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Science Response 2016/005

HABITAT, PASSAGE AND STOCKING CONSIDERATIONS FOR GASPEREAU AT SANDY LAKE, NOVA SCOTIA

Context

The Indian River (44.6918°N, 63.9103°W) drains into St. Margaret's Bay, Halifax County. For much of the past century, all areas upstream to the outflow of Sandy Lake have been inaccessible to diadromous fish species; originally due to a mill dam that was subsequently converted for hydro-electric power generation in the 1920s. In 2015, the current operator, Nova Scotia Power Incorporated, is constructing a fishway to allow for fish passage into Sandy Lake and connected tributaries. This fishway is expected to provide upstream passage into Sandy Lake for several diadromous species, primarily Alewife (*Alosa pseudoharengus*), but potentially Blueback Herring (*Alsoa aestivalis*), American Eel (*Anguilla rostrata*), Atlantic Salmon (*Salmo salar*) and sea-run Brook Trout (*Salvelinus fontinalis*).

It has been proposed that Alewife and/or Blueback Herring (collectively called Gaspereau hereafter) could be stocked into Sandy Lake upon completion of the fishway in order to expedite population establishment in the river system. Although it has not been scientifically documented that Alewife or Blueback Herring were native to Indian River prior to the construction of the dam at Sandy Lake, the range of both these diadromous fishes includes Nova Scotia and it is likely that they were found historically in the Indian River. Currently, the river is expected to have adequate water quality to support Gaspereau. This response provides scientific advice with respect to the following objectives:

1. Estimate the area of potential fish habitat that will be made available to Gaspereau by providing fish passage at the Sandy Lake dam, with further consideration in the estimate of assuming fish passage at Big Indian Lake dam;
2. Estimate of the abundance of Gaspereau this area could theoretically support;
3. Evaluate potential population growth of Gaspereau from an initial small population size, including any estimated time frame(s) for expected growth;
4. Identify factors that should be considered in stocking the system with Gaspereau (e.g. species sensitivity, sources of fish, etc.), including the identification of alternate sources of information; and
5. Identify other factors that should be considered with respect to fish passage and a potential Gaspereau stocking program (e.g. passage efficiency), including assumptions, limitations, and sources of uncertainty.

This response will make use of the available scientific literature as well as previously peer-reviewed methodologies. In general, much more information exists on the dynamics of Alewife populations relative to those of Blueback Herring, so the information in this document pertains predominantly to Alewife.

This Science Response Report results from the Science Response Process of October 15, 2015, on the Considerations for Fish Habitat, Passage, and Gaspereau Stocking at Sandy Lake, Nova Scotia.

Analysis and Response

Estimate of Potential Habitat Area Made Available

Alewife spawn almost exclusively in lakes and large stillwaters, while Blueback Herring are also able to spawn in moving water (Loesch 1987). Here we focus on the spawning habitat of Alewife because the productive capacity of Alewife habitat has been estimated (e.g. Gibson and Myers 2003a, 2003b), while it is largely unknown for Blueback. Therefore, this estimate of the amount of habitat made available by the fishway is a sum of the upstream lake areas from Sandy Lake dam.

These lakes were identified using the hydrologically-connected network for the Indian River developed by Bowlby et al. (2014). These include: Rafters Lake, Island Lake, Back Lake and the Muskrat Lakes (Figure 1). In total, these lakes are estimated to contain 4.15 km2 of accessible spawning habitat (Table 1). Extremely small lake polygons (e.g. to the right of Rafters Lake or at the bottom of Sandy Lake; see Figure 1) were excluded from this estimate.

There also exists a dam at the head of Rafters Lake, downstream to the entrance of Big Indian Lake (Figure 1). If passage was also provided at Big Indian Lake dam, an additional 15 km2 of habitat would be made accessible to Gaspereau, the majority of which is contained in Big Indian Lake and Five Mile Lake (Table 1).

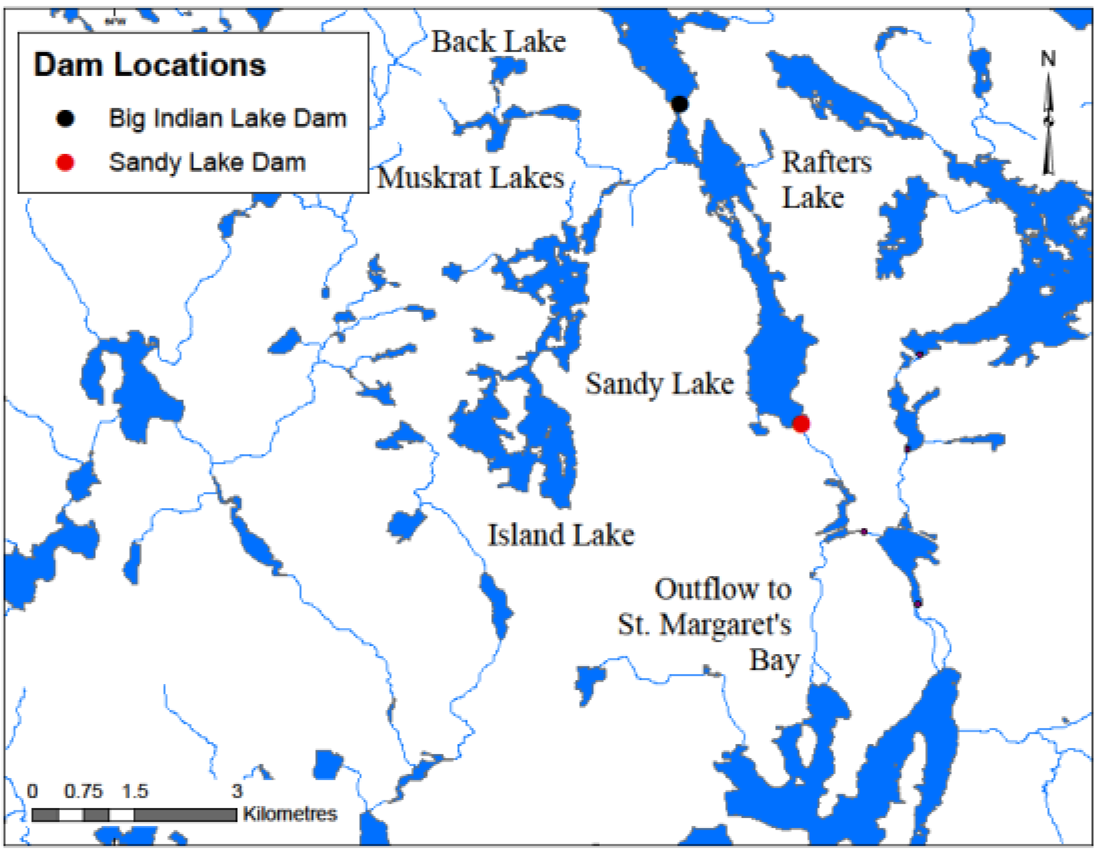

Figure 1. Location of the hydrologically-connected lake areas above Sandy Lake dam.

Table 1. Estimated habitat areas and potential production at carrying capacity in metric tonnes (mt), numbers (#), and numbers at 20% of carrying capacity (#20%) for the area made accessible above Sandy Lake dam, as well as potential area and production above Big Indian Lake dam.

Location	Lake area (km^2)	Production at Carrying Capacity		
		mt	#	$\#_{20\%}$
Island Lake	2.13	117	488,600	97,720
Sandy Lake	1.12	62	257,307	51,461
Muskrat Lakes	0.22	12	50,208	10,042
Rafters Lake	0.59	32	134,750	26,950
Back Lake	0.09	5	20,789	4,158
Totals	**4.15**	**228**	**951,655**	**190,331**
*Big Indian Lake	6.03	331	1,381,137	276,227
*Bezanson Ponds	0.10	6	23,022	4,604
*Uniacke Lake	0.39	22	90,242	18,048
*Five Mile Lake	6.21	342	1,424,005	284,801
*Granite Lake	0.24	13	54,329	10,866
*Clements Lake	0.30	17	68,781	13,756
*Five Island Lake	0.15	9	35,514	7,103
*Sandy Lake (#2)	0.26	14	59,312	11,862
*Bowsprit Lake	0.14	8	31,687	6,337
*Daley Lake	0.10	5	22,870	4,574
*Island Lake	0.47	26	108,086	21,617
*Blind Lake	0.22	12	49,635	9,927
*Big Walsh Lake	0.15	8	35,016	7,003
*Melvin Lake	0.15	8	34,557	6,911
*Brunswick Lake	0.09	5	21,249	4,250
***Potential Total**	**15.01**	**494**	**3,439,442**	**687,888**

**Potential habitat area if the dam at the outflow to Big Indian Lake was made passable.*

Estimate of Abundance from Newly Accessible Habitat

Gaspereau are currently not present in the Indian River, so there is no direct data that can be used to evaluate the productive capacity of the river system (the abundance that this area could theoretically support). However, a meta-analysis by Gibson and Myers (2003a, 2003b) suggests that the median carrying capacity of lake habitats for Alewife is 55 mt/km^2 (80% C.I. = 33, 93). It is assumed that Alewife habitat in the Indian River is of median quality and have used this median estimate for subsequent calculations; although it is recognize that it can be quite variable among rivers.

At carrying capacity, a total of 228 mt would be expected to be produced from 4.15km^2 of lake area. Assuming that alewives have an average weight of 240 grams (as in Jessop 1999), this equates to approximately 230,000 fish/km^2, or approximately 952,000 individuals. It is important to note that that if the average weight of Alewife is smaller than 240 grams, this is an underestimate, while it would be an overestimate if the average weight is larger.

A newly established population would be expected to take decades to increase to numbers approaching the estimated carrying capacity. Thus, we have used 20% of carrying capacity as a reference value to evaluate population growth over shorter timeframes. From the 4.15 km^2 of habitat made accessible by the fishway, 20% of carrying capacity equates to a total of 190,331 fish (Table 1). If the dam at Big Indian was also made accessible, the total becomes 878,219 fish, over 4.5 times higher.

Timeframes and Potential for Population Growth from Stocking

Alewife populations can be highly productive (Gibson and Myers 2003a), and it is possible that any population introduced into Sandy Lake could quickly increase in size. However, there would still be a considerable time lag for population growth, given the 5-6 year generation time of Alewife.

To demonstrate this time lag, 20% of carrying capacity for the area above Sandy Lake dam was plotted relative to projections of potential population growth for Alewife from the St. Croix River, New Brunswick (Figure 2). These were calculated from a logistic growth model which incorporated auto-correlated annual deviates in vital rates (to calculate confidence intervals) and a starting population size of 10,000 individuals (IJC 2010). These model projections are not directly comparable to Sandy Lake given differences in the estimated carrying capacity between the two systems. However, the IJC (2010) analysis suggested that a median of approximately 10 years (80% C.I. = 5-15 years) would be required for populations to grow in excess of 200,000 individuals if they were highly productive (i.e. an intrinsic rate of increase of 50% per year). If productivity were lower (25%), the median estimate is 15 years (80% C.I. = 10-25 years; Figure 2).

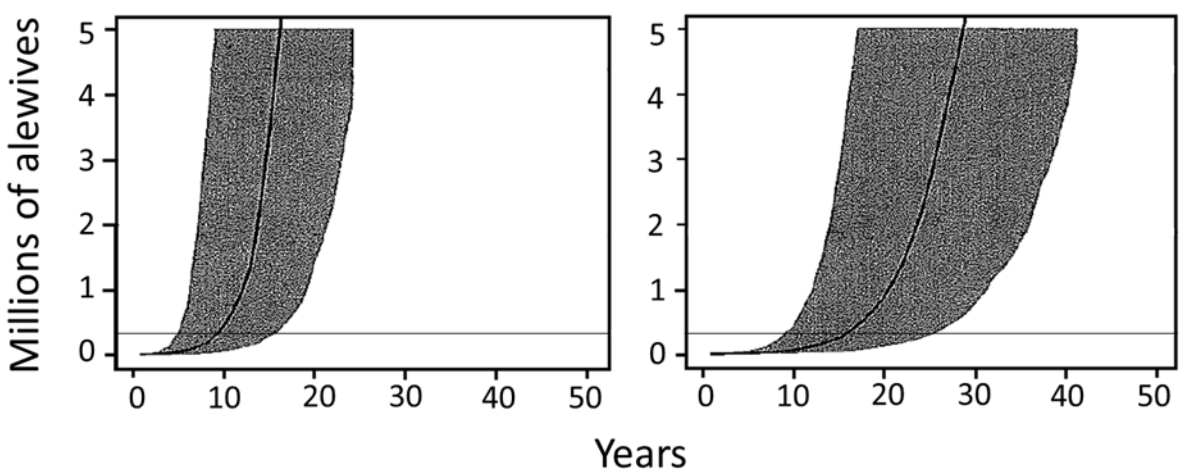

Figure 2. Example of projected population increase for Alewives from an initial population size of 10,000 individuals, assuming logistic population growth and an intrinsic rate of increase of 50% (left panel) and 25% (right panel), including the 90% confidence interval for the projections (grey shading). A horizontal line representing 200,000 individuals was added for reference. Figure adapted from IJC (2010).

These projections were for an established population in the St. Croix River. In contrast, population growth in Indian River would not occur in the first four years following any stocking event because the majority of Alewives only return to spawn for the first time as 4 year-olds. Therefore, estimated timeframes extend to approximately 14 years and 19 years, respectively, relative to those noted above. In addition, there are four main factors (either alone or in combination) that would prolong these timelines further:

1. smaller starting population sizes;
2. lower intrinsic population growth rates;
3. lower carrying capacity of lake habitats; and
4. unaccounted sources of mortality. It is important to recognize that the effect of these factors could be substantial (e.g. extending timelines by decades), or could even prevent population establishment in Sandy Lake.

Factors to be Considered for Stocking

Genetic differentiation among Alewife and Blueback Herring populations is relatively substantial at a regional level (McBride et al. 2014, Palkovacs et al. 2014). This suggests that Gaspereau typically return to their river of origin for spawning (as do other anadromous species such as Atlantic Salmon), and stray into surrounding rivers at relatively low rates. Therefore, the highest probability of success for population establishment from stocking into Indian River would be to release fish from an adjacent or nearby river with similar characteristics. There is also the possibility that individuals from surrounding populations will stray into the Indian River once it has been made accessible. The number of strays would depend on the relative sizes and stray rates of surrounding populations, both of which are unknown. Thus it is not possible to determine whether substantial population growth or population establishment might be expected for Gaspereau in the absence of stocking.

In order to maximize the potential for imprinting (i.e. learning the chemosensory cues necessary to relocate natal freshwater habitats) and thus maximize return rates from stocked fish, adults would be the best life stage to release into Indian River. Adults would also be expected to be more robust than juveniles and thus have higher survival during capture, transfer and release. Expertise related to transport and adult releases is available from staff operating the fish lift at Mactaquac Dam on the Saint John River, New Brunswick.

Broodstock collection will impact the donor population by reducing current abundance as well as future reproductive potential. If the donor population also has a commercial or Aboriginal fishery for Gaspereau, these losses could have economic and social impacts as well. Currently, there are no commercial fishermen reporting catches of Gaspereau in rivers surrounding the Indian River (including Hubbards, Ingram, Northeast, East or Sackville Rivers), any of which could be a potential watershed for broodstock collection. Catches are being reported in the Nine Mile River (between the East and Sackville watersheds) and in Coastal District 23, which includes most of St. Margaret's Bay. Compared to other areas (e.g. Southwest Nova Scotia), there is relatively little commercial fishing activity for Gaspereau in the vicinity of Indian River. However, Food, Social and Ceremonial (FSC) licences are issued annually to several First Nations and Aboriginal organizations, including Acadia, Bear River, Glooscap, Sipekne'katik and the Native Council of Nova Scotia. These licences grant access to Gaspereau in watersheds throughout the St. Margaret's Bay area.

The status of the potential donor populations is unknown, so it is not possible to determine how any removals may impact their viability. The most recent review of status categorizes Alewife populations in the Nine Mile, Ingram, and East Rivers as declining and in the Sackville River as increasing (Rulifson 1994), although the method used to determine status is not given. For each of these rivers, the status of Blueback Herring is listed as unknown. There is no assessment information that either confirms or contradicts the presence of Blueback Herring in the potential donor rivers.

It is also relatively unknown whether translocated repeat-spawning adults would remain in the Indian River or would return to their river of origin for subsequent spawning events. This would influence reproductive effort among years. If stocking was initiated, it would be useful to release adults for a minimum of three years to ensure continual reproductive output in Sandy Lake and to ensure a more natural age distribution among cohorts (i.e. to prevent a pattern where spawning essentially takes place in 4-year increments). In the fourth year, age 4 spawners originating from the initial stocking event would be expected to return to Indian River.

Monitoring population increase from a stocking program would need to occur over similar timeframes as predicted for population increase (e.g. 10-15 years), in order to definitively evaluate the success of the program (where success is taken to be population establishment and substantial population increase from initial releases). Monitoring would also be an essential component if success in Sandy Lake would provide the impetus for fish passage being considered at Big Indian Lake dam. Video monitoring of adults is commonly used to estimate escapement, and is an option for the fishway at Sandy Lake. Unfortunately, the amount of effort required to watch such video does not depend on population size (i.e. you do not watch less video if the population is smaller), which makes this a very labour-intensive method of monitoring. More automated systems are very expensive, need to be calibrated with field observations, and impose strong limitations on system design and set-up (i.e. fish need to move through the field of observation essentially single-file in laminar as opposed to turbulent flow). As such they have yet to be implemented for Gaspereau population monitoring in the Maritimes region.

The ecosystem-level consequences of introducing Alewife (as well as opening up fish passage) are relatively unknown for Indian River. Changes to the nutrient dynamics of watersheds are expected after the introduction of Alewives in a river, where the net effect may depend on population size (West et al. 2010). Multiple fish species presently inhabit the watershed; notably, recreationally-fished species such as Brook Trout, Yellow Perch and Smallmouth Bass in the areas upstream of Sandy Lake dam, as well as American eel in the areas downstream. These species may also move through the fishway once it is accessible, leading to potential changes in their community dynamics as well as disease transfer. In the St. Croix River, where passage has been provided for Alewife at historically impassable dams, an adaptive management plan was first put in place to help mitigate any unintended changes in Smallmouth Bass productivity (IJC 2010).

Uncertainties, Assumptions and Limitations

It is important to recognize that there is a possibility that Gaspereau will not establish or that an Alewife or Blueback population will not grow rapidly from stocking (or straying) into the Indian River. For Sandy Lake, introduction success will depend not only on the number of animals released and where they are released, but also on factors affecting population vital rates (e.g. mortality rates) as well as the actual productive capacity and connectivity of the habitat.

Factors that would reduce or eliminate the capability of populations to increase in size or would change the estimates of theoretical production include:

1. Low upstream passage efficiency of the constructed fishway. The projections above assume 100% passage efficiency; if it were lower, it would have the equivalent effect to higher mortality, reducing population productivity and extending timelines for population growth.
2. Less habitat connectivity. From the flow network used in these analyses (characterized from 1:50,000 images), all of the lakes appear accessible. However, partial barriers would reduce

productive capacity by restricting access, making production lower on a per-unit-area basis. Note that any obstruction in the waterway downstream of the fishway would have the same effect.

3. Higher or lower carrying capacity in the habitat above Sandy Lake dam. This would change the estimates of abundance that the habitat could theoretically support as well as how quickly the population would be expected to increase in size (assuming logistic growth).
4. Capture in commercial fisheries in other areas. By-catch in marine fisheries or capture in commercial fisheries in adjacent rivers would increase mortality even though there is no fishery for Gaspereau in the Indian River.
5. Mortality associated with downstream movement by juveniles and adults (i.e. any by-pass inefficiency or turbine mortality) at Sandy Lake dam. This would reduce the number of juveniles produced from any spawning cohort and/or increase mortality rates on repeat-spawning adults.
6. Decreased homing ability due to the introduction of a non-natal population. In particular this could affect the contribution to the population from repeat-spawners if the translocated fish returned to their river of origin in subsequent years.
7. Inaccurate or uncertain species identification. Stocking a mixture of Alewife and Blueback proportionately reduces the abundance of each species and would be the equivalent of releasing a smaller number of animals. Also, any hybridization between the two species (McBride et al. 2014) would be expected to reduce spawning success.

If stocking were to be pursued, it would be beneficial to address some of the identified uncertainties in a step-wise manner in order to maximize success. As related to the potential for population growth, the two key issues to address for Indian River are: estimation of upstream and of downstream passage efficiency at the newly constructed fishway (# 1 above) and verification of habitat connectivity for the lakes above Sandy Lake dam, as well as verification of an unobstructed waterway between Sandy Lake and St. Margaret's Bay (# 2 above). As related to logistical considerations for fish collection and release, the key issue would be to evaluate the presence of Blueback Herring in the chosen donor population (# 7 above).

Conclusions

Estimates of the amount of spawning habitat made accessible by the fishway at Sandy Lake dam are relatively small (i.e. 4.15 km^2), although there is substantial future potential if the dam at Big Indian Lake is also made passable (an additional 15 km^2).

In the absence of population-specific information on productivity, applying results from other analyses to inform estimates of theoretical population increase or timelines for population growth are dependent on assumptions. Alewife populations can be highly productive and it is possible that a population may quickly establish in the Indian River. However, even under situations of extremely fast population growth, approximately 15-20 years would still be expected before appreciable population sizes would be reached.

Stocking adults from a geographically proximate watershed would be expected to maximize survival and the potential for population establishment in the Indian River, as well as to have minimal effect on the commercial fishery. How broodstock collection would influence the viability of any donor population is unknown. The information in this response pertains predominantly to Alewife, and there would be fewer uncertainties associated with stocking if the species composition of the donor population was known.

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