Achieving the Benefits of Sea Lamprey Control While Minimizing Effects on Nontarget Species: Conceptual Synthesis and Proposed Policy

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ABSTRACT. Managers of the fishery within the Laurentian Great Lakes basin consistently strive to minimize potential nontarget environmental effects of methods used to control nonnative sea lampreys (Petromyzon marinus). This paper develops a framework for achieving the benefits of sea lamprey control while minimizing effects on nontarget species. It is a synthesis of discussions held by a working group assigned this task during the Sea Lamprey International Symposium II. The first part of the paper examines conceptually how inclusion of effects on nontarget species in the decision-support system used by the Great Lakes Fishery Commission (GLFC) can affect overall control costs and treatment success. The second part summarizes reasons why the identification and interpretation of nontarget effects are challenging and complicated. The last part proposes an initial, lake-wide policy framework the GLFC and its agents could use to guide the accommodations made to reduce nontarget effects. The framework seeks to achieve the lake-wide benefits of sea lamprey control while accommodating lake-wide and regional effects on species other than the sea lamprey.

INDEX WORDS: Biological control, Great Lakes, exotic species, nontarget effects, Petromyzon marinus.

INTRODUCTION

The benefits of controlling nonnative sea lampreys (Petromyzon marinus) in the Laurentian Great Lakes have been documented widely. Management of sea lampreys has played an integral role in the successful restoration of native lake trout (Salvelinus namaycush) in Lake Superior and in ongoing efforts to rehabilitate lake trout in Lakes Huron, Michigan, Erie, and Ontario (Krueger et al. 1995, Great Lakes Fishery Commission 2001). In addition, it has directly benefited other native fishes, such as lake whitefish (Coregonus clupeaformis), burbot (Lota lota), catostomids (Catostomus spp.), and species of deepwater cisco (Coregonus spp.) (Smith 1968, Henderson 1986, Collins 1988, Liu and Jensen 1992). It also has directly benefited introduced Pacific salmon and trout (Oncorhynchus spp.) (Great Lakes Fishery Commission 2001). Further, through trophic cascades it may have indirectly benefited small, native fishes such as kiyi (Coregonus kiyi) and deepwater sculpin (Myoxocephalus thompsoni), and helped curtail populations of nonnative alewife (Alosa pseudoharengus) and rainbow smelt (Osmerus mordax) (Eshenroder and Burnham-Curtis 1999). Sea lamprey management is carried out by the Great Lakes Fishery Commission (GLFC) under

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the Convention on Great Lakes Fisheries (1954)—a treaty between Canada and the United States. The Department of Fisheries and Oceans Canada and the United States Fish and Wildlife Service serve as agents contracted by the GLFC to conduct the field operations of the program. These agents comply with federal, provincial, and state laws and achieve concurrence on control measures within provincial, state, and tribal jurisdictions.

The potential for unwanted effects of sea lamprey control on nontarget species has been a long-standing concern for the GLFC and its agents. In this paper, effect refers to a change in an attribute of a biological system (hormonal system, individual, ecosystem) that extends outside the normal variation observed for that system, presumably in response to a human action. Early in the sea lamprey management program, considerable effort was devoted to finding a chemical that would selectively kill sea lampreys with minimal environmental side effects (Applegate and King 1962). This led to the adoption of a control program involving periodic treatment of streams with the lampricide 3-trifluromethyl-4-nitrophenol (TFM) or a combination of TFM and 2,5-dichloro-4’-nitrosalicylanilide (Bayer 73). Since then, there have been numerous studies examining the effects of lampricides on plant, invertebrate, and vertebrate taxa (Dahl and McDonald 1980, Gilderhus and Johnson 1980, National Research Council Canada 1985, Boogaard et al. 2003, Hubert 2003, Weisser et al. 2003). In addition, control agents have carried out literature searches and toxicity testing in response to concerns for specific species. More recently, in response to growing concern about the introduction of chemicals into the environment, the GLFC pledged to reduce its reliance on chemical control through the development of alternative control methods (Great Lakes Fishery Commission 1992, 2001).

Today, fishery managers continue to press for control techniques that minimize nontarget effects. For example, the lake sturgeon (Acipenser fulvescens) is listed as endangered, threatened, or of special concern in many states surrounding the Great Lakes (Anonymous 2001). Early life stages (< 100 mm total length) of lake sturgeon exhibit low tolerance to lampricide exposure, but their tolerance increases as they grow (Anonymous 2001, Boogaard et al. 2003). Consequently, streams where sea lampreys and lake sturgeon co-exist are being treated both with lower concentrations of lampricide and later in the field season, when the lake sturgeon remaining in streams are larger and more tolerant to lampricide exposure (Johnson et al. 1999, Anonymous 2001). Similarly, in response to concern for mudpuppies (Necturus maculosus), which also are sensitive to lampricide, control agents are treating Ohio tributaries with reduced concentrations of TFM (Christie 2000).

Nontarget effects of both traditional and developing alternative methods of sea lamprey control present new challenges. Traditional use of low-head barriers as an alternative to chemical control of sea lampreys poses concerns about the fragmentation of biological linkages between lakes and rivers (Porto et al. 1999, Dodd et al. 2003). This has created a need to install barrier designs that selectively block spawning runs of sea lampreys, yet allow the passage of other fishes. In addition, accommodations involving a switch between different forms of control, such as from lampricide applications to a sea lamprey barrier, will require consideration of the advantages and disadvantages of the alternatives. Finally, additional species in the Great Lakes may receive conservation designations in the future from Canada and the United States. Recent biodiversity initiatives in both countries are expected to foster greater public appreciation of biodiversity and greater public concern about the effects of human actions on the environment (President’s Committee of Advisors on Science and Technology Panel on Biodiversity and Ecosystems 1998, Steering Committee 2001). In this respect, native lampreys are particularly noteworthy because efforts to control sea lampreys have likely altered the abundances and distributions of these species (D. Cuddy, Fisheries and Oceans Canada, Sault Ste. Marie, ON, 2001, personal communication).

Ideally, the benefits of sea lamprey control in the Great Lakes should not be achieved by affecting nontarget organisms. Yet achieving cost-efficient and effective sea lamprey control while accommodating undesirable nontarget effects presents significant challenges. Some accommodations for nontarget effects, such as treating later in the field season, add to overall control costs. Others, such as treating with lower concentrations of lampricide, often reduce the effectiveness of sea lamprey control. Reduced effectiveness may then require that streams be treated more frequently, which increases treatment costs, increases exposure of nontarget species, and potentially increases the possibility of sea lampreys evolving resistance to lampricides (Gardner et al. 1998). The issue is complicated further because requests for accommodations may come from a regulatory agency within one jurisdic-
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Incorporating Nontarget Effects into Control Decisions

Following Sawyer (1980), the GLFC’s sea lamprey management program adopted features of an integrated pest management approach (Koonce et al. 1993). Program changes included an Integrated Management of Sea Lamprey (IMSL) support system to define the program requirements and the allocation of control and assessment efforts among streams. Target levels for sea lamprey abundance have been established for each lake. Nevertheless, for each lake the abundance of sea lampreys at which the costs of additional control do not produce commensurate benefits (the economic injury level) needs to be developed further (Koonce et al. 1993, Great Lakes Fishery Commission 2001).

For chemical treatment of streams, the consequences of accommodating nontarget effects of sea lamprey control can be demonstrated conceptually by examining how the number of sea lampreys entering a lake (escapement) declines as control effort increases. Figure 1a depicts this relationship in the absence of accommodations for nontarget species.

**FIG. 1.** A graphical model illustrating how the number of sea lampreys allowed into a lake changes with control effort when accommodations for effects on nontarget organisms are not made (a), when accommodations for nontarget effects are made and the target level of sea lamprey escapement is fixed at N* (b), and when accommodations for nontarget effects are made and the level of control effort is fixed at C* (c).
The decision support system determines the target number of sea lampreys entering the lake (N*) and the control effort required (C*). Increasing control effort above C* may not provide commensurate benefits in terms of reduced abundance of sea lampreys and, hence, increased abundances of suitable host fishes (overtreatment). Reducing control effort below C* reduces costs, but allows more sea lampreys into the lake and reduces the abundance of host fishes (undertreatment).

Incorporating accommodations for nontarget species shifts the sea lamprey-abundance curve to the right because of the added effort required for the accommodations (Fig. 1b). Greater effort (C') is therefore required to reach the lake target for sea lampreys (N*; Fig. 1b). An alternative option, in the face of budgetary constraints, is to hold control effort at C*. In this case, the number of sea lampreys entering the lake (N') is greater than the target level of sea lampreys (N*; Fig. 1c), and populations of host fishes will decline. Between the alternatives in Figures 1b and 1c, a range of control options involving various levels of increased control effort and cost and different treatment regimes.

**TYPES OF NONTARGET EFFECTS AND THEIR INTERPRETATION**

The decision to respond to nontarget effects requires both the detection of an effect and the assessment of whether some form of response is warranted. Ideally, the GLFC and its agents would respond to all nontarget effects considered to be detrimental. This section identifies five related issues that complicate both the detection of effects and the determination of whether an effect is detrimental. These issues create complex valuations between sea lamprey, the suite of Great Lakes species that benefit from sea lamprey control, and the nontarget species found in the streams where control efforts are carried out. In addition, this section identifies criteria that are potentially important in determining which policy action to pursue; a consideration typically not included in formal policy documents.

i) **Effects can be detected at a wide variety of biological levels, from cells and tissues to populations, communities, and ecosystems (Adams 1990a).** At the lowest level, there are biochemical and molecular effects, such as changes in enzyme activities or cellular concentrations of RNA and DNA. These changes may induce detectable effects at the level of integrated physiological systems, such as hormone regulation, immune responses, or bioenergetics. At the level of individuals, nontarget effects may include aspects of an individual’s behavior (learning) and ability (swimming performance), as well as components of Darwinian fitness, including growth, survival, and reproduction. At the population level, changes in death and birth rates can alter the abundance or even presence of a nontarget species within a given habitat or region. Nontarget effects may further include alterations in the movement of individuals, and their genes, among neighbouring populations or subpopulations, thereby affecting possibilities for local adaptation or extinction (Hanski 1999). At the community level, changes in the abundances of nontarget species can lead to alterations in the abundance of other species (prey, competitors) and the flow of energy and matter among trophic levels (Mangel et al. 1996). This multi-level perspective of effects similarly applies to the benefits of sea lamprey control (Introduction).

ii) **Effects vary in the nature and magnitude of their expression and in the temporal and spatial scales at which they are observed.** These aspects are reflected in the diverse qualifiers used to classify nontarget effects. Effects can be severe, but relatively short in duration (acute), or persistent and recurring (chronic) (Adams 1990b). An effect can also be classified as direct or indirect (Adams 1990b). Lampricide treatment has a direct effect on the abundance of sea lampreys and an indirect effect on the abundance of its prey. The magnitude of an effect can be further classified as low or high. How the magnitude of an effect changes in relation to the magnitude of a disturbance can be continuous or abrupt (a threshold effect).

Thorough characterization of an effect also includes specification of temporal and spatial aspects of measurement. On a temporal scale, the effect can be characterized as a “pulse effect,” if its duration is short-lived before the system returns to normal, or a “press effect,” if it is permanent (Underwood 1991). On a spatial scale, effects can occur locally or regionally. Scale specifications also can influence the perceived magnitude of an effect. A given reduction in abundance may be considered less important for a nontarget population with a high intrinsic rate of increase, and hence a high propensity for recovery, than for a population with a low intrinsic rate of increase. It may also be considered
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less important if restricted to a small region for a species with a broad geographic distribution than for a species with a fragmented or narrower geographic distribution.

iii) The forms and levels of effect that do not warrant a response are rarely clear. Generally, effects at one biological level are the consequence of effects at lower levels (Adams 1990b). This linkage is intuitively appealing and is the basis for biological indicator approaches where measures focusing on lower-level effects (physiological and reproductive traits), with their generally shorter response times, are intended to provide early warning signals of larger-scale effects (population declines) before potentially irreversible damage occurs (Adams 1990b, Jones and Kaly 1996). It also is the basis of proposed sentinel monitoring frameworks (Gibbons and Munkttrick 1994). In addition, it has led to suggestions that monitoring programs consider indicators from a variety of levels (Adams 1990b).

Unfortunately, attempts to use effects from lower levels to predict effects at a higher level have met with variable success (Jones and Kaly 1996), presumably because the causal links are complex and poorly understood, because effects at one level may be dampened at higher levels, and because there has been insufficient time to examine the links adequately (Jones and Kaly 1996, Power and McCarty 1997). In addition, comprehensive monitoring programs are expensive and affordable programs can have low statistical power (MacGregor et al. 2002). With such uncertainty, fishery managers focusing on lower-level effects risk devoting considerable effort to effects that are transient, while managers focusing solely on effects at higher levels risk missing signs of impending population- and community-level changes until considerable damage has already occurred. Focusing solely on higher-level effects can ignore the role that unplanned observations of potential lower-level effects, such as unusual behavior or fish kills, can provide in initiating rigorous scientific investigations of whether meaningful higher-level effects, such as declining population growth, are occurring.

iv) Whether an effect is measured, how it is interpreted, and the response it receives depend upon societal values and perceptions that differ among individuals. Values are motivational factors that dispose people to act (Crawford and Morito 1997). They represent an assessment of worth of some object to an individual in a particular situation (Barber and Taylor 1990) and are part of an integrated system (an ethic) that determines the difference between right and wrong human behavior (Crawford and Morito 1997).

Human valuations for fishes are influenced by at least six factors that are not mutually exclusive. One is the economic importance of the species. A second, related factor is cultural importance of a species as, for example, with subsistence fishing (Berkes 1990). A third factor is a species’ conservation status with regulatory agencies, which may recognize the species as a unique component of the biota within a region and its heightened susceptibility to extinction because of human activities (Olver et al. 1995). A fourth factor, related to the third, is rarity. Species that are rare or have restricted distributions are often valued higher than species that are abundant or have broad distributions. In addition, species that are rare throughout their range are often valued higher than species that are rare locally. A fifth factor is aesthetic appeal. Taxa higher in the food web, such as predators, are often valued more than those lower in the food web and taxa closely related to humans, such as other mammals, are often valued more than distantly related taxa, such as insects. Taxa that are familiar, such as frogs, or perceived as inherently beautiful, such as brook trout (Salvelinus fontinalis), also tend to be valued highly. A final factor is a species’ origin. Invading and exotic species, for example, can be valued differently outside and inside their native range. The sea lamprey is viewed a pest in the Laurentian Great Lakes, because it is not part of the native community of Lakes Superior, Michigan, Huron, Erie, and probably Ontario, and because of its negative effect on the native fish communities. It is not viewed as a pest within its native marine range (Gilbert and Snelson 1992).

v) Management and conservation agencies differ in the conservation concepts that guide their operations, the jurisdictions for which they are responsible and, therefore, the significance they place on the different types of effects. For example, the concerns of fishery managers can focus on demographic effects, while those of environmental regulators are often more general (Adams 1990b). Such variation is an inevitable consequence of the issues highlighted above and makes the valuation of effects context-dependent. This dependency is at the heart of the lake-wide concerns about reducing the effectiveness of sea lamprey control and, hence, efforts to rehabilitate native fishes in the lakes, while responding to regional concerns for stream
species that are aesthetically appealing locally or are assigned a local conservation designation when they are at the edge of their range, yet common elsewhere.

A POLICY FRAMEWORK TO GUIDE ACCOMMODATIONS FOR NONTARGET EFFECTS

This section proposes the framework for a policy guiding how chemical treatment of streams could be adjusted consistently and thoughtfully in response to anticipated negative effects on nontarget organisms. The proposed framework responds to nontarget effects by designating one of three treatment options that depend on the conservation or socioeconomic status of the nontarget species under consideration, the expected severity of the standard stream treatment on the nontarget species, and the population growth trajectory of the affected species. Streams inhabited by species with more restrictive conservation designations (endangered) will require more restrictive treatment options, including even no treatment. The policy pertains to only nontarget species known to be sensitive to lampricides—hence the focus on anticipated effects.

**Treatment Options**

The first of the three treatment options (option A; Table 1) is straightforward: continue to treat using standard application procedures. Under this option, the abundance of sea lampreys in the lake would decrease with increasing control effort as per Figure 1a. Monitoring the nontarget population would remain a priority.

Under the second option (option B; Table 1), the treatment protocol for a stream or subset of streams would be altered, possibly at increased expense or effort, but not in ways that increase the number of sea lampreys entering the lake (maintaining the target level of sea lamprey suppression for the lake) (Fig. 1b). For example, to avoid affecting a nontarget species that occurs seasonally within a treated area, a stream or subset of streams could be treated during the period of non-residency. Or, a stream could be treated more frequently with lower concentrations of lampricide to achieve the same level of sea lamprey suppression expected from a standard treatment.

The third option (option C; Table 1) involves curtailing or even eliminating a stream treatment, thus allowing more sea lampreys into the lake (Fig. 1c).

**TABLE 1. Treatment options proposed in response to effects of sea lamprey control on sensitive nontarget species. Each option depends on the conservation or socioeconomic status of the nontarget species, the perceived magnitude of the effect of standard stream treatment on the species (low or high), and the population growth trajectory of the nontarget species (declining, stable, or increasing throughout the lake basin). A = no change, but continued monitoring. B = procedures that increase costs, but do not increase sea lamprey escapement. C = increase escapement as needed to protect nontarget species.**

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If, by forgoing treatment, the escapement of sea lampreys into the lake is expected to be sizable, then the stream could be treated with a lower than normal concentration of lampricide that is not toxic to the nontarget organism. This low-concentration approach would only be used when the anticipated suppression of sea lampreys is justified economically. Subsequent low-concentration treatments would not be allowed in the same year. Under this treatment option, efforts to rehabilitate the lake’s fish community would be traded off to protect stream fishes or other taxa.
Criteria for Selecting Treatment Options

Selection of treatment options would be based on three criteria. The first criterion is whether the non-target species is listed as endangered, threatened, or of special concern, or, if not listed in one of the first three categories, is recognized as being of significant social or economic importance across the lake (Table 1).

In this paper, endangered refers to species in danger of extirpation or extinction, threatened refers to species likely to become endangered in the foreseeable future, and of special concern refers to species that are rare within a region, have a restricted geographic range or habitat requirements, or possess characteristics that make them particularly sensitive to human activities or natural events. Definitions of these terms represent a synthesis of definitions provided by the federal and state natural resource agencies in the Great Lakes basin. Socioeconomically important refers to species of cultural, recreational, or commercial significance in the Great Lakes basin. An example of a socioeconomically important species is the walleye (Stizostedion vitreum).

The categories are useful means of prioritizing the large number of potential nontarget species in the Laurentian Great Lakes basin. They are stressed in definitions of conservation principles (Olver et al. 1995). In addition, the categories help simplify how the many nontarget species found in the Great Lakes basin can be considered for accommodation. With fishes alone, for example, 85 of the 171 species found in the basin have some form of conservation listing or status (N. Mandrak, Fisheries and Oceans Canada, Burlington, ON, 2002, personal communication), but few of these are sensitive to lampricides. Admittedly, these conservation categories are qualitative and the rationale for them is not always documented well, but the designations provide the best available conservation assessment of existing scientific data and local knowledge. There are significant jurisdiction- and scale-related issues in assigning nontarget species to these categories and these are addressed later (Additional Considerations).

The second criterion is the perceived magnitude of the effect that lampricide treatments have on the sensitive, nontarget species. In the framework, magnitude is rated as either low or high. The magnitude of effect is considered low if the standard stream treatment occasionally kills a minor portion of the nontarget species inhabiting a stream. The magnitude is considered high if standard stream treatment consistently kills a significant portion of the nontarget population inhabiting the stream, as for example with native lampreys.

The third criterion is the population growth trajectory of the nontarget species at a lake-wide scale. Three trajectories are possible: declining (–), stable (0), or increasing (+). Population trajectories of nontarget species should be based on long-term population trends that reflect normal fluctuations for that species within the lake basin. Population size was omitted as a possible fourth criterion because it should be reflected in the conservation designations. This omission means the framework does not accommodate for any lag between the time of population decline and the assignment of a conservation listing.

Selecting a Treatment Option

The treatment option allowing more sea lampreys to enter a lake (option C) is appropriate for streams harboring a lampricide-sensitive endangered species with a declining or stable population trajectory, regardless of whether the magnitude of the effect of a standard stream treatment is low (Table 1a). The treatment option that increases treatment cost, but does not affect the target level of sea lampreys in a lake (option B) is appropriate when the population trajectory of a sensitive, endangered species is increasing. Option C could conceivably hasten the recovery of an endangered species whose population is already increasing, but it is unlikely the species would be rebounding if it were sensitive to lampricide treatment.

The treatment option allowing more sea lampreys into a lake (option C) is also appropriate for streams harboring a threatened species when the lake-wide population trajectory of the species is declining, regardless of whether the effect of the standard treatment on that species is low (Table 1b). It is also the appropriate option when the lake-wide population is stable and the effect of a standard stream treatment is high.

The treatment option allowing for increased cost, but not increased escapement of sea lampreys into a lake (option B) is appropriate when the population of a threatened species is stable and the effect of treatment is low (Table 1b). This option is also appropriate when the population of a threatened species is increasing lake-wide and the effect of a standard stream treatment is high. In addition, treatment option B is appropriate for streams harboring...
a species of special concern (Table 1c), except when the population is increasing lake-wide and the effect of treatment is low. In the latter situation, normal treatment with continued monitoring (option A) is appropriate.

Nontarget species of socioeconomic importance, by definition, have advocacy groups and are particularly problematic for the control program. A consistent approach is needed to achieve equity among jurisdictions having a stake in rehabilitation of Great Lakes fish communities. In recognition of this constraint, option B is appropriate only when a given species of socioeconomic importance is declining lake-wide and the effect of treatment is high (Table 1d). Otherwise, special efforts are not warranted for these species.

Examples of Implementation

Three examples of how the framework could be implemented are provided. The first example focuses on lake sturgeon in Lake Huron. Lake sturgeon are classified as threatened in Michigan, and the standard stream treatment affects very young lake sturgeon, but the effect is considered low. In fact, lake sturgeon streams in this state are already being treated with lower concentrations of lampricide than normal later in the field season (option B). Based on the framework, option B is appropriate providing that populations of lake sturgeon are stable lake-wide (Table 1b). Option C is appropriate if populations are declining and option A is appropriate if they are increasing. If future research concludes the effect of the standard stream treatment on sturgeon is high, then option B would be appropriate only when the population is increasing lake-wide. If the population within the lake is stable or declining, the benefits of sea lamprey control should be traded off for protection of sturgeon (option C).

The second example focuses on those native lampreys that are being considered to receive a conservation designation of threatened under new Species at Risk legislation pending in Canada. Migratory silver lampreys (Ichthyomyzon unicuspis) are of particular concern because stream treatments with lampricide or control via barriers could have large, negative effects on their abundance and distribution. If silver lampreys are classified as threatened in Canada, streams on the Canadian side of the Great Lakes that harbor silver lampreys would come under option C because the effect of standard stream treatment on native lampreys is high and their population growth trajectory is not increasing (Table 1b).

The third example focuses on mudpuppies, which are a species of socioeconomic concern in Ohio. Standard treatment of streams has a large effect on mudpuppies, and the lampricide concentrations applied to Ohio streams have been reduced in response to concerns of the Ohio Environmental Protection Agency. The option of standard treatment (option A; Table 1d) is appropriate for streams harboring mudpuppies throughout Lake Erie because there is no evidence that the lake-wide population growth trajectory of mudpuppies is declining. Mudpuppies are abundant in the basin, and they have regularly recovered from past stream treatments.

Additional Considerations

Variability in How Species are Assigned to Conservation Categories

Conservation assignments are made by a variety of conservation and natural resource agencies having international, federal, state, or provincial interests and responsibilities, and different geographical perspectives. This creates at least four challenges for the policy. One challenge is that some agencies use ranking classifications other than the classification employed in the policy. The system of ranking species as endangered, threatened, or of special concern is considered to be the most appropriate for the proposed policy because it is the system most consistent with the classification systems used by the U.S. Endangered Species Act, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the state natural resource agencies around the Great Lakes basin. However, even some of these agencies differ in the designations they use. For example, Pennsylvania and Ohio agencies use “at risk” and “of special interest,” respectively, instead of special concern, while the state of Illinois lacks a designation for species of special concern. Development of equivalencies between classification systems may be required, especially if consideration of the designations assigned by agencies using different classification systems is needed.

A second challenge is that a nontarget species may have a restrictive designation at the state level and a less restrictive designation, or no designation at all, at the federal level, or possibly vice versa. For example, the lake sturgeon is listed as endangered, threatened, or of special concern in states surrounding the Great Lakes, but is not on the U.S. Endangered Species List. In such situations, it is
recommended the treatment option be based on the most restrictive conservation designation that applies to the jurisdiction where the stream is located.

A third challenge is that a species’ conservation designation can differ among provinces or states around a lake basin. For example, in Lake Erie the northern brook lamprey (Ichthyomyzon fossor) is listed as endangered in Ohio and Pennsylvania, of special concern in Ontario, but not listed in New York. In the absence of basin-wide congruence, it is recommended that the treatment option for a stream be based on the nontarget species’ designation for the state or province where the stream is located, providing there is not a more restrictive federal designation.

A fourth challenge will be specifying species of socioeconomic importance. One possible approach would be for one of the GLFC’s basin-wide policy committees, in consultation with local fishery managers and the public using the stream, to specify species sensitive to lampricides and of socioeconomic concern.

Uncertainty Surrounding the Decision Criteria

Conclusions regarding the magnitude of effect and the lake-wide population trajectory for a nontarget species may differ between the GLFC and other natural resource or environmental agencies. When such differences arise, the GLFC should temporarily adopt the more conservative view that the effect of standard stream treatment on the nontarget species is high and the lake-wide abundance of the nontarget species is stable or declining, until evidence is presented to the contrary.

Incorporating Regional Concerns for Lake Fishes

The framework does not explicitly consider the protection that stream treatments provide for unique populations or stocks of native fishes in a given part of a Great Lake. For example, there is a naturally reproducing remnant population of native lake trout in Lake Huron that spawns near sea lamprey producing streams and warrants consideration for added protection from sea lampreys (Reid et al. 2001). To address this problem, it is suggested the conservation of rare or unique lake fishes be reflected in the target levels of sea lampreys set for the lake. This approach is consistent with the GLFC’s desire to incorporate social and ecological values into the economic injury levels (Great Lakes Fishery Commission 2001).

Prioritizing Multiple Requests for Accommodation

Because of budgetary limitations, the GLFC may not be able to implement treatment options requiring additional cost (option B) in all relevant situations. In this event, streams harboring a species sensitive to lampricide treatment and listed as endangered should take precedence over streams harboring a species listed as threatened, which should take precedence over streams harboring a species listed as of special concern. Further, species with a federal designation should take precedence over species with a state designation. Should accommodations requiring option C be limited by funding as, for example, with more frequent low-concentration treatments (Introduction), requests allowing smaller increases to target levels of sea lampreys within a lake should take precedence over those requiring larger increases to target levels.

Conflict Resolution

It is recommended that the appropriate lake committee be notified when a regulatory agency seeks a more stringent treatment option than is indicated by the policy framework. Lake committees are made up of representatives from the state, provincial, and intertribal fishery agencies from around a Great Lake and they develop fish community objectives and management plans for the lake. The committee representative from the affected jurisdiction could then act as an intermediary between the lake committee and the regulatory agency. Because sea lamprey targets express a policy for a lake, all lake committee members need to be appraised of actions that increase escapement of sea lampreys over the target level set for the lake.

CONCLUSION

How the GLFC can best achieve the benefits of sea lamprey control while minimizing effects on nontarget species is a complex challenge involving science, societal values, and management principles. Moreover, the challenge will likely become greater as new control methods are developed and implemented, and as the GLFC and its agents strive to improve the effectiveness of each control method and reduce effects on nontarget species. This paper provides a framework that the GLFC can use to help achieve effective sea lamprey control while minimizing effects on nontarget organisms. The framework will help ensure accommodations are
made consistently across the Great Lakes basin in ways that balance concerns for lake and stream communities. Finally, in cases of disagreement, the framework provides a starting point for discussions toward a resolution and identifies key criteria that will need to be addressed.

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APPENDIX 1. Names and affiliations of participants for the Sea Lamprey International Symposium II working group that considered ways to achieve the benefits of sea lamprey control while minimizing effects on nontarget organisms. Terry Bills, Department of Interior, United States Geological Service, La Crosse, WI; Brian Chipman, Vermont Department of Fish and Wildlife, Essex Junction, VT; Verdel Dawson, Department of Interior, United States Geological Service, La Crosse, WI; Amy Derosier, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI; Randy Eshenroder, Great Lakes Fishery Commission, Ann Arbor, MI; Chris Goddard, Great Lakes Fishery Commission, Ann Arbor, MI; Dan Hayes, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI; David Johnson, United States Fish and Wildlife Service, Ludington, MI; Dennis Lavis, United States Fish and Wildlife Service, Ludington, MI; Ellen Marsden, School of Natural Resources, University of Vermont, Burlington, VT; Scott McKinley, Department of Biology, University of Waterloo, Waterloo, ON; Ro McLaughlin, Department of Zoology and Institute of Ichthyology, University of Guelph, Guelph, ON; Sid Morkert, United States Fish and Wildlife Service, Ludington, MI; Terry Morse, United States Fish and Wildlife Service, Marquette, MI; Fraser Neave, Fisheries and Oceans Canada, Sault Ste. Marie, ON; Larry Schleen, Fisheries and Oceans Canada, Sault Ste. Marie, ON; Ron Schollefield, United States Geological Survey, Biological Resources Division, Millerburg, MI; Brian Stevens, Fisheries and Oceans Canada, Sault Ste. Marie, ON; Paul Sullivan, Fisheries and Oceans Canada, Sault Ste. Marie, ON; and John Weisser, United States Fish and Wildlife Service, Marquette, MI.