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Commentary

Shifting baselines and social license to operate: Challenges in communicating sea lamprey control

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ABSTRACT

Sea lampreys (*Petromyzon marinus*) invaded the Great Lakes in the early twentieth century and caused considerable economic and ecological harm. People who fished the Great Lakes suffered crippling losses and successfully lobbied elected officials in Canada and the United States to create a sea lamprey control program which the Great Lakes Fishery Commission implements under the 1954 Convention on Great Lakes Fisheries. The control program relies on two primary methods: chemical lampricides and physical barriers. Sea lamprey control has been a tremendous success; although the urgency to act is apparent to certain publics and although control methods are deemed by professionals to be safe and effective, continued public advocacy for and acceptance of the control program is not ensured. Many people in the control program are concerned that the urgency to act is not commensurate with the risk sea lampreys continue to pose and that societal acceptance of the primary control methods could wane. This commentary reflects on issues of "shifting baselines" (changes in perceived risk) and the "social license to operate" (trust in authorities to make responsible decisions regarding current and planned control methods) and suggests a course to better understand these issues. Improved understanding of these issues will inform communication efforts for all involved in the control program. Moreover, the case examined here is potentially relevant and informative for other environmentally related actions where there may be erosion of the social license.

Introduction

About a century ago, a noxious invasive species, the sea lamprey (*Petromyzon marinus*), swam into the upper Great Lakes. Few people at the time imagined the ecological and economic damages that would ensue. By the mid-1940s, sea lampreys had fully infested every corner of the Great Lakes basin, and only the most dedicated optimist would venture to anticipate the successful sea lamprey control program that began in the late 1950s and that continues to this day. Sea lamprey control, despite its success, is fragile as it must be ongoing and continually supported. The degree of perceived urgency to address the sea lamprey threat, and the level of acceptance for control techniques, might have shifted over time.

Sea lampreys attach to fish with a suction cup mouth and feed on the fish's blood and body fluids. The species is native to the Atlantic Ocean and tributaries along eastern North America and western Europe, but not the Great Lakes. When they entered the system after a major modification to the Welland Canal in 1919, they caused dramatic shifts in Great Lakes food web dynamics, ecological collapse of several fish populations, and economic hardship (Brant, 2019; Eshenroder, 2014). The major damage sea lampreys inflicted on the basin's commercial fishers prompted a political response: a bi-national agreement called the 1954 Convention on Great Lakes Fisheries, which created the Great Lakes Fishery Commission (GLFC), charged with developing and then implementing a border-blind sea lamprey control program. For the people harmed by the sea lamprey, control could not come fast enough.

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After formation of the GLFC, a coordinated effort to kill the stream-dwelling sea lamprey larvae began. The GLFC and its partners discovered a chemical, TFM (3-trifluoromethyl-4′-nitrophe nol), that would kill larval sea lampreys yet leave other non-target species unaffected at the concentrations applied (Brant, 2019). Because TFM is selective for lampreys at the concentrations applied, the chemical pesticide is called a "lampricide." The GLFC also relies on physical barriers as a control technique. Sea lampreys do not jump, so barriers, even relatively low weirs, can prevent sea lampreys from reaching their spawning grounds, thus limiting the number of rivers in the basin that produce sea lampreys (Hrodey et al., This issue). Barriers also reduce the number of tributary miles that require lampricide treatments. In the Great Lakes basin, more than 900 dams, large and small, passively serve a sea lamprey control function; the GLFC has also constructed or modified 77 dams explicitly for sea lamprey control (Lavis et al., 2003; Zielinski et al., 2019).

Since sea lamprey control began in 1958, the program has been a tremendous success, resulting in a 90–95% reduction in sea lamprey populations in most areas of the Great Lakes basin and saving tens of millions of pounds of fish annually. The sea lamprey control program is widely seen as one of the best examples of invasive species control, particularly control at scale as grand as the Great Lakes (Siefkes, 2017).

Despite this success, there is unease. During the 2019 Sea Lamprey International Symposium III (SLIS III), participants voiced concerns about communicating and cultivating public support for the sea lamprey control program in light of current perceptions about the sea lamprey threat and therefore potential loss of support for primary (and envisaged) sea lamprey control methods. The concerns echo what many people in the sea lamprey control program have contemplated for some time; although the urgency to act is apparent to certain publics and although control methods are deemed by professionals to be safe and effective, continued public advocacy for and acceptance of the control program is not ensured.

This commentary reflects on issues of changes in perceived risk ("shifting baselines") and trust in authorities to make responsible decisions regarding current and planned control methods (the "social license to operate") and suggests a course to better understand these issues. Improved understanding of these issues will inform communication efforts for all involved in the control program. Moreover, the case examined here is potentially relevant and informative for other environmentally related actions where there may be erosion of the social license.

Shifting baselines and social license

Shifting baseline syndrome

According to Pauly (1995), shifting baseline syndrome occurs when each new generation of fishery users or natural resources professionals considers the baseline health of the ecosystem (usually described as diversity, stock-size, or other quantitative stock-assessments) as it occurred at the start of their career or generation as "normal," or a key reference point for interpreting change.

In fisheries, the shifting baseline syndrome has been shown to be a problem for defining and understanding "pristine" or historically "healthy" baseline fish populations ranging from small-scale artisanal to global-scale fisheries (Pinnegar and Engelhard, 2008), and it occurs on both an individual and generational level of fisheries professionals. Moreover, the loss of historical perspective undermines the ability of fishery managers and the engaged public to understand the depth of current and emerging problems and appreciate the need for policy responses (Jackson and Alexander, 2011). Jackson and Alexander (2011) assert that, because of shifting baseline syndrome, policy makers today might not fully appreciate the urgency or need for certain actions because previous managers had understood the pre-change conditions, while current managers may not.

Similarly, those who did experience and understand the implications of prior conditions might have passed away, accepted the new reality, or lowered their policy-outcome expectations. The result is at least two possible negative consequences of shifting baseline syndrome: people might not appreciate the need for management responses to address ongoing problems, and people might accept the degraded condition of a fishery as normal. From a policy perspective, this syndrome leaves current and future generations of managers vulnerable to accepting less than what the fishery could offer or, perhaps worse, doomed to repeating past mistakes. Alternatively, by overcoming shifting baseline syndrome, a new generation of managers and users can institute policies that maximize fishery restoration benefits and learn from the lessons of the past.

It is important to note that our emphasis on understanding the baseline does not necessarily imply that managers and stakeholders are thinking entirely in terms of the past and, perhaps, returning to or avoiding a baseline condition. In some cases, ecosystems are altered (e.g., habitat loss, climate change) such that "restoration" to a previous state might not be possible. In other cases, stakeholder preferences and values might have shifted toward different uses of a water body (e.g., toward boating from fishing) and, thus, away from the baseline state. Arlinghaus et al. (2020), for instance, documented a shift in the developed world from "anthropocentric" views of fisheries toward "biocentric" views; such a shift, of course, could alter fishery management objectives. Knowing about shifts in the baseline and what caused them is valuable in increasing the understanding of human-induced and natural changes in a system so that managers and stakeholders could have a fulsome understanding of how current policies could influence future conditions. Moreover, such an understanding helps communicators frame management actions and objectives in terms that resonate with affected stakeholders.

Shifting baselines approaches are not the only literature that addresses changing attention given to resource issues, such as sea lamprey abundance and impacts, as well as control mechanisms. Nearly 50 years ago, Downs (1972) wrote of an "issue attention cycle", whereby topics perceived as crises attract a great deal of public attention, and once perceived as "solved" are replaced by new crises and fade to the background. Certainly, sea lamprey control is an example of one such issue where public attention has waxed and waned with cycles of lamprey abundance and damage.

Although Pauly (1995) restricts his analysis to resource managers, we expand the shifting baseline concept to include a wider variety of stakeholders in the Great Lakes fishery because stakeholders convey the social license that underpins management, as described below. Problems resulting from shifting baseline syndrome can be addressed with data, analysis, and communications (Safina, 2011).

Social license to operate (SLO)

The concept of SLO refers to society's general approval or acceptance of a particular operation (Allen et al., 2019; Gunningham et al., 2006; Moffat et al., 2015; Yates and Hovarth, 2013). SLO is about whether stakeholders, local communities, interested publics, or whoever trust the actions and accept the practices of a particular organization or industry as legitimate (Gehman et al., 2017; Jijelava and Vanclay, 2017; Prno and Slocombe, 2012).

The use of pesticides in agricultural production provides an example of changes in the SLO in the food sector. The so called

"Green Revolution" that began in the middle part of the 20th century saw tremendous advances in food production in response to rapidly rising populations. Cropland became more efficient through investments in infrastructure, fertilizers and, to some degree, more and better pesticide use (Pingali, 2012). By the 1970s, influenced by Rachel Carson's (1962) book, *Silent Spring*, public perceptions about pesticides had begun to sour (Sachs et al., 1987) and today (particularly in the developed world) preferences are increasing for organic foods, produced naturally and without pesticides (Saba and Messina, 2003). Still, surveys also suggest people are somewhat conflicted about pesticides, indicating deep concern about their use but also acknowledging they are required if people are to be fed (Dunlap and Beus, 1992; Molnar et al., 2002).

To date, the SLO concept has focused on mining, forestry, and agriculture sectors; the use of the concept in understanding conservation is growing (Kendal and Ford, 2017). Here, we suggest that the SLO can apply to fishery management, particularly sea lamprey control, which also operates under a social license and relies, in part, on a pesticide. The SLO relates strongly to "shifting baseline syndrome:" what people accept in terms of sea lamprey control techniques is considered within the context of the perceived sea lamprey risk. When the pre-control baseline was established for the sea lamprey problem (the late 1940s and early 1950s), the magnitude of sea lamprey threat helped to establish a broad social license for its control; any technique that would work and was deemed safe was embraced. A potentially decreased risk perception (the "new normal," as described above) may also come with a change in the SLO for sea lamprey control. Today, the potential sea lamprey risk is no less present, though the perceptions of risk might have changed due to shifting baselines. People who perceive the sea lamprey risk as low may also question whether the use of some techniques—particularly chemicals and dams—are cost-effective or are worth the perceived risks to the environment or human health.

The *social* license to operate is an imprecise concept, much like an "unwritten social contract" (Moffat et al., 2015). In contrast, the *regulatory* license to operate is a legal concept that serves as the foundation for an entity's actions. The connections between social and regulatory licenses to operate are complex. One may have the regulatory license to operate; but, without the social acceptance, the lasting ability to function would likely be limited (Gunningham et al., 2006) and could lead to a decrease in regulatory license. Being unwritten and informal, the SLO is not bestowed in a direct sense on an operation; rather, it is "granted" by the collective views of the community (Yates and Hovarth, 2013).

The concept of SLO has become more important in natural resources during the past few decades owing to increased public sensitivity to environmental risk and the growth of stakeholder involvement in decision-making (Moffat et al., 2015). Affected communities exert societal pressures that could, in fact, be more difficult to manage than official rules, as discussions may occur in the "court of public opinion" where the burden of proof is qualitatively different from the regulatory license to operate. Just as it is difficult to know how the social license is granted, it is also difficult to know when or how it is threatened or lost.

The baseline for sea lamprey risk

Pauly's construct of shifting baselines, applied to the case of sea lampreys in the Great Lakes, works as follows: the baseline in many people's minds is the current low presence/impact of sea lampreys, with some, perhaps many, people being unaware of the influence of effective management over the past seven decades in creating that low impact condition. This is now the "normal" or referent condition. Most people today have not experienced, or have no memory of, pre-control sea lamprey devastation. Today's low sea lamprey abundance may therefore equate to "no threat" in people's minds. This change in perception is precisely what Pauly (1995) meant by "shifting baseline syndrome," whereby people do not appreciate the urgency of past problems and the associated need for effective management.

Bauch and Galvani (2013), speaking from the perspective of epidemiology, note there is a cyclical element to actions and reactions when social and biological networks collide. As an example, they suggest that people, when confronted with disease, demand protection in the form of vaccinations. When disease is thus reduced or eliminated, people perceive the problem as having gone away and then focus on the risk of the vaccine itself rather than the risk of the disease. The resultant rebound of the disease leads to human harm and renewed demands for a vaccine. The application of this scenario to the sea lamprey case of invasion, harm, control, skepticism toward control measures, sea lamprey rebound is certainly apt. Unfortunately for the Great Lakes fishery and ecosystem, a lapse in control, while society catches up to the need, would cause significant damage and hardship, just as the lapse in vaccine use would lead to an increase in human suffering.

To better understand previous baseline perceptions of the fishery, the GLFC, in 2015, launched an Oral History Project exploring how sea lampreys affected the people who fished the Great Lakes. What was the level of concern at the time of the sea lamprey invasion? What political processes did people (primarily scientists and commercial fishers) go through to convince governments to act? What did it take to establish the sea lamprey control program and what was the level of support for various techniques? Through a partnership with the University of Michigan's Water Center, the GLFC interviewed people who remembered the invasion or participated in early sea lamprey control. A variety of materials were also collected and reviewed, e.g., primary documents and multiple types of media including photographs, old films, artifacts, etc. In all, the PIs collected more than 100 oral histories with individuals who spent their career connected to Great Lakes fisheries and/or to sea lamprey control, along with thousands of photographs and documents.

Early results from the history project, documented partially in Brant (2019), demonstrate that the decline of commercially important fishes throughout the Great Lakes, mainly lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*), was obvious by the 1930s as a cumulative result of overfishing, habitat loss, pollution, and sea lamprey damage (Gaden et al., This issue; Smith and Tibbles, 1980). Most fishes caught in commercial nets were wounded or dead from sea lamprey attacks, and nonsalable. In 1951, Claude Ver Duin, a commercial fisherman from Grand Haven, Michigan, testified before Congress about the sea lamprey threat. He couched his testimony in stark terms: "I would like to point out that we find ourselves in pretty desperate straits" (U.S. House of Representatives, 1951, p. 34). The following year, during a subsequent hearing, he reported that commercial fishermen were "very, very depressed" about their economic losses and again urged for a control program (U.S. House of Representatives, 1952, p. 37).

As the Great Lakes fishery continued to collapse, it became clear that federal resources would be needed to overcome the sea lamprey problem. The response to the sea lamprey invasion was the 1954 Convention on Great Lakes Fisheries, a treaty between Canada and the United States, which in turn created the GLFC (Gaden et al., This issue). Ver Duin and many others successfully lobbied Congress and Parliament to create the GLFC and charge it with the responsibility of developing and carrying out a sea lamprey control program. The GLFC's mission over the past 65 years

has been to control sea lampreys, advance Great Lakes fisheries science, and help agencies work together protecting fisheries of common concern.

Some quotations from the history project interviews give a small taste of the richness of data that has informed the baseline related to the perception of risk posed by sea lampreys:

During a Congressional field hearing in 1945, Clarence Mertz of Rogers City, a commercial fisher, testified:

> "I will touch on the sea lamprey eel, which I think is doing more damage to our freshwater varieties today than all the commercial fishing done in the Lakes. Last year I dropped back into the lake approximately 550 lb of whitefish that were so marked up, but still alive, that wouldn't have been marketable. Four years ago we noticed most of our trout being marked, and last year the trout were gone, so it indicates as the lamprey gets larger and gets on the fish, we don't see the fish any more" (U.S. House of Representatives, 1945, p. 53).

In 2015, Brant (2019) interviewed Ms. Beatrice (nee Mertz) Skaggs, Clarence Mertz' niece. (Researchers for the GLFC's history project obtained written permission from all interviewees for their identities to be published.) Ms. Skaggs, who fished commercially alongside her mother, recounted her father warning her about the looming lamprey menace. She recalls,

> "I was only four [c. 1934] but I can still picture my dad sitting at the table telling us about the sea lamprey coming into the Great Lakes. He kept telling us that it was going to be an evil thing." After the death of her father in a fishing accident, Ms. Skaggs and her mother continued the fishing business and young Beatrice had the job of removing sea lamprey heads because her father told her 'no live sea lamprey is to go back into the lake'" (Skaggs, 2015).

During a Congressional hearing in 1949, Claude Ver Duin, a commercial fisher and future member of the GLFC, testified that:

> "We feel that the fisheries of Lake Michigan are doomed, along with those of Lake Huron, unless some method of control can be inaugurated to cut down this supply of lampreys, and some method used to restock the lakes and to bring back our fish. Now we say this because at first it was believed that if the trout would disappear we could still go ahead and catch other species of fish that were left. I think it was wishful thinking on the part of some people to think that lamprey would only attack lake trout" (U.S. House of Representatives, 1949, p. 12).

In 2017, Brant interviewed Mr. George Purvis of Meldrum Bay, Ontario. Mr Purvis, like Ms. Skaggs, comes from a long-serving commercial fishing family. He recalled the sea lamprey threat at the time of the invasion:

> "By 1944, the lake trout were pretty-well gone. The fish were dead on the bottom of the lake, especially in the fall when they were spawning. If you swept your nets a bit on the bottom, when you're pulling them up, the tugs would stink so bad you couldn't stand to be on the boat. So when you kill all the parents first, and then they attack the smaller fish later on, it doesn't take long to decimate a population, and [sea lampreys] did it in about 10 years. 1947, we didn't have one lake trout—we never caught one fish in '47" (Purvis, 2015).

A crucial part of this history is the desperation people felt at the time about the sea lamprey problem and how their concerns were translated into government action. Even at the start of the program, the notion of considering stakeholder perceptions and relative risk/benefit was important. In the early days, danger to people and wildlife versus the benefit of controlling an aquatic invasive species (AIS) was on the minds of officials. The desperation, along with political pressures, hearings in Parliament and Congress, social mobilization, and stories of economic hardships, all of which led to the establishment of the sea lamprey control program, are documented in Brant (2019) and Gaden et al. (This issue). These works, in addition to the ongoing GLFC Oral History Project, help establish the baseline to which current perspectives about sea lamprey risk and control methods can be compared.

Loss of social license? Has the baseline shifted?

Today, sea lamprey control and research are administered through a binational program coordinated by the GLFC and carried out with Fisheries and Oceans Canada, the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, and the U.S. Geological Survey. Several hundred streams around the Great Lakes are treated with lampricides annually, while barriers continue to block new stream sections from becoming suitable sea lamprey spawning habitat (Miehls et al., 2020; Siefkes, 2017; Wilkie et al., 2019). Sea lamprey populations throughout the Great Lakes are reduced 90% from historic numbers, which has allowed Indigenous, sport, and commercial fisheries to thrive; aided successful fish restoration efforts; and contributed to some degree of ecological stability.

The sea lamprey control program, like other initiatives, is subject to the social license to operate. In many respects, the program has much going for it, with support from elected officials and key stakeholders such as environmentalists and anglers, mainly because sea lampreys have a direct impact on the fishery and, therefore, on the lives of those who use the Great Lakes. These are enviable positives.

Now in 2020, although sea lamprey control has demonstrated its effectiveness, the GLFC and its partners run the risk of being victims of their own success. People today do not experience the full impact of sea lampreys. Few fish have sea lamprey wounds, and the successful control program is estimated to save more than 100 million pounds of fish annually, resulting in rehabilitated fisheries throughout the basin (Robinson et al., This issue; Siefkes, 2021; Siefkes et al., 2013; Swink, 2003). People naturally might assume that the sea lamprey problem has simply "gone away." However, lamprey populations are ready to rebound if controls are relaxed.

In contemporary times, the lack of sea lamprey control in a few areas of the Great Lakes provide cautionary tales about the sea lamprey's ability to rebound with force. As an example, the St. Marys River, the large connecting channel between Lake Superior and Lake Huron, was highly polluted by industries for much of the twentieth century. As the river gradually became cleaner, it gained considerable sea lamprey spawning habitat. The river was too large for the lampricide, liquid TFM, to be effective, and so it produced hundreds of thousands of lampreys each year (Criger et al., This issue; Schleen et al., 2003). The sea lamprey from the St. Marys River caused massive fish loss in Lake Huron and northern Lake Michigan such that agencies ceased stocking fish in the late 1990s until control was attained through the use of granular Bayluscide (2′, 5-dichloro-4′-nitrosalicylanilide), another type of lampricide (Criger et al., This issue; Morse et al., 2003). Similarly, in the mid-1990s, the GLFC called for a reduction in the use of lampricides to save resources and to incorporate more alternative, non-chemical techniques into the control program (GLFC, 1991). The GLFC also sought to reduce lampricide concentrations to protect sensitive fish, particularly lake sturgeon (*Acipenser fulvescens*) (Sullivan et al., This issue). The result of this experiment in lampricide reduction was a significant increase in sea lamprey abundances and lake trout wounding (Sullivan et al., This issue). The fact that sea lamprey numbers spike without control is likely not

well understood among the larger public, especially given the time that has elapsed between the pre-control days and the present.

Participants at SLIS III, among others, expressed concern about potential erosion in the social license because the two current sea lamprey control techniques, however successful they may be, can be on the wrong side of broad societal trends. Those current techniques, chemical lampricides and barriers, may be viewed negatively for reasons beyond the GLFC's program. Emerging control techniques, particularly genetic manipulation of sea lampreys and/or their prey, may also be subject to rejection by society.

Lampricides

The GLFC and its agents discovered that the chemical TFM is selectively lethal to sea lamprey larvae at the concentrations used and have been applying the lampricide since 1958. Bayluscide, applied as a solid is a booster to dissolved TFM, has been used since the 1960s. TFM and Bayluscide are safe in the environment, break down quickly, and do not bio-accumulate (Dawson, 2003; Hubert, 2003). However safe they are, society's tolerance for chemicals in the environment has decreased over time. Generally, people negatively perceive risk of chemicals/toxins in the environment (Mertz et al., 1998) and may have concerns about agency competence (Slovic, 1993). As such, the public may be pre-disposed to oppose chemical treatment of sea lamprey with lampricides. Even with strong support among key stakeholders, the GLFC cannot take the social license to use chemicals for granted.

Barriers

Dams/barriers are another crucial component of control (Lavis et al., 2003; Miehls et al., 2020). Prior to the discovery and use of lampricides, control agents tried barriers to sea lamprey migration, mostly with low levels of success (Brant, 2019). Starting in the 1970s, the GLFC revisited barriers as a control method and since has purpose-built or modified 77 structures to serve as a control technique (Zielinski et al., 2019). In addition, hundreds of thousands of human-made barriers, big and small, exist in the Great Lakes region and 930 of those "de facto" barriers (barriers for a purpose other than sea lamprey control) are integral to the sea lamprey control program (Zielinski et al., 2019). In fact, sea lamprey biologists acknowledge that control would not be possible without those purpose-built and de-facto barriers (Hrodey et al., This issue). However, globally, as well as in the Great Lakes region, dams are deteriorating and are often seen as environmentally harmful. Generally, there is a great deal of enthusiasm among the public for dam removal, especially among environmentalists. American Rivers (2020) shows nearly 2000 dams removed in the last century, but most in the last decade or two, as public support for removal has surged. While there are undoubtable environmental benefits for removing dams, including passage of anadromous fish, often less recognized is the possibility of inadvertently opening up pathways for AIS, including sea lamprey (McLaughlin et al., 2013; Rahel, 2013; Zielinski et al., 2019).

Genetic control

Genetic control of sea lamprey, while still decades away as a technique, nevertheless represents another element of sea lamprey management that relates to the SLO. Genetically modified organisms (mostly in the world of agriculture but increasing in other realms) are viewed suspiciously in much of the developed world (Marques et al., 2014; NASEM, 2016; Pew Research Center, 2015). The GLFC funded a project to examine whether genetic manipulations of sea lamprey would be a feasible control technique and to gauge stakeholder perceptions of various options. The preliminary study, which was based in part on workshops with stakeholders and fishery managers, concluded that broad support exists for research into and development of some genetic control options (Thresher et al., 2019). Although experts have assessed the risk of genetic control options for sea lamprey as low to extremely low (Thresher et al., 2019), stakeholders and ethicists, nevertheless, will ask tough questions about unintended consequences and pitfalls.

The issues surrounding genetic manipulation of organisms does raise the question about whether the GLFC could ever have the social license to launch a research program to explore genetic controls, let alone to deploy genetic controls in the field. Little consensus exists about where society is in terms of genetic modification of organisms for control; some people are even conflicted, exhibiting enthusiasm for new control techniques yet deep concern about unintended environmental consequences (Sharpe, 2014). The use of genetics in sea lamprey control likely would stimulate similar conflict, and the GLFC would be in considerable straits if it invested millions of dollars and spent decades of time developing genetic controls only to find the lack of social license to implement such controls.

Similar to the views expressed during SLIS III about the SLO of lamprey control, the history project has yielded considerable data related to how people today view the sea lamprey risk and the use of current control techniques. When juxtaposed against risk perceptions from the past, the history project provides some indication of the shifting baseline and concerns over the loss of the social license. One interviewee, an avid Great Lakes angler from Illinois stated:

> "As far as the fate of sea lamprey control, I worry about it mostly because of money. As time goes on, money becomes tighter... If people don't understand and the public isn't yelling for this control, and they don't even know anything about it, then it's hard to get funds. I know here in Illinois our members of Congress are behind it and that's good, and they're knowledgeable of it, so I appreciate that. But I worry about moving forward. And if [sea lamprey control] slows down or stalls... I hope it doesn't ever stop because if it stops it would decimate the Great Lakes, but even if it slows down, it's going to have a huge impact on the fishing in Lake Michigan and the general health of all the Great Lakes."

A Great Lakes fishery manager from Ontario had this to say about the future of sea lamprey control and social license:

> "The sea lamprey control folks are doing a fantastic job. But can we keep it up using the same techniques? I would speculate it's going to be difficult, just based on cost alone over time. And I'm confident, though, that some smart people are going to come up with some new tools and techniques and they'll find a better way. And so we're in the frontier time right now, so let's keep working together to find that solution and I think we have to keep reminding the public on how important this program is, because it's too easy to forget."

One first-generation sea lamprey control biologist, who began work in Ontario in 1960 during the earliest lampricide treatments, reflected on the most challenging part of his 30+ year-long career:

> "The hardest thing was to convince people that we were going to have to use a pesticide or a lampricide if you will... [If someone was to ask] 'what was the hardest part of the whole program,' it was dealing with the public, introducing the public to the program. Explaining to them why it's going to be a lot better after we treated [with lampricide]."

A quote from a second-generation sea lamprey control biologist in the US shows concern about the social license and the need for more investigation:

> "There is a percentage of the public out there who are against pesticides. Especially, say, introducing pesticides into trout streams or very good quality water streams that we have to treat. And they're asking the question, 'could this be treated in another way?' So that's ongoing. We have a lot of questions from people that we encounter. There are people that still call [the lampricide] poison to this day. They look upon the use of pesticides in a negative way, and a lot of it is not understanding the program—it has been the key tool, TFM has been the key tool that has been used against [invasive sea lamprey] since the late '50s."

Overall, the GLFC cannot count on society's support for lampricides, even relatively selective ones. Moreover, society, at least in North America, has become less tolerant of aquatic barriers because they impede environmental goals. As barriers crumble, the increasing default is to remove them. The ability to develop and launch a program involving genetic manipulation of lamprey or their prey still faces strong headwinds in terms of ethics and public support.

Future course to improve understanding

Despite all that is known about the impacts of sea lamprey and the effectiveness of control efforts, there has been relatively little empirical work investigating public preferences/acceptance of sea lamprey management or trust in decision-makers. Smyth et al. (2009) inquired about sea lamprey presence as one of a suite of ecosystem considerations in choice experiment-based research on management of Lake Champlain, though the project did not focus on sea lamprey management and, thus, provides limited insights into sea lamprey-related perceptions specifically. Another project by Thresher and Jones (2019) made use of the social license framework, exploring the feasibility/acceptability of a variety of genetics-based management techniques to control sea lamprey in the Great Lakes. Following an expert panel to elicit/judge risks associated with genetic control, discussions were held with a wide range of stakeholders, including avid anglers, resulting in an online survey assessing these risks. Although insightful, this work did not focus on the approaches that dominate current control—lampricides and barriers. The public might see chemicals and barriers as conflicting with other environmental objectives like pollution abatement, reduction in chemical use, and aquatic connectivity. Those environmental priorities, coupled with a sense that the sea lamprey problem has been solved, could erode support for the control program. That said, whether or not such views exist has not been investigated through research.

To focus more closely on shifting baselines and social license issues in the sea lamprey control program, we need a much deeper understanding of people's attitudes and beliefs, and we need to gauge how these perceptions have changed over time. To achieve these objectives, here we outline a thorough research program that will improve understanding in ways that will be of practical benefit to the GLFC, to communicators, and to policymakers. We have identified key participants for this research agenda including managers, stakeholders, and Indigenous communities. The term "manager" refers to those in authority who have the responsibility to manage fisheries, issue permits (e.g., to apply pesticides, remove dams), or otherwise act in an official capacity related to policy development and decision making. At the time of the sea lamprey invasion, "managers" mostly comprised state, provincial, and federal fishery authorities. Today, the term must also include tribal and First Nation fishery managers and state, tribal, First Nation, and provincial environmental agencies.

The term "stakeholders" comprises the foundational commercial fishing interests at the time of the sea lamprey invasion and must also comprise interested parties that have emerged since the sea lamprey were brought under control; parties such as charter fishers, recreationalists like canoeists and fishers, those engaged in recreational industries (e.g., marina operators and bait shop owners), boaters, and environmentalists.

Beyond managers and fishers, special attention should also be granted to tribal and First Nation perspectives on sea lamprey control as rights holders. Indigenous communities have deep connections to land and water systems, unique systems of governance, and sophisticated practices for sharing oral histories (Berkes, 2017). Indigenous perspectives may differ from those of other communities.

We believe it is particularly important to understand the heterogeneity in perspectives; to expand beyond the traditional "fishery" stakeholders and get a deeper understanding of the range of beliefs about the program. In some ways, this broadening of understanding represents a shift in thinking, as the definition of stakeholders is more open now than historically (Arlinghaus et al., 2020). More groups now have access and interest in the GLFC's work while earlier, management was for dominant stakeholders such as commercial fishery interests (Gaden et al., This issue). Critical in understanding the heterogeneity is also acknowledging that even views of the baseline condition is affected by one's "affiliation" (Stedman, 2016). For instance, is one paying attention mostly to sportfish catch rates, or to water quality or pollution issues? Of course, there has always been a diversity of voices in Great Lakes fisheries but, historically, mostly the dominant voices emerged. Today, researchers are more inclusive in recognizing and engaging this diversity in inquiry and management approaches.

To best understand shifting baselines in the sea lamprey control program, research projects should:

- **Establish a retrospective "baseline" for perceptions about the sea lamprey threat (i.e., characterize historical perceptions)**. It is important to understand how people viewed the sea lamprey threat prior to control so that the threat actually experienced can be known, communicated, and appreciated. Under the tenets of shifting baseline theory, the passage of time has likely made many people forget about how destructive sea lampreys were to the system and how desperate stakeholders were for a solution. Sea lampreys bounce back quickly when uncontrolled, and people from the past, who speak to us through meeting minutes and their descendants, would certainly warn against forgetting the urgency of the problem. Establishing the baseline, thus, will make the justification for sea lamprey control more apparent in the event policymakers are not aware of the true threat.
- **Understand current attitudes and beliefs about sea lamprey risk.** Perceived risks are not simply quantitative ("high/low") but instead vary by key attributes: controllability, extent, severity, degree of personal threat, and others (Slovic 1993). It is crucial that we understand these dimensions of risk. Further, perceived risk depends on beliefs, or cognitions, i.e., what key stakeholders and rights holders believe to be true about sea lampreys, their effects, their population, their habits, etc. Understanding current attitudes and beliefs about risk are crucial because communication efforts and advocacy for sea lamprey control need to be tailored toward specific audiences based on the audiences' perception of risk. If communicators assume a particular dimension of risk, and that assumption is incorrect, communication efforts will be misdirected, inefficient, and not influential in terms of informing policy.

- **Understand how these attitudes and beliefs vary (e.g., by stakeholder group, location, and socio-demographic factors)**. Risks and cognitions are neither universally perceived (i.e., everyone does not perceive them the same), nor is the variation in perceived risk random. Instead, risk perception varies systematically and is often shared within groups and social networks. Researchers need to explore the basis of this variation, across factors such as knowledge, geographic location, fishing avidity, levels of environmental concern, traditions, and group membership. A deep and nuanced understanding of the range of risk among people, and why they think the way they do, is essential so that that communications can be best targeted and formulated in the most effective ways. Without such an understanding, communication efforts would be too general to have much success in properly engaging audiences and affecting policy.
- **Understand how attitudes and beliefs have changed over time.** To engage the shifting baseline hypothesis, we need to understand change over time. While we would like to have pre-post measures, we lack a scholarly articulation of attitudes and beliefs that existed before sea lamprey control began. Thus, we need to approximate these factors by looking retrospectively at the memories of those involved at early stages. The pre-control condition (which varies by lake but, generally, is before 1962, the year success became generally known) becomes essential as an initial baseline, as it indicates the sentiments of the affected publics and how they converted such sentiments into political action and policy. In contrast, many current decision makers and affected stakeholders hold a baseline perception formulated only in the post-control era characterized by relatively low sea lamprey abundance and impact. By charting the shift in attitudes and beliefs over time, researchers can demonstrate the degree to which shifting baseline syndrome has occurred. Communicators, thus, would be in a better position to understand the level of understanding about the sea lamprey threat among affected publics and be able to tailor messaging to emphasize the true risk as opposed, perhaps, to the perceived risk, which might have changed over time.

To best understand social license to operate in the sea lamprey control program, research projects should:

- **Understand attitudes and beliefs about sea lamprey control techniques among key stakeholders and rights holders**. Views of control techniques are crucial to understand and may operate at least somewhat independently of views about sea lampreys. We cannot assume that simply because people do not like sea lampreys, and perceive strong risks associated with them, that they automatically support the specific measures needed to control them. In many cases, they have low knowledge of what is actually required to do the managing; in others, they may perceive negative side effects of management and judge those side effects to be more consequential than the fishery impacts caused by sea lamprey. Without understanding attitudes and beliefs about sea lamprey control techniques, policymakers are in danger of assuming past support ensures future support. With a deeper understanding, communicators can better formulate messaging to address questions and concerns about control methods. Moreover, with this understanding, the GLFC can better justify investments in supplemental control techniques if the acceptance of current techniques is not robust.
- **Characterize attitudes and beliefs about use of chemicals in invasive species control, generally, and use of TFM in sea lamprey control specifically.** Chemicals in the environment have, for decades, been a primary concern among the citizenry (Mertz et al., 1998); government agencies are not always viewed as competent in addressing the threats of toxic chemicals (Slovic, 1993). As such, the public may be pre-disposed to oppose chemical treatment of sea lamprey with lampricides. However, these general concerns may or may not translate to more specific views of chemical treatment of sea lamprey with lampricides. It is therefore important to assess both general levels of concern and more specific perceived risk. The lampricide TFM is environmentally benign and effective in killing sea lampreys at the concentrations applied. If the public, however, does not perceive TFM that way, then the GLFC will be hard pressed over time to assure people that TFM use is safe. With a better understanding about the perceptions of TFM, communication efforts can be better formulated and targeted to address concerns about TFM's use in the environment.
- **Characterize attitudes and beliefs about barriers and dams generally, and sea lamprey barriers and dams specifically**. Barriers are a prime instance where well-intentioned public sentiment may work against sea lamprey management. People may support policies that undercut the ability to manage sea lamprey, even as they perceive sea lamprey negatively and support other approaches to manage them. Therefore, as with lampricides, it is important to understand both the general views towards dam removal and attitudes toward sea lamprey barriers in particular, assessing perceived risk and benefits and beliefs about effectiveness. By understanding the public's perceptions of dams and dam use, the GLFC will be in a better position to communicate a nuanced position that dams thwart connectivity but do block harmful invasive species like sea lampreys. By better understanding the pros and cons of dams, society and mangers might be less prone to default toward dam removal and, instead, work with the GLFC to construct or retrofit barriers with sea lamprey control in mind and to support measures like the GLFC's FishPass project that aims to test technologies that sort fish, pass desirable fish around barriers, and block harmful fish like sea lampreys.
- **Understand how attitudes and beliefs about sea lamprey control techniques vary and why (e.g., by stakeholder group, by location, and socio-demographic factors)**. Again, "stakeholders" comprise sport, commercial, and tribal and First Nation fishers; fishery managers; state, provincial, and tribal environmental managers (e.g., a state EPA); those engaged in recreational industries (e.g., marina operators and bait shop owners); charter fishers; recreationalists like canoeists and fishers; boaters; and environmentalists. For both lampricides and barriers, we need to ask (1) How much variation/consensus is there; and (2) What are the key predictors of support/opposition? This understanding helps communicators and policymakers understand more clearly the variety of beliefs that the various stakeholders have about sea lamprey control techniques. With a better understanding of the variation of perceptions and beliefs, the GLFC will be in a better position to engage the various audiences most effectively and in ways that demonstrate empathy for their concerns.
- **Improve our understanding of genetic manipulation of organisms in general and gauge more deeply society's acceptance of genetic manipulation to aid in sea lamprey control.** Considerable research exists globally about perceptions regarding genetic manipulation of plants to improve agriculture and the ethics of genetically modifying organisms for any purpose. Thresher and Jones (2019) provide a solid foundation for application of genetic manipulation in the sea lamprey control program. Research needs to build upon their work so that future members of the GLFC can make informed decisions about

whether to embark on a lengthy and (potentially) expensive research and development effort, not only in terms of efficacy but also in terms of the social license to conduct the research, let alone apply it. Without this understanding, the GLFC could spend precious time, effort, and resources only to learn that the social license does not exist for genetic control methods.

- **Understand how to most effectively and respectfully engage with diverse stakeholders, rights holders, and other parties about sea lamprey control.** Anecdotal evidence from regulators, scientists, representatives of advocacy groups, and members of Indigenous communities suggests that a good deal of skepticism and opposition to existing control methods (including those that involve chemicals as well as barriers) is present within Indigenous communities, and that this may pose a serious challenge to sea lamprey control efforts in the near and long terms. Indigenous communities in the Great Lakes basin have unique perspectives, concerns, and knowledge bases that could inform current management and practice. Social science research to understand Indigenous perspectives (including the range of perspectives and their grounding in knowledge and values), coupled with Indigenous methodologies, would inform ongoing communication and the public engagement activities needed to maintain the social license to deliver the sea lamprey control program.

Application of research and conclusion

Sea lamprey control requires societal support, as management agencies must respond to their constituents and stakeholders. Decreased perceived risk or a weakening of societal support for control techniques can threaten the viability of the Great Lakes fishery if the sea lamprey control program were to be diminished. During the recent SLIS III (and other venues), participants recommended rigorous research into those phenomena. The information from such research is vital to the GLFC and its partners, particularly Fisheries and Oceans Canada, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, the U.S. Army Corps of Engineers, the eight Great Lakes states and the Province of Ontario, and Indigenous authorities, among many others.

Sea lamprey control officials could use the results of the research described above to better formulate messaging and engage key publics. As an example, the GLFC is guided by a comprehensive communications plan that identifies the primary audiences it wishes to reach, outlines the specific messages to be conveyed to each audience, and denotes the best way to deliver the messages. Successful communication plans are informed by deep analyses of whether audiences have received and how they have interpreted the messages. Given the long-standing history of the sea lamprey control program, the diversity of control tactics used, and the complexity of the stakeholder, rights holder and decision-making community (spanning two countries, eight states, the Province of Ontario, and many Indigenous jurisdictions), there are also lessons in the program's history that are relevant to other environmental issues where shifting baselines occur and there is concern about maintaining the social license to operate. Because the analyses that help understand those lessons are costly, organizations like the GLFC have hitherto not devoted the resources needed to gather information related to shifting baselines and the social license to operate. The time to do so has arrived.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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