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Habitat-Based Carrying Capacity Estimates for Alewife (*Alosa pseudoharengus*) in the Skutik (St. Croix) River Watershed

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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TABLE OF CONTENTS

ABSTRACT

The anadromous alewife (*Alosa pseudoharengus*) of the Skutik (St. Croix) River watershed have been negatively affected by dams, overfishing, and pollution over the last several hundred years. The population of alewives decreased to as low as 900 adults observed migrating upstream at Milltown Dam near the head of tide in 2002. The productive capacity of alewife in the Skutik watershed has been estimated several different ways for different areas of the watershed, leading to ambiguity in the total carrying capacity of the watershed for alewife. The objectives here are to estimate alewife nursery area in the Skutik watershed and to provide a median estimate and range of carrying capacity. Alewife nursery area is estimated from shapefiles of waterbodies from the Canadian National Hydrographic Network and cross-referenced for accuracy against satellite imagery. In total, 423.957 km^2 (104,762 acres) of nursery area were categorized as accessible or potentially accessible, and 13.77 km^2 (3,403 acres) were categorized as artificially inaccessible, for a combined total of 438.218 km^2 (108,286 acres). A median estimate and range of carrying capacity (51.4 mt/km^2, with an 80% confidence interval of 30.0 mt/km^2 to 88.1 mt/km^2) and spawning stock biomass in the absence of anthropogenic effects (SSB_0) (48.7 mt/km^2, with an 80% confidence interval of 28.4 mt/km^2 to 83.4 mt/km^2) were applied to the total nursery area estimate for a carrying capacity of 22,533 mt and an SSB_0 of 21,338 mt. These estimates of carrying capacity consider the size the population could grow to in the absence of anthropogenic effects, contrasting with historical estimates of productive capacity that are based on exploited populations. The estimates of carrying capacity and SSB_0 here are based on estimated nursery area rather than population-specific data. Should sufficient population-specific data become available, carrying capacity and reference points for the Skutik alewife population should be estimated and replace the values presented here.

INTRODUCTION

THE SKUTIK RIVER AND ALEWIFE

The Skutik River, also referred to as the St. Croix 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 (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) (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).

Several dams on the main stem of the Skutik impede the migration of fishes (Figure 1), especially diadromous fishes. The first dam spanning the entire width of the Skutik was constructed at the head of tide in 1836 at what is now Milltown (St. Stephen, New Brunswick). This dam had no fishway until 1960 when an ineffective pool and weir fishway was constructed (Barber 2018). An improved pool and weir fishway was constructed in 1981 (Barber 2018). In 2023, the Milltown Dam was removed, resulting in free fish passage in the spring of 2024. Upstream from the former Milltown Dam is the Woodland Dam, constructed in 1905, and the Grand Falls Dam, constructed in 1912 (Flagg 2007), both fitted with Denil fishways (Maine Department of Inland Fisheries and Game 1967). The vast majority of waterbody area in the Skutik watershed is upstream of these dams; access to those waterbodies by anadromous fishes are further impeded by barriers including Vanceboro and Forest City dams on the main stem of the river, West Grand Dam and a dam at the outlet of Sysladobsis Lake on the West Branch, all of which have fishways (Dill et al. 2010, Clarke et al. 2022). Waterbodies upstream of impoundments or dams have been artificially created, increasing the amount of potential nursery area for alewife. relative to pre-dam conditions.

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 can be viewed as density-dependent during the juvenile life stage in freshwater, and density-independent while immature fish are recruiting to the spawning stock at sea. 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 2024a).

Improved fish passage and water quality of the Skutik resulted in an increased alewife population by the early 1980's (Dill et al. 2010). While alewives had relatively free access to a majority of the Skutik watershed after 1980, their access began to be intentionally restricted in 1988, starting at the Vanceboro dam with the closure of its fishway. This was part of broader recommendations made by the St Croix River Fisheries Steering committee in response to perceived negative impacts of alewives on non-native smallmouth bass (*Micropterus dolomieu*) productivity (Flagg 2007). In a further response to the perceived effects of alewife on smallmouth bass productivity (Dill et al. 2010), the Maine Legislature passed legislation that ordered the closure of the Woodland and Grand Falls fishways in 1995 to prevent the passage of alewives. With the 1995 prohibition of alewife passage at the Woodland and Grand Falls fishways, over 98% of the available nursery area was made inaccessible to alewife (Dill et al. 2010). The result was a decline in alewife abundance in the Skutik from 2.6 million in 1987 to 900 in 2002 (Flagg 2007). In 2001, an effort to change the 1995 prohibition of alewife passage at the Woodland and Grand Falls fishways failed, which led to DFO initiating a trap and truck operation to transport alewives around the Woodland Dam (Dill et al. 2010). Fish returns have increased since the reopening of the dams in 2008 at Woodland Dam and 2013 at Grand Falls Dam. In 2021 an estimated 550,123 river herring (both alewife and blueback herring) passed through the fishway at Milltown Dam, representing one tenth of its original design capacity (Clarke et al. 2022). In 2022, an estimated 712,878 river herring passed through the fishway at Milltown Dam (SCIWC pers comm.). These recent counts are potentially orders of magnitude lower than historical numbers (Flagg 2007). One observer in the first half of the 19th century commented at the time, prior to the construction of the Union dam in 1825 that did not have fish passage, "*Gaspereaux, (alewives) came in such [numbers] that it was supposed they could never be destroyed*" (Foster and Atkins 1867, p.188). 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). A quote from the Skutik Watershed Strategic Sea-run Fish and River Restoration Plan reads:

"The Skutik River once supported one of the largest runs of river herring in Atlantic Canada and other northeastern United Sates, but current runs are a small fraction of historical numbers" (Clarke et al. 2022, p.9).

The restoration plan, commissioned by the Peskotomuhkati Nation and updated in 2022, considered the largest area of potential nursery area in the Skutik and included potential nursery area not previously considered in other sources (e.g., Dill et al. 2010; Barber 2018). All alewife nursery area in Canada and the United States was included in the restoration plan (Clarke et al. 2022).

PRODUCTION ESTIMATES FOR SKUTIK RIVER ALEWIFE

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 nursery area. 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 nursery area. 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 (Nova Scotia) contains production estimates for alewife in the Skutik. The authors of the management plan suggested that adult alewife production varies from 150 lbs/acre (168 mt/km^2) to as much as 700 lbs/acre (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 suggested 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. With respect to management measures, the 15% escapement was achieved by limiting fishing to six days a week with a one-day closure. However, Maine no longer recommends a one-day closure for fishing river herring (DMR 2024a).

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 the 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 the carrying capacity for alewife 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. This process will provide scientific advice using theoretical nursery area carrying capacity estimates (Gibson and Myers 2003b) with respect to the following objectives:

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 spawning stock biomass in the absence of anthropogenic effects (SSB_0) for Skutik River 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.

METHODS

ALEWIFE NURSERY AREA

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 (0.04047 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. The total area that waterbodies less than 10 acres contribute to the total watershed was investigated to determine the effect of their exclusion on the total assessed nursery area.

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 2024b). 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 upstream of an anthropogenic barrier without fish passage were considered artificially inaccessible. Temporary barriers like beaver dams were not considered as natural barriers for the purposes of this analysis.

The shapefiles used in this assessment differed slightly in shape and size from those used previously by Billard and Hoar (Appendix H of Clarke et al. 2022). The change in shape and size of the waterbodies could reflect actual changes in the waterbodies or improved estimates of waterbody shape from updated satellite imagery and is not viewed as a source of error. Some polygons in the shapefile were merged or split when compared to the polygons used in the 2022 assessment. The decision on where to trim polygons is arbitrary and may have resulted in slight changes to the measured area of various waterbodies. We investigated the differences between this assessment and the 2022 assessment by conducting a pairwise comparison of the two datasets. We calculated the percent difference between the waterbody surface area previously calculated and the surface area calculated in this document using the following formula:

$$\frac{new\ area - old\ area}{\frac{new\ area + old\ area}{2}} * 100\%$$

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 nursery area carrying capacity for alewife. Median 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 (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. Theoretical 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 alewives 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 sizes 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 theoretical nursery area 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 theoretical nursery 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), theoretical 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 theoretical 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). Carrying capacity and SSB_0 are also presented as a number of fish by multiplying the biomass values by the mean mass of fish. For this report, 213 g was selected as the mean mass of alewife, based on the 2024 biological characteristics data collected from the population at Woodland dam (SCIWC 2024). This mean mass was calculated from 59 lethally sampled alewife, which were sampled throughout the migration, approximately in proportion to daily run abundance. Its use in converting SSB_0 biomass to numbers of fish is subject to change if Skutik River alewife population demographics change. The mean mass should be updated in the future to account for changes in alewife population demographics or sampling design within the Skutik River.

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. The typicality of the Skutik River and its alewife population was not directly investigated; however, similar to the populations modeled in the meta-analysis (Gaspereau River, Damariscotta River) the Skutik River contains impoundments, is within the same geographic range, and has faced population declines due to over fishing and poor fish passage. Furthermore, since the meta-analysis of Gibson (2004) only considered nursery area quantity rather than quality, it is not possible to incorporate metrics of nursery area quality into this analysis.

RESULTS

ALEWIFE NURSERY AREA

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, 19 were considered artificially inaccessible, and three were considered naturally inaccessible. Over 400 waterbodies smaller than 10 acres were not included in this analysis. Collectively, the area of these excluded waterbodies was approximately 4.856 km^2 (1200 acres). In total, 423.957 km^2 (104,762 acres) of accessible or potentially accessible area, 13.77 km^2 (3,403 acres) of artificially inaccessible area, and 0.490 km^2 (121 acres) of naturally inaccessible area combine for a total of 438.218 km^2 (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 2).

The waterbody surface areas tabulated here were compared against those presented by Billard and Hoar in Appendix H of the Skutik Watershed Strategic Sea-run Fish and River Restoration Plan (Clarke et al. 2022). There were several differences in this assessment beyond the small changes in size and shape of waterbodies. The waterbody at coordinates 45.7669, -67.8521 is listed as Longfellow Lake in this document, while it is listed as Deering Lake in the Clarke et al. (2022) assessment. McAdams pond, originally included as accessible in 2022, was considered inaccessible in this analysis, due to no indication of flow lines connecting in the shapefiles from the NHN, and no indication of a flow connection from satellite imagery. Canoose Flowage was excluded from this assessment due to the Canoose Flowage dam removal in Fall of 2024. Palfrey Lake, the northeastern arm of Spednic Lake, is included as a separate waterbody from Spednic Lake; the two areas can be combined for a direct comparison with Spednic Lake from the 2022 assessment. Additional waterbodies were identified over the course of this review that were not included in the 2022 assessment and are indicated with an asterisk (*) in Table A1. One unnamed pond of 0.04 km^2 (11 acres) was included in the 2022 assessment but not identified in this assessment. The mean percent difference between the waterbody areas here and those presented in 2022 was 0.13% with a standard deviation of 2.45 and ranged from -

8.4% (Cranberry Lake) to 21.8% (Upper Canoose Flowage). The median absolute precent difference, to account for negative and positive changes in waterbody area, was 0.17%. The percent difference between the new total area and the old total area was -0.08%. Overall, the various metrics of percent difference are all much less than 1% and the updated waterbody surface areas presented here differed minimally from those reported by Billard and Hoar (Clarke et al. 2022).

CARRYING CAPACITY ESTIMATES

To calculate carrying capacity and SSB_0, we converted the nursery areas tabulated above from acres to square kilometers and multiplied them by the median estimate, lower, and upper confidence limits of the theoretical nursery area carrying capacity. For example, the SSB_0 based on accessible and potentially accessible nursery area was calculated by converting 104,762 acres to 424.80 km^2 and multiplying 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 3).

Assuming a mean mass per adult alewife of 213 g (SCIWC 2024), the biomass estimates of carrying capacity and SSB_0 can be presented as a number of fish (Table 4).

DISCUSSION

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).

It is necessary to make a number of assumptions to complete this work. The magnitude of the bias on the estimates of carrying capacity and SSB_0 introduced from those assumptions ranges from negligible to potentially major (Table 5). 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 acknowledge that the nursery area quantified here captures the nursery area as it currently is, including the artificial nursery area that was 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.

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 5). Biomass values of the carrying capacity and SSB_0 estimates are presented here and are converted to numbers of fish, assuming a mean mass per adult alewife of 213 g (SCIWC 2024). 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).

Previous estimates of theoretical carrying capacity for Skutik alewife differed in value and calculation method (Anon 1988, Flagg 2007, Dill et al. 2010, Clarke et al. 2022). We present the equilibrium spawning stock biomass in the absence of anthropogenic effects to be approximately 21,000 mt, similar to the value and approach taken by Clarke et al. (2022). The theoretical carrying capacity or “production” estimates provided by other sources are based on exploited populations, and better described as equilibrium points that a population would reach under certain conditions. Similarly, reference points based on maximum sustainable yield (MSY) for alewife can be calculated from SSB_0, following the approach described by Gibson et al. (2017). The Upper Stock Reference Point is the spawning stock biomass that would result from fishing at MSY (an exploitation rate of 53%) which is 14.85% of SSB_0, or 3,000 mt (Gibson et al. 2017). Combined with the expected long-term annual yield of approximately 3,000 mt, total annual abundance would be approximately 6,000 mt. It would not be possible to maintain a population at SSB_0 while fishing; with increased fishing pressure and increased removals, the equilibrium point of the spawning stock biomass, and the total abundance, decrease. The equilibrium population size for any population will change depending on the mortality rates affecting the population. In this document, we present estimates of the spawning stock biomass in the absence of fishing or other anthropogenic activities. When no fish are removed from the population, the spawning stock biomass and the total abundance prior to fishing activities are equal. When comparing these values, it is important to compare the same types of equilibrium population size.

The method applied here of estimating theoretical 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 theoretical carrying capacity. It is recommended to replace the estimates of theoretical 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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TABLES

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

*Table 2. Surface areas of alewife nursery area in each reach of the Skutik watershed, the percent of the total accessible nursery area within each reach, and the cumulative amount of nursery area within and upstream of each reach. Note that the reach upstream of Grand Falls dam is divided in two, east and west, but since there are no barriers within that reach, the percent of area within and upstream of the two reach divisions are the same (denoted by an *). Km² values are converted from acres and reported to an equivalent number of significant figures.*

Reach	Accessible or potentially accessible area (km^2 | acres)	Percent of area within reach	Percent of area within and upstream of the reach
Downstream of former Milltown Dam	3.08 | 761	0.81	100
Upstream of former Milltown Dam and downstream of Woodland Dam	3.52 | 869	0.83	99.19
Upstream of Woodland Dam and downstream of Grand Falls Dam	4.662 | 1,152	1.10	98.36
Upstream of Grand Falls Dam (west) and downstream of West Grand Dam	85.247 | 21,065	20.09	97.26*
Upstream of West Grand Dam and downstream of Sysladobsis Dam	111.63 | 27,585	26.31	34.00
Upstream of Sysladobsis Dam	32.61 | 8,058	7.69	7.69
Upstream of Grand Falls Dam (east) and downstream of Vanceboro Dam	4.383 | 1,083	1.03	97.26*
Upstream of Vanceboro Dam and downstream of Forest City Dam	104.83 | 25,904	24.71	42.15
Upstream of Forest City Dam	73.997 | 18,285	17.44	17.44

Table 3. 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 (104,762 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

Table 4. 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, presented as numbers of fish. Biomass estimates are calculated for all (108,286 acres) or only accessible and potentially accessible (104,762 acres) nursery area in the watershed. Numbers of fish are calculated assuming 213 g per fish.

Nursery Area	Metric	Median Estimate	Lower 80% confidence limit	Upper 80% confidence limit
All	Carrying Capacity	105,786,789	61,743,310	181,247,887
All	SSB_0	100,180,089	58,470,915	171,641,751
Accessible or potentially accessible	Carrying Capacity	102,547,319	59,852,568	175,697,606
Accessible or potentially accessible	SSB_0	97,112,315	56,680,385	166,385,629

Table 5. 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 theoretical 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 theoretical carrying capacity estimate

Variable	Description	Assumption	Direction and magnitude of bias introduced on carrying capacity and SSB_0
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
Mean Mass	To convert the estimates of theoretical 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 theoretical 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

FIGURES

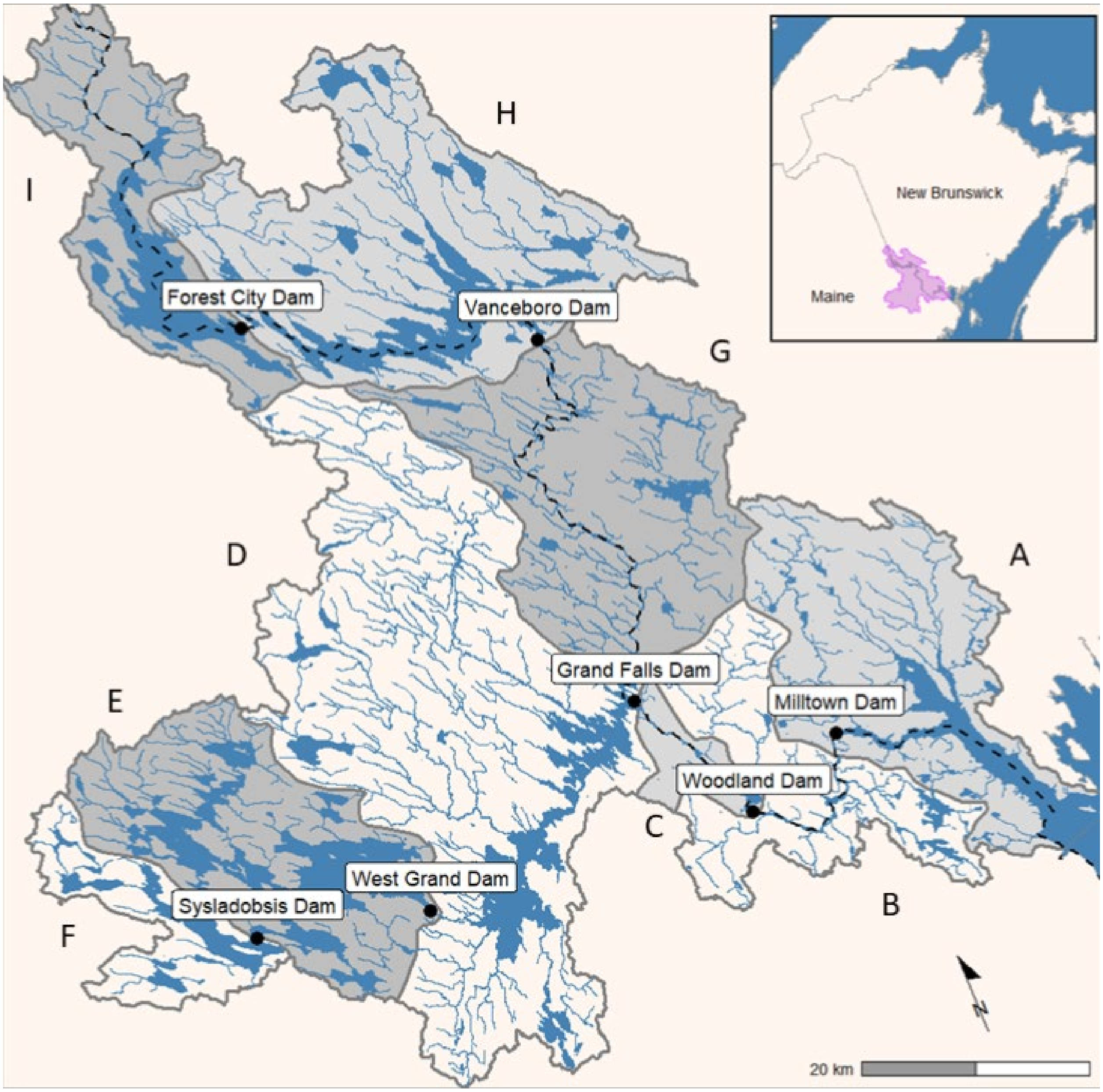

Figure 1. A map of the Skutik (St. Croix) River watershed. The border between Canada and the United States is represented by a black dashed line. Major dams are marked with a black point and labeled with the name of the dam. The watershed is subdivided into the following reaches with corresponding labels A through I: A) Downstream of former Milltown Dam; B) Upstream of former Milltown Dam and downstream of Woodland Dam; C) Upstream of Woodland Dam and downstream of Grand Falls Dam; D) Upstream of Grand Falls Dam and downstream of West Grand Dam; E) Upstream of West Grand Dam to Sysladobsis Dam; F) Upstream of Sysladobsis Dam; G) Upstream of Grand Falls Dam and downstream of Vanceboro Dam; H) Upstream of Vanceboro Dam and downstream of Forest City Dam; I) Upstream of Forest City Dam. The map inset shows the extent of the watershed in pink relative to Maine and New Brunswick.

APPENDIX

Table A1. Accessible and potentially accessible waterbodies for alewife in the Skutik watershed. Waterbodies marked with an asterisk were not identified in the Appendix H of the Skutik Watershed Strategic Sea-run Fish and River Restoration Plan but were identified during this assessment.

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
North Lake	45.8258, -67.7476	985	3.99	Monument Brook	Forest City Dam	Upstream of Forest City Dam
East Grand Lake	45.7396, -67.7925	15,798	63.935	Forest City Stream	Forest City Dam	Upstream of Forest City Dam
Big Greenland Lake	45.6056, -67.7482	89	0.36	Unnamed	Forest City Dam	Upstream of Forest City Dam
Little Greenland Lake	45.6054, -67.7547	42	0.17	Unnamed	Forest City Dam	Upstream of Forest City Dam
Longfellow Lake	45.7669, -67.8521	506	2.08	Unnamed	Forest City Dam	Upstream of Forest City Dam
Brackett Lake	45.7467, -67.8606	582	2.36	Unnamed	Forest City Dam	Upstream of Forest City Dam
Longley Lake	45.7897, -67.8446	82	0.33	Unnamed	Forest City Dam	Upstream of Forest City Dam
Sucker Lake	45.6750, -67.8217	201	0.813	Unnamed	Forest City Dam	Upstream of Forest City Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Spednic Lake	45.6159, -67.6332	15,688	63.489	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Liddle Lake	45.7118, -67.7222	341	1.38	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Palfrey Lake *	45.6429, -67.4765	1,870	7.568	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Musquash Lake	45.6910, -67.6431	344	1.39	Musquash Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Bolton Lake	45.7001, -67.5852	688	2.78	Bolton Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Pirate Lake	45.7169, -67.6558	29	0.12	Pirate Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
East Brook Lake	45.6815, -67.5175	348	1.41	East Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Mud Lake (2)	45.8381, -67.5361	107	0.433	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Skiff Lake	45.8214, -67.5238	1,520	6.151	Palfrey Stream	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Grassy Lake	45.8112, -67.4792	409	1.66	Grassy Lake Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Moose Lake	45.8151, -67.4576	33	0.13	Unnamed	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
La Coute Lake	45.7624, -67.5333	264	1.07	Little La Coute Stream	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
First Lake	45.6111, -67.4092	190	0.769	Diggity Stream	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Mud Lake	45.6714, -67.7222	226	0.915	Forest City Stream	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Sixth Lake	45.7237, -67.4567	365	1.48	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Fifth Lake	45.7140, -67.4242	898	3.63	North Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Third Lake	45.6386, -67.4000	154	0.623	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Modsley Lake	45.6266, -67.3473	969	3.92	Modlsey Lake Thoroughfare	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Thompsons Lake	45.6604, -67.3640	143	0.578	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Foster Lake	45.6239, -67.2922	263	1.06	McAdam Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Wauklahegan Lake	45.6048, -67.3628	840	3.40	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Tuttle Lake	45.6449, -67.5323	58	0.23	Tuttle Brook	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
LaCoute Lake	45.5785, -67.4539	157	0.635	N/A	Vanceboro Dam	Upstream of Vanceboro, downstream of Forest City Dam
Grand Falls Flowage	45.2597, -67.5370	6,284	25.43	N/A	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Lewy Lake	45.2257, -67.5826	474	1.92	N/A	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Long Lake	45.2157, -67.6129	603	2.44	N/A	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Big Lake	45.1615, -67.6928	10,444	42.267	N/A	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Bonney Brook Lake *	45.1972, -67.7659	10	0.040	Bonney Brook	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Malcome Bog	45.4586, -67.7444	13	0.053	Jim Brown Brook	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Tomah Lake	45.5908, -67.7427	59	0.24	Tomah Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Simon Pond	45.4305, -67.6844	15	0.061	Tomah Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Little Tomah Lake	45.4784, -67.7275	146	0.591	Little Tomah Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Tomah Stream	45.5765, -67.7322	40	0.16	Tomah Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Patten Pond	45.3061, -67.6945	127	0.514	Flipper Creek	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Farrow Lake	45.4259, -67.7673	287	1.16	Deadman Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
East Musquash Lake	45.4066, -67.7977	818	3.31	Deadman Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Upper Flood Lake	45.3675, -67.8162	33	0.13	Unnamed	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
West Musquash Lake	45.3360, -67.8311	1,606	6.499	West Branch Musquash Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Orie Lake	45.3661, -67.8528	43	0.17	Unnamed	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Little Musquash Lake*	45.0573, -67.8112	20	0.081	Little Musquash Stream	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Monroe Lake	45.0855, -67.7946	43	0.17	Little River	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Simquish Lake	45.4641, -67.5234	141	0.571	Simquish Brook	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of Vanceboro Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Hound Brook Lake	45.4156, -67.5027	310	1.25	Unnamed	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of Vanceboro Dam
King Brook Lake	45.3347, -67.4081	79	0.32	King Brook	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of Vanceboro Dam
Blackwater Lake *	45.3315, -67.4014	12	0.049	King Brook	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of Vanceboro Dam
Enoch Lake	45.3321, -67.5184	20	0.081	Enoch Brook	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of Vanceboro Dam
Lambert Lake	45.5516, -67.5617	521	2.11	Scott Brook	Grand Falls Dam	Upstream of Grand Falls Dam, downstream of Vanceboro Dam
Woodland Flowage	45.1759, -67.4006	1,152	4.662	N/A	Woodland Dam	Upstream of Woodland Dam, downstream of Grand Falls Dam
Vose Pond	45.1278, -67.2446	38	0.15	East Branch	Milltown Dam	Upstream of former Milltown Dam, downstream of Woodland Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Howard Lake	45.0711, -67.2174	542	2.19	Unnamed	Howard Mill Flowage Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Howard Mill Flowage	45.1041, -67.2607	54	0.22	Magurrewock Stream	Howard Mill Flowage Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Conic Lake	45.1016, -67.3158	40	0.16	Conic Stream	Milltown Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Potters Lake	45.2229, -67.3475	117	0.473	Huckleberry Brook	Milltown Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Kendricks Lake	45.2147, -67.3354	78	0.32	Huckleberry Brook	Milltown Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Moores Mills Lake	45.2853, -67.2676	129	0.522	Dennis Stream	N/A	Downstream of former Milltown Dam
Cranberry Lake	45.3020, -67.2969	69	0.28	Dennis Stream	N/A	Downstream of former Milltown Dam
Gallop Lake	45.2973, -67.2280	42	0.17	Gallop Stream	N/A	Downstream of former Milltown Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Limeburners Lake*	45.1791, -67.1026	137	0.554	Greenlaws Brook	N/A	Downstream of former Milltown Dam
Shattuck Lake*	45.1042, -67.1680	24	0.097	Unnamed	N/A	Downstream of former Milltown Dam
Keene Lake*	45.1100, -67.1730	92	0.37	Unnamed	N/A	Downstream of former Milltown Dam
Flowed Land Ponds	45.1279, -67.1784	44	0.18	Flowed Lands Ponds	N/A	Downstream of former Milltown Dam
Middle Lake	45.3165, -67.2658	64	0.26	Dennis Stream	Unknown Dam 1	Downstream of former Milltown Dam
Foster Lake	45.3172, -67.2318	117	0.473	Dunham Brook	Unknown Dam 1	Downstream of former Milltown Dam
Indian Pond	45.3506, -67.2664	43	0.17	Dennis Stream	Unknown Dam 1	Downstream of former Milltown Dam
West Grand Lake	45.2290, -67.8340	14,476	58.584	Grand Lake Stream	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Upper Oxbrook Lake	5.2920, -67.8342	434	1.76	Oxbrook Stream	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Lower Oxbrook Lake	45.2809, -67.8432	341	1.38	Oxbrook Stream	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Little River Lake	45.1588, -67.8188	74	0.30	Grand Lake Brook	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Pork Barrel Lake	45.2996, -67.9060	30	0.12	Unnamed	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Pocumcus Lake	45.1937, -67.9121	2,211	8.948	N/A	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Wabassus Lake	45.1494, -67.8773	989	4.00	N/A	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Norway Lake	45.2724, -67.9657	129	0.522	N/A	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Horseshoe Lake	45.2630, -68.0058	248	1.00	N/A	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Junior Lake	45.2942, -68.0009	4,210	17.04	N/A	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Bottle Lake	45.3098, -68.0562	258	1.04	Bottle Lake Stream	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Keg Lake	45.3244, -68.0552	371	1.50	Bottle Lake Stream	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Duck Lake (2)	45.3401, -68.0473	262	1.06	N/A	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Mill Privilege Lake	45.3426, -68.0179	112	0.453	Unnamed	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Scraggly Lake	45.3272, -67.9558	1,641	6.641	N/A	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Shaw Lake	45.3448, -67.9617	249	1.01	Unnamed	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Pleasant Lake	45.3532, -67.9220	1,550	6.273	Unnamed	West Grand Dam	Upstream of West Grand dam, downstream of Sysladobsis Dam
Sysladobsis Lake	45.2250, -68.0146	5,431	21.98	N/A	Sysladobsis Dam	Sysladobsis Dam
Lower Chain Lake	45.2103, -68.0315	173	0.700	N/A	Sysladobsis Dam	Sysladobsis Dam
Middle Chain Lake	45.2197, -68.0776	225	0.911	Chain Stream	Sysladobsis Dam	Sysladobsis Dam
Upper Chain Lake	45.2075, -68.0816	721	2.92	Chain Stream	Sysladobsis Dam	Sysladobsis Dam
Upper Sysladobsis Lake	45.2963, -68.1083	1,061	4.294	Upper Sysladobsis Stream	Sysladobsis Dam	Sysladobsis Dam
Lower Pug Lake	45.3096, -68.1135	104	0.421	Unnamed	Sysladobsis Dam	Sysladobsis Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Upper Pug Lake	45.3209, -68.1111	66	0.27	Unnamed	Sysladobsis Dam	Sysladobsis Dam
Lombard Lake	45.3397, -68.1325	277	1.12	Lombard Stream	Sysladobsis Dam	Sysladobsis Dam

Table A2. Inaccessible waterbodies for alewife in the Skutik watershed. Waterbodies marked with an asterisk were not identified in the Appendix H of the Skutik Watershed Strategic Sea-run Fish and River Restoration Plan, but were identified during this assessment.

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
McAdam Pond	45.5878, -67.3278	29	0.12	Unnamed	McAdam Pond Culverts	Upstream of Vanceboro Dam, downstream of Forest City Dam
Nashs Lake	45.1084, -67.2087	855	3.46	East Branch	Nash Lake Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Moneymaker Lake	45.0941, -67.1679	26	0.11	Unnamed	Nash Lake Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Rand Lake	45.0872, -67.1870	18	0.073	Unnamed	Nash Lake Dam	Upstream of former Milltown Dam, downstream of Woodland Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Pine Lake	45.1142, -67.2255	27	0.11	N/A	Nash Lake Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Beaver Lake	45.1321, -67.2092	90	0.36	Beaver Brook	Nash Lake Dam	Upstream of former Milltown Dam, downstream of Woodland Dam
Clifford Lake	45.0677, -67.6970	1,247	5.046	Clifford Stream	Clifford Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Silver Pug Lake	45.0317, -67.6983	212	0.858	N/A	Clifford Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Hosea Pug Lake	45.0374, -67.6821	58	0.23	Unnamed	Clifford Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam
Carole Pond	45.0535, -67.6644	12	0.049	Carole Brook	Clifford Dam	Upstream of Grand Falls Dam, downstream of West Grand Dam

Waterbody Name	Latitude, Longitude	Area (acres)	Area (km^2)	Tributary	Barrier	Reach
Upper Canoose Flowage	45.4752, -67.3279	461	1.87	Canoose Stream	Upper Canoose Dam	Upstream of Grand Falls Dam, downstream of Vanceboro Dam
Lowell Lake	45.3760, -68.0929	122	0.494	Unnamed	Lowell Dam	Upstream of West Grand Dam, downstream of Sysladobsis Dam
Goldsmiths Lake*	45.2049, -67.1179	46	0.18	Goldsmiths Stream	Unnamed Dam 2	Downstream of former Milltown Dam
Long Lake*	45.2186, -67.1035	41	0.17	Goldsmiths Stream	Unnamed Dam 2	Downstream of former Milltown Dam
Twin Lakes*	45.2360, -67.0761	144	0.583	Unnamed	Unknown Dam 3	Downstream of former Milltown Dam
Doyle Lake*	45.2620, -67.0775	15	0.061	Unnamed	Unknown Dam 3	Downstream of former Milltown Dam
Western Lake*	45.0713, -67.1718	69	0.28	Western Stream	Unnamed Falls	Downstream of former Milltown Dam
Goulding Lake*	45.0731, -67.1862	18	0.073	Western Stream	Unnamed Falls	Downstream of former Milltown Dam
Eastern Lake*	45.0841, -67.1532	34	0.14	Eastern Stream	Unnamed Falls	Downstream of former Milltown Dam

Table A3. Barriers to alewife passage present within the Skutik River.

Name	Latitude, Longitude	Barrier Type	Passable	Description
Milltown Dam	45.1758, -67.2930	Dam	Yes	Former concrete dam with pool and weir fish ladder, removed in 2023
Woodland Dam	45.1586, -67.4022	Dam	Yes	Dam with fish ladder
Vanceboro Dam	45.5693, -67.4273	Dam	Yes	Concrete dam with fish ladder
Forest City Dam	45.6646, -67.7340	Dam	Yes	Wooden crib dam with fish ladder
West Grand Dam	45.1812, -67.7779	Dam	Under current management no, but should be possible	Concrete dam with fish ladder. Anecdote on a fishing forum about a large jump at the top to exclude the landlocked alewives present downstream in big lake and elsewhere
Grand Falls Dam	45.2747, -67.4791	Dam	Yes	Dam with fish ladder
Sysladobsis Dam	45.2116, -67.9698	Dam	Yes	Wooden crib dam with pool and weir fish ladder
Clifford Dam	45.0960, -67.6858	Dam	No	Wooden dam with no fish passage
Nash Lake Dam	45.1254, -67.2229	Dam	No	Stone wall dam with no fish passage
Canoose Dam	45.3974, -67.3447	Dam	Yes	Dam removed in Fall of 2024
Upper Canoose Dam	45.4681, -67.3365	Dam	No	Dam owned by Ducks Unlimited
Lowell Dam	45.3671, -68.0921	Dam	No	Dam with no fish passage
Howard Mill Flowage Dam	45.1059, -67.2614	Dam	Yes	Concrete dam with fish ladder

Name	Latitude, Longitude	Barrier Type	Passable	Description
Upper Magurrewock Dam	45.1411, -67.2754	Dam	Yes	Concrete dam with fish ladder
Middle Magurrewock Dam	45.1516, -67.2855	Dam	Yes	Dam with Alaskan steep pass fishway
Lower Magurrewock Dam	45.1531, -67.2920	Dam	Yes	Dam with Denil fish ladder
Mud Lake Falls	45.6891, -67.7302	Waterfall	Yes	Falls that are passable under ideal flow conditions
McAdam Pond Culverts	45.5903, -67.3269	Dam	No	Multiple perched culverts
Unknown Dam 1	45.3155, -67.2721	Dam	Yes	Assessment from PRGI confirms pool and weir fish ladder with adequate passage
Unknown Dam 2	45.2043, -67.1253	Dam	No	Dam with no fish passage
Unknown Dam 3	45.2318, -67.0843	Dam	No	Concrete dam with no fish passage
Unknown Dam 4	45.6303, -67.4045	Dam	No; however it is not restricting access to further upstream locations as there is access via Colter brook flowing from Wauklahegan Lake	Dam with no fish passage
Unnamed Falls	45.0582, -67.1183	Waterfall	No	Falls with significant drop