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

Gulf Region

Canadian Science Advisory Secretariat
Science Advisory Report 2025/019

HABITAT-BASED CARRYING CAPACITY ESTIMATES FOR ALEWIFE (*ALOSA PSEUDOHARENGUS*) IN THE SKUTIK (ST. CROIX) RIVER WATERSHED

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

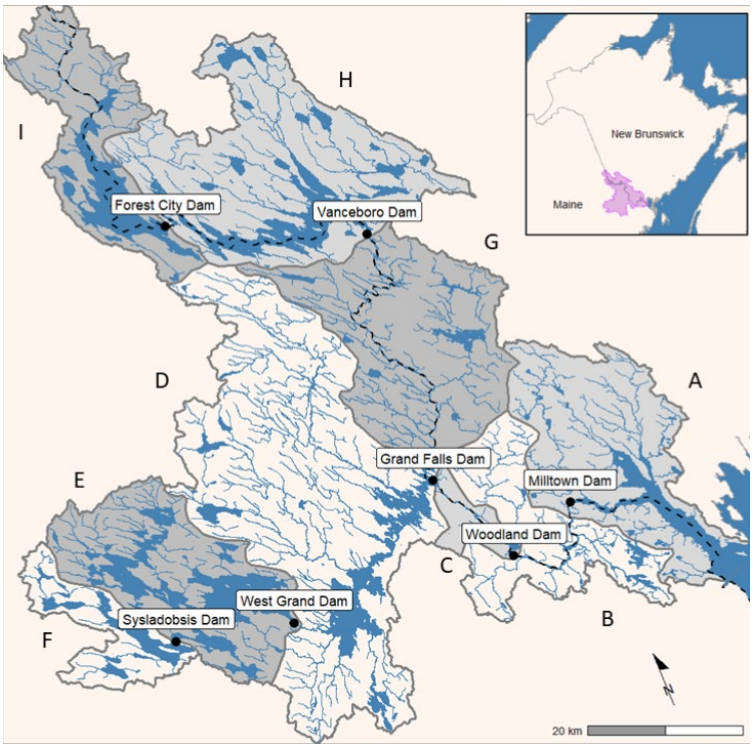

Figure 1. Skutik (St. Croix) River watershed, divided into reaches by seven major dams. The border between Canada and the United States is represented by a black dashed line. The map inset shows the extent of the watershed in pink relative to Maine and New Brunswick.

CONTEXT

Alewife (*Alosa pseudoharengus*) in the Skutik (St. Croix) River have been historically affected by dams, fishing and pollution, leading to the near extirpation of the species. In recent history, the abundance of alewife has increased due to mitigation of the aforementioned effects. The theoretical carrying capacity for alewife in the Skutik River was requested by Fisheries and Oceans Canada's Fish and Fish Habitat Protection Program to aid in future decisions related to alewife restoration and conservation within the Skutik River watershed. It is anticipated that further population specific analyses and information may be required to support any future well-defined population restoration goals.This Science Advisory Report is from the November 25-26, 2024, regional peer review on Habitat-Based Carrying Capacity Estimates for Alewife (*Alosa*

pseudoharengus) in the Skutik (St. Croix) River Watershed. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Alewife are a small anadromous, iteroparous fish native to the Skutik River watershed that spawn in lakes and slow flowing bodies of water. Alewife productivity is partly determined by the density dependence of the juvenile life stage in freshwater lakes.
- Nursery areas for alewife in the Skutik River were estimated using satellite imagery and shapefiles from the National Hydrographic Network. Theoretical carrying capacity and theoretical spawning stock biomass in the absence of anthropogenic effects (SSB_0) for Skutik River alewife were estimated by applying the meta-analysis of the habitat carrying capacity for alewife to the estimated nursery area. Biological reference points in accordance with the Fisheries Management framework were not estimated in this process.
- Methods from a previously reviewed meta-analysis of the habitat carrying capacity for alewife were applied according to the framework for the assessment of river herring.
- The Skutik River watershed contains 104,762 acres of accessible or potentially accessible nursery area, 121 acres of naturally inaccessible nursery area, and 3,403 acres of artificially inaccessible nursery area which combine for a total of 108,286 acres of alewife nursery area, when including waterbodies greater than 10 acres.
- The theoretical carrying capacity and SSB_0 for accessible and potentially accessible nursery area was estimated to be 21,817 mt (10^{th} percentile of 12,734 mt, 90^{th} percentile of 37,380 mt) and 20,661 mt (10^{th} percentile of 12,059 mt, 90^{th} percentile of 35,399 mt), respectively.
- A number of uncertainties are outlined, with the largest being the wide range of the confidence intervals for theoretical carrying capacity and SSB_0 derived from the meta-analysis of the habitat carrying capacity for alewife, and that the nursery area and alewife population of the Skutik River are typical and well-represented by the populations modeled in the meta-analysis.
- The estimates of theoretical carrying capacity and SSB_0 presented here are calculated under the assumption of 100% fish passage at anthropogenic barriers, where passage efficiency less than that will limit population growth. It is unlikely that fish passage will be 100% at any barrier.
- The nursery area quantified here captures the nursery area as it currently is, including the potential nursery area that was artificially created by building dams and impoundments throughout the watershed. Any future changes to the quantity of nursery area by removing dams or providing access to currently inaccessible nursery areas would require updating the estimated quantities herein.

BACKGROUND

In the Skutik (St. Croix) River watershed, New Brunswick and Maine, movement of diadromous fishes has been limited by dams for over a century. With the removal of the Milltown Dam in 2023 resulting in free fish passage in the spring of 2024, there has been renewed interest in

restoring diadromous fish populations. Efforts are being made to improve fish passage at several remaining dams on the river. The species of interest are mainly alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*), collectively known as gaspereau or river herring. Acknowledging there is not currently sufficient information to include blueback herring in such analysis, the Fish and Fish Habitat Protection Program (FFHPP) has asked for estimates of the potential productivity of alewife in this system to help inform restoration goals, including fish passage objectives.

The Skutik River (Figure 1) forms 185 km of the border between New Brunswick and Maine and is composed of 183 tributary streams (Dill et al. 2010). Its headwaters begin in Monument Brook, upstream of North Lake, above the Forest City Dam, while its main stem runs along the international border before draining into the Passamaquoddy Bay. The Peskotomuhkati Nation have a present and historical relationship with the Skutik River watershed and multiple species that inhabit (or have inhabited) its waters. Dams, overfishing, and pollution have all had negative impacts on the river and have contributed to declines in native fish populations including Atlantic salmon (*Salmo salar*), American shad (*Alosa sapidissima*), American eel (*Anguilla rostrata*), alewife, and blueback herring (Clarke et al. 2022). Anadromous fish abundance in the Skutik began to decline in the 1860s because of dams and water pollution (Dill et al. 2010, Barber 2018). Waterbodies upstream of impoundments or dams have been artificially created, increasing the amount of potential nursery area for alewife relative to pre-dam conditions. In Canada, the Peskotomuhkati Nation holds treaty rights to fish in the Skutik, however the historical and intentional blockage of fish migrations has prevented them from meaningfully exercising those rights (Clarke et al. 2022).

Alewife, or *siqonomeq* to the Peskotomuhkati, is a species of anadromous fish indigenous to the eastern United States and Canada. Adults are typically sexually mature after three to six years, and broadcast spawn in freshwater lakes and slow-moving bodies of water in the spring after migrating inland from coastal waters of the Atlantic Ocean (Collette and Klein-MacPhee 2002). After spawning, many adults return to the Atlantic where they remain until the following spring. Young of the year typically remain in freshwater until the fall when they move downstream to estuarine habitat, however juvenile movement is variable and dependent on the river system (Gibson et al. 2017). The alewife life cycle is often viewed as density-dependent during the juvenile life stage in freshwater, and density-independent while immature fish are growing in estuarine and marine habitats. Alewife fisheries have local economic value and are geographically widespread with numerous participants. Gear type varies among rivers and alewife fisheries are typically managed with effort controls in the Maritimes Region of Canada (Gibson et al. 2017). In Maine, commercial alewife fisheries are managed by municipalities according to state and Federal regulations. Site-specific harvest plans are developed to ensure adequate escapement for municipal fisheries and must be approved each year prior to the fishing season. A mandatory 72-hour closure and a 2012 moratorium on intercept fishing in marine waters are intended to reduce over-exploitation (DMR 2024).

Several different estimates of carrying capacity for alewife in the Skutik River watershed have been presented in the last several decades. These estimates are typically presented as a total number of fish, or as a number of fish or biomass per acre of nursery area. Dill et al. (2010) reported several carrying capacity estimates for alewife in the Skutik, including an estimate from White and Squires (1989) of 7.5 million to 9.5 million adults for a portion of the watershed upstream of Milltown Dam and downstream of West Grand Dam and Vanceboro Dam, and an estimate from Watt (1987) of 20 million adults for the entire watershed “exclusive of the West Branch above Princeton”. There was no explanation from Watt (1987) as to how the figure of 20 million fish was arrived at. The original text of White and Squires (1989) could not be located

to evaluate how those values were derived. Flagg (2007) suggested the values of 117.5-235 adults per acre of spawning habitat. These values are derived from long term annual yields of alewife from the Damariscotta and St George Rivers during the 1950s to 1980s, which were 190 and 270 pounds (86.2 and 122 kg) per acre respectively. Alewife were estimated to weigh 0.5 pounds (0.227 kg) each and spawning escapement was assumed to be 15% of long-term annual yields; combined these values produce 117.5-235 adults per acre of spawning habitat. This range of values represents equilibrium points for the population, i.e. the total abundance of alewives supported by this system under a constant fishing mortality rate. A long-term management plan for the diadromous fisheries of the St. Croix River (Anon 1988) jointly authored by Atlantic Sea-Run Salmon Committee (Maine), Department of Marine Resources (Maine), Inland Fisheries (Maine), and DFO (Maritimes Region) contains production estimates for alewife in the Skutik. The authors of the management plan assert that adult alewife production varies from 150 lbs/acre (168 mt/km^2) to as much as 700 lbs/acres (784 mt/km^2), and conservatively estimate the productive capacity of Skutik alewife to be 200 lbs/acre (224 mt/km^2), due the many eutrophic lakes in the watershed. Using a value of 445 km^2 of lakes and ponds and the above estimate of alewife production, the authors of the management plan state that the watershed can produce 10,000 mt of adult alewives. The authors claim that successful alewife fisheries are maintained with a spawning escapement of 15% (assumed to be 15% of total annual abundance) and that the watershed below West Grand Lake could produce a total of 5,140 mt of adult alewives, of which 4,370 mt could be harvested annually at an 85% exploitation rate. The authors do not differentiate between equilibrium points of exploited and unexploited populations. The 15% escapement was achieved by regulating fishing to six days a week with a one-day closure. Maine no longer recommends a one-day closure for fishing river herring (DMR 2024). The carrying capacity used in the Skutik Watershed Strategic Sea-run Fish and River Restoration Plan (Clarke et al. 2022) for alewife is 845.7 fish/acre, which is directly obtained from Gibson et al. (2017), the same source from which the following analyses are based upon.

The purpose of this process is to develop estimates of carrying capacity to inform efforts of restoring fish populations in the Skutik River. This analysis is an estimate of theoretical carrying capacity, it is anticipated that detailed restoration plans would rely on further nursery area and population specific information. Using theoretical nursery area carrying capacity estimates (Gibson and Myers 2003b) the following objectives are addressed:

1. Estimate the potential nursery area available to alewife in the Skutik River watershed.
2. Estimate the median and range of carrying capacity for alewife that the Skutik River watershed could theoretically support.

Additionally, a median estimate and range of the theoretical spawning stock biomass in the absence of anthropogenic effects (SSB_0) for Skutik alewife is provided. Should adequate population-specific data become available, a population model should be used to estimate carrying capacity and reference points for the Skutik River alewife in replacement of the values herein.

ANALYSIS

Estimate of Nursery Area for Alewife

An assessment of the Skutik watershed was completed to determine the amount of nursery area available for alewife. The methods for this assessment are based on a similar assessment completed for the Saint John River watershed upstream of Mactaquac dam (DFO 2024). The

Skutik watershed was divided into nine reaches, defined by seven major dams (Figure 1): Milltown, Woodland, Grand Falls, Vanceboro, Forest City, West Grand, and Sysladobsis. Although Milltown dam has recently been removed, it was included here as a division between reaches to facilitate comparison against previous assessments. The reaches are as follows:

- Downstream of former Milltown Dam
- Upstream of former Milltown Dam and downstream of Woodland Dam
- Upstream of Woodland Dam and downstream of Grand Falls Dam
- Upstream of Grand Falls Dam and downstream of West Grand Dam
- Upstream of West Grand Dam to Sysladobsis Dam
- Upstream of Sysladobsis Dam
- Upstream of Grand Falls Dam and downstream of Vanceboro Dam
- Upstream of Vanceboro Dam and downstream of Forest City Dam
- Upstream of Forest City Dam

Surface area of all waterbodies within each reach were assessed using ArcMap (version 10.8.2). Shapefiles were downloaded from the National Hydro Network (NHN) GeoBase and projected with Universal Transverse Mercator for NAD 1983 UTM Zone 19N. While performing this analysis, shapefiles were cross-referenced with Google Maps satellite imagery to ensure the polygons of waterbodies were representative of alewife nursery area. Shapefiles used were last updated in 2020. Any waterbody greater than 10 acres (0.004047 km^2) in size was identified as a potential nursery area. A surface area of 10 acres was selected as the threshold for inclusion in the analysis due to increased uncertainty of nursery area suitability and connectivity with smaller waterbodies; however the total area those waterbodies less than 10 acres contribute to the total watershed was investigated.

Accessibility of waterbodies to alewife was determined using multiple sources of information. The Canadian Aquatic Barrier Database (CABD) was used to identify barriers and associated passage throughout the watershed (CWF 2024). The Maine Stream Habitat viewer was used to identify barriers and associated passage for the portion of the watershed within the state of Maine (DMR 2024). Publicly available satellite imagery from Google Maps (a composite of images taken between 2020 and 2024) and photographs were also used to help determine accessibility of waterbodies. The Passamaquoddy Recognition Group Incorporated (PRGI) provided additional updated information on barriers in the watershed (Alexa Meyer, pers. comm.). Each waterbody was categorized as accessible or potentially accessible, or artificially inaccessible, following the methods used for the Saint John River (DFO 2024). Waterbodies with no evident barrier or obstruction were considered accessible, whereas waterbodies upstream of a barrier such as a rapids or fishway that may be impassable under certain flow conditions were considered potentially accessible. Waterbodies located upstream of anthropogenic barriers without fish passage were considered artificially inaccessible, while those obstructed by natural barriers, such as falls, were considered to be naturally inaccessible. Temporary barriers like beaver dams were not considered as natural barriers for the purposes of this analysis.

A total of 119 waterbodies were identified as nursery area for alewife in the Skutik watershed. Of those, 97 were considered accessible or potentially accessible, 17 were considered artificially inaccessible, and three were considered naturally inaccessible. Over 400 waterbodies smaller than 10 acres were not included in this analysis, although their collective area made up

approximately 1200 acres. In total, 104,762 acres of accessible or potentially accessible area and 3,403 acres of artificially inaccessible area combine for a total of 108,286 acres of alewife nursery area in the Skutik watershed (Table 1). More than 97% of accessible nursery area for alewife lies upstream of Grand Falls Dam, with approximately 43% lying on the main stem branch, and 55% lying on the west branch.

Table 1. Total surface areas of alewife nursery area in each reach of the Skutik watershed, categorized as naturally inaccessible, artificially inaccessible, or as accessible or potentially accessible. Km² values are converted from acres and reported to an equivalent number of significant figures.

Reach	Accessible or potentially accessible area (km² | acres)	Artificially inaccessible area (km² | acres)	Naturally inaccessible area (km² | acres)	Total area (km² | acres)
Downstream of former Milltown Dam	3.08 | 761	0.996 | 246	0.490 | 121	4.565 | 1,128
Upstream of former Milltown Dam and downstream of Woodland Dam	3.52 | 869	4.112 | 1,016	0 | 0	7.628 | 1,885
Upstream of Woodland Dam and downstream of Grand Falls Dam	4.661 | 1,152	0 | 0	0 | 0	4.661 | 1,152
Upstream of Grand Falls Dam (west) and downstream of West Grand Dam	85.247 | 21,065	6.188 | 1,529	0 | 0	91.435 | 22,594
Upstream of West Grand Dam and downstream of Sysladobsis Dam	111.63 | 27,585	0.494 | 122	0 | 0	112.12 | 27,707
Upstream of Sysladobsis Dam	32.61 | 8,058	0 | 0	0 | 0	32.61 | 8,058
Upstream of Grand Falls Dam (east) and downstream of Vanceboro Dam	4.383 | 1,083	1.86 | 461	0 | 0	6.248 | 1,544
Upstream of Vanceboro Dam and downstream of Forest City Dam	104.83 | 25,904	0.12 | 29	0 | 0	104.95 | 25,933
Upstream of Forest City Dam	73.997 | 18,285	0 | 0	0 | 0	73.997 | 18,285
All	423.957 | 104,762	13.77 | 3,403	0.490 | 121	438.218 | 108,286

Carrying Capacity Estimates

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 nursery area 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 theoretical nursery area carrying capacity for alewife. Median theoretical nursery area carrying capacity for blueback herring has not been estimated and is therefore not included in this analysis, despite blueback herring being present in the Skutik River. The results of the meta-analysis were applied to the Tusket River, Yarmouth County, NS, deriving a Limit Reference Point (LRP) and an Upper Stock Reference Point (USR) based on the accessible nursery area 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). Most recently, the results of the meta-analysis were used to calculate reference points for alewife based on nursery area upstream of the Mactaquac Dam on the Saint John River (DFO 2024).

In this analysis, carrying capacity and SSB_0 are estimated for Skutik River alewife; the definitions for these terms are as follows. Carrying capacity for alewife is defined as the recruitment asymptote of the stock recruitment relationship; the maximum lifetime recruitment achieved by an infinite spawner biomass (Gibson 2004). In plain language, carrying capacity is the theoretical maximum number of alewife an environment can support. SSB_0 is often defined as the population's equilibrium spawning stock biomass in the absence of fishing (Gibson 2004); here, we expand the definition to be the equilibrium spawning stock biomass of the population in the absence of anthropogenic effects, which can include fishing, turbine mortality, or inadequate fish passage. Simply put, SSB_0 is the size a population will stabilize at when there are no human effects. These definitions account for anthropogenic effects in addition to fishing, and allow for the calculation of reference points consistent with DFO's precautionary approach (DFO 2006). Productivity estimates that are based on an exploited population implicitly assume those sources of removals are constant over time and fail to describe the equilibrium point a population would reach if those removals from anthropogenic effects are changed or eliminated. Exploited populations will stabilize at population size smaller than unexploited populations. This is the basis for the application of the results of the meta-analysis of Gibson (2004) to alewife in the Skutik watershed rather than other productivity estimates for alewife.

From the meta-analysis of the habitat carrying capacity for alewife, Gibson (2004) states that the random effects distribution for the log of carrying capacity has a mean of 3.94 and a standard deviation of 0.42, which corresponds to a median habitat carrying capacity of to 51.4 mt/km^2, with an 80% confidence interval of 30.0 mt/km^2 to 88.1 mt/km^2. As described by Gibson et al. (2017), carrying capacity is an important input in population dynamics models whereas SSB_0 is more useful in other contexts such as fisheries reference points. SSB_0 is 94.7% of carrying capacity and can be presented as a median and range per unit area, equal to 48.7 mt/km^2, with an 80% confidence interval of 28.4 mt/km^2 to 83.4 mt/km^2. Theoretical carrying capacity and SSB_0 are calculated for a specific watershed by multiplying the corresponding value per unit area by the nursery area and converting units as appropriate (DFO 2024).

A necessary assumption when applying this method is to assume that the Skutik alewife population is typical and representative of the other alewife populations that comprised the meta-analysis of Gibson (2004), and that the nursery area of the Skutik watershed is also typical and representative. Whether the Skutik River and its alewife population are typical was not directly investigated, however, the river contains impoundments like some of the populations modeled in the meta-analysis (Gaspereau River, Damariscotta River), is within the same geographic range as the other populations, and has faced population declines due to over fishing and poor fish passage like many of the other populations. Since the meta-analysis of Gibson (2004) only considered nursery area quantity rather than quality, it is not possible to incorporate metrics of nursery quality into this analysis.

To calculate carrying capacity and SSB_0, we converted the nursery areas tabulated above from acres to square kilometers, and multiplied them by median estimate, and lower and upper CL's of the theoretical nursery area carrying capacity. For example, the SSB_0 based on accessible and potentially accessible nursery area was calculated by converting 104,970 acres to 424.80 km^2, which was multiplied by the median estimate of 48.7 mt/km^2 to yield an SSB_0 of 20,685 mt. In summary, carrying capacity and SSB_0 for all nursery area was estimated to be

22,533 mt and 21,338 mt respectively, and 21,843 mt and 20,685 mt for carrying capacity and SSB_0 for only accessible or potentially accessible nursery area (Table 2).

Table 2. Biomass estimates of the median, lower and upper 80% confidence limits of carrying capacity and spawning stock biomass at equilibrium in the absence of anthropogenic effects (SSB_0) for alewife in the Skutik watershed. Biomass estimates are calculated for all (108,286 acres) or only accessible and potentially accessible (104,849 acres) nursery area in the watershed.

Nursery Area	Metric	Median estimate (kg)	Lower 80% confidence limit (kg)	Upper 80% confidence limit (kg)
All	Carrying Capacity	22,532,586	13,151,325	38,605,800
All	SSB_0	21,338,359	12,454,305	36,559,693
Accessible or potentially accessible	Carrying Capacity	21,817,401	12,733,902	37,380,451
Accessible or potentially accessible	SSB_0	20,661,079	12,059,005	35,399,287

Sources of Uncertainty

It is necessary to make a number of assumptions to complete this work. The magnitude of the bias on the estimates of theoretical carrying capacity and SSB_0 introduced from those assumptions ranges from negligible to potentially major (Table 3). Following the methods employed for the Saint John River (DFO 2024), estimates of carrying capacity and SSB_0 were not corrected for nursery area quality, fish passage efficiency, or temporary natural barriers (e.g., high/low environmental flows or beaver dams). The estimates of theoretical carrying capacity and SSB_0 presented here are calculated under the assumption of 100% fish passage at anthropogenic barriers, where passage efficiency less than that will limit population growth. It is unlikely that fish passage will be 100% at any barrier (Hershey 2021). Fish passage less than 100% will limit the population from growing to SSB_0, but it does not change the value of SSB_0, since inefficient fish passage at fishways is an anthropogenic effect that can be improved. Furthermore, fluctuations in nursery area quality, quantity and accessibility are not considered in this analysis, and any marked changes in nursery area quantity or accessibility may warrant a recalculation of carrying capacity and SSB_0.

It is important to consider the relationship between biomass and numbers of fish, and that a long-term reliance on only one of the two metrics can mask changes in the population (Table 3). If abundance of a population was estimated to remain constant over time while the mean mass of adult alewives decreased over time, the biomass of the population would be expected to shrink. This decrease in biomass would not be quantified without measuring and comparing mean mass or total biomass to reference points or historical trends (Gibson et al. 2017, DFO 2024).

Table 3. Descriptions of the assumptions made in this analysis, and the direction and approximate magnitude of bias these assumptions can have on estimates of carrying capacity and SSB_0.

Variable	Description	Assumption	Direction and magnitude of bias introduced on carrying capacity and SSB_0
Beaver dams	Beaver dams are a natural occurrence and vary throughout time.	Nursery area potentially inaccessible due to beaver dams is included in the estimates.	Positive; likely small
Minimum nursery area size	10 acres (0.004047 km^2) was selected as the minimum nursery area size for inclusion in this analysis.	That nursery area smaller than 10 acres is not suitable or not accessible, despite there being evidence to the contrary.	Negative; likely small. ~1% of the total area was excluded
Typical population	It is necessary to assume that the Skutik River alewife population is typical and well represented by the populations modeled in the meta-analysis.	That the Skutik River alewife population is typical. It is within the geographic range of the other populations and has faced historic declines in abundance.	Unknown direction, unknown magnitude
Typical nursery area quality	It is necessary to assume that the nursery area quality for alewife in the Skutik River is typical and well represented by the nursery area of populations modeled in the meta-analysis.	That the nursery area quality within the Skutik River watershed is typical. It is within the geographic range of the other populations.	Unknown direction, unknown magnitude

Variable	Description	Assumption	Direction and magnitude of bias introduced on carrying capacity and SSB_0
Effects of dams	There are dams and, both with and without fish passage throughout the watershed. Upstream fish passage, downstream fish passage and survival, and the alteration of habitat would affect the alewife population	That the effect of dams on the Skutik River alewife population would be similar to the effect of dams on the populations included in the meta-analysis, such as the Gaspereau River and Damariscotta River alewife populations.	Unknown direction, Unknown magnitude
Potentially accessible nursery area due to uncertain fish passage efficiency	Some nursery area is upstream of barriers with questionable or time-varying accessibility for alewife, including natural (such as falls) and anthropogenic barriers (such as fishways).	All potentially accessible nursery area is included with accessible area. Fish passage at fishways are assumed to be 100%, despite that not being the case. Any limitation in fish passage would limit the growth of the population.	Positive; likely small for potentially accessible nursery areas.
Meta-analysis	The meta-analysis of theoretical nursery area carrying capacity for alewife provides a median and range of carrying capacity per unit area of nursery area.	N/A	Unknown direction, but potentially large magnitude. Expressed as a percentage, the 80% CI ranges from -42% to +71% of the median carrying capacity estimate
Current state of the watershed	The nursery area tabulated herein reflects the state of the watershed as of November 2024.	N/A	Likely negative; draining of reservoirs as dams are removed reduces nursery area, natural changes to waterbodies could be positive or negative

Variable	Description	Assumption	Direction and magnitude of bias introduced on carrying capacity and SSB_0
Mean Mass	To convert the estimates of carrying capacity from a biomass to a number of fish, a mass per fish must be selected.	The mean mass of an alewife is most recently estimated at 213 g, as represented by the 2024 data collection (SCIWC 2024). The relationship between mean mass and its effect on carrying capacity as a number of fish is explained in greater detail in DFO (2024).	No effect on biomass estimate; would affect the conversion of biomass to numbers of fish

CONCLUSIONS AND ADVICE

The results of this study include an estimate of alewife nursery area in the Skutik River watershed and theoretical estimates of alewife carrying capacity and SSB_0 following the alewife nursery area productivity estimates of the meta-analysis in Gibson (2004). These results are not an articulation of DFO management objectives for the alewife population restoration in the Skutik River watershed. Rather, they represent a source of information for the development of DFO conservation goals for alewife in the Skutik River watershed and may be used in the context of other DFO fish and fish habitat or fisheries management objectives. Furthermore, these results do not represent reference points developed using the DFO precautionary approach for the purpose of fisheries management (Gibson et al. 2017).

Here, we estimate the carrying capacity and SSB_0 for Skutik River alewife to be 21,842 mt and 20,685 mt based on the accessible and potentially accessible nursery area. It is important to acknowledge that the nursery area quantified here captures the nursery area as it currently is, including the potential nursery area that was artificially created by building dams and impoundments throughout the watershed. Furthermore, any future changes to the quantity of nursery area by removing dams or other means would require updating the estimated quantities herein.

The method applied here of estimating carrying capacity and SSB_0 for alewife is recommended when sufficient population-specific data are not available (Gibson et al. 2017). As discussed, it is not without its limitations and requires assumptions, including that the population of interest and its nursery area are typical. Sufficient population-specific data would constitute at a minimum several years and ideally several alewife generations of data such as age, total abundance, escapement, removals if applicable, or other types. Data collected over a wide range of population sizes would be required for robust estimates of carrying capacity. It is recommended to replace the estimates of carrying capacity and SSB_0 in this document with estimates derived from population-specific data once those data have been collected and a population model developed for the Skutik River alewife.

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Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-77035-2 Cat. No. Fs70-6/2025-019E-PDF

Correct Citation for this Publication:

DFO. 2025. Habitat-Based Carrying Capacity Estimates for Alewife (*Alosa Pseudoharengus*) in the Skutik (St. Croix) River Watershed. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2025/019.

Aussi disponible en français :

*MPO. 2025. Estimation de la capacité biotique du gaspareau (*Alosa pseudoharengus*) dans le bassin hydrographique de la rivière Skutik (Sainte-Croix) en fonction de l'habitat. Secr. can. des avis sci. du MPO. Avis sci. 2025/019.*