Pacific herring

*Clupea pallasii*

British Columbia
Purse Seine, Gillnet

October 21, 2014
John Driscoll, Consulting researcher

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.
About Seafood Watch®

The Monterey Bay Aquarium Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the North American marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. The program’s mission is to engage and empower consumers and businesses to purchase environmentally responsible seafood fished or farmed in ways that minimize their impact on the environment or are in a credible improvement project with the same goal.

Each sustainability recommendation is supported by a seafood report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program’s sustainability criteria to arrive at a recommendation of “Best Choice,” “Good Alternative,” or “Avoid.” In producing the seafood reports, Seafood Watch utilizes 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 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 seafood reports will be updated to reflect these changes. Both the detailed evaluation methodology and the scientific reports, are available on seafoodwatch.org.

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**Guiding Principles**

Seafood Watch® defines sustainable seafood as originating from sources, whether fished 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 capture fisheries must possess to be considered sustainable by the Seafood Watch program:

- **Stocks are healthy and abundant.**
- **Fishing mortality does not threaten populations or impede the ecological role of any marine life.**
- **The fishery minimizes bycatch.**
- **The fishery is managed to sustain long-term productivity of all impacted species.**
- **The fishery is conducted such that impacts on the seafloor are minimized and the ecological and functional roles of seafloor habitats are maintained.**
- **Fishing activities should not seriously reduce ecosystem services provided by any fished species or result in harmful changes such as trophic cascades, phase shifts, or reduction of genetic diversity.**

Based on these guiding principles, Seafood Watch has developed a set of four sustainability **criteria** to evaluate capture fisheries for the purpose of developing a seafood recommendation for consumers and businesses. These criteria are:

1. Impacts on the species under assessment
2. Impacts on other species
3. Effectiveness of management
4. Habitat and ecosystem impacts

Each criterion includes:
- Factors to evaluate and score
- Evaluation guidelines to synthesize these factors and to produce a numerical score
- A resulting numerical score and **rating** for that criterion

Once a score and rating has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ratings and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

**Best Choice/Green:** Are well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

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

**Avoid/Red:** Take a pass on these for now. These items are overfished or caught or farmed in ways that harm other marine life or the environment.

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1 “Fish” is used throughout this document to refer to finfish, shellfish and other invertebrates.
Summary

This report addresses the commercial fisheries that target Pacific herring in Canada’s Pacific waters. The fisheries included in this report use purse seine and/or gillnet gear to target herring for roe, spawn on kelp, and food and bait. Herring products are primarily destined for export to Japan and China, with a comparatively small fraction exported to the U.S.

The status of the Pacific herring stocks in the five major areas ranges from 'low' concern in Central Coast (CC), Haida Gwaii (HG), and West Coast Vancouver Island (WCVI), where the stocks are showing signs of increasing abundance, to 'very low' conservation concern in Strait of Georgia (SOG) and Prince Rupert District (PRD). Fishing mortality for CC, HG, and WCVI is a matter of greater concern, however, as these stocks' apparent increases in abundance have taken place only over the past one to two years, and also because there are concerns regarding the effectiveness of the herring harvest control rule during periods of low stock productivity.

Bycatch concerns for the herring fisheries are minimal. While the discard rate is not known, it is assumed to be well under 20% of landings.

The management of the Pacific herring fisheries requires improvement on several fronts. Recent research has indicated that the current herring harvest control rule may not be an effective management tool for maintaining healthy stock sizes or rebuilding stocks to $B_{MSY}$ during periods of low productivity. Furthermore, recent events surrounding the opening of commercial fisheries in CC, HG, and WCVI diminish this assessment's scores for the management regime's adherence to science advice and its effective inclusion of stakeholders in decision making.

The fishing gears used in the herring fisheries are purse seine and midwater gillnets. These gears are not expected to cause substantial damage to marine habitats as part of their normal operations. However, the overall score for Criterion 4 is moderated by the current management’s lack of consideration for herring’s role as a vital ecosystem component.

Table of Conservation Concerns and Overall Recommendations

<table>
<thead>
<tr>
<th>Stock / Fishery</th>
<th>Impacts on the Stock</th>
<th>Impacts on Other Spp.</th>
<th>Management</th>
<th>Habitat and Ecosystem</th>
<th>Overall Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Herring: Central Coast - Gillnet, Midwater</td>
<td>Yellow (3.05)</td>
<td>Green (5.00)</td>
<td>Red (2.00)</td>
<td>Green (3.24)</td>
<td>Good Alternative (3.154)</td>
</tr>
<tr>
<td>Pacific Herring: Prince Rupert District - Gillnet, Midwater</td>
<td>Green (3.83)</td>
<td>Green (5.00)</td>
<td>Red (2.00)</td>
<td>Green (3.24)</td>
<td>Good Alternative (3.338)</td>
</tr>
<tr>
<td>Pacific Herring: Strait of Georgia - Gillnet, Midwater</td>
<td>Green (4.28)</td>
<td>Green (5.00)</td>
<td>Red (2.00)</td>
<td>Green (3.24)</td>
<td>Good Alternative (3.432)</td>
</tr>
</tbody>
</table>
### 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, and neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern, and no more than one Red Criterion, and no Critical scores, and does not meet the criteria for Best Choice (above)
- **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 in Canada’s Pacific waters. The fisheries included in this report use purse seine and/or gillnet gear to target herring for roe, spawn on kelp, and food and bait.

Overview of the species and management bodies

Pacific herring (*Clupea pallasii*; hereafter referred to as “herring”), are found from California to Korea (Haegele, C.W. & Schweigert, J.F. 1985). In British Columbia, herring are a key species for both coastal ecosystems and traditional ways of life for the local communities. The annual herring spawn plays an important role in the seasonal movements and diets of seabirds, marine mammals, and fish (see Factor 4.3), and has long provided coastal communities with spawn on kelp, (a delicacy that is a staple of both diets and trade). Juvenile and adult herring are important prey for a number of other species (see Factor 4.3).

In British Columbia, herring migrate from summer offshore feeding grounds to overwintering areas, and then to nearshore waters to spawn (Hay, D.E. 1985). There are several overwintering locations in Canada’s Pacific (Hay, D.E. 1985). The spawning season runs from January through May, with most spawning occurring during March and April (Hay, D.E. 1985). Spawning occurs in sheltered intertidal and upper subtidal waters (Haegele, C.W. & Schweigert, J.F. 1985). Spawning locations vary from year to year: Hay and McCarter (2006) note that, during a 75-year period, up to 19% of the British Columbia coastline recorded at least one spawning event, but only 1%–2% of the coast consistently hosted spawning events throughout multiple years. Along the coast, there are between 300-500 discrete spawning events each year (Hay, D.E. 1985); spawning occupies approximately 1.8% of the coastline in a typical year (Hay, D.E. & McCarter, P.B. 2006).

For management purposes, Pacific herring are managed as five major stocks and two minor stocks (Figure 1; DFO 2014):

**Major stocks**

- Haida Gwaii (HG) (Area 2E)
- Prince Rupert District (PRD)
- Central Coast (CC)
- Strait of Georgia (SOG)
- West Coast Vancouver Island (WCVI)
**Minor stocks**

- Area 2W (Haida Gwaii)
- Area 27 (West Coast Vancouver Island)

![Figure 1. Pacific herring stock areas in British Columbia (Figure from Schweigert et al. 2010).](image)

Pacific herring have been the subject of important fisheries for millennia. Herring bones dominate the fish taxa found in many archaeological sites in British Columbia (McKechnie, I., et al., 2014), and herring spawn on kelp has long been harvested for food and for trade by First Nations communities (Haida Marine Traditional Knowledge Study 2011; Uu-a-thluk 2014).

Commercial fisheries for Pacific herring started in 1877 (Taylor, F. 1955), and the first major commercial fishery arose during the first decade of the 20th century in response to new demand for dry-salted herring in Asia (Taylor, F. 1955). The fishery for the dry-salted market expanded after World War I (Taylor, F. 1955). Catches declined from the 1920s through the mid-1930s due to reduced demand from the dry-salted market, but annual catches increased in the late 1930s as herring were targeted for reduction into fishmeal and fish oil (Taylor, F. 1955). The reduction fishery saw the geographic expansion of the fishery, as well: whereas effort had been concentrated first on the lower east coast of Vancouver
Island, and then on the west coast of Vancouver Island in the 1920s and 1930s, effort expanded northward during the 1940s and 1950s (Figure 1 in Taylor, F. 1955). Overfishing and poor recruitment led to the collapse and closure of the reduction fishery in 1967 (DFO 2014). The roe fishery was initiated in 1971, and rapidly expanded throughout the 1970s (DFO 2014). The commercial spawn on kelp fishery, in which herring are captured by purse seine prior to spawning, held in an enclosure with kelp for deposition of spawn, and released alive, was initiated in 1975 (DFO 2014, Haida Marine Traditional Knowledge Study 2011). Recently, a significant amount of SOG quota was shifted from the SOG roe fishery to the SOG food and bait fishery. As a result, the SOG quota available to the food and bait fishery increased from 300 tons for the 2011/2012 season (DFO 2011) to 6,000 tons for the 2012/2013 season (DFO 2013b), and 4,445 tons for the 2013/2014 season (DFO 2013).

A note on interpreting the results of this assessment: the SOG food and bait and SOG purse seine roe fisheries were assessed independently of each other, but were found to have the same scores. Therefore, for operational purposes, information and scores for the SOG food and bait and SOG purse seine roe fisheries were combined under the gear name "purse seine." The scores and information presented for "Strait of Georgia purse seine," therefore, apply to both of these fisheries. Similarly, the information and scores for the purse seine spawn on kelp and purse seine roe fisheries were combined for HG and WCVI, and also were combined with the purse seine food and bait fishery for PRD.

Additionally, at several points in the report, the descriptions of the stocks and fisheries include seemingly nonsensical descriptions of the body of water in which the fishery takes place—"Central Pacific" for the Central Coast fishery, and so on. This stock/fishery naming convention is an artifact of the operational requirements of Seafood Watch’s SWAT analysis program, and was done to differentiate each major stock area in the SWAT program. The reader should therefore disregard "Central Pacific," "Northeast Pacific," "North Pacific," etc., when those terms are encountered. All fisheries addressed in this report take place in the waters off of British Columbia, Canada.

Finally, it should be noted that 2013 biomass estimates were corrected for a sampling error that had been underestimating biomass by approximately 15% (D. Hay pers. comm.).

Production Statistics

Roe was the primary product in both total catch and total wholesale value in 2012, but spawn on kelp was the most valuable product on a per unit basis (Figures 2 and 3).
After declining in 2011, roe harvest and wholesale value increased by 30.3% and 26.0%, respectively, in 2012 (B.C. Ministry of Agriculture 2014). While food and bait landings increased by approximately 9.8% in 2012, the wholesale value of the food and bait products rose 35.5% (B.C. Ministry of Agriculture 2014).
2014). Spawn on kelp landings declined 20.0%, but the wholesale value actually increased by 23.1% (B.C. Ministry of Agriculture 2014).

**Importance to the US/North American market**

Herring products are destined primarily for export to Japan and China, with a comparatively small fraction exported to the U.S. In 2013, roe products accounted for approximately 83.6% of the total value of exported herring products (B.C. Ministry of Agriculture 2014b), with exports to Japan and China accounting for 98.5% of the total value of exported roe products (B.C. Ministry of Agriculture 2014b). Exports to the U.S. accounted for approximately 6.7% of total export value of herring products in 2013, and came primarily in the form of frozen and fresh herring (B.C. Ministry of Agriculture 2014b).

**Common and market names**

In Japan, herring roe is known as kazunoko (BC Seafood.ca 2014). Roe on kelp is known as komochi konbu and kazunoko konbu (BC Seafood.ca 2014a).

**Primary product forms**

The primary products derived from the herring fisheries are roe, spawn on kelp, and food and bait products (B.C. Ministry of Agriculture 2014). Food products made from herring include fresh and frozen whole fish, and pickled, canned, smoked, and/or salted fish (BC Seafood.ca 2014b).
Assessment

This section assesses the sustainability of the fishery(ies) relative to the Seafood Watch Criteria for Fisheries, available at http://www.seafoodwatch.org.

**Criterion 1: Stock for which you want a recommendation**

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. The inherent vulnerability to fishing rating influences how abundance is scored, when abundance is unknown. 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.

**Criterion 1 Summary**

<table>
<thead>
<tr>
<th>PACIFIC HERRING: CENTRAL COAST</th>
<th>Inherent Vulnerability</th>
<th>Abundance</th>
<th>Fishing Mortality</th>
<th>Subscore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet, Midwater</td>
<td>3.00:Low</td>
<td>4.00:Low Concern</td>
<td>2.33:Moderate Concern</td>
<td>Yellow (3.053)</td>
</tr>
<tr>
<td>Purse seine</td>
<td>3.00:Low</td>
<td>4.00:Low Concern</td>
<td>2.33:Moderate Concern</td>
<td>Yellow (3.053)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PACIFIC HERRING: HAIDA GWAII (2E)</th>
<th>Inherent Vulnerability</th>
<th>Abundance</th>
<th>Fishing Mortality</th>
<th>Subscore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purse seine</td>
<td>3.00:Low</td>
<td>4.00:Low Concern</td>
<td>2.33:Moderate Concern</td>
<td>Yellow (3.053)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PACIFIC HERRING: PRINCE RUPERT DISTRICT</th>
<th>Inherent Vulnerability</th>
<th>Abundance</th>
<th>Fishing Mortality</th>
<th>Subscore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet, Midwater</td>
<td>3.00:Low</td>
<td>4.00:Low Concern</td>
<td>3.67:Low Concern</td>
<td>Green (3.831)</td>
</tr>
<tr>
<td>Purse seine</td>
<td>3.00:Low</td>
<td>4.00:Low Concern</td>
<td>3.67:Low Concern</td>
<td>Green (3.831)</td>
</tr>
</tbody>
</table>
**PACIFIC HERRING: STRAIT OF GEORGIA**

<table>
<thead>
<tr>
<th>Region / Method</th>
<th>Inherent Vulnerability</th>
<th>Abundance</th>
<th>Fishing Mortality</th>
<th>Subscore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet, Midwater</td>
<td>3.00:Low</td>
<td>5.00:Very Low Concern</td>
<td>3.67:Low Concern</td>
<td>Green (4.284)</td>
</tr>
<tr>
<td>Purse seine</td>
<td>3.00:Low</td>
<td>5.00:Very Low Concern</td>
<td>3.67:Low Concern</td>
<td>Green (4.284)</td>
</tr>
</tbody>
</table>

**PACIFIC HERRING: WEST COAST OF VANCOUVER ISLAND**

<table>
<thead>
<tr>
<th>Region / Method</th>
<th>Inherent Vulnerability</th>
<th>Abundance</th>
<th>Fishing Mortality</th>
<th>Subscore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet, Midwater</td>
<td>3.00:Low</td>
<td>4.00:Low Concern</td>
<td>2.33:Moderate Concern</td>
<td>Yellow (3.053)</td>
</tr>
<tr>
<td>Purse seine</td>
<td>3.00:Low</td>
<td>4.00:Low Concern</td>
<td>2.33:Moderate Concern</td>
<td>Yellow (3.053)</td>
</tr>
</tbody>
</table>

Preface: The structure of the British Columbia Pacific herring stocks is a matter of concern for many stakeholders. While a full dissertation on the subject of Pacific herring stock structure is beyond the scope of this report, a brief review of an admittedly limited set of sources (Appendix A) indicates that the bulk of British Columbia’s Pacific herring biomass can be understood to belong to a single metapopulation comprising several large-scale migratory stocks, which are connected through gene flow that is thought to be sufficient to preclude genetic differentiation at the scale of the stocks. However, research indicates that sub-populations exist in some locations (Appendix A).

The status of the Pacific herring stocks in the five major areas ranges from ‘low’ concern in CC, HG, and WCVI, where the stocks are showing signs of increasing abundance, to ‘very low’ conservation concern in SOG and PRD. Fishing mortality for CC, HG, and WCVI is a matter of greater concern, however, as these stocks' apparent increases in abundance have taken place only over the past one to two years, and as there are concerns regarding the effectiveness of the herring harvest control rule during periods of low stock productivity.

**Criterion 1 Assessment**

**Factor 1.1 - Inherent Vulnerability**

*Scoring Guidelines*

- **Low**—The FishBase vulnerability score for species is 0-35, OR species exhibits life history characteristics that make it resilient to fishing, (e.g., early maturing).
- **Medium**—The FishBase vulnerability score for species is 36-55, OR species exhibits life history characteristics that make it neither particularly vulnerable nor resilient to fishing,
(e.g., moderate age at sexual maturity (5-15 years), moderate maximum age (10-25 years), moderate maximum size, and middle of food chain).

- **High**—The FishBase vulnerability score for species is 56-100, OR species exhibits life history characteristics that make it particularly vulnerable to fishing, (e.g., long-lived (>25 years), late maturing (>15 years), low reproduction rate, large body size, and top-predator).

Note: The FishBase vulnerability scores is an index of the inherent vulnerability of marine fishes to fishing based on life history parameters: maximum length, age at first maturity, longevity, growth rate, natural mortality rate, fecundity, spatial behaviors (e.g., schooling, aggregating for breeding, or consistently returning to the same sites for feeding or reproduction) and geographic range.

**Factor 1.2 - Abundance**

**Scoring Guidelines**

- 5 (Very Low Concern)—Strong evidence exists that the population is above target abundance level (e.g., biomass at maximum sustainable yield, BMSY) or near virgin biomass.
- 4 (Low Concern)—Population may be below target abundance level, but it is considered not overfished.
- 3 (Moderate Concern)—Abundance level is unknown and the species has a low or medium inherent vulnerability to fishing.
- 2 (High Concern)—Population is overfished, depleted, or a species of concern, OR abundance is unknown and the species has a high inherent vulnerability to fishing.
- 1 (Very High Concern)—Population is listed as threatened or endangered.

**Factor 1.3 - Fishing Mortality**

**Scoring Guidelines**

- 5 (Very Low Concern)—Highly likely that fishing mortality is below a sustainable level (e.g., below fishing mortality at maximum sustainable yield, FMSY), OR fishery does not target species and its contribution to the mortality of species is negligible (≤ 5% of a sustainable level of fishing mortality).
- 3.67 (Low Concern)—Probable (>50%) chance that fishing mortality is at or below a sustainable level, but some uncertainty exists, OR fishery does not target species and does not adversely affect species, but its contribution to mortality is not negligible, OR fishing mortality is unknown, but the population is healthy and the species has a low susceptibility to the fishery (low chance of being caught).
• 2.33 (Moderate Concern)—Fishing mortality is fluctuating around sustainable levels, OR fishing mortality is unknown and species has a moderate-high susceptibility to the fishery and, if species is depleted, reasonable management is in place.
• 1 (High Concern)—Overfishing is occurring, but management is in place to curtail overfishing, OR fishing mortality is unknown, species is depleted, and no management is in place.
• 0 (Critical)—Overfishing is known to be occurring and no reasonable management is in place to curtail overfishing.

PACIFIC HERRING: CENTRAL COAST

Factor 1.1 - Inherent Vulnerability

Gillnet, Midwater
Purse seine

Low

Pacific herring are a small, rapidly-growing pelagic species. The species' inherent vulnerability is considered to be 'low,' due to the species' intrinsic vulnerability score (28; Cheung, W.W.L., et al. 2005) and the species' Seafood Watch productivity-susceptibility score (2.667) (Table 1).

Table 1. Seafood Watch productivity-susceptibility analysis for Pacific herring

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>SFW Score</th>
<th>Reference (if necessary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age at maturity</td>
<td>3 years</td>
<td>3</td>
<td>(Hay, D.E. 1985)</td>
</tr>
<tr>
<td>Average maximum age</td>
<td>9 years</td>
<td>3</td>
<td>(Ware, D.M. 1985)</td>
</tr>
<tr>
<td>Fecundity</td>
<td>&gt;100 eggs/yr.</td>
<td>N/A</td>
<td>(Hay, D.E. 1985)</td>
</tr>
<tr>
<td>Average maximum size</td>
<td>33 cm</td>
<td>3</td>
<td>(Ware, D.M. 1985)</td>
</tr>
<tr>
<td>Average size at maturity</td>
<td>&lt; 40 cm</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Reproductive strategy</td>
<td>Broadcast</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Trophic level</td>
<td>3.2 ± 0.4 (conservative)</td>
<td>1</td>
<td>FishBase</td>
</tr>
<tr>
<td>Average SFW score</td>
<td></td>
<td></td>
<td>2.667</td>
</tr>
<tr>
<td>SFW Inherent Vulnerability</td>
<td></td>
<td></td>
<td>Low</td>
</tr>
</tbody>
</table>
**Factor 1.2 - Abundance**

**Gillnet, Midwater**

**Purse seine**

**Low Concern**

Estimates of the CC stock's spawning biomass were below the \( SB_{25\%} \) cutoff in recent years, but have sharply increased since 2011. In the most recent assessment, the CC \( SB_{2013} \) estimate was approximately 54% greater than the \( SB_{2012} \) estimate. The median estimate of CC \( SB_{2013} \) was estimated to be 48% (5%–95% C.I. = 29%–78%) of \( SB_0 \) and was therefore above \( SB_{25\%} \). Given the recent increase of the biomass increase, and the recent sub-target status of the stock, invite a cautious interpretation of abundance. Abundance of CC herring is therefore scored ‘low’ concern.

**Rationale**

The CC stock’s spawning biomass underwent several fluctuations of relatively equal magnitude during the 1980s and 1990s, before declining to less than \( SB_{25\%} \) during the late 2000s (Figure 4). The CC stock’s spawning biomass is estimated to have undergone an increase over the past several years. The median estimate for \( SB_{2013} \) (29,597 t; 5%–95% = 17,844-48,974 t) was nearly double \( SB_{25\%} \) (15,405 t) and was estimated to be 48% (5%–95% = 29%–78%) of \( SB_0 \) (Table 3 in DFO 2014).

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**Factor 1.3 - Fishing Mortality**

**Gillnet, Midwater**

**Purse seine**

**Moderate Concern**

For 2013/2014, commercial herring fisheries are allowed in all five major stock areas, as well as minor stock areas 2W and 27. For the three major areas that have not supported recent fisheries (HG, CC, and WCVI), 2013/2014 harvest options were selected based on a target harvest rate of 10%. Due to the reasons outlined below, fishing mortality in HG, CC, and WCVI is scored ‘moderate’ concern.

Recent research indicates that the herring harvest control may be associated with a low probability (\( P<0.4 \)) of maintaining or rebuilding stock biomass during periods of low productivity (see Appendix B). The authors of that research suggest that the use of the productivity-independent target rate of 20% has a more substantial influence on the performance of the stock than does the biomass reference.
point. While the target harvest rate for the fisheries in HG, CC, and WCVI is 10%, rather than 20%, there is no available information to indicate that it is appropriate for the productivity of these three stocks. Given the fact that the biomasses of these three stocks have been slow to rebuild, even without recent fishing mortality, and given that the biomasses of these three stocks have only recently exceeded their respective biomass reference points, a cautious interpretation of fishing mortality is required for fisheries that will contribute to the 10% target harvest rate for these three areas. Furthermore, caution is suggested by the potential for fisheries in these three areas to exceed the 10% target harvest rate. In two of the recently opened areas (WCVI and CC), the probability that the 2014 ‘expected use’ will exceed the target harvest rate is essentially 0.5, while this same probability is 0.25-0.32 for the third recently opened area (HG) (see Appendix C).

See Appendices B and C for additional analysis of productivity-independent harvest rates and expected mortality in the recently opened areas.

### PACIFIC HERRING: HAIDA GWAI (2E)

**Factor 1.1 - Inherent Vulnerability**

**Purse seine**

**Low**

Pacific herring are a small, rapidly-growing pelagic species. The species' inherent vulnerability is considered to be 'low,' due to the species' intrinsic vulnerability score (28; Cheung, W.W.L., et al. 2005) and the species' Seafood Watch productivity-susceptibility score (2.667) (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>SFW Score</th>
<th>Reference (if necessary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age at maturity</td>
<td>3 years</td>
<td>3</td>
<td>(Hay, D.E. 1985)</td>
</tr>
<tr>
<td>Average maximum age</td>
<td>9 years</td>
<td>3</td>
<td>(Ware, D.M. 1985)</td>
</tr>
<tr>
<td>Fecundity</td>
<td>&gt;100 eggs/yr.</td>
<td>N/A</td>
<td>(Hay, D.E. 1985)</td>
</tr>
<tr>
<td>Average maximum size</td>
<td>33 cm</td>
<td>3</td>
<td>(Ware, D.M. 1985)</td>
</tr>
<tr>
<td>Average size at maturity</td>
<td>&lt; 40 cm</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Reproductive strategy</td>
<td>Broadcast</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Trophic level</td>
<td>$3.2 \pm 0.4$</td>
<td>1</td>
<td>(conservative) FishBase</td>
</tr>
<tr>
<td>Average SFW score</td>
<td>2.667</td>
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<td></td>
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Factor 1.2 - Abundance

Purse seine

Low Concern

Estimates of the HG stock’s spawning biomass were similar to SB25% in recent years, but have sharply increased since 2011. In the most recent assessment, the HG SB2013 estimate was approximately 57% greater than the SB2012 estimate. The median estimate of HG SB2013 was 80% (5%-95% C.I. = 42%-149%) of SB0, and was therefore above SB25%. The recency of the biomass increase, and the recent near-target status of the stock, invites a cautious interpretation of abundance. Abundance of HG herring is therefore scored ‘low’ concern.

Rationale

The HG stock’s spawning biomass declined from the early 1980s through the middle of the 1990s, and stayed relatively low, at a level close to SB25%, during the 2000s (Figure 4). However, HG spawning biomass has increased over the past several years. The median estimate of HG SB2013 was 28,294 t (5%-95% = 14,357-54,537 t; Table 3 in DFO 2014). This is 80% (42%–149%) of SB0, and exceeded both the median estimate and the upper 95% credibility interval for SB25% (Table 3 in DFO 2014). The median estimate of SB2013 was more than double that for SB2010 (Table 2 in DFO 2014).

Factor 1.3 - Fishing Mortality

Purse seine

Moderate Concern

For 2013/2014, commercial herring fisheries are allowed in all five major stock areas, as well as minor stock areas 2W and 27. For the three major areas that have not supported recent fisheries (HG, CC, and WCVI), 2013/2014 harvest options were selected based on a target harvest rate of 10%. Due to the reasons outlined below, fishing mortality in HG, CC, and WCVI is scored ‘moderate’ concern.

Recent research indicates that the herring harvest control may be associated with a low probability (P<0.4) of maintaining or rebuilding stock biomass during periods of low productivity (see Appendix B). The authors of that research suggest that the use of the productivity-independent target rate of 20% has a more substantial influence on the performance of the stock than does the biomass reference point. While the target harvest rate for the fisheries in HG, CC, and WCVI is 10%, rather than 20%, there is no available information to indicate that it is appropriate for the productivity of these three stocks. Given the fact that the biomasses of these three stocks have been slow to rebuild even without recent
fishing mortality, and given that the biomasses of these three stocks have only recently exceeded their respective biomass reference points, a cautious interpretation of fishing mortality is required for fisheries that will contribute to the 10% target harvest rate for these three areas. Furthermore, caution is suggested by the potential for fisheries in these three areas to exceed the 10% target harvest rate. In two of the recently opened areas (WCVI and CC), the probability that the 2014 ‘expected use’ will exceed the target harvest rate is essentially 0.5, while this same probability is 0.25-0.32 for the third recently opened area (HG) (see Appendix C).

See Appendices B and C for additional analysis of productivity-independent harvest rates and expected mortality in the recently opened areas.

PACIFIC HERRING: PRINCE RUPERT DISTRICT

Factor 1.1 - Inherent Vulnerability

Gillnet, Midwater

Purse seine

Low

Pacific herring are a small, rapidly-growing pelagic species. The species' inherent vulnerability is considered to be 'low,' due to the species' intrinsic vulnerability score (28; Cheung, W.W.L., et al. 2005) and the species' Seafood Watch productivity-susceptibility score (2.667) (Table 1).

Table 1. Seafood Watch productivity-susceptibility analysis for Pacific herring

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>SFW Score</th>
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<tr>
<td>Average age at maturity</td>
<td>3 years</td>
<td>3</td>
<td>(Hay, D.E. 1985)</td>
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<td>Average maximum age</td>
<td>9 years</td>
<td>3</td>
<td>(Ware, D.M. 1985)</td>
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<tr>
<td>Fecundity</td>
<td>&gt;100 eggs/yr.</td>
<td>N/A</td>
<td>(Hay, D.E. 1985)</td>
</tr>
<tr>
<td>Average maximum size</td>
<td>33 cm</td>
<td>3</td>
<td>(Ware, D.M. 1985)</td>
</tr>
<tr>
<td>Average size at maturity</td>
<td>&lt; 40 cm</td>
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<td>Reproductive strategy</td>
<td>Broadcast</td>
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<td></td>
</tr>
<tr>
<td>Trophic level</td>
<td>3.2 ± 0.4</td>
<td>1 (conservative)</td>
<td>FishBase</td>
</tr>
<tr>
<td>Average SFW score</td>
<td></td>
<td>2.667</td>
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<td>SFW Inherent Vulnerability</td>
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</table>
Factor 1.2 - Abundance

<table>
<thead>
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<th>Gillnet, Midwater</th>
<th>Purse seine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Concern</strong></td>
<td></td>
</tr>
</tbody>
</table>

Prior to 2013, estimates of the PRD stock's spawning biomass had been relatively steady at a level similar to SB\textsubscript{25\%} for several years. However, in the most recent assessment, PRD SB\textsubscript{2013} was approximately 46% greater than the SB\textsubscript{2012} estimate. The median estimate of PRD SB\textsubscript{2013} was 49% (5\%-95\% C.I. = 25\%-90\%) of SB\textsubscript{0}, and was therefore above SB\textsubscript{25\%}. The recency of the biomass increase, and the recent near-target status of the stock, invite a cautious interpretation of Abundance. Abundance of PRD herring is therefore scored ‘low’ concern.

**Rationale**

The PRD stock’s spawning biomass has been relatively constant for the past two decades, and is not estimated to have been less than SB\textsubscript{25\%} since the late 1970s (Figure 6). The median estimate of PRD SB\textsubscript{2013} was 32,568 t (5\%-95\% = 16,762-60,283 t), which was approximately double the estimated SB\textsubscript{25\%} (16,232 t) and was 49% (5\%-95\% = 25\%-90\%) of SB\textsubscript{0} (Table 3 in DFO 2014).

Factor 1.3 - Fishing Mortality

<table>
<thead>
<tr>
<th>Gillnet, Midwater</th>
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<tbody>
<tr>
<td><strong>Low Concern</strong></td>
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</tbody>
</table>

For 2013/2014, commercial herring fisheries are allowed in all five major stock areas, as well as minor stock areas 2W and 27. For the PRD and SOG stock areas, which have supported fisheries in recent years, the target harvest rate is 20%.

While recent research indicates that the target 20% harvest rate may not effectively maintain or rebuild biomass during low productivity scenarios, it also shows that the 20% harvest rate does not preclude the maintenance or rebuilding of biomass during high productivity scenarios (see Appendix B for review). Biomass has been above SB\textsubscript{25\%} in PRD and SOG for several decades, and has increased in recent years.
even with the presence of commercial fisheries. Therefore, concerns regarding the productivity of the stock, and the appropriateness of the 20% target harvest rate, are somewhat mitigated. In addition, the probabilities that the total expected uses of SOG and PRD herring will exceed target levels are relatively low (see Appendix C).

See Appendices B and C for additional analysis of productivity-independent harvest rates and expected mortality in the major stock areas.

**PACIFIC HERRING: STRAIT OF GEORGIA**

**Factor 1.1 - Inherent Vulnerability**

**Gillnet, Midwater**

**Purse seine**

*Low*

Pacific herring are a small, rapidly growing pelagic species. The species' inherent vulnerability is considered to be 'low,' due to the species' intrinsic vulnerability score (28; Cheung, W.W.L., et al. 2005) and the species' Seafood Watch productivity-susceptibility score (2.667) (Table 1).

Table 1. Seafood Watch productivity-susceptibility analysis for Pacific herring

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<td>Reproductive strategy</td>
<td>Broadcast</td>
<td>3</td>
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<tr>
<td>Trophic level</td>
<td>3.2 ± 0.4</td>
<td>1 (conservative)</td>
<td>FishBase</td>
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<td>Average SFW score</td>
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</tr>
<tr>
<td>SFW Inherent Vulnerability</td>
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</table>

**Factor 1.2 - Abundance**
**Estimates of the SOG stock's spawning biomass have been above SB_{25\%} since the late 1960s, and have increased sharply since 2010. The median estimate of SOG SB_{2013} was 97\% (5\%–95\% C.I. = 62\%–148\%) of SB_0, and was therefore well above SB_{25\%}. The Abundance of SOG herring is therefore scored 'very low' concern.**

**Rationale**
The recent stock assessment indicates that the SOG stock’s spawning biomass has not been below SB_{25\%} at any point in the past four decades (Figure 7). The SB_{2013} median estimate for the SOG stock (136,258 t; 5\%–95\% = 83,196-220,752 t) was nearly four times greater than SB_{25\%}, and was 97\% (5\%–95\% = 62-148\%) of estimated SB_0 (Table 3 in DFO 2014).

**Factor 1.3 - Fishing Mortality**

**For 2013/2014, commercial herring fisheries are allowed in all five major stock areas, as well as minor stock areas 2W and 27. For the PRD and SOG stock areas, which have supported fisheries in recent years, the target harvest rate is 20\%.**

While recent research indicates that the target 20\% harvest rate may not effectively maintain or rebuild biomass during low productivity scenarios, it also shows that the 20\% harvest rate does not preclude the maintenance or rebuilding of biomass during high productivity scenarios (see Appendix B for review). Biomass has been above SB_{25\%} in PRD and SOG for several decades, and has increased in recent years even with the presence of commercial fisheries. Therefore, concerns regarding the productivity of the stock, and the appropriateness of the 20\% target harvest rate, are somewhat mitigated. In addition, the probabilities that the total expected uses of SOG and PRD herring will exceed target levels are relatively low (see Appendix C).

See Appendices B and C for additional analysis of productivity-independent harvest rates and expected mortality in the major stock areas.
PACIFIC HERRING: WEST COAST OF VANCOUVER ISLAND

Factor 1.1 - Inherent Vulnerability

Gillnet, Midwater
Purse seine

Low

Pacific herring are a small, rapidly-growing pelagic species. The species' inherent vulnerability is considered to be 'low,' due to the species' intrinsic vulnerability score (28; Cheung, W.W.L., et al. 2005) and the species' Seafood Watch productivity-susceptibility score (2.667) (Table 1).

Table 1. Seafood Watch productivity-susceptibility analysis for Pacific herring

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<td></td>
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<td>Trophic level</td>
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<td>1 (conservative)</td>
<td>FishBase</td>
</tr>
<tr>
<td>Average SFW score</td>
<td>2.667</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SFW Inherent Vulnerability</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Factor 1.2 - Abundance

Gillnet, Midwater
Purse seine

Low Concern

Estimates of the WCVI stock's spawning biomass were below SB25% in recent years, but have increased since 2008. Still, WCVI biomass is estimated to be near historic lows. The median estimate of WCVI SB2013 was 40% (5%–95% C.I. = 23–66%) of SB0, and was therefore above SB25%. The recency of the
biomass increase, the continuing low status of the stock relative to historic levels, and the recent sub-target status of the stock combine to invite a cautious interpretation of Abundance. Abundance of WCVI herring is therefore scored ‘low’ concern.

**Rationale**

The WCVI stock’s spawning biomass is estimated to be very near its lowest point in several decades, and is now only marginally above SB\(_{25\%}\) after being below it for several consecutive years (Figure 8). The median estimate of the WCVI stock’s SB\(_{2013}\) was 22,464 t (5%–95% = 12,782-38,799 t), which exceeds SB\(_{25\%}\) (14,221 t; 5%–95% = 11,398-18,012 t) and was approximately 40% (5%–95% = 23%–66%) of the median estimate of SB\(_{0}\) (Table 3 in (DFO 2014)).

**Factor 1.3 - Fishing Mortality**

**Gillnet, Midwater**

**Purse seine**

**Moderate Concern**

For 2013/2014, commercial herring fisheries are allowed in all five major stock areas, as well as minor stock areas 2W and 27. For the three major areas that have not supported recent fisheries (HG, CC, and WCVI), 2013/2014 harvest options were selected based on a target harvest rate of 10%. Due to the reasons outlined below, fishing mortality in HG, CC, and WCVI is scored ‘moderate’ concern.

Recent research indicates that the herring harvest control may be associated with a low probability (P<0.4) of maintaining or rebuilding stock biomass during periods of low productivity (see Appendix B). The authors of that research suggest that the use of the productivity-independent target rate of 20% has a more substantial influence on the performance of the stock than does the biomass reference point. While the target harvest rate for the fisheries in HG, CC, and WCVI is 10%, rather than 20%, there is no available information to indicate that it is appropriate for the productivity of these three stocks. Given the fact that the biomasses of these three stocks have been slow to rebuild, even without recent fishing mortality, and given that the biomasses of these three stocks have only recently exceeded their respective biomass reference points, a cautious interpretation of fishing mortality is required for fisheries that will contribute to the 10% target harvest rate for these three areas. Furthermore, caution is suggested due to the potential for fisheries in these three areas to exceed the 10% target harvest rate. In two of the recently opened areas (WCVI and CC), the probability that the 2014 ‘expected use’ will exceed the target harvest rate is essentially 0.5, while this same probability is 0.25-0.32 for the third recently opened area (HG) (see Appendix C).

See Appendices B and C for additional analysis of productivity-independent harvest rates and expected mortality in the recently opened areas.
**Criterion 2: Impacts on Other Species**

All main retained and bycatch species in the fishery are evaluated in the same way as the species under assessment were evaluated in Criterion 1. 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. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard rate score (ranges from 0-1), which evaluates the amount of non-retained catch (discards) and bait use relative to the retained catch. 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.*

### Criterion 2 Summary

<table>
<thead>
<tr>
<th>Species</th>
<th>Inherent Vulnerability</th>
<th>Abundance</th>
<th>Fishing Mortality</th>
<th>Subscore</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PACIFIC HERRING: CENTRAL COAST</strong></td>
<td>Low</td>
<td>4.00: Low Concern</td>
<td>2.33: Moderate Concern</td>
<td>3.053</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Inherent Vulnerability</th>
<th>Abundance</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>PACIFIC HERRING: CENTRAL COAST</strong></td>
<td>Low</td>
<td>4.00: Low Concern</td>
<td>2.33: Moderate Concern</td>
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<th>Species</th>
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<th>Fishing Mortality</th>
<th>Subscore</th>
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<tbody>
<tr>
<td><strong>PACIFIC HERRING: HAIDA GWAII (2E)</strong></td>
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<td>4.00: Low Concern</td>
<td>2.33: Moderate</td>
<td>3.053</td>
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<td>Species</td>
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<td>Abundance</td>
<td>Fishing Mortality</td>
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<td>PACIFIC HERRING: PRINCE RUPERT DISTRICT</td>
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<td>PACIFIC HERRING: STRAIT OF GEORGIA</td>
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<td>3.67: Low Concern</td>
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<td>PACIFIC HERRING: WEST COAST OF VANCOUVER ISLAND</td>
<td>Low</td>
<td>4.00: Low Concern</td>
<td>2.33: Moderate Concern</td>
<td>3.053</td>
</tr>
</tbody>
</table>
Bycatch concerns for the herring fisheries are minimal. While the discard rate is not known, it is assumed to be well under 20% of landings.

**Criterion 2 Assessment**

**Factor 2.4 - Discard Rate**

| Gillnet, Midwater Purse seine | < 20% |

Bycatch data are not available, but bycatch of non-herring species is minimal (Kanno, R. pers. comm. 2014). The discard:landings rate is not known, but is assumed to be <20%.

It should be noted that although the roe fishery only uses female herring, the males are used for other purposes and therefore do not qualify as discards under this criterion.
**Criterion 3: Management effectiveness**

Management is separated into management of retained species (harvest strategy) and management of non-retained species (bycatch strategy).

The final score for this criterion is the geometric mean of the two scores. 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 or either the Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern = Red or High Concern

Rating is Critical if either or both of Harvest Strategy (Factor 3.1) and Bycatch Management Strategy (Factor 3.2) ratings are Critical.

**Criterion 3 Summary**

<table>
<thead>
<tr>
<th>Region / Method</th>
<th>Management of Retained Species</th>
<th>Management of Non-Retained Species</th>
<th>Overall Recommendation</th>
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<tr>
<td>Gillnet, Midwater</td>
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<td>All Species Retained</td>
<td>Red(2.000)</td>
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<tr>
<td>Purse seine</td>
<td>2.000</td>
<td>All Species Retained</td>
<td>Red(2.000)</td>
</tr>
</tbody>
</table>

**Factor 3.1: Harvest Strategy**

Scoring Guidelines

Seven sub-factors are evaluated: Management Strategy, Recovery of Species of Concern, Scientific Research/Monitoring, Following of Scientific Advice, Enforcement of Regulations, Management Track Record, and Inclusion of Stakeholders. Each is rated as ‘ineffective,’ ‘moderately effective,’ or ‘highly effective.’

- 5 (Very Low Concern)—Rated as ‘highly effective’ for all seven sub-factors considered.
- 4 (Low Concern)—Management Strategy and Recovery of Species of Concern rated ‘highly effective’ and all other sub-factors rated at least ‘moderately effective.’
- 3 (Moderate Concern)—All sub-factors rated at least ‘moderately effective.’
- 2 (High Concern)—At minimum, meets standards for ‘moderately effective’ for Management Strategy and Recovery of Species of Concern, but at least one other sub-factor rated ‘ineffective.’
- 1 (Very High Concern)—Management exists, but Management Strategy and/or Recovery of Species of Concern rated ‘ineffective.’
- 0 (Critical)—No management exists when there is a clear need for management (i.e., fishery catches threatened, endangered, or high concern species), OR there is a high level of Illegal, unregulated, and unreported fishing occurring.

**Factor 3.1 Summary**

<table>
<thead>
<tr>
<th>Region / Method</th>
<th>Strategy</th>
<th>Recovery</th>
<th>Research</th>
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<th>Enforce</th>
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<th>Inclusion</th>
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<tr>
<td>Purse seine</td>
<td>Moderately Effective</td>
<td>Moderately Effective</td>
<td>Highly Effective</td>
<td>Moderately Effective</td>
<td>Highly Effective</td>
<td>Moderately Effective</td>
<td>Ineffective</td>
</tr>
</tbody>
</table>

**Subfactor 3.1.1 – 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? To achieve a highly effective rating, there must be appropriate management goals, and evidence that the measures in place have been successful at maintaining/rebuilding species.

**Gillnet, Midwater**

**Purse seine**

**Moderately Effective**

The management of the Pacific herring fisheries is scored "moderately effective" for Management Strategy and Implementation. This score is informed by concerns regarding the appropriateness of the herring harvest control rule in low productivity scenarios and the recent decision to open fisheries in three major areas that had been closed to commercial fishing for much of the past decade due to low abundance.

**Rationale**

The Seafood Watch criteria evaluate Management Strategy and Implementation via several key management components. These components, and the degree to which the Pacific herring management regime meets them, are summarized below.

1. **Appropriate reference points**: A single biomass reference point ($SB_{25\%}$) is used; when a stock's abundance is above the reference point, commercial fisheries are allowed to fish. An evaluation of the performance of the herring harvest control rule vs. DFO's national harvest policy (which uses lower and
upper reference points that are derived from estimates of $B_{\text{MSY}}$ yield results that suggested that the herring harvest control rule was slightly more conservative than the national harvest policy (Cleary, J., et al. 2010). However, the authors of that study note that the herring reference point may not protect stocks adequately during periods of low stock productivity, as it was derived from a productivity-independent estimate of $SB_0$, rather than a productivity-dependent estimate of $SB_{\text{MSY}}$ (Cleary, J., et al. 2010) (See Appendix B for a review of this issue).

2. Harvest control rule that adjusts for declining biomass: When biomass approaches the reference point, the herring harvest control rule adjusts, allowing fishing mortality from a maximum of 0.20 towards 0.00 in the following manner: $(SB_x - SB_{25\%}) SB_x$. Cleary and colleagues (2010) note that the herring harvest control rule may allow for a 20% harvest rate in situations of low productivity, when rebuilding would be the more appropriate response.

3. Chooses risk-averse policies rather than yield-maximizing, higher-risk policies, and buffers for scientific uncertainty: For the 2013/2014 fishing year, DFO made the decision to open commercial fisheries in CC, HG, and WCVI. This decision does not appear to be risk-averse for the following reasons:

a. For these three areas, biomass had been similar to or below the biomass reference point in recent years, and there had been no commercial fisheries allowed for much of the past decade.

b. Relative to their lengthy periods of low abundance, the abundance increases noted for these three stocks are very recent. These three stocks were estimated to be above their respective reference points only in the latest stock assessment; the previous stock assessment had generated forecasts of $SB_{2013}$ that were below $SB_{25\%}$ for CC and WCVI, and slightly greater than $SB_{25\%}$ for HG (DFO 2012).

c. The expected use (Appendix 4 in DFO 2013) and the selected harvest options for CC and WCVI had probabilities of approximately 0.50 of exceeding the target harvest rate (10%) chosen for those areas (Table 3 in DFO 2013).

Subfactor 3.1.2 – Recovery of Species of Concern

Considerations: When needed, are recovery strategies/management measures in place to rebuild overfished/threatened/endangered species or to limit fishery’s impact on these species and what is their likelihood of success? To achieve a rating of ‘highly effective,’ rebuilding strategies that have a high likelihood of success in an appropriate timeframe must be in place when needed, as well as measures to minimize mortality for any overfished/threatened/endangered species.
Gillnet, Midwater
Purse seine

**Moderately Effective**

As described for the Abundance scores in Criterion 1, the HG, CC, and WCVI stocks were below the SB\textsubscript{25%} biomass cutoff for much of the past decade. While these stocks are currently estimated to be slightly over the cutoff, their recovery from historically low levels has been slow, even in the absence of fishing afforded them in recent years. The slow recovery of these stocks warrants a score of ‘moderately effective’ for ‘recovery of stocks of concern.’

**Subfactor 3.1.3 – Scientific Research and Monitoring**

*Considerations: How much and what types of data are collected to evaluate the health of the population and the fishery’s impact on the species? To achieve a ‘highly effective’ rating, population assessments must be conducted regularly and they must be robust enough to reliably determine the population status.*

Gillnet, Midwater
Purse seine

**Highly Effective**

The management process is informed by regular stock assessments. In addition, significant research effort has been focused on improving understanding of stock structure (see Appendix A).

**Subfactor 3.1.4 – Management Record of Following Scientific Advice**

*Considerations: How often (always, sometimes, rarely) do managers of the fishery follow scientific recommendations/advice (e.g., do they set catch limits at recommended levels)? A ‘highly effective’ rating is given if managers nearly always follow scientific advice.*

Gillnet, Midwater
Purse seine

**Moderately Effective**

As a result of a document presented during a recent court decision (Secher, K. 2014), it is evident that the decision to open the herring fisheries in the CC, HG, and WCVI areas was a result of the Minister of Fisheries and Oceans overriding the advice of herring fishery managers, who had suggested the fisheries
remain closed. The herring fishery managers, in turn, had made this recommendation based upon recent stock assessment information. While there are no other recent examples of the advice of science-based decisions being overridden, the implications of this example (the opening of areas to fishing despite advice to the contrary) are troubling.

Sub-factor 3.1.5 – 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.

Gillnet, Midwater

Highly Effective

The roe fishery is subject to 100% dockside validation of catch weights, and a pilot at-sea observer program is in place (DFO 2013).

Purse seine

Highly Effective

Dockside validation of both landed and processed spawn on kelp is conducted by third-party monitors; operators in the spawn on kelp fishery must provide evidence of an agreement with the monitoring service provider prior to receiving a license for the spawn on kelp fishery (DFO 2013). Operators are also required to hail information to the monitoring service provider at regular intervals during the spawn on kelp process (DFO 2013). Mandatory logbooks and separate fishery validation forms are also required for all vessels involved in the spawn on kelp fishery; validation forms accompany the product through landing and processing stages, while logbooks are submitted to the monitoring service provider at the end of the season (DFO 2013).

Subfactor 3.1.6 – Management Track Record

Considerations: Does management have a history of successfully maintaining populations at sustainable levels or a history of failing to maintain populations at sustainable levels? A ‘highly effective’ rating is given if measures enacted by management have been shown to result in the long-term maintenance of species overtime.

Gillnet, Midwater
For much of the past decade, herring abundances in CC, HG, and WCVI have been close to or below the biomass reference point and have been similar to historic lows (see Factor 1.2). As a result, commercial fishing has not been allowed in these areas for much of the past decade. During that time, the PRD stock’s status remained relatively steady at a level above the biomass reference point but similar to historic lows (see Factor 1.2). Currently, of the five major stock areas, only SOG has a current Abundance that is well above both the biomass reference point and historic minimums (see Factor 1.2). While the management regime cannot be held responsible for the failure of the CC, HG, and WCVI stocks to rebuild in the absence of commercial fishing pressure, the persistently low abundances of four of the five stocks, and the potential for the herring harvest control rule to be ineffective in low productivity scenarios (Cleary, J., et al. 2010), suggest a conservative score for ‘track record.’

Subfactor 3.1.7 – 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 and includes stakeholder input.

While the herring fishery management regime would generally receive a score of ‘highly effective’ or ‘moderately effective’ for ‘stakeholder inclusion’ due to its regular consultations with the Integrated Herring Harvest Planning Committee, a recent event precludes this score. In February 2014, five First Nations filed an injunction against the opening of herring fisheries in WCVI (Secher, K. 2014a). A Federal Court judge ruled in favor of the injunction, which prevented fisheries in WCVI from being opened (Ryan, D. 2014). Due to the potential for similar actions in CC and HG, the fishermen’s union also urged members to not fish in those two areas (Secher, K. 2014b). Ultimately, the fishing industry agreed to not fish in HG, but the CC fishery proceeded, which drew on-the-water actions from Central Coast First Nations (Hume, M. 2014). These actions all took place after these fisheries were opened due to the decision of the Minister of Fisheries and Oceans to override advice from DFO herring fishery managers (see ‘Scientific Advice’). Uncertainty and inter-stakeholder tension characterized the 2013/2014 fishery, as stakeholders felt the need to address tensions with other stakeholders by voluntarily abstaining from fishing in certain areas, and by patrolling disputed areas. At the time of this
report, DFO, First Nations, and the Herring Industry Advisory Board had not resolved issues around harvest levels for the 2014-15 fishing season in areas of recently recovered stocks. Although it appears that a repeat of the 2013/14 scenario, in which the minister overrode management advice, is highly unlikely, this score will remain as ‘ineffective’ and will be revised in the future once an established process has been agreed to by all sectors.

Bycatch Strategy

<table>
<thead>
<tr>
<th>Region / Method</th>
<th>All Kept</th>
<th>Critical</th>
<th>Strategy</th>
<th>Research</th>
<th>Advice</th>
<th>Enforce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet, Midwater</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Purse seine</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

There are no bycatch species caught in substantial amounts in the herring fisheries and, as such, the management of bycatch species was not assessed.
**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 (plus the mitigation of gear impacts score) and the Ecosystem Based Fishery Management 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 cannot be Critical for Criterion 4.

**Criterion 4 Summary**

<table>
<thead>
<tr>
<th>Region / Method</th>
<th>Gear Type and Substrate</th>
<th>Mitigation of Gear Impacts</th>
<th>EBFM</th>
<th>Overall Recomm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillnet, Midwater</td>
<td>5.00:None</td>
<td>0.25:Minimal Mitigation</td>
<td>2.00:High Concern</td>
<td>Green (3.240)</td>
</tr>
<tr>
<td>Purse seine</td>
<td>5.00:None</td>
<td>0.25:Minimal Mitigation</td>
<td>2.00:High Concern</td>
<td>Green (3.240)</td>
</tr>
</tbody>
</table>

The fishing gears used in the herring fisheries are purse seine and midwater gillnets. These gears are not expected to cause substantial damage to marine habitats as part of their normal operations. However, the overall score for Criterion 4 is moderated by the current management’s lack of consideration for the herring’s role as a vital ecosystem component.

**Justification of Ranking**

**Factor 4.1 – Impact of Fishing Gear on the Habitat/Substrate**

**Scoring Guidelines**

- 5 (None)—Fishing gear does not contact the bottom
- 4 (Very Low)—Vertical line gear
- 3 (Low)—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. Bottom seine on resilient mud/sand habitats. Midwater trawl that is known to contact bottom occasionally (
• 2 (Moderate) — Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Bottom seine except on mud/sand
• 1 (High) — Hydraulic clam dredge. Dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)
• 0 (Very High) — 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.

Gillnet, Midwater
Purse seine
None

The gear used in the herring fisheries does not regularly contact the seafloor, and the gears used are considered to have very low impacts on habitat (Chuenpagdee, R., et al. 2003). In accordance with the Seafood Watch criteria’s score for gear that does not touch the bottom, the fishing gears used in Canada’s Pacific herring fisheries receive a score of ‘no concern.’

Factor 4.2 – Mitigation of Gear Impacts

Scoring Guidelines

• +1 (Strong Mitigation)—Examples include large proportion of habitat protected from fishing (>50%) with gear, fishing intensity low/limited, gear specifically modified to reduce damage to seafloor and modifications shown to be effective at reducing damage, or an effective combination of ‘moderate’ mitigation measures.
• +0.5 (Moderate Mitigation)—20% of habitat protected from fishing with gear or other measures in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing.
• +0.25 (Low Mitigation)—A few measures are in place (e.g., vulnerable habitats protected but other habitats not protected); there are some limits on fishing effort/intensity, but not actively being reduced.
• 0 (No Mitigation)—No effective measures are in place to limit gear impacts on habitats.
Minimal Mitigation

Measures to protect herring spawning areas from gillnet and seine damage include the establishment of no-fishing areas via the identification of shallow water net boundaries by managers. In addition, several closed areas have been established in HG via the Gwaii Haanas National Marine Conservation Area, the Haida Heritage Site, and in WCVI, SOG, PRD, and CC (DFO 2013). These measures meet the Seafood Watch criteria for ‘minimal’ mitigation of gear impacts on habitat.

Factor 4.3 – Ecosystem-Based Fisheries Management

Scoring Guidelines

- **5 (Very Low Concern)**—Substantial efforts have been made to protect species’ ecological roles and ensure fishing practices do not have negative ecological effects (e.g., large proportion of fishery area is protected with marine reserves, and abundance is maintained at sufficient levels to provide food to predators).
- **4 (Low Concern)**—Studies are underway to assess the ecological role of species and measures are in place to protect the ecological role of any species that plays an exceptionally large role in the ecosystem. Measures are in place to minimize potentially negative ecological effect if hatchery supplementation or fish aggregating devices (FADs) are used.
- **3 (Moderate Concern)**—Fishery does not catch species that play an exceptionally large role in the ecosystem, or if it does, studies are underway to determine how to protect the ecological role of these species, OR negative ecological effects from hatchery supplementation or FADs are possible and management is not place to mitigate these impacts.
- **2 (High Concern)**—Fishery catches species that play an exceptionally large role in the ecosystem and no efforts are being made to incorporate their ecological role into management.
- **1 (Very High Concern)**—Use of hatchery supplementation or fish aggregating devices (FADs) in the fishery is having serious negative ecological or genetic consequences, OR fishery has resulted in trophic cascades or other detrimental impacts to the food web.

Gillnet, Midwater

Purse seine

High Concern

Pacific herring is a species of significant ecological importance for the ecosystems of the northeast Pacific coast. Many species forage upon herring eggs, juveniles, and/or adults; the annual herring spawn
represents a particularly important pulse of nutrients into nearshore ecosystems. Currently, the management of the herring fisheries does not account for ecosystem considerations when determining Abundance, allowable catches, or the acceptable spatial-temporal characteristics of the fisheries. Furthermore, there is no science to indicate whether or not the herring biomass reference point (SB\text{25%}) is an appropriate reference point from an ecosystem perspective. As herring is an important source of food for a variety of species, the lack of ecosystem considerations in the determination of the biomass reference point and in the fisheries' overall management warrants a score of 'high' concern.

**Rationale**

**Ecological Importance of Herring: A Brief Introduction**

Herring spawning events represent pulses of nutrients and energy that are used by a wide variety of organisms. Herring roe has a greater density of energy than most marine invertebrates (Lewis, T.L., et al. 2007), and herring roe is deposited in dense concentrations of up to 2 to 3 kg/m² during spawning (Haegele, C.W. 1993). Predation on herring eggs is such that only one adult is thought to be produced for every 10,000 eggs (DFO 2013).

Haegele (1993) estimated that seabirds consumed 3.1% and 3.8% of herring eggs deposited in one part of Strait of Georgia during the 1989 and 1990 spawning events, respectively, but noted that the proportion of eggs lost to seabird predation may be much higher at times of light herring spawn. Research indicates that some seabird species target herring spawning events. Gull species may move from one spawning event to another (Haegele, C.W. 1993), harlequin ducks relocate from overwintering locations to aggregate in large numbers over herring spawning events (Rodway, M.S., et al. 2003), premigratory scoters shift from invertebrate prey to herring roe during the herring spawn (Lewis, T.L., et al. 2007), and surf scoters have been found to have a “close spatiotemporal association” with herring spawning events during the scoters’ northward migration (Lok, E.K., et al. 2012). Other bird species, including north-western crows, brant, and Canada geese, have been observed feeding on herring spawn as well (Haegele, C.W. 1993).

While one recent attempt to accurately delineate the relative importance of herring eggs to the diet and body composition of two seabird species yielded somewhat ambiguous results (Anderson, E.M., et al. 2009), the importance of spawning events to seabirds is demonstrated in other sources. Rodway and colleagues (2003) estimated that 55%–87% of the total overwinter population of harlequin ducks in the northern Strait of Georgia fed upon the herring spawn during the period 1995–2001. Surf and white-winged scoters have been found to spend approximately 50% less time foraging when feeding on herring roe than on their winter diet (bivalves); by meeting their energetic demands with fewer dives, the scoters are possibly afforded more time on the surface for courtship of potential mates (Lewis, T.L., et al. 2007). In a satellite telemetry study, approximately 60% of tracked scoters stopped at ≥1 spawning site during the scoters’ northward migration (Lok, E.K., et al. 2012).

While seabird predation on herring eggs is a phenomenon that is easily observed, the herring spawn may have other ecological consequences that are not so readily apparent. For example, a recent paper
by Fox and colleagues (2014) indicates that herring eggs contribute lipids and nutrients to semi-terrestrial amphipods, which in turn are preyed upon by terrestrial organisms (Fox, C.H., et al. 2014). The role of salmon as vectors for the delivery of marine-sourced nutrients to terrestrial ecosystems is well known (see references in Fox, C.H., et al. 2014), and it is possible that herring may play a similar role, due to their seasonal migrations to inshore waters and their release of significant amounts of nutrients in those inshore waters, and energy in the form of eggs.

Juvenile and/or adult Pacific herring are an important forage for species including humpback whales, northern fur seals, California sea lions, and harbor seals (Schweigert et al. 2010), Steller sea lions (Thomas and Thorne 2001), groundfish including Pacific cod (Walters et al. 1986), Pacific hake, sablefish, arrowtooth flounder, Pacific halibut, Pacific cod, spiny dogfish, and lingcod (Schweigert et al. 2010), Chinook salmon (Healey 1991).

The importance of herring in the diets of Chinook salmon is a matter of particular interest, as Chinook salmon are the preferred prey of endangered resident killer whales (COSEWIC 2008). Pacific herring, in turn, are among the most important prey species for Chinook salmon (Healey, M.C. 1991). The issue of Chinook salmon availability is a vital one for the resident killer whale populations, as annual mortality of the killer whales is strongly correlated with reduced Chinook salmon abundance (Ford, J.K., et al. 2010). Low Chinook abundance may be limiting the population size of resident killer whales (COSEWIC 2008), and several of the recovery measures put forward in the draft action plan for the northern and southern resident killer whales in Canada deal specifically with Chinook salmon (DFO 2014b). As a primary prey species for Chinook salmon, Pacific herring may play a role in the Chinook salmon/killer whale relationship.

Incorporation of Ecosystem Considerations in Herring Fisheries Management Decisions

The herring FMP states that there is currently "no information available on the appropriate conservation limits for herring based on ecosystem considerations" (DFO 2013). The FMP does note that juvenile herring should not be significantly affected by the fishery and, as such, are expected to be available for ecosystem processes (DFO 2013). Still, ecosystem considerations, including the various linkages between herring and predator species, are not explicitly accounted for when determining an appropriate biomass reference point for determining target harvest rates, or when determining the spatial and temporal characteristics of the fishery.

A recent expert review synthesized concepts, important considerations, and recommendations for the management of fisheries for forage fish (Pikitch, E., et al. 2012). In light of this expert review, the appropriateness of the harvest control rule stands out as being of particular concern for the Pacific herring fishery.

The authors of the review modeled five harvest control rules for their effects on seabirds and non-seabird predators, and on the risk of collapse of the managed forage fish. The modeled harvest control rule that was most similar to the Pacific herring control rule was the "20% biomass limit step function"
(20% BLSF) harvest control rule, in which the harvest rate is held constant until biomass reaches 20% of \( B_0 \), whereupon it is immediately reduced to zero. The results of the modeling exercise indicated that the 20% BLSF was the second worst performer for effects on predators, seabirds, and the managed forage fish species (Figures 6.6 and 6.7 in Pikitch, E., et al. 2012). Control rules that performed better, in terms of lower declines of predators and seabirds and reduced likelihood of collapsed forage fish stocks, had either more conservative biomass cutoffs (e.g., 40% of \( B_0 \)), or managed mortality using conservative upper reference points (e.g., 100% of \( B_0 \)) and lower reference points below which mortality was set to zero (Figures 6.6 and 6.7 in Pikitch, E., et al. 2012). The authors stated that the 20% BSLF approach was "often just as risky" as the worst performer, which was a constant fishing mortality rate with no biomass cutoffs. While the Pacific herring harvest control rule is more conservative than the modeled 20% BSLF, the similarities are enough to indicate that the Pacific herring harvest control rule may not be the best option for seabirds and other predators of herring, and may be risky for the herring stock as well.

The authors of the expert review recommend that fisheries’ managers, with access to ‘intermediate’ information about the forage species and the ecosystem, should leave 40% of \( B_0 \) in the ocean; and managers with ‘high’ information should leave at least 30% of \( B_0 \) in the ocean (Box 7.1 in Pikitch, E., et al. 2012). The Pacific herring fishery likely falls between the ‘intermediate’ and ‘high’ information levels (Table 7.1 in Pikitch, E., et al. 2012), yet its biomass cutoff (\( SB_{25\%} \)) is lower than those prescribed for either of those levels.

While the expert review drew on examples from around the world and did not assess Canada’s Pacific herring fishery per se, its results and recommendations suggest that the fishery’s harvest control rule may be putting herring, and the predators that prey upon herring, at risk of declines.
Acknowledgements

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

Seafood Watch® would like to graciously thank Martin Krkosek of the University of Toronto, Tony Pitcher of the University of British Columbia, Luke Rogers of the University of Toronto, and two anonymous reviewers for reviewing this report for scientific accuracy.
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Appendix A: Stock structure and associated uncertainties and concerns

Introduction

The structure of the British Columbia Pacific herring stocks is a matter of concern for many stakeholders. The twin questions of whether or not localized, genetically distinct sub-populations of herring used to occur and were diminished or extirpated by the reduction fishery of the mid-20th century, and whether or not such localized sub-populations may still exist in at least some areas, are not settled. Traditional and local ecological knowledge suggests an affirmative answer to the former, and perhaps the latter, while recent DFO research cannot address the former and leaves open the possibility of the latter, even while indicating that British Columbia’s Pacific herring biomass is dominated by one metapopulation.

Archaeological Evidence

McKechnie and colleagues (2014) evaluated spatial and temporal aspects of herring bones found in archaeological sites throughout Alaska, British Columbia, and Washington. Results of note include:

- Herring bones were found in 169 out of 171 sampled sites and represented 49% of the fish bones identified in those sites,
- Herring bones were particularly dominant in the records from sites found in British Columbia’s Central Coast, West Coast Vancouver Island, and Salish Sea, while sites to the north (northern B.C., southern Alaska) and south (lower mainland of B.C. and Puget Sound) had lower proportions of herring bones relative to other fish taxa (Figure A.1),
- Even within a region (Salish Sea) where herring were a dominant species, there was substantial variability between sub-regions,
- For individual sites, variance through time was low: relative abundance of herring bones varied less than 10% between strata in samples taken from 50 sites,
- Sites at which herring bones were most dominant (i.e., composed >80% of all fish bones) were significantly closer to known herring spawning areas than were sites where herring were of proportionally lower importance.
In regard to Pacific herring stock structure, these results indicate broad but not uniform distribution of Pacific herring throughout the study area, with substantial site-to-site variability but relatively low temporal variability within sampled sites. The authors suggest that the consistent importance of herring in the samples and the low variance between sampled layers indicates that herring abundance was higher than it has been in the past century, while variability may have been similar to or less than that seen in the past century. If variability was indeed high, its effects on harvests may have been offset by higher overall abundance.

**Traditional and local ecological knowledge**

Hessing-Lewis and colleagues (2011) used semi-directed interviews with 28 Heiltsuk community members to gather traditional ecological knowledge regarding changes to the spatial extent of Central Coast herring spawning areas. The resulting maps were digitized, the spawning areas mapped, and changes to the spawning areas quantified. The resulting data indicate that the total area identified as being used by spawning herring declined by approximately 50% between the 1970s and the 2000s (Figure 2 in Hessing-Lewis et al., 2011). The decline was particularly pronounced for areas on the outer coast of the study area (Figure 3 in Hessing-Lewis et al., 2011); however, herring may have initiated spawning in some new areas as well (Hessing-Lewis et al., 2011).

Knowledgeable people from Haida Gwaii were interviewed regarding herring (Haida Marine Study). All interviewees reported that herring abundance had declined; some of the interviewees believed that Haida Gwaii herring abundance was still demonstrating the effects of the reduction fishery, which was closed in 1968. In particular, herring in Skidegate Inlet were not thought to have recovered since the closure of the reduction fishery; the seine fishery for roe is also implicated. Interviewees also affirmed that, prior to declines in recent decades, localized populations of herring were known to exist, and were
known to display physical and behavioral characteristics that differentiated them from other localized populations (Haida Marine Study).

Ainsworth and Pitcher (2005) compared stock assessment data to local ecological knowledge (LEK) for trends in herring abundance. The LEK data were gathered from 48 knowledgeable community members in Prince Rupert and Haida Gwaii. When plotted together, abundance trends based on LEK and stock assessment data were strongly divergent for herring (Figure A.2.). While the LEK trend showed a persistent decline to historically low levels, the stock assessment trend showed a variable yet generally increasing trend since the 1970s (Figure A.2). Furthermore, the majority of comments by both “experts” and “non-experts” did not agree with the stock assessment data for herring (Figure 1 in Ainsworth and Pitcher, 2005); flatfish were the only functional group that had a stronger negative correlation between interviewee responses and stock assessment information (Figure 4 in Ainsworth and Pitcher, 2005). The authors of the study suggest that reduced correlation between LEK and stock assessment information may be expected for species with substantial inter-annual variability, as the LEK trend may not detect fine-scale change.

![Figure A.2. Weighted LEK abundance trend vs. stock assessment data for Pacific herring in statistical areas 1-10. LEK trend is represented by dots, while stock assessment is represented by solid line. Figure from Ainsworth and Pitcher 2005.](image)

**DFO Science**

The question of whether or not localized, distinct sub-populations of herring exist has long been a focus of government research. Taylor (1955) identified the question as being particularly important for the management of the fishery. In his review of the information, Taylor stated:
“Small local populations occur in nearly all sub-districts but more particularly in the middle east coast, upper east coast and central sub-districts. The existence of distinct populations was demonstrated by racial studies involving, in particular, mean vertebral number...and by a tagging and tag recovery program” (Taylor 1955).

Taylor notes that the studies of mean vertebral number indicated limited mixing between purportedly discrete populations on the west coast sub-district, but that analyses of tagging data indicated substantial mixing across purported populations (Taylor 1955).

Hay (1985) notes that there “appear” to be non-migratory herring that do not make the seasonal migration to offshore feeding areas. Hay (1985) also notes that herring regularly spawned in Naden Harbour, Haida Gwaii, at extremely early times of year (e.g., late January to early February), and contrasted this localized early spawn with the much later spawning that took place in nearby areas. Hay and Outram (1985) reported on a project that obtained herring samples in 10 months over a 12-month period Porlier Pass, SOG; this indicates that at least some herring were present at the sampling area throughout the year. In that effort, sampling over a four-day period in late February encountered an apparent subset of female herring with size and sexual maturity characteristics that distinguished them from other female herring taken in the same samples: the apparently unique females were larger than the majority of those that composed the study’s samples, but had a much lower index of gonadal development (Table 5 in Hay and Outram, 1981). The authors of that study concluded that this subset of female herring may have been migratory females, while the population that supplied most of the female herring in their samples was a resident population (Hay and Outram, 1985).

**Spatial fidelity and dispersal**

Ware and colleagues (2000) analyzed data from tagging efforts during the 1950-1955 and 1980-1992 periods. The 1950-1955 period was one in which the majority of the herring catch was taken in a reduction fishery, which fished between mid-November through mid-March (Ware et al., 2000). Herring recovered during the 1980-1992 period were caught in the roe fishery, which operated just prior to spawning (Ware et al., 2000). The results of this analysis indicate that fidelity rates were between 75%-96% for the five major stocks during these periods; straying was higher during the 1980-1992 period; straying into other stocks declined with distance, with most straying occurring between adjacent stocks, and straying rates were density-dependent (Ware et al., 2000). The authors of this study conclude that the levels of straying noted in their study likely minimized genetic differentiation between the populations, but may have allowed for some degree of localized adaptations (Ware et al., 2000).

Hay and colleagues (2001) analyzed data from two multi-decade herring tagging programs in B.C. The majority of the tags were released between February and April, during the spawning season (Hay et al., 2001). The authors found that straying rates tended to vary with the size of the focal area: mean straying rates were 40% for statistical areas, 83% for sections, and nearly 99% for specific locations (Hay et al., 2001). The smallest sections (2) had no detectable fidelity, but larger sections (200-500 km$^2$) had fidelity rates of 10-80% (Hay et al., 2001). The authors suggest that straying and immigration at the
levels seen in their analysis may prevent genetic differentiation between populations, but may allow for localized adaptations (e.g., unique spawning times) (Hay et al., 2001).

Genetic differentiation

Beacham and colleagues (2002) analyzed microsatellite variation to test for the presence of genetic differentiation indicative of population structure at the scale of neighboring bays and inlets, and also to test for genetic differentiation between the five major stocks (Beacham et al., 2002). The samples for this study were collected from a variety of locations from March to May (Beacham et al., 2002). The authors report a number of findings regarding genetic differentiation:

Differentiation between major stocks: The authors found evidence of “weak regional structure” in the major stocks, as the herring that spawn on the mainland side of Johnstone Strait were distinct from the major stocks. Otherwise, there was a lack of genetic differentiation between the five major stocks; the authors suggest that high levels of gene flow between the major stocks are likely to be responsible for the general lack of differentiation.

Differentiation within stocks: There was no evidence of population sub-structure within the North Coast, Central Coast, or West Coast Vancouver Island stocks (although Beacham et al., 2001 reported potential differentiation for a single sample taken from Winter Harbour).

• There was no “significant” population sub-structure within Johnstone Strait, although the herring that spawn on the mainland side of Johnstone Strait may be distinct.

• For the east and west coasts of Haida Gwaii, the only evidence of a distinct sub-population was for herring spawning in Skidegate Inlet.

• For the Strait of Georgia stock, herring that spawn in Portage Inlet/Esquimalt Harbour were “clearly distinct.” The authors suggested that the southwest boundary of the SOG management area should be revisited to ensure that the SOG area manages one population. Herring that spawn in Secret Cove may also be distinct, but the authors suggested that more research is necessary.

• The SOG stock and the Esquimalt Harbour population were both differentiated from herring in Cherry Point, Washington.

British Columbia as a whole: Overall, B.C. herring were “very distinct” from those in California, and B.C. herring were characterized by high levels of genetic diversity, indicating that there has not been a recent population bottleneck.

The authors of the microsatellite report suggest that differences in the timing of spawning may have provided the necessary isolation for genetic differentiation of herring in Skidegate Inlet, Secret Cove and Esquimalt Harbour, with geographic isolation also potentially playing a role in the differentiation of the Esquimalt Harbour herring (Beacham et al., 2002).
The authors of the microsatellite study concluded that the mixing of individuals across the five major stocks is the most likely explanation for the lack of genetic differentiation between the stocks. Despite the lack of evidence for genetic structure between these five stocks, the authors suggested that the management of B.C. herring continue to use the five stock approach, as straying levels between the five stocks may not be enough to offset localized overexploitation that may occur if B.C. herring were managed as one unit (Beacham et al., 2002). The study’s authors also conclude that genetically distinct sub-populations of herring do occur, and that differences in the timing of spawning are likely to provide the isolation necessary for the differentiation of these populations. The authors recommended additional study into the potentially distinct herring spawning in Portage Inlet/Esquimalt Harbour and Secret Cove, and measures to ensure the conservation of populations that are found to be distinct from the larger SOG stock.

**Spawning site disappearance and recolonization**

Ware and Tovey (2004) analyzed historical spawning records for 76 herring spawning sections in the five major stock areas and Johnstone Strait. Overall, 55% of the analyzed sections had at least one “disappearance” event between 1943-2002 (Table 3 in Ware and Tovey, 2004), with disappearance defined as at least five consecutive seasons without evidence of spawning. Of the 42 sections that had at least one disappearance event, 23 had more than one such event (Ware and Tovey, 2004). The mean length of the disappearance events was 11.0 years, with significant differences between the major stock areas; six sections had disappearance events that lasted from 20-28 years and that ended in recolonization (Ware and Tovey, 2004). Smaller sections were more likely to have experienced at least one disappearance (Figure 10 in Ware and Tovey, 2004). There were 18 areas that were vacant at the time of the analysis, with an average vacancy of 15.7 years; these sections had significantly smaller average spawning habitat and had significantly more examples of disappearance events throughout the time series (Ware and Tovey, 2004). Additionally, 13 of the 18 vacant sections were located in “southern BC” (Ware and Tovey, 2004). Ware and Tovey (2004) suggest that the historical prevalence of disappearances and recolonizations of herring spawning sections is consistent with the “metapopulation” concept, as this concept holds that not all suitable habitats are occupied at the same time.

**Implications for this report**

This brief review of an admittedly limited set of sources indicates that the bulk of British Columbia’s Pacific herring biomass can be understood to belong to a single metapopulation comprising several large-scale migratory stocks, which are connected through gene flow that is thought to be sufficient to preclude genetic differentiation at the scale of the stocks. However, research also indicates the existence of localized sub-populations.

This report’s treatment of specific examples of potentially distinct sub-units is as follows:

**Skidegate Inlet (HG):** Traditional ecological knowledge and genetic analysis indicate that herring spawning in Skidegate Inlet may be a distinct sub-population. Ware and Tovey (2004) report a spawn “disappearance event” in which no spawn was recorded between 1989-1995; a failed recolonization
occurred in 1996, and as of 2004 there was no spawning in Skidegate Inlet (Ware and Tovey, 2004). Skidegate Inlet is not included in the assessment of the HG herring stock, nor is it within the current fishery management area. As such the commercial fisheries for roe and spawn on kelp will not take place in Skidegate Inlet in 2013/2014.

**Portage Inlet (SOG):** Genetic analysis has indicated that herring spawning in Portage Inlet may be a distinct sub-population, but the results were not conclusive and the authors suggested that additional research was necessary. Portage Inlet is within the current boundaries of the SOG management area, and as noted by the authors of the genetic analysis, commercial fisheries may affect the diversity represented by this potential sub-population.

**Secret Cove (SOG):** Genetic analysis has indicated that herring spawning in Secret Cove may be a distinct sub-population, but the results were not conclusive and the authors suggested that additional research was necessary. Secret Cove is within the current boundaries of the SOG management area, and as noted by the authors of the genetic analysis, commercial fisheries may affect the diversity represented by this potential sub-population.

**Winter Harbour (WCVI):** Genetic analysis indicates that herring spawning in Winter Harbour may be genetically distinct from the WCVI population. Winter Harbour is within the minor stock Area 27, and as such the potential sub-population may be affected by the spawn on kelp fishery.
Appendix B: Review and Summary of Cleary, J.S. et al., 2005

The herring HCR’s 20% harvest rate has a basis in analyses of stock dynamics, and has been reviewed by the Centre for Science Advice Pacific (CSAP) (DFO 2013). The results of the CSAP analysis supported the use of the 20% harvest rate for stocks that are “well above” SB25%, but adjusted the approach for stocks that are marginally above the cutoff. In areas where the stock is projected to be marginally above SB25%, allowable catch is limited to the stock forecast minus the SB25% estimate (FMP 2014). This approach is meant to be applied for situations in which application of the default 20% harvest rate would result in a sub-SB25% biomass (FMP 2014).

Cleary and colleagues (2010) evaluated the capacity of the herring HCR, and an alternate strategy put forward in Canada’s national “Fishery Decision-Making Framework Incorporating the Precautionary Approach”, to maintain stock biomass and to rebuild depleted stocks.

These two management approaches primarily differ in their respective use of reference points and associated adjustments to allowable harvest rates: whereas the existing herring HCR uses one biomass reference point (SB25%), the national HCR uses an upper stock reference point (USRP = 0.8*BMSY) and a limit reference point (LRP = 0.4*BMSY), and reduces allowable mortality as biomass declines from the USRP to the LRP.

In the Cleary et al. simulation of the national HCR, the harvest rate was set to 0.2 when SBX exceeded the USRP, was reduced as per the policy as SBX declined from the USRP to the LRP, and was zero when SBX was below the LRP. In the simulations of the existing herring HCR, the harvest rate was set to zero when SBX was below SB25%, and when SBX exceeded SB25%, was set to the lesser of either 0.2 or

\[
\frac{(SBX-SB25%)}{SBX}
\]

The two HCRs were evaluated by modeling management performance in “high productivity” and “low productivity” scenarios.

The results indicate that, during a high productivity regime, the herring HCR is likely to rebuild biomass to BMSY (P>0.9), to maintain biomass at a level ≥BMSY over 10, 20, and 30 year projection periods (P = 0.81, 0.86, and 0.86, respectively), and to prevent biomass from falling under a critical stock size of 0.5*BMSY over the same three periods (P≥0.97 for all periods) (Table 2 in Cleary et al., 2010). However, during a low productivity regime, the probabilities of the herring HCR accomplishing these three objectives are substantially reduced (Table 2 and Figure 2 in Cleary et al., 2010). The authors note that, if an even lower productivity regime had been modeled, biomass may have dropped into DFO’s “critical zone” (0.4*BMSY) before the herring HCR would trigger a reduction in harvest rate (Cleary et al., 2010). In such a situation, the herring HCR would suggest the exploitation of the stock, even though rebuilding efforts would be the appropriate action (Cleary et al., 2010).
The results of the comparison indicate that the existing herring HCR is slightly more conservative than the national HCR (Cleary et al., 2010); however, both approaches yielded similar probabilities of rebuilding the stock to $B_{MSY}$ in high and low productivity scenarios (Figure B.1.). Therefore, the simulations indicate that differences in the two management strategies’ reference points had relatively minor effects on the performance of the two HCRs, in comparison to the effects of high vs. low productivity. This result suggests that the success or lack of success of the herring HCR is strongly influenced by the relationship of the default 20% harvest rate to a stock’s productivity. Indeed, the authors state,

“The two HCRs were sensitive to stock productivity, because the effect of a target harvest rate (20%) that is independent of productivity was much larger than the effects of biomass reference point choices. We therefore recommend further research on estimating reference points and sustainable harvest rates for Pacific herring, so that HCRs may be made more responsive to changes in productivity.”

Figure B.1. Probability of stock rebuilding to $B_{MSY}$ under the existing herring HCR (filled circles) and DFO’s national policy (open circles) under simulated low and high productivity periods (Figure from Cleary et al., 2010).
**Appendix C: Review of expected herring mortality in 2013/2014 fisheries**

For the 2013/2014 fishing year, the commercial herring fisheries may occur in all five major stock areas, as well as minor stock areas 2W and 27 (DFO 2013). Target harvest rates for 2013/2014 are 20% for SOG and PRD, and 10% for HG, CC, and WCVI and minor stock areas 2W and 27 (Tables 2-4 in {DFO 2013}). The opening of the fisheries in HG, CC, and WCVI represents a significant change from previous years, as no commercial fisheries have taken place in these three areas since 2005, 2008, and 2006, respectively (DFO 2014).

A particular concern for fishing mortality in these three areas is the potential for target harvest rates to be inappropriate for stock productivity. A recent performance evaluation of the herring HCR under regimes of high and low productivity indicates that the herring HCR has much lower probability of maintaining or rebuilding stock biomass in low productivity conditions than it does in high productivity conditions ([Cleary, J., et al., 2010]; see Appendix B for review). The authors of that study note that the 20% target harvest rate is independent of stock productivity, and the results of their simulation indicate that the 20% target harvest rate, used in conjunction with either the SB_{25%} reference point or with an alternative set of reference points, resulted in poor management performance in low productivity scenarios (see Appendix B). While the target harvest rate for the three recently opened areas is 10%, rather than 20%, the fact remains that it is independent of the productivity of these stocks. Given the slow recovery of these three stocks in the absence of recent fishing pressure, stock productivity is a concern - and therefore, the appropriateness of the target harvest rate of 10% is a concern.

In the 2013/2014 FMP, a range of potential “harvest options” is presented for each area, along with the probability that each option would result in a harvest rate in excess of the target rate (Tables 2-4 in {DFO 2013}). Ultimately, the “harvest option” that was selected for each area was the one associated with a 50% probability of exceeding area-specific target harvest rates (DFO 2013). The FMP also presents fishery and area-specific “expected use” values for 2013/2014, which were derived from the “harvest options” and stakeholder input (Appendix 4 in {DFO 2013}). Table C.1 presents the “expected use” of herring by fishery and area, in short tons, for the 2013/2014 fishing season, and compares the total of each area’s “expected use” levels to the relevant “harvest option” levels.

**Table C.1. Expected use (short tons) of Pacific herring in 2013/2014, by area and fishery, and a comparison of total expected use to area-specific harvest options (short tons). Data from Appendix 4 in {DFO 2013}.**

<table>
<thead>
<tr>
<th>Area</th>
<th>SOK</th>
<th>Roe</th>
<th>Winter F&amp;B</th>
<th>Special Use</th>
<th>Total Expected Use</th>
<th>Harvest Option ( P(U_{2014} &gt; U_{\text{target}}) = 0.5 )</th>
<th>E.U./H.O.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2W</td>
<td>500</td>
<td>500</td>
<td>496</td>
<td>1.008</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
When each area’s “expected use” values are totaled and compared to “harvest options” (Table C.1), it is apparent that expected catches in two major stock areas (CC and WCVI) are essentially equal to those areas’ “harvest option” levels. As such, expected 2013/2014 catches have a 50% probability of exceeding the target harvest rate of 10% for these two stocks. The “expected use” values in minor stock areas 2W and 27 are also >90% of the “harvest option” levels (Table C.1).

For HG, SOG, and PRD, however, the “expected use” values are substantially lower than the selected “harvest options”. Table C.2 presents modeled probabilities of area-specific target harvest rates being exceeded when catch levels are similar to the “expected use” values for HG, SOG, and PRD (from Tables 2 and 3 in {DFO 2013}). This comparison indicates that PRD “expected use” is highly unlikely to exceed the target harvest rate (P<0.10); that SOG “expected use” has a probability of approximately 0.20 of exceeding the target harvest rate, and that the probability that HG “expected use” will exceed the target harvest rate is between 0.25-0.32 (Table C.2).

Table C.2. Comparison of 2013/2014 “expected use” values for HG, PRD, and SOG to relevant 2013/2014 “Harvest Options” for the same areas, and associated probabilities of those harvest options exceeding target harvest rates. (Expected use values are from Appendix 4 in {DFO 2013}; harvest options and probabilities are from Tables 2 and 3 in {DFO 2013}).

<table>
<thead>
<tr>
<th>Area</th>
<th>2013/2014 Expected Use (short tons)</th>
<th>2013/2014 Potential Harvest Options (short tons)</th>
<th>Probability of Relevant Harvest Option Exceeding Target Harvest Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haida Gwaii</td>
<td>2,350</td>
<td>2,205</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,425</td>
<td>0.32</td>
</tr>
<tr>
<td>Prince Rupert District</td>
<td>3,930</td>
<td>2,756</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5,512</td>
<td>0.10</td>
</tr>
<tr>
<td>Strait of Georgia</td>
<td>22,470</td>
<td>22,046</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27,558</td>
<td>0.42</td>
</tr>
</tbody>
</table>
Table C.3 shows the percentage of each area-specific “expected use” amount that is projected to be taken by each fishery. From Table C.3, it is apparent that the spawn on kelp, roe, and winter food and bait fisheries are expected to be substantial contributors to fishing mortality in at least one major stock area. The spawn on kelp J License fishery is also the sole source of fishing mortality for three minor stock areas.

Table C.3. Percentage of area-specific “expected use” projected to be taken in each fishery

<table>
<thead>
<tr>
<th>Area</th>
<th>SOK</th>
<th>Roe</th>
<th>Winter</th>
<th>Special Use</th>
<th>FSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2W</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HG</td>
<td>42.6</td>
<td>51.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRD</td>
<td>25.5</td>
<td>20.4</td>
<td>30.5</td>
<td></td>
<td>5.1</td>
</tr>
<tr>
<td>CC</td>
<td>21.2</td>
<td>24.2</td>
<td>30.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOG</td>
<td></td>
<td>33.6</td>
<td>27.1</td>
<td>35.6</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCVI</td>
<td></td>
<td>15.0</td>
<td>48.4</td>
<td>30.9</td>
<td></td>
</tr>
</tbody>
</table>

Table C.4 summarizes the information presented in Tables C.2 and C.3 by showing the fisheries expected to make substantial contributions to fishing mortality in each area and the probabilities that each area’s total “expected use” will exceed target harvest rates (Table C.4).

Table C.4. Fisheries expected to make substantial contributions to 2013/2014 fishing mortality of herring (by major area), with comparison to probabilities that an area’s total “expected” fishing mortality will exceed relevant target harvest rates.

<table>
<thead>
<tr>
<th>Area</th>
<th>$U_{Target}$</th>
<th>$P$</th>
<th>Spawn on Kelp</th>
<th>Roe</th>
<th>Winter F&amp;B</th>
<th>Special Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>HG</td>
<td>10%</td>
<td>0.25-0.32</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>PRD</td>
<td>20%</td>
<td>0.00-0.10</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CC</td>
<td>10%</td>
<td>0.5</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOG</td>
<td>20%</td>
<td>0.19-0.42</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>WCVI</td>
<td>10%</td>
<td>0.5</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

1 = For CC and WCVI, the “expected use” amounts are essentially equal to the selected “harvest option” amounts (see Table C.1). The selected “harvest option” has a probability of 0.5.

2 = For SOG, the “expected use” for 2013/2014 is much closer to the harvest option associated with the lower of these two probabilities; (see Table C.2).
References:

DFO 2013

DFO 2014

Cleary, J., et al. 2010

Appendix D: Appendix D. 2014-2015 Information
At the time of this report, science advice for 2014-15 was not publicly available, but a summary was made available to the author. The forecasts in 2014-15 do not change the rankings.

Figure D.1. 2014-2015 Biomass Forecast. (Source: DFO Personal Communication)