Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/051

HABITAT-BASED REFERENCE POINTS FOR SAINT JOHN RIVER ALEWIFE, UPSTREAM OF THE MACTAQUAC DAM

*Alewife (*Alosa pseudoharengus*)*
Credit: Mark Billard

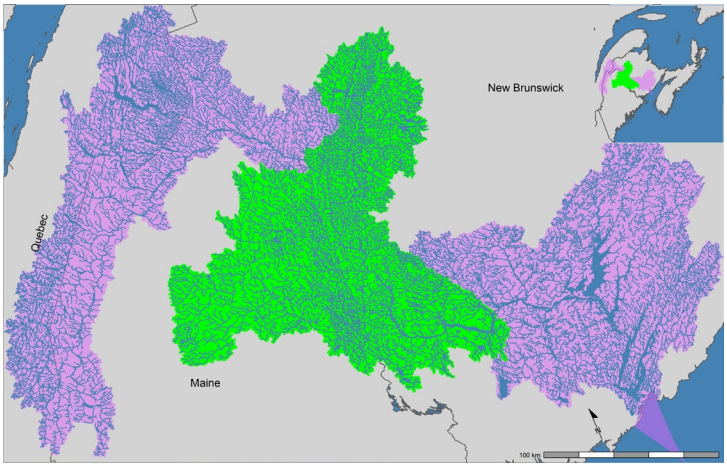

Figure 1. Saint John River watershed. Green represents assessed area, purple represents watershed area upstream of Grand Falls or downstream of the Mactaquac Dam that was not assessed.

Context:

*The construction of the Mactaquac Dam in 1967 has increased the amount of accessible nursery habitat for Saint John River Alewife (*Alosa pseudoharengus*), providing the potential for stock subunit expansion. Advice on reference points for the Saint John River Alewife stock subunit upstream of the Mactaquac Dam was requested by Fisheries and Oceans Canada (DFO) Resource Management to help determine the potential for stock size expansion of this Alewife stock subunit. Fish passage efficiency and the exploitation rate would jointly influence productivity of Alewife in the Saint John River system. Given current and historical conditions, the number of spawners reaching the Mactaquac Dam is independent of proposed upstream reference points. These reference points will provide a goal of potential productivity that may be achieved from habitat upstream of the Mactaquac Dam.*

This Science Advisory Report is from the January 12–13, 2023, regional peer review on Science Advice on Habitat-based Reference Points for Saint John River Alewife, Upstream of Mactaquac Dam.

SUMMARY

- Reference points were developed for the Saint John River Alewife stock subunit upstream of the Mactaquac Dam, in accordance with a previously peer-reviewed framework for the development of reference points for Alewife based on estimated nursery area and the median habitat carrying capacity per unit area.
- A nursery area of 58,676 acres, the sum of all habitat characterized as accessible or potentially accessible, was used to calculate reference points. This nursery area includes all

accessible or potentially accessible nursery area above Beechwood, Tobique, and Tinker dams in New Brunswick.

- At 195 kg/acre, the spawning stock biomass in the absence of anthropogenic mortality (SSB_0) was calculated to be 11,400,000 kg. The corresponding limit reference point (LRP) and proposed upper stock reference (USR) are 1,140,000 kg and 1,690,000 kg, respectively.
- If the 13,783 acres of nursery area upstream of anthropogenic barriers were accessible, the total nursery area would be 72,459 acres. For this amount of nursery area, the SSB_0 is 14,100,000 kg. The corresponding LRP and proposed USR are 1,410,000 kg and 2,090,000 kg, respectively.
- Biomass reference point recalculation may be considered following new information on habitat accessibility and/or changes to the amount of available habitat resulting from modifications to passage efficiency or barrier removal.

BACKGROUND

The construction of the Mactaquac Dam in 1967 increased the amount of accessible nursery habitat for Alewife providing the potential for stock subunit expansion. Advice on reference points for the Saint John River Alewife (*Alosa pseudoharengus*) stock subunit upstream of the Mactaquac Dam was requested by Fisheries and Oceans Canada (DFO) Resource Management to support the determination of the potential for stock size expansion of this Alewife stock subunit.

As per DFO (2006), the limit reference point (LRP) is the stock level below which productivity is sufficiently impaired to cause serious harm and defines the critical to cautious boundary. The LRP is based on biological criteria and is identified by Science. The upper stock reference (USR) is the stock level threshold below which the removal rate should be reduced to avoid reaching the LRP. The USR also defines the cautious to healthy boundary. The USR can also be a target determined by productivity objectives for the stock, broader biological considerations, and social and economic objectives for the fishery (DFO 2009). Fish passage efficiency and the exploitation rate would jointly influence productivity of Alewife in the Saint John River system. Given current and historical conditions, the number of spawners reaching the Mactaquac Dam is independent of proposed upstream reference points. The reference points will provide a goal of potential productivity that may be achieved from habitat upstream of the Mactaquac Dam.

Alewife Biology

The Alewife is a diadromous, pelagic, schooling fish, native to the east coast of North America (Loesch 1987). Alewives range from South Carolina to Newfoundland (Berry 1964, Winters et al. 1973). Populations of Alewife inhabit most accessible rivers with suitable habitat, including the Saint John River and its tributaries (Messieh 1977, Rulifson 1994). Blueback Herring (*Alosa aestivalis*) are similar in appearance and biology to Alewives, and typically migrate alongside Alewives in the spring; collectively the two species are referred to as gaspereau or river herring (Loesch 1987). Blueback Herring are present in similar numbers to Alewives in the Saint John River at the Mactaquac Dam (Beaumaster et al. 2020). Although the species are fished collectively, this analysis only includes reference points for Alewife.

Alewives spend the majority of their lives in a marine environment, returning to freshwater to spawn once sexually mature, typically at three to six years of age (Loesch 1987). Alewives are

iteroparous, and have been observed to spawn up to four times once mature (Jessop and Parker 1988). Alewife spawning migrations in DFO's Maritimes Region typically begin in April, peak in mid-May, and end in late June (Jessop 2001). Timing of spawning migrations is largely dependent on the hydrology and habitat of a river system, as well as water temperatures (Loesch 1987). Once the Alewives return to freshwater, spawning takes place in still or slow-flowing bodies of water such as lakes, ponds, and reservoirs (Loesch 1987). Adult post-spawning Alewives will migrate downstream and back to sea after several days or weeks, depending on the system (Bigelow and Schroeder 1953). Juveniles will migrate downstream during summer and fall, influenced by precipitation, and the resulting change in drainage (Cooper 1961, Gibson and Daborn 1998). However, the ecology of juvenile Alewives is highly variable from system to system (Gibson et al. 2017). Alewives are an important vector of marine-derived nutrients to freshwater systems, a prey species for aquatic and terrestrial predators, and a predator of many zooplankton species (Durbin et al. 1979, Loesch 1987, Mills et al. 1992).

Throughout DFO’s Maritimes Region, gaspereau fisheries are economically important to local communities, and are commonly sold for bait (DFO 2001). Gaspereau are harvested in a variety of ways, typically through the use of gill, trap, or dip nets depending on the river system (DFO 2001, Gibson et al. 2017). In general, Alewives in DFO’s Maritimes Region are caught alongside Blueback Herring when present, and are not differentiated, but reported as gaspereau. The gaspereau fishery on the Saint John River consists mainly of trap nets and gillnets; gillnets are used in the Saint John Harbour, while trap nets are primarily used upriver (DFO 2001). The last assessment of the gaspereau fishery in the Saint John River was in 2001, which reported catches in the range of hundreds to thousands of tons annually, most of which is attributed to the upriver trap net fishery (DFO 2001).

Saint John River

The Saint John River is the largest river in Atlantic Canada, and has historically supported economically and ecologically important populations of gaspereau (Jessop 2001, Kidd et al. 2011). The river also hosts many hydroelectric dams that generate electricity, and modify the habitat that gaspereau and other fishes use (Kidd et al. 2011). The largest of these dams, the Mactaquac generating station, was constructed in 1967 on the main stem of the Saint John River approximately 140 river kilometers from the Saint John Harbour and is a barrier for migrating fishes (Jessop 1990). Prior to construction of the dam, limited numbers of gaspereau ascended the rapids that previously existed there (Perley 1852). Gaspereau, alongside American Shad (*Alosa sapidissima*) and Atlantic Salmon (*Salmo salar*), have been passed over the Mactaquac Dam via a trap and truck system, despite the original fish passage system being primarily designed for Atlantic Salmon (Jessop 1990). Recent fish passage efficiency studies at the Mactaquac Dam have shown passage efficiency estimates within the passage structure for Alewife at 36.4% in 2020 and 25.5% in 2021 (Harrison et al. 2022). Beechwood Dam, on the main stem of the Saint John River, is equipped with an automatic fish lift and can pass multiple species (Smith 1979). A peak of over 60,000 gaspereau were moved over Beechwood Dam in 1971, but fish passage rates of gaspereau declined after 1973 to less than 4,000 fish (Smith 1979, Ingram 1981). The Tobique Dam includes a technical fishway to provide fish passage upstream; however, the fishway was not designed to pass gaspereau (Smith 1979). Little information exists on the capability of the Beechwood, Tobique, and Tinker fish passage facilities to pass large numbers of gaspereau. Tinker Dam on the Aroostook River historically passed Atlantic Salmon over the natural Aroostook Falls following passage construction in 1936; however, the passage was modified to use a trap and truck system that is still in use (Warner 1956, Chateauvert et al. 2018). Passage for species other than Atlantic Salmon at the

Tinker Dam has not been reported (DFO 2022a, MDMR 2021). Grand Falls dam is built on a large, natural falls that is considered impassable and represents the upper extent of upstream migration for gaspereau (Kidd et al. 2011).

The gaspereau fishery on the Saint John River occurs entirely downstream of the Mactaquac Dam. Escapement of gaspereau past the fishery includes, but is not limited to, all fish that are trucked over the dam. (Jessop 2001). Gaspereau escapement has varied historically, in large part, due to logistical reasons as opposed to changes in fish abundance (Jessop 1990, Jessop 2001, Beaumaster et al. 2020). Notably, beginning in 1974, fish in excess of the escapement targets were directly removed, under a commercial contract issued by DFO, from the trap and truck operation (Jessop 1990). From 1995 to 2019 targets of 800,000 Alewives and 200,000 Blueback Herring were in place as the numbers of fish that should be trucked above the Mactaquac Dam (Jessop 2001). Specific annual escapement numbers tended to vary from the targets (Beaumaster et al. 2020). After 2019, DFO ceased issuance of the commercial contract for removal of fish in excess of the escapement targets and began trucking as many fish as can be passed above the dam with the existing infrastructure. Since 2019, annual escapement has been in the range of 2,000,000 to 2,500,000 fish, the apparent maximum capacity of the existing fish passage infrastructure. Approximately 1,000,000 of the fish that escaped were Alewives (unpublished data).

Meta-analysis of Carrying Capacity for Alewife

In the absence of an adequate spawner-recruit time series, reference points for Alewife can be calculated by estimating nursery area and applying the median habitat carrying capacity for Alewife (Gibson et al. 2017). The meta-analysis by Gibson and Myers (2001, 2003a, 2003b) and Gibson (2004) provides an estimate of the median habitat carrying capacity for Alewife. Carrying capacity for Alewife here is defined as the recruitment asymptote of the stock recruitment relationship; the maximum lifetime recruitment achieved by an infinite spawner biomass (Gibson 2004). Gibson (2004) states that the median habitat carrying capacity for Alewife populations ranged from 3.0 mt/km^2 to 86.1 mt/km^2, with a median habitat carrying capacity of 51.4 mt/km^2. Median habitat carrying capacity has not been estimated for Blueback Herring.

Reference points for Alewife are calculated as a percentage of the equilibrium spawning stock biomass in the absence of anthropogenic mortality (SSB_0), including fishing, turbine mortality, and inefficient fish passage (Gibson et al. 2017). The SSB_0 is 94.7% of the carrying capacity, a value of 48.7 mt/km^2 (Gibson et al. 2017). The identified limit reference point (LRP) and proposed upper stock reference (USR) are 10% and 14.85% of the SSB_0, respectively (Gibson et al. 2017).

The results of the meta-analysis were applied to the Tusket River, Yarmouth County, NS, deriving an LRP and USR based on the accessible habitat of that river system (Bowlby and Gibson 2016). The results of the meta-analysis have also been applied to Sandy Lake, Halifax County, NS, to inform the effects of stocking and installing fish passage in that river system (DFO 2016). Here, we apply the results of the meta-analysis to calculate reference points for Alewife based on nursery area upstream of the Mactaquac Dam.

ASSESSMENT

Estimate of Nursery Area for Alewife Between the Mactaquac Dam and Grand Falls

Alewives spawn in still or slow-flowing bodies of water, such as lakes, ponds, and reservoirs (Loesch 1987). To calculate the amount of suitable nursey area for Alewives in the Saint John River upstream of the Mactaquac Dam, the surface area of these waterbodies in the Saint John River watershed was calculated in ArcMap version 10.7.1 (ESRI 2023) using shapefiles from the National Hydrographic Network GeoBase Series (GeoInfo 2020). The shapefiles were cross referenced with Google Maps satellite imagery to verify they were representative of water bodies. Shapefiles used in this analysis were last updated in 2019 and 2020.

Any waterbody greater than or equal to 10 acres was identified as potential Alewife nursery area and included in this analysis. Waterbodies that appeared to be mostly swamp or vegetation when examined with satellite imagery were not included in this analysis. Generally, the main stems of rivers were not included, but the main stem of the Saint John River was included due to its considerable size and quality generally matching that of Alewife nursery area, unlike smaller brooks and streams with fast-flowing, riffled water.

Each waterbody was determined to be inaccessible, partially accessible, or accessible to upstream migrating Alewife using multiple sources of information. In-river barriers, such as dams or waterfalls, were identified through literature review, use of satellite imagery, publicly available photographs of the barriers, and by searching the Canadian Aquatic Barrier Database (CABD) from the Canadian Wildlife Federation (CWF 2023). The CABD contains information on fish passage barriers across Canada including names, latitude and longitude, passability status, and data source details. Accessibility status of each barrier was determined using these sources of information. All lakes that were connected, regardless of distance from the Mactaquac Dam, were considered accessible.

The total lake surface area was calculated and categorized as accessible or potentially accessible, naturally inaccessible, or artificially inaccessible (Table 1). A naturally inaccessible area was defined here as a lake upstream of a waterfall or some other naturally occurring impassable obstruction, while an artificially inaccessible area is defined here as a lake upstream of some anthropogenic barrier, such as a dam or culvert. When calculating habitat area, no habitat was included above impassible barriers (both natural and artificial). All accessible or potentially accessible areas were included, and were not decremented based on potential accessibility.

The watershed area upstream of the Mactaquac Dam and downstream of Grand Falls was assessed for Alewife nursery area (Figure 1). For presentation purposes, the Saint John River watershed was divided into four reaches, defined by five major dams: Mactaquac, Beechwood, Tinker, Tobique, and Grand Falls. The reaches include all tributaries, and are:

- Upstream of Mactaquac Dam and Downstream of Beechwood Dam
- Upstream of Beechwood Dam and Downstream of Tinker, Tobique, and Grand Falls dams
- Upstream of Tinker Dam (Aroostook River)
- Upstream of Tobique Dam (Tobique River)

Table 1. Total surface areas of Alewife habitat in each reach of the Saint John River watershed. The accessible or potentially accessible area is used for the reference point calculation.

Reach	Total area (acres)	Naturally inaccessible area (acres)	Artificially inaccessible area (acres)	Accessible or potentially accessible area (acres)
Upstream of Mactaquac Dam and Downstream of Beechwood Dam	33,764	2,250	1,798	29,716
Upstream of Beechwood Dam and Downstream of Tinker, Tobique, and Grand Falls dams	4,002	0	0	4,002
Upstream of Tinker Dam (Aroostook River)	22,431	304	215	21,912
Upstream of Tobique Dam (Tobique River)	14,816	0	11,770	3,046
All	**75,013**	**2,554**	**13,783**	**58,676**

Alewife Reference Points from Estimated Nursery Area

Reference points for Alewife were calculated using the estimated nursery area upstream of the Mactaquac Dam as follows. The median SSB_0 of 48.7 mt/km^2 was converted to a mass per acreage of 0.195 mt/acre, which was further converted to 195 kg/acre. Reference points consistent with DFO's precautionary approach (DFO 2006) were established for Alewife by Gibson et al. (2017). The LRP is calculated as 10% of the SSB_0. The proposed USR is calculated as 14.85% of the SSB_0.

A nursery area of 58,676 acres, the sum of all habitat characterized as accessible or potentially accessible, was used to calculate reference points. This nursery area includes all accessible or potentially accessible nursery area above the Beechwood, Tobique and Tinker dams. At 195 kg/acre, the SSB_0 was calculated to be 11,400,000 kg. The corresponding LRP and proposed USR are 1,140,000 kg and 1,690,000 kg, respectively.

Considering the artificially inaccessible area, the 13,783 acres of nursery area upstream of artificial barriers, the total nursery area could be 72,459 acres. The calculated SSB_0 for this amount of nursery area is 14,100,000 kg and the corresponding LRP and proposed USR would be 1,410,000 kg and 2,090,000 kg, respectively.

Reference points in units of biomass can be converted to a number of fish by multiplying the biomass reference point by the mean mass of an Alewife. For example, using a mean mass of 0.210 kg per Alewife, the LRP and proposed USR, based on currently accessible nursery area, are 5,450,000 and 8,090,000 fish, respectively. The mean mass per Alewife used in these calculations should be regularly updated with the most recently available data. Weight-at-age of Alewife can change over time, requiring a larger number of smaller fish to provide the same amount of spawning stock biomass (Figure 2, Jessop 2001).

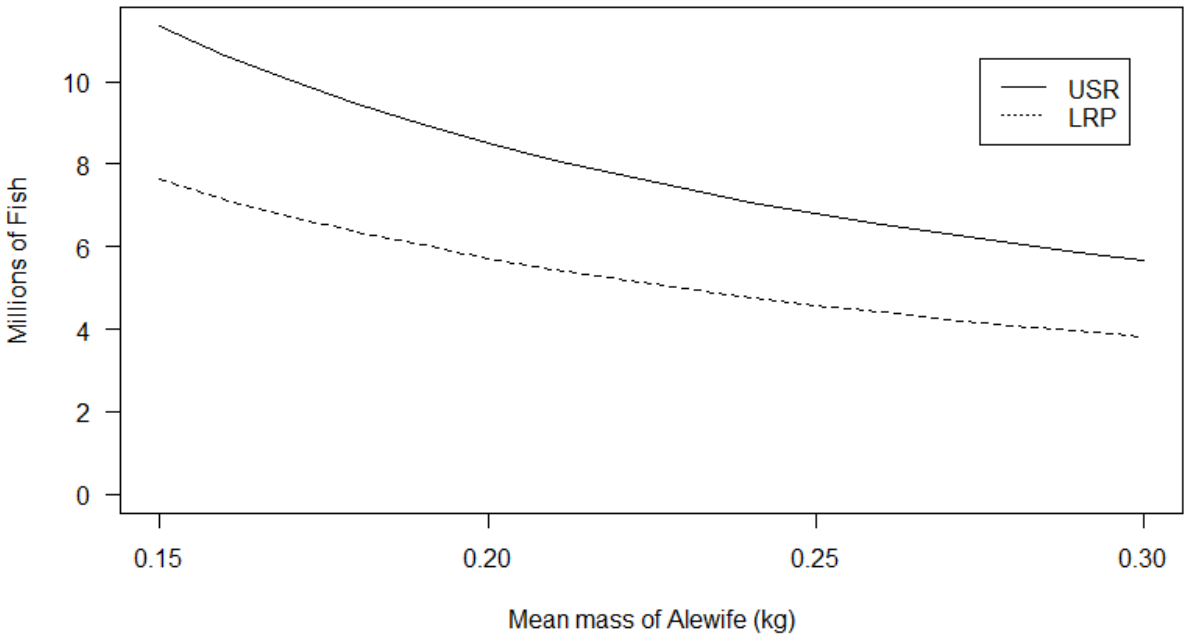

Figure 2. The number of fish required to achieve the limit reference point (LRP) and proposed upper stock reference (USR) for a given mean mass of Alewife. The LRP has a value of 1,140,000 kg and the proposed USR has a value of 1,690,000 kg.

Sources of Uncertainty

An exact estimate of nursery area is impossible. Water levels, and therefore surface areas, vary seasonally and year-to-year. It is unclear if the shapefiles used to calculate the lake surface areas are of minimum, typical, or maximum lake sizes. Nursery area accessibility fluctuates with changing flows; certain sections of river can become impassable under specific flow conditions. Additionally, this analysis does not account for any seasonal or year-to-year fluctuations in accessibility. Nursery area quality is assumed to be constant across all lakes in this analysis, although in reality it would vary spatially and temporally.

A conversion of biomass reference points to a number of fish was used for this analysis, as previously described. While this is necessary in order to provide reference points that can be compared to an abundance or escapement in number of fish, it does introduce additional sources of error (Gibson et al. 2017). First, the average mass of a fish in a population can change over time. For example, a trend in decreasing weight and length-at-age has been observed in Alewife populations in the Margaree River (DFO 2022b), and in the Gaspereau River (unpublished data). In the United States, many age classes in various rivers have demonstrated a significant decline in length-at-age over time; however, that trend has reversed to a significant increase for some age classes when using only data from 2006 to 2015 (ASMFC 2017a). If annual measurements of fish mass are not obtained, the average mass used may be inaccurate (Figure 2). Second, the number of recruits produced annually is more closely related to the number of eggs released, rather than the number of spawning fish that reach the spawning grounds. The number of eggs released by a fish is dependent on the mass of the fish, with larger fish producing more eggs than smaller fish. Furthermore, a mass of large fish may produce more eggs than an equal mass of small fish since egg production increases volumetrically. These concepts should be kept in mind when discussing the status of a

population in terms of number of fish. While the conversion to numbers is convenient, it can mask fluctuations or trends in the spawning stock biomass.

Gibson (2004) presented a carrying capacity estimate for Alewife in the Mactaquac headpond. The carrying capacity estimates from Gibson were calculated using a spawner-recruit time series, whereas the carrying capacity, SSB_0, and reference points calculated herein, are based on nursery area and the median habitat carrying capacity estimate from Gibson (2004). The spawner-recruit time series used by Gibson was primarily data from a period of low abundance, rather than an ideal time series across a range of spawner abundances. Not only does the current analysis provide carrying capacity estimates for nursery area upstream of the Mactaquac headpond, but using the median habitat carrying capacity estimate avoids the problem of a low abundance spawner-recruit time series. However, applying the meta-analysis assumes that the population is well represented by the populations used in the meta-analysis. Any unique characteristics of this population that affect productivity would not be captured in the reference points, the way it would if population specific data in the form of a spawner-recruit time series was used to calculate the reference points.

All accessible or potentially accessible habitat is assumed to be within a range of possible Alewife spawning migration, regardless of distance from the estuary. The possible migration distances required to reach all accessible or potentially accessible nursery habitat in this analysis are larger than other systems in DFO's Maritimes Region. In the Tobique watershed, Trousers Lake is approximately 452 river kilometers from the Saint John Harbour, while Long Lake is approximately 449 river kilometers, and Sisson Branch Reservoir is approximately 413 river kilometers from the harbour. In the Aroostook watershed, Munsungan Lake is approximately 500 river kilometers and Scopan Lake is approximately 426 river kilometers from the Saint John Harbour. These distances are similar to the migratory distances of river herring in the Connecticut River, where a major dam is located at river kilometer 139, and Blueback Herring were observed to migrate nearly 320 kilometers from the ocean (ASMFC 2017b). If Alewife do not migrate to all potentially accessible or accessible habitat, the reference points calculated here would be overestimated.

Fish passage efficiency at barriers that allowed some potential for fish passage was assumed to be 100% in this analysis. Fish passage efficiency at each barrier upstream of the Mactaquac Dam is unknown. Any fish passage less than 100% will limit the size to which the population could grow, in much the same way increased fishing pressure will reduce population size. Therefore, reference points were calculated in the absence of all anthropogenic effects.

CONCLUSIONS AND ADVICE

Reference points were developed for the stock subunit above the Mactaquac Dam to provide the potential for stock subunit expansion from its current state. The reference points presented here, an LRP of 1,140,000 kg and a proposed USR of 1,690,000 kg are based on the currently accessible and potentially accessible nursery area for Alewife upstream of Mactaquac Dam. This nursery area includes all accessible or potentially accessible nursery area above the Beechwood, Tobique, and Tinker dams, but does not include any nursery area upstream of dams without fish passage. Any changes to accessibility of nursery area would warrant a recalculation of reference points. A more diverse range of observed spawner abundances in addition to adequate population specific data would also warrant a direct estimation of reference points following the approach described by Gibson et al. (2017).

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Abby Daigle	Science, Gulf Region
Angeline LeBlanc	Fish and Fish Habitat Protection Program, Gulf Region
Brady Stevenson	Resource Management, Maritimes Region
Bryan Hulbert	Fish and Fish Habitat Protection Program, Gulf Region
Cassandra Colwell	Indigenous Fisheries Management, Maritimes Region
Cindy Breau	Science, Gulf Region
Darek Moreau	Science, Maritimes Region
Derek Hogan	Science, Maritimes Region
George Nau	Science, Maritimes Region
Hannah Bradford	New Brunswick Department of Agriculture, Aquaculture and Fisheries
Heather Bowlby	Science, Maritimes Region
Ian Luddington	Fish and Fish Habitat Protection Program, Gulf Region
Jarrad Sitland	Resource Management
Jean-Francois Mallet	Fish and Fish Habitat Protection Program, Gulf Region
Lily Priest	Science, Maritimes Region
Mario Cormier	Advisory Committee Co-chair/Industry
Mark Billard	Science, Maritimes Region
Parise Ouellette	New Brunswick Department of Natural Resources and Energy Development
Peter Comeau	Science, Maritimes Region
Phil Harrison	Canadian Rivers Institute
Tara McIntyre	Science, Maritimes Region
William Polchies	Woodstock First Nation

SOURCES OF INFORMATION

This Science Advisory Report is from the January 12–13, 2023, regional peer review on Science Advice on Habitat-based Reference Points for Saint John River Alewife, Upstream of Mactaquac Dam.

[ASMFC] Atlantic States Marine Fisheries Commission. 2017a. River Herring Stock Assessment Update. Volume I: Coastwide Summary.

[ASMFC] Atlantic States Marine Fisheries Commission. 2017b. River Herring Stock Assessment Update. Volume II: State-Specific Reports.

Beaumaster, R., Harris, L.E., and Anderson, L. 2020. Mactaquac Dam, New Brunswick gaspereau report 2019. Can. Data Rep. Fish. Aquat. Sci. 1301: iii + 5 p.

Berry, F.H. 1964. Review and Emendation of Family *Clupeidae*. Copeia. 1964(4): 720–730.

Bigelow, H.B., and Schroeder, W.C. 1953. Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service, United States Government Printing Office, Washington, D.C.

Bowlby, H.D., and Gibson, A.J.F. 2016. River Herring Assessment for the Tusket River, Nova Scotia. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/106. v + 45 p.

Chateauvert, C.A., Linnansaari, T., Samways, K., and Curry, R.A. 2018. Fish Passage at Tobique-Narrows, Beechwood, and Mactaquac Hydropower Generating Facilities in the Saint John River System, New Brunswick. Mactaquac Aquatic Ecosystem Study Report Series 2018-024. Canadian Rivers Institute, University of New Brunswick, 52 p.

Cooper, R.A. 1961. Early life history and spawning migration of the alewife, *Alosa pseudoharengus*. Master's thesis. University of Rhode Island, Kingston, Rhode Island, USA.

CWF [Canadian Wildlife Federation]. 2023. Canadian Aquatic Barriers Database. Canadian Wildlife Federation. [05 August 2022].

DFO. 2001. Gaspereau Maritime Provinces Overview. DFO Sci. Stock Status Rep. D3-17(2001).

DFO. 2006. A Harvest Strategy Compliant with the Precautionary Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/023.

DFO. 2009. A fishery decision-making framework incorporating the precautionary approach. Last updated 2009-03-23.

DFO. 2016. Habitat, Passage and Stocking Considerations for Gaspereau at Sandy Lake, Nova Scotia. DFO Can. Sci. Advis. Sec. Sci. Resp. 2016/005.

DFO. 2022a.Graphical Report: Atlantic Salmon Rivers Index. [Accessed 22 December 2022].

DFO. 2022b. Stock status of Alewife and Blueback Herring (Gaspereau) in the DFO Gulf Region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/014.

Durbin, A.G., Nixon, S.W., and Oviatt, C.A. 1979. Effects of the Spawning Migration of the Alewife, *Alosa pseudoharengus*, on Freshwater Ecosystems. Ecology. 60(1): 8–17.

ESRI [Environmental Systems Research Institute]. 2022 ArcGIS Desktop: version 10.7.1. Redlands, California.

GeoInfo 2020. National Hydro Network - NHN - GeoBase Series. Natural Resources Canada. [21 July 2022].

Gibson, A.J.F. 2004. Dynamics and Management of Anadromous Alewife (*Alosa pseudoharengus*) Populations. Doctoral dissertation. Department of Biology, Dalhousie University, Halifax, NS.

Gibson, A.J.F., and Daborn, G.R. 1998. The Ecology of Young-of-the-Year Alewives in Gaspereau Lake with Reference to Water Management Strategies in the Black River - Gaspereau River Watershed. Acadia Centre for Estuarine Research Publication No 45. Wolfville, NS. 68 p.

Gibson, A.J.F., and Myers, R.A. 2001. Gaspereau River Alewife Stock Status Report. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/061.

Gibson, A.J.F., and Myers, R.A. 2003a. Biological Reference Points for Anadromous Alewife (*Alosa pseudoharengus*) Fisheries of the Maritimes Provinces. Can. Tech. Rep. Fish. Aquat. Sci. 2468. 50 p.

Gibson, A.J.F., and Myers, R.A. 2003b. A Meta-analysis of the Habitat Carrying Capacity and the Maximum Lifetime Reproductive Rate of Anadromous Alewife in Eastern North America. Am. Fish. Soc. Symp. 35: 211–221.

Gibson, A.J.F., Bowlby, H.D., and Keyser, F.M. 2017. A Framework for the Assessment of the Status of River Herring Populations and Fisheries in DFO's Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/105. vi + 69 p.

Harrison, P., Hill, C.R., Yamazaki, G., and Curry, R.A. 2022. Fishway Efficiency, PIT Tagging Study, 2020 and 2021: Data Report. Mactaquac Aquatic Ecosystem Study Report Series 2022-078. Canadian Rivers Institute, University of New Brunswick, 16 p.

Ingram, J.H. 1981. Fish-count data at Beechwood Dam fish-collection facilities, 1972 -76. Can. Data Rep. Fish. Aquat. Sci. No. 254. viii + 41 p.

Jessop, B.M. 1990. Passage and harvest of river herring at the Mactaquac Dam, Saint John River: an attempt at active fishery management. N. Am. J. Fish. Manag. 10(1): 33–38.

Jessop, B.M. 2001. Stock status of alewives and blueback herring returning to the Mactaquac Dam, Saint John River, N.B. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/059.

Jessop, B.M. and Parker, H.A. 1988. The alewife in the Gaspereau River, Kings County, Nova Scotia, 1982-1984. Can. Man. Rep. Fish. Aquat. Sci. 1992. 29 p.

Kidd, S.D., Curry, R.A., and Munkittrick, K.R. 2011. The Saint John River: A state of the environment report. Canadian Rivers Institute, University of New Brunswick.

Loesch, J.G. 1987. Overview of Life History Aspects of Anadromous Alewife and Blueback Herring in Freshwater Habitats. Am. Fish. Soc. Symp. 1: 89–103.

[MDMR] Maine Department of Marine Resources. 2021. Historical Trap Counts. [Accessed 22 December 2022].

Messieh, S.B. 1977. Population structure and biology of alewives (*Alosa pseudoharengus*) and blueback herring (*A. aestivalis*) in the Saint John River, New Brunswick. Environ. Biol. Fishes. 2: 195–210.

Mills, E.L., O'Gorman, R., DeGisi, J., Heberger, R.F., and House, R.A. 1992. Food of the alewife (*Alosa pseudoharengus*) in Lake Ontario before and after the establishment of *Bythotrephes cederstroemi*. Can. J. Fish. Aquat. Sci. 49(10): 2009–2019.

Perley, M.H. 1852. Reports on the sea and river fisheries of New Brunswick. 2nd edition. Edited by J. Simpson. Queen's Printer, Fredericton, New Brunswick.

Rulifson, R.A. 1994. Status of Anadromous Alosa Along the East Coast of North America: pp. 134–158. Edited by J.E. Cooper, R.T. Eades, R.J. Klauda, and J.G. Loesch. Anadromous Alosa Symposium. American Fisheries Society – Tidewater Chapter, Bethesda, Maryland.

Smith, K.E.H. 1979. Capture and distribution of all fish species at Saint John River Power Dams, New Brunswick, from construction years to 1971. Can. Data Rep. Fish. Aquat. Sci. No. 171. viii + 55 p.

Warner, K. 1956. Aroostook River: Salmon Restoration and Fisheries Management. Maine Department of Inland Fisheries and Game and Atlantic Salmon Commission. Augusta, Maine.

Winters, G.H., Moores, J.A., and Chaulk, R. 1973. Northern Range Extension and Probable Spawning of Gaspereau (*Alosa pseudoharengus*) in the Newfoundland Area. J. Fish. Res. Board Can. 30(6): 860–861.

THIS REPORT IS AVAILABLE FROM THE:

Center for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
Bedford Institute of Oceanography
1 Challenger Drive, PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2

E-Mail: DFO.MaritimesCSA-CASMaritimes.MPO@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-73530-6 Cat. No. Fs70-6/2024-051E-PDF

Correct Citation for this Publication:

DFO. 2024. Habitat-Based Reference Points for Saint John River Alewife, Upstream of the Mactaquac Dam. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/051.

Aussi disponible en français :

MPO. 2024. Points de référence fondés sur l'habitat pour le gaspareau de la rivière Saint-Jean, en amont du barrage de Mactaquac. Secr. can. des avis sci. du MPO. Avis sci. 2024/051.