



STOCK STATUS UPDATE OF WILD GEODUCKS IN BRITISH COLUMBIA FOR 2023

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, and based on current knowledge, Geoduck populations form a single genetic stock along the BC coast (Miller et al. 2006; Suárez-Moo et al. 2016).

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 2023, there were 2,951 documented Geoduck beds on the BC coast made up of 5,252 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, in line with DFO's Precautionary Approach (DFO 2009). The purpose of this Canadian Science Advisory Secretariat (CSAS) Science Response (SR) is to summarize 2023 updates to BC wild Geoduck biomass estimates provided to fishery managers for setting Geoduck quotas for the 2024-2025 fishing season and to provide updated stock index and stock status. This Science Response Report results from the regional peer review of February 2, 2024 on the Stock Status Update of Wild Geoducks in British Columbia for 2023.

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 \$56 million for the 2022-2023 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 2024). 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.

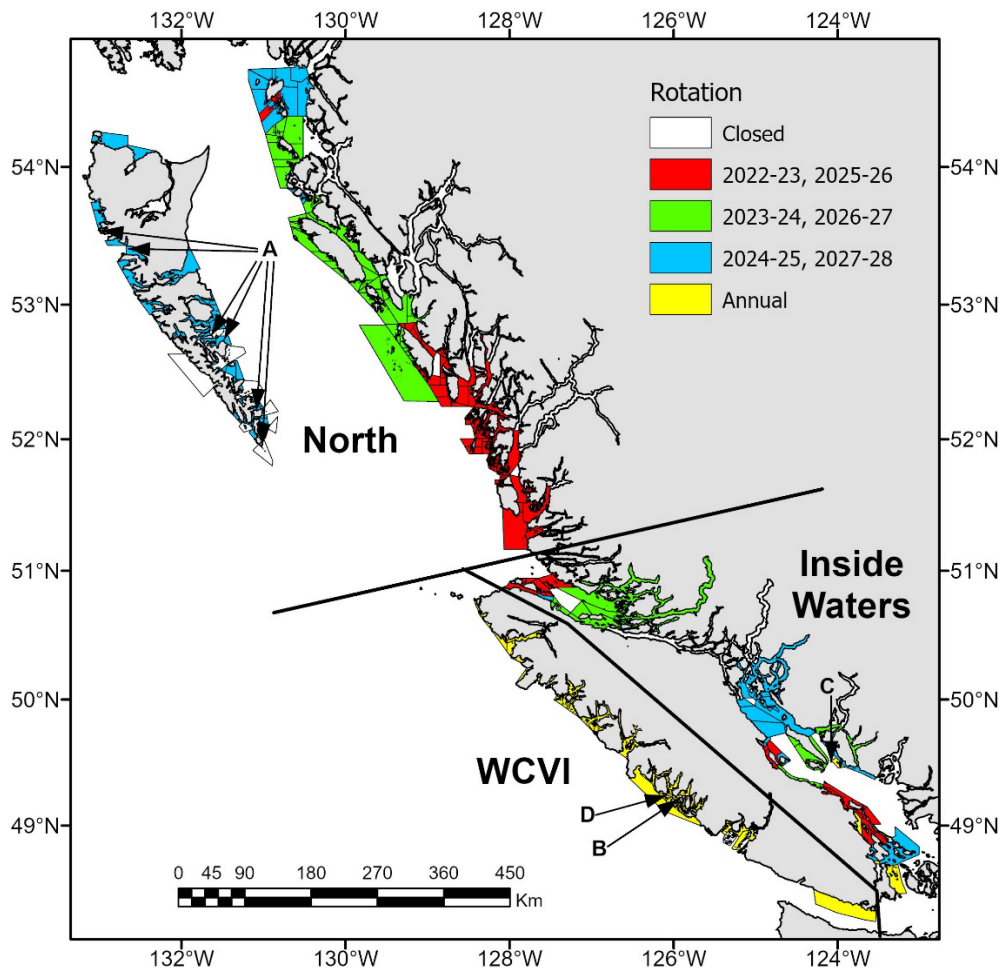


Figure 1. Map of British Columbia coast showing Geoduck “Quota Areas” (North, WCVI = West Coast of Vancouver Island, and Inside Waters, separated by solid lines) and “Rotational Areas” (different colours). Location of 2022 Geoduck density surveys indicated by letters: A = Carpenter Bay, Dodge Point, Tanu, Hippa Island, Rennell Sound, and Kunghit Island; North Coast, B = Father Charles, Dunlap and Yellow Bank; WCVI, and C = Thormanby Island to East Texada Island; Inside Waters. Location of 2023 Geoduck density survey in Russell Channel; WCVI, indicated by letter D.

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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 remained unchanged for the 2023-2024 and 2024-2025 seasons (DFO 2024). There has been 100% dockside 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 1, 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 and 2023-2024 seasons ran from May 1, 2022 to April 15, 2023, and from April 16, 2023 to March 31, 2024, respectively. The two seasons were reduced by two weeks to shift back the start date to April 1. The 2024-2025 season will run from April 1, 2024 to March 31, 2025.

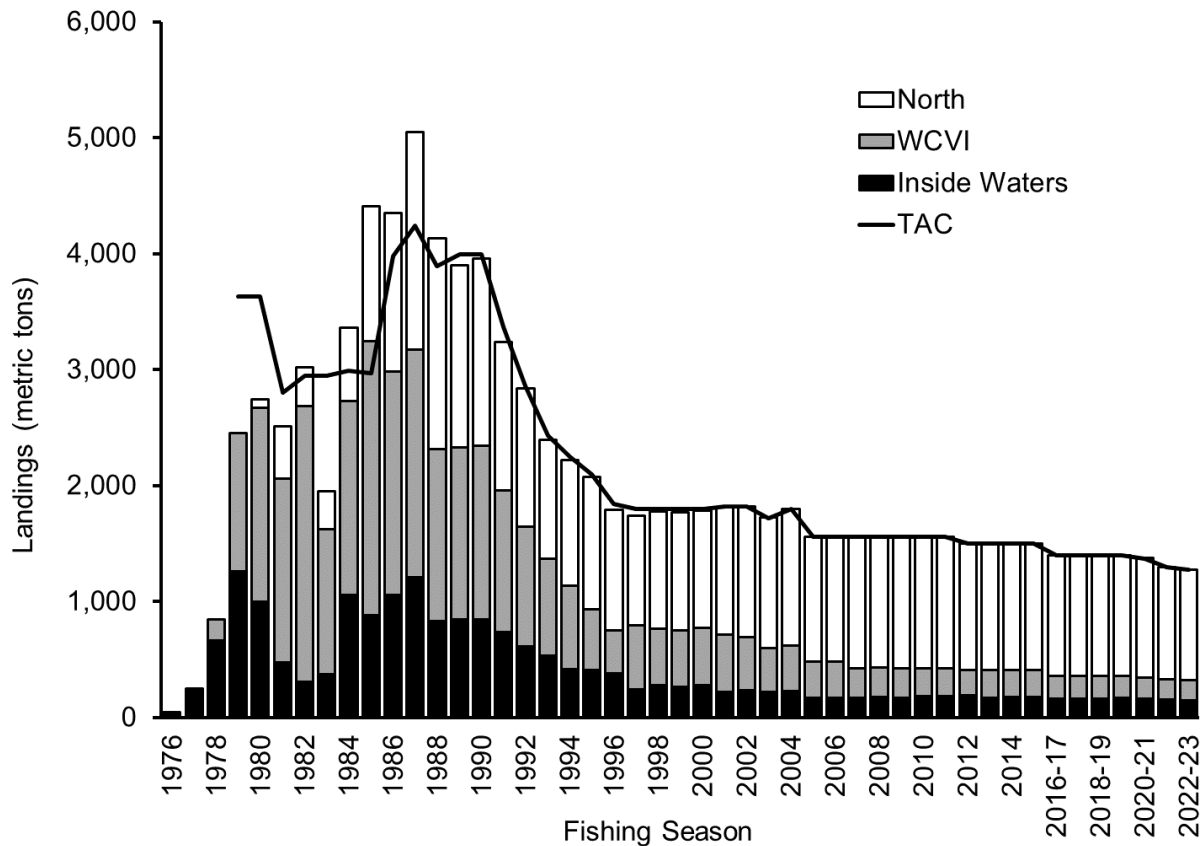


Figure 2. History of landings (metric tons) for the BC Geoduck fishery.

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 979 ha are surveyed annually and 624 ha were surveyed in 2022. 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 2023 stock status update incorporates new data from Geoduck fishery-independent density dive surveys conducted in 2022 as well as revisions to mean weight and bed area estimates based on the 2021-2022 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 the fishing season before the latest season (latest season data are not available when biomass estimates are updated) 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 22,404 ha, of which 15,809 ha are potentially available to harvest over three rotations (Table 1). Beds that were impacted by closures represented 3,228 ha (14%) 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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Density

In 2022, density dive surveys were conducted on a portion of the Geoduck beds in the following areas of the BC coast (Figure 1):

- Carpenter Bay, Dodge Point, Tanu, Hippa Island, Rennell Sound, and Kunghit Island; North Coast
- Father Charles, Dunlap and Yellow Bank; WCVI
- Thormanby Island to East Texada Island; Inside Waters
- Density data from a 2023 survey conducted in Russell Channel; WCVI, were used in the 2023 update to Geoduck biomass estimates. Their use was an exception and typically the data from density dive surveys from the previous year are used in the yearly updates to biomass estimates.

The 2022 Geoduck density surveys covered 70 beds representing 624 ha of area, and the 2023 Russell Channel survey covered one bed representing 252 ha of area. To date, 1,647 beds have been surveyed, representing 16,158 ha of bed area (72% of total) (Table 2). Of the surveyed beds, 576 have been surveyed more than once, representing 10,100 ha (45% 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).

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 1.11 kg coastwide (n=978), 1.13 kg in the North Coast (n=726), 0.99 kg on the WCVI (n=130) and 1.10 kg in the Inside Waters (n=122) (Table 2). Mean weight estimates ranged from 0.57 to 1.83 kg. Mean Geoduck weight was between 1.0 and 1.5 kg for 74% of the beds while 25% of beds had a mean weight between 0.5 and 1.0 kg (Table 4).

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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	2,285	448	0	1,836
102	10	10	0	0
3	193	5	0	188
4	685	6	0	679
5	791	37	28	727
6	1,288	23	46	1,219
106	95	1	0	94
7	1,247	104	538	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	749	148	0	600
14	3,761	22	0	3,739
15	1,427	532	0	894
16	726	59	0	667
17	693	173	0	521
18	138	6	0	132
19	587	75	0	512
28	30	30	0	0
29	164	6	0	158
20	299	0	0	299
23	1,263	863	0	400
24	2,291	299	540	1,452
124	14	0	0	14
25	1,039	3	1,033	3
26	612	198	390	24
27	679	0	679	0
Coastwide	22,404	3,228	3,368	15,809

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Table 2. Current Geoduck density (mean and range) on surveyed beds, number of beds and bed area surveyed, by region. Geoduck mean weight by region, from commercial harvest data for beds where bed-specific mean weight data are available. Haida Gwaii = PFMA 1 and 2; Prince Rupert = PFMA 3 to 6, and 106; Central Coast = PFMA 6 to 10; and Strait of Georgia = PFMA 13 to 19, 28 and 29. Central Coast's northern boundary is the north end of Aristazabal Is. and Prince Rupert region begins at Moore Islands.

Region	Number of Surveyed Beds	Density (Geoducks/m ²)		Bed Area Surveyed (ha)	Mean Geoduck Weight (kg)
		Mean	Range		
Haida Gwaii	349	1.67	(0.00–5.25)	1,992	1.23
Prince Rupert	465	2.63	(0.14–11.09)	2,391	1.12
Central Coast	529	2.20	(0.09–12.04)	1,671	1.06
North - All	1,343	2.21	(0.00–12.04)	6,054	1.13
Area 12	45	1.01	(0.09–2.69)	483	1.17
Strait of Georgia	96	0.30	(0.04–1.6)	6,043	1.08
Inside Waters - All	141	0.53	(0.04–2.69)	6,526	1.10
Area 24	48	1.30	(0.05–6.28)	2,098	1.06
Area 23	42	0.82	(0.24–1.77)	367	1.01
Area 23 Closures	49	1.75	(0.35–4.06)	447	1.10
Rest of WCVI	24	0.41	(0.00–1.28)	666	0.93
WCVI - All	163	1.18	(0.00–6.28)	3,578	0.99
Coastwide	1,647	1.97	(0.00–12.04)	16,158	1.11

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	578	35.1	35.1	10,429	64.5	64.5
1 to <2	465	28.2	63.3	3,081	19.1	83.6
2 to <3	273	16.6	79.9	1,064	6.6	90.2
3 to <4	145	8.8	88.7	767	4.7	94.9
4 to <6	127	7.7	96.4	578	3.6	98.5
6 to <8	33	2.0	98.4	183	1.1	99.6
≥8	26	1.6	100.0	58	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 [from commercial harvest] 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	241	24.6	24.6	3,713	22.2	22.2
1.0 to <1.5	722	73.7	98.4	12,872	77.0	99.2
1.5 to <2.0	16	1.6	100.0	132	0.8	100.0
≥2.0	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. Geoducks are one of a wide variety of invertebrates preyed upon by Sea Otters, however the impact of this predation is difficult to quantify because dietary specialization of Sea Otters develops based on occupation time, sex and reproductive status, and habitat type (Rechsteiner et al. 2019).

The Geoduck stock biomass for all available sub-beds in BC was estimated at 184,210 t (95% confidence limits (CL): 102,214–315,738 t, Table 5). The Geoduck stock biomass for all documented sub-beds coastwide was estimated at 241,156 t (95% CL: 124,820–439,061 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.

Harvest Options

Since 2007, harvest options have been based on estimates of current biomass (B_c) and regional annual exploitation rates of 1.2–1.8% (Zhang and Hand 2006, 2007). Harvest options are calculated for each individual sub-bed by applying the regional exploitation rate to estimates of current biomass (Bureau et al. 2012). Harvest options for portions of the coast under a three year rotation are three times the annual rate once every three years.

For all available Geoduck sub-beds in BC, the sum of the lower 95% confidence limits of annual harvest options was 1,739 t.

Stock Index, Stock Status and Removal Reference

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 (Bureau 2017; DFO 2017). The coastwide stock index is re-estimated yearly when biomass estimates are updated. The value of total coastwide unfished biomass was estimated at 284,173 t (95% CL: 155,287–535,079 t). The value of coastwide unfished biomass within available beds was estimated at 200,223 t (95% CL: 117,333–352,872 t).

The stock index based on total documented coastwide Geoduck biomass was estimated at 85% (for all beds). The stock index of Geoduck biomass within available beds was estimated at 92%.

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 2023 was estimated at 113,669 t (95% CL: 62,115–214,031 t).

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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, reported to be impacted by Sea Otter predation by harvesters, 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	1,206	298–3,511	0	54	1,259	304–3,698
2	33,941	18,367–57,458	0	7,506	41,447	21,497–72,038
102	0	-	0	144	144	18–502
3	3,576	1,696–6,363	0	15	3,591	1,702–6,390
4	24,135	14,244–37,788	0	107	24,241	14,287–38,024
5	22,492	14,161–33,817	476	281	23,249	14,633–35,074
6	32,659	16,448–56,029	797	308	33,765	16,860–58,207
106	4,815	3,160–7,686	0	2	4,817	3,161–7,690
7	13,191	5,492–27,412	11,647	892	25,731	10,887–53,972
8	3,944	1,800–7,353	0	0	3,944	1,800–7,353
9	944	342–2,866	115	0	1,060	362–3,302
10	1,019	389–2,055	132	4	1,154	420–2,633
11	0	-	0	228	228	25–620
111	0	-	0	151	151	0–627
12	4,716	2,169–8,694	1,340	934	6,990	3,187–13,892
13	1,017	602–1,951	0	280	1,297	753–2,774
14	6,281	4,460–8,874	0	65	6,346	4,499–9,030
15	1,377	502–4,675	0	753	2,130	797–7,409
16	2,564	1,633–4,747	0	150	2,714	1,721–5,075
17	1,349	739–3,355	0	455	1,804	831–5,677
18	814	520–1,369	0	8	823	523–1,406
19	925	235–4,425	0	176	1,101	273–5,549
28	0	-	0	52	52	11–330
29	350	150–1,082	0	10	360	152–1,140
20	744	0–2,842	0	0	744	0–2,842
23	3,510	1,832–5,552	0	17,164	20,674	8,739–35,368
24	18,278	12,879–24,901	3,816	1,247	23,340	15,851–32,932
124	204	10–659	0	0	204	10–659
25	38	14–57	3,221	7	3,266	312–11,600
26	123	74–214	1,831	630	2,584	938–6,766
27	0	-	1,948	0	1,948	269–6,485
Coastwide	184,210	102,214–315,738	25,324	31,622	241,156	124,820–439,061

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 2023 was estimated at 142,086 t (95% CL: 77,643–267,539 t). The total coastwide current biomass was estimated at 241,156 t in 2023, placing the stock in the Healthy Zone, as defined by DFO’s Precautionary Approach Framework (DFO 2009).

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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.

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 (see Conclusions).

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 is unclassified or classified as prohibited or restricted by Environment and Climate Change Canada. 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 2023 for the 2024-2025 Geoduck harvesting season, the coastwide Geoduck stock index was 85% 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 2023 was estimated at 184,210 t (95% CL: 102,214–315,738 t, Table 5). Total coastwide biomass for all documented sub-beds was estimated at 241,156 t (95% CL: 124,820–439,061 t, Table 5), well above the LRP of at 113,669 t and the USR of 142,086 t. Therefore, the Geoduck stock is in the Healthy Zone.

The TAC for the BC commercial Geoduck fishery for the 2024-2025 fishing season was set at 1,272 t by fishery managers (DFO 2024); which is below the sum of the lower 95% confidence limit of harvest options for all available Geoduck sub-beds in BC (1,739 t).

The actual Geoduck annual harvest rate, defined as the TAC divided by biomass, for the 2024-2025 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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April 30, 2024

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This Report is Available from the:

Centre for Science Advice (CSA)
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Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-3769

ISBN 978-0-660-71904-7 Cat. No. Fs70-7/2024-027E-PDF

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Department of Fisheries and Oceans, 2024



Correct Citation for this Publication:

DFO. 2024. Stock Status Update of Wild Geoducks in British Columbia for 2023. DFO Can. Sci. Advis. Sec. Sci. Resp. 2024/027.

Aussi disponible en français :

MPO. 2024. Mise à jour de 2023 sur l'état des stocks de panopes sauvages en Colombie-Britannique. Secr. can. des avis sci. du MPO. Rép. des Sci. 2024/027.