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Gulf Region

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Science Advisory Report 2022/014

STOCK STATUS OF ALEWIFE AND BLUEBACK HERRING (GASPEREAU) IN THE DFO GULF REGION

Blueback Herring (Alosa aestivalis) (upper) and Alewife (Alosa pseudoharengus) (lower)
Credit: New Jersey Department of Environmental Protection.

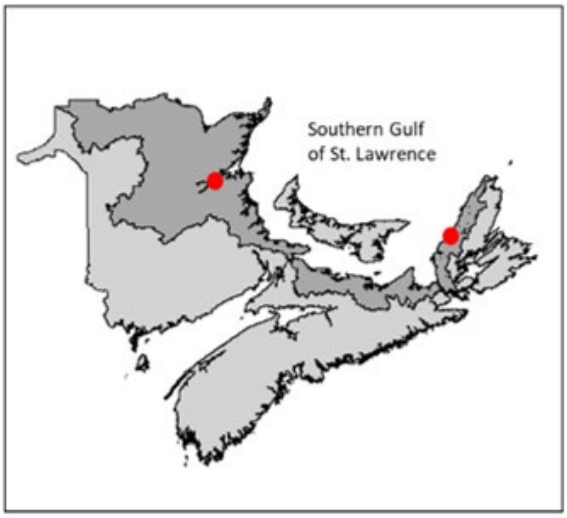

Figure 1.Two rivers (Miramichi River (New Brunswick) and Margaree River (Nova Scotia), red circles) in DFO Gulf Region (dark grey) where gaspereau are monitored.

Context:

Alewife (Alosa pseudoharengus) and Blueback Herring (Alosa aestivalis), collectively referred to as gaspereau or river herring, are anadromous clupeids that return to spawn in practically all rivers in the southern Gulf of St. Lawrence. Mature gaspereau are relatively small fish, with body lengths ranging from 20 cm to a maximum of just over 30 cm. In exploited stocks, most fish in the spawning runs are three to generally less than ten years old.

Gaspereau are fished during their upstream spawning migrations that occur in May to early July. The gaspereau stocks of the two largest fisheries in the southern Gulf, the Miramichi River (NB) and the Margaree River (NS), were last assessed in 2001 (DFO 2001). At that time, the exploitation rates in these fisheries were estimated to have exceeded the fishing removal rate references for Alewife and Blueback Herring stocks in these rivers.

In support of management considerations for these fisheries, Fisheries and Oceans Canada (DFO) Ecosystems and Fisheries Management Branch requested an update of the stock status of gaspereau in DFO Gulf Region including where possible, an assessment of status relative to reference points that conform to the Precautionary Approach.

This Science Advisory Report is from the April 20-21, 2021 meeting on the assessment of the status of gaspereau stocks of the southern Gulf of St. Lawrence. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Alewife and Blueback Herring are anadromous species of fish collectively referred to as gaspereau or river herring.
- Alewife and Blueback Herring in individual rivers are considered to be different stocks. The two species have different migration timing and spawning areas and therefore, stock assessments are conducted at river-specific scale and separately for each species.
- In the Gulf Region, reported commercial landings of gaspereau from DFO Statistics Branch have declined over the time series from 1917 to 2019. These are known to be incomplete and may not reflect abundance.
- There are very few region-wide indicators of abundance. At the regional scale, the bottom-trawl surveys show a decline in catch rates of gaspereau over time although it is unclear how well the survey indices reflect abundance.
- Indicators of stock status for Alewife and Blueback Herring are available in the Margaree River. Catch per unit effort in the commercial gaspereau fisheries peaked in the 1980s and has fluctuated around a mean of 61 kg/hour since the last management changes were implemented in 2001.
- Over the sampling period of 1983 to 2019, the average size of Alewife and Blueback Herring in the Margaree River commercial fisheries declined 41% and 53% by length and 10% and 13% by weight, respectively.
- Variations of age-structured stock assessment models were used to evaluate the status of Alewife in the Margaree River. Estimates of spawner biomass varied between 26 metric tonnes (t) to 1,370 t from 1983 to 2019. Exploitation rates varied from 0.29 to 0.89 during the same time period.
- Population-specific reference values are developed for Alewife and Blueback Herring. The limit reference point (LRP) is set equal to the spawner biomass that produces half the maximum recruitment (K). The VPA model estimated LRP to be at 113.9 t (more conservative) whereas the SCA model estimated LRP to be 64.3 t. The upper stock reference (USR), is set equal to the biomass of spawning alewife at maximum sustainable yield (B_{msy}). The VPA model was more conservative with a USR of 590.8 t whereas the SCA model gave of USR of 276.0 t. Low abundance during the time series causes uncertainty in their estimated values. Both reference points will need to be re-assessed if stock size increases.
- Although the values of abundance and reference points differ among the models, the estimated biomass of Alewife in the Margaree River before the fishery has generally been in the cautious zone since the mid-1990s and after fishing, spawning escapement has been in the critical zone in over half the years.
- The target removal rate is set at $U_{90\%msy}$ (VPA model: 0.33 and SCA 3 model: 0.41). The maximum removal rate is defined as U_{msy} (VPA model: 0.51 and SCA 3 model: 0.60) and should not be exceeded. Both the target and maximum removal rates only apply in the healthy zone.
- Although the absolute values of the realized exploitation rates and the removal rate reference points differ between the two models, the estimated exploitation rates have generally been above the target removal rate in all years and above the maximum removal rate references more than half the time from 1983 to 2019.

- Indicators of stock status for Alewife and Blueback Herring in the Southwest and Northwest Miramichi River were collected from DFO research trapnets upstream of where fishing occurs. Catches of both species have declined on the Southwest Miramichi River whereas catches on the Northwest Miramichi River have been variable.
- The commercial gaspereau fisheries in the Miramichi River have not been sampled since 2000. Indicators of stock status are inferred from catches at research trapnets. Catches declined on the Southwest branch during 1994 to 2019 and were highly variable on the Northwest over the 1998 to 2019 time series. When last assessed in 2000, the exploitation rate in the Miramichi River gaspereau fisheries were high and above the removal rate references defined for those stocks.
- Catch curve analysis of catches at Miramichi research trapnets indicate that exploitation rates remain high on that river and are most likely above the removal reference rate for other gaspereau stocks.
- Assessment of the status of other Alewife and Blueback Herring stocks in DFO Gulf Region was not possible due to data limitations. Sampling of the fisheries other than the one in the Margaree River has not been conducted since 2000.
- Gaspereau fisheries are conducted on a large number of rivers in the Gulf Region and systematic sampling of the fisheries catches has only been conducted on one river. In order to assess the status of gaspereau stocks in the region, additional effort will be required to sample these fisheries on an intermittent and rotational basis, and the development and validation of other indicators of status such as by examination of age composition and catch curve analyses will be required.

BACKGROUND

“Gaspereau” is a colloquial name for two anadromous species of fish, Alewife (*Alosa pseudoharengus*) and Blueback Herring (*Alosa aestivalis*), that are also collectively referred to as “river herring”. The two species are sympatric throughout much of their range, although Blueback Herring have a larger and more southerly range (Nova Scotia to Florida) than Alewife (Labrador to South Carolina). Both species are harvested and marketed together as “gaspereau”.

Mature gaspereau are relatively small fish, with body lengths ranging from 20 cm to a maximum of just over 30 cm. In exploited stocks, most fish in the spawning runs are three to generally less than ten years old.

Gaspereau are fished during their upstream spawning migrations that occur in May to early July. Fishing occurs in estuaries and rivers using trapnets, gillnets, dipnets and seines, depending upon the location. Some gaspereau are also captured in coastal trapnets set in Gulf Nova Scotia waters and around the northern tip of Cape Breton Island. Historically, gaspereau were salted, and marketed outside Canada. In recent years, there has been an increasing demand for bait to supply the large spring fisheries for crustaceans in the southern Gulf of St. Lawrence and an increasing proportion of the gaspereau harvested is being used for that purpose.

Fisheries are managed using effort controls that include a fixed number of licences, gear configurations, seasons, and weekly closures in most areas. There are no total allowable catch limits. The highest landings in the southern Gulf since 1917 were recorded in 1952 at 14,600 t. Landings averaged 4,400 t during the period 1978 to 2000.

Gaspereau have not been regularly assessed in DFO Gulf Region. The last published assessment was in 2001. During the last assessment, for the Miramichi River, gaspereau were found to be exploited at or above reference levels (DFO 2001). Alewife in the Margaree River was found to be at low abundance, although recent management measures were thought to have reduced exploitation rates to near reference levels (DFO 2001). In other southern Gulf rivers, fishing exploitation rates were found to be high and landings were expected to remain low relative to historical levels until such time as exploitation rates were reduced and spawning escapements increased (DFO 2001).

DFO Ecosystems and Fisheries Management Branch requested an update of the stock status of gaspereau in DFO Gulf Region including where possible, an assessment of status relative to reference points that conform to the Precautionary Approach. The information used to develop this advice was presented virtually at the science peer review of April 21-22, 2021.

The terms of reference for this assessment and peer review process are:

- Description of present and recent management measures and catches to the end of 2019, including best estimates of total removals by all fisheries.
- Overview of species biology and characteristics (e.g., size at age, age at maturity).
- Indicators of stock status and trends (commercial catch rates, fishery independent indices) by size and age group (if available).
- Estimates of total biomass as derived from population models for the Margaree River.
- Estimates of absolute fishing mortality rates for the stocks.
- Develop reference points by species against which to assess stock status.
- Description of the impacts of fishing activities for gaspereau on other species and fish habitat.
- Description of the impacts of fishing activities for other species on gaspereau stocks.
- Description of ecosystem components which are modifying the species abundance and population dynamics (for ex. temperature, predators, prey).
- Develop indicators of stock status which can be used to inform fisheries management in the intervening years of the multi-year assessment and management cycle.

Species biology

The life cycles of Alewife and Blueback Herring are similar. In Nova Scotia, New Brunswick and Prince Edward Island, adult fish migrate up coastal rivers to spawn in freshwater during the spring (late-March to early-July), with the majority of the combined runs returning to rivers in May and June. After spawning, they return to the ocean. Young-of-the-year move downstream in the late summer and early fall to grow to maturity and overwinter at sea. The fish mature at two to seven years of age at which time they return to the rivers to spawn. Alewife and Blueback Herring are iteroparous and in non-impacted populations may spawn as many as four to six times throughout their lives. The distribution patterns for the two species in the marine environment are unknown but, populations of the two species are thought to be mixing.

Alewife and Blueback Herring are important species ecologically. They are prey species both at sea and in freshwater, and are also important predators that can alter zooplankton community composition within lakes. They also serve as a vector for nutrient transport from the oceans to inland waters, as well as from inland waters to the sea. As a result, human activities such as

fishing and the construction of dams that impact upon gaspereau population size may indirectly alter the productivity and community structure within their natal watersheds.

Alewife and Blueback Herring in individual rivers are considered separate stocks. The river scale is considered the appropriate level for assessing stock status of these species. Fisheries located in rivers and estuaries primarily target these individual stocks.

ANALYSIS

Indicators of Stock Abundance and Status

Information pertaining to the status of gaspereau populations in the Gulf Region is available on different spatial scales and are summarized in Appendix 1. These include trends in commercial landings and biological characteristics, marine abundance indices, assessment model output for the Margaree River Alewife population and estimates of the exploitation rates for Blueback Herring and Alewife in the Miramichi River. Where Alewife and Blueback Herring data are combined (i.e., gaspereau) caution is warranted when interpreting trends because the abundance of one species could be decreasing while the overall gaspereau abundance is not.

Commercial Landings

Where Alewife and Blueback Herring co-occur, they are harvested and marketed together as “gaspereau”. Fisheries are geographically widespread in the Gulf Region, with fishing practices and gear types that differ among rivers. Fisheries are managed primarily through effort controls. Management measures for commercial and recreational gaspereau fisheries have remained the same since 2001 and are described in DFO’s Integrated Fisheries Management Plan 2007-2012. Recreational fishing is allowed in Gulf New Brunswick and Gulf Nova Scotia without the obligation of having a permit or registering catches.

In the Gulf Region, reported commercial landings of gaspereau from DFO Statistics Branch have declined over the time series from 1917 to 2019. These are known to be incomplete and may not reflect abundance.

Reported commercial landings of gaspereau in the Gulf Region peaked in the early 1950s, fluctuated between 2,000 and 7,000 t from 1960 to 2010 and has remained below 2,000 t since 2011 (Figure 2). The lower landings since 2011 may result from the increased demand for bait to supply the large spring fisheries for crustaceans in the southern Gulf and an increasing proportion of the gaspereau harvests being used for that purpose. Landings in the DFO Gulf Region were driven by the gaspereau fisheries in New Brunswick which comprised 69 to 91% of the yearly landings followed by coastal areas in Nova Scotia (4 to 17%) and Prince Edwards Island (2 to 7%). Gaspereau landings were highly variable among years with large landings often followed by a sharp decline in subsequent years.

Gulf Region Marine Abundance Indices

There are very few region-wide indicators of abundance. In the marine environment, both the September bottom-trawl (1975-2019) and Northumberland Strait (2007-2019) surveys show lower gaspereau abundance and reduced spatial coverage in recent years compared to the earlier time series (Figure 3) however, it is unknown how well these survey indices reflect abundance.

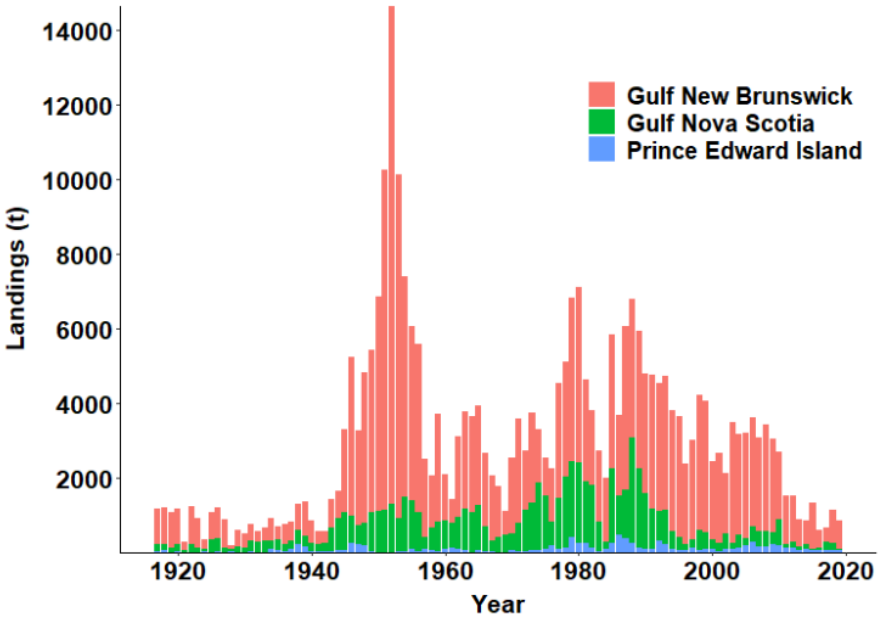

Figure 2. Reported commercial landings (t) of gaspereau (Alewife and Blueback Herring) in the Gulf Region collected by the DFO Statistics Department, 1917 to 2019.

Margaree River Indices

Most of the indices available for Alewife and Blueback Herring in the Margaree River, including landings, catch-per-unit-effort (CPUE) and the size of fish, declined over the period of 1983 to 2019 (Appendix 1). An exception is the proportion of repeat spawners which were variable for Alewife and increasing for Blueback Herring. CPUE in the commercial gaspereau fisheries was higher from 1983-1990 than from 1991-2019 (Figure 4). CPUE in the commercial gaspereau fisheries has fluctuated around a mean of 61 kg/hour since the last management changes were implemented in 2001.

Trends in body size

The length and weight of Alewife and Blueback Herring in the Margaree River commercial fisheries have declined over the time series 1983 to 2019 with declines in weight of 41% for Alewife and 53% for Blueback Herring. The declines in weight are associated with smaller fish over time being captured in the fishery, with fork lengths declining by 10% for Alewife (Figure 5) and 13% for Blueblack Herring (Figure 6).

Trends in size-at-age

Trends in size-at-age show significant declines for Alewife and Blueback Herring from 1983 to 2019 which could be indicative of a change in growth rate (Figures 7 and 8, respectively).

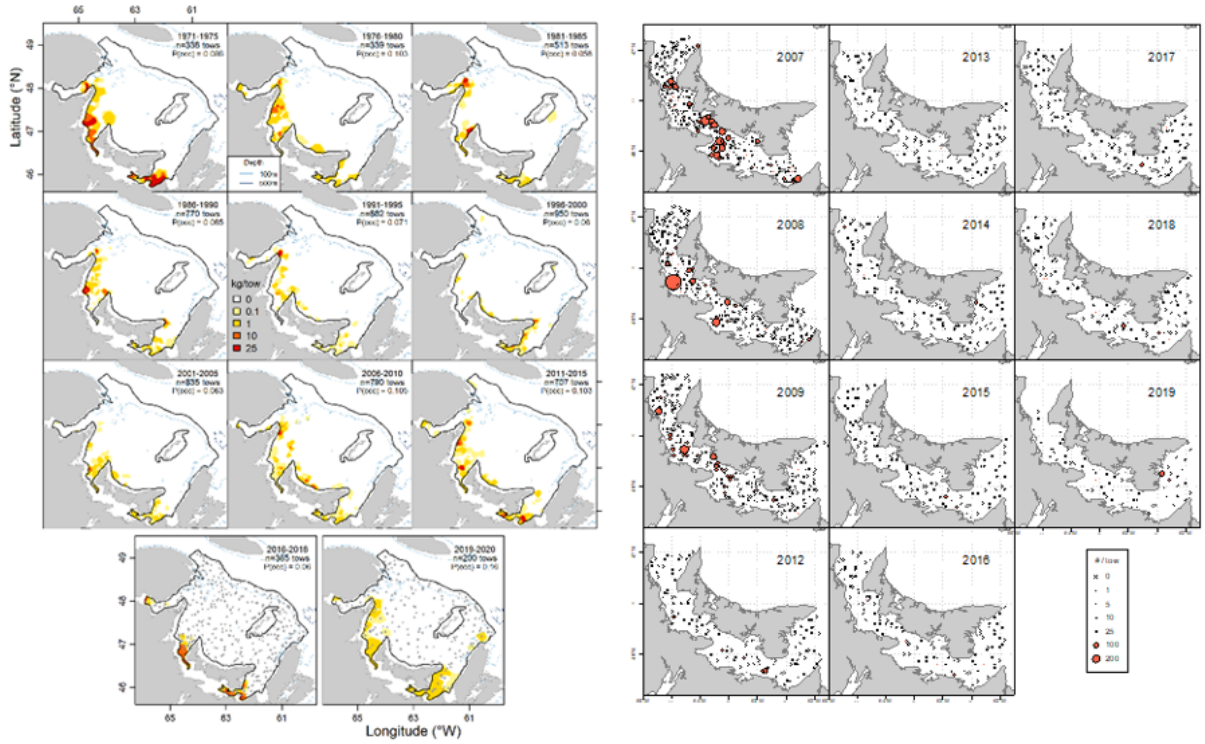

Figure 3. Spatial distribution of gaspereau relative abundance in the DFO southern Gulf of St. Lawrence September bottom-trawl survey (strata 401-439) during 1971 to 2020 (left panel) and from the DFO Northumberland Strait trawl survey during 2007 to 2019 (except 2010 to 2011) (right panel). Catches in the Northumberland Strait trawl survey were standardized to a standard tow length of 0.625 nautical miles. Catches with no gaspereau are shown as Xs.

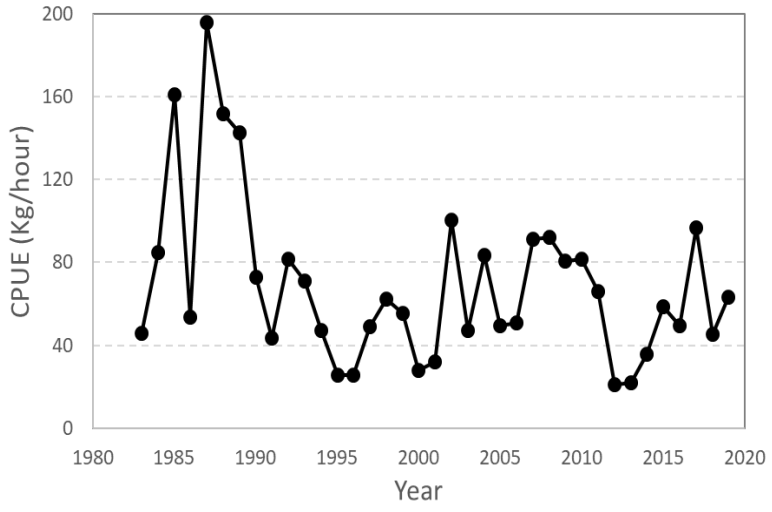

Figure 4. Annual catch per unit effort (CPUE), estimated from returned fishers logbooks as total daily landings divided by the number of hours fished, in the Margaree River, 1983 to 2019.

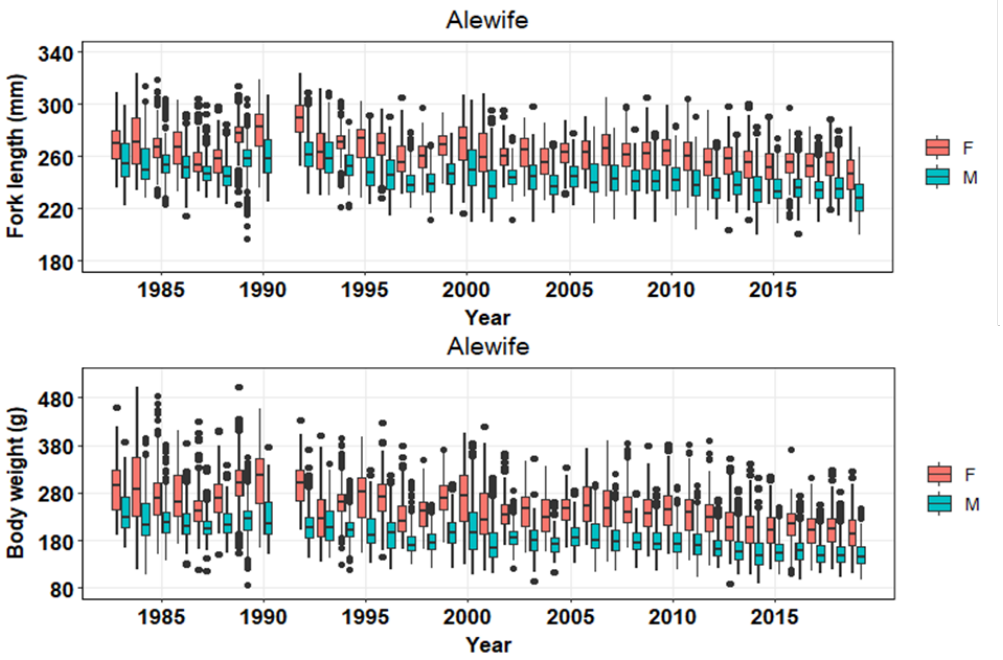

Figure 5. Trends in fork length (mm) and body weight (g) for male (M) and female (F) Alewife from biological samples collected from the commercial gaspereau fisheries in the Margaree River during 1983 to 2019.

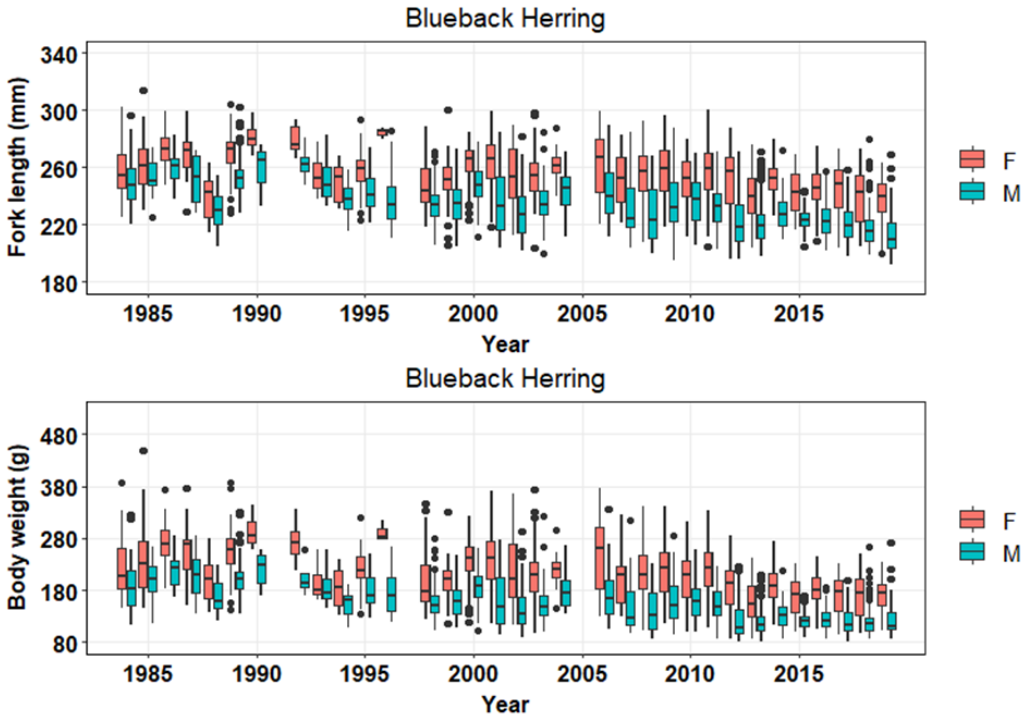

Figure 6. Trends in fork length (mm) and body weight (g) for male (M) and female (F) Blueback Herring from biological samples collected from the commercial gaspereau fisheries in the Margaree River during 1983 to 2019.

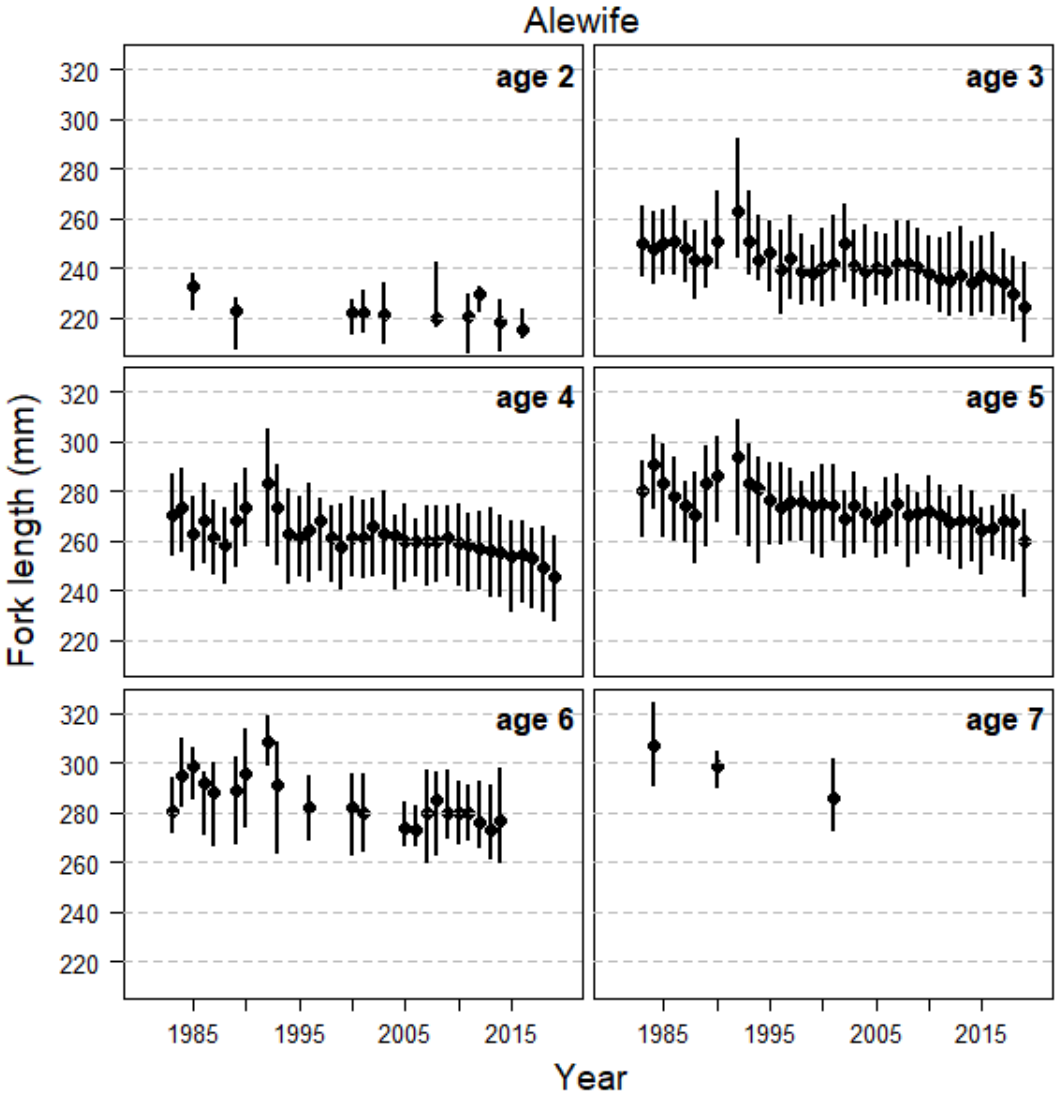

Figure 7. Trends in fork length (mm) and body weight (g) for Alewife from biological samples collected from the commercial gaspereau fisheries in the Margaree River during 1983 to 2019.

Miramichi River Indices

The Miramichi gaspereau fishery was last assessed using data from 1983 to 2000 (Chaput and Atkinson 2001). No sampling of the fishery occurred after 2000 and the data after 2000 come exclusively from catches and sampling at DFO estuary index trapnets in the Miramichi. Indicators of stock status for Alewife and Blueback Herring in the Southwest and Northwest Miramichi rivers were collected from DFO research trapnets. Catches in these trapnets are indicative of spawner escapements because commercial gaspereau fisheries occur downstream of the trapnets. Catches of both species have declined on the Southwest Branch whereas catches on the Northwest Branch have been variable (Figure 9). Unlike the Margaree River, no obvious trend was observed in the biological characteristics data from 2006 to 2013, which may result from the shorter time series (7 years).

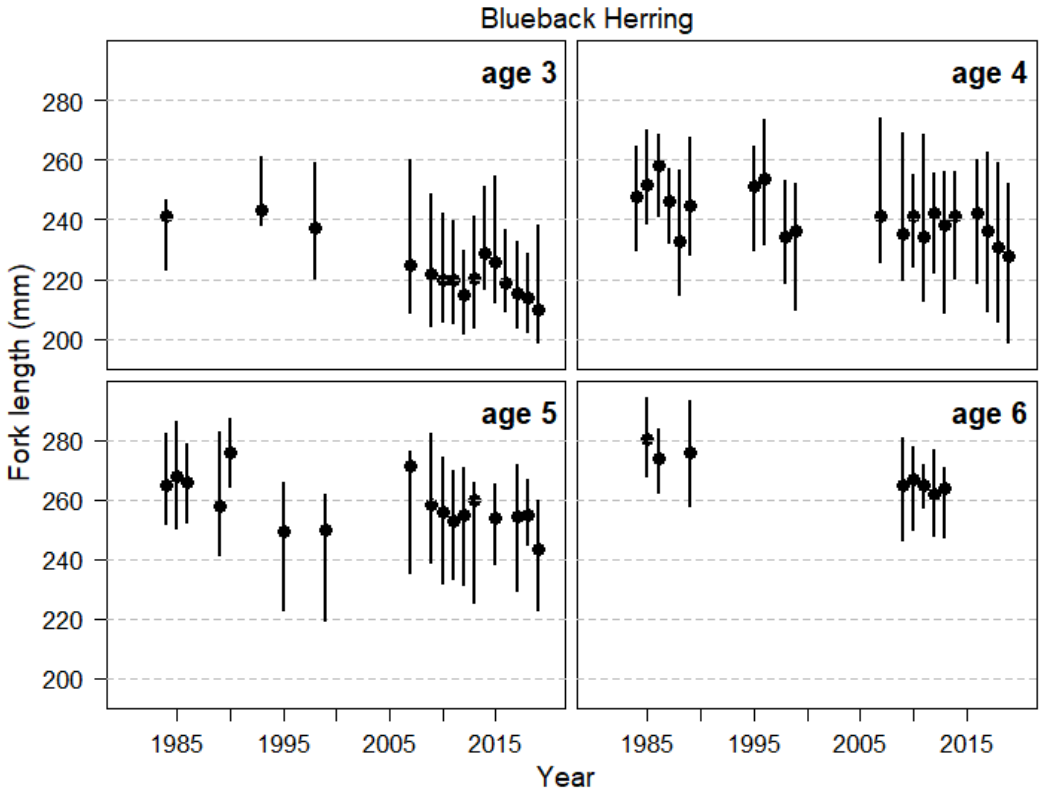

Figure 8. Trends in fork length (mm) and body weight (g) for Blueback Herring from biological samples collected from the commercial gaspereau fisheries in the Margaree River during 1983 to 2019.

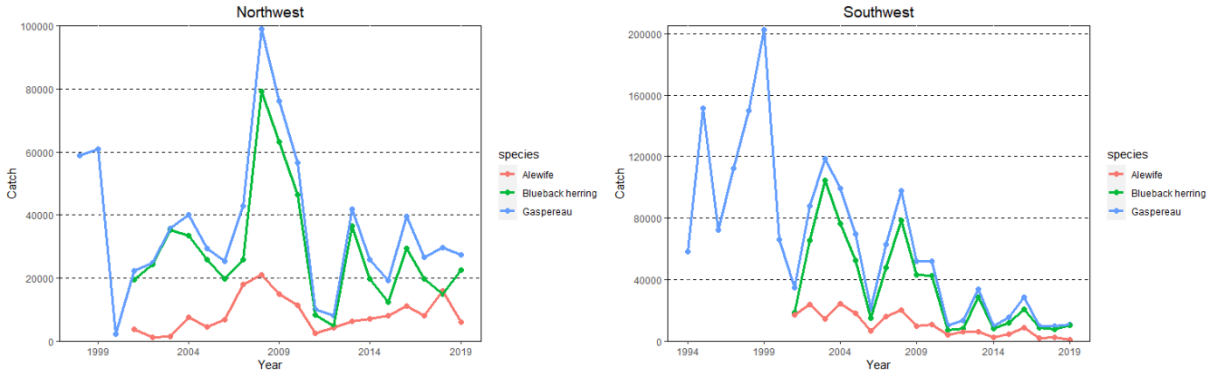

Figure 9. Annual catch of Alewife and Blueback Herring captured at DFO research trapnets on the Northwest (left panel) and Southwest (right panel) branch on the Miramichi River, 1994 to 2019. Note: different y-axis. Gaspereau includes both Alewife and Blueback Herring.

Reference Points Consistent with the Precautionary Approach

In 2006, Fisheries and Oceans Canada published a framework to support the conservation and the sustainable use of fisheries resources (DFO 2009). This precautionary approach (PA) framework provides a strategy to keep abundance and harvest rates at appropriate levels. The PA framework has three main parts:

1. References points and stock status zones (Figure 10),
2. Harvest strategies and harvest decision rules, and
3. The requirement to incorporate uncertainty and risk in the development of reference points and the implementation of decision rules.

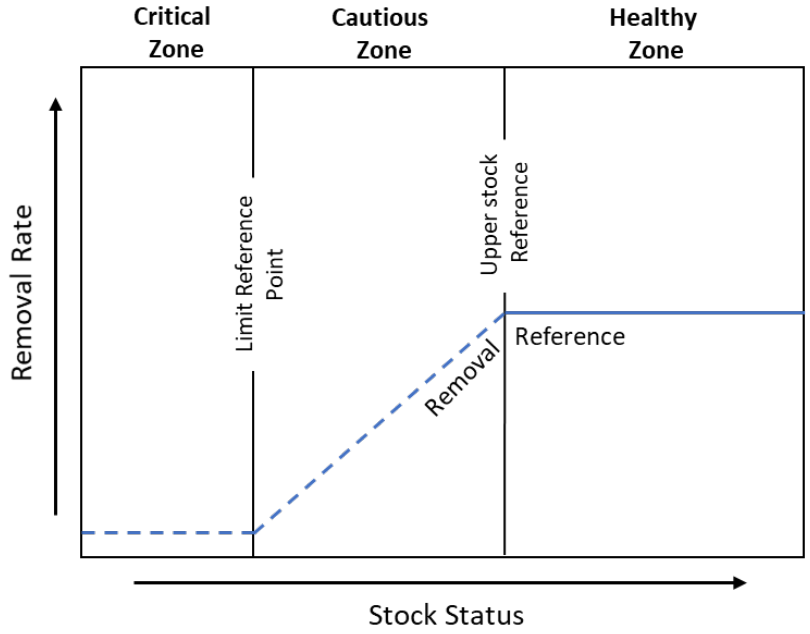

Figure 10. Fisheries management framework consistent with the Precautionary Approach (redrawn from DFO 2006).

The three stock status zones in the PA framework are separated by biological reference points (RPs). The Limit Reference Point (LRP) defines the boundary between the critical and cautious zones and represents the biomass below which the population faces serious harm. The LRP should be set to avoid risk of stock extinction, and detrimental effects to the ecosystem and long-term fishing opportunities. The Upper Stock Reference (USR) defines the boundary between the cautious and healthy zone below which removal must be reduced to avoid reaching LRP. The USR must be set at a level far enough from LRP to allow Fisheries Management to act upon the change in status and stocks to respond to management changes.

When a stock is in the healthy zone, a Removal Reference Level (RRL) is set as the maximum acceptable removal rate and includes all anthropogenic mortality. A target removal reference rate, which is lower than the maximum RRL, can also be established. The removal rates should be lower in cautious zone and near zero in the critical zone. Serious harm in the PA framework includes both human-caused mortality and ecosystem changes not related to human activities. Although RPs are in place to protect stocks, social and economic perspectives are considered in the establishment of the RPs.

The selection of RPs within the framework depends in part on the data available for the fish populations and fisheries. Here, the spawner biomass (SSB) that produces ½ the maximum recruitment (*K*) is used as the LRP (Table 1). K has the advantage that it depends only on the stock recruitment relationship and does not scale with the adult natural mortality rate. This approach is consistent with the idea that when avoiding serious harm, the PA framework should include both human-caused mortality and ecosystem changes not related to human activities.

Based on an objective of maximum sustainable yield (MSY), the spawner biomass of Alewife at maximum sustainable yield B_{msy} is used as the USR. Here, the spawner biomass (SSB) is the biomass available to spawn after the fishery in a given year.

Table 1. Reference points for the management of gaspereau populations for status determination. Removal reference points are exploitation rates (the proportion of the mature stock being removed).

Reference level	Acronym	Value	Definition
Upper stock reference level	USR	B_{MSY}	The biomass of spawners that produces MSY.
Limit reference point	LRP	K	The spawner biomass that produces ½ the asymptotic recruitment in a Beverton-Holt stock recruitment model.
Maximum removal reference level within the healthy zone	RRL_{max}	U_{MSY}	The exploitation rate that produces MSY.
Target exploitation rate within the healthy zone	RRL_{target}	$U_{90\%.MSY}$	The exploitation rate that produces 90% of MSY.

When assessing stock status, the biomass of fish returning to the river before the fishery can be compared against these values. However, when determining whether the biomass of fish spawning in the river in a given year is sufficient to obtain MSY or to avoid serious harm, the biomass of fish remaining after the fishery can be compared to these reference values.

Gaspereau fisheries are inherently variable and both abundance and fishing mortality rates can vary markedly from year-to-year. Rather than providing a single removal reference level for an Alewife fishery in the healthy zone, both a target removal reference rate and a maximum removal reference rate are provided. A population is considered “fully-exploited” if the exploitation rate, u, is between the target and maximum removal reference rate and is considered “over-exploited” if u is above the maximum removal reference rate. The exploitation rate that produces MSY (U_{MSY}) is used here as the maximum removal rate; and the exploitation rate that produces 90% of MSY ($U_{90\%MSY}$)is used as the target exploitation rate. These rates only apply when the population is in the healthy zone; rates should be lower if the population is in the cautious zone.

The Margaree River Alewife population and fishery is currently the only river in the Gulf Region with sufficient data to estimate and apply these reference points. For other populations, mortality rates can be estimated from age and previous spawning composition data and used to determine whether the exploitation rates are appropriate. However, status determinations with respect to abundance or biomass cannot be made from age and previous spawning data alone. In the case of the Miramichi River Alewife and Blueback Herring, there is the possibility of using the trapnet catches to evaluate status, although it is not presently clear how this would be achieved without prior knowledge of the status at some point in time.

Status of Margaree River Alewife

Estimation of abundance and exploitation rates

Age structured assessment models were used to assess the status of the Margaree River Alewife population and fishery. Five models were compared: a virtual population analysis (VPA) used in the last assessment, and 4 variants of a statistical catch-at-age (SCA) set up for this

assessment. These models varied with respect to data inputs, whether or not natural mortality was estimated or assumed, and how the model was fit to the data (Table 2).

Table 2. Summary of the five age structured model variants used to assess the status of Margaree River Alewife. The two models used for advice are in bold.

Parameter	**VPA**	SCA 1	SCA 2	**SCA 3**	SCA 4
Indices Included	**CPUE**	CPUE, larval	None	**CPUE**	None
Catch-at-age likelihood	**Correlation**	Multinomial	Multinomial	**Multinomial**	Normal
Natural mortality rate	**Assumed**	Estimated	Assumed	**Estimated**	Assumed

The biomass values estimated in the models are the total biomass of mature Alewife available to the fishery as well as the realized spawner stock biomass (SSB) after the fishery. Both exploitation rate and SSB estimates varied among the five models (Figure 11), but general trends were similar among models. When estimated with the VPA, SCA 2 and SCA 4, exploitation rates were higher and SSB estimates lower, most likely due to the difference in the natural mortality rates used in the models. Exploitation rate estimates from the VPA, SCA 1 and SCA 2 drop during the final few years, a pattern not evident in the SCA models without the indices (2 and 4). Confidence intervals are large for the last few years for the models without the indices, weakening the support for these estimates.

A set of qualitative evaluation criteria were used to choose preferred models. The results from the VPA and SCA 3 were carried forward and used for final status determinations. The VPA and SCA 3 model output bracket two different understandings of natural mortality and population size which results in a range of status determinations.

Reference point values

Reference points for the Margaree River Alewife population and fishery were derived using a production model developed for gaspereau. The model is standard approach for estimating reference points for fisheries adapted to the unique characteristics of gaspereau and their fisheries. The model consists of three components: a Beverton-Holt stock recruitment (SR) relationship, a spawner-biomass-per-recruit relationship and a yield-per-recruit relationship. Inputs for the model are from the catch-at-age models and reference points are calculated assuming the population is at an equilibrium for the given input values. Reference points for the application of the precautionary approach from the VPA and SCA 3 are provided in Table 3. The differences in the estimates arise largely because of the different values for the natural mortality rate between the model (assumed equal to 0.40 for the VPA, and estimated to be 0.61 using SCA 3).

Output from the production model indicates that spawner biomass has been low relative to the potential size of the stock if it were unfished; and the SR data show a lot of variability around the fitted relationship. Both of these issues can lead to uncertainty in the reference point estimates. Markov chain Monte Carlo simulations were used to assess parameter uncertainty associated with fitting the spawner-recruit model. To illustrate the issue, results are provided from SCA 3 in Table 4. The overall effect could lead to an overestimation of the removal reference levels and an underestimation of biomass reference levels.

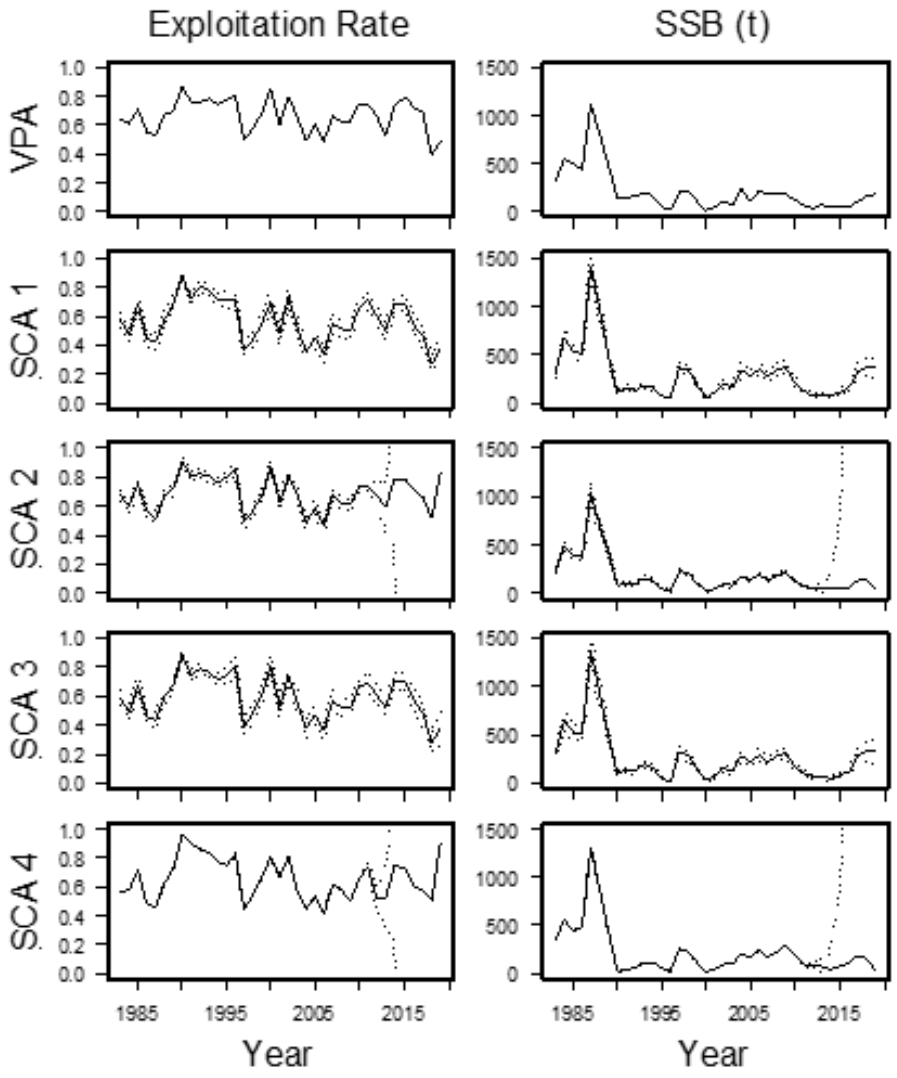

Figure 11. Comparison of the estimated exploitation rates and spawner stock biomasses (SSB) after the fisheries from five model variations used for Margaree River Alewife in this assessment. Dashed lines indicate 95% confidence intervals for the estimates.

Status

Although the estimated biomasses, exploitation rates and reference points differ somewhat, the status determinations are similar among models. As determined using the VPA (Figure 12), the biomass of fish entering the river has been in the cautious zone since 1994, and the effect of fishing has been to reduce the biomass of fish that survive to spawn to near the critical cautious boundary. Based on this model, the exploitation rate has exceeded the maximum removal reference from 1983 to 2017, with the exception of three years. Status determinations based on SCA 3 are somewhat more optimistic (Figure 12). Here the biomass of fish entering the river has been in the healthy zone most years, but the effects of fishing has been to reduce the biomass of fish that survive to spawn to the cautious zone near the LRP boundary in the majority of years since 1990. From 1983 to 2017, exploitation rates were above the target

removal reference rate in all but 3 years, and have been above the maximum removal reference levels in the majority of years.

Table 3. Maximum likelihood estimates of the precautionary Approach reference levels for the Margaree River Alewife population and fishery as estimated using output from the VPA and SCA 3.

Reference level	Acronym	Value	VPA	SCA 3
Upper stock reference level	USR	B_{MSY}	590.8 t	276.0 t
Limit reference point	LRP	*K*	113.9 t	64.3 t
Maximum removal reference level	RRL_{max}	U_{MSY}	0.51	0.60
Target exploitation rate within the fully exploited zone	RRL_{target}	$U_{90\%MSY}$	0.33	0.41

Table 4. The maximum likelihood estimate and percentiles of reference points calculated from the Markov chains for alpha and K from the analysis of uncertainty in the spawner-recruit data from SCA 3.

Parameter	MLE	10%	25%	50%	75%	90%
B_{MSY} (t)	276.0	63.24	112.83	211.56	379.97	758.93
K (t)	64.3	6.14	21.06	68.48	181.13	469.58
U_{msy}	0.60	0.37	0.43	0.52	0.66	0.77
$U_{90\%MSY}$	0.41	0.25	0.29	0.35	0.45	0.54

Miramichi River

The commercial gaspereau fisheries in the Miramichi River were sampled from 1983 to 2000 but, have not been sampled since 2000. Commercial landings from 1983 to 2000 varied. Data available for estimating the total mortality rates and exploitation rates for each species are DFO research trapnet data collected on each branch upstream of the commercial gaspereau fisheries. These include the age and previous spawning data, currently available from 2006 to 2013, excluding 2011. Catches of gaspereau at trapnets declined on the Southwest branch from 1994 to 2019 and were highly variable on the Northwest over the 1998 to 2019 time series. For both species, most fish spawn for the first time at age 3 and 4, with high variability in the number of first time spawners. For Blueback Herring in both branches, there are few fish that are spawning for a third time, and, for Alewife, there are few fish spawning for a second time.

Estimation of total mortality rates and exploitation rates

The number of years with age data is low for fitting a cohort-based model and number caught in the trapnet are variable from year-to-year. For these reasons, catch curves are used to provide estimates of the instantaneous total mortality rate. Exploitation rates are calculated from total mortality using the instantaneous natural mortality rates from the Margaree River Alewife analyses (the VPA and SCA 3).

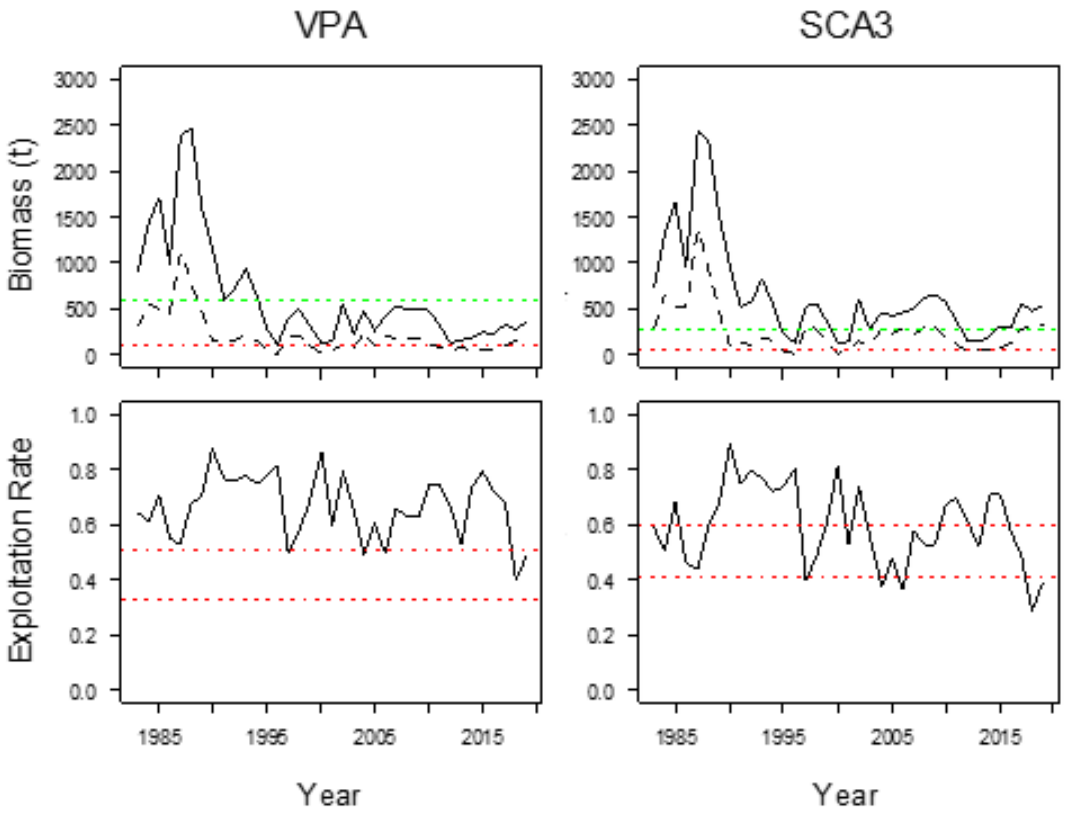

Figure 12. Time series for the Margaree River Alewife population and fishery showing the status relative to the biomass reference points (top row) and removal rate reference points (bottom row) as determined from the VPA (left column) and SCA 3 (right column). In the biomass plots, the red dotted lines show the USR (upper line) and LRP (lower line). The solid black line shows the total biomass before the fishery, whereas the dashed black line shows the spawner biomass remaining after the fishery. In the removal rate figures, the red dotted lines show the maximum removal rate (top line) and the target removal reference rate (bottom line). The values for the last four years are questionable due to retrospective issues with the model (exploitation rates are underestimated and biomass overestimated during those years).

Reference points

Currently available data are not sufficient to estimate reference points for the Miramichi River populations. For this reason, exploitation rate estimates are compared to the reference levels derived for the Margaree River Alewife population.

Status

For Alewife in the Northwest branch, the results indicate that the population was over-exploited in all years for which there are data, regardless of the model being used (Table 5).

For Alewife in the Southwest branch, the results indicate that the population was over-exploited in 5 of the 7 years, and fully exploited in the other two years. The results for Blueback Herring in the Northwest branch are more variable, being over exploited in 4 years and fully exploited in 3 years. Instantaneous total mortality rates are lower for the Southwest Blueback Herring. This population was fully exploited in six years and over-exploited in one year. When last assessed

in 2000, the exploitation rate in the Miramichi River were high. The catch curve analysis of catches from research trapnets indicates that the estimated exploitation rates are very high for both Alewife and Blueback Herring and have remained high since previous assessments (DFO 2001; Chaput and Atkinson 2001).

Table 5. Status relative to exploitation rate reference points by year for Alewife and Blueback herring (BB) fisheries in the Miramichi River, as estimated using catch curves. Z est. and Z s.e. are the estimates of the of the instantaneous total mortality rate for each species in each branch. U is the calculated exploitation rate based on the value of the instantaneous natural mortality rate from either SCA 3 (M=0.61) or the VPA (M=0.4). Status is relative the removal rate reference zone from each model (over=above U_{MSY}, fully=above $U_{90\%.MSY}$ but below U_{MSY}, under= below $U_{90\%.MSY}$).*

					Exploitation Rate		Status	
Branch	Species	Year	Z est.	Z s.e.	SCA 3	VPA	SCA 3	VPA
Northwest	Alewife	2006	2.58	0.61	0.86	0.89	over	over
Northwest	Alewife	2007	2.13	0.31	0.78	0.82	over	over
Northwest	Alewife	2008	2.53	0.27	0.85	0.88	over	over
Northwest	Alewife	2009	1.78	0.34	0.69	0.75	over	over
Northwest	Alewife	2010	2.07	0.32	0.77	0.81	over	over
Northwest	Alewife	2012	2.03	0.45	0.76	0.80	over	over
Northwest	Alewife	2013	2.22	0.37	0.80	0.84	over	over
Northwest	BB	2006	2.11	0.45	0.78	0.82	over	over
Northwest	BB	2007	1.24	0.16	0.47	0.57	fully	over
Northwest	BB	2008	1.86	0.15	0.72	0.77	over	over
Northwest	BB	2009	1.16	0.09	0.43	0.53	fully	over
Northwest	BB	2010	1.78	0.15	0.69	0.75	over	over
Northwest	BB	2012	0.91	0.27	0.27	0.40	fully	fully
Northwest	BB	2013	2.18	0.22	0.79	0.83	over	over
Southwest	Alewife	2006	1.62	0.26	0.64	0.71	over	over
Southwest	Alewife	2007	1.17	0.27	0.43	0.54	fully	over
Southwest	Alewife	2008	1.78	0.20	0.69	0.75	over	over
Southwest	Alewife	2009	1.28	0.33	0.49	0.58	fully	over
Southwest	Alewife	2010	1.99	0.31	0.75	0.80	over	over
Southwest	Alewife	2012	1.92	0.36	0.73	0.78	over	over
Southwest	Alewife	2013	3.58	1.06	0.95	0.96	over	over
Southwest	BB	2006	1.05	0.16	0.36	0.48	fully	fully
Southwest	BB	2007	1.01	0.12	0.34	0.46	fully	fully

					Exploitation Rate		Status	
Branch	Species	Year	Z est.	Z s.e.	SCA 3	VPA	SCA 3	VPA
Southwest	BB	2008	1.07	0.09	0.38	0.49	fully	fully
Southwest	BB	2009	0.80	0.08	0.18	0.33	fully	fully
Southwest	BB	2010	1.17	0.10	0.44	0.54	fully	over
Southwest	BB	2012	0.63	0.16	0.02	0.20	fully	fully
Southwest	BB	2013	2.75	0.31	0.88	0.90	over	over

Alewife and Blueback Herring stock status in other rivers

Reference points could not be defined for other Alewife and Blueback Herring stocks in the Gulf Region.

Gibson et al. (2016) proposed that collection of data for fitting catch curves (proportions by age and previous spawning history) could be used as a method to assess whether exploitation rates (or total mortality) are in the appropriate range. Despite their inherent issues, the use of catch curves as an assessment method, coupled with reasonably frequent management changes to increase or decrease the exploitation rate, can bring the exploitation rate into the appropriate range. Gibson et al. (2016) proposed this method as something that could be applied in the short term, recognising factors that can affect fishery productivity (e.g., recruitment failure) could drive a population to extinction while the exploitation rate is in the appropriate range. Additionally, this approach is not fully compliant with the precautionary approach because the LRP and USR are not defined. However, it is a first step for determining stock status for a stock not assessed. If catch curves will be used as an interim assessment method, a key consideration is how to ensure that the samples are representative of the population.

Sources of Uncertainty

Strong assumptions are made on the dynamics of Blueback Herring in the assessment. We assumed that biological characteristics and behaviour are similar for the two species however, the two species are different (i.e. different migration timing and spawning areas). Although the timing of spawning migration overlap for the two species, Alewife enter rivers two to four weeks prior to Blueback Herring. Alewife spawn in slower habitats such as lakes, ponds and slow-flowing sections of the river whereas Blueback Herring spawn in fast-flowing sections of streams. Alewife migrations are structured with older fish entering the river earlier followed by younger fish. Data to assess population structure is lacking for Blueback Herring. These differences may influence the determination of reference points and stock status for Blueback Herring.

Currently, there is insufficient data to quantitatively assess the status of all the gaspereau stocks and fisheries in DFO Gulf Region. Alternate approaches for assessing status of these fisheries are required. Intermittent collection of age composition data and other biological characteristics could potentially be used to assess status using alternate methods such as catch curve analyses, validated using assessed stocks such as on the Margaree River.

Catch data from different user groups are incomplete. Logbooks programs are important as these provide daily detailed information on catch and effort for individual stocks. Official landings, as registered by buyers, may also be lower due to a higher demand for bait to supply the spring fisheries for crustaceans in the southern Gulf and an increasing proportion of the gaspereau harvests being used for that purpose. There is also no reporting of removals from

recreational fishing. First Nations and Aboriginal organizations throughout the Gulf Region harvest gaspereau under the Food, Social and Ceremonial (FSC) and the commercial communal licenses. No estimate of annual harvest from these sources was available for this assessment.

Natural mortality rate is a key parameter in stock assessment models and there is much uncertainty in its value, whether it varies with age, and if it is stationary over time. In this assessment, constants values were proposed based on theoretical relationships as well as being estimated within the assessment model. Although the different approaches produce different estimates of abundance and exploitation rates, they give consistent predictions of status: that the populations are not in the healthy zone and that the maximum removal reference level has been exceeded in many years.

Estimation of the reference points for a stock that has generally been at low abundance is extremely difficult, and such data can lead to an overestimation of the maximum removal rate and an underestimation of the biomass reference points. If these reference points are used without acknowledging this source of bias, the stock may inadvertently continue to be overfished and put at risk. For the Margaree River assessment, the stock is considered to have been overfished over most of its assessment history and the biomass to have been most often in the cautious zone and in a few years in the critical zone before fishing. If the reference points are biased because they were estimated from a stock which is heavily exploited, the status of the Margaree River Alewife stock may actually be worse than assessed. If the population starts to rebuild, reference levels should be re-calculated when data are available over a wider range of abundances. Rebuilding the population is required in order for this to occur.

No estimates of poaching and illegal removals of gaspereau were available to be incorporated in this assessment.

CONCLUSIONS AND ADVICE

Region-wide marine abundance indices and reported commercial gaspereau fisheries catches in the DFO Gulf Region have declined over the time series. It is unknown how well these indices reflect abundance.

Catches and biological characteristics of gaspereau in the commercial fisheries in the Margaree River all show significant declines which could be indicative of changes in growth rates. The fish are smaller at a given age compared to the earlier time series. This could be of concern for estimation of biomass as smaller fish requires more individuals to reach a specific biomass level. This change could also influence the determination of reference points and stock status.

Reference points could only be defined for the Margaree River Alewife population. Data is lacking for other Alewife and Blueback Herring stocks in DFO Gulf Region because no sampling of the fisheries has been conducted since 2000.

A limit reference point (LRP) should be based on biological considerations independently of fisheries exploitation to conform to the PA policy. LRP for the Margaree River Alewife population is set equal to the spawner biomass that produces half the maximum recruitment (K). There was no model consensus for LRP value. The LRP from the VPA model is set at 113.9 t (more conservative) whereas the SCA model estimated LRP to be 64.3 t.

An Upper Stock Reference (USR) point consistent with the Precautionary Approach (PA) was defined for the Margaree River Alewife population. The biomass of spawning Alewife at maximum sustainable yield (B_{msy}) is proposed as the USR. There was no model consensus for the USR value. The VPA model was more conservative with a USR of 590.8 t whereas the SCA

model gave of USR of 276.0 t. Both the LRP and USR will need to be re-assessed if stock size increases above the low values observed from 1983 to 2019.

All models indicate that the Alewife spawner biomass in the Margaree River is near the critical cautious boundary or in the cautious zone and that exploitations rates exceed the reference removal rate for the majority of years from 1983 to 2019. Exploitations rates should be reduced below reference levels by adjusting seasons or weekly closures to improve recruitment to the river and increase reproductive capacity of the stocks. The reduction of fishing effort in gaspereau fisheries in the DFO Maritimes Region has led to increased recruitment.

For Alewife and Blueback Herring in the Southwest Miramichi River, the results indicate that the population was over-exploited in most years. The results for Blueback Herring in the Northwest Miramichi River are more variable ranging from fully exploited to over-exploited. Instantaneous total mortality rates are lower for the Southwest Blueback Herring population which was mostly fully-exploited. Exploitations rates should also be reduced by adjusting fishing effort to improve recruitment to these rivers and increase reproductive capacity of the stocks.

There is insufficient data to quantitatively assess the status of all the gaspereau stocks and fisheries in DFO Gulf Region. Alternate approaches for assessing status of these fisheries are required. Intermittent collection of age composition data and other biological characteristics in gaspereau fisheries could potentially be used to assess status using alternate methods such as catch curve analyses, validated using assessed stocks such as on the Margaree River. Species-specific samples are to be collected throughout the river-specific migration period. Detailed biological characteristics of a subset of fish are to be processed. In conjunction with landings and effort exerted in the fisheries, indicators of stock status may be developed.

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SOURCES OF INFORMATION

This Science Advisory Report is from the April 20-21, 2021 regional advisory meeting on the assessment of the status of gaspereau stocks of the southern Gulf of St. Lawrence. Additional publications from this meeting will be posted on the *Fisheries and Oceans Canada (DFO) Science Advisory Schedule* as they become available.

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APPENDIX

Appendix 1. Summary for indicators of stock status. Gaspereau refers to Alewife and Blueback Herring combined as species identification was not done.

Geographic Region	Species	Indicator	Trend or value	Comments
DFO Gulf Region	Gaspereau	Commercial landings	Declined from 1978 to 2019	Commercial landings may be indicative of abundance, but are also sensitive to changes in effort and changes in reporting
Gulf New Brunswick	Gaspereau	Commercial landings	Declined from 1978 to 2019	Commercial landings may be indicative of abundance, but are also sensitive to changes in effort and changes in reporting
Gulf Nova Scotia	Gaspereau	Commercial landings	Declined from 1978 to 2019	Commercial landings may be indicative of abundance, but are also sensitive to changes in effort and changes in reporting
Prince Edward Island	Gaspereau	Commercial landings	Declined from 1978 to 2019	Commercial landings may be indicative of abundance, but are also sensitive to changes in effort and changes in reporting
Margaree River	Gaspereau	Commercial landings	Landings are lower from 2001-2019 compared to 1984-2000	Commercial landings may be indicative of abundance, but are also sensitive to changes in effort and changes in reporting

Geographic Region	Species	Indicator	Trend or value	Comments
Margaree River	Gaspereau	Catch per unit effort in the commercial fishery	CPUE are stable from 1991-2019	1-Catches in a fishery may not be indicative of abundance. 2-Commercial CPUE may be indicative of abundance, but also can vary with environmental factors such as river water levels and fishermen behaviour.
Margaree River	Alewife	Proportion of repeat spawners	Variable	1-The proportion of repeat spawners is expected to decrease with increasing exploitation rate. 2-The proportion of repeat spawners is sensitive to the number of recruits in the spawning run.
Margaree River	Blueback Herring	Proportion of repeat spawners	Increasing	1-The proportion of repeat spawners is expected to decrease with increasing exploitation rate. 2-The proportion of repeat spawners is sensitive to the number of recruits in the spawning run.
Margaree River	Alewife	Proportion at age	Lower proportion of age 5 and older fish from 2001-2019 compared to 1983-2000	Could be indicative of increased mortality or increased recruitment.
Margaree River	Blueback Herring	Proportion at age	Lower proportion of age 5 and older fish from 2007-2019 compared to 1983-1994	Could be indicative of increased mortality or increased recruitment.

Geographic Region	Species	Indicator	Trend or value	Comments
Margaree River	Alewife	Average fork length, body weight	Declining trends from 1983 to 2019	Could be indicative of increased mortality or increased recruitment or a change in growth rate.
Margaree River	Blueback Herring	Average fork length, body weight	Decline in body weight from 1983 to 2019	Could be indicative of increased mortality or increased recruitment or a change in growth rate.
Margaree River	Alewife	Length at age, weight at age	Decline for age 3 to 7 from 1983 to 2019	Could be indicative of a change in growth rate.
Margaree River	Blueback Herring	Length at age, weight at age	Decline for all ages with data (3-6) from 1983 to 2019	Could be indicative of a change in growth rate.
Southwest Miramichi River	Alewife	Catches at research trapnet	Catches declined from 2001-2019	1-Trapnets are located upstream of commercial gaspereau fisheries. 2-Estimates are indicative of spawner escapements. 3-Short time series. Margaree and ASMFC (2017) show declining trends.
Southwest Miramichi River	Blueback Herring	Catches at research trapnet	Catches are lower from 2008-2019 compared to 2001-2007	1-Trapnets are located upstream of commercial gaspereau fisheries. 2-Estimates are indicative of spawner escapements. 3-Short time series. Margaree and ASMFC (2017) show declining trends.

Geographic Region	Species	Indicator	Trend or value	Comments
Northwest Miramichi River	Alewife	Catches at research trapnet	Catches variable from 2001-2019	1-Trapnets are located upstream of commercial gaspereau fisheries. 2-Estimates are indicative of spawner escapements. 3-Short time series. Margaree and ASMFC (2017) show declining trends.
Northwest Miramichi River	Blueback Herring	Catches at research trapnet	Catches are lower from 2008-2019 compared to 2001-2007	1-Trapnets are located upstream of commercial gaspereau fisheries. 2-Estimates are indicative of spawner escapements. 3-Short time series. Margaree and ASMFC (2017) show declining trends.
Northwest Miramichi River	Blueback Herring	Proportion at age	No obvious trend from 2006-2013	Short time series.
Southwest and Northwest Miramichi River	Alewife	Length at age, weight at age	No obvious trend from 2006-2013	Short time series.
Southwest and Northwest Miramichi River	Blueback Herring	Length at age, weight at age	No obvious trend from 2006-2013	Short time series.
Northumberland Strait survey	Gaspereau	Abundance	Abundance from 2012 to 2019 lower compared to 2007-2009 period	N/A

Geographic Region	Species	Indicator	Trend or value		Comments
Northumberland Strait survey	Gaspereau	length-frequency	After 2012, fish >25cm were not captured with overall length-frequency shifted to smaller fish	N/A	
Southern Gulf of St. Lawrence September bottom-trawl survey	Gaspereau	Abundance	Biomass and spatial coverage reduced since the1980s	N/A	

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