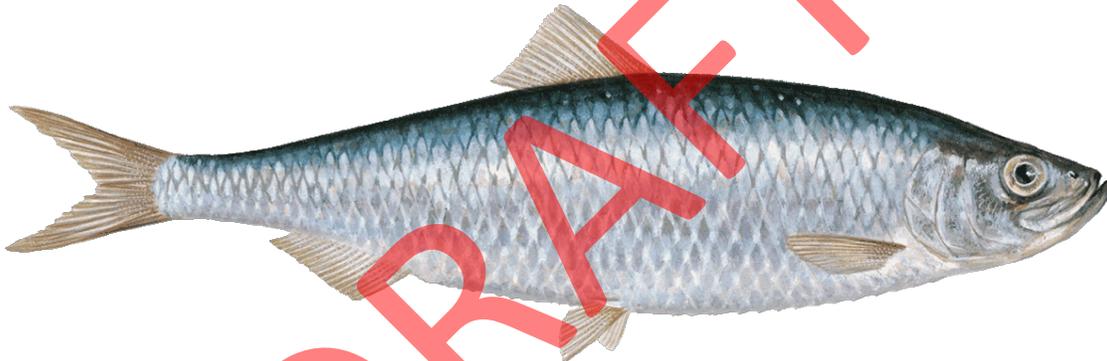




Monterey Bay Aquarium Seafood Watch®

Pacific Herring (British Columbia)

Clupea pallasii



Pacific, Northeast

Purse seines, Set gillnets

Seafood Watch Consulting Researcher

Draft Report - June 2021

Seafood Watch Standard used in this assessment: Fisheries Standard v4

Disclaimer

Seafood Watch strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch program or its recommendations on the part of the reviewing scientists. Seafood Watch is solely responsible for the conclusions reached in this report.

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the ecological 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. Seafood Watch makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. 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.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Watch Assessment. Each assessment synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices," "Good Alternatives" or "Avoid." This ethic is operationalized in the Seafood Watch standards, available on our website here. In producing the assessments, Seafood Watch seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying assessments will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Watch assessments in any way they find useful.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished¹ 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, we develop an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guide 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 overfished, lack strong management or are caught or farmed in ways that harm other marine life or the environment.

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

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Summary

This report provides analysis and recommendations for commercial fisheries for Pacific herring in British Columbia (B.C.), Canada using purse seines and gillnets. Fisheries and Oceans Canada (DFO) manages the fisheries for this key forage fish species. Scores are provided for six herring fisheries that operated in 2021, including: Strait of Georgia food and bait (purse seine), Strait of Georgia roe (purse seine), Strait of Georgia roe (set/anchored gillnet), Central Coast Spawn-On-Kelp (purse seine), Prince Rupert Spawn-On-Kelp (purse seine), and 'non-major stocks' Spawn-On-Kelp (purse seine).

Criterion 1 scored "yellow" for all fisheries, except the 'non-major stocks' Spawn-On-Kelp fishery which was scored "red." Concerns for fisheries that scored yellow included: uncertainty about appropriateness of lower reference points, lack of a designated upper reference point for assessing stock health, and lack of a fishing mortality reference point (or estimate of total fishing mortality). The fishery that scored red targeted stocks/areas that were not included in stock assessments and scored as high concern in a Productivity-Susceptibility Analysis.

Criterion 2 scored "red" for all fisheries. This was due to high concern levels for highly vulnerable species groups defined under the Unknown Bycatch Matrix that may be impacted by B.C. herring fisheries.

Criterion 3 scored "yellow" for all fisheries, except the 'non-major stocks' Spawn-On-Kelp fishery which was scored "red." Concerns for fisheries that scored yellow included uncertainties about management strategies for herring, uncertainties in bycatch impacts and limited bycatch management strategies and limited bycatch data collection. The fishery that scored "red" had an ineffective management strategy and data collection procedures, as well as similar uncertainties about bycatch.

Criterion 4 scored "red" for all fisheries. Herring fishing gear was assumed to have no impact on nearshore habitats where the fishery occurs due to fishing in the water column rather than on the seafloor. However, there is concern in the scientific community that management strategies (harvest control rules, etc.) are not conservative enough to ensure long-term success of herring and dependent predators under variable environmental conditions.

In summary, all six fisheries received overall recommendations of "avoid" (i.e., red).

Final Seafood Recommendations

SPECIES FISHERY	CRITERION 1 TARGET SPECIES	CRITERION 2 OTHER SPECIES	CRITERION 3 MANAGEMENT	CRITERION 4 HABITAT	OVERALL RECOMMENDATION
Pacific herring Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Food and Bait Fishery	2.644	1.732	3.000	3.162	Avoid (2.567)
Pacific herring Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Roe Fishery	2.644	1.732	3.000	3.162	Avoid (2.567)
Pacific herring Central Coast Stock Pacific, Northeast Purse seines Canada British Columbia Central Coast Herring Spawn-on-Kelp Fishery	2.644	1.732	3.000	3.162	Avoid (2.567)
Pacific herring Prince Rupert District Stock Pacific, Northeast Purse seines Canada British Columbia Prince Rupert Herring Spawn-on-Kelp Fishery	2.644	1.732	3.000	3.162	Avoid (2.567)
Pacific herring Minor stock Pacific, Northeast Purse seines Canada British Columbia Minor Stocks Herring Spawn-on-Kelp Fishery	1.732	1.732	1.000	3.162	Avoid (1.755)
Pacific herring Strait of Georgia Stock Pacific, Northeast Set gillnets Canada British Columbia Strait of Georgia Herring Roe Fishery	2.644	1.000	3.000	3.162	Avoid (2.238)

Summary

All fisheries for herring assessed in this report receive an Avoid rating, based on concerns regarding whether the management system adequately takes into account the needs of dependent predators and the potential risk to bycatch species.

Eco-Certification Information

There are currently no Marine Stewardship Council (MSC) eco-certifications for the fisheries included in this report.

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.

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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).

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Introduction

Scope of the analysis and ensuing recommendation

This report addresses the commercial fisheries that target Pacific herring (*Clupea pallasii*) in Canada's Pacific waters. The fisheries included in this report use purse seine or gillnet gear to target Pacific herring for food and bait, roe and spawn-on-kelp. Pacific herring are also caught as bycatch in other fisheries in Canada but must be released; discards in non-directed fisheries were not available and were assumed to be low. Several directed fisheries for Pacific herring that were operated in British Columbia have been closed to fishing over the years due largely to stock declines and management concerns. This report provides recommendations for six Pacific herring fisheries in British Columbia that were open to fishing in 2021, as follows:

- Strait of Georgia Herring Food and Bait Fishery (purse seine)
- Strait of Georgia Herring Roe Fishery (purse seine)
- Strait of Georgia Herring Roe Fishery (set/anchored gillnet)
- Central Coast Herring Spawn-On-Kelp Fishery (purse seine)
- Prince Rupert Herring Spawn-On-Kelp Fishery (purse seine)
- Non-Major Stocks Herring Spawn-On-Kelp Fishery (purse seine) – Areas: 2W, 27, 10, 12

Species Overview

Pacific herring (*Clupea pallasii*; hereafter referred to as "herring") is a pelagic schooling fish distributed around the continental shelf of the North Pacific. Herring range in the western Pacific from Tiksi Bay in Siberia to the Yellow Sea in South Korea and in the eastern Pacific from the Beaufort Sea to San Diego Bay, California (Wespestad and Barton 1979). Most adult herring mix in the open ocean feeding grounds before aggregating in October to December to begin migrating to sheltered bays in British Columbia (B.C.) to spawn (Hourston and Haegele 1980); however, tagging information indicates a smaller percentage of adult herring may remain in the vicinity of spawning areas year-round rather than migrating to offshore areas {Hay et al. 1999}. Eggs are deposited on vegetation (e.g., kelp) over rocky substrate in waters just below the intertidal zone, typically in depths 6 m or less (up to 25 m) (Hourston and Haegele 1980). The spawning season is January through May, peaking in March and April, and fish may make multiple spawning migrations during their lives (Hay 1985)(DFO 2021a). During 1928-2014, roughly 18% of the B.C. coastline was classified as a herring spawning area, but spawning only occurred in 1.8% of this area in a given year {Hay and McCarter 2015}. Herring reach maturity primarily between ages three and five (DFO 2021a). Herring rarely exceed nine inches but can attain a maximum size of 18 inches; they may live up to eight years in Southeast Alaska and up to 16 years in the Bering Sea (Funk 2007). Fecundity is approximately 20,000 eggs {Rickman et al. 2000}; however, the survival rate is only about one adult per 10,000 eggs, due primarily to predation by numerous species (Hay 1985).

Forage species play an important role in food webs because they: 1) exhibit high connectance to other organisms in the ecosystem and 2) a large amount of energy is channeled through that species (Plagányi and Essington 2014). Based on the level of connectance, Plagányi and Essington (2014) classified herring in B.C. as a forage species. The annual herring spawn in B.C. affects seasonal movements and diets of many predator species, and has been a key part of native Alaskans' diet (DFO 2021a). Predators on herring include seabirds, (especially diving birds such as cormorants and murre), fish (such as salmon, perch, and hake), and several marine mammals (including sea lions and cetaceans) (DFO 2021a).

The Canadian herring fishery is managed by Fisheries and Oceans Canada (DFO). The fishery may target five major stocks and two minor stocks as defined within DFO stock management areas: Haida Gwaii (HG), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SoG), West Coast Vancouver Island (WCVI), Area 2W (Haida Gwaii) and Area 27 (West Coast Vancouver Island) (Figure 1). Two areas (Areas 10 and 12) outside these stocks are also fished commercially for herring in some years. Of note, recent studies on herring genetics indicate the possibility of several populations with spatially and temporally distinct spawning in each DFO stock management area (Petrou et al. 2021)(Beacham et al. 2008). DFO conducted a stock assessment for all major herring stocks in 2018 and previously in 2014, with annual stock status updates in most intervening years. Areas 2W, 27, 10, 12 are not included in stock assessment modeling. A recently developed Integrated Fishery Management Plan (IFMP) for herring in B.C. establishes DFO management strategies for 2020-2021 (DFO 2021a). The IFMP covers several management issues, including: stock assessments, traditional knowledge, cultural and economic values, fishery performance, allocation, shared stewardship with First Nations and other organizations, as well as management objectives and performance criteria.

Commercial herring fisheries consist of three types. Food and bait (FB) fisheries produce whole fish for human consumption or use as bait in other fisheries using purse seines. Roe fisheries harvest female herring to sell eggs for human consumption using gillnets or purse seines. Gillnets are anchored in place with identifying buoys attached and may be fished without monitoring by fishers for up to 12 hours (M. Keefe, personal communications, April 14, 2021). Spawn-on-kelp (SOK) fisheries either harvest kelp with herring eggs naturally deposited (i.e., open ponding method) or catch herring using purse seines and keep them in netted 'pounds' where harvested kelp is suspended on lines for herring to lay eggs, then the kelp and eggs are sold (DFO 2021a)(M. Keefe, personal communication, March 29, 2021). The harvest of giant kelp (*Macrocystis integrifolia*) for SOK operations is carried out under a license issued by the B.C. Ministry of Forests, Lands, Natural Resource Operations & Rural Development (M. Keefe, personal communication, March 29, 2021). Treaty and aboriginal commercial fisheries may occur in some specific management regions. Four modern treaties (Nisga'a, Tsawwassen, Maa-nulth, and Tla'amin) have been ratified in B.C. that includes FSC harvest of fish (DFO 2021a). On the West Coast of Vancouver Island, five Nuu-chah-nulth First Nations have Aboriginal rights to fish for herring. On the Central Coast, Heiltsuk First Nation has an Aboriginal right for commercial SOK herring fishing and typically uses open ponding harvest methods. Food, Social and Ceremonial (FSC) fisheries conducted by First Nations also occur (harvested for community use rather than sold), and may include any of the commercial fishing methods as well as spawn-on-tree boughs (similar to SOK but using tree boughs placed in the ocean) (DFO 2021a). Minimal harvest also occurs by a recreational fishery using dip nets, herring jigs, herring rakes, or cast nets (DFO 2021a). All directed herring fisheries with the exception of FB operate during the main herring spawning period, primarily March and April. FB fisheries can operate

at different times during the year, primarily May-February (M. Keefe, personal communications, March 18, 2021).

In 2019, the B.C. herring fishery was the 11th largest Canadian fishery by volume and 21st largest in value (~\$15 million) (DFO 2021b)(DFO 2021c). In contrast, the Atlantic herring fishery was the fourth largest fishery in Canada by volume in 2019. The commercial B.C. Pacific herring fishery began in the 19th century, quickly expanding into a dry salt fishery for export to Asia before that trade declined in the early 1930s (DFO 2021a). In 1937, a reduction fishery was established to produce fish meal and fish oil (Hourston and Haegele 1980). Landings data were available since 1950 and were variable but relatively high until a peak in 1963 of nearly 260,000 t (Figure 2) (FAO 2021). Landings declined precipitously in the late-1960s and the fishery was then closed entirely due to a combination of overfishing, unfavorable environmental conditions, and a low spawning biomass (DFO 2021a). Landings rebounded somewhat in the late-1970s before beginning a fairly steady decline through 2010, but have since increased slightly and remained fairly stable (FAO 2021). In 2020, the primary B.C. herring commercial fisheries were roe and FB fisheries in SoG (DFO 2021d). The only other B.C. commercial herring fishery in 2020 was a small SOK fishery targeting the CC stock. There were also FSC fisheries conducted by B.C. First Nations in 2020. In 2021, commercial fisheries were planned in SoG, CC, PRD, Area 2W, Area 27, Area 10 and Area 12 (as well as FSC fisheries in some of these areas). Because fisheries on other stocks were not expected to open in the foreseeable future, they were not included in this report.

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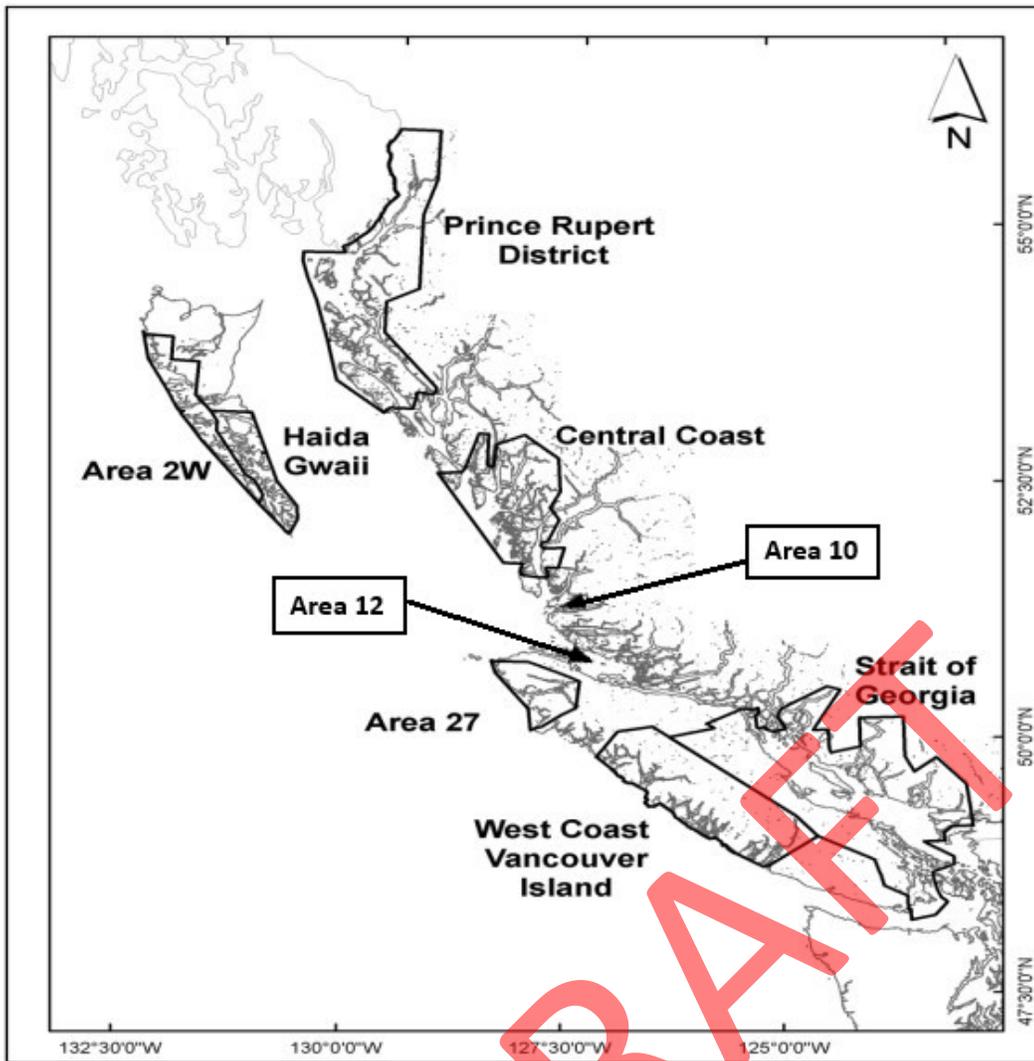


Figure 1: Map of herring fishing areas in B.C. (DFO 2021a)(M. Keefe, personal communication, April 8, 2021).

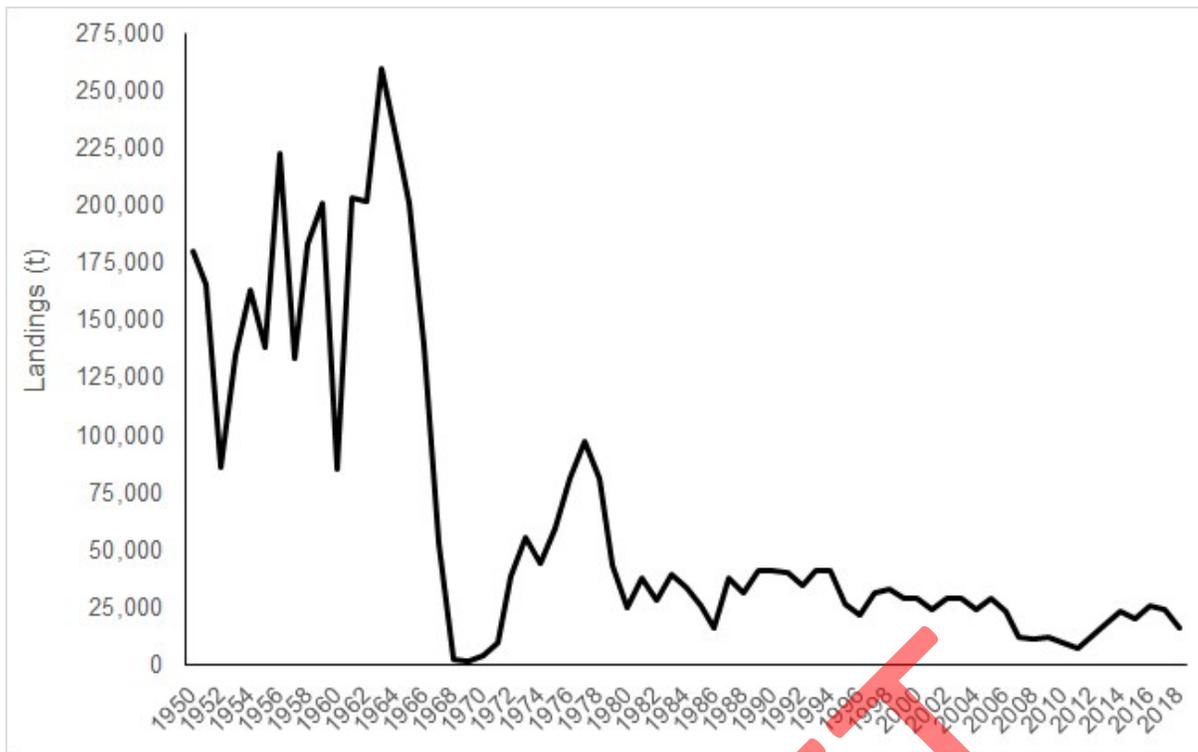


Figure 2: Pacific herring landings in Canada, 1950-2018 (FAO 2021).

Production Statistics

Global production of Pacific herring has experienced several large fluctuations with multiple countries participating in the fishery since landings records became available in 1950 (Figure 3). In 1950-1965, landings were relatively high and occurred mostly in Canada and Japan. In the late-1960s and early 1970s, landings were at the lowest level in the time-series and were mostly in Japan. China began landing fairly large amounts of herring in the 1970s and Canada began to increase landings again slowly. In the early 1980s, landings in Japan, China and Canada declined but increased in the U.S. Since the late-1980s, global landings of Pacific herring generally increased and were dominated by the Russian Federation. Global herring landings during 1950-2018 peaked at more than 530,000 t in 2017 (FAO 2021). Global production has been increasing in 2012-2018, due largely to production by the Russian Federation (FAO 2021). The average contributions to global production in 2014-2018 were 80% from the Russian Federation, 6% from the U.S., 5% from South Korea, 4% from Canada, 3% from China, and 2% from Japan.

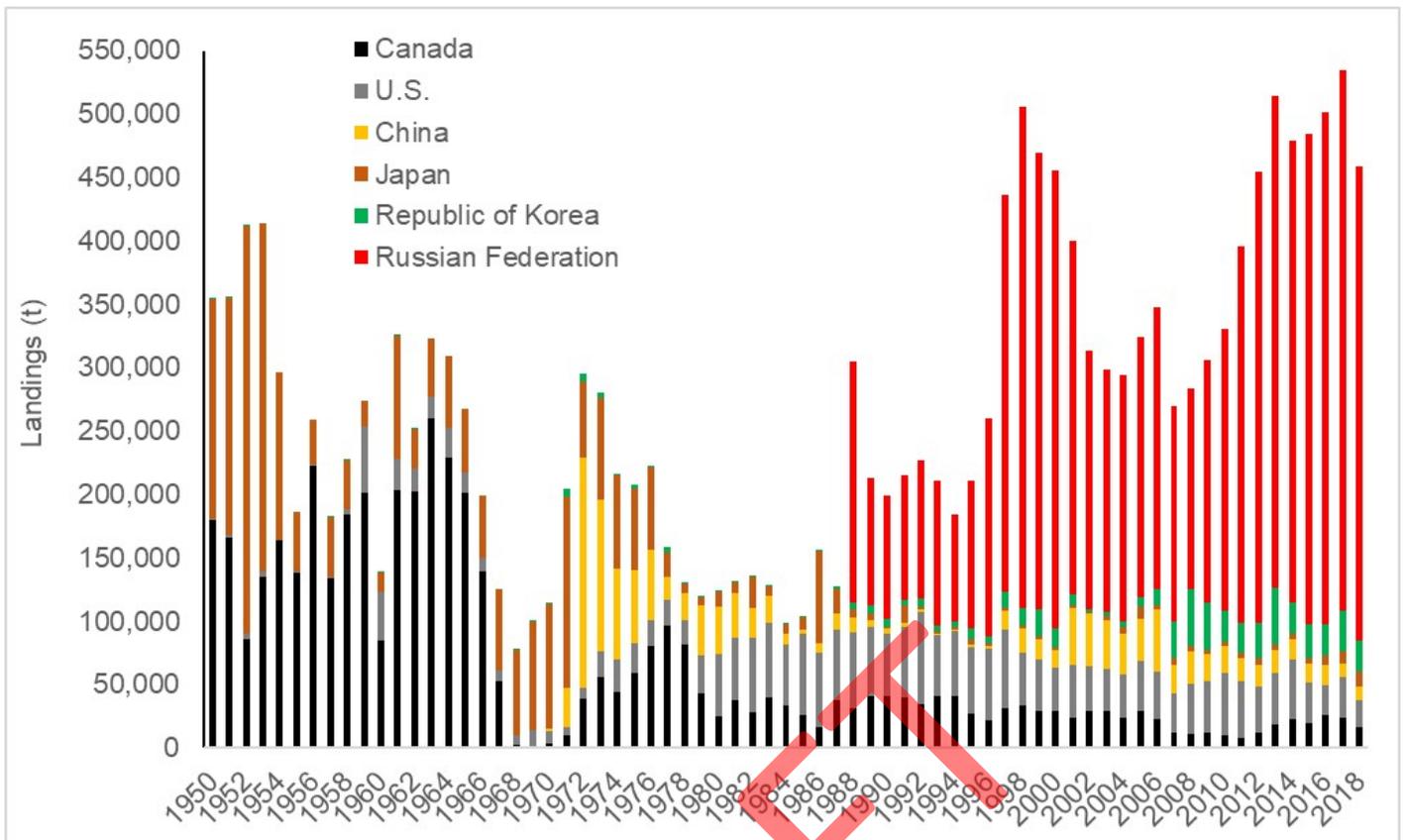


Figure 3: Pacific herring landings by country, 1950-2018 (FAO 2021).

The proportion of landings of the five major B.C. herring stocks has varied since these fisheries began. Prior to 1970, herring landings were very high relative to harvest post-1970 (DFO 2021d). Since the 1970s, catch has generally declined for major herring stocks, except the SoG stock (Figure 3) (DFO 2021d). Since 2010, landings across fisheries have generally increased, although landings in HG and WCVI have not occurred since the early 2000s. Most B.C. herring harvest since 1970 was by gillnet or purse seine for roe (Figures 4 and 5) (DFO 2021d). FB fisheries using purse seine in SoG have also become a larger portion of herring harvest in recent years (Figure 4).

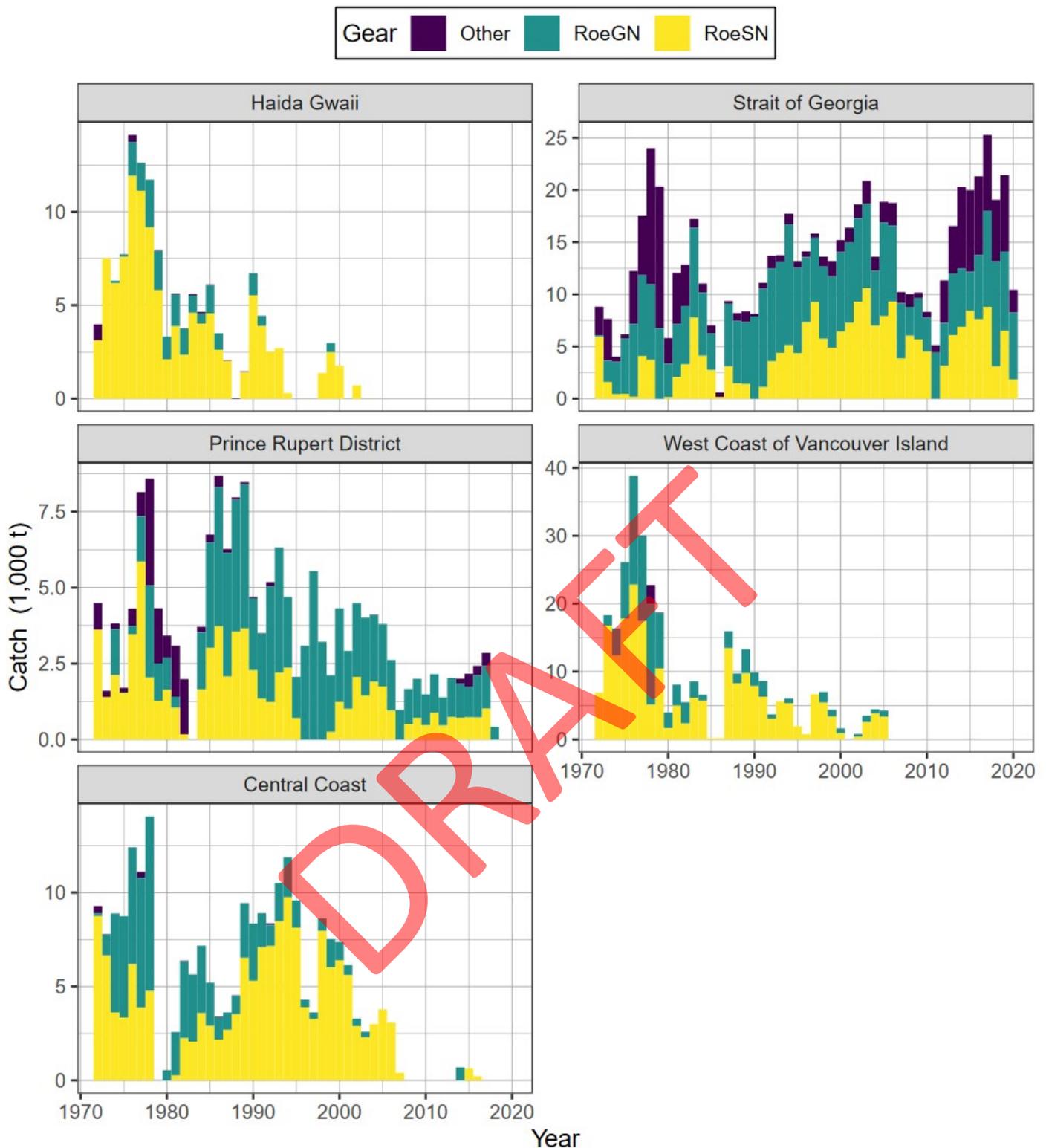


Figure 4: Pacific herring landings in B.C., by herring stock and gear, 1970-2020 (DFO 2021d). 'RoeGN' is herring roe harvested by gillnet, 'RoeSN' is herring roe harvested by purse seine, and 'other' includes all other fisheries primarily herring FB and SOK fisheries using purse seines.

Landings and Landed Value of Herring

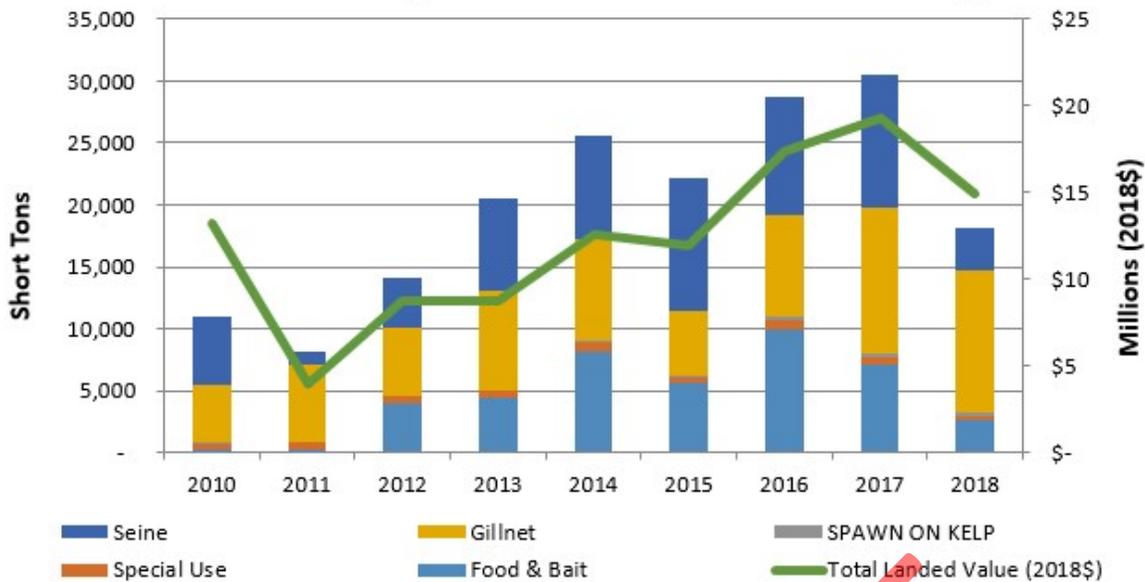


Figure 5: Pacific herring harvest (bars) and value (green line) by gear type, 2010-2020 (DFO 2021a). Special Use gear may include purse seine, gillnet, or other gears. Spawn-On-Kelp fisheries use purse seines for initial harvest and may contain herring within these nets until spawning occurs.

Importance to the US/North American market.

The supply of Pacific herring in the U.S. was not available, as imports and exports are generally referred to as 'herring,' which could be Atlantic or Pacific herring (or other herring species). Approximately 16,410 t of herring of all species were imported to the U.S. from all countries in 2018; approximately 61% (~10,000 t) was from Canada (Pacific and Atlantic herring), and the rest was from a large number of countries (mostly in Europe or Asia) (NOAA 2021). Roughly 1,000 t of Canada Pacific herring were imported to the U.S. from Canada in 2018 (DFO 2021a); the remainder (roughly 9,000 t) of herring imports from Canada were Atlantic herring. The U.S. exported 25,230 t of herring in 2018 (24,488 t of herring exported as whole fish and 652 t of herring roe). U.S. 2018 landings of all sea herring was 145.8 mill lb (66,134 t). Therefore, the supply of all sea herring in the U.S. in 2018 was 57,314 t.

Common and market names.

Market names for Pacific herring include: herring, sea herring, and sild (FDA 2021). Herring eggs are generally referred to as 'roe.' The Haida (a First Nation in B.C.) name for herring is Iinang and k'aaw is the Haida word for herring eggs (Jones 1999). Herring eggs harvested attached to kelp are referred to as spawn-on-kelp (SOK) (DFO 2021a). In Japan, herring SOK is known as komochi konbu (Berberoglu 2021).

Primary product forms

The primary forms for commercial herring are whole fish (for food and bait), roe (eggs), and spawn-on-kelp (DFO 2021a). Roe can be frozen or salted for preservation (DFO 2021a). Spawn-on-kelp (including

both eggs and kelp) is typically packed in brine or frozen for preservation and shipment (Berberoglu 2021). Whole herring are eaten a variety of ways, including: fresh, canned, and smoked.

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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

PACIFIC HERRING			
REGION / METHOD	ABUNDANCE	FISHING MORTALITY	SCORE
Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Food and Bait Fishery	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Roe Fishery	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Central Coast Stock Pacific, Northeast Purse seines Canada British Columbia Central Coast Herring Spawn-on-Kelp Fishery	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Prince Rupert District Stock Pacific, Northeast Purse seines Canada British Columbia Prince Rupert Herring Spawn-on-Kelp Fishery	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

Minor stock Pacific, Northeast Purse seines Canada British Columbia Minor Stocks Herring Spawn-on-Kelp Fishery	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Strait of Georgia Stock Pacific, Northeast Set gillnets Canada British Columbia Strait of Georgia Herring Roe Fishery	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

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.

Pacific herring

Factor 1.1 - Abundance

Central Coast Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Moderate Concern

Reference points for biomass were used to evaluate stock status in the most recent stock status update of the CC herring stock (DFO 2021d). An LRP for this fishery is defined at $0.3SB_0$ {Kronlund et al. 2017}. Four candidate USRs were identified, but a USR has not been selected for evaluating biomass. However, a USR of $0.6SB_0$ ($2*LRP$) was included in the stock status update. Abundance estimates of herring in PRD were derived from a catch-at-age biomass estimation model with fishery-dependent and fishery-independent inputs. An annual herring egg deposition survey is used to estimate a relative index of spawner biomass (i.e., spawn index). Current biomass is high relative to levels since 2010 and has been increasing in recent years, though it remains lower than levels in the 1990s and early 2000s (DFO 2021d). In 2020, the CC biomass was at 37,592 t, equal to 69.9% of SB_0 (53,780 t), which is above the LRP (16,134 t) and the proposed USR (32,268 t).

There was a general increase in the CC spawn index in recent years prior to 2020 (Figure 6)(DFO 2021d).

There is uncertainty in the scientific community regarding the appropriateness of the current LRP for this stock, especially given the lack of an approved USR. The MCC recommended an LRP based on the following idea: $B_t > B_{ave}$ with a 75% or greater possibility under all plausible natural mortality scenarios (PMCC 2021). One concern is the spawning stock biomass time-series estimated for the stock assessment begins in 1951, well after the B.C. commercial fishery began harvesting large amounts of herring (DFO 2021d). Assuming the spawning stock was markedly reduced due to fishing prior to 1951, the LRP may be set lower than it would be if B_0 were known prior to the fishery onset, and if so the stock may not be as healthy relative to historic (pre-1951) levels as indicated by the recent DFO stock assessments (Gray and Scott 2020). There may not be a way to estimate B_0 prior to 1951 as the B.C. herring spawn survey - a key component of the current stock assessment methodology - began in 1951 and other relevant historic stock data may not be available.

Although there are no clear signs the CC herring stock is declining, there is uncertainty regarding the appropriateness of the LRP and a USR has yet to be finalized. Therefore, abundance was considered a moderate concern for this stock.

Justification:

A recent DFO study tested fixed vs. dynamic reference points for use in management of herring and recommended use of fixed reference points as a more conservative approach (Cox et al. 2019).

Minor stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

High Concern

Stock assessments were not completed for the two herring minor stock areas or for the fishing areas outside the major/minor stock areas (Areas 10 and 12). Spawn surveys were completed most years for Areas 2W and 27 (Figure 7). The Area 2W herring spawn estimate was relatively high in 2020, whereas the Area 27 spawn abundance has been declining and was relatively low in 2019 (2020 data were not available) (DFO 2021d). Spawn survey data or other indicators of stock health were not available for Areas 10 and 12. Due to lack of a quantitative or data-limited assessment for these stocks, a Productivity-Susceptibility Analysis (PSA) was conducted that applies to all these areas. Results of the PSA (score = 3.22) suggested herring in these areas has high vulnerability (Table 1).

Based on the PSA results, abundance was considered to be a high concern for herring targeted by these fisheries.

Justification:

Table 1. PSA for herring in Areas 2W, 27, 10 and 12.

Productivity (P) attributes	Relevant information	Score (1=low risk, 2=medium risk, 3=high risk)
Average age at maturity	4 years (typically 3-5 years) (DFO 2021a)	1
Von Bertalanffy (K)	>0.25 (Patrick et al. 2009)	1
Fecundity	20,000 eggs/year - central B.C. and straight of Georgia estimates averaged (Rickman 2000)	2
Average Maximum Size (Lmax)	46 cm {Funk 2000}	1
Average size at maturity (Lm)	20 cm (Rickman 2000)	1
Reproductive Strategy	Broadcast spawner (Funk 2007)	1
Total	$P = (1+1+2+1+1+1)/6$	1.17

Susceptibility (S) attributes	Relevant information	Score (1=low risk, 2=medium risk, 3=high risk)
Areal overlap	Overlap is unknown but likely >30% of the species concentration is fished due to targeting spawning aggregations, bycatch of herring also occurs in other B.C. fisheries at unknown levels	3
Vertical overlap	Overlap is unknown but likely high (i.e., < 33% of species depth range is unfished).	3
Seasonality	Seasonal migrations increase overlap with the fishery (i.e., fishery focuses on spawning aggregations)	3
Selectivity	Fishery targets spawning aggregations	3
Post-capture Mortality	Post-capture mortality rate is not known for this species and fishery. Herring are required to be retained in directed fisheries and survival for any accidental discards is likely low due to abrasion and crowding stress from net gear.	3

Vulnerability score (V)= $\sqrt{P^2+S^2}$

$$V = \sqrt{(1.37+9)}$$

V= 3.22 = High vulnerability

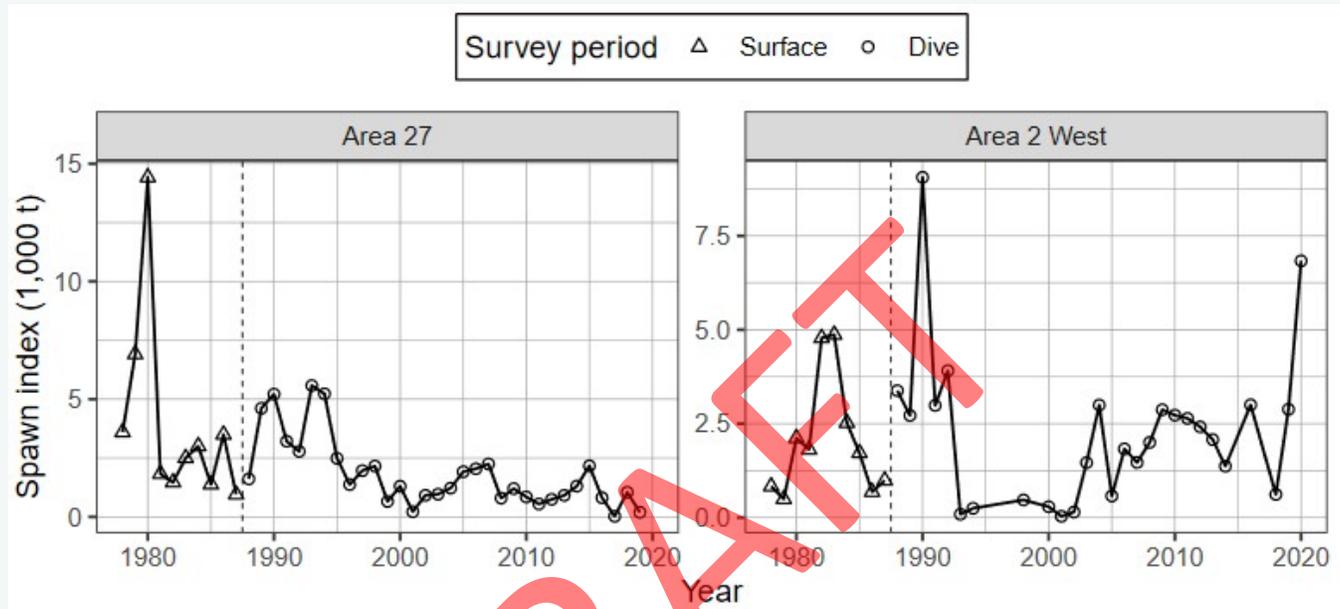


Figure 6: Time series of Pacific Herring spawn index from 1978 to 2020 in the minor stock assessment regions (DFO 2021d). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1978 to 1987), and dive surveys (1988 to 2020). The dashed vertical line is the boundary between these two periods.

Prince Rupert District Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Moderate Concern

Reference points for biomass were used to evaluate stock status in the most recent stock status update of the PRD herring stock (DFO 2021d). An LRP is defined at $0.3SB_0$ {Kronlund et al. 2017}. Four candidate USRs were identified, but a USR has not been selected for evaluating biomass. However, a USR of $0.6SB_0$ ($2*LRP$) was included in the stock status update. Abundance estimates of herring in PRD were derived from a catch-at-age biomass estimation model with fishery-dependent and fishery-independent inputs. An annual herring egg deposition survey is used to estimate a relative index of spawner biomass (i.e., spawn index). Current biomass is high relative to levels since 2010 and has been increasing in recent years, though it remains lower than levels in the 1990s and early 2000s (DFO 2021d). In 2020, the PRD biomass was at 27,552 t, equal to 45.2% of SB_0 (60,955 t), which is above the LRP (18,286 t) and below the proposed USR (36,573 t),

but a USR has not been officially selected. There was a general decline in the PRD spawn index in recent years prior to 2020 (Figure 6).

There is uncertainty in the scientific community regarding the appropriateness of the current LRP for this stock, especially given the lack of an approved USR. The MCC recommended an LRP based on the following idea: $B_t > B_{ave}$ with a 75% or greater possibility under all plausible natural mortality scenarios (PMCC 2021). One concern is the spawning stock biomass time-series estimated for the stock assessment begins in 1951, well after the B.C. commercial fishery began harvesting large amounts of herring (DFO 2021d). Assuming the spawning stock was markedly reduced due to fishing prior to 1951, the LRP may be set lower than it would be if B_0 were known prior to the fishery onset, and if so the stock may not be as healthy relative to historic (pre-1951) levels as indicated by the recent DFO stock assessments (Gray and Scott 2020). There may not be a way to estimate B_0 prior to 1951 as the B.C. herring spawn survey - a key component of the current stock assessment methodology - began in 1951 and other relevant historic stock data may not be available.

Although there are no clear signs the PRD herring stock is declining, the spawn index was declining prior to an increase in 2020. Also, there is uncertainty regarding the appropriateness of the LRP and a USR has yet to be finalized. Therefore, abundance was considered a moderate concern for this stock.

Justification:

A recent DFO study tested fixed vs. dynamic reference points for use in management of herring and recommended use of fixed reference points as a more conservative approach (Cox et al. 2019).

Strait of Georgia Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery
Strait of Georgia Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery
Strait of Georgia Stock | Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Moderate Concern

Reference points for biomass were used to evaluate abundance in the most recent stock status update for the SoG herring stock (DFO 2021d). A static biological limit reference point (LRP) was defined at $0.3SB_0$ (Kronlund et al. 2018). Four candidate upper stock references (USR) were also identified, and a USR of $0.6SB_0$ ($2*LRP$) was included in the stock status update, but a USR has not yet been formally selected for evaluating biomass. Abundance estimates of herring were derived from a catch-at-age biomass estimation model with fishery-dependent and fishery-independent inputs. An annual herring egg deposition survey is used to estimate a relative index of spawner biomass (i.e., spawn index). Current biomass in SoG is high relative to levels since 2010 and has been increasing in recent years, though it remains lower than levels in the 1990s and early 2000s (DFO 2021d). In 2020, the SoG biomass was at 89,869 t, 63.7% of SB_0 (141,081 t), which is well

above the LRP (42,324 t) and the candidate USR (84,648 t). However, uncertainty in the spawning biomass estimates is high for 2020, which may be due to a general decline in the spawn index in recent years prior to 2020 (Figure 6)(DFO 2021d).

There is uncertainty in the scientific community regarding the appropriateness of the current LRP for this stock, especially given the lack of an approved USR. The Pacific Marine Conservation Caucus (PMCC) recommended an LRP based on the following idea: B_t > B_{ave} with a 75% or greater possibility under all plausible natural mortality scenarios (PMCC 2021). One concern is the spawning stock biomass time-series estimated for the stock assessment begins in 1951, well after the B.C. commercial fishery began harvesting large amounts of herring (DFO 2021d). Assuming the spawning stock was markedly reduced due to fishing prior to 1951, the LRP may be set lower than it would be if B₀ were known prior to the fishery onset, and if so the stock may not be as healthy relative to historic (pre-1951) levels as indicated by the recent DFO stock assessments (Gray and Scott 2020). There may not be a way to estimate B₀ prior to 1951 as the B.C. herring spawn survey - a key component of the current stock assessment methodology - began in 1951 and other relevant historic stock data may not be available.

Although there is no clear sign that SoG stock abundance is declining, the spawn index decreased in recent years. Also, there is uncertainty regarding the appropriateness of the LRP (and the overall stock assessment results) and a USR has yet to be finalized. Therefore, abundance was considered a moderate concern for this stock.

Justification:

A recent DFO study tested fixed vs. dynamic reference points for use in management of herring and recommended use of fixed reference points as a more conservative approach (Cox et al. 2019).

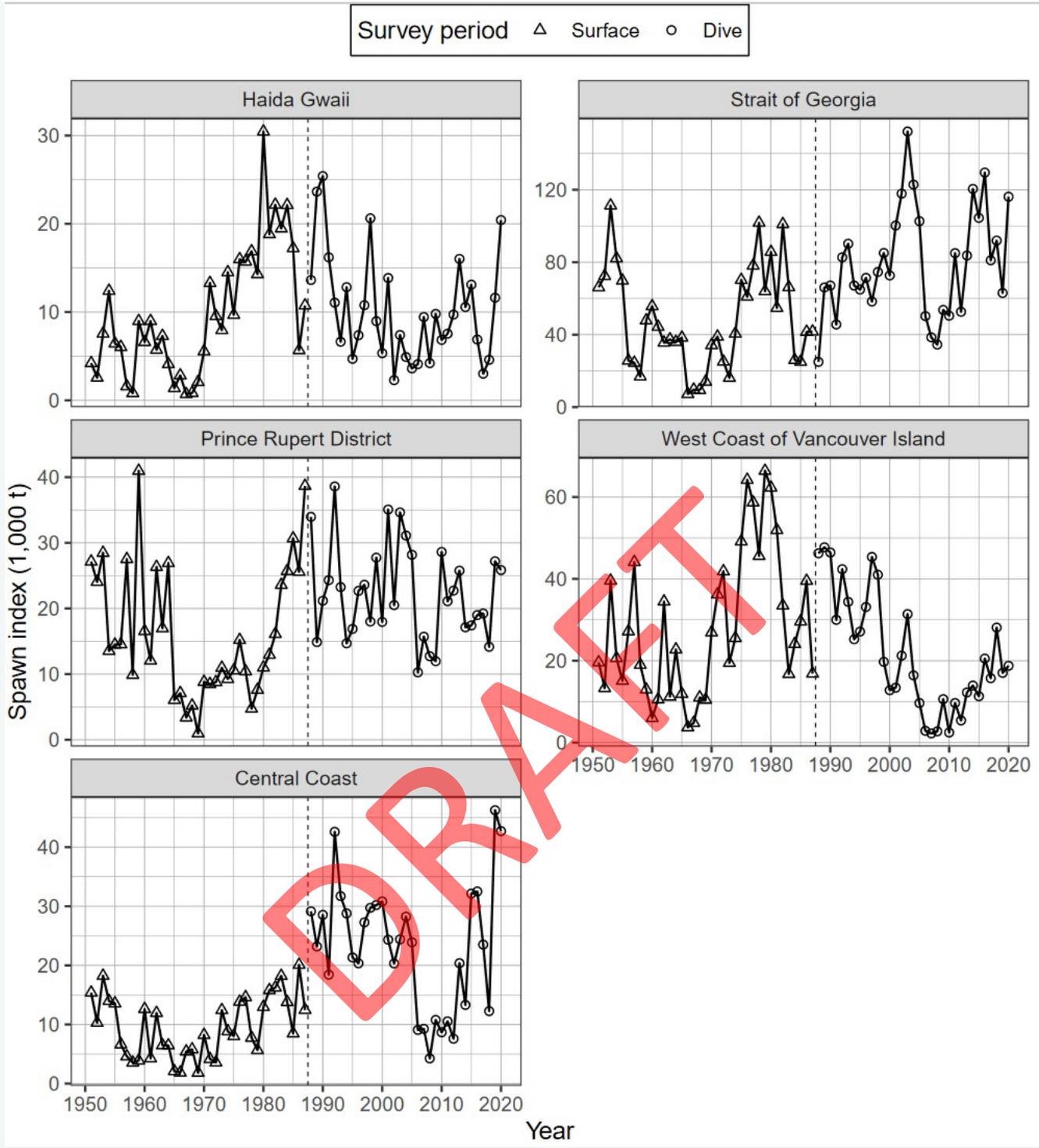


Figure 7: Time series of B.C. herring spawn index from 1951 to 2020 in each of the major stock regions (DFO 2021d). The spawn index has two distinct periods defined by the dominant survey method: surface surveys (1951 to 1987), and dive surveys (1988 to 2020). The dashed vertical line is the boundary between these two periods.

Factor 1.2 - Fishing Mortality

Central Coast Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Moderate Concern

Overall fishing mortality and reference points were not estimated for the CC stock. From 1986 to 2007 the effective harvest rate for this stock fluctuated around, but frequently exceeded, the 20% target harvest rate (DFO 2021d). Following a commercial fishery closure from 2007 to 2013, the CC stock reopened to a small commercial roe fishery in 2014, 2015, and 2016 and the harvest rate was well below 20% (Figure 8). A commercial SOK fishery also operated annually from 2014 to 2020, and the herring IFMP recommended FSC and SOK fishing opportunities only in 2021, up to a maximum of 1,865 tons, equal to a 5% harvest rate [DFO 2021a]. SOK removals as well as recreational and FSC harvest are not included as catch inputs in the stock assessment so overall fishing mortality is currently unknown (DFO 2021a). There are also some discards of Pacific herring in other Canada fisheries, including groundfish fisheries, but estimates were not yet available (M. Keefe, personal communication, April 8, 2021). There is uncertainty in the scientific community regarding the appropriateness of the harvest strategy in this fishery for the future health of the herring stock (Cox et al. 2019)(Gray and Scott 2020) (PMCC 2021).

Although total fishing mortality is not estimate and there is not a fishing mortality reference point appropriate for this stock defined, neither is there a clear signal that overfishing as the estimated harvest rate has been low in recent years. Due to the unknown nature of fishing mortality relative to an appropriate reference point for the stock, this factor was considered a moderate concern.

Justification:

Herring weight-at-age declined steadily for the CC stock from the mid-1980s to 2012 (Figure 9)(DFO 2021d). Declining weight-at-age could be due to fishing effects (i.e., gear selectivity), environmental effects (e.g., changes in ocean productivity), or changes in sampling protocols (e.g., shorter time frame over which samples are collected) (DFO 2021d). Weight-at-age increased for the stock from 2012 to 2020, but it remains well below historic levels. Although weight-at-age declines could be due to factors aside from fishing, it is a potential contributing factor.

Currently DFO does not have a method for validating mortality imposed on the population by the SOK fishery, however methods for estimating SOK mortality are being developed (DFO 2021d).

Minor stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Moderate Concern

Relatively small SOK fisheries are planned in Areas 2W, 27, 10 and 12 in 2021. The 2020-21 DFO IFMP recommended commercial SOK fisheries at a 10% harvest rate, applied to the 2020 spawning biomass. Area 27 was scheduled to have limited opportunity upon request and Area 2W was allowed to harvest up to 753 tons in 2021. Areas 10 and 12 were allowed to harvest up to 135 t and 100 t in 2021. However, fishing mortality is not estimated and reference points were not estimated for herring in these areas. The harvest rate for commercial fisheries targeting these stocks is reportedly determined after providing for FSC needs through consultation with First Nations (M. Keefe, personal communication, April 8, 2021). As a stock forecast is not used for these fishery areas, the harvest rate may be underestimated, as annual herring stock abundance can vary

considerably.

Reference points or estimates of fishing mortality are lacking and there is uncertainty about harvest strategy; however, harvest has been low in these areas. Therefore, fishing mortality was considered unknown and a moderate concern.

Justification:

Currently DFO does not have a method for validating mortality imposed on the population by the SOK fishery, however methods for estimating SOK mortality are being developed (DFO 2021d).

Prince Rupert District Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Moderate Concern

Overall fishing mortality and reference points were not estimated for the PRD stock. Commercial fisheries have occurred annually in PRD since the mid-1980s, with the exception of 2019 and 2020, and the effective harvest rate was estimated to be at or below the 20% harvest rate target in all years except 1989 (Figure 8)(DFO 2021d). For 2021, a harvest rate of 5% (maximum of 1,003 tons) was recommended for this fishery in the herring IFMP (DFO 2021a). SOK removals as well as recreational and FSC harvest are not included as catch inputs in the stock assessment so overall fishing mortality is unknown (DFO 2021a). There are also some discards of Pacific herring in other Canada fisheries, mainly the groundfish fisheries, but these estimates were not yet available (M. Keefe, personal communication, April 8, 2021). There is uncertainty in the scientific community regarding the appropriateness of the harvest strategy in this fishery for the future health of the herring stock (Cox et al. 2019)(Gray and Scott 2020) (PMCC 2021).

Although total fishing mortality is not estimate and there is not a fishing mortality reference point appropriate for this stock defined, neither is there a clear signal that overfishing as the estimated harvest rate has been low in recent years. Due to the unknown nature of fishing mortality relative to an appropriate reference point for the stock, this factor was considered a moderate concern.

Justification:

Herring weight-at-age declined steadily for the PRD stock from roughly 1970 to 2008 (Figure 9) (DFO 2021d). Declining weight-at-age could be due to fishing effects (i.e., gear selectivity), environmental effects (e.g., changes in ocean productivity), or changes in sampling protocols (e.g., shorter time frame over which samples are collected) (DFO 2021d). Weight-at-age increased very slightly for the stock from 2009 to 2020, but it remains well below historic levels. Although weight-at-age declines could be due to factors aside from fishing, it is a potential contributing factor.

Currently DFO does not have a method for validating mortality imposed on the population by the SOK fishery, however methods for estimating SOK mortality are being developed (DFO 2021d).

Strait of Georgia Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Strait of Georgia Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery
Strait of Georgia Stock | Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Moderate Concern

Overall fishing mortality for this stock was not estimated in recent stock assessments. Although most of the fishing mortality occurs in the targeted SoG herring fisheries evaluated in this report, catch input to the stock assessment model does not include mortality from any recreational or FSC harvest (DFO 2021a). There are also some discards of Pacific herring in other Canada fisheries, mainly the groundfish fisheries, but these estimates were not yet available (M. Keefe, personal communication, April 8, 2021).

DFO uses a 20% target harvest rate, based on an independent analysis of stock dynamics that suggested this level will stabilize both catch and spawning biomass (Hall et al. 1988). Harvest in the SoG fishery has fluctuated around the target harvest rate of 20%, dropping below in 2020 (Figure 8)(DFO 2021d). There is uncertainty in the scientific community regarding the appropriateness of a 20% harvest rate in this fishery, for the future health of the herring stock as well as dependent predators (Pikitch et al. 2012) (Cox et al. 2019)(Gray and Scott 2020) (PMCC 2021).

Although total fishing mortality is not estimate and there is not a fishing mortality reference point appropriate for this stock defined, neither is there a clear signal that overfishing as the estimated harvest rate has been low in recent years. Due to the unknown nature of fishing mortality relative to an appropriate reference point for the stock, this factor was considered a moderate concern.

Justification:

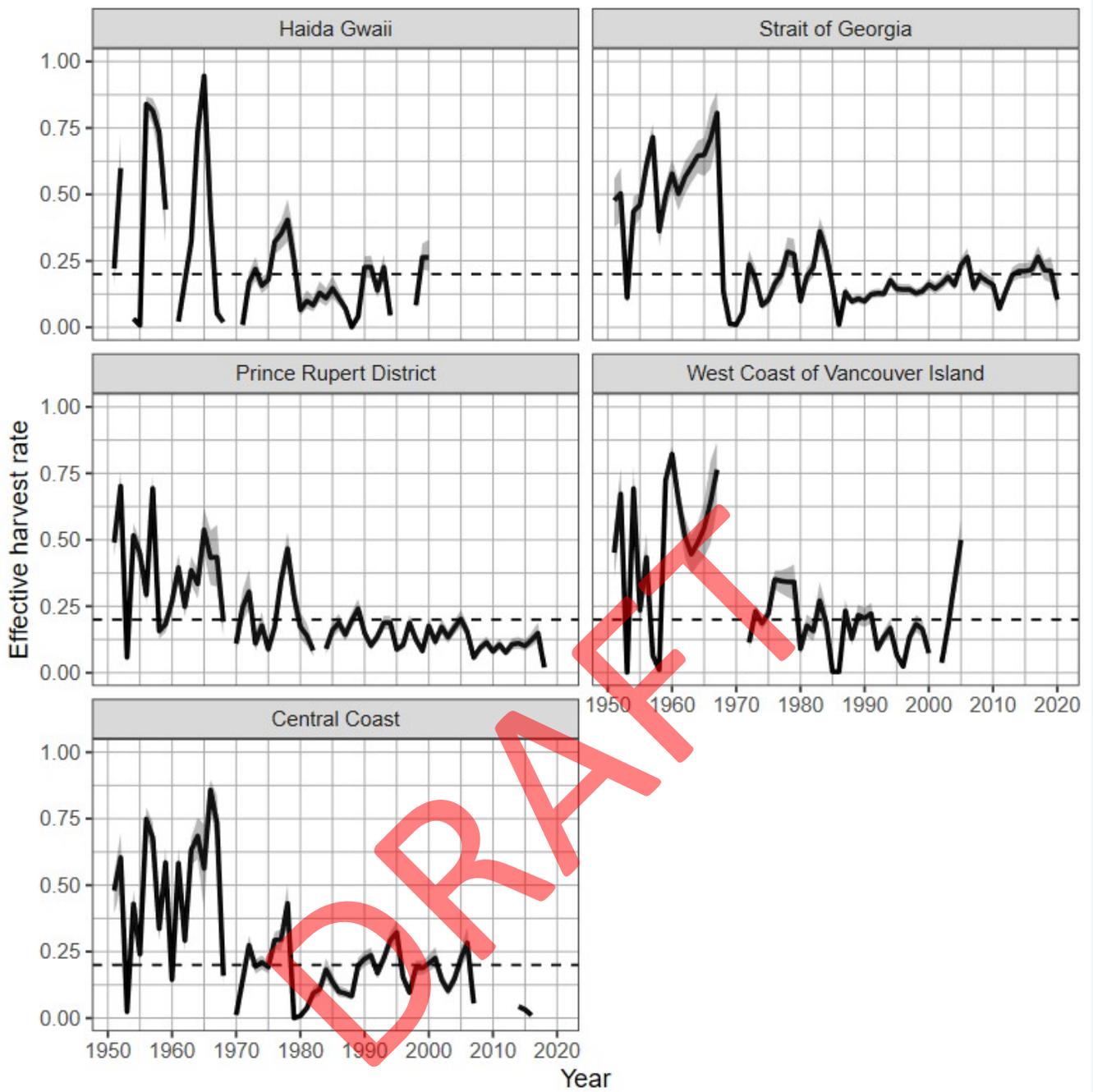


Figure 8: Time series of effective harvest rate for B.C. Pacific herring fisheries from 1951 to 2020 for major stocks (DFO 2021d). Black lines represent median harvest rates and shaded ribbons are 90% confidence intervals. Horizontal dashed lines indicate the target harvest rate of 0.2.

Weight-at-age declined steadily for the SoG stock from roughly 1970 to 2012 (Figure 9)(DFO 2021d). Declining weight-at-age could be due to fishing effects (i.e., gear selectivity), environmental effects (e.g., changes in ocean productivity), or changes in sampling protocols (e.g., shorter time frame over which samples are collected) (DFO 2021d). Weight-at-age increased for the stock from 2012 to 2020, but this metric remains well below historical levels. Although weight-at-age declines could be due to factors aside from harvesting above a sustainable level, this is a potential contributing factor.

DRAFT

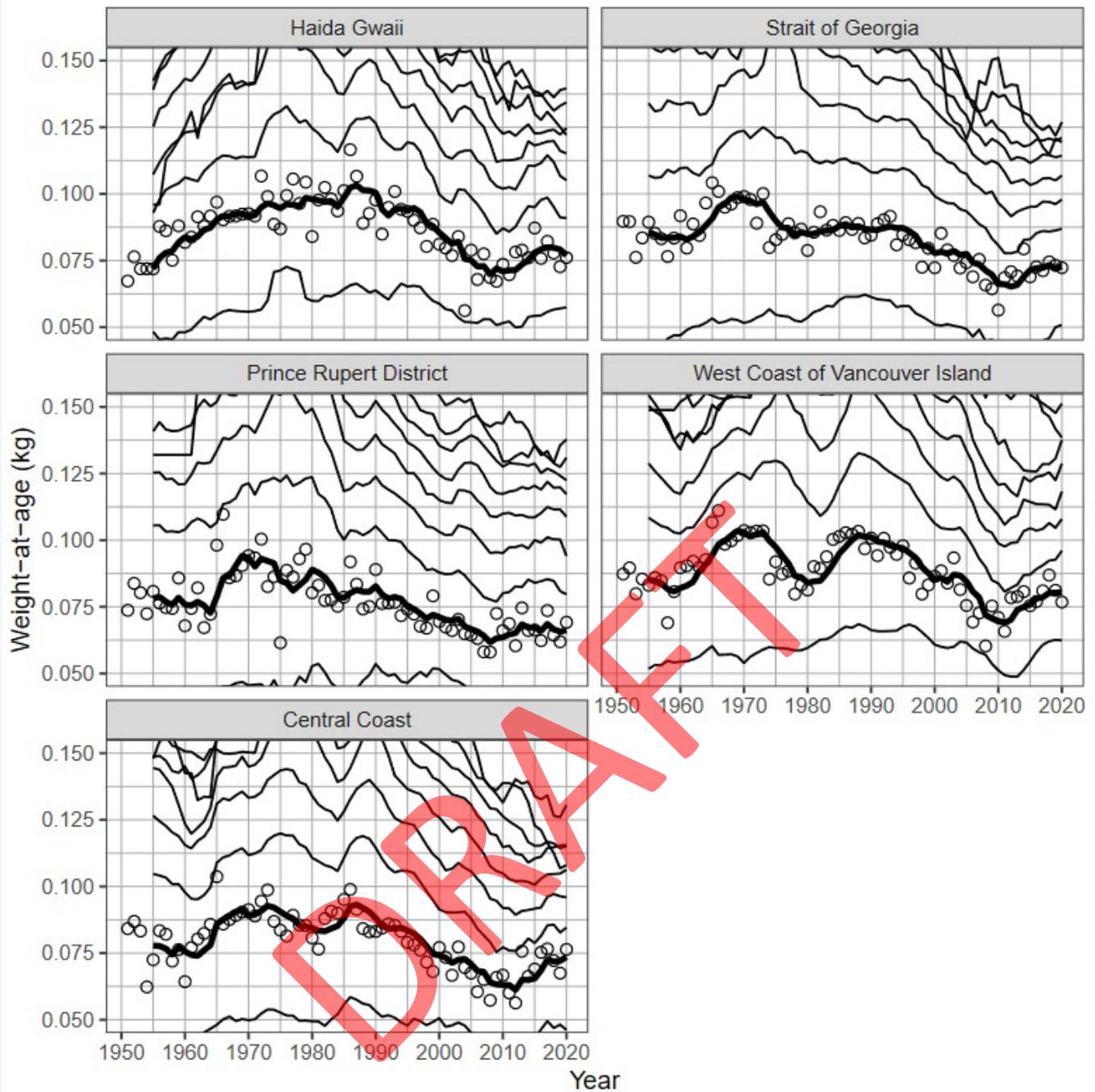


Figure 9: Time series of Pacific Herring weight-at-age in kilograms (kg) for age-3 (circles) and 5-year running mean weight-at-age (lines) from 1951 to 2020 in the major stock assessment regions (DFO 2021d). Lines show 5-year running means for age-2 to age-10 herring (incrementing up from bottom line); the thick black line highlights age-3 herring.

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 Critical

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.

PACIFIC HERRING			
REGION / METHOD	SUB SCORE	DISCARD RATE/LANDINGS	SCORE
Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Food and Bait Fishery	1.732	1.000: < 100%	Red (1.732)
Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Roe Fishery	1.732	1.000: < 100%	Red (1.732)
Central Coast Stock Pacific, Northeast Purse seines Canada British Columbia Central Coast Herring Spawn-on-Kelp Fishery	1.732	1.000: < 100%	Red (1.732)
Prince Rupert District Stock Pacific, Northeast Purse seines Canada British Columbia Prince Rupert Herring Spawn-on-Kelp Fishery	1.732	1.000: < 100%	Red (1.732)
Minor stock Pacific, Northeast Purse seines Canada British Columbia Minor Stocks Herring Spawn-on-Kelp Fishery	1.732	1.000: < 100%	Red (1.732)

Strait of Georgia Stock Pacific, Northeast Set gillnets Canada British Columbia Strait of Georgia Herring Roe Fishery	1.000	1.000: < 100%	Red (1.000)
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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.

PACIFIC, NORTHEAST PURSE SEINES CANADA BRITISH COLUMBIA CENTRAL COAST HERRING SPAWN-ON-KELP FISHERY			
SUB SCORE: 1.732		DISCARD RATE: 1.000	SCORE: 1.732
SPECIES	ABUNDANCE	FISHING MORTALITY	SCORE
Marine mammals	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sharks	1.000: High Concern	5.000: Low Concern	Yellow (2.236)
Forage fish	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Pacific herring	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

PACIFIC, NORTHEAST PURSE SEINES CANADA BRITISH COLUMBIA MINOR STOCKS HERRING SPAWN-ON-KELP FISHERY			
SUB SCORE: 1.732		DISCARD RATE: 1.000	SCORE: 1.732
SPECIES	ABUNDANCE	FISHING MORTALITY	SCORE
Marine mammals	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Pacific herring	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sharks	1.000: High Concern	5.000: Low Concern	Yellow (2.236)
Forage fish	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

PACIFIC, NORTHEAST PURSE SEINES CANADA BRITISH COLUMBIA PRINCE RUPERT HERRING SPAWN-ON-KELP FISHERY			
SUB SCORE: 1.732		DISCARD RATE: 1.000	SCORE: 1.732
SPECIES	ABUNDANCE	FISHING MORTALITY	SCORE
Marine mammals	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sharks	1.000: High Concern	5.000: Low Concern	Yellow (2.236)
Forage fish	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Pacific herring	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

PACIFIC, NORTHEAST | PURSE SEINES | CANADA | BRITISH COLUMBIA | STRAIT OF GEORGIA
HERRING FOOD AND BAIT FISHERY

SUB SCORE: 1.732		DISCARD RATE: 1.000	SCORE: 1.732
SPECIES	ABUNDANCE	FISHING MORTALITY	SCORE
Marine mammals	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sharks	1.000: High Concern	5.000: Low Concern	Yellow (2.236)
Forage fish	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Pacific herring	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

PACIFIC, NORTHEAST | PURSE SEINES | CANADA | BRITISH COLUMBIA | STRAIT OF GEORGIA
HERRING ROE FISHERY

SUB SCORE: 1.732		DISCARD RATE: 1.000	SCORE: 1.732
SPECIES	ABUNDANCE	FISHING MORTALITY	SCORE
Marine mammals	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Sharks	1.000: High Concern	5.000: Low Concern	Yellow (2.236)
Forage fish	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)
Pacific herring	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

PACIFIC, NORTHEAST | SET GILLNETS | CANADA | BRITISH COLUMBIA | STRAIT OF GEORGIA
HERRING ROE FISHERY

SUB SCORE: 1.000		DISCARD RATE: 1.000	SCORE: 1.000
SPECIES	ABUNDANCE	FISHING MORTALITY	SCORE
Marine mammals	1.000: High Concern	1.000: High Concern	Red (1.000)
Sharks	1.000: High Concern	1.000: High Concern	Red (1.000)
Finfish	2.330: Moderate Concern	1.000: High Concern	Red (1.526)
Forage fish	2.330: Moderate Concern	1.000: High Concern	Red (1.526)
Seabirds	1.000: High Concern	3.000: Moderate Concern	Red (1.732)
Pacific herring	2.330: Moderate Concern	3.000: Moderate Concern	Yellow (2.644)

Species were included in Criterion 2 if: (1) they represented >5% of total catch from the herring fishery in 2016-2020; (2) they were listed as Endangered, Threatened or Protected (ETP) species and were caught as bycatch in the fishery, or there was evidence of fishing gear causing entanglements, that resulted in mortality at >5% of a sustainable level during 2011-2020 (or the impact of the fishery was

unknown); (3) there was evidence of non-ETP species being impacted by the herring fishery (e.g., caught in nets or incidentally entangled in gear), resulting in >20% of total fishing mortality during 2011-2020 (or the fishing mortality rate was unknown).

DFO indicated bycatch captured in B.C. herring fishing gear is minimal based on observations of 100% of the catch at the dockside as well as at-sea observer (ASO) data from the purse seine FB fishery in SoG (M. Keefe, personal communication, March 18, 2021). However, ASO data were not available for the FB fishery due to confidentiality concerns and ASOs are not typically deployed in the roe (purse seine or gillnet) of SOK fisheries. Independent bycatch studies were not available for this fishery. Encounters with SARA-listed species (e.g., Steller sea lions), other marine mammals, and seabirds may occur in herring fisheries (DFO 2021a). Information describing the scope and severity of these interactions was very limited. Because Steller sea lions are listed as 'special concern' under SARA and it is not clear whether reported interactions with the herring fishery represent a complete estimate for this species and other marine mammals, the Unknown Bycatch Matrix (UBM) was used for scoring bycatch impacts of marine mammals. Due to uncertainty regarding species and numbers of seabirds potentially impacted by the SoG herring gillnet fishery the UBM was used to score impacts to seabirds from the herring gillnet fishery. Based on the UBM, impacts to seabirds from purse seines in the northeast Pacific are low enough that evaluating this group for herring purse seine fisheries (roe, FB, and SOK) in the report is not necessary. The UBM was also used to score sharks as three ETP species are found in B.C. herring fishery areas and may be impacted {COSEWIC 2007}{DFO 2012}. Based on the UBM, impacts to finfish bycatch from purse seines in the northeast Pacific are low enough that evaluating impacts to this group of species for herring purse seine fisheries (roe, FB, and SOK) in the report was not necessary. Although DFO indicated landed bycatch of finfish species (not including herring or other forage fish) is very low, species composition and discards at-sea were unknown and it was unclear whether finfish bycatch represents more than 5% of the catch for herring gillnet fisheries; therefore, finfish were scored using the UBM for the SoG gillnet fishery. Similarly, it was uncertain whether bycatch of other forage fish species (aside from herring) represents more than 5% of the catch for herring gillnet fisheries, and both purse seines and gillnets can impact this group of species; therefore, 'forage fish' were scored using the UBM for B.C. herring purse seines and gillnet fisheries. The UBM scores sea turtles in the North Pacific as a high concern for gillnet fisheries and minimal concern for purse seine fisheries. However, it was determined that the leatherback sea turtle (*Dermochelys coriacea*), the primary sea turtle species found in B.C., is highly unlikely to be present in the B.C. herring fishing areas during typical herring roe gillnet operations in March-April {COSEWIC 2012}. Due to minimal concern for herring purse seine fisheries and lack of overlap with herring gillnet fisheries, sea turtles were not included as a main species or scored using the UBM.

Two species/groups limited scores for Criterion 2:

1. The 'Marine Mammals' group limited scores for all fisheries. Using the UBM, 'marine mammals' were scored as high concern due to the high vulnerability of the taxon in Factor 2.1, and as a high concern for the gillnet fishery and moderate concern for purse seine fisheries based on potential impacts to marine mammals from these gears in the Northeast Pacific (Factor 2.2).
2. The 'Sharks' group limited scores for the herring gillnet fishery. Using the UBM, 'sharks' were scored as high concern due to the high vulnerability of the taxon in Factor 2.1, and as a high concern for the gillnet fishery based on potential impacts to sharks from this gear in the Northeast

Pacific (Factor 2.2).

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

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Finfish

Factor 2.1 - Abundance

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Moderate Concern

Although the species of finfish caught as bycatch in the B.C. herring fishery are unknown, it is not suspected that any of these are ETP species or otherwise species of concern. In this case, applying the UBM results in a score of moderate concern for the 'finfish' group.

Factor 2.2 - Fishing Mortality

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

High Concern

Although DFO indicated bycatch of finfish is low in B.C. herring fisheries, the species and amounts were not available (M. Keefe, personal communication, March 18, 2021). Application of the UBM to the 'finfish' group (not including forage fish species) for midwater gillnets in the northeast Pacific results in a score of high concern.

Forage fish

Factor 2.1 - Abundance

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Moderate Concern

Although the species of forage fish (aside from Pacific herring) caught as bycatch in the B.C. herring fishery are unknown, it is not suspected that any of these are ETP species or otherwise species of concern. In this case, applying the UBM results in a score of moderate concern for the 'forage fish' group.

Factor 2.2 - Fishing Mortality

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Moderate Concern

Although DFO indicated bycatch of forage fish (aside from herring) is low in B.C. herring fisheries, the species and amounts were not available (M. Keefe, personal communication, March 18, 2021). Application of the UBM to the 'forage fish' group for pelagic purse seines in the northeast Pacific results in a score of moderate concern.

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

High Concern

Although DFO indicated bycatch of forage fish (aside from Pacific herring) is low in B.C. herring fisheries, the species and amounts were not available (M. Keefe, personal communication, March 18, 2021). Application of the UBM to the 'forage fish' group for midwater gillnets in the northeast Pacific results in a score of high concern.

Marine mammals

Factor 2.1 - Abundance

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

High Concern

Marine mammal species impacted by B.C. herring fisheries are known to include Steller sea lion, California sea lion, and humpback whale. Other marine mammal species may also be impacted. The overall number and severity of interactions between B.C. herring fisheries and marine mammals is unclear. Due to the high vulnerability of marine mammals to impacts from fisheries, application of the UBM results in a score of high concern.

Factor 2.2 - Fishing Mortality

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Moderate Concern

Encounters with SARA-listed species (e.g. Steller sea lions) and other marine mammals may occur in herring fisheries (DFO 2021a). DFO reports that sea lions have become entangled in fishing gear for the roe and FB fisheries, at times resulting in mortalities; there have also been recorded

instances of humpback whales, sea lions, and seabirds becoming entangled in enclosure webbing in the SOK fishery (DFO 2021a). Since 2011, marine mammal interactions in B.C. commercial fisheries must be reported, and mortalities of sea birds are requested to be reported (DFO 2021a). DFO provided records of 11 sea lion mortalities from 2015-2019, including: 2 Steller sea lions, 1 California sea lion, and 8 unidentified sea lions (M. Keefe, personal communication, March 18, 2021).

As the impact of these fisheries relative to a sustainable level is unknown, the UBM for the 'marine mammals' group for purse seines (non-tuna) in the northeast Pacific has been applied which results in a score of moderate concern.

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

High Concern

Encounters with SARA-listed species (e.g. Steller sea lions) and other marine mammals may occur in herring fisheries (DFO 2021a). DFO reports that sea lions have become entangled in fishing gear for the roe and FB fisheries, at times resulting in mortalities; there have also been recorded instances of humpback whales, sea lions, and seabirds becoming entangled in enclosure webbing in the SOK fishery (DFO 2021a). Since 2011, marine mammal interactions in B.C. commercial fisheries must be reported, and mortalities of sea birds are requested to be reported (DFO 2021a). DFO provided records of 11 sea lion mortalities from 2015-2019, including: 2 Steller sea lions, 1 California sea lion, and 8 unidentified sea lions (M. Keefe, personal communication, March 18, 2021).

As the impact of these fisheries relative to a sustainable level is unknown, the UBM for the 'marine mammals' group for gillnet in the northeast Pacific has been applied which results in a score of high concern.

Seabirds

Factor 2.1 - Abundance

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

High Concern

The seabird species involved, as well as the number and severity of interactions with B.C. herring fisheries and seabirds, is unclear. Due to the high vulnerability of seabirds to impacts from fisheries, application of the UBM results in a score of high concern.

Factor 2.2 - Fishing Mortality

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Moderate Concern

Encounters with seabirds may occur in herring fisheries (DFO 2021a). DFO indicated records of seabird mortalities from the herring fishery were not available at this time due to operational constraints of Environment and Climate Change Canada, the government department responsible for this information (M. Keefe, personal communication, April 14, 2021). Other researchers have indicated a concern regarding seabird interactions in the B.C. herring fishery (D. Wiedenfeld, personal communication, April 14, 2021).

Application of the UBM to the 'seabirds' group for set gillnets in the northeast Pacific results in a score of moderate concern.

Sharks

Factor 2.1 - Abundance

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

High Concern

The shark species involved, as well as the number and severity of interactions with B.C. herring fisheries and sharks, is unclear. Due to the high vulnerability of sharks to impacts from fisheries, application of the UBM results in a score of high concern.

Factor 2.2 - Fishing Mortality

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Low Concern

Three ETP shark species are found in B.C. herring fishery areas and may be impacted by the fishery. The bluntnose sixgill shark (*Hexanchus griseus*) and tope shark (*Galeorhinus galeus*) are listed as 'special concern' in the SARA and are known to feed on herring {DFO 2012}. The basking shark (*Cetorhinus maximus*) is listed as endangered in the SARA, the species is known to feed on herring, and there have been rare reports of entanglements in herring fishery gear {COSEWIC

2007}. Overall impacts from the fishery on these three species were unclear; however, the primary threats to shark species in Canada were determined to be fishery bycatch and entanglements (DFO 2021a).

Application of the UBM to sharks for purse seines (non-tuna) in the northeast Pacific results in a score of low concern.

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

High Concern

Three ETP shark species are found in B.C. herring fishery areas and may be impacted by the fishery. The bluntnose sixgill shark (*Hexanchus griseus*) and tope shark (*Galeorhinus galeus*) are SARA-listed as 'special concern' in and are known to feed on herring {DFO 2012}. The basking shark (*Cetorhinus maximus*) is SARA-listed as endangered, the species is known to feed on herring, and there have been rare reports of entanglements in herring fishery gear {COSEWIC 2007}. Overall impacts from the fishery on these three species were unclear; however, the primary threats to shark species in Canada were determined to be fishery bycatch and entanglements (DFO 2021a).

Application of the UBM to the 'sharks' group for set gillnets in the northeast Pacific results in a score of high concern.

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Factor 2.3 - Discard Rate/Landings

Strait of Georgia Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Strait of Georgia Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Central Coast Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Prince Rupert District Stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Minor stock | Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Strait of Georgia Stock | Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

< 100%

Catch of non-herring species in B.C. herring fisheries is reportedly minimal with 100% dockside observation of landings (M. Keefe, personal communication, 2021). Bycatch data (including discards at sea) were not available for generating estimates. Herring caught in directed B.C. fisheries are required to be landed so there are no discards of herring aside from fish that accidentally fall out of nets during operations etc. (M. Keefe, personal communication, 2021). Although the roe fishery only uses female herring, the males caught in this fishery are used for other purposes (pet food etc.) and therefore are not considered discards. It is unknown whether any species caught in herring fisheries are discarded at sea.

The discards to landings ratio is unknown for this fishery, but based on personal communication with DFO, bycatch was assumed to be <100% of herring landings.

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	DATA COLLECTION AND ANALYSIS	ENFORCEMENT	INCLUSION	SCORE
Pacific, Northeast Purse seines Canada British Columbia Central Coast Herring Spawn-on-Kelp Fishery	Moderately Effective	Moderately Effective	Moderately Effective	Moderately Effective	Moderately Effective	Yellow (3.000)

Pacific, Northeast Purse seines Canada British Columbia Minor Stocks Herring Spawn-on-Kelp Fishery	Ineffective	Moderately Effective	Ineffective	Moderately Effective	Moderately Effective	Red (1.000)
Pacific, Northeast Purse seines Canada British Columbia Prince Rupert Herring Spawn-on-Kelp Fishery	Moderately Effective	Yellow (3.000)				
Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Food and Bait Fishery	Moderately Effective	Yellow (3.000)				
Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Roe Fishery	Moderately Effective	Yellow (3.000)				
Pacific, Northeast Set gillnets Canada British Columbia Strait of Georgia Herring Roe Fishery	Moderately Effective	Yellow (3.000)				

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 managers 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

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Ineffective

The management strategy for minor herring stocks (Areas 2W and 27) and fisheries outside the minor and major stocks (Areas 10 and 12) is less developed than for major stocks. These stocks/areas are not included in stock assessment modelling and, as such, do not have defined reference points for biomass/abundance. A target harvest rate is set prior to the fishing season by managers, in the past this rate has varied (up to 20%) but for 2021 the target harvest rate was 10% (DFO 2021a). A spawn index is calculated for Areas 2W and 27 (Figure 7), but a forecast for the following year is not provided. After providing for FSC needs, proposed commercial SOK harvest levels are decided by DFO after consultation with First Nations and commercial fishery representatives (M. Keefe, personal communication, April, 8, 2021). It is unknown whether the current 10% harvest rate is appropriate to provide sufficient buffers for the relevant herring stocks and dependent predators. The status of these herring stocks is also unknown and abundance may be declining in some cases based on spawn survey data.

The fishery lacks management measures that are expected to be effective for ensuring the health of herring in these fishing areas. Therefore, the management strategy was considered ineffective.

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Moderately Effective

Pacific herring in SoG, CC, and PRD are assessed and managed by DFO separate stocks (one in

each area); however, research has indicated there may be multiple stocks (or substocks) in these areas (The Salish Sea Pacific Herring Assessment and Management Strategy Team 2018). Research suggests unique substocks or populations could exist within these stocks, at the level of bays or inlets. For example, herring that spawn later in the year at Metlakatla are currently included in the PRD management area, and they spawn in locations very similar to those of the much more prevalent primary-spawning stock (Beacham et al. 2008). This later spawn timing has provided enough reproductive isolation for genetic differentiation to occur (Beacham et al. 2008). Genetic differentiation of herring within SoG and CC based on spawn timing has also been found (Okamoto et al. 2018)(Petrou et al. 2021). Genetics and tagging data indicate a mix of “resident” and “migratory” herring in these areas (Beacham et al. 2008)(Hay et al. 1999). This population structure may increase the vulnerability of herring to unintentional overexploitation by fisheries targeting more abundant populations/stocks within a region (Keeling et al. 2017)(Okamoto et al. 2018)(Petrou et al. 2021). Temporal population structure may be vulnerable to fisheries targeting early spawners also incidentally exploit smaller late-spawning populations (Petrou et al. 2021).

Management is similar for the five B.C. fisheries that targeted major herring stocks in 2021. Annual Pacific Herring IFMPs are developed by DFO that encompass all B.C. herring populations. The most recent IFMP was released in 2021, and describes a variety of management issues for the stocks and fisheries (DFO 2021a). A LRP ($0.3B_0$) has been in use since 2017. Proposed USRs have been developed, although they have not yet been implemented for management of B.C. herring stocks. Although fishing mortality reference points are not currently in use for management, harvest control rules (HCRs) have been in place since the 1980s for these stocks. The HCR includes target harvest rates and a commercial fishing threshold that ceases fishing once the stock falls below a certain biomass level (DFO 2016). Under the HCR used through 2018 for this fishery, a 20% harvest rate was applied if the projected spawning biomass was above a threshold of 25% of the unfished spawning biomass (SB_0) in the next fishing year (Hall et al. 1988)(DFO 2021a). The 20% harvest rate was based on an analysis of stock dynamics, which indicated this rate would stabilize catch and spawning biomass over the long term (Hall et al. 1988). Based on the HCR, the harvest rate can be lowered as the estimated biomass approaches reference points. In recent years, DFO scientists and studies by independent researchers have suggested the HCR was not necessarily effective at preventing stock declines under a variety of environmental conditions (i.e., conservation buffers were not sufficient) (DFO 2016)(Surma et al. 2018)(Cox et al. 2019). Additionally, studies have found that fishing at 100% F_{MSY} led to collapse in some forage species (Pikitch et al. 2012); some B.C. herring stocks may currently be fished at or near 100% F_{MSY} , but this is uncertain given currently available information.

DFO is currently evaluating the performance of HCRs for herring, using closed-loop feedback simulations through a Management Strategy Evaluation (MSE) process (DFO 2021a). Objectives that includes LRPs, USRs, and Target Reference Points (TRPs) are being developed by DFO in coordination with stakeholders to meet management goals and ensure consistency with the DFO Precautionary Approach Framework. During development of the 2021 DFO herring IFMP, stakeholder input included recommendations for lower target harvest rates (below 20%) and lower LRPs in B.C. herring fisheries (PMCC 2021). The 2021 IFMP recommended no change in the LRP

and a 20% harvest rate for SoG fisheries, but also recommended a harvest rate of 5% for PRD and CC stocks. The MSE process identifies a range of management procedures (MPs) that are predicted to keep herring stocks below the LRP with at least 75% probability for PRD, CC, SoG, and WCVI management areas (DFO 2021d). Based on MPs, DFO recommended that the WCVI fishery remain closed in 2021 (DFO 2021a). For the HG herring stock, none of the MPs tested could meet the conservation objective with at least 75% probability so harvest options were not provided for 2021 (DFO 2021a). DFO has committed to developing and implementing a rebuilding plan for HG herring by the end of fiscal year 2020/21, and the HG commercial herring fishery remains closed in 2021 (DFO 2021a). Until the MSE development process is complete and implemented for a period of time, it is not possible to evaluate the success for improving management of herring.

Although there is positive progress being made in developing an effective MSE for herring stocks in B.C, the new MSE has not been fully implemented so success cannot be evaluated. It is not clear that the current harvest strategy is conservative enough to ensure a healthy herring stock under variable environmental conditions. Additionally, although there is a timeline for developing a recovery plan for the HG stock, this plan is not available yet. Despite these concerns regarding management, it is unlikely that the herring fisheries open in 2021 are having serious negative impacts on targeted herring stocks given the current status of these stocks. Based on this situation, the management strategy was considered to be moderately effective.

Justification:

In 2016, testing of the HCR found that modelling assumptions in 1988 were likely unrealistic for the herring stocks in B.C. (DFO 2016). DFO survey data and stock assessment results as of 2016 suggested the herring HCR had not performed according to the 1988 predictions for three stocks (HG, CC and WCVI) (DFO 2016). Data indicated herring weight at age was declining and, therefore, the assumption of constant growth rate over time was not valid. Additionally, recent modelling results demonstrated natural mortality varies over time and may have increased in recent years. A recent DFO study compared different LRP and HCR options and found the current DFO management procedure may need to be revised to ensure B.C. herring stocks long-term health (Cox et al. 2019). Based on these findings, DFO began using simulations to test the performance of different HCRs against conservation, biomass, and yield objectives under three natural mortality scenarios. In 2020, the second round of MP evaluations were performed for the SOG and WCVI; one round of evaluations was conducted for HG, PRD and CC stocks in 2019 (DFO 2021d).

The MSE includes four DFO proposed fisheries management objectives, applied to each major stock:

1. Avoid the LRP ($0.3SB_0$) with at least 75% probability over three herring generations (i.e., the 'conservation objective');
2. Maintain spawning biomass at or above the USR ($0.6SB_0$) with at least 50% probability over three herring generations;
3. Maintain average annual variability (AAV) in catch below 25% over three herring generations, and

4. Maximize average annual catch over three herring generations (goal reflecting catch biomass).

Some First Nations, the Herring Industry Advisory Board, the Marine Conservation Caucus, and the Sport Fish Advisory Board have proposed including additional B.C. herring fishery management objectives in the MSE beyond the four listed in the explanation section above. DFO continues to work with coastal First Nations to develop area-specific objectives specific to FSC and commercial fisheries. DFO is also engaging with the herring industry, government, and non-government organizations to describe broader objectives related to conservation, economics, and access.

An forage fish expert review Pikitch et al. (2012) found that a HCR with a 20% biomass limit step function (BSLF), wherein the harvest rate is held constant until biomass declines to 20% B_0 and then is reduced to zero (similar to the B.C. herring HCR), may be problematic for dependent predators and the managed forage fish species. HCRs that had less chance of declines of dependent predators and forage fish stocks had more conservative biomass cutoffs (e.g., 40% B_0) or managed mortality using more conservative upper and lower reference points (Pikitch et al. 2012). The 20% BSLF approach was found to be nearly as risky as using a constant fishing mortality rate with no biomass cutoffs. While the B.C. herring HCR is somewhat more conservative than the modeled 20% BSLF, the similarities are enough to indicate it may not be adequately protective for dependent predators and may be risky for the herring stocks. Pikitch et al. (2012) recommended that managers with access to "intermediate" information about a forage species and the ecosystem should allow fishing mortality at most 50% F_{MSY} and the amount of fish left in the ocean should be at least 40 percent of B_0 ; managers with "high" information should leave at least 30% of B in the ocean. The B.C. herring fishery likely falls between the "intermediate" and "high" information levels according to Table 7.1 in Pikitch et al. (2012), yet the current biomass cutoff is lower than those prescribed for either of those levels. While this expert review did not evaluate the B.C. herring fishery per se, results and recommendations suggest the fishery's HCR may be putting herring and dependent predators at risk of decline.

Factor 3.2 - Bycatch Strategy

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Moderately Effective

B.C. herring fisheries are not known to have large amounts of bycatch; however, bycatch data were not available. A low level of bycatch of finfish (aside from herring) likely occurs in the fisheries.

There are also known interactions with marine mammals and seabirds, and there may be impacts to sharks (DFO 2021a).

The only recorded interactions with marine mammals from the B.C. herring fisheries reported by DFO were 11 sea lion mortalities in 2015-2019 (M. Keefe, personal communication, March 18, 2021). Most of these were unidentified sea lion species, but some were Steller sea lions which are SARA-listed. It is unclear whether these reports represent a full estimate of marine mammals impacts from the B.C. herring fisheries. Impacts to other marine mammals (e.g., humpback whales) have occurred but were not reported by DFO (DFO 2021a). Since 2011, there has been a requirement to report interactions with marine mammals, but the effectiveness of these management measures at reducing interactions is unknown (DFO 2021a).

There may be injuries/mortalities of seabirds in herring fisheries, especially in the SoG gillnet fishery. Large numbers of seabird mortalities have been estimated for the salmon gillnet fishery that operates in the Strait of Georgia and other parts of B.C. (Bertram et al. 2021). Abundance of some seabird species found in B.C. herring fishing areas has been declining, and interactions with fisheries is one of the largest sources of mortality in B.C. (Vilchis et al. 2014)(Bertram et al. 2021). There is a request to report seabird mortalities and a request to avoid setting fishing gear among seabirds, but the effectiveness of these management measures at reducing interactions is unknown (DFO 2021a).

Three ETP shark species are found in B.C. herring fishing areas, including: basking shark, bluntnose sixgill shark, and tope shark. Data are not available to determine potential impacts on ETP shark species from herring fisheries; however, all three ETP species prey on herring and basking shark has been reported entangled in herring fishing gear. A 'Code of Conduct for Shark Encounters' document was developed by DFO in an effort to reduce the mortality of ETP shark species resulting from entanglement and bycatch in commercial, aquaculture, and recreational fisheries (DFO 2021a)(DFO 2021e). The effectiveness of this document in reducing impacts from the herring fishery is unknown.

Ghost gear may be an issue in B.C. herring fisheries, especially in the gillnet fishery, based on limited available literature on this subject (Antonelis 2013)(CETUS 2013). As of 2020, it became a condition of the license for commercial herring harvesters to report lost fishing gear, as well as the retrieval of any lost gear (M. Keefe, personal communication, April 14, 2021). DFO indicates there has been no gear reported as lost from the herring fishery; however, this new rule has not been in effect long enough to determine its effectiveness and to conclude ghost gear is not occurring. The potential impacts of lost gear are also unclear.

Species potentially impacted from herring fisheries include marine mammals, seabirds and sharks. Impacts from the fisheries on these species and the effectiveness of management measures to reduce interactions are unclear. There is also a potential issue with ghost gear, but the severity is uncertain. Based on these considerations, the Bycatch Strategy was considered to be moderately effective.

Factor 3.3 - Scientific Data Collection and Analysis

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Ineffective

Basic information is collected regarding minor herring stocks and fishing areas outside major/minor stock areas (Areas 2W, 27, 10 and 12) in B.C. including landings and, in some locations and years, a spawn survey. This information is not sufficient to determine stock status of these areas and quantitative or data-limited stock assessments were not conducted for these areas. As such, it is not possible to determine whether fisheries occurring in these areas are sustainable.

The main targeted stocks/areas in this fishery are not evaluated through stock assessments, data collection is minimal, and it is not possible to determine the health of these stocks or impacts from fishing. Therefore, scientific data collection and analysis was considered to be ineffective for these areas.

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Moderately Effective

For major herring stocks in B.C., fishery dependent and fishery independent time series of data are used as inputs to the catch-at-age biomass estimation models for herring. Catch and biological samples from commercial fisheries as well as biological samples from the test fishery program, and a herring egg deposition survey (i.e., spawn survey), which is used to estimate a relative index of spawner biomass. In 2010-2020, quantitative stock assessments were completed in 2011, 2012,

2014 and 2018 and annual stock status reports were completed in the intervening years. Peer-reviews of these annual reports occur as needed when the stock assessment model changes, most recently in 2018 (M. Keefe, personal reference, April 27, 2021). Although the largest sources of herring fishing mortality were included in stock assessments, other harvest was not, including: commercial SOK fisheries, FSC fisheries, recreational fisheries and non-targeted fisheries.

100% of herring catches are monitored dockside and bycatch is reportedly very low (Marisa Keefe, personal communication, March 29, 2021). At-sea observers (ASOs) are reportedly required for herring purse seine fisheries in B.C., but data were not available from DFO (due to privacy concerns); however several observed mortalities of sea lions were reported. Any bycatch discarded at sea, and other injuries to marine mammals or seabirds due to fishing operations are unknown. Seabird mortalities commonly occur in B.C. salmon gillnet fisheries {Hamel et al. 2009}(Bertram et al. 2021), but ASO data are not collected in the herring gillnet fishery to confirm whether this is also a source of seabird mortality.

Ghost gear may occur in B.C. herring fisheries. Relevant literature suggests a potential issue with ghost gear, especially from the SoG herring drift gillnet fishery (Antonelis 2013)(CETUS 2013). DFO requires reporting of lost fishing gear as part of the commercial fishing license since 2020 and is developing initiatives to improve tracking and mitigation for ghost gear (M. Keefe, personal reference, April 14, 2021). While lost herring gear has not yet been reported to DFO, it is unclear how much lost gear occurs in B.C. herring fisheries, or what has been done to remove it. Based on limited available information, impacts to species and habitats from ghost gear are not suspected to be high.

Data related to herring stock abundance and health are collected and used in stock assessments and status updates for monitoring and maintaining the major stocks. Bycatch is monitored dockside, but ASO are not deployed for some herring fisheries, and data were unavailable for fisheries with ASOs deployed. Ghost gear that may impact species caught in nets and although mechanisms are in place to track lost gear, efficacy and impacts are unknown as the regulations are relatively new and no lost gear has yet been reported. Based on this information, the scientific research and monitoring of this fishery was considered moderately effective.

Factor 3.4 - Enforcement of and Compliance with Management Regulations

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Moderately Effective

DFO's Conservation and Protection (C&P) program is responsible for enforcing the Fisheries Act and related regulations and legislation (DFO 2021a). Enforcement activities are carried out by Fishery Officers who conduct patrols on land, at sea and in the air. Fishery Officers conduct a range of activities to promote compliance during herring fisheries. These activities include attending industry and herring working group meetings, defining key enforcement concerns with Fisheries Management prior to the commercial fishery, conducting patrols, at sea boardings and plant inspections during the fishery and detailed post season reporting. Additionally, C&P reportedly strives to meet with First Nations groups to build relationships and conduct joint patrols with First Nations fisheries representatives (DFO 2021a).

Although TACs are used for management, the DFO Pacific herring IFMP indicates a moderate to high potential to over-harvest in the roe and FB purse seine and roe gillnet fisheries (DFO 2021a). Additionally, because the roe herring fisheries operate under a pool structure, compliance is difficult to enforce effectively, This poses a potential risk to the stocks, although DFO indicates the risk to overharvesting the overall annual B.C. herring TAC is low. Aside from the potential for overharvest, the only other issue of concern related to compliance is reported non-compliance in some SOK fisheries for fishery monitoring components, including hail requirements (DFO 2021a).

Enforcement appears to be in place for these fisheries, with fairly minimal issues reported.

However, overharvest by individual fisheries (above TACs) is reportedly possible and may endanger stock health to some degree. Given the importance of a well-enforced TAC to the management strategy, this issue should be high priority for managers to resolve. Based on this information, enforcement was considered moderately effective.

Factor 3.5 - Stakeholder Inclusion

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

Moderately Effective

Consultation for management includes (DFO 2021a): 1) Hold pre-season planning meetings and seek stakeholder and First Nations advice on development of the IFMP allowing up to 30 days for review and feedback on IFMP draft content; 2) Engage in bilateral consultations supported by Tier Two engagement processes with Indigenous communities, and participate in collaborative engagement meetings with First nations from watershed groups and industry to discuss fishing plans and priorities for the management of the fishery; 3) Hold post-season meetings to review issues encountered and to develop options for addressing and resolving them.

In the past, there have been high profile conflicts surrounding commercial herring fisheries, especially in the 2014-2015 fishing seasons. In 2014, five First Nations filed an injunction against the opening of herring fisheries in WCVI, which prevented fisheries in WCVI from being opened (Ryan 2014). In 2015, a CC fishery proceeded, which drew on-the-water action and occupation of a DFO office by Central Coast First Nations (Hume 2015). This fishery was opened due to the decision of the Canada Minister of Fisheries and Oceans to override advice from DFO herring fishery managers. Since 2015, there have not been repeats of conflicts at this level; however, some First Nations continue to express concern about whether some herring stocks can support FSC access and commercial fisheries while ensuring long-term conservation and sustainability. DFO reportedly is continuing efforts to consult and collaborate with First Nations (and others) regarding the management approach for herring. DFO has broadened pre-season and post-season consultation with First Nations to share science and other information for planning purposes. Technical representatives from Indigenous groups and nations also participate in the Herring Technical Working Group, which contributes to the annual stock assessment and forecast.

First Nations, the Herring Industry Advisory Board, the Marine Conservation Caucus (MCC), and the Sport Fish Advisory Board (SFAB) have proposed including additional B.C. herring fishery management objectives in the MSE (DFO 2021a). Additionally, some Canadian conservation groups have ongoing campaigns to reduce or end herring fishing in SoG due to recent declines in this stock

as well as other B.C. herring stocks, to ensure sufficient herring for dependent predators and First Nation FSC harvest (Gray and Scott 2020){Pacific Wild 2021}(PMCC 2021). DFO reports engaging with the herring industry, government, and non-government organizations to describe broader objectives related to conservation, economics, and access (DFO 2021a).

The Integrated Herring Harvest Planning Committee (IHHPC) is the primary stakeholder body providing input and advice to DFO's decision making processes for Pacific Herring fisheries (DFO 2021a). The goal of the IHHPC is to support the development of fishing plans that are coordinated and integrated, to identify potential conflicts, and to make recommendations for resolving disputes. Membership in the IHHPC is comprised of representatives from Indigenous communities coastwide, the Herring Industry Advisory Board (HIAB), the SOK fishery, the Special Use fishery, the MCC, SFAB, the Province of BC, and DFO. Although this is helpful in preventing disputes, the process for resolving disputes that occur is not clear.

Efforts are clearly being made by DFO to increase participation by stakeholders and include input from these groups in the management process for herring. It is not clear what conflict resolution occurs in the management process. There have been serious conflicts in this fishery in the past, and although these issues seem to be somewhat less contentious currently, this could change quickly. Based on this information, stakeholder inclusion was considered moderately effective.

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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	FORAGE SPECIES?	SCORE
Central Coast Stock Pacific, Northeast Purse seines Canada British Columbia Central Coast Herring Spawn-on-Kelp Fishery	5	0	High Concern		Red (3.162)
Minor stock Pacific, Northeast Purse seines Canada British Columbia Minor Stocks Herring Spawn-on-Kelp Fishery	5	0	High Concern		Red (3.162)
Prince Rupert District Stock Pacific, Northeast Purse seines Canada British Columbia Prince Rupert Herring Spawn-on-Kelp Fishery	5	0	High Concern		Red (3.162)
Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Food and Bait Fishery	5	0	High Concern		Red (3.162)
Strait of Georgia Stock Pacific, Northeast Purse seines Canada British Columbia Strait of Georgia Herring Roe Fishery	5	0	High Concern		Red (3.162)

Strait of Georgia Stock Pacific, Northeast Set gillnets Canada British Columbia Strait of Georgia Herring Roe Fishery	5	0	High Concern	Red (3.162)
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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.*

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

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

5

Purse seines and set (anchored) gillnets are used to target spawning aggregations of herring throughout the water column, typically in fairly shallow waters. It was unknown how often these fishing gears contacting the seafloor while targeting herring, but this likely does occur given the shallower waters and vertical distribution of herring. However, a DFO risk assessment did not identify the SoG herring roe and FB fisheries to be a high risk to the benthic habitat (DFO 2021a). Additionally, DFO reports that during the fishery, efforts are made to conduct fisheries in areas which avoid impact to sensitive spawning habitat, such as eelgrass beds (M. Keefe, personal communication, April 8, 2021). For closed ponding methods used in some SOK fisheries, DFO risk assessment found potential for impacts to the benthic habitat in the event of gear contact and/or biofouling of substrate from mortalities and fish waste (DFO 2021a). However, DFO requires that closed ponding enclosure nets remain 3 m above the seafloor at all times (DFO 2021a).

Although gear may contact the seafloor, it is not known to do so commonly, therefore it was considered to be equivalent to gear that does not contact the seafloor and scored as '5.'

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

0

This factor was not assessed for B.C. herring fisheries as Factor 4.1 was scored the highest potential score of '5' for gear that does not contact the bottom.

Factor 4.3 - Ecosystem-based Fisheries Management

Pacific, Northeast | Set gillnets | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Food and Bait Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Strait of Georgia Herring Roe Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Central Coast Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Prince Rupert Herring Spawn-on-Kelp Fishery

Pacific, Northeast | Purse seines | Canada | British Columbia | Minor Stocks Herring Spawn-on-Kelp Fishery

High Concern

Although most of the five major B.C. herring stocks have remained stable or increased in recent years, there remains controversy around the management strategy. Concerns from stakeholders include whether the current LRP is high enough to ensure herring stock health, the appropriateness of the target 20% harvest rate currently being used for the SOG stock, and lack of in-season adjustments to the harvest strategy (PMCC 2021). In 2021, the Pacific Marine Conservation Caucus

(PMCC) recommended a 10% target harvest rate for the SoG FB fishery and a lower LRP (PMCC 2021). The PMCC recommended a LRP based on the following idea: Bt>Bave with a 75% or greater possibility under all plausible natural mortality scenarios. The PMCC suggested that the 20% harvest rate does not take into account reference points, potential stock declines or spatial structure. Regardless of this input, the DFO 2020-2021 IFMP recommended no change to the LRP for herring stocks and a USR has not been approved yet (DFO 2021d). A 20% harvest rate for SoG fisheries (FSC, FB, roe, and special use fisheries), was recommended in the IFMP; however, a 5% harvest rate was implemented for PRD and CC stocks (SOK and FSC fisheries), and a 10% harvest rate was used for minor stocks (SOK fisheries).

There is no indication that the Lenfest Forage Fish Task Force Recommendations, including a harvest rate buffer to account for dependent predators, are being used for management of herring in B.C. (Pikitch et al. 2012). Herring serve a critical, foundational role in the ecosystem, supporting numerous other marine species including: seabirds (especially diving birds such as cormorants and murre), fish (salmon, hake, etc.), and several marine mammals (sea lions, whales, etc.) (DFO 2021a). The current harvest rates used by herring fishery managers are based on mature spawning biomass forecasts, leaving juvenile fish and a proportion of the adult population available to support ecosystem processes. However, a concern raised by several conservation groups, as well as some First Nations, is the portion that remains in the ocean after harvest occurs may not be sufficient for a healthy ecosystem (including supporting dependent predator populations) and that the harvest rate may be too high to prevent herring stock declines (Cox et al. 2019)(Gray and Scott 2020) (PMCC 2021). The fishery also targets herring spawning aggregations, which allows for harvest of large numbers of herring with lower bycatch; however, this can also lead to overharvesting through disruption of spawning and removes large amounts of herring from areas where predators may congregate to feed.

Although detrimental food web impacts could occur due to these fisheries, there is no clear evidence of major food web disruptions occurring in B.C. currently. However, research indicates a decline of diving seabird populations in B.C. (including Straight of Georgia), which depend on forage fish for a large portion of their diet {Vilchis et al. 2014}(Bertram et al. 2021). The factors leading to the lower seabird numbers are not well understood and it is not clear that fishing has caused this decline, but fishing interactions have been identified as one of the largest sources of human-induced mortality for seabirds in B.C. (Bertram et al. 2021).

B.C. herring fisheries currently lack a conservative HCR that is consistent with the Lenfest Forage Fish Task Force Recommendations, with buffers built-in to account for the needs of dependent predators. There is uncertainty among the scientific community about whether LRPs are appropriate given the species ecological role, and USRs have not yet been finalized. The harvest rate is also considered by some stakeholders and researchers to be too high to clearly account for the needs of dependent predators. Therefore, Ecosystem Based Management was considered a high concern for all B.C. herring fisheries.

Justification:

DFO and First Nations are developing a network of marine protected areas (MPAs) which would include areas of the B.C. coast. A stakeholder input has been collected and DFO presented the

report to the MPA Technical Team in March 2020. The planning process is being developed under the policy direction outlined in the National Framework for Canada's Network of MPAs as well as the Canada-British Columbia MPA Network Strategy (Kronlund et al. 2018). Revising the draft MPA scenario will occur during winter 2021, after which there will be further public engagement.

Information on MPA Network Planning can be found at: <http://www.mpanetwork.ca>

Giant kelp (*Macrocystis*) is harvested each year for the B.C. herring SOK fishery. For open-ponding SOK methods, herring spawn on kelp growing in the wild and kelp and eggs are harvested. In closed-ponding, kelp is harvested and suspended on lines in the ocean within netted enclosures containing herring ready to spawn; after spawning occurs the kelp and attached eggs are harvested. Kelp provides important ecosystem functions as shelter and a food source that can enhance species diversity and productivity (Krumhansl et al. 2017). *Macrocystis* can recover from damage to fronds through the growth of new fronds from the holdfast to form a new surface canopy, and growth can be up to 30 cm/day depending on temperature and light levels (Krumhansl et al. 2017). A study of harvesting *Macrocystis* in B.C. at higher rates (90–100% canopy removal) resulting in a decline in kelp biomass after several weeks, while lower harvest (0–15%) resulted in little to no change in biomass after the same time period (Krumhansl et al. 2017). In recent years, harvest of *Macrocystis* in B.C. for the SOK fishery has been 250-400 t (Lindop 2017). The most recent inventory of kelp (2007) measured more than 28,000 t of giant kelp along the central coast of BC (Sutherland et al. 2008). Assuming the giant kelp population has not greatly diminished since 2007, kelp harvest for B.C. SOK fisheries is a very small percentage (<2%) of the overall kelp available in B.C. and likely represents a small impact on the kelp forest and associated biota.

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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.

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