canada

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Centre for Science Advice (CSA)
Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

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