Modeling Sea Lamprey Abundance in Lake Huron After Stopping Lampricide Treatment on Specific Rivers

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Background

Each year, streams across the Great Lakes are treated with lampricides that target larval populations of the invasive sea lamprey, as part of a bi-national program to control this invasive species and the damage it inflicts on fish that support recreational Indigenous and commercial fisheries. Sea lamprey control efforts have successfully reduced the number of parasitic sea lamprey that prey on large-bodied fish in the lakes, and remains a cornerstone of fishery rehabilitation. Although highly selective, lampricides can also impact other stream-dwelling fishes, particularly those individuals already stressed by disease, reproduction, or degraded water quality. As well, certain species or life stages exhibit sensitivity to lampricides and non-target mortality can be a concern when it involves ecologically important or culturally significant fish species such as lake sturgeon. Exposure to lampricides at concentrations used to control sea lamprey does not present undue risk to human health, according to the U.S. Environmental Protection Agency or Health Canada, however; it is commonly raised as a concern by water users.

The Garden and Mississagi Rivers were last treated in 2014 and 2013 respectively. The Garden River was proposed for treatment in 2016 and 2017 to address a large number of larvae that survived the 2014 treatment, as well as new recruits. Similarly, treatment of the Mississagi River was proposed in 2017 to prevent juveniles from the 2014 larval cohort from escaping to Lake Huron. These treatments were deferred to provide the Garden River and Mississauga First Nations adequate time to review information and material that DFO provided relative to the history of treatment, its role in supporting fish stocks in Lake Huron, and environmental and health impacts related to Lampricide exposure. To date, the two First Nations have not supported proposals to treat these two rivers.

Here we model the changes in spawning sea lamprey abundance in response to a cessation of sea lamprey control in the Garden and Mississagi Rivers. We also include the effects on spawner abundance caused by skipping lampricide treatment on the Root and Echo Rivers which serve as the west and east boundaries of the Garden River Reserve because there is concern that the First Nations may not support treatment of these rivers in 2018.

Methods

We used a stochastic simulation model (see Jones et al. 2009) called SLAMSE (Sea Lamprey Management Strategy Evaluation), which estimates sea lamprey spawner abundance given a set of parameters and a control budget. To simulate the cessation of sea lamprey control on each river, we also employed a model feature (Jensen 2017) which allows lampricide treatment to be stopped on selected rivers and tributaries. Other model parameters specific to Lake Huron and the St Marys River are the same as those used by Irwin et al. (2012) except for the control budget and target mean abundance of spawning sea lamprey, which were updated to reflect the current time period (Table 1).

Before being used for simulation modeling, the SLAMSE model is calibrated to match the mean observed spawner abundance under a given control budget. During calibration, we adjusted survival of larval sea lamprey and a scalar used to determine the movement of age-0 larvae from streams to lentic areas. When we were within 10% of the target spawner abundance, we conducted 300 simulations over 100 years for each scenario to allow the system to reach a steady-state level of sea lamprey abundance.

We calibrated the model using the mean control budget from 2009-2015 ($2,313,034 US) and the mean spawner abundance from 2011-2017 (142,939 spawners). The spawner abundance was lagged two years from the control budget to account for the delay between treatment and effect on spawner abundance (Table 1). Other parameters we used to run the model are shown in Table 1. Each stream also has specific values in the model that define its size, structure, sea lamprey characteristics, and control information (Table 2). We removed each of the rivers (and all of its tributaries) individually, to create four removal scenarios: Garden, Mississagi, Root, and Echo rivers. We also ran a scenario where all four rivers were removed at the same time.

Results

We present the mean sea lamprey spawner abundance and the mean number of parasitic sea lamprey over the last 10 years when the model reaches equilibrium, as indicators of the response to each scenario. Spawners are adult sea lamprey that have spent time in the lake in their parasitic phase. Parasitic sea lamprey are juveniles that haven yet to mature but have migrated to the lake. We apply a fixed annual mortality to the number of parasites to determine the number of spawners that return to the tributaries and would need to be controlled via lampricide treatment.

During model calibration, which tunes the model to spawner abundance, we obtained a 2% difference between observed mean spawner abundance between 2011 and 2017 and the model estimate of spawner abundance when using a larval survival rate of 0.41 and the overflow rate of 0.00125. Our estimated number of mean spawners was 145,311. This larval survival rate falls within the expected range of survival based on a limited number of studies (Dawson et al., 2016). We did not adjust the outflow scalar. All parameters and stream data used in the simulations are shown in Tables 1 and 2.

The estimated number of mean spawners for each stream scenario increased when lampricide treatments were stopped (Table 3) and indicate that additional lampricide treatment could be needed to keep the spawner abundance as low as previous years when the excluded streams were eligible for treatment. Because of the direct relationship between number of spawners and number of parasites, the size of the parasitic lamprey population increases when mean spawners increase. The number of parasitic sea lamprey in the lake and the number of spawners that would potentially be entering Lake Huron streams varies by river and is affected by the properties of each river system (Table 2), the control budget, and the other streams that could be treated when the removed stream's budget is freed up for treatments (Table 3).

Stopping sea lamprey control on smaller systems, such as the Root and Echo rivers, impacted the mean spawner abundance significantly less than the larger Garden and Mississagi rivers (Table 3). The small relative change in spawner abundance in the Root (6.4%) and the Echo (3.5%) rivers indicate that stopping lampricide treatment in these systems has a smaller impact on sea lamprey spawner abundance and thus the number of parasitic sea lamprey entering Lake Huron. When lampricide is not applied to the Garden River, there would be approximately a 29% increase in the mean spawner abundance (Table 3). A more significant impact on spawner abundance is seen when lampricide treatment is stopped on the Mississagi River where an additional 278 thousand spawners survive representing almost a doubling of the number of mean spawners (Table 3) that are normally in Lake Huron. The biggest impact on mean spawner abundance occurs when lampricide is not applied to all four rivers.

Conclusion

Any time lampricide treatment is stopped on a river that supports spawning sea lamprey habitat, an increase in the number of spawning sea lamprey could be expected. The actual increase is based on many parameters that are lake- and stream-specific, the control budget, and the size and potential abundance of spawning sea lamprey that reside in streams that become eligible for treatment when portions of the control budget are not used to treat the removed streams.

There are numerous places where uncertainty plays a role in this model and doing many simulations of many years allows the model to come to an equilibrium. However, the results are still subject to the other uncertainties built into the model as well as uncertainties that surround the parameters and the stream data that are key input to the model. Our results should provide a basic understanding of how stopping lampricide treatment on specific streams will impact the mean spawner abundance in Lake Huron.

There are rivers that are either smaller or provide less sea lamprey spawning habitat that will always produce fewer spawners and thus stopping treatment will not increase the spawner abundance as much. Here we showed that stopping treatment on the Echo and Root rivers will have much less impact on the mean spawners than stopping treatment on the Garden or Mississagi rivers. In particular, the Mississagi River can support a significant number of spawners and cause a doubling of spawners in the Lake Huron system. In the absence of feedbacks (e.g., lower survival of parasitic stage sea lamprey or change in their feeding behavior), such an increase would be expected to lead to an approximate doubling of attacks and deaths on the fish host species in Lake Huron (Bence et al., 2003).

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Table 1 – Parameters used in the SLAMSE model

Parameter	Value	Source
Control budget	$2,313,034 US	Mean control budget 2009-2015
Mean spawner abundance	142,939	Mean spawner abundance in Lake Huron between 2011-2017
Larval survival	0.41	Adjusted during calibration to match within 10% of mean spawner abundance between 2011-2017
Amount (%) of untreated lentic area	2	Irwin et al. 2012
Lake: Size (ha) of lentic habitat available for treatment	12	Irwin et al. 2012
Lake: Lentic units	1	Irwin et al. 2012
St Marys River: Size (ha) of lentic habitat available for treatment	700	Accounts for St Marys River; Irwin et al. 2012
St Marys River: Lentic units	56	Irwin et al. 2012
Outflow scalar	0.00125	Irwin et al. 2012

Additional model settings used in these simulations:

1. In *Special Options*, click “Apply barrier removal”
2. In *dbStreamTable*, each stream that will stop receiving treatment must have the field “Barrier_TreatmentSwitch” set to 1. All other streams must be set to 0.

Table 2 – Lake Huron stream data used in SLAMSE model.

River	Tributaries (as defined in SLAMSE)	Drainage Area	Default Infested Length	Average Daily Growth	Default Proportion Type1	Default Proportion Type2
Echo	Echo River, Bar Creek and Iron Creek	930	8,424	0.1300	0.075	0.489
Garden	Main	1,019	58,165	0.1500	0.042	0.572
	Tributaries		13,079	0.1500	0.039	0.177
Mississagi	M001	9,271	2,534	0.1700	0.126	0.769
	M002 & M003		27,403	0.1700	0.045	0.725
	Tributaries		7,887	0.1700	0.339	0.370
Root	Main excluding estuary	174	21,859	0.1781	0.007	0.283
	Estuary		1,426	0.1781	0.086	0.877
	Crystal Creek		5,702	0.1800	0.089	0.467
	West Root & Cannon Cr.		13,781	0.1781	0.159	0.194

Other stream data that is the same for all streams listed

Growth parameter ID	9
Annual mortality rate	0.70
Default habitat type 2to1 conversion ratio	0.44
Season days	188
Transformation curve ID	14

Table 3 – Simulation results summarized for the last 10 years in each scenario. The model was calibrated to the estimated spawner abundance between 2011 and 2017 of 142,939 spawners. Our calibrated value, used here to determine additional spawners and relative change, was 145,311. We also present the number of parasites which is the sea lamprey abundance present in the lake before annual mortality is applied and transition to the spawner stage occurs. This value represents all parasites estimated to be in the lake including those not impacted by these changes in lampricide treatment. Parasites are lamprey in the lake that impact fish populations and spawners are adults that return to spawn and need to be addressed via lampricide treatment.

Scenario	Number of tributaries not treated	Mean Spawners (from SLAMSE)	Additional spawners due to no treatment	Relative change in spawners	Mean Parasites (from SLAMSE)
Remove Echo	1	150,396	5,085	0.035	220,691
Remove Garden	2	187,604	42,293	0.291	250,888
Remove Mississagi	3	423,653	278,342	1.915	562,871
Remove Root	4	154,620	9,310	0.064	204,905
Remove all four	10	486,559	341,249	2.348	648,779