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Canadian Science Advisory Secretariat
Science Advisory Report 2010/064

STOCK ASSESSMENT REPORT ON PACIFIC HERRING IN BRITISH COLUMBIA IN 2010

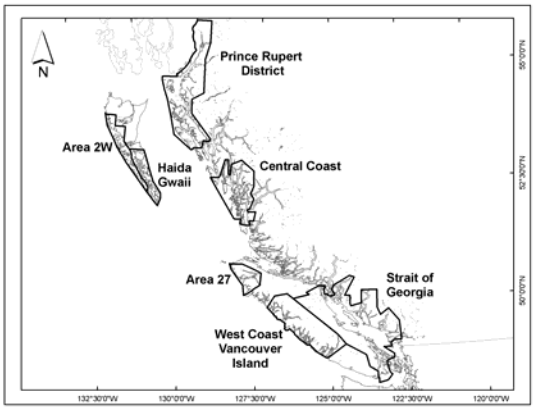

Figure 1. The five major and two minor British Columbia herring stock assessment regions

Context

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Meeting. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Pacific herring is a pelagic species inhabiting inshore and offshore waters of the North Pacific. In the eastern Pacific, herring distribution ranges from California to the Beaufort Sea. Herring annually migrate between feeding and spawning areas. Fish mature and recruit to the spawning stock primarily between ages 2 and 5. In British Columbia (BC) herring predominantly recruit at age 3. BC herring stocks are managed using five major and two minor stock areas. The five major BC herring stocks are Haida Gwaii, Prince Rupert District, Central Coast, Strait of Georgia, and West Coast of Vancouver Island, while the two minor herring stocks are Area 2W and Area 27 (Figure 1). Catch and survey information is collected independently for each of these seven areas and science advice is provided on the same scale.

The BC herring fishery began in the late 1800s but did not become extensive until the expansion of the dry-salted fishery in the late 1920s and reduction fishery in the 1930s. The stocks declined as part of the coastwide collapse from overfishing in the early 1960s, and the commercial reduction fishery was closed in 1967. Following a combination of favourable environmental conditions and a low harvest rate, the stocks recovered by the early-1970s. The current roe fishery began in 1972.

Fisheries and Aquaculture Management Branch annually requests science advice respecting the status of herring stocks in BC and harvest options. Annual stock assessments and forecasts of abundance are carried out using a catch-at-age model. This report summarizes the results of the 2010 annual assessment and provides recommendations on harvest options.

SUMMARY

The 2010 herring spawning stock biomass (SSB) and forecasted 2011 pre-fishery mature stock biomass was assessed using previously reviewed stock assessment frameworks. The following is a summary of the assessment results and advice by management area.

Haida Gwaii

- All herring spawning from Cumshewa Inlet in the north to Louscoone Inlet in the south are assumed to be part of the Haida Gwaii stock that migrates inshore from Hecate Strait in the late fall and leaves, after spawning, in late March and early April.
- No commercial herring fishery occurred in this area in 2010 (or 2003-2009).
- The forecast of mature stock biomass for 2011 is 4,140 tonnes (assuming poor recruitment), which is below the fishing threshold (10,700 tonnes).

Prince Rupert District

- All herring spawning in Statistical Areas 3 to 5 are assumed to belong to the Prince Rupert District stock that migrates inshore from Hecate Strait in the late fall and leaves, after spawning, in late March and early April.
- The roe herring seine total allowable catch in 2010 was 454 tonnes and the validated catch was 474 tonnes (approximately 5% of the total coast-wide catch). The roe herring gillnet total allowable catch in 2010 was 941 tonnes and the validated catch was 1,010 tonnes (approximately 10% of the total coast-wide catch).
- The forecast of mature stock biomass for 2011 is 19,172 tonnes (assuming average recruitment), which is above the fishing threshold (12,100 tonnes). When applying a 20% harvest rate (see Management Framework), the maximum available yield for 2011 is 3,834 tonnes.

Central Coast

- All herring spawning in Kitasu Bay (Statistical Area 6), in Statistical Area 7, and in part of Statistical Area 8 (Kwakshua Channel and Fitzhugh Sound) are assumed to be part of the Central Coast stock that migrates inshore in the late fall and leaves, after spawning, in late March and early April.
- No commercial herring fishery occurred in this area in 2010 (or 2008-2009).
- The forecast of mature stock biomass for 2011 is 6,374 tonnes (assuming poor recruitment), which is below the fishing threshold (17,600 tonnes).

Strait of Georgia

- All herring spawning in Statistical Areas 14 to 19, 28 and 29 (excluding Section 293), and part of 13 (Herring Sections 132 and 135, Deepwater Bay area south) are assumed to belong to the Strait of Georgia herring stock that migrates into the Strait in the late fall and leaves, after spawning, in March.
- The roe herring seine total allowable catch in 2010 was 4,554 tonnes and the validated catch was 4,540 tonnes (approximately 50% of the total coast-wide catch). The roe herring gillnet total allowable catch in 2010 was 3,157 tonnes and the validated catch was 3,244 tonnes (approximately 33% of the total coast-wide catch).

- The forecast of mature stock biomass for 2011 is 68,886 tonnes (assuming good recruitment), which is above the fishing threshold (21,200 tonnes). When applying a 20% harvest rate (see Management Framework), the maximum available yield for 2011 is 13,777 tonnes.

West Coast Vancouver Island

- All herring spawning in Statistical Areas 23 to 25 are assumed to belong to the West Coast of Vancouver Island herring stock that migrates inshore in the late fall and leaves, after spawning, in late February through March.
- No commercial fishery occurred on the west coast of Vancouver Island in 2010 (or 2006-2009).
- The forecast of mature stock biomass for 2011 is 8,778 tonnes (assuming average recruitment), which is below the fishing threshold (18,800 tonnes).

Area 2W

- All herring spawning in Statistical Area 2W (except Herring Section 006) are assumed to belong to this Haida Gwaii minor stock.
- A small commercial spawn-on-kelp fishery occurred in this area in 2010.
- No 2011 forecast of mature stock biomass for Area 2W is available from the stock assessment model. Given that there is no other currently available information to assess this stock, the 2010 spawn index can be used to estimate the 2011 pre-fishery mature stock biomass stock. When applying a 10% harvest rate to the 2010 spawn index estimate of 2,532 tonnes, the maximum available yield for 2011 is 253 tonnes.

Area 27

- All herring spawning in Statistical Area 27 are assumed to belong to this West Coast of Vancouver Island minor stock.
- A small commercial spawn-on-kelp fishery occurred in this area in 2010.
- The forecasted mature stock biomass for 2011 is 935 tonnes (assuming average recruitment). When applying a 10% harvest rate (see Management Framework), the maximum available yield for 2011 is 94 tonnes.

INTRODUCTION

Species Biology

Pacific herring is a pelagic species migrating between inshore spawning and offshore feeding areas of the North Pacific. In the eastern Pacific, herring distribution ranges from California to the Beaufort Sea. Herring mature and recruit to the spawning stock predominantly between ages 2 and 5. Age-at-recruitment tends to increase with latitude within this range.

Stock Structure

For the purposes of evaluation and management, British Columbia herring stocks are defined as five major and two minor stocks (Fig. 1). Stock structure is supported both by multi-year tagging

and genetic studies (Hourston, 1982, Beacham et al., 2008). The major stocks are: Haida Gwaii (HG, also referred to as Area 2E and formerly referred to as Queen Charlotte Islands), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SOG) and West Coast of Vancouver Island (WCVI). The two minor herring stocks are Area 2W and Area 27. Smaller scale spatial delineations related to fishing and sampling activities are Statistical Areas (http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/areas-secteurs/index-eng.htm) and Herring Sections (http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/default0-eng.htm).

Ecosystem Considerations

As a forage species, herring play a role in the marine ecosystem and are a food source for a variety of species (Schweigert et al., 2010). However, there is little information available to develop ecosystem-based conservation limits for herring. The harvest rate of 20% of the mature biomass should ensure that a large fraction of the spawning-stock biomass is available to predator species or is protected for future production (Hall et al. 1988).

Herring are an important prey species to many piscivores including Pacific hake, halibut, arrowtooth flounder, and dogfish. They are also believed to be important in the diet of marine mammal predators such as Steller and California sea lions, harbour and northern fur seals, harbour porpoises, Pacific white-sided dolphins, and humpback whales. Because no targeted commercial harvest of immature herring takes place, most juveniles remain available to support ecosystem processes. Research continues to develop a fuller understanding of ecosystem processes and the role that herring play in maintaining ecosystem integrity and function.

History of the Fishery

Herring have been harvested for many years to provide a variety of food products. First Nations have historically collected herring for food, social and ceremonial purposes, especially for spawn-on-kelp product, and continue to do so today. From the early 1930s to the late 1960s, herring were commercially harvested and processed (reduced) into relatively low-value products such as fishmeal and oil. Figure 2 shows trends depicting total quantities of commercial removals from 1951 to 2010. Commercial catches increased dramatically in the early 1960s but were unsustainable. By 1965, most of the older fish had been removed from the spawning population by a combination of overfishing and by a sequence of weak year-classes attributed to unfavourable environmental conditions and a low spawning biomass. As a result, the commercial fishery collapsed and was closed by the federal government in 1967 to permit the resource to rebuild. During the closure from 1967-1973, limited fishing activity occurred at low levels for food and bait (Hourston, 1980). At this time, there was a growing interest in harvesting roe herring for export to Japan, where herring stocks had become decimated. A small experimental roe harvest began in 1971 and expanded rapidly until 1983, when fixed quotas were introduced to regulate the catch. A series of above average year-classes occurred in the early 1970s, rapidly rebuilding stocks and permitting the re-opening of areas for commercial fishing. Today, the fishery is comprised of: commercial fishing opportunities for food and bait herring, spawn-on-kelp products, and roe herring; a food, social, and ceremonial fishery for First Nations; and recreational opportunities. Table 1 shows combined commercial removals from 2006 to 2010 from roe, food and bait and special use fisheries operating in the five major BC herring stock assessment areas.

Rationale for Assessment

Advice was requested by Fisheries and Aquaculture Management on the status of the five major and two minor herring stocks and forecasts of biomass for 2011 by stock area for application of the BC Herring management framework.

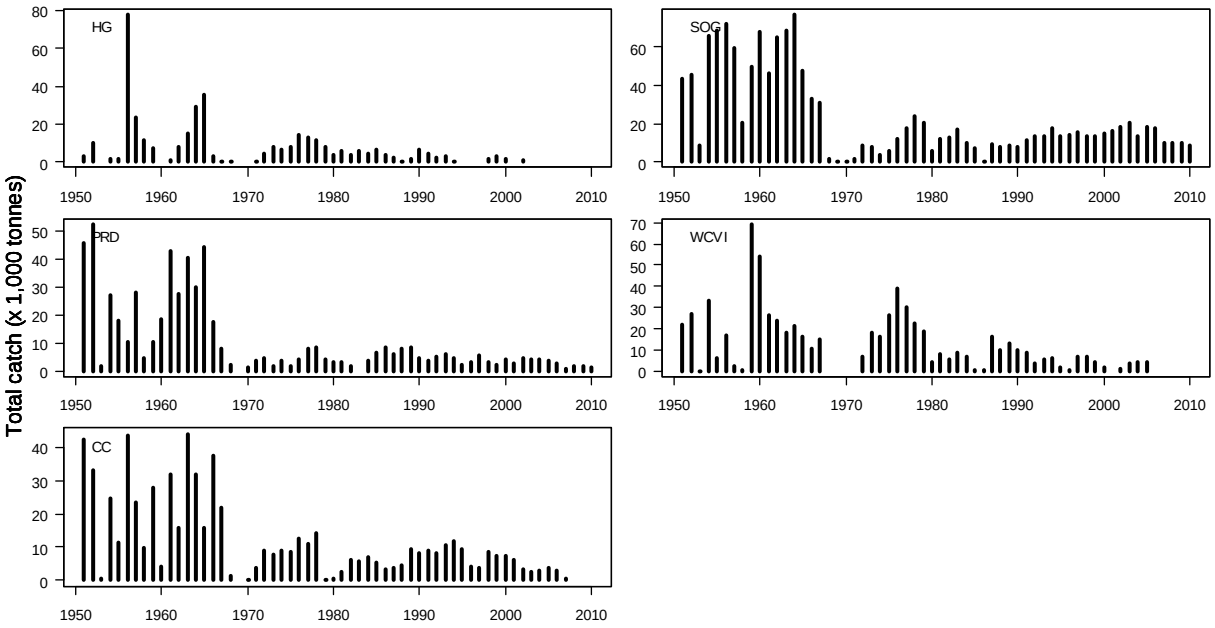

Figure 2. Combined commercial removals from reduction, roe, food and bait and special use fisheries operating in the five major BC herring stock assessment areas, 1951-2010. Removals associated with the spawn-on-kelp fishery are not included in totals.

Table 1. Combined commercial removals from roe, food and bait and special use fisheries operating in the five major BC herring stock assessment areas (tonnes), 2006-2010. Removals associated with the spawn-on-kelp fishery are not included in totals.

	2006	2007	2008	2009	2010
Haida Gwaii	0	0	0	0	0
Prince Rupert District	2,617	970	1,662	2,000	1,484
Central Coast	3,072	398	0	0	0
Strait of Georgia	17,955	9,822	9,934	10,170	8,324
West Coast Vancouver Island	0	0	0	0	0

Management Framework

The objective of the current herring fisheries is to sustainably manage the available biomass in a manner that conserves and protects Pacific herring stocks, their habitat, and ecosystem processes, and provides fishing opportunities for First Nations, commercial, and recreational harvesters. The present-day fishery is managed using a management framework developed based on previously reviewed and endorsed science advice (Haist et al. 1986, Stocker, 1993) that incorporates a fixed harvest rate policy and a formal harvest control rule, in the form of a commercial fishing threshold or “cutoff.”

Maximum available commercial harvest for each of the major stock areas is 20% of the forecasted mature stock biomass (males and females combined) when the forecasted mature stock biomass is above the commercial fishery threshold or "cutoff." The cutoff is established as 25% of unfished biomass (0.25 B_0), currently based on 1996 estimates of B_0. Past simulation studies support the use of cutoffs in their ability to maintain the reproductive capacity of each major stock (Haist et al. 1986, Stocker, 1993). A full, closed-loop simulation study is proposed to evaluate compliance of the current management framework with the DFO Harvest Policy Compliant with the Precautionary Approach (DFO, 2009).

For the minor herring stocks (Area 2W and Area 27) a precautionary 10% harvest rate is applied to the forecasted mature stock biomass to establish maximum available yield. Commercial fishery thresholds are not established for minor stock areas and recruitment is always assumed to be average.

ASSESSMENT

Methodology and Sources of Information

Data collected for use in the assessment of herring stocks are: spawn survey data, commercial catch landings, and age composition data taken from biological samples of the commercial fishery, test fishery charters, and research catches. Herring stock assessment uses information from biological samples for determining the population age composition and average weight-at-age, historical catch, and an assessment of the distribution and intensity of egg deposition in each stock assessment area.

Annual herring stock assessments produce estimates of current abundance, spawning biomass and recruitment, as well as forecasts of mature stock biomass for the upcoming year. Detailed information on the 2010 assessment is reported in Cleary and Schweigert (2010). Biomass estimates represent median estimates of statistical distributions resulting from modelled parameters.

For the major areas, forecasts of mature stock biomass are made by adding estimates of surviving repeat spawners to estimates of age-3 recruits. Recruitment of age-3 fish is estimated as the number of age-3 fish recruited to the stock at the beginning of each year. Recruitment is categorized as poor, average or good, and model estimates of recruitment are calculated as the means of the lower 33%, middle 33% and upper 33% of the number of age-3 fish over the entire time series.

Forecasted estimates of age-3 recruits are determined for the Strait of Georgia and West Coast of Vancouver Island stocks based on independent estimates from a summer trawl survey (Tanasichuk, 2000, 2002). Forecasted estimates of age-3 recruits for the other three major areas are determined using recruitment forecast rules, which were developed in 2004 (DFO. 2004). These rules state that:

1. If the pre-fishery biomass was below cutoff in the previous year, then assume "poor" recruitment for the forecast.
2. If the pre-fishery biomass was above cutoff in the previous year and recruitment has been "good" in the two previous years, then assume "good" recruitment for the forecast.
3. If neither Rule 1 nor Rule 2 apply, then assume "average" recruitment for the forecast.

Forecasted estimates of age-3 recruits for the two minor herring stocks (Area 2W and Area 27) are determined by assuming “average” recruitment.

Stock Trends and Status

Time-series estimates of pre-fishery biomass, the spawning stock biomass and the spawn index are presented in Figure 3; recruitment estimates of age-3 fish to each stock appear in Figure 4.

Haida Gwaii (QCI 2E)

Spawning biomass for the stock is estimated at 6,046 tonnes in 2010, a decline from 7,172 tonnes in 2009 (Fig. 3). Recruitment has alternated between poor and average over the last 10-years (Fig. 4), with 2010 estimated as poor recruitment, contributing to the continuing low level of abundance. Fish greater than age-4 dominated the 2010 mature stock and accounted for 63% of the total while age-3 fish contributed only 7%. There has been little evidence of stock recovery in this area, despite the removal of fishing pressure over the past decade.

Prince Rupert District

Spawning biomass for the stock is estimated at 19,039 tonnes in 2010, an increase from 14,866 tonnes in 2009 (Fig. 3). During the past decade, recruitment for most year-classes has been average or better, with the exception of 2004 and 2008 which were poor (Fig. 4). The 2010 recruitment is estimated as average. In 2010, recruiting age-3 fish contributed 37% and age-4 fish contributed 32% of the total returns.

Central Coast

Spawning biomass for the stock is estimated at 7,974 tonnes in 2010, declining from 9,991 tonnes in 2009 (Fig. 3). Over the past decade, recruitment has fluctuated between poor and average with one good year, 2003 (Fig. 4). The 2010 recruitment is estimated as poor. Age-4 fish dominated the 2010 returns accounting for 65%, whereas recruiting age-3 fish contributed only 16%.

Strait of Georgia

Spawning biomass for the stock is estimated at 48,262 tonnes in 2010, similar to the 2009 level of 47,966 tonnes (Fig. 3). Recruitment during the past decade has been average or better in all years, except for poor recruitment in 2008 and 2010 (Fig. 4). Some of the largest recruitment levels observed in the past 60 years occurred in the early 2000s, 2007 and 2009. The recruiting age-3 fish comprised only 2% of the 2010 mature stock biomass, whereas age-4 and age-5 fish contributed 76% and 6%, respectively.

West coast Vancouver Island

Spawning biomass for the stock is estimated at 3,335 tonnes in 2010, declining from 5,112 tonnes in 2009 (Fig. 3). Abundance in 2006 through 2010 is well below the lowest level observed in the 60-year time series of data for this stock. During the past decade most year-classes have been poor, except for 2001 to 2003 which were average (Fig. 4). The recruiting age-3 fish comprised 31% of the 2010 returns, whereas the age-4 and age-5 fish contributed 46% and 6%, respectively.

Area 2W

Spawning biomass for the stock is estimated at 2,532 tonnes for 2010, similar to the 2009 level of 2,860 (Fig. 3). The recruiting age-3 comprised 32% of the 2010 returns, whereas the age-4 and age-5 fish contributed 36% and 3%, respectively.

Area 27

Spawning biomass for the stock is estimated at 998 tonnes in 2010, similar to the 2009 estimate of 1,627 tonnes (Fig. 3). The majority of the 2010 run consisted of age 3+ fish, contributing 55% of total returns. Age-3 and age-4 fish contributed 13% and 9%, respectively.

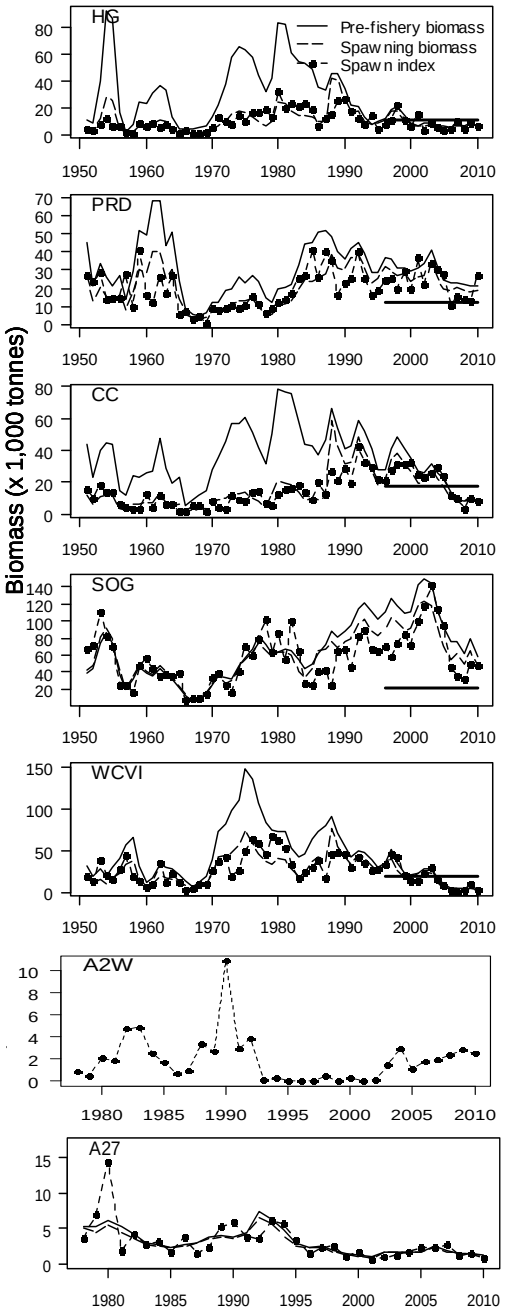

Figure 3. Estimates of pre-fishery stock biomass, spawning stock biomass and spawn index. Solid line denotes cutoff for each major stock for 1996-2010.

Note: y-axis scales differ in each figure.

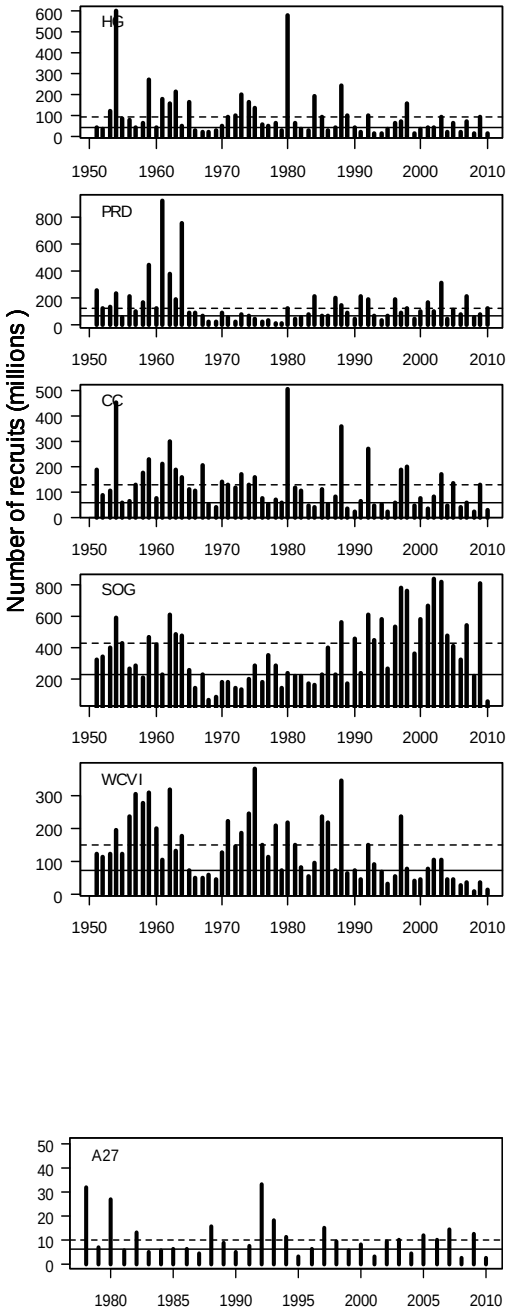

Figure 4. Estimated numbers of age-3 recruits. Horizontal solid line represents lower 33rd percentile of recruits; horizontal dashed line represents upper 67th percentile of recruits.

Figure unavailable for Area 2W.
Note: y-axis scales differ in each figure.

2011 Biomass Forecasts

Table 2 provides forecasts of pre-fishery mature stock biomass for each major and minor area. When recruitment forecasting rules are applied, 2011 recruitment is estimated as "poor" for the Haida Gwaii and Central Coast stocks, "average" for the Prince Rupert, West Coast of Vancouver Island and the two minor stock areas (Area 2W, Area 27), and "good" for the Strait of Georgia.

Table 2. Forecasts of pre-fishery mature stock biomass for BC herring stocks for 2011. Bold values indicate recruitment forecasts assumed for 2011. The recommended commercial fishery cutoffs are based on the methods of Haist et al. (1986) and cutoff values were last revised in 1996.

Stock Assessment Areas	Recruitment Option			Commercial Fishery Cutoff
	Poor	Average	Good	
Haida Gwaii Area 2E	**4,140**	6,830	17,340	10,700
Prince Rupert District	15,757	**19,172**	31,472	12,100
Central Coast	**6,374**	9,940	18,768	17,600
Strait of Georgia	38,669	49,570	**68,886**	21,200
West Coast Vancouver Island	4,339	**8,778**	18,372	18,800
Area 2W [1]	NA	NA	NA	NA
Area 27	601	**935**	1,695	NA

[1] *No 2011 forecast is available because spawn observations were not obtained for Area 2W in the mid 1990s (thus obstructing model performance).The 2010 spawn index is 2,532 tonnes.*

Sources of Uncertainty

Recruitment is considered to be the most important process determining the productivity of British Columbia herring populations. Various studies have suggested that herring recruitment is determined by variations in the size of the parent stock, and environmental conditions during the first year of life. Long-term research has shown that both recruitment and adult survival tend to be below average in warm years, particularly when migratory herring-predators (like Pacific hake and mackerel) are abundant off the west coast of Vancouver Island (Ware 1991). The West Coast of Vancouver Island herring stock shows an inverse relationship between sea-surface temperature (SST) and herring production. Research is on-going and includes: monitoring of juvenile herring stocks in the SOG and CC stock areas and monitoring of zooplankton abundance for the WCVI.

Currently the assessment framework assumes: (1) surface spawn surveys (1951-1987) provide a relative index of spawner abundance (q estimated), (2) dive spawn surveys (1988-2010) provide absolute estimates of spawner abundance (q=1), and (3) natural mortality is time-variant but constant across age. Uncertainties in the estimation of natural mortality (M) and the conversion factor between spawn index and spawner biomass (q) have a significant influence on the estimation of key management parameters (e.g. current biomass, proportions-at-age). There is also uncertainty associated with estimates of mortality in the spawn-on-kelp fishery.

CONCLUSIONS AND ADVICE

The 2010 herring spawning stock biomass (SSB) and forecasted 2011 pre-fishery mature stock biomass was assessed using previously reviewed stock assessment frameworks. The existing herring catch-at-age model was reviewed and accepted in 2007 and 2008 for the provision of Science advice for the five major and two minor herring stock areas. Along with Table 3, the following is a summary of the conclusions and advice arising from the September 2010 assessment and science review:

- The Haida Gwaii and West Coast of Vancouver Island stocks show no signs of rebuilding, despite limited or no commercial harvest for most of the last decade. The Central Coast stock has remained below the cutoff for the past three years. The recruitment forecast for 2011 is classified as “poor” for both the Haida Gwaii and Central Coast stocks and “average” for the West Coast of Vancouver Island. The forecasted 2011 mature stock biomass for these three stocks remains below their respective commercial fishery cutoffs, established in the current management framework.
- Assessment of the Strait of Georgia stock indicates that abundance has declined steadily since the historic high in 2003; but has remained above the commercial fishery cutoff. The 2010 SSB is estimated to be 48,262 tonnes, similar to the 2009 SSB. The recruitment forecast for 2011 is classified as “good”, resulting in a forecasted pre-fishery mature stock biomass of 68,886 tonnes. The current management framework commercial fishery cutoff is 21,200 tonnes.
- Assessment of the Prince Rupert District stock indicates that abundance has remained relatively constant in recent years, with the 2010 SSB estimated to be 19,039 tonnes. The recruitment forecast for 2011 is classified as “average”, resulting in a forecasted pre-fishery mature stock biomass of 19,172 tonnes. The current management framework commercial fishery cutoff is 12,100 tonnes.
- Assessment of the Area 2W stock indicates the spawn index has remained relatively constant in recent years, with the 2010 index estimated at 2532 tonnes. In the absence of a forecast for the 2011 pre-fishery mature stock biomass based on the assessment model for this area, the 2010 spawn index was used for predicting the pre-fishery mature stock biomass in 2011.
- Assessment of the Area 27 stock indicates that abundance has remained relatively constant over the last decade. The 2010 SSB estimate for Area 27 is 998 tonnes. “Average” recruitment is assumed for 2011, resulting in forecasted pre-fishery mature stock biomass of 935 tonnes for Area 27.

Table 3. Summary of stock assessment advice and maximum available yield for 2011.

Assessment Area	Forecasted Recruitment	Forecasted Mature Stock Biomass (tonnes)	Commercial Fishery Cutoff (tonnes)	Maximum Available Yield (tonnes)[1]
Haida Gwaii Area 2E	Poor	4,140	10,700	0
Prince Rupert District	Average	19,172	12,100	3,834
Central Coast	Poor	6,374	17,600	0
Strait of Georgia	Good	68,886	21,200	13,777
West Coast Vancouver Island	Average	8,778	18,800	0
Area 2W	Average	NA	NA	253[2]
Area 27	Average	935	NA	94

[1] *Maximum available yield based on previously approved methods that establish a stock-specific commercial fishery cutoff and a harvest rate of 20% for major stock assessment areas and 10% harvest rate for minor stock assessment areas.*

[2] *Maximum available yield based on a 10% harvest rate applied to the 2010 spawn index (given that no 2011 forecast is available).*

SOURCES OF INFORMATION

This Science Advisory Report has resulted from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Meeting of September 1-2, 2010 on *Pacific Herring Stock Assessment and Review of bio-sampling design.* Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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