



# STOCK STATUS UPDATE OF WILD GEODUCKS IN BRITISH COLUMBIA FOR 2024

## CONTEXT

DFO Fisheries Management Branch has requested that Science Branch provide yearly updates of the BC wild Geoduck ([Geoduck and horse clam 2025/2026 Integrated Fisheries Management Plan](#)) 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 2024 updates to BC wild Geoduck biomass estimates provided to fishery managers for setting Geoduck quotas for the 2025-2026 fishing season and to provide updated stock index and stock status. This Science Response Report is from the regional peer review of March 4, 2025 on the 2024 Stock Status of British Columbia Wild Geoducks.

## SCIENCE ADVICE

### Status

- Mean Geoduck biomass on available sub-beds (i.e., not impacted by closures and not reported to be impacted by Sea Otters) on the BC coast in 2024 was estimated at 184,693 t (95% CL: 102,741–317,243 t). Mean total coastwide biomass for all documented sub-beds was estimated at 241,430 t (95% CL: 125,191–440,904 t).
- Mean total coastwide Geoduck biomass is above the Limit Reference Point (LRP) of 113,872 t and the Upper Stock Reference (USR) of 142,340 t. Therefore, the Geoduck stock is in the Healthy Zone.
- Based on biomass estimated in 2024 for the 2025-2026 Geoduck harvesting season, the coastwide Geoduck stock index (i.e., ratio of current biomass to pre-fishery biomass) was 85% for all documented sub-beds on the coast; above the 50% USR. The actual Geoduck annual harvest rate, defined as the Total Allowable Catch (TAC) divided by current coastwide biomass, for the 2025-2026 fishing season is estimated to be 0.5% of the estimated mean total documented biomass (i.e. biomass on all documented sub-beds) and 1.0% of the estimated lower 95% confidence limit of total documented biomass; below the 1.8% removal reference.

### Trends

- Biomass trend data are only available since 2018 due to changes to biomass estimation methods over time.
- Biomass has been stable since the 2018 assessment.

## Ecosystem and Climate Change Considerations

- Sea Otter predation on Geoducks has led to decreased quotas and/or reductions in the area fished in some portions of the BC coast (i.e., portions of the Central Coast and West Coast of Vancouver Island).
- Continued expansions of Sea Otter range and abundance along the BC coast (Nichol et al. 2020) is likely to lead to further declines in Geoduck biomass and reduction in quotas in the future.

## Stock Advice

- The recommended regional harvest rates of 1.2 to 1.8% used in the estimation of harvest options, were selected with the management objective of keeping biomass over 50% of pre-fishery biomass over 50 years (Zhang and Hand 2007).

# BASIS FOR ASSESSMENT

## Assessment Details

### Year Assessment Approach was Approved

2012 (Bureau et al. 2012) revised in 2014 (DFO 2014) and 2017 (Bureau 2017, DFO 2017).

### Assessment Type

Full Assessment

### Most Recent Assessment Date

1. Last Full Assessment: 2023. (DFO 2024)

### Assessment Approach

1. Broad category: Index-based (trends in empirical indices only), single stock assessment model. Other: harvest rates derived from age-structured projection modeling, applied to yearly biomass estimates.
2. Specific category: Index-based (including fishery-dependent and fishery-independent indices).

Geoduck stock biomass is estimated following the methods presented in the Geoduck stock assessment framework (Bureau et al. 2012) and later modifications (DFO 2014; Bureau 2017; DFO 2017). Geoduck biomass is estimated annually on a by-Geoduck-sub-bed basis as the product of Geoduck density, mean weight, and sub-bed area, incorporating the latest available data (see Data section). This 2024 stock status update incorporates new data from Geoduck fishery-independent density dive surveys conducted in 2023 as well as revisions to mean weight and bed area estimates based on the 2022-2023 fishing season harvest events (fishery-dependent data). Regional annual harvest rates of 1.2-1.8% are applied to biomass estimates (Zhang and Hand 2006, 2007) to yield harvest options.

Estimates of Geoduck habitat are one of the principal inputs to the biomass estimation process. Each year, harvest events from the fishing season before the latest season are reviewed to refine bed areas (Bureau et al. 2012). Any new beds discovered or revisions 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.

Geoduck beds in some areas are not harvested due to the impact of Sea Otter 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, based on feedback from harvesters.

### Stock Structure Assumption

Stock overview information: The biology of Pacific Geoduck (*Panopea generosa*) was outlined in Bureau et al. (2012) and DFO (2025). The stock is assessed following methods described in the stock assessment framework (Bureau et al. 2012), and later modifications (DFO 2014; Bureau 2017; DFO 2017). Details of current management measures for the commercial dive fishery are provided in the Geoduck and Horse Clam Integrated Fisheries Management Plan (DFO 2025).

Pacific Geoduck 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). Therefore, the LRP and USR are applied on a coastwide spatial scale and stock status is determined coastwide. Pacific Geoduck has been proposed as a Batch 2 stock for listing under the Fish Stock Provisions of Bill C-68.

Biomass estimation and management of the fishery are conducted on the spatial scale of individual Geoduck sub-beds. Fisheries management operational control points, previously known as harvest control rules, are applied at the individual sub-bed level, to ensure the sustainability of the fishery.

In 2024, there were 2,953 documented Geoduck beds on the BC coast made up of 5,249 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).

### Reference Points

- Limit Reference Point (LRP): The LRP for BC Geoducks 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; Zhang and Hand 2007). The LRP for the BC Geoduck stock in 2024 was estimated at 113,872 t.
- Upper Stock Reference (USR): The 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 value of the USR for the BC Geoduck stock in 2024 was estimated at 142,340 t.
- Removal Reference (RR): 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).
- Target Reference Point (TRP): No TRPs developed for this stock.

### Data

The three inputs to biomass estimation for Geoducks are bed area, density and mean weight and are updated annually for some beds. Estimation methods for these parameters are provided in Bureau et al. (2012) and DFO (2014).

**Bed Area (Ha)**

The area of each bed is estimated in GIS based on locations of fishing events, dive survey data, and hydro-acoustic bed mapping data. The total area of documented Geoduck beds in BC, in 2024, was estimated to be 22,387 ha (Table 1). Available bed area refers to beds not impacted by closures and not reported to be impacted by Sea Otters.

**Density (Geoducks/m<sup>2</sup>)**

Geoduck density is estimated from fishery-independent dive surveys. Mean density for each surveyed bed is estimated and confidence limits are estimated using bootstrapping methods (Bureau et al. 2012).

The Geoduck dive survey program started in 1992. Since then, 218 surveys have been conducted covering 72% of the total coastwide documented bed area (Tables 2 and 3). Forty-six percent of the coastwide bed area has been surveyed more than once. Eighty-one percent of available bed area has been surveyed and 53% has been surveyed more than once.

The 2023 Geoduck density dive surveys (Figure 1) covered 112 beds representing 661 ha of area.

**Mean Weight (kg)**

Geoduck mean weights are estimated from commercial fishery landings data from 1997 onwards (i.e., landed weight and number of Geoducks, on a by-bed basis). 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.

For beds where bed-specific estimates of mean weight are available, mean weight estimates ranged from 0.57 to 1.83 kg (Tables 2 and 4).

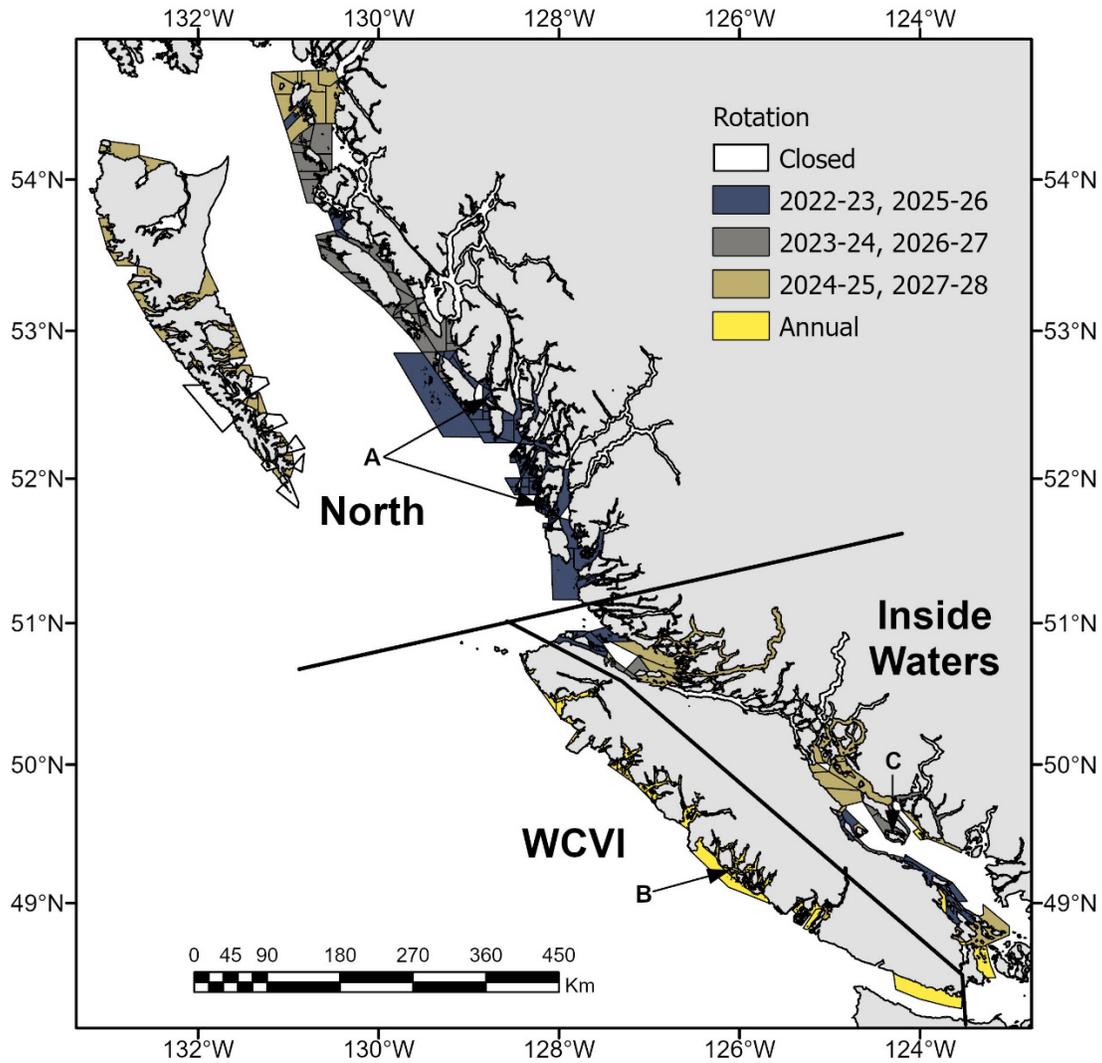


Figure 1. Map of British Columbia coast showing Geoduck “Quota Areas” (North, WCVI = West Coast of Vancouver Island, and Inside Waters, separated by solid lines) and “Rotational Areas” (different colours). Note that rotational areas are subject to change. Location of 2023 Geoduck density surveys indicated by letters: A = Spider Anchorage and Laredo Inlet to West Higgins Passage; Central Coast, B = Russell Channel; WCVI, and C = Lasqueti Island; Inside Waters.

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 reported to be impacted by Sea Otter predation (and may or may not be closed). "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	688	6	0	682
5	791	37	28	727
6	1,264	41	45	1,179
106	95	1	0	94
7	1,242	66	535	641
8	156	0	0	156
9	104	0	7	97
10	108	1	13	94
11	21	21	0	0
111	43	43	0	0
12	712	109	96	506
13	749	148	0	600
14	3,762	22	0	3,740
15	1,427	566	0	860
16	714	58	0	655
17	699	168	0	531
18	138	6	0	132
19	587	75	0	512
28	30	30	0	0
29	165	6	0	159
20	299	0	0	299
23	1,265	863	0	402
24	2,298	299	541	1,458
124	14	0	0	14
25	1,039	3	1,033	3
26	612	198	390	24
27	679	0	679	0
Coastwide	22,387	3,237	3,366	15,783

Table 2. Current Geoduck density (mean by bed, range, and mean weighted by bed area) on surveyed beds, number of beds and bed area surveyed, by Pacific Fishery Management Area (PFMA) from fishery-independent dive surveys. Geoduck mean weight by PFMA, from commercial harvest data for beds where bed-specific mean weight data are available. 23 is open portions of PFMA 23 and 23 CL is Area 23 Closures (i.e., beds in the Pacific Rim National Park Reserve and Bamfield Marine Sciences Centre closures).

PFMA	Number of Surveyed Beds	Density (Geoducks/m <sup>2</sup> )			Bed Area Surveyed (ha)	Mean Geoduck Weight (kg)
		Mean by bed	Range	Mean weighted by bed area		
1	3	0.28	(0.23-0.36)	0.28	100	1.15
2	346	1.69	(0.0-5.25)	1.52	1,892	1.23
102	-	-	-	-	-	-
3	21	1.44	(0.24-4.2)	1.74	173	1.07
4	139	3.21	(0.44-11.09)	3.24	617	1.15
5	129	2.01	(0.24-6.18)	2.75	734	1.11
6	271	2.53	(0.23-12.04)	2.43	1,192	1.08
106	13	4.00	(0.14-8.38)	4.83	85	1.12
7	363	2.28	(0.09-10.42)	2.00	977	1.07
8	27	2.64	(0.66-6.37)	2.31	133	1.12
9	20	0.55	(0.25-0.91)	0.68	61	1.08
10	40	0.99	(0.12-2.32)	1.17	94	0.92
11	-	-	-	-	-	-
111	-	-	-	-	-	-
12	45	1.01	(0.09-2.69)	0.77	484	1.18
13	23	0.13	(0.04-0.33)	0.15	640	1.07
14	27	0.20	(0.04-0.57)	0.15	3,677	1.19
15	11	0.16	(0.04-0.48)	0.12	752	1.00
16	29	0.58	(0.15-1.43)	0.48	553	1.01
17	12	0.53	(0.09-1.6)	0.27	349	1.04
18	3	1.15	(0.84-1.34)	0.89	78	1.05
19	-	-	-	-	-	1.29
28	-	-	-	-	-	-
29	3	0.62	(0.45-0.85)	0.53	31	0.93
20	-	-	-	-	-	-
23	42	0.82	(0.24-1.77)	0.79	369	1.02
23 CL	49	1.75	(0.35-4.06)	1.84	447	1.10
24	48	1.30	(0.05-6.28)	0.98	2,105	1.06

PFMA	Number of Surveyed Beds	Density (Geoducks/m <sup>2</sup> )			Bed Area Surveyed (ha)	Mean Geoduck Weight (kg)
		Mean by bed	Range	Mean weighted by bed area		
124	-	-	-	-	-	-
25	8	0.48	(0.0-1.28)	0.23	253	0.91
26	6	0.50	(0.31-0.94)	0.82	210	0.92
27	10	0.30	(0.04-0.65)	0.25	202	0.98
<b>Coastwide</b>	<b>1,688</b>	<b>1.95</b>	<b>(0.00-12.04)</b>	<b>1.11</b>	<b>16,207</b>	<b>1.11</b>

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

Mean Current Density Geoducks/m <sup>2</sup>	Surveyed Beds			Bed Area		
	Number	%	Cumulative % Number	Hectares	%	Cumulative % Area
0 to <1	604	35.8	35.8	10,440	64.4	64.4
1 to <2	478	28.3	64.1	3,098	19.1	83.5
2 to <3	274	16.2	80.3	1,109	6.8	90.4
3 to <4	141	8.4	88.7	736	4.5	94.9
4 to <6	132	7.8	96.5	584	3.6	98.5
6 to <8	33	2.0	98.5	183	1.1	99.6
≥8	26	1.5	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	244	24.3	24.3	3,711	22.1	22.1
1.0 to <1.5	745	74.1	98.4	12,924	77.1	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

### ASSESSMENT

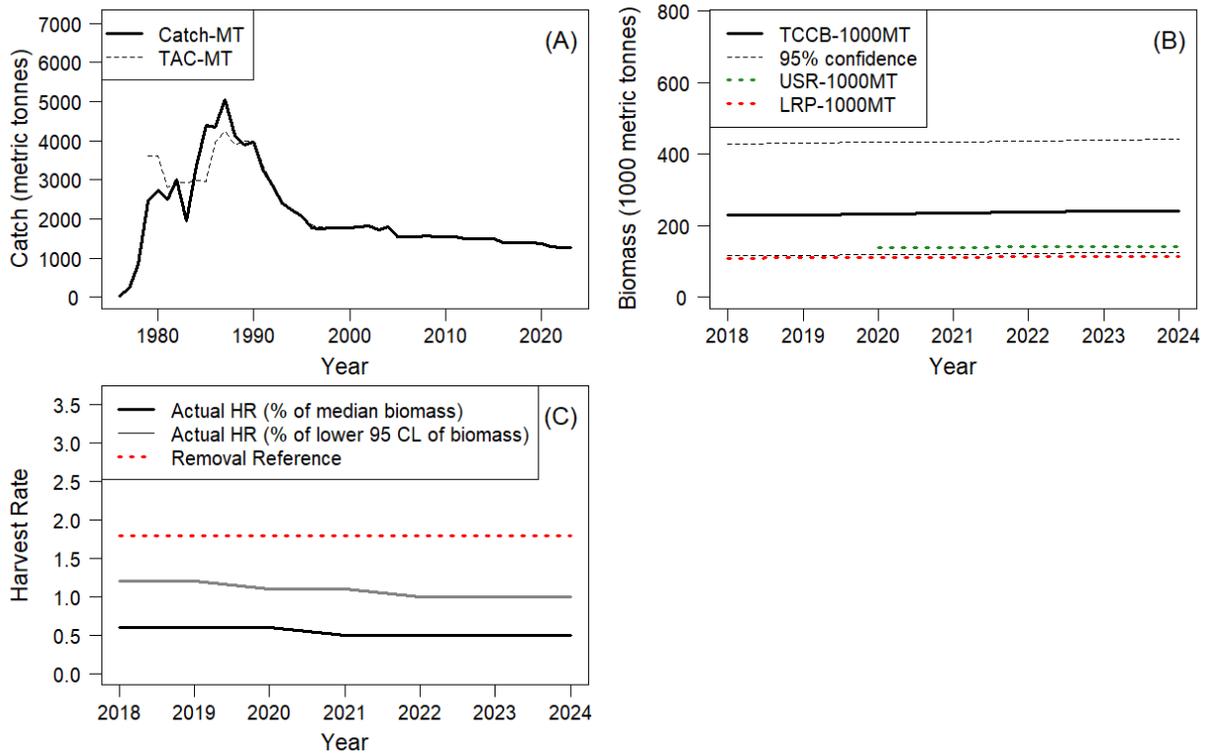


Figure 2. (A) Catch and Total Allowable Catch (TAC) in metric tonnes, (B) Total coastwide current biomass (TCCB, in 1000 metric tonnes) in relation to the Limit Reference Point (LRP; 113,872 t) and Upper Stock Reference (USR; 142,340 t), (C) Actual annual harvest rate (TAC/biomass) in relation to the Removal Reference (RR).

### Historical and Recent Stock Trajectory and Trends

#### Catch vs TAC

Commercial catch has been consistently in line with the TAC since 1989 (Figure 2A) when 100% dockside validation of commercial landings by a third-party service provider was implemented. The TAC was relatively stable between 1996 and 2004, but has since seen several decreases, mainly due to the implementation of closures (e.g., Gwaii Haanas National Marine Conservation Area Reserve) and the impacts of Sea Otter predation (DFO 2021b).

#### Biomass

Geoduck biomass is reported by Pacific Fishery Management Area (PFMA), for several categories of sub-beds (Table 5). Geoduck biomass on available sub-beds on the BC coast in 2024 was estimated at 184,693 t (95% CL: 102,741–317,243 t). Total coastwide biomass for all documented sub-beds was estimated at 241,430 t (95% CL: 125,191–440,904 t). The estimated mean Geoduck biomass is above the LRP of 113,872 t and the USR of 142,340 t. Therefore, the Geoduck stock is in the Healthy Zone.

The low 95% confidence limit of biomass is between the USR and LRP, there is therefore a low probability that the biomass is below the USR.

Trends data are only available since the 2018 assessment for the 2019-2020 harvest season due to changes to biomass estimation methods over time. Biomass since 2018 has been stable (Figure 2B).

*Table 5. Estimated Geoduck biomass (mean; 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 (may or may not be open), impacted by closures and total. 95% CLs are low and high 95% confidence limits.*

PFMA	Available		Otters Mean	Closures Mean	Total	
	Mean	95% CLs			Mean	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	24,276	14,304 – 38,115	0	107	24,383	14,347 – 38,351
5	22,490	14,158 – 33,816	476	281	23,246	14,631 – 35,073
6	31,933	16,272 – 53,776	882	379	33,194	16,829 – 56,122
106	4,852	3,187 – 7,738	0	2	4,854	3,189 – 7,742
7	13,587	5,858 – 27,410	11,540	438	25,566	10,900 – 52,993
8	3,982	1,818 – 7,414	0	0	3,982	1,818 – 7,414
9	936	346 – 2,853	119	0	1,055	372 – 3,302
10	1,010	384 – 2,038	128	4	1,141	413 – 2,612
11	0	-	0	229	229	25 - 624
111	0	-	0	152	152	0 - 631
12	4,732	2,180 – 8,704	1,359	932	7,023	3,209 – 13,937
13	1,030	602 – 2,076	0	291	1,321	753 – 3,003
14	6,343	4,509 – 9,051	0	66	6,409	4,549 – 9,222
15	1,410	485 – 5,129	0	829	2,240	803 – 8,350
16	2,733	1,704 – 5,359	0	153	2,886	1,800 – 5,706
17	1,414	754 – 3,655	0	488	1,901	846 – 6,123
18	831	527 – 1,478	0	9	839	530 – 1,526
19	998	239 – 5,581	0	199	1,197	278 – 6,899
28	0	-	0	59	59	11 - 390
29	367	153 – 1,266	0	11	378	155 – 1,336
20	744	0 – 2,842	0	0	744	0 – 2,842
23	3,559	1,855 – 5,626	0	17,192	20,751	8,772 – 35,494
24	18,380	12,946 – 25,052	3,810	1,246	23,436	15,913 – 33,075
124	204	10 - 659	0	0	204	10 - 659
25	38	14 - 57	3,221	7	3,266	312 – 11,600

## Pacific Region

## 2024 Geoduck Stock Status

PFMA	Available		Otters Mean	Closures Mean	Total	
	Mean	95% CLs			Mean	95% CLs
26	123	74 - 214	1,831	630	2,584	938 – 6,766
27	0	-	1,948	0	1,948	269 – 6,485
<b>Coastwide</b>	<b>184,693</b>	<b>102,741 – 317,243</b>	<b>25,314</b>	<b>31,423</b>	<b>241,430</b>	<b>125,191 – 440,904</b>

### Stock Index

The stock index is defined as the ratio of total coastwide current biomass to total coastwide unfished biomass ( $B_c/B'$ ) and is estimated for the Geoduck stock as a whole (Bureau 2017; DFO 2017). The coastwide stock index is re-estimated yearly when biomass estimates are updated. Based on biomass estimated in 2024 for the 2025-2026 Geoduck harvesting season, the coastwide Geoduck stock index was 85% for all documented sub-beds on the coast; above the 50% USR.

The stock index has been consistently above the USR since status started being assessed against the references points in the 2018 BC Geoduck Stock Status Update (DFO 2020).

### Removal reference

The TAC for the BC commercial Geoduck fishery for the 2025-2026 fishing season was set at 1,247 t by fishery managers (DFO 2025); which is below the sum of the lower 95% confidence limit of harvest options for all available Geoduck sub-beds in BC (1,748 t).

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 2025-2026 fishing season will be 0.5% of the estimated mean 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), which is below the removal reference of 1.8%.

The actual Geoduck annual harvest rate has been consistently below the removal reference since status started being assessed against the references points in the 2018 BC Geoduck Stock Status Update (DFO 2020) (Figure 2C).

### Stock Status

Total coastwide Geoduck biomass is above the LRP and USR, and the actual annual harvest rate is below the removal reference. Therefore, the Geoduck stock is in the Healthy Zone. The Geoduck stock has been consistently in the Healthy Zone since status started being assessed against the references points in the 2018 BC Geoduck Stock Status Update (DFO 2020).

### History of Management; TAC and Landings

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 2025).

For TAC and landings history see Catch vs TAC section above.

The BC Geoduck fishery is managed with a total allowable catch, individual vessel quotas, scheduled openings, area quotas and bed-specific quotas (DFO 2025). It operates on a three year spatial rotation in the North Coast and portions of the Inside Waters areas, while the West Coast of Vancouver Island area is fished annually.

### Harvest Options

Since 2007, harvest options have been based on estimates of current biomass ( $B_c$ ) and recommended regional annual exploitation rates of 1.2–1.8% (Zhang and Hand 2006, 2007). Harvest options are estimated 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.

### Future Scenarios

Although the total area of Geoduck beds on the BC coast has been stable (~22,000 Ha), the amount of Geoduck bed area available for commercial harvest has been decreasing over time due to marine spatial planning initiatives, fishery closures and the impact of Sea Otters. Additional spatial closures (e.g., marine protected areas) are expected along the BC coast in coming years and will result in further loss of access to some Geoduck grounds for the commercial fishery. The range of Sea Otters along the BC coast is expanding (Nichol et al. 2020) and they are likely to impact Geoducks in other parts of the coast in the future, therefore, continued range expansion will likely lead to decreased abundance of Geoducks (Zhang and Hand 2007). Both these factors are likely to lead to reduced quotas and TAC in the future.

## Ecosystem and Climate Change Considerations

### Bed Area

The total area of documented Geoduck beds in BC was estimated to be 22,387 ha, of which 15,783 ha are potentially available to commercial harvest over three rotations (Table 1). Beds that were impacted by closures represented 3,237 ha (14%) of the bed area on the BC coast (Table 1).

### Sea Otters

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).

Geoduck beds in some areas are not harvested due to the impact of Sea Otter predation on Geoduck stocks. Beds reported to be impacted by Sea Otter predation represented 3,366 ha (15%) of the bed area on the BC coast (Table 1), and 10% of Geoduck biomass on the BC coast is reported to be impacted by Sea Otter predation (Table 5). Beds in areas where Sea Otters are reported to have had an impact may or may not have quota assigned to them.

### Ocean Conditions

In the past Geoduck growth had a positive correlation with sea surface temperature (Black et al. 2009, Edge et al., 2021). However, it is unknown how Ocean Acidification (OA) will affect Geoducks in the future. The effect of OA stress exposure on Geoducks is life-stage dependent. While juvenile Geoduck have shown positive carryover effects after exposure to OA conditions, including increased respiration rates, organic biomass and shell size (Gurr et al. 2020, Gurr et al. 2021), larval performance is negatively impacted under OA exposure with elevated energetic

demand on Geoduck larvae, resulting in delayed development and disruptions to normal molecular developmental pathways (Timmins-Schiffman et al. 2019).

## SOURCES OF UNCERTAINTY

Because the locations of Geoduck beds are delineated primarily from fishery-dependent data, i.e., the location of commercial harvest events, only areas where Geoducks are commercially harvestable are documented. Geoduck beds therefore do not represent a full inventory of locations where Geoducks occur on the BC coast.

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 five years. Geoducks extend to shallower and/or greater depths than where harvest takes place in many locations. The biomass of Geoducks outside of documented Geoduck beds, including the portion of the population that exists deeper than harvestable depths, is unknown. Therefore, the actual Geoduck biomass in BC is greater than the biomass estimates presented here.

An additional margin of safety for Geoduck conservation exists because portions of the Geoduck stock are sheltered from harvest, due to closures or water quality. Some beds are located in areas that fall under a variety of closure types (contamination closures, parks, research closures, management closures, etc.), and some beds are in areas where water quality is unclassified or classified as prohibited or restricted by Environment and Climate Change Canada and thus cannot be harvested. Some Geoducks exist in areas that are un-harvestable due to substrate characteristics.

Geoduck surveys occur in different portions of the BC coast each year and only a portion of the beds are surveyed each year. Due to the size of the BC coast and extensive number of Geoduck beds there may be several years between repeat surveys in a given area. On average 969 ha are surveyed annually and 661 ha were surveyed in 2023. Therefore, each year, density estimates are updated for some beds.

Estimates of sub-bed area and mean weights are also updated annually 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.

Few surveys have been conducted in areas impacted by Sea Otters. Density estimates in some of these areas may be outdated, consequently, there is greater uncertainty in the biomass estimates in these areas.

It is unclear how the spatial closures that are expected along the BC coast in coming years may impact future assessments.

Population connectivity between beds and source/sink dynamics are not well understood.

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, some believe 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.

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