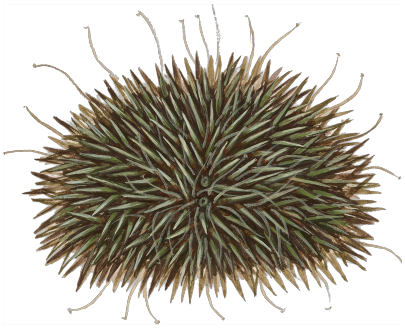
Red Sea Urchin and Green Sea Urchin

Mesocentrotus franciscanus and *Strongylocentrotus droebachiensis*



Canada: British Columbia, Newfoundland and Labrador, New Brunswick, Nova Scotia, Quebec

Diver, Towed dredges

Report ID 27934

Published: November 5, 2018 | Updated: August 1, 2022 – see Appendix for details

Seafood Watch Standard used in this assessment: Fisheries Standard v3

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the environmental sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Seafood Watch's science-based ratings are available at www.SeafoodWatch.org. Each rating is supported by a Seafood Watch assessment, in which the fishery or aquaculture operation is evaluated using the Seafood Watch standard.

Seafood Watch standards are built on our guiding principles, which outline the necessary environmental sustainability elements for fisheries and aquaculture operations. The guiding principles differ across standards, reflecting the different impacts of fisheries and aquaculture.

- Seafood rated Best Choice comes from sources that operate in a manner that's consistent with our guiding principles. The seafood is caught or farmed in ways that cause little or no harm to other wildlife or the environment.

- Seafood rated Good Alternative comes from sources that align with most of our guiding principles. However, one issue needs substantial improvement, or there's significant uncertainty about the impacts on wildlife or the environment.

- Seafood rated Avoid comes from sources that don't align with our guiding principles. The seafood is caught or farmed in ways that have a high risk of causing harm to wildlife or the environment. There's a critical conservation concern or many issues need substantial improvement.

Each assessment follows an eight-step process, which prioritizes rigor, impartiality, transparency and accessibility. They are conducted by Seafood Watch scientists, in collaboration with scientific, government, industry and conservation experts and are open for public comment prior to publication. Conditions in wild capture fisheries and aquaculture operations can change over time; as such assessments and ratings are updated regularly to reflect current practice.

More information on Seafood Watch guiding principles, standards, assessments and ratings are available at www.SeafoodWatch.org.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long term without jeopardizing the structure or function of affected ecosystems.

The following guiding principles illustrate the qualities that fisheries must possess to be considered sustainable by the Seafood Watch program (these are explained further in the Seafood Watch Standard for Fisheries):

- Follow the principles of ecosystem-based fisheries management.
- Ensure all affected stocks are healthy and abundant.
- Fish all affected stocks at sustainable levels.
- Minimize bycatch.
- Have no more than a negligible impact on any threatened, endangered, or protected species.
- Managed to sustain the long-term productivity of all affected species.
- Avoid negative impacts on the structure, function, or associated biota of aquatic habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.

These guiding principles are operationalized in the four criteria in this standard.Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and rating

Once a rating has been assigned to each criterion, Seafood Watch develops an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guides and online guide:

Best Choice/Green: Buy first; they're well managed and caught or farmed responsibly.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught, farmed or managed.

Avoid/Red: Take a pass on these for now; they're caught or farmed in ways that harm other marine life or the environment.

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[1] "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates

Summary

This report provides recommendations for the Canadian fisheries for sea urchins, which include the red sea urchin (*Mesocentrotus franciscanus*) and the green sea urchin (*Strongylocentrotus droebachiensis*). Both species of sea urchin are found in kelp forest and rocky reef habitats. In Canada, the green sea urchin fisheries operate across multiple provinces on both the Pacific and Atlantic coasts, while the red sea urchin fishery is located along the Pacific coast of British Columbia. Fisheries are managed separately by four different regional offices of Fisheries and Oceans Canada (DFO). This report covers the single red sea urchin fishery in British Columbia and the green sea urchin fisheries in British Columbia, Newfoundland and Labrador, New Brunswick, Nova Scotia, and Quebec.

In British Columbia, red sea urchin and green sea urchin populations are considered healthy, and current fishing levels are sustainable. Both species are regularly assessed and monitored with fishery-independent and fishery-dependent data. Fishery impacts on green sea urchin populations on the Atlantic coast of Canada are not well-known for most of the fisheries because stock assessments do not exist. Some fisheries do collect catch per unit effort (CPUE) data, but this is known to be a poor indicator of abundance in sea urchin fisheries. Green sea urchin has a medium inherent vulnerability to fishing pressure, so concern for these data-poor Atlantic stocks is moderate.

Fishery impacts on other species are low for all diver fisheries, which are highly selective. The limited by-catch data from the New Brunswick drag fishery for green sea urchin indicates by-catch of kelp and a number of invertebrate and finfish species. In addition, there is a relatively high discard rate for undersized sea urchin. Although there are no major concerns for any one of the species recorded as being caught, there is significant uncertainty about the impacts on kelp and other species generally, given that the current data are out of date and dredge fisheries frequently have significant by-catch concerns.

All the Canadian sea urchin fisheries use a limited-entry system, and all have some form of formal management. The British Columbia, New Brunswick, and Quebec fisheries directly control fishing mortality through some form of quota or daily fishing limit, though only the British Columbia fishery has regular stock abundance estimates that directly inform the quota numbers. No explicit control of fishing mortality exists for the Newfoundland and Labrador and Nova Scotia fisheries, though the Nova Scotia fishery does protect reproductive stock through some areas that are closed to harvest. Formal scientific advice is currently used in the British Columbia, New Brunswick, and Quebec fisheries, though only British Columbia has recent fisheries-independent data to inform this advice. The role of fisheries-dependent data and scientific advice in the Newfoundland and Labrador and Nova Scotia fisheries is absent or highly uncertain. In New Brunswick, the recommended assessment schedule has not been followed; too few data are available to determine whether the agreed-upon harvesting rate is being exceeded. Stakeholder engagement and enforcement measures are in place for all the fisheries.

The key concern with fishery impacts on the habitat and ecosystem is the physical impact of urchin drags on rocky reef habitat. The habitat impacts of the diver fisheries are minimal because harvest is done by hand. All the Canadian green urchin fisheries implement some form of area quotas or area licensing that can help reduce the risk of localized depletion; several have areas that are closed to harvest and protect reproductive stock. But, none specifically manages for the ecological role of sea urchins, and the green sea urchin fisheries on the Atlantic coast are known to have a moderate-to-high risk of fisheries-induced alternative stable states.

Overall, green sea urchin and red sea urchin caught in British Columbia by divers is rated a Best Choice. Green sea urchin caught in Newfoundland and Labrador, Nova Scotia, New Brunswick, and Quebec by divers is a Good Alternative. Green sea urchin caught in New Brunswick with towed dredges is an Avoid.

Final Seafood Recommendations

SPECIES | FISHERY	CRITERION 1 TARGET SPECIES	CRITERION 2 OTHER SPECIES	CRITERION 3 MANAGEMENT	CRITERION 4 HABITAT	OVERALL RECOMMENDATION
Green sea urchin | Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin	4.284	5.000	5.000	4.000	**Best Choice (4.549)**
Green sea urchin | Northwest Atlantic | Diving | Canada | Quebec	2.644	5.000	3.000	3.464	**Good Alternative (3.424)**
Green sea urchin | Northwest Atlantic | Diving | Canada | New Brunswick	2.644	5.000	2.000	3.464	**Good Alternative (3.094)**
Green sea urchin | Northwest Atlantic | Diving | Canada | Newfoundland and Labrador	2.644	5.000	2.000	3.464	**Good Alternative (3.094)**
Green sea urchin | Northwest Atlantic | Diving | Canada | Nova Scotia	2.644	5.000	2.000	3.464	**Good Alternative (3.094)**
Green sea urchin | Northwest Atlantic | Towed dredges | Canada | New Brunswick	2.644	2.560	2.000	1.732	**Avoid (2.200)**
Red sea urchin | Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin	4.284	5.000	5.000	4.000	**Best Choice (4.549)**

Summary

This report was updated in July 2022, but the overall recommendations for all fisheries remained unchanged.

Green sea urchin and red sea urchin caught in British Columbia by divers is a Best Choice. Both stocks appears to be healthy and overfishing is unlikely. Management is rated highly effective because there are appropriate conservation measures in place that are based on scientific advice. Removing urchin can lead to major changes in the ecosystem, but there are measures in place that are expected to minimize harmful impacts. There are no by-catch concerns, and habitat impacts are minimal.

Green sea urchin caught in Newfoundland and Labrador and Quebec by divers is a Good Alternative. The stock status is unknown due to limited data collection. Although there are measures to monitor the stock and control fishing levels, management is rated moderately effective overall, because its effectiveness is uncertain. Removing urchin can lead to major changes in the ecosystem, and few measures are in place to minimize harmful impacts. There are no by-catch concerns, and habitat impacts are minimal.

Green sea urchin caught in Nova Scotia and New Brunswick by divers is a Good Alternative. The stock status is unknown due to limited data collection. Although there are some measures to control fishing levels, management is rated ineffective overall, because not enough timely research and monitoring is taking place. Removing urchin can lead to major changes in the ecosystem, but there are some measures in place that should help to minimize harmful impacts. There are no by-catch concerns, and habitat impacts are minimal.

Green sea urchin caught in New Brunswick with towed dredges is an Avoid. The stock status is unknown due to limited data collection. The limited observer data suggest that only urchin and kelp are caught in significant amounts, and although no species of concern are caught, there is a great amount of uncertainty on the impacts to these other species. There are also high discard rates of undersized or poor-quality urchins, and it is unknown if they survive. There are measures in place that help control fishing levels, but there is evidence that not enough timely research and monitoring is taking place to ensure that the measures are effective. Urchin dredges (called "drags") can have considerable impacts on the seafloor, especially when towed over rocky ledges and boulder habitat. Removing urchin can lead to major changes in the ecosystem,

but there are some measures in place that should help to minimize harmful impacts.

Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

Best Choice/Green = Final Score >3.2, and no Red Criteria, and no Critical scores

Good Alternative/Yellow = Final score >2.2-3.2, and neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern2, and no more than one Red Criterion, and no Critical scores

Avoid/Red = Final Score ≤2.2, or either Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern or two or more Red Criteria, or one or more Critical scores.

[2] Because effective management is an essential component of sustainable fisheries, Seafood Watch issues an Avoid recommendation for any fishery scored as a Very High Concern for either factor under Management (Criterion 3).

Introduction

Scope of the analysis and ensuing recommendation

This report provides recommendations for the Canadian fisheries for red and green sea urchins. This includes the green sea urchin fisheries in Quebec, Nova Scotia, Newfoundland (Atlantic coast), and the red and green sea urchin fisheries in British Columbia (Pacific coast). Although sea urchins are harvested by divers on both coasts, vessel-towed urchin drags are only used on the Atlantic coast. Gear use varies between and within the different fisheries.

Species Overview

The red sea urchin is a large sea urchin species that is found in kelp forest and rocky reef habitats throughout the Pacific coast of North America. It is harvested for its roe, and commercial fisheries exist in Mexico (Baja California), the United States (California, Oregon, Washington, and Alaska), and Canada (British Columbia). Red sea urchin populations are artificially high in some areas due to extirpation of sea otters, which limit urchin populations (DFO 2021c).

Green sea urchin (*Strongylocentrotus droebachiensis*) is smaller in size and has a large, circumpolar distribution. It is found in northern Europe, northern Japan, and along both coasts of North America. The European distribution includes Russia, Scandinavia, and the British Isles. On the Atlantic coast of North America, it is found from the Arctic to Cape Cod, Massachusetts. On the Pacific coast, it ranges from Washington to Alaska. It is commercially harvested in Canada (Pacific and Atlantic coasts), the United States, Iceland, and Norway.

The Canadian sea urchin fisheries are governed by the federal Fisheries Act and managed by Fisheries and Oceans Canada (DFO). Four different DFO regional offices oversee the management of green sea urchin fisheries in Canada: Quebec, Maritimes, Newfoundland and Labrador, and Pacific.

The British Columbian sea urchin fisheries are managed by the Pacific region DFO office. Red sea urchin is harvested throughout the extensive coastline, and licenses are divided between the north and south coast. There is an integrated fisheries management plan in place, and management occurs through a consultative process with stakeholders. The fishery is limited-entry and quota-based, with a minimum harvest size. This is a diver-only fishery.

The British Columbian green sea urchin fishery operates within a much smaller spatial range around Vancouver Island. The fishery is divided into two fishing regions: Northeast Vancouver Island and Southeast Vancouver Island. There is an integrated fisheries management plan in place, and management occurs through a consultative process with stakeholders. The fishery is quota-based, with individual vessel quotas, area-specific quotas, and a minimum harvest size. This is a diver-only fishery.

The Newfoundland and Labrador green sea urchin fishery is a relatively new commercial fishery and is managed by the Newfoundland and Labrador (NL) DFO regional office. Fishing areas for green sea urchin align with lobster fishing areas, with most fishing activity taking place on the eastern side of Newfoundland and the southern Labrador coast. There is an integrated fisheries management plan, and the fishery is managed through area licensing and a minimum harvest size. This is a diver-only fishery.

The New Brunswick green sea urchin fishery is managed by DFO's Maritimes regional office. Sea urchin fisheries operate primarily in two fishing areas in the Bay of Fundy that align with lobster fishing areas (LFA 36 and LFA 38). These fishing areas are managed separately, using similar management strategies. Conservation and Harvesting Plans (CHPs) are developed in consultation with license holders in the fisheries. The fishery is quota-based, with a minimum harvest size. LFA 36 operates competitively, while LFA 38 issues individual nontransferable quotas. Fishing seasons and minimum harvest size are also in place. The fishery includes both diver harvesting and vessel-towed lightweight dredges ("urchin drags").

The Nova Scotia green sea urchin fishery is managed by DFO's Maritimes regional office. The fisheries in eastern Nova Scotia and southwestern Nova Scotia are managed separately, using similar strategies. Conservation and Harvesting Plans (CHPs)

are developed in consultation with license holders in the fisheries. Some license holders hold exclusive rights to specific fishing zones, and the rest are licensed according to county. No official quotas are in place. There is a limited fishing season and a minimum harvest size. This is a diver-only fishery (DFO 2011)(DFO 2013)(Miller and Nolan 2008).

The Quebec green sea urchin fishery is managed under the Quebec regional DFO office. There are 14 green sea urchin fishing areas, mostly along the north and west shores of the Gulf of St. Lawrence; all areas except Area 9 are exploratory fisheries. Most of Quebec's landings come from two fishing areas (Areas 9 and 11), where fishing effort is concentrated (DFO 2016e). Regulations include a limited fishing season, area licensing, a minimum harvest size, and gear restrictions. Area 9 also has a limited number of fishing days allocated to each license (DFO 2016e). The fishery has licenses for diver harvesting and the use of traps, but no trap fishing has occurred since 2007 (pers. comm., J. Dallaire).

Production Statistics

Global production of sea urchins increased rapidly starting in the mid-1970s with the development and expansion of commercial urchin fisheries outside Japan, particularly in Chile and the United States. Global landings peaked in the mid-1990s (Figure 1).

The Chilean fishery dominates global production, and the Chilean sea urchin has made up over half of all landings in the past decade. Canadian sea urchin fisheries (for green and red sea urchins) represent 5% to 9% of global production in the past decade. Sea urchin commercial aquaculture is mostly limited to China, and represents about 10% of global production in the last decade.

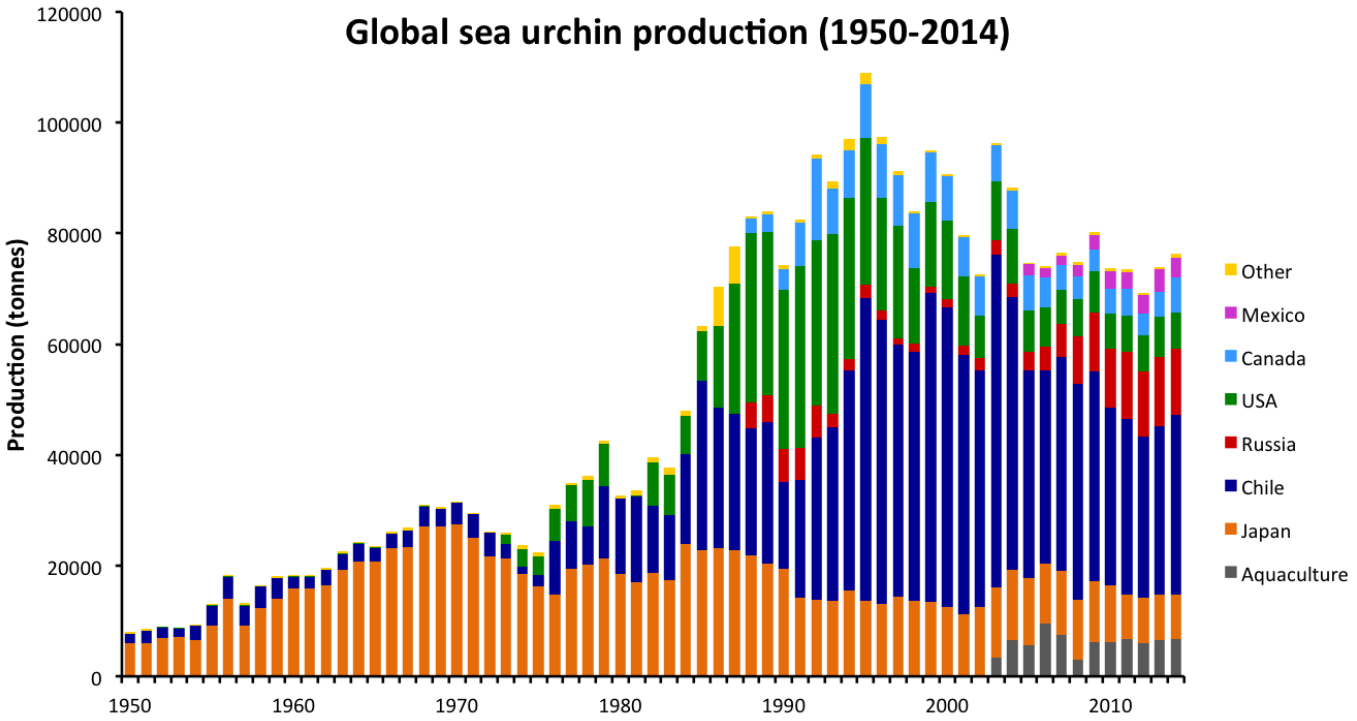

Figure 1. Global sea urchin production by country from 1950 to 2014. This includes multiple sea urchin species.

Canadian production of sea urchins peaked in the mid- to-late 1990s, following global trends (Figures 2 and 3). Earlier production was dominated by the red sea urchin fishery in British Columbia, though green sea urchins have made up 40% to 65% of production in the last decade. Most green sea urchin landings come from the Atlantic coast fisheries, with the largest landings coming from New Brunswick. Aquaculture production facilities for the green sea urchin have existed in Canada since the 1990s, but none of these operations have yet become fully commercialized (Eddy et al. 2015)(James et al. 2015).

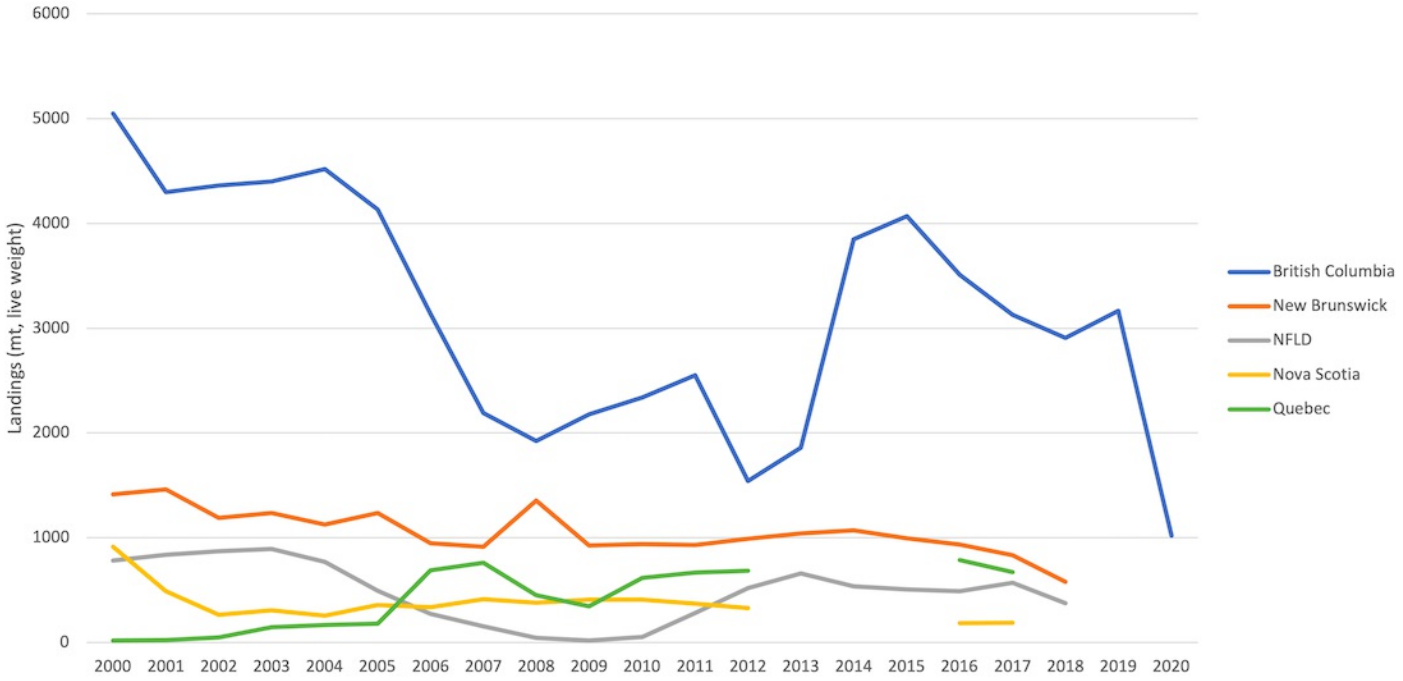

Figure 2. Canadian harvest of the sea urchin by fishery from 2000–2020. Data gaps are for years in which data were suppressed to meet confidentiality requirements. Data from DFO.

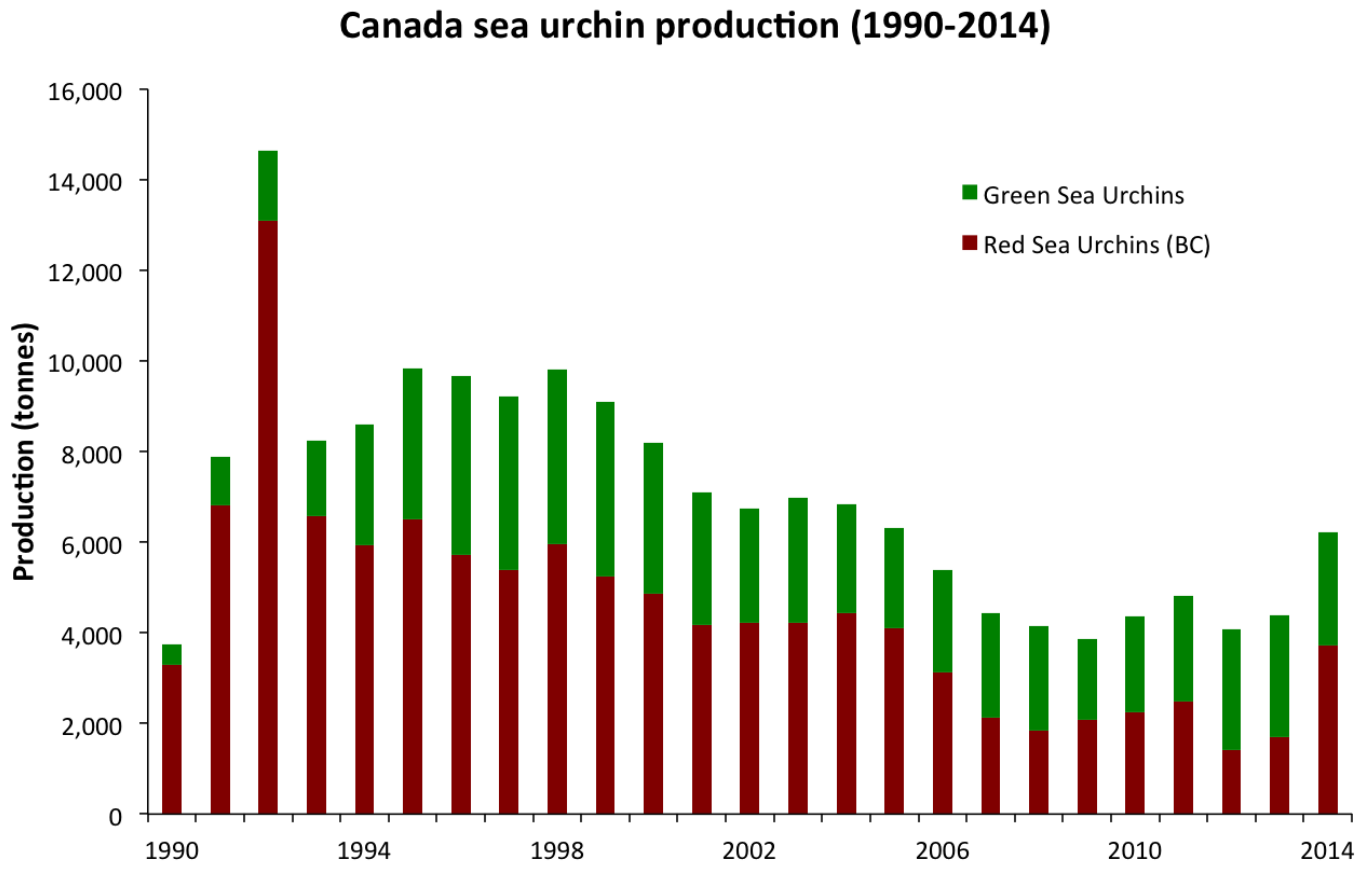

Figure 3. Canadian harvest of red (*M. franciscanus*) and green (*S. droebachiensis*) sea urchins from 1990–2014. Data from DFO.

Importance to the US/North American market.

Canada is the largest source of sea urchin imports into the United States market (Figure 4). From 2012 to 2021, over 90% of U.S. sea urchin product imports (including live, fresh, frozen, and preserved) have come from Canada. Less than 10% of

U.S. sea urchin imports are re-exported, though the fraction of re-exports has increased over the past decade. Japan, China, and Taiwan are the main re-export markets. NOAA trade statistics do not distinguish different sea urchin species, so these import numbers also include green and purple sea urchins.

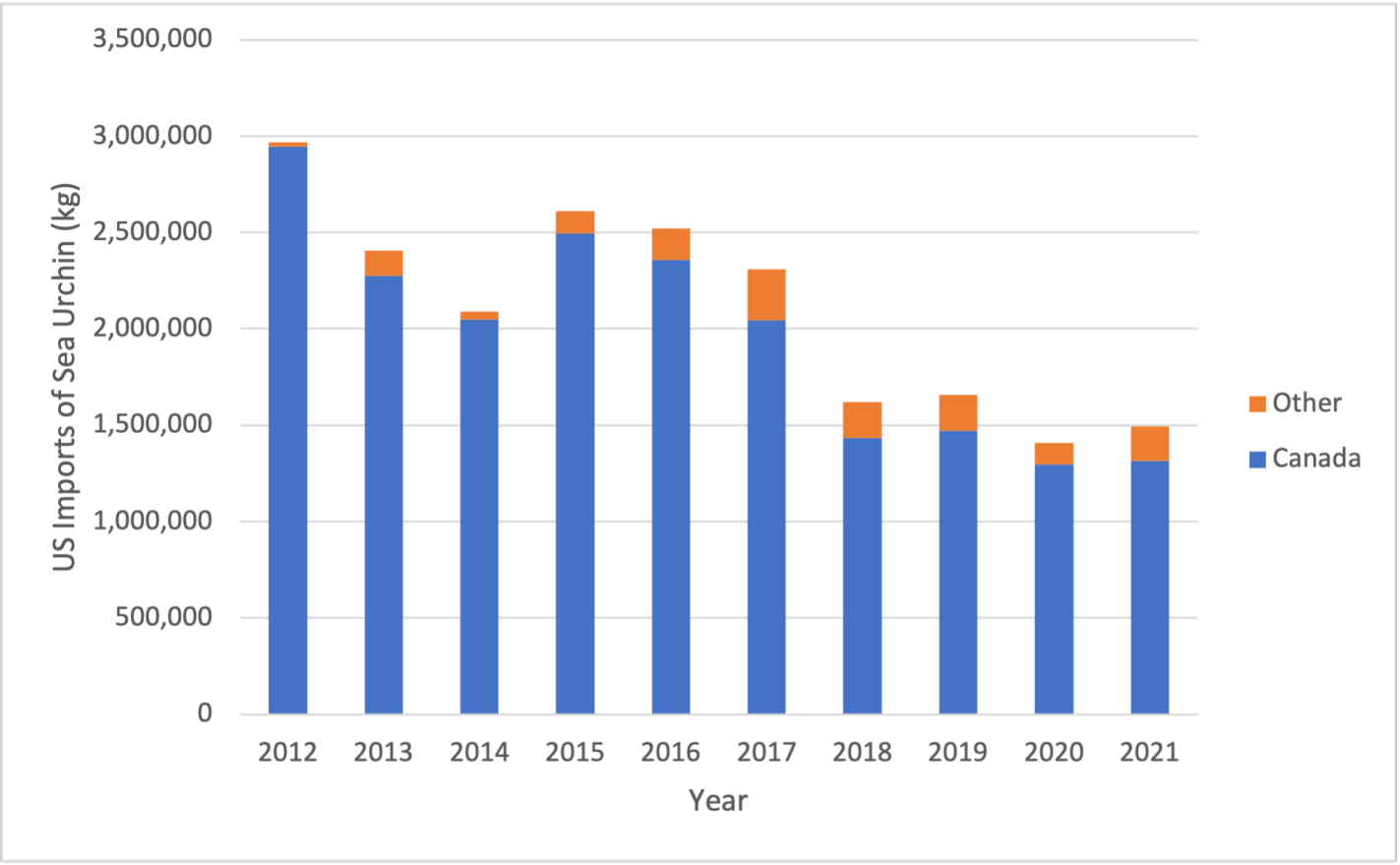

Figure 4. Sea urchin product imports to the U.S. in kilograms, by country from 2012–2021. Data taken from NMFS, which does not distinguish between sea urchin species in its statistics.

Common and market names.

Mesocentrotus franciscanus is commonly known as the red sea urchin and *Strongylocentrotus droebachiensis* is commonly known as the green sea urchin. The roe of both species is marketed as *uni*.

Primary product forms

Red and greed sea urchins are harvested for their reproductive organs (gonads) or roe. Sea urchin is typically sold in the form of fresh roe (uni), where the test (shell) has been broken and the roe extracted for consumption. They may also be sold as fresh or live whole animals, with the test and spines intact. A much smaller amount is frozen or preserved for consumption.

Assessment

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Standard for Fisheries, available at www.seafoodwatch.org. The specific standard used is referenced on the title page of all Seafood Watch assessments.

Criterion 1: Impacts on the species under assessment

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. When abundance is unknown, abundance is scored based on the species' inherent vulnerability, which is calculated using a Productivity-Susceptibility Analysis. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 1.3 (Fishing Mortality) is Critical.

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level*

Criterion 1 Summary

GREEN SEA URCHIN			
REGION / METHOD	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin	3.670: Low Concern	5.000: Low Concern	Green (4.284)
Northwest Atlantic | Diving | Canada | Quebec	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Northwest Atlantic | Diving | Canada | New Brunswick	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Northwest Atlantic | Diving | Canada | Nova Scotia	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Northwest Atlantic | Towed dredges | Canada | New Brunswick	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

RED SEA URCHIN			
REGION / METHOD	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin	3.670: Low Concern	5.000: Low Concern	Green (4.284)

Criterion 1 Assessments

SCORING GUIDELINES

Factor 1.1 - Abundance

Goal: Stock abundance and size structure of native species is maintained at a level that does not impair recruitment or

productivity.

- *5 (Very Low Concern) — Strong evidence exists that the population is above an appropriate target abundance level (given the species' ecological role), or near virgin biomass.*
- *3.67 (Low Concern) — Population may be below target abundance level, but is at least 75% of the target level, OR data-limited assessments suggest population is healthy and species is not highly vulnerable.*
- *2.33 (Moderate Concern) — Population is not overfished but may be below 75% of the target abundance level, OR abundance is unknown and the species is not highly vulnerable.*
- *1 (High Concern) — Population is considered overfished/depleted, a species of concern, threatened or endangered, OR abundance is unknown and species is highly vulnerable.*

Factor 1.2 - Fishing Mortality

Goal: Fishing mortality is appropriate for current state of the stock.

- *5 (Low Concern) — Probable (>50%) that fishing mortality from all sources is at or below a sustainable level, given the species ecological role, OR fishery does not target species and fishing mortality is low enough to not adversely affect its population.*
- *3 (Moderate Concern) — Fishing mortality is fluctuating around sustainable levels, OR fishing mortality relative to a sustainable level is uncertain.*
- *1 (High Concern) — Probable that fishing mortality from all source is above a sustainable level.*

Green sea urchin

Factor 1.1 - Abundance

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin

Low Concern

The British Columbia fishery conducts fishery-independent transect surveys to estimate biomass at index sites in both fishing regions. Stock assessments are updated every 3 years, with the last published in 2021 (DFO 2021b). Catch per unit effort (CPUE) from the fishery and fishery-independent biomass surveys are both used in stock assessment models, which produce estimates of MSY but not B_{MSY}. Stock biomass and abundance of green sea urchin in both regions exhibit stable or increasing trends over the past 7 to 8 years. Changes in population size frequency and mean urchin size have been observed due to strong recruitment, but there are no indications of declines in large individuals. In 2018, legal-sized biomass density in PFMA 12 was 3.8 urchins/m^2 and in PFMA 19 was 4.3 urchins/m^2, placing the stocks in the Healthy Zone (DFO 2021b). Seafood Watch considers several data-limited assessment methods when a fishery lacks a quantitative stock assessment, including changes in CPUE, average size, and density ratios; other examples of appropriate methods can be found in Appendix 7 of the Seafood Watch Fisheries Standard F3.2.

Although the fishery does not have a full quantitative stock assessment (with B_{MSY}), the species is not highly vulnerable; multiple data-limited stock indicators suggest that the stock is healthy, so abundance is scored a low concern.

Justification:

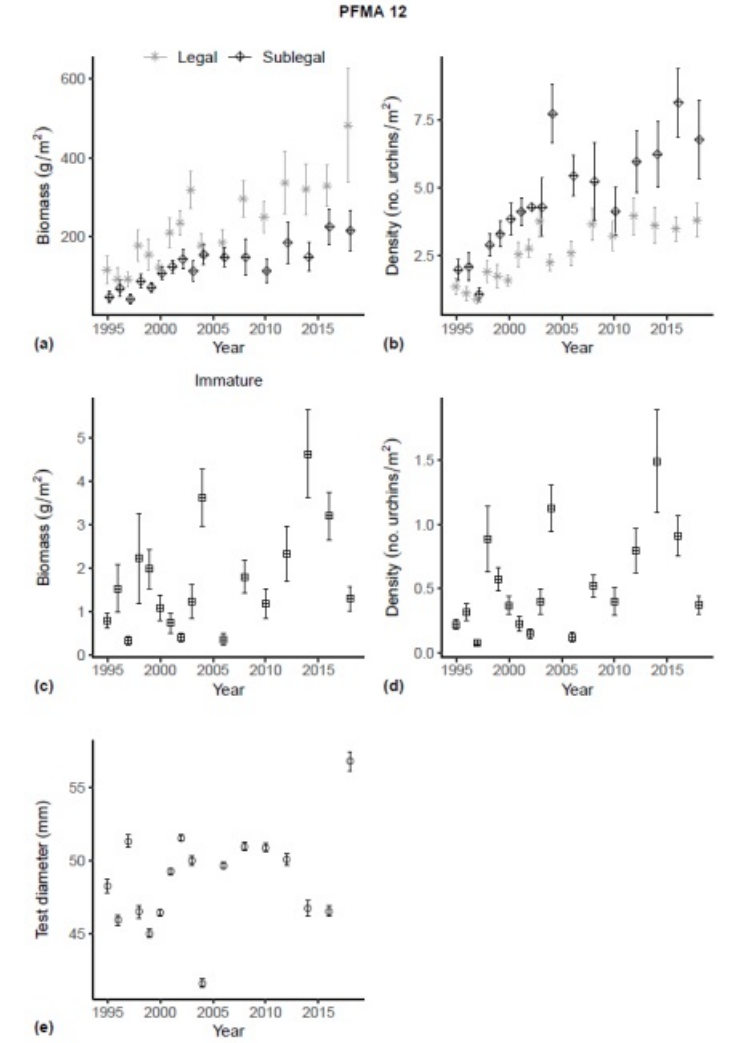
PFMA 12
Legal
Sublegal
Biomass (g/m²)
Density (no. urchins/m²)
Year
(a)
(b)
Immature
(c)
(d)
Test diameter (mm)
(e)

Figure 1: The estimated mean (±1 standard error) of legal-sized (≥55 TD mm) and sublegal-sized (<55 TD mm) green sea urchin in PFMA 12 (a) biomass (g/m^2) and (b) density (no. urchins/m^2); as well as immature (<25 TD mm) (c) biomass and (d) density; and (e) test diameter; from fall, fishery-independent dive surveys. In some cases, the standard errors are small and appear within the markers. Note that points are offset to improve legibility (DFO 2021b).

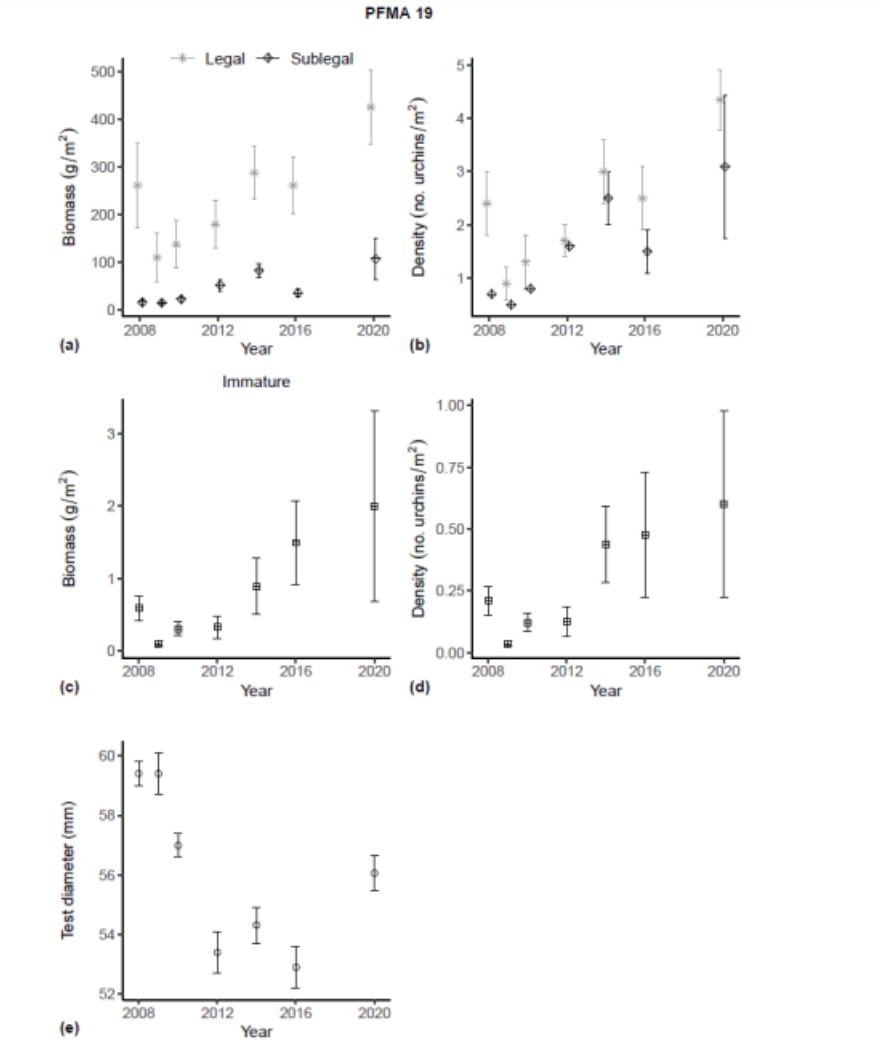

Figure 2: The estimated mean (±1 standard error) of legal-sized (≥55 TD mm) and sublegal-sized (<55 TD mm) green sea urchin in PFMA 19 (a) biomass (g/m^2) and (b) density (no. urchins/m^2); as well as immature (<25 TD mm) (c) biomass and (d) density; and (e) test diameter; from spring, fishery-independent dive surveys. In some cases, the standard errors are small and appear within the markers (DFO 2021b).

Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia

Northwest Atlantic | Towed dredges | Canada | New Brunswick

Moderate Concern

Too few data are collected in the Atlantic Canada fisheries to assess the status of green sea urchin. Therefore, inherent vulnerability is estimated using the productivity-susceptibility analysis (PSA), where vulnerability = $\sqrt{(1.67^2 + 2.325^2)} = 2.86$ (medium vulnerability). Stocks with medium vulnerability and unknown stock status are scored a moderate concern.

Justification:

New Brunswick

Managers have conducted two fisheries-independent surveys for the main areas of the New Brunswick fishery (DFO 2010c)(DFO 2010d). Total biomass in the Bay of Fundy LFA 36 appeared to have changed little between those periods (1992 to 1994 and 2002 to 2003) and, though there did appear to be a decline of estimated fishable biomass, the significance of the result was confounded by high uncertainty. Similar patterns for total biomass and fishable biomass were shown in the Bay of Fundy LFA 38 (survey years 1992 and 2005). The fisheries also collect CPUE data; however, CPUE is known to correlate poorly with abundance in a similar green sea urchin fishery, particularly at low stock abundances (Chen and Hunter 2003).

Newfoundland and Labrador

The Newfoundland and Labrador fishery only collects landings data, which are insufficient to assess the stock (DFO 2007)(Pisces Consulting Ltd. 2014).

Nova Scotia

There are no stock assessment data for the Nova Scotia fisheries (DFO 2011)(DFO 2013). But, logbook data are collected and an initial assessment in 2000 was used to determine the number of licenses that a piece of coastline could support (DFO 2000).

Quebec

The Quebec fishery collects annual CPUE data and has conducted several fisheries-independent surveys in recent years (DFO 2012)(DFO 2016e). But, CPUE is known to correlate poorly with abundance in a similar green sea urchin fishery, particularly at low stock abundances (Chen and Hunter 2003), and the survey data are insufficient to estimate temporal trends. Trends in CPUE were stable in Subarea 9-1 and Area 11 from 2004 to 2015, and the average size taken from commercial samples has been relatively stable from 2010–2015 in Subarea 9-1 (DFO 2016e). DFO considers the status of green sea urchin in Area 11 as unknown, due to a lack of information (DFO 2016e).

Productivity-Susceptibility Analysis

PRODUCTIVITY ATTRIBUTE	RELEVANT INFO	REFERENCE	SCORE
Average age at maturity	<5 years	(Meidel and Scheibling 1999)	1
Average maximum age	>50 years	(Russell et al. 1998)	3
Fecundity	>1 million eggs	(Thompson 1979)	1
Reproductive strategy	Broadcast spawner	(Thompson 1979)	1
Trophic level	<2.75	(Scheibling and Hatcher 2013)	1
Density dependence	Allee effects exist	(Wahle and Peckman 1999)	3
Productivity Score (P)			**1.67**

SUSCEPTIBILITY ATTRIBUTE	RELEVANT INFO	SCORE

Areal overlap	Unknown, so default score is used (>30% across their geographic range, considering all fisheries)	3
Vertical overlap	Green sea urchin is a targeted species, so default score used (high degree of overlap between fishing depths and depth range of species)	3
Selectivity of fishery	Green sea urchin is a targeted species, but gear type and size limits reduce susceptibility so default score is used (species is targeted, or is incidentally encountered AND is not likely to escape the gear, BUT conditions under "high risk" do not apply).	2
Post-capture mortality	Green sea urchin is the targeted species, so the default score is used (retained species, or majority dead when released, or unknown).	3
Susceptibility Score (S)		**2.325**

Factor 1.2 - Fishing Mortality

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin

Low Concern

DFO now uses an empirical reference point based on the lowest observed density from the index sites time series from which recovery took place without management intervention (DFO 2021). The upper stock reference (USR) = 0.9 urchins/m^2 and the limit reference point (LRP) of 0.5 × USR = 0.45 urchins/m^2 are only considered appropriate for the two fished and highly productive management regions (DFO 2021). Maximum sustainable yield (MSY) estimates are produced from a productivity model, but these estimates should be treated with caution (DFO 2021b). There is a predicted probability of <4.5% that the 2018–2021 quotas for green sea urchin in Northeast Vancouver Island and Southeast Vancouver Island exceed the MSY (see Table 1 in DFO 2021b for details). Landings in the commercial fishery have not exceeded quotas since 1995 (DFO 2021b).

DFO estimates that these quotas correspond to a ≤5% probability of exceeding the true MSY for the fishery (DFO 2021) (DFO 2021b). Quotas are generally revised every 3 years, and the fishery has never exceeded its quota. Because fishing mortality is very likely to be below a sustainable level in this fishery, it is scored a low concern.

Justification:

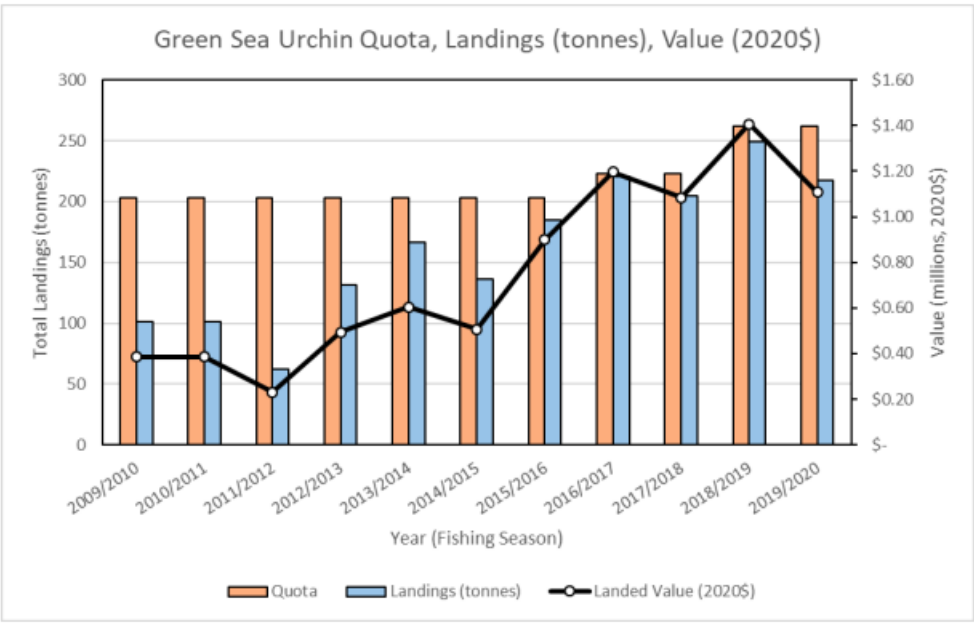

Figure 3: Commercial landings and quota for the BC green urchin fishery from 2009–2019 (DFO 2021).

Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia
Northwest Atlantic | Towed dredges | Canada | New Brunswick

Moderate Concern
A paucity of data collection and reference points means that fishing mortality relative to a sustainable level is unknown, so this factor is scored a moderate concern.

New Brunswick

The most recent estimates of fishing mortality, based on 2005 population surveys, were 7.9% in LFA 36 and 1.5% in LFA 38, but the fishery has no reference points (DFO 2010d)(DFO 2010c).

Newfoundland and Labrador, Nova Scotia

Fishing mortality in the Newfoundland and Labrador and Nova Scotia fisheries is unknown. There were reports of declining abundance of larger urchins in Newfoundland, but that decline was not quantified (Pisces Consulting Ltd. 2014).

Quebec

The majority of landings in Quebec occur in Areas 9 and 11, with Subarea 9-1 accounting for between 44% and 91% of landings in Quebec since 2004 (DFO 2016e). Landings have been relatively stable since 2011 (DFO 2016e), but there are no fishing mortality reference points to assess the sustainability of current fishing levels.

Calculations based on a 2010/2011 urchin biomass survey estimated fishing mortality at 12% to 19% in Area 8 and at 5% in Area 9 (DFO 2012), but the fishery has no reference points.

Red sea urchin

Factor 1.1 - Abundance

Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Low Concern
DFO conducted fisheries-independent surveys within commercial harvested areas from 1994 through 2016 (Lochead et al. 2019). Stocks appear to be stable, with fisheries-independent surveys showing no significant decrease in populations at the two index sites representing the most heavily fished areas (harvest rates at almost 100% TAC; pers. comm., D. Leus 2018). Red sea urchin was recently assessed as in the healthy zone, but the surveys were designed to estimate biomass at the regional level, not to be representative of stock status (DFO 2021c). DFO lacks the resources to monitor the coastwide stock, but a coastwide multi-species survey has been in development since 2016. The survey design will undergo scientific review in 2022, and DFO has no concern for the stock at present (DFO 2021c).

Red urchins in three areas are above the target reference points when assessed at the regional scale and when they are combined (Lochead et al. 2019). The recommended provisional upper stock reference (USR) (i.e., target reference point) is 0.6 RSU/m^2, and the estimated mature red sea urchin densities for 2018 are as follows: 2.51 RSU/m^2 for Haida Gwaii, 1.7 RSU/m^2 for the Mainland North Coast, 0.89 RSU/m^2 for the South Coast Inside Waters, and 1.44 RSU/m^2 for all regions combined (Lochead et al. 2019). In addition, current populations of red sea urchin are thought to be artificially high in some areas because of extirpation of sea otters, which have historically limited urchin populations (DFO 2021c).

Because there is no evidence of conservation concern for red sea urchin, and there is some data to suggest that stocks are above potential target reference points, this factor is scored a low concern.

Factor 1.2 - Fishing Mortality

Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Low Concern
DFO recently developed length-based models to assess red sea urchin in British Columbia (Lochead et al. 2019) and recommend reference points to align the fishery with DFO's SSF and PA (DFO 2021c). Beginning in 2019, DFO set total allowable catches (TAC) based on harvest rate recommendations and probabilities of breaching recommended limit reference points (DFO 2021c). The red sea urchin TAC was set using a harvest rate between 1% and 2% of legal biomass, but was increased to 5% in areas known to be affected by urchin barrens (DFO 2021c). Time-series data from two index sites indicate that this level of fishing mortality has been sustainable over a decade's time (DFO 2021c), and simulated densities remain stable over 100 years under a modeled harvest rate of 2% (Lochead et al. 2019). Fishing mortality is scored a low concern, because it is probable that fishing mortality is at or below a sustainable level.

Justification:

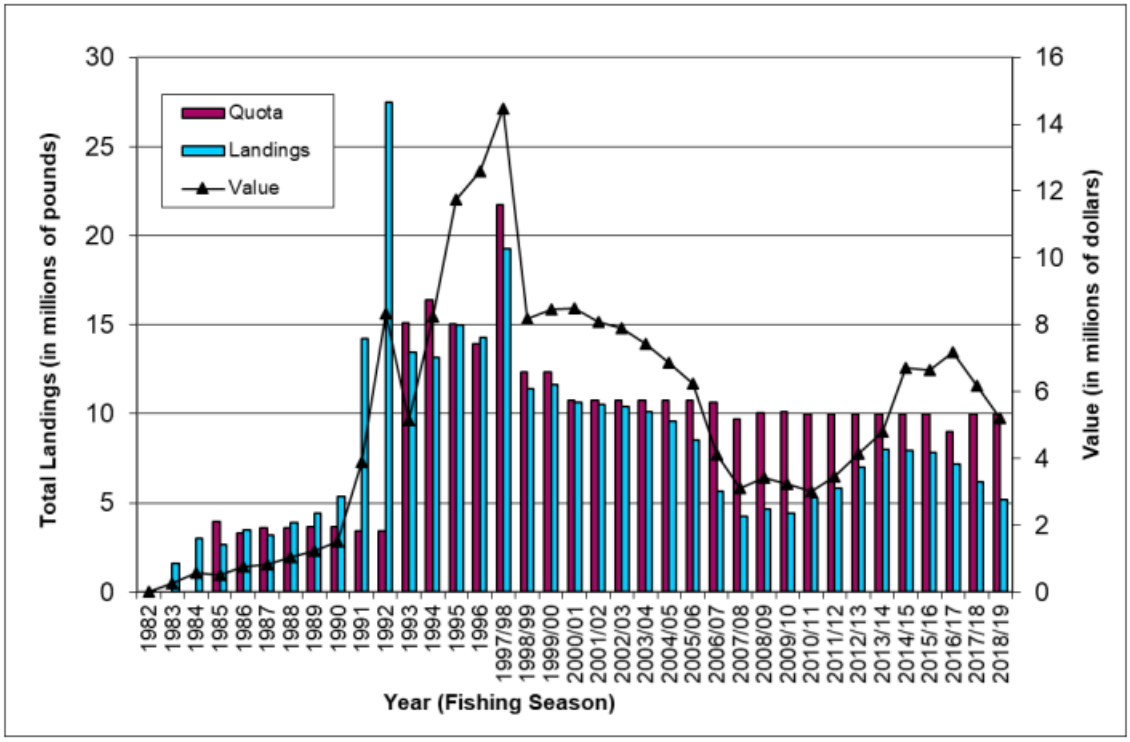

Figure 4: Annual red sea urchin quota, landings (lb.) and value for British Columbia, 1982 to 2019 (DFO 2021c).

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery's potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Factor 2.3 (Fishing Mortality) is Crtitical

Guiding principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*
- *Minimize bycatch.*

Criterion 2 Summary

Criterion 2 score(s) overview

This table(s) provides an overview of the Criterion 2 subscore, discards+bait modifier, and final Criterion 2 score for each fishery. A separate table is provided for each species/stock that we want an overall rating for.

GREEN SEA URCHIN			
REGION / METHOD	**SUB SCORE**	**DISCARD RATE/LANDINGS**	**SCORE**
Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin	5.000	1.000: < 100%	Green (5.000)
Northwest Atlantic | Diving | Canada | Quebec	5.000	1.000: < 100%	Green (5.000)
Northwest Atlantic | Diving | Canada | New Brunswick	5.000	1.000: < 100%	Green (5.000)
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador	5.000	1.000: < 100%	Green (5.000)
Northwest Atlantic | Diving | Canada | Nova Scotia	5.000	1.000: < 100%	Green (5.000)
Northwest Atlantic | Towed dredges | Canada | New Brunswick	3.413	0.750: >= 100%	Yellow (2.560)

RED SEA URCHIN			
REGION / METHOD	**SUB SCORE**	**DISCARD RATE/LANDINGS**	**SCORE**
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin	5.000	1.000: < 100%	Green (5.000)

Criterion 2 main assessed species/stocks table(s)

This table(s) provides a list of all species/stocks included in this assessment for each 'fishery' (as defined by a region/method combination). The text following this table(s) provides an explanation of the reasons the listed species were selected for inclusion in the assessment.

NORTHEAST PACIFIC | DIVING | CANADA | BRITISH COLUMBIA | BC GREEN URCHIN			
SUB SCORE: 5.000	DISCARD RATE: 1.000	**SCORE: 5.000**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Green sea urchin	3.670: Low Concern	5.000: Low Concern	Green (4.284)

NORTHEAST PACIFIC | DIVING | CANADA | BRITISH COLUMBIA | BC RED URCHIN			
SUB SCORE: 5.000	DISCARD RATE: 1.000	**SCORE: 5.000**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Red sea urchin	3.670: Low Concern	5.000: Low Concern	Green (4.284)

NORTHWEST ATLANTIC | DIVING | CANADA | NEW BRUNSWICK			
SUB SCORE: 5.000	DISCARD RATE: 1.000	**SCORE: 5.000**	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Green sea urchin	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

NORTHWEST ATLANTIC | DIVING | CANADA | NEWFOUNDLAND AND LABRADOR			
SUB SCORE: 5.000	DISCARD RATE: 1.000	SCORE: 5.000	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Green sea urchin	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

NORTHWEST ATLANTIC | DIVING | CANADA | NOVA SCOTIA			
SUB SCORE: 5.000	DISCARD RATE: 1.000	SCORE: 5.000	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Green sea urchin	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

NORTHWEST ATLANTIC | DIVING | CANADA | QUEBEC			
SUB SCORE: 5.000	DISCARD RATE: 1.000	SCORE: 5.000	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Green sea urchin	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

NORTHWEST ATLANTIC | TOWED DREDGES | CANADA | NEW BRUNSWICK			
SUB SCORE: 3.413	DISCARD RATE: 0.750	SCORE: 2.560	
SPECIES	**ABUNDANCE**	**FISHING MORTALITY**	**SCORE**
Green sea urchin	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Sugar kelp	2.330: Moderate Concern	5.000: Low Concern	Green (3.413)

The diver-based fisheries are selective and no other species are caught.

According to DFO, efforts are underway to better understand the impacts of discards in the New Brunswick drag fishery, including urchin survivability (see Criterion 3.3) (pers. comm., DFO August 2018). In the meantime, the present assessment uses the best available data on discards, which is a study based on observer data from trips conducted in 2007 and 2008 (DFO 2010d). At that time, urchin accounted for over 90% of the catch (excluding kelp). Roughly half of the sea urchin catch is discarded (48% during Dec. 2007 trips, and 55% during the Jan. 2008 trips) (DFO does consider the estimates out of date, because the rate has not been calculated in recent years). Sea urchins are assessed under Criterion 1.

Other taxa caught included kelp, blue mussels, various crab species (including rock and Jonah crabs), various fish species (including winter flounder), and other benthic invertebrates (including scallops and unidentified shrimps). All except kelp were caught in relatively low volumes (<1% of the catch when kelp is excluded, except for blue mussels at 3.7% to 4.9%), and none are of particular conservation concern, so they are not included further in this assessment.

Kelp by-catch by weight can be significant (14.1% during the Jan. 2008 trips and 36.2% during the Dec. 2007 trips) and appears to be a combination of drift or wrack material and attached plants that are pulled off the bottom by the drag. According to DFO, although repeated dragging over the same kelp bed could reduce kelp density, this is more than compensated for by removing the urchin grazing pressure through fishing (DFO 2010d).

In short, kelp is included in the assessment for the New Brunswick drag fishery and does drive the Criterion 2 score for that fishery. This approach reflects the uncertainty in the impacts on kelp and other species, given that current data are out of

date and dredge fisheries frequently have significant by-catch concerns (as reflected in the Seafood Watch Standard for Fisheries, Unknown By-catch Matrices, Appendix 3).

Statistics on the percent of the by-catch in observed LFA 38 sea urchin fishing trips for each species during the week of 17–21 December 2007 (five trips), and the week of 7–11 January 2008 (five trips). From (DFO 2010d).

	17–21 Dec. 2007				**7–11 Jan. 2008**			
	Catch (Kg)	**Percent of Catch (with Kelp)**	**Percent**	**of Catch (no Kelp)**	**Catch (Kg)**	**Percent of Catch (with Kelp)**	**Percent**	**of Catch (no Kelp)**
Total Weekly Catch	**16876**	100%			**15296**	100%		
Total Weekly Catch (No Kelp)	**10772**		100%		**13134**		100%	
Sea Urchins Discarded	4729	28.0%	43.9%		6772	44.3%	51.6%	
Sea Urchins Kept	5071	30.0%	47.1%		5487	35.9%	41.8%	
Blue Mussel	524	3.1%	4.9%		489	3.2%	3.7%	
Ocean Pout	3	0.02%	0.03%		2	0.01%	0.01%	
Green Crab	90	0.5%	0.8%		47	0.3%	0.4%	
Hermit Crab	99	0.6%	0.9%		99	0.6%	0.8%	
Hyas coarctatus	0	0.0%	0.0%		4	0.0%	0.0%	
Jonah Crab	4	0.0%	0.0%		41	0.3%	0.3%	
Lumpfish	1	0.0%	0.0%		1	0.0%	0.0%	
Rock Crab	58	0.3%	0.5%		29	0.2%	0.2%	
***Sabinea* sp.**	0	0.0%	0.0%		84	0.6%	0.6%	
Sand Lance	0	0.0%	0.0%		5	0.0%	0.0%	
Scallop	22	0.1%	0.2%		0	0.0%	0.0%	
Sculpin	52	0.3%	0.5%		12	0.1%	0.1%	
Sea Mouse	3	0.0%	0.0%		4	0.0%	0.0%	
Sea Raven	8	0.0%	0.1%		0	0.0%	0.0%	
Seaweed (Kelp)	6104	36.2%			2162	14.1%		
Shrimp	92	0.5%	0.9%		47	0.3%	0.4%	
Winter Flounder	16	0.1%	0.1%		12	0.1%	0.1%	

Criterion 2 Assessment

SCORING GUIDELINES

Factor 2.1 - Abundance
(same as Factor 1.1 above)

Factor 2.2 - Fishing Mortality
(same as Factor 1.2 above)

Factor 2.3 - Modifying Factor: Discards and Bait Use
Goal: Fishery optimizes the utilization of marine and freshwater resources by minimizing post-harvest loss. For fisheries that use bait, bait is used efficiently.

Scoring Guidelines: The discard rate is the sum of all dead discards (i.e. non-retained catch) plus bait use divided by the total retained catch.

Ratio of bait + discards/landings	Factor 2.3 score
<100%	1
>=100	0.75

Sugar kelp

Factor 2.1 - Abundance

Northwest Atlantic | Towed dredges | Canada | New Brunswick

Moderate Concern
No information is available on the status of kelp in New Brunswick waters, but Laminariads are fast-growing, broadcast-spawning, short-lived perennials (http://www.ukmarinesac.org.uk/communities/infralittoral/ik3_2.htm). We were unable to find evidence of any significant directed harvest of kelp off the Maritimes. Population status is therefore considered unknown and a moderate concern.

Factor 2.2 - Fishing Mortality

Northwest Atlantic | Towed dredges | Canada | New Brunswick

Low Concern
According to DFO, although repeated dragging over the same kelp bed could reduce kelp density, this is more than compensated for by removing the urchin grazing pressure through fishing (DFO 2010d).

Factor 2.3 - Discard Rate/Landings

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin
Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

< 100%
No data are available for discard rates in Canadian diver fisheries, but they are expected to be small (<100%) due to the selective nature of hand collection (DFO 2021)(DFO 2021c). Therefore, the fishery receives a score of 1.

Northwest Atlantic | Towed dredges | Canada | New Brunswick

>= 100%
Limited data from at-sea observers indicate that sea urchin discards to landings were between 93% and 125%. Discards may consist of sublegal sea urchins and those with poor gonad quality. The survival of discarded live sea urchins is unknown (DFO 2010d). Because the discard-landings ratio may exceed 100%, the fishery receives a score of 0.75.

Criterion 3: Management Effectiveness

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

- *5 (Very Low Concern) — Meets the standards of 'highly effective' for all five factors considered.*
- *4 (Low Concern) — Meets the standards of 'highly effective' for 'management strategy and implementation' and at least 'moderately effective' for all other factors.*
- *3 (Moderate Concern) — Meets the standards for at least 'moderately effective' for all five factors.*
- *2 (High Concern) — At a minimum, meets standards for 'moderately effective' for Management Strategy and Implementation and Bycatch Strategy, but at least one other factor is rated 'ineffective.'*
- *1 (Very High Concern) — Management Strategy and Implementation and/or Bycatch Management are 'ineffective.'*
- *0 (Critical) — Management Strategy and Implementation is 'critical'.*

The Criterion 3 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Rating is Critical if Management Strategy and Implementation is Critical.

Guiding principle

- The fishery is managed to sustain the long-term productivity of all impacted species.

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

Criterion 3 Summary

FISHERY	MANAGEMENT STRATEGY	BYCATCH STRATEGY	RESEARCH AND MONITORING	ENFORCEMENT	INCLUSION	SCORE
Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin	Highly effective	Highly effective	Highly effective	Highly effective	Highly effective	**Green (5.000)**
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin	Highly effective	Highly effective	Highly effective	Highly effective	Highly effective	**Green (5.000)**
Northwest Atlantic | Diving | Canada | New Brunswick	Moderately Effective	Highly effective	Ineffective	Highly effective	Moderately Effective	**Red (2.000)**
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador	Moderately Effective	Highly effective	Ineffective	Moderately Effective	Highly effective	**Red (2.000)**
Northwest Atlantic | Diving | Canada | Nova Scotia	Moderately Effective	Highly effective	Ineffective	Highly effective	Moderately Effective	**Red (2.000)**
Northwest Atlantic | Diving | Canada | Quebec	Moderately Effective	Highly effective	Moderately Effective	Highly effective	Moderately Effective	**Yellow (3.000)**
Northwest Atlantic | Towed dredges | Canada | New Brunswick	Moderately Effective	Moderately Effective	Ineffective	Highly effective	Moderately Effective	**Red (2.000)**

As part of the report review in April 2022, Seafood Watch determined that there were no major changes in the management strategies for Canadian sea urchin fisheries that would result in a scoring change for Criterion 3. Updated integrated fishery

management plans for green sea urchin and red sea urchin in British Columbia were published in 2021 (DFO 2021)(DFO 2021c); the fisheries continue to have highly effective management strategies. An integrated fishery management plan for Newfoundland and Labrador was published in 2019, but the fishery continues to lack strategies (e.g., reference points and precautionary policies) required to score highly effective for Criterion 3.1. Finally, DFO recently released Conservation Harvesting Plans (CHP) for sea urchin fisheries in Quebec (DFO 2020a)(DFO 2020b) but, without stock assessments or reference points, the appropriateness of the quotas in these areas is unknown.

Criterion 3 Assessment

SCORING GUIDELINES

Factor 3.1 - Management Strategy and Implementation
Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do manages follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

Factor 3.2 - Bycatch Strategy
Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

Factor 3.3 - Scientific Research and Monitoring
Considerations: How much and what types of data are collected to evaluate the fishery's impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population assessments must be conducted for target or retained species, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

Factor 3.4 - Enforcement of Management Regulations
Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

Factor 3.5 - Stakeholder Inclusion
Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

Factor 3.1 - Management Strategy And Implementation

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Highly effective
The British Columbia green and red sea urchin fisheries operate and are assessed and managed at different spatial scales due to logistics and market demand, rather than any conservation concerns (Lochead et al. 2019)(DFO 2021b) (DFO 2021)(DFO 2021c).

The green urchin fishery is limited-entry. Management defines harvest reference points based on stock model-estimated maximum sustainable yield (MSY). These are operationalized in the form of annual total allowable catches (TAC), which are divided into individual quotas among license holders. Fisheries-independent surveys are conducted regularly (every 2 to 3 years) and used to revise reference points and quota options. Quotas are generally reviewed every 3 years. There is some evidence that management is effective: stock abundances are stable or increasing, and population size structure is being maintained (DFO 2021). Management strategy and implementation in this fishery is scored highly effective, because there are appropriate targets and management strategies that are based on scientific advice, and there is evidence of effectiveness.

The red urchin fishery is larger than the green urchin fishery and is assessed and managed differently. Recent reference points were suggested for red sea urchin in British Columbia waters (Lochead et al. 2019). Management specifically aims to maintain current levels of sea urchin biomass. This is a limited-entry fishery. Fishing mortality is controlled through TACs, which are set using fishery-independent survey data and a surplus production model. TACs are reviewed and set annually. Size limits on harvested individuals are designed to be precautionary and allow mature individuals to spawn for several years before entering the fishery; market preferences also provide some *de facto* protection for the largest (>14 cm) and most fecund individuals. DFO considers this "reserve" of sublegal and very large individuals as an additional buffer in managing the fishery. Time-series data from two index sites suggest that harvesting at close to 100% of quota has been sustainable (DFO 2021c). Management strategy and implementation in this fishery is scored highly effective, because there are appropriate targets and management strategies that are based on scientific advice, and there is evidence of effectiveness.

Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia
Northwest Atlantic | Towed dredges | Canada | New Brunswick

Moderately Effective
Sea urchin fisheries in Atlantic Canada are managed with a mix of measures designed to limit effort or protect the stock, but their overall effectiveness is uncertain. This factor is scored moderately effective.
Justification:
New Brunswick

This is a limited-entry fishery. The fishery uses annual quotas to control fishing mortality, though these are based on dated population assessments (1992 to 1994 diver surveys). DFO monitors catch per unit effort (CPUE) annually, and has implemented multiple reductions in total allowable catch (TAC) in response to CPUE decreases in one fishing zone (A38). Any overage in TAC is subtracted for the next year's TAC. There are also areas closed to harvesting, which are expected to protect reproductive stock (DFO 2010a)(DFO 2010b). But, the most recent assessment of LFA 36 indicated that the TAC may allow a harvest rate that exceeds the rate approved in 1996, and no change in TAC has taken place since that assessment (see Scientific Research and Monitoring below). Because there are insufficient data on stock abundance, the effectiveness of management is uncertain (DFO 2010a)(DFO 2010b).

Newfoundland and Labrador

This is a relatively new commercial fishery and recently published an integrated fisheries management plan (DFO 2019). It is a limited-entry fishery and is primarily managed through area licensing, a limited harvest season, logbook requirements, and minimum size limits. There are no measures in place to explicitly control fishing mortality. No stock assessment information is available for the fishery (Pisces Consulting Ltd. 2014)(DFO 2019).

Nova Scotia

This is a limited-entry fishery and is managed through a limited harvest season and a minimum size limit. Licensing is either by area (county) or by exclusive harvest zones for some license holders (DFO 2011)(DFO 2013), and the stock assessment in 2000 was used to help determine the appropriate number of licenses that the fishery could support (DFO 2000). Some local-scale management may occur within individual exclusive harvest zones (Miller and Nolan 2008), but there are no specific measures in place to control fishing mortality and there are no updated stock assessment data available for the fisheries. Some areas are closed to harvesting, which are expected to protect reproductive stock (DFO 2017), though a possible consequence could be heavier fishery pressure in open areas.

Quebec

This is a limited-entry fishery with license requirements, catch limits (Area 9 and Subarea 8), a maximum number of fishing days (Areas 9 and 11), and seasonal closures (DFO 2020a)(DFO 2020b). Additional measures include a minimum size limit and a limited number of divers per boat (Sainte-Marie and Paille 2020). Because there are insufficient data to directly estimate fishing mortality, fishery management focuses primarily on controlling fishing effort. In Area 9, a limited number of fishing days are allotted for each harvesting license, with a catch limit per fishing day. There are quotas for some areas, but there are no defined management targets to assess the effectiveness of current quotas, and effectiveness is mostly unknown. CPUE is monitored, but it may not be a good correlate of stock abundance for urchin fisheries (Chen and Hunter 2003).

Factor 3.2 - Bycatch Strategy

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin
Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Highly effective
Harvest of sea urchin by divers on scuba is highly selective and produces minimal or no by-catch of nontarget species. Because there is no by-catch or other species landed, by-catch strategy in these fisheries is scored highly effective.

Northwest Atlantic | Towed dredges | Canada | New Brunswick

Moderately Effective
Available data suggest that there are no particular concerns (at the population level) with by-catch in the fishery; however, the fishery is not highly selective (total discards and by-catch species including kelp are >50% of the catch; see Criterion 2). No measures are in place currently to reduce these impacts. Furthermore, DFO considers the available data out of date and plans to improve the monitoring program in the coming years (see Criterion 3.3). This is key to understanding the need for by-catch mitigation measures (of which there are currently none), especially given that by-catch impacts in dredge fisheries are often significant (see the Unknown Bycatch Matrices in Appendix 2 of the Seafood Watch Standard for Fisheries). The license conditions for the drag fishery, which specify that scallop dredges may not be used and that sea urchin dredges are limited in size, may also reduce by-catch impacts: "They are only authorized to fish for sea urchins with sea urchin drag gear. This gear is defined as a type of bottom-contact mobile gear towed in the sea by a vessel and that consists of a bag-like net of steel meshes and twine meshed, having a maximum width steel

frame opening of 1.8 meters (6 feet), with a mouth opening of 10 inches, and the bottom of the drag consisting of a maximum of 3/8" hardened chain to form a chain sweep, and the top of the drag consisting of twine running back to a cod end" (pers. comm., DFO Aug 2018). Until further data are available, by-catch management is scored moderately effective.

Factor 3.3 - Scientific Research And Monitoring

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Highly effective
Management makes use of fishery-independent diver surveys of red and green sea urchin populations, as well as fishery-dependent data such as catch per unit effort (CPUE), which is collected more frequently. These data are incorporated into scientific advice for the fishery, which is peer-reviewed through DFO's Centre for Scientific Advice. Fishing mortality from First Nations and recreational harvests are not monitored, though these are thought to be minor (DFO 2016d)(DFO 2016). Because the fishery collects appropriate data and uses an up-to-date, peer-reviewed stock assessment, scientific research and monitoring is scored highly effective.

Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Towed dredges | Canada | New Brunswick

Ineffective
DFO collects annual data on catch per unit effort (CPUE) for the fishery, though this is not a very good correlate of stock abundance (Chen and Hunter 2003). Fisheries-independent surveys of sea urchin populations have also been conducted for two time periods (early 1990s and early 2000s). These data are used in scientific advice for the fishery, which is peer-reviewed through DFO's Center for Science Advice (DFO 2010a)(DFO 2010b). Although some data on stock abundance are collected and used in scientific advice for the fishery, data are limited and may not be the most appropriate. The last assessments conducted (DFO 2010c)(DFO 2010d) recommended that the next assessment be conducted in 5 years. There has not been an assessment since then (pers. comm., DFO August 2018). Furthermore, the 2010 assessment for LFA 36 found that the total allowable catch (TAC) of 900 metric tons (MT) may be set at a level that allowed a harvesting rate (7.9%) that exceeded the harvesting rate approved in 1996 (6.8%), but a lack of surveying in one area that was fished (Passamaquoddy Bay) made the 7.9% an overestimate (DFO 2010c). The TAC has not been changed since this 2010 assessment (pers. comm., DFO Aug 2018).

In addition, by-catch data for the dredge fishery are more than 10 years old. DFO does plan on further developing observer coverage and port sampling for the urchin and other secondary/small-scale fisheries. For sea urchin specifically, this coverage would have observers look specifically at what percent of the urchin catch is sublegal size and poor quality, and at survivability post-release (pers. comm., DFO Aug 2018).

Although some data related to catch composition, stock abundance, and health are (or have been) collected and analyzed, and there are plans to improve understanding of the impacts of discards, the recommended assessment schedule has not been followed, and too few data are available to determine whether the agreed-upon harvesting rate is being exceeded. For these reasons, research and monitoring is scored ineffective for the New Brunswick fisheries.

Northwest Atlantic | Diving | Canada | Newfoundland and Labrador

Ineffective
Fishing trip and landings data are collected in this fishery, but they are not verified, and do not appear to be used in informing management. There has not been a stock assessment and there is no Precautionary Approach framework for green sea urchin in Newfoundland and Labrador (DFO 2019). Although at-sea observer coverage is a condition of licensing, interviews with harvesters indicate that this has not been carried out in recent years (Pisces Consulting Ltd. 2014). Scientific research and monitoring in this fishery is scored ineffective, because only minimal data have been collected, the target species is unassessed, and regulations to constrain fishing mortality are lacking.

Northwest Atlantic | Diving | Canada | Nova Scotia

Ineffective
Fishing trip and landings data are collected in this fishery, but it is highly unclear if they are used to inform management. The most recent stock report and scientific recommendation is over 15 years old (DFO 2000), and no scientists are currently involved with the fishery (pers. comm., R. Miller 2018). Some informal monitoring may be done by individual fishers within their exclusive zones (Miller and Nolan 2008). Scientific research and monitoring in this fishery is scored ineffective, because there are minimal data used for management.

Northwest Atlantic | Diving | Canada | Quebec

Moderately Effective
DFO collects annual data on catch per unit effort (CPUE) for the fishery, though this is not a very good correlate of stock abundance (Chen and Hunter 2003). Several fisheries-independent surveys of green sea urchin populations have been conducted in harvest areas since 2008, and DFO is trying to secure resources to implement annual surveys. Available data are used to produce peer-reviewed scientific advice from the Canadian Science Advisory Secretariat. There is a mandatory vessel monitoring system (VMS) in place in Quebec, as well as logbook requirements. Conservation Harvesting Plans (CHP) are available for the North Shore subarea and the Gaspe-Lower St. Lawrence subarea. These plans include minimum catch size requirements, subarea quotas, and closed seasons (DFO 2020a)(DFO 2020b). Green sea urchin was last assessed in Quebec waters (Areas 9 and 11) in 2016 using fishery-dependent data (DFO 2016e). Although fishery-independent data were collected in subarea 8E in 2021 (pers. comm., DFO 2022), these data have not yet informed stock assessments.

Scientific research and monitoring in this fishery is scored moderately effective, because some data on stock abundance are collected and used in scientific advice for the fishery, but stock assessments do not contain both fishery-independent and fishery-dependent data.

Factor 3.4 - Enforcement Of Management Regulations

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin

Highly effective
All harvesters are required to make use of an external agency ("service provider") to monitor the times and locations of harvest activity while at sea. Fishing vessels communicate with the service provider before fishing, after fishing, and before landing their catch, to relay this information. Vessels are required to confirm their remaining quota before fishing. Under the dockside monitoring program, all catch is weighed and verified against logbooks by an independent, DFO-certified observer when it is landed at port (DFO 2021)(DFO 2021c). Copies of logbooks and harvest charts for each vessel are submitted to DFO at the end of each month (DFO 2021). Because there is regular enforcement and

independent verification of management measures, the fishery's enforcement of management regulations is scored highly effective.

Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Highly effective
All harvesters are required to make use of an external monitoring agency ("service provider") to monitor the times and locations of harvest activity, and to keep track of remaining quota while at sea. Designated communicators on the fishing vessels keep in contact with the service provider to relay this information. In the north coast, where transshipments occur, the catch is weighed upon transfer to the packer vessel and the amount is relayed to the service provider. Under the dockside monitoring program, this catch weight is verified by an independent, DFO-certified observer when the packer vessel lands the catch at port. A pilot vessel monitoring system (VMS) program is also in place for about half the north coast fishing vessels. In the south coast, urchin harvesters land their own catch at port, and catch weight is verified by a DFO-certified observer. Verified harvest logs are submitted to DFO at the end of each month of fishing activity. Because there is regular enforcement and independent verification of management measures, the fishery's enforcement of management regulations is scored highly effective.

Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Towed dredges | Canada | New Brunswick

Highly effective
All harvesters are required to hail out and hail in to a dockside monitoring company on each fishing trip. Of landings, 50% or 100% are subject to dockside verification. For landings not subject to dockside verification (LFA 36), a record of landings must be submitted to DFO via the dockside monitoring company. Because there is regular enforcement and independent verification of management measures, the fishery's enforcement of management regulations is scored highly effective.

Northwest Atlantic | Diving | Canada | Newfoundland and Labrador

Moderately Effective
All harvesters are required to submit logbooks with recorded landings to DFO. Local buyers and processors of the harvested sea urchin are required to submit sales purchase slips. No dockside verification of landings exists for this fishery, and there is some evidence that unreported landings have occurred each year (Pisces Consulting Ltd. 2014). The fishery's enforcement of management regulations is scored moderately effective, because there is some monitoring of compliance, but there is no independent verification and the effectiveness is uncertain.

Northwest Atlantic | Diving | Canada | Nova Scotia

Highly effective
Harvesters are required to hail-in to a dockside monitoring company before returning to port. A set percentage of all fishing trips are subject to dockside monitoring of landings (20% of trips for Nova Scotia). Records of all fishing trips and landings must be submitted to DFO via the dockside monitoring company (DFO 2011)(DFO 2013). The fishery's enforcement of management regulations is scored highly effective, because there is enforcement and independent verification of management measures.

Northwest Atlantic | Diving | Canada | Quebec

Highly effective
In Area 9, harvesters have a limited number of fishing days, with a catch limit for each fishing day. Fishing activity is monitored with a mandatory vessel monitoring system (VMS), which is required to transmit a signal to DFO every 15 minutes (DFO 2016b), and all landings are verified using a dockside monitoring system. In both Areas 8 and 9, logbooks are mandatory for all harvesters and are submitted to DFO. Because there is regular enforcement and independent verification of management measures, the fishery's enforcement of management regulations is scored highly effective.

Factor 3.5 - Stakeholder Inclusion

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin

Highly effective
Management and planning for the fishery are done through a consultative process, generally involving representatives from DFO, commercial and recreational harvesters, vessel owners, processors, First Nations, and the British Columbia Ministry of Agriculture and Lands. Annual planning meetings are open to the public, and are publicly announced on DFO's fishery notice system. Draft fisheries management plans are made available to all interested parties (DFO 2021). Stakeholder inclusion is scored highly effective, because the fishery's management process is transparent and includes stakeholder input.

Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Highly effective
Management of this fishery involves a consultative process involving representatives from Fisheries and Oceans Canada (DFO), the British Columbia Ministry of Agriculture and Lands, commercial harvesters and vessel owners, and First Nations communities (collectively, the Red Sea Urchin Sectoral Committee). The Committee meets annually to review and advise on management plans, although DFO has final decision-making authority. Participation in stakeholder meetings is open to the public, and meeting announcements are made public on DFO's fishery notice system. There is a clear process for including stakeholder comments and concerns into the process of monitoring fisheries abundances and determining annual quotas (DFO 2021c). Stakeholder inclusion is scored highly effective, because the fishery's management process is transparent and includes stakeholder input.

Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Towed dredges | Canada | New Brunswick

Moderately Effective
Conservation Harvesting Plans (CHP) were developed by DFO in consultation with all fishery license holders. Management measures are reviewed annually with the fishery license holders and other industry members. Stakeholder inclusion for this fishery is scored moderately effective, because the management process is transparent and includes stakeholder input, but may not effectively consider all user groups.

Northwest Atlantic | Diving | Canada | Newfoundland and Labrador

Highly effective
Stakeholder consultation meetings are held annually, before the start of each fishing season, to review the fishery and discuss recommendations and plans for management. This generally includes DFO, harvesters, processors, the

Newfoundland and Labrador Department of Fisheries (DFA), the Canadian Fish, Food, and Allied Workers Union (FFAWU), and any other interested parties {DFO 2007 NL}. Stakeholder inclusion is scored highly effective, because the fishery's management process is transparent and includes stakeholder input.

Northwest Atlantic | Diving | Canada | Nova Scotia

Moderately Effective

Conservation Harvesting Plans (CHP) are reviewed by DFO and industry in consultation with stakeholders, including all license holders (DFO 2011){DFO 2013a}. Stakeholder inclusion for this fishery is scored moderately effective, because the management process is transparent and includes stakeholder input, but may not effectively consider all user groups.

Northwest Atlantic | Diving | Canada | Quebec

Moderately Effective

Regular consultative meetings are held between DFO and industry (primarily harvesters) to review scientific advice and management measures. The consultative process produces Conservation Harvesting Plans (CHP) that are approved by sector directors. Stakeholder inclusion for this fishery is scored moderately effective, because the management process is transparent and includes stakeholder input, but may not effectively consider all user groups.

Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score (factor 4.1 + factor 4.2) and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- ***Score >3.2=Green or Low Concern***
- ***Score >2.2 and ≤3.2=Yellow or Moderate Concern***
- ***Score ≤2.2 = Red or High Concern***

Guiding principles

- Avoid negative impacts on the structure, function or associated biota of marine habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.
- Follow the principles of ecosystem-based fisheries management.

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

FISHERY	FISHING GEAR ON THE SUBSTRATE	MITIGATION OF GEAR IMPACTS	ECOSYSTEM-BASED FISHERIES MGMT	SCORE
Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin	4	0	Low Concern	**Green (4.000)**
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin	4	0	Low Concern	**Green (4.000)**
Northwest Atlantic | Diving | Canada | New Brunswick	4	0	Moderate Concern	**Green (3.464)**
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador	4	0	Moderate Concern	**Green (3.464)**
Northwest Atlantic | Diving | Canada | Nova Scotia	4	0	Moderate Concern	**Green (3.464)**
Northwest Atlantic | Diving | Canada | Quebec	4	0	Moderate Concern	**Green (3.464)**
Northwest Atlantic | Towed dredges | Canada | New Brunswick	1	0	Moderate Concern	**Red (1.732)**

Sea urchins are ideal candidates for ecosystem-based fisheries management because of their key role in community structure (Rogers-Bennett 2007). In other regions, the creation of no-take marine protected areas (MPA) is a recommended tool for managing fishing impacts on red sea urchin (Rogers-Bennett 2007) and, when coupled with kelp restoration, MPAs can increase the reproductive potential of red sea urchin by protecting larger individuals (Claisse et al. 2013). But, this may not be the case in British Columbia, because red urchin overabundances can lead to the creation of urchin barrens (DFO 2021c). Farther south, the high densities of purple sea urchin (*Strongylocentrotus purpuratus*) are largely responsible for overgrazing kelp forests and maintaining urchin barrens (Dudley et al. 2021)(Rogers-Bennett and Catton 2019). In addition, fishing

pressure on urchin predators (e.g., California spiny lobster and California sheephead) is thought to drive trophic cascades in southern California rock reef ecosystems, and decreasing fishing mortality on predators increases the resilience of kelp forests (Dunn et al. 2017). In British Columbia, the presence or absence of sea otters is the driving factor affecting red sea urchin stock levels. Stocks are at artificially high levels in areas without sea otters and at levels too low to support a commercial fishery in areas with sea otters. Sunflower star is an important mesopredator on urchin populations that has been mostly absent since 2014 due to sea star wasting disease; the absence of this important predator has further increased issues with urchin barrens (for both red and green sea urchins). There are a number of factors that may cause kelp forests to convert to alternative stable states, but the likelihood of trophic cascades resulting from the fishery are low, and spatial management is used to protect ecosystem functioning in British Columbia.

It is important to distinguish the ecological roles and the potential impacts of Canadian fisheries for sea urchins on the Pacific coast from those for green sea urchin (*Strongylocentrotus droebachiensis*) on the Atlantic coast. Green sea urchin is the only herbivorous sea urchin in shallow coastal waters in Atlantic Canada (Scheibling 1996), is the only benthic grazer capable of controlling algal abundance in the western North Atlantic (Steneck et al. 2013), and largely determines the structure and dynamics of nearshore rocky ecosystems (Scheibling 1996). Overfishing of this keystone species in Maine led to alternative stable states (Steneck et al. 2013). Therefore, the evaluation of ecosystem-based management is different for the green sea urchin fisheries.

Criterion 4 Assessment

SCORING GUIDELINES

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate
Goal: The fishery does not adversely impact the physical structure of the ocean habitat, seafloor or associated biological communities.

- *5 - Fishing gear does not contact the bottom*
- *4 - Vertical line gear*
- *3 - Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.*
- *2 - Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.*
- *1 - Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 - Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)*
  Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts
Goal: Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.

- *+1 —>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery's footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of 'moderate' mitigation measures.*
- *+0.5 —At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery's footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.*
- *0 —No effective measures are in place to limit gear impacts on habitats or not applicable because gear used is benign and received a score of 5 in factor 4.1*

Factor 4.3 - Ecosystem-Based Fisheries Management
Goal: All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web. Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity. Even non-native species should be considered with respect to ecosystem impacts. If a fishery is managed in order to eradicate a non-native, the potential impacts of that strategy on native species in the ecosystem should be considered and rated below.

- *5 — Policies that have been shown to be effective are in place to protect species' ecological roles and ecosystem functioning (e.g. catch limits that ensure species' abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.*
- *4 — Policies are in place to protect species' ecological roles and ecosystem functioning but have not proven to be effective and at least some spatial management is used.*
- *3 — Policies are not in place to protect species' ecological roles and ecosystem functioning but detrimental food web impacts are not likely or policies in place may not be sufficient to protect species' ecological roles and ecosystem functioning.*
- *2 — Policies are not in place to protect species' ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.*
- *1 — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.*

Factor 4.1 - Impact of Fishing Gear on the Habitat/Substrate

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin
Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

4
Diver harvest of sea urchins is generally done with small, handheld rakes. These tools may make contact with algae and invertebrate communities on rocky reefs in shallow waters (<18 m), but do not drag along the bottom. They do not affect sensitive species such as corals or sponges. The impacts of hand raking have not been formally assessed, but are expected to be very low or negligible (DFO 2021)(DFO 2021c). This results in a score of 4.

Northwest Atlantic | Towed dredges | Canada | New Brunswick

1
Urchin drags are similar to scallop dredges but are smaller and lighter; they are used similarly to scallop dredges, and make contact with rocky ledge and cobble-boulder habitat, including areas with kelp beds and other macroalgae (Wahle 1999). The Maritimes dredge fishery does not overlap with two species of wolffish classified as "Threatened" under Canada's Species at Risk Act (SARA), but fishing by bottom trawl and drag may alter habitat of Atlantic wolffish, a SARA Species of Concern (DFO 2020d). Hard substrates provide the preferred habitat of green sea urchin, though the species is sometimes found on soft bottoms (Sainte-Marie and Paille 2020), but the impacts of urchin drags on bottom habitats in New Brunswick have not been evaluated (DFO 2010d)(DFO 2010c). Although it has been suggested that this

particular fishery primarily operates over mud, sand and mud, and discontinuous bedrock substrates (pers. comm., DFO April 2022), the locations of drag tows have not been available since 2007 due to privacy requirements (pers. comm., DFO May 2022).

Green sea urchin primarily inhabits hard substrates, and there is no updated spatial data on the footprint of urchin drags relative to bottom habitats. The dredge fishery receives a score of 1, because it operates over gravel, cobble, or boulder habitat.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin
Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia
Northwest Atlantic | Towed dredges | Canada | New Brunswick
Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

0
There are no existing measures aimed at limiting gear impacts on habitats. This results in a score of 0.

Factor 4.3 - Ecosystem-based Fisheries Management

Northeast Pacific | Diving | Canada | British Columbia | BC Green Urchin

Low Concern
The fishery does not specifically manage for ecosystem function, but sets conservative reference points to prevent population decreases and thus maintain the current ecological role of sea urchin. DFO believes that current harvesting practices have little impact on the surrounding ecosystem. Area quotas are used to prevent localized depletion of green sea urchin and are revised regularly (DFO 2016); there are numerous permanent closures for red sea urchin harvest in British Columbia waters (see pp. 24–35 of (DFO 2021c)) and green sea urchin harvest (see pp. 15–19 of (DFO 2021)). There are also fishery closures for research purposes, kelp restoration, and in areas affected by sea otter predation (DFO 2021c). In 2017, the Province of British Columbia, First Nations, and stakeholders developed the Pacific North Coast Integrated Management Area (PNCIMA) to provide direction on ecosystem-based management and to develop a marine protected area network (DFO 2021).

Because the fishery uses measures that are expected to protect ecosystem functioning, but there is no assessment of their effectiveness for this purpose, ecosystem-based management is scored a low concern.

Northeast Pacific | Diving | Canada | British Columbia | BC Red Urchin

Low Concern
The fishery does not specifically manage for ecosystem function, but conservative harvest rates are set to avoid any population decreases and thus maintain the current ecological role of sea urchins. Area quotas are used to prevent

localized depletion and are revised annually. With the range expansion of northern sea otter, management has excluded sea otter habitat from many quota areas and reduced the quota amount in others. Managers are currently exploring more spatially explicit, flexible strategies to address both the impacts of sea otter and the impacts of urchin barrens, through the flexible movement of quota (DFO 2016). Because the fishery uses measures that are expected to protect ecosystem functioning, but there is no assessment of their effectiveness for this purpose, ecosystem-based management is scored a low concern.

Northwest Atlantic | Diving | Canada | Quebec
Northwest Atlantic | Diving | Canada | New Brunswick
Northwest Atlantic | Diving | Canada | Newfoundland and Labrador
Northwest Atlantic | Diving | Canada | Nova Scotia
Northwest Atlantic | Towed dredges | Canada | New Brunswick

Moderate Concern
Existing management strategies do not directly account for sea urchin's ecological role, but there are spatial management measures in place in each fishery. Some areas are closed to urchin harvest in New Brunswick (DFO 2010a) (DFO 2010b) and Nova Scotia (DFO 2018b), which allows for the protection of sea urchin populations and ecological function. Elsewhere, there are marine protected areas (MPA) that may protect ecosystem functioning. The St. Anns Bank MPA in Nova Scotia covers an area of 4,364 km^2, with commercial fishing by diving permitted in Zone 2 only (DFO 2020c); the Banc-des-Americains MPA in Quebec covers 1,000 km^2 (DFO 2020c); Eastport MPA in Newfoundland consists of a no-take zone of only 2 km^2 (DFO 2013b); and Gilbert Bay MPA in Labrador covers 60 km^2, but Zones 2 and 3 are open to commercial fishing for any species other than Atlantic cod (DFO 2013c).

Fishery-induced loss of sea urchin's ecological role has caused ecosystem state changes in the similar, neighboring Maine fishery (Steneck et al. 2013), but there are no data on whether this is likely to happen in the fisheries assessed here. Ecosystem-based management is scored a moderate concern, because detrimental ecosystem impacts are possible, there is some ecosystem-based management in place, but stronger policies may be needed to fully protect the ecological role of green sea urchin.

Acknowledgements

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch would like to thank five anonymous reviewers for graciously reviewing this report for scientific accuracy.

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Appendix A: Report Review and Update

Updates to the Canada Sea Urchin Report

This report was reviewed in April 2022 for any significant stock status and management updates to the fishery. None were found that would indicate that the final rating is no longer accurate. But, information updates were added to Criterion 1 (BC green sea urchin) and the Synthesis sections of Criteria 3 and 4.

Overall Recommendations for red sea urchin caught by divers in British Columbia remain unchanged. Information and criterion updates are outlined below.

C1.1: BC red sea urchin upgraded from moderate to low concern, because there is evidence that populations are above target levels.

Overall Recommendations for green sea urchin caught by divers in New Brunswick, Newfoundland and Labrador, Nova Scotia, Quebec, and British Columbia, and green sea urchin caught by dredges in New Brunswick remain unchanged. Information and criterion updates are outlined below.

C4.3: Upgraded from high to moderate concern for the Quebec and the Newfoundland and Labrador fisheries, because detrimental ecosystem impacts are possible but there is some ecosystem-based management in place.