



STOCK STATUS UPDATE OF WILD GEODUCKS IN BRITISH COLUMBIA FOR 2022

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 2022, there were 2,947 documented Geoduck beds on the BC coast made up of 5,248 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).

DFO Fisheries Management Branch has requested that Science Branch provide yearly updates of the BC wild Geoduck biomass estimates, stock index and stock status, relative to DFO's Precautionary Approach (DFO 2009). The purpose of this Canadian Science Advisory Secretariat (CSAS) Science Response (SR) is to summarize 2022 updates to BC wild Geoduck biomass estimates provided to fishery managers for setting Geoduck quotas for the 2023-2024 fishing season and to provide updated stock index and stock status. This Science Response Report results from the Science Response Process of March 1, 2023 on the Stock status update of wild Geoducks in British Columbia for 2022.

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, estimated at approximately CAD \$49 million for the 2021-2022 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.

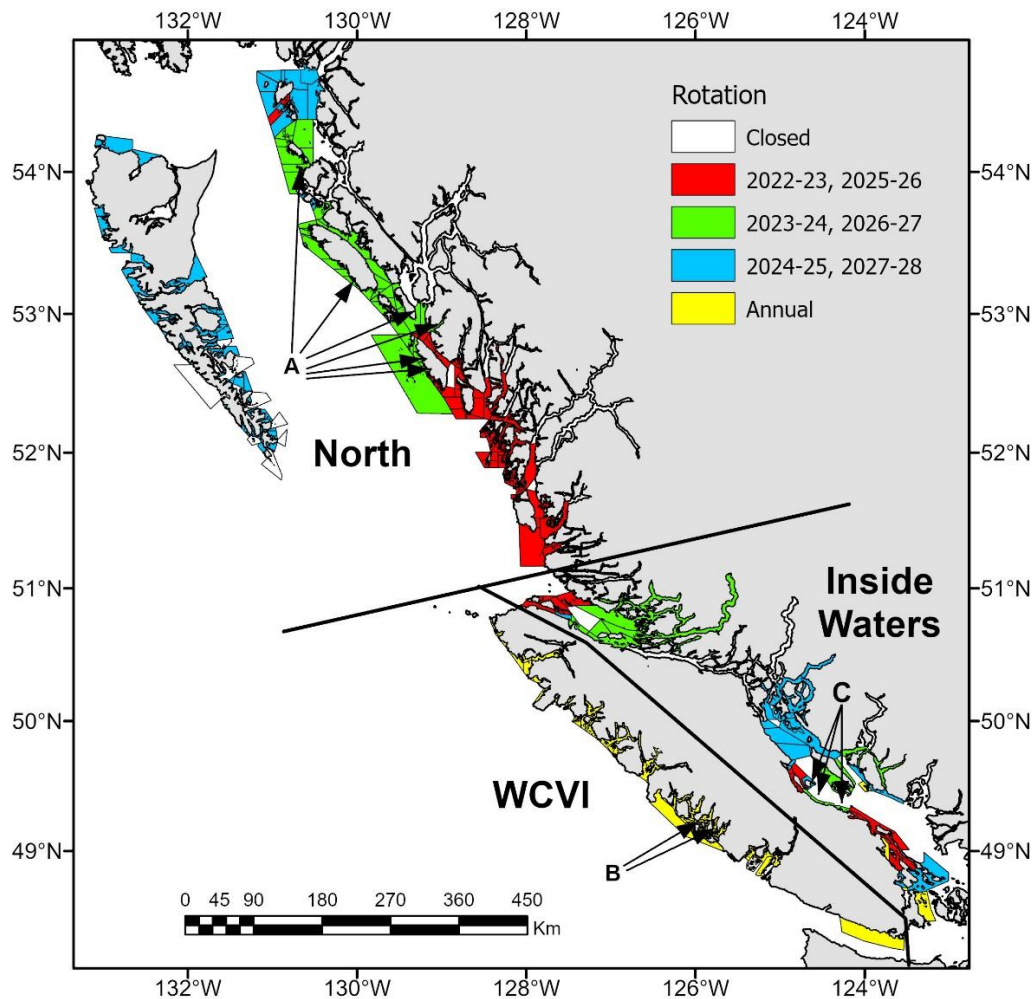


Figure 1: Map of British Columbia coast showing Geoduck “Quota Areas” (North, WCVI = West Coast of Vancouver Island, and Inside Waters, separated by solid lines) and “Rotational Areas” (different colors). Location of 2021 Geoduck density surveys indicated by letters: A = Campania Island, Clifford Bay, Edey Passage, Kettle Inlet, Oval Bay, South Banks Island, and Surf Inlet; North Coast, B = Epper Passage and Fortune Channel; WCVI, and C = Qualicum, Rath Trevor, and Tribune Bay; 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) and remains unchanged for the 2023-2024 season (DFO 2023). 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 ran from May 1, 2022 to April 15, 2023, and the 2023-2024 season will run from April 16, 2023 to March 31, 2024. The two seasons were reduced by two weeks to shift back the start date to April 1.

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). More recently, 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), and the USR for the BC Geoduck stock was defined as 50% of total coastwide estimated unfished documented biomass (DFO 2021a). Harvest options for portions of the coast under a three year rotation are three times the annual rate once every three years.

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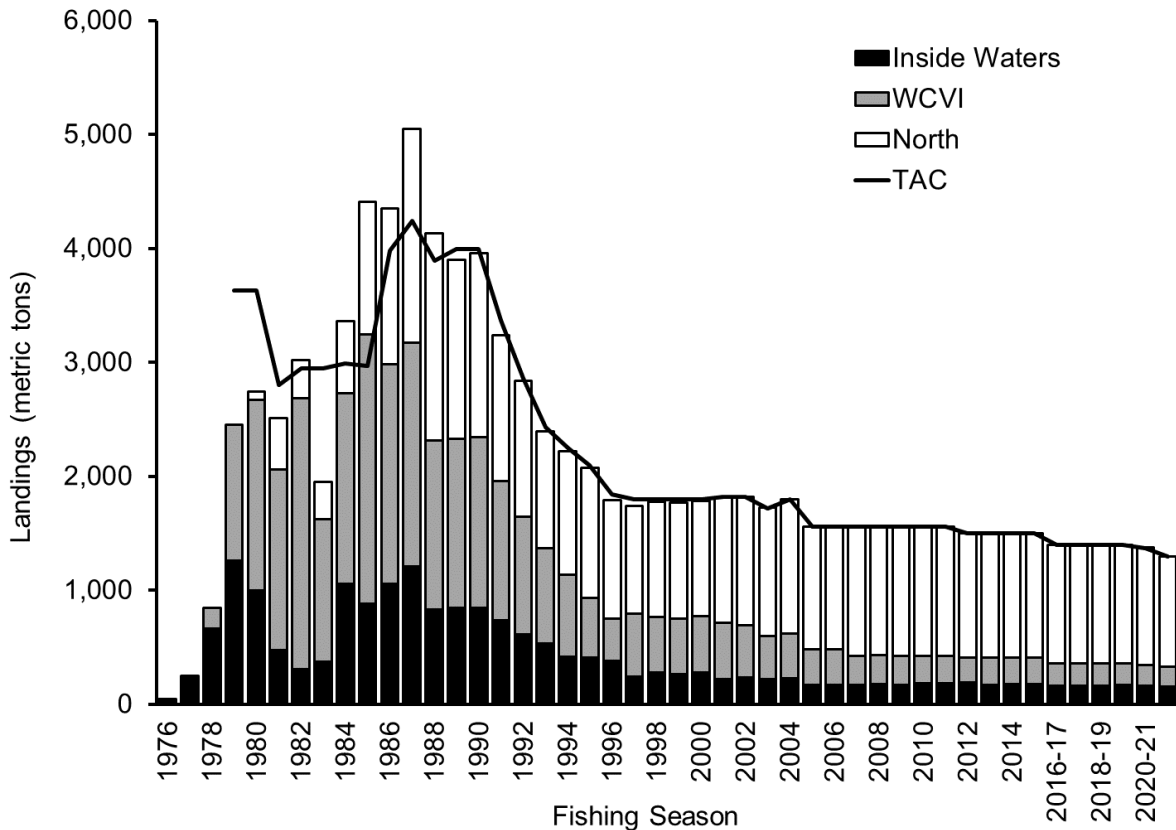


Figure 2: History of landings (metric tons) for the BC Geoduck fishery.

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 989 ha are surveyed annually and 821 ha were surveyed in 2021. 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 2022 stock status update incorporates new data from Geoduck fishery-independent density dive surveys conducted in 2021 as well as revisions to mean weight and bed area estimates based on the 2020-2021 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 22,379 ha, of which 15,522 ha are potentially available to harvest over three rotations (Table 1). Beds that were impacted by closures represented 3,488 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	448	0	1,851
102	10	10	0	0
3	190	5	0	185
4	681	6	0	675
5	791	37	28	727
6	1,288	23	46	1,219
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	710	109	95	505
13	746	148	0	598
14	3,757	22	0	3,735
15	1,421	532	0	889
16	731	59	0	672
17	691	173	0	518
18	138	6	0	132
19	585	75	0	510
28	30	30	0	0
29	164	6	0	158
20	299	0	0	299
23	1,260	863	0	397
24	2,275	565	539	1,171
124	14	0	0	14
25	1,039	3	1,033	3
26	608	195	389	24
27	679	0	679	0
Coastwide	22,379	3,488	3,368	15,522

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Density

In 2021, density dive surveys were conducted on a portion of the Geoduck beds in the following areas of the BC coast (Figure 1):

- Campania Island, Clifford Bay, Edey Passage, Kettle Inlet, Oval Bay, South Banks Island, and Surf Inlet; North Coast
- Epper Passage and Fortune Channel; WCVI
- Qualicum, Rathtrevor, and Tribune Bay; Inside Waters

The 2021 Geoduck density surveys covered 90 beds representing 821 ha of area. To date, 1,626 beds have been surveyed, representing 16,074 ha of bed area (72% of total) (Table 2). Of the surveyed beds, 537 have been surveyed more than once, representing 9,628 ha (43% of total). The average of current density estimates from all surveyed beds was 1.97 Geoducks/m² (Table 2). Average density was higher in the North Coast than in the South Coast (Inside Waters and WCVI) (Table 2). 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	1.61	(0.00-5.25)	1,979
Prince Rupert	465	2.64	(0.14-11.09)	2,385
Central Coast	529	2.23	(0.09-12.04)	1,671
North - All	1327	2.22	(0.00-12.04)	6,035
Area 12	45	1.02	(0.09-2.69)	482
Strait of Georgia	95	0.30	(0.04-1.67)	6,024
Inside Waters - All	140	0.53	(0.04-2.69)	6,506
Area 24	44	1.17	(0.05-3.65)	2,058
Area 23	42	0.82	(0.24-1.78)	367
Area 23 Closures	49	1.75	(0.35-4.06)	447
Rest of WCVI	24	0.41	(0.00-1.28)	661
WCVI - All	159	1.14	(0.00-4.06)	3,533
Coastwide	1626	1.97	(0.00-12.04)	16,074

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	583	35.9	35.9	10,491	65.3	65.3
1 to <2	440	27.1	62.9	2,927	18.2	83.5
2 to <3	275	16.9	79.8	1,101	6.8	90.3
3 to <4	142	8.7	88.6	725	4.5	94.8
4 to <6	126	7.7	96.3	602	3.7	98.6
6 to <8	31	1.9	98.2	165	1.0	99.6
≥8	29	1.8	100.0	63	0.4	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=971), 1.13 kg in the North Coast (n=719), 0.99 kg on the WCVI (n=130) and 1.10 kg in the Inside Waters (n=122). Mean weight estimates ranged from 0.57 to 1.83 kg. Mean Geoduck weight was between 1.0 and 1.5 kg for 73% of the beds while 25% 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	246	25.3	25.3	3,752	22.5	22.5
1.0 to <1.5	709	73.0	98.4	12,784	76.6	99.1
1.5 to <2.0	16	1.6	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 Geoducks younger than 5 years.

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 180,666 t (95% confidence limits (CL): 99,596 – 312,594 t, Table 5). The Geoduck stock biomass for all documented sub-beds coastwide was estimated at 237,921 t (95% CL: 122,595 – 437,040 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% CLs are low and high 95% confidence limits.

PFMA	Available		Otters Median	Closures Median	Total	
	Median	95% CLs			Median	95% CLs
1	1,151	295 – 3,531	0	49	1,200	301 – 3,724
2	32,093	16,766 – 55,778	0	7,256	39,349	19,713 – 70,644
102	0	–	0	130	130	17 – 518
3	3,475	1,646 – 6,207	0	15	3,489	1,653 – 6,233
4	24,038	14,179 – 37,764	0	107	24,145	14,223 – 38,000
5	22,528	14,191 – 33,869	476	281	23,284	14,664 – 35,126
6	32,924	16,720 – 56,338	830	309	34,062	17,165 – 58,548
106	4,867	3,213 – 7,744	0	2	4,869	3,214 – 7,747
7	13,366	5,672 – 27,684	11,791	881	26,038	11,194 – 54,529
8	4,030	1,888 – 7,455	0	0	4,030	1,888 – 7,455
9	944	348 – 2,899	115	0	1,059	368 – 3,338
10	1,020	391 – 2,059	128	4	1,152	422 – 2,647
11	0	–	0	229	229	24 – 617
111	0	–	0	151	151	0 – 625
12	4,749	2,191 – 8,728	1,357	950	7,056	3,225 – 13,957
13	1,009	597 – 1,952	0	278	1,288	747 – 2,778
14	6,324	4,504 – 8,943	0	64	6,388	4,543 – 9,100
15	1,385	494 – 4,758	0	746	2,130	784 – 7,541
16	2,489	1,532 – 4,879	0	142	2,632	1,617 – 5,199
17	1,350	740 – 3,372	0	358	1,708	822 – 5,473
18	803	519 – 1,350	0	8	811	521 – 1,387
19	893	224 – 4,624	0	174	1,067	260 – 5,754
28	0	–	0	52	52	11 – 334
29	352	153 – 1,117	0	10	362	155 – 1,176
20	744	0 – 2,842	0	0	744	0 – 2,842
23	3,455	1,819 – 5,462	0	17,036	20,492	8,680 – 35,047
24	16,330	11,419 – 22,424	3,841	1,894	22,065	14,887 – 31,379
124	189	10 - 546	0	0	189	10 – 546
25	38	14 – 57	3,223	7	3,268	312 – 11,600
26	121	73 – 212	1,812	603	2,535	910 – 6,689
27	0	–	1,948	0	1,948	269 – 6,485
Coastwide	180,666	99,596 – 312,594	25,521	31,734	237,921	122,595 – 437,040

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 92%.

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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 2022 was estimated at 112,866 t (95% CL: 61,365– 213,174 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 2022 was estimated at 141,082 t (95% CL: 76,706 – 266,467 t). The total coastwide current biomass was estimated at 237,921 t in 2022, 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. Fisheries management operational control points, previously known as harvest control rules, are applied at smaller spatial scales.

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 would occur 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 2022 for the 2023-2024 Geoduck harvesting season, the coastwide Geoduck stock index was 84% and 92%, 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 2022 was estimated at 180,666 t (95% CL: 99,596 – 312,594 t, Table 5). Total coastwide biomass for all documented sub-beds was estimated at 237,921 t (95% CL: 122,595 – 437,040 t, Table 5), well above the LRP of 112,866 t (95% CL: 61,365– 213,174 t) and the USR of 141,082 t (95% CL: 76,706 – 266,467 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 limits of annual harvest options was 1,701 t. The TAC for the BC commercial Geoduck fishery for the 2023-

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2024 fishing season was set at 1,272 t by fishery managers (DFO 2023); below the lower 95% confidence limit 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 2023-2024 fishing season will be 0.5% of the estimated median total documented biomass and 1.0% of the estimated lower 95% confidence limit of total documented biomass (i.e. biomass on all documented sub-beds); well below the 1.8% removal reference.

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