A Mid-Decade Review of Progress under a *Strategic Vision of the Great Lakes Fishery Commission 2011-2020*

Great Lakes Fishery Commission

Miscellaneous Publication 2017-01

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States, which was ratified on October 11, 1955. It was organized in April 1956 and assumed its duties as set forth in the Convention on July 1, 1956. The Commission has two major responsibilities: first, develop coordinated programs of research in the Great Lakes, and, on the basis of the findings, recommend measures that will permit the maximum sustained productivity of stocks of fish of common concern; second, formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes.

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A MID-DECADE REVIEW OF PROGRESS UNDER A *STRATEGIC VISION OF THE GREAT LAKES FISHERY COMMISSION 2011-2020*

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INTRODUCTION

For 25 years, the operations of the Great Lakes Fishery Commission (GLFC) have been guided by a series of policy documents, called strategic visions (GLFC 1992; GLFC 2008), that identify issues, establish objectives and strategies, and provide the associated rationales. Each strategic vision encompassed a 10-year period, aligning with calendar decades, and each required a report of progress at the middle and end of that decade. This report, the third in the series, reviews progress from 2011 to 2015, the first half of the period covered by the GLFC's third strategic vision. It is intended primarily as a self-examination to allow for midcourse corrections in the second half of the decade but also, in a larger sense, to ensure that progress is consistent with the aspirations of those who framed the *Convention on Great Lakes Fisheries* (GLFC 1954).

The major policy objectives within the current strategic vision (GLFC 2011) are described metaphorically as pillars, one for each of the three focal areas within the GLFC, i.e., healthy ecosystems/sustainable fisheries, sea lamprey (*Petromyzon marinus*) control, and alliances/partnerships. Each pillar is supported by a strategic formulation of what is to be accomplished in the broadest sense and it, in turn, is operationally defined by one or more goals, each to be effected by one or more strategies all having specified outcomes. The outcomes are measurable and, in the aggregate, provide an assessment of progress for each pillar.

The commitment to operate under the framework of a strategic vision implied a challenge to achieve outcomes that, in many cases, would require approaches yet to be determined. This operational philosophy was intended to be inspirational notwithstanding the risks of not meeting or only partially meeting a particular outcome. This philosophy is evident in the scope of the commitment. The healthy ecosystems/sustainable fisheries pillar comprises three goals, 13 strategies, and 11 outcomes. The sea lamprey control pillar comprises two goals, 10 strategies, and 10 outcomes. The alliances/partnerships pillar comprises four goals, 9 strategies, and 12 outcomes. Formal reporting is obviously required to track an endeavor this complex whose eventual outcomes are dependent on so many other players, many of who are beyond the GLFC's direct influence. This report is thus essential for assessing progress, now, at the halfway point in this decade's effort. Supporting material is available from info@glfc.org.

PILLAR ONE: HEALTHY ECOSYSTEMS AND SUSTAINABLE FISHERIES

The Great Lakes Fishery Commission (GLFC) will encourage the conservation and rehabilitation of healthy Great Lakes ecosystems that sustain fisheries and benefit society.

Goal 1: Eliminate Further Losses of Native Species and Rehabilitate Depleted Populations

Strategy 1: Prevent the loss of native fish species from any Great Lake.

Outcome: No native fish species will have been lost from any Great Lake.

Status: Since 2011, no species of native fish have been reported lost from any Great Lake. Of extant native species, the American eel (*Anguilla rostrate*) remains the most threatened. The cisco (*Coregonus artedi*) is now considered extirpated from Lake Erie, and the deepwater ciscoes of Lake Huron are considered a hybrid swarm. Although only recently reported, these changes occurred well before 2000.

Performance: Meets expectations. Special attention is still being given to the American eel and lake sturgeon (*Acipenser fulvescens*). In addition, a major coregonine (subfamily of trout and salmon containing whitefishes and ciscoes) rehabilitation program has been launched.

Prognosis: During the first half of this decade, extirpation of the American eel from Lake Ontario and the upper St. Lawrence River was averted, but this sub-population remains fragile despite numerous efforts identified in the previous reporting period (2000-2010) and continuing efforts in this reporting period (2011-2015). Given that the Lake Ontario sub-population is part of a much-larger panmictic population, opportunities to increase the Lake Ontario sub-population will depend almost exclusively on conservation efforts launched outside of the convention area. Additional progress may require considerable secretariat input because negotiations and subsequent fishery-management agreements would need to occur on a continental scale, including the Caribbean and northern South America, to substantially reduce harvest pressure on glass eels (a juvenile life stage). Even a nominal effort to increase prospects for improving the panmictic population would require the services of specialists, most likely those with diplomatic experience negotiating international fishery issues.

In Lake Superior, good evidence exists that the shortjaw cisco (*Coregonus zenithicus*) population is now recovering such that listing is no longer being considered by the U.S. Fish and Wildlife Service. This recovery is believed to have resulted from increased predation by lake trout (*Salvelinus namaycush*) on bloater (*Coregonus hoyi*) (a sister species), which can displace other ciscoes if not suppressed. This turnaround owes ultimately to a more than half-century effort by the GLFC and its partners to control sea lamprey and rehabilitate lake trout in Lake Superior. By contrast, recent efforts to synthesize available data and assess status of the ciscoes in the Great Lakes (Eshenroder et al. 2016) have shown that *C. artedi* is extirpated from Lake Erie, and the deepwater ciscoes of Lake Huron collapsed beginning in the 1950s into a hybrid swarm. These changes occurred well before this reporting period but are just now being documented. The status of ciscoes *Coregonus* spp. in each of the Great Lakes needs quantitative assessment. The native fish restoration theme continues to be the most active of the GLFC's research focal areas. However, the Great Lakes Restoration

Initiative contribution to the native fishes theme needs to be rolled into the GLFC's base budget to ensure continuance of the science, monitoring, and assessment necessary to minimize threats, like new introductions, to native fishes. The Council of Lake Committees (CLC) held a workshop in December 2016 to determine basinwide management priorities for cisco rehabilitation.

Strategy 2: Encourage management actions to increase natural reproduction of lake trout.

Outcome 1: Rehabilitation of lake trout will be achieved and maintained throughout Lake Superior.

Status: Lake trout have been rehabilitated in Lake Superior. This achievement is the greatest fish restoration effort ever in any lake.

Performance: Above expectations. Although lake trout in Lake Superior are considered rehabilitated, recent research suggests that genetic and morphological diversity has been lost. Efforts to understand the implications of these losses are underway.

Prognosis: Although the fingerprint of morphological and ecological diversity in Lake Superior lake trout persists, a 61% reduction in genetic divergence among lake trout morphs (the morphs have become more alike) since the 1990s was recently reported. Although the lake trout population appears to have recovered to near historical levels of abundance, fishery managers should be encouraged to consider the reduced morphological and genetic diversity when setting fishing policies. In addition, siscowet—the deepwater fatty form of lake trout—is by far the most-abundant form in the lake, which is a reversal from the past when the lean nearshore form was thought to dominate. Refuges played an important role in lake trout recovery, and their maintenance should be promoted as a fishery-management tool.

Outcome 2: Rehabilitation of the shallow-water form of lake trout will be achieved in Lake Huron's main basin.

Status: The shallow-water form of lake trout in Lake Huron continues to increase in abundance with wild recruits representing more than 50% of the population.

Performance: Above expectations. The Lake Huron Committee will implement reductions in lake trout stocking beginning in 2018.

Prognosis: Wild recruitment has been observed in Lake Huron since the early 2000s and has continued to increase during the past decade. For the first time following more than 40 years of stocking, wild fish represent more than 50% of the lake trout population. Resurgence of wild lake trout in Lake Huron has benefited from the near elimination of alewife (*Alosa pseudoharengus*) from the system. Reductions in Pacific salmon (*Oncorhynchus* spp.) stocking have also been undertaken. Should the alewife rebound, it is unknown if it would become abundant enough to once more negatively impact lake trout, potentially reversing the recent resurgence.

Outcome 3: Progress towards lake trout rehabilitation in Lakes Erie, Michigan, and Ontario will be demonstrated by an increase in the population of naturally reproduced juvenile lake trout.

Status: Naturally reproduced lake trout are increasing in abundance in Lake Michigan. Naturally reproduced juvenile lake trout have been increasing in recent years off the Niagara Bar in Lake Ontario. No evidence of natural recruitment has been documented in Lake Erie.

Performance: Meets expectations. Lake trout are long-lived, and rehabilitation takes many generations. Natural reproduction in Lakes Michigan and Ontario is very encouraging following decades of failure. A recent expansion of the adult population of stocked lake trout in Lake Erie is also encouraging.

Prognosis: Dramatic shifts in the Lake Michigan food web have resulted in widespread increases in lake trout recruitment, perhaps in conjunction with decreased alewife abundance and expansion of the round goby (*Neogobius melanostomus*) population, a more-suitable diet item. The prognosis for continuance of this lake trout recovery may depend on if anglers want increased availability of lake trout and value its role as a major consumer of round goby, an otherwise underutilized introduced species. Anglers are putting extensive pressure on Lake Michigan agencies to reduce stocking of lake trout at a time when natural production is increasing but before the population is recovered. Their goal is to free up more alewives for salmon. As for Lake Ontario, natural recruitment is likely to continue its increase as long as adult abundance is maintained. In Lake Erie, more-consistent control of sea lamprey to target levels will be required to achieve any hope of lake trout rehabilitation.

Strategy 3: Promote development and implementation of rehabilitation plans for depleted native fishes.

Outcome 1: Rehabilitation plans for deepwater ciscoes will be developed and implemented.

Status: Rehabilitation plans for deepwater ciscoes have not been developed or implemented during the first half of this decade. The Lake Ontario Committee is the only lake committee to produce a plan, and it remains unapproved.

Performance: Not meeting expectations. Formal rehabilitation plans have not been adopted, although three lake committees are interested in rehabilitation of deepwater ciscoes.

Prognosis: The CLC held a workshop in December 2016 to develop basinwide rehabilitation priorities that can guide development of lake-specific rehabilitation plans. Lake committee rehabilitation plans are expected to be developed during the second half of the reporting period.

Outcome 2: Naturally produced populations of deepwater ciscoes will increase in Lake Ontario.

Status: Naturally produced populations of deepwater ciscoes have not increased in Lake Ontario, although bloater have been stocked in increasing numbers since 2012, and a few have been captured.

Performance: Not meeting expectations. This outcome was impracticable within the first half of this reporting period owing to the time needed to establish and ramp up culture. The first bloaters were stocked into Lake Ontario only during 2012, which may allow for a modest level of recruitment by the end of the decade but not before.

Prognosis: This strategy and its outcome were not envisioned as occurring during the first half of the decade, and success by the end of the decade is optimistic but possible. Substantial learning about how to culture deepwater ciscoes and to collect gametes during the foul-weather winter months has occurred and will continue. Development of brood stocks is underway. The number of bloater stocked into Lake Ontario has steadily increased since 2012 with as many as 250,000 programmed for stocking in fall 2016. Stocked bloater were collected in assessment gear during 2015—an impressive accomplishment considering a stocked deepwater cisco had never been recovered before then. Development of dependable brood stocks, improvement of egg fertilization rates, and more production capacity remain as challenges. Nevertheless, the outlook for increased stocking remains good. Re-establishing bloater populations is essentially a trial-and-error process.

Outcome 3: Natural recruitment of lake sturgeon will increase in many Great Lakes tributaries.

Status: Natural recruitment of lake sturgeon has increased in Great Lakes tributaries.

Performance: Above expectations. Lake sturgeon abundance has increased throughout the Great Lakes basin, and much of that increase is a result of natural reproduction.

Prognosis: Lake sturgeon recruitment has improved thanks to sustained control of sea lamprey, improved water quality and access to spawning habitat, promulgation of commensurate regulations between the U.S. and Canada, increased enforcement, and cooperative fishery management. The outlook for lake sturgeon remains positive as long as sea lamprey control effectiveness is maintained. Recent outreach and communication efforts have been well received. Selective fish passage could make more tributaries accessible to lake sturgeon in future years, resulting in reproduction beyond that envisioned in the current outcome.

Goal 2: Stop Invasions of Aquatic Species

Strategy 1: Support establishment of statutory and regulatory authority to prevent non-native aquatic species from entering the Great Lakes through all vectors.

Outcome: Laws and regulations that seek to prevent the entry of aquatic invasive species into the Great Lakes will be promulgated.

Status: Legislation in both Canada and the U.S., at national and sub-national levels, has been introduced and passed, and regulations have been promulgated, but more needs to be done.

Performance: Mixed, below expectations. Annex 6 of the amended Great Lakes Water Quality Agreement (GLWQA) of 2012 emphasizes the threats posed by aquatic invasive species to the biodiversity of the Great Lakes. Progress under Annex 6 was rated as "poor and deteriorating" at a Great Lakes public forum held in October 2016 by the Parties to the GLWQA. At this same forum, the effort to control sea lamprey was rated as "fair and improving." In regards to the ballast-water vector, the International Maritime Organization's Convention on Ballast Water was adopted by the requisite number of countries representing the requisite amount of global tonnage in 2016 and takes effect in 2017. Revised regulations in support of this convention will come into force in Canada in 2017, and the U.S. Coast Guard is in the process of developing administrative rules governing implementation. These regulations will not apply to interlake vessels. In regards to importation/trade of live organisms, legislation was introduced on several occasions to reform the Lacey Act in the U.S. and to establish a suitable risk evaluation process, but legislation has stalled and shows no signs of passage. Canada has promulgated regulations concerning the movement of live organisms. Preventing non-native aquatic species from entering the Great Lakes is a monumental task, and the outcome sought here seeks only some progress in rule making, which did occur. More needs to be done, and this issue remains a staff priority.

Prognosis: Legislation and regulation to address the vectors for invasive species remains a high priority. The legislative and regulatory process is notoriously cumbersome. The GLFC is doing considerable work in this area, and a midcourse correction is not needed.

Strategy 2: Prevent the movement of non-native species through man-made connections between the Great Lakes and historically separate drainages.

Outcome: Species not already established in the Great Lakes will be denied entry from historically separated drainages.

Status: No new aquatic invasive species have become established in the Great Lakes since 2006.

Performance: Above expectations. At the time the current strategic vision was drafted, the rate of introduction was one new species approximately every year. The halting of new introductions is likely due to the implementation of ballast-water practices, the impeded movement of Asian carps through the Chicago Area Waterway System (CAWS), and vigorous law enforcement.

Prognosis: Consideration of recommendations arising from the Great Lakes Mississippi River Interbasin Study (GLMRIS) is proceeding, although at a slow pace. No concrete plan is in the works to modify infrastructure on the CAWS, although a study is in progress that may make specific recommendations for a project at the Brandon Road Lock and Dam. Further, no concrete plan to achieve physical separation of the Great Lakes and Mississippi River basins is being formulated. The slow-moving or stalled population of carps in the CAWS is largely attributed to assessment and control efforts by the Monitoring and Response Working Group (MRWG) working with the Asian Carp Regional Coordination Committee (ACRCC).

Strategy 3: Encourage management actions that prevent Asian carps from establishing populations in the Great Lakes.

Outcome: Asian carps will not establish populations in the Great Lakes.

Status: Bighead (*Hypophthalmichthys nobilis)*, silver (*H. molitrix*), and black (*Mylopharyngodon piceus*) carps are neither present nor established in the Great Lakes basin. Grass carp (*Ctenopharyngodon idella*) is present, although far from abundant.

Performance: Meets expectations for bighead, silver, and black carps; below expectations for grass carp The Lake Erie Committee (LEC) and the CLC issued position statements concerning the importance of preventing introductions of Asian carps into the Great Lakes. The secretariat actively participates in the ACRCC and is co-chair of the MRWG. Efforts have been underway to prevent the movement of Asian carps into the Great Lakes. Grass carp, which has been present in a small number of locations for decades, appears to be on the brink of establishment in Lake Erie and is being observed in increasing numbers in Lake Ontario.

Prognosis: Since release of the GLMRIS report in January 2014, the GLFC has focused on three objectives: interim actions, permanent solutions, and ongoing management measures.The Commissioners and secretariat remain deeply engaged in the ACRCC process, providing advice to the GLMRIS and various stakeholder groups while supporting the LEC in its efforts to control grass carp. The GLFC also has been heavily involved in the development of binational risk assessments for grass carp and black carp, which are expected to be completed during the second half of the reporting period. These and other efforts are aimed at preventing the movement of Asian carps (excludes grass carp) into the Great Lakes. As such, no course correction is needed.

Goal 3: Conduct, Coordinate, and Communicate Research to Facilitate Informed Fishery-Management Decisionmaking

Strategy 1: Quantify the effects of physical processes on recruitment of fishes.

Strategy 2: Identify the causes of nutrient changes and their effects on fisheries.

Strategy 3: Describe the natural diversity present historically in deep-water communities, identify impediments to their rehabilitation, and propose commensurate actions.

Strategy 4: Determine the effects of changing human demographics on fisheries and fishery management.

Strategy 5: Determine the sources, effects, and ecological conditions that foster disease outbreaks within fish populations.

Strategy 6: Promote the exchange of information on issues affecting the large lakes of the world through sponsorship of and participation in workshops and symposia, research, and scientific publication.

Strategy 7: Facilitate information sharing and communicate the results of research to better inform fishery managers.

Outcome (all): Fishery managers and other stakeholders will have access to knowledge and information about Great Lakes ecosystems sufficient to make informed and effective decisions.

Status: Research in support of Strategies 1-5 is being conducted, coordinated, and communicated to support fishery-management decision making. Strategy 6 is supported through participation in international workshops and conferences, partnering in the U.S. State Department-led Great Lakes to Great Lakes Project, and contributing to associated publications. A reprogrammed Science Transfer Board was launched in fall 2015 in support of Strategy 7 with the goal of identifying the science and science products needed by management for informed decision making.

Performance: Above expectations. The Fishery and Sea Lamprey Research programs and new Science Transfer Program continue to generate internationally recognized science and to better communicate that science to fishery managers and sea lamprey control agents. The GLFC will contribute to the 2017 International Coregonid Symposium and is lead host for the 2018 International Charr Symposium.

Prognosis: Fishery and sea lamprey research themes, developed to implement Strategies 1-6, are periodically reviewed and updated. A new theme "Energy and Nutrient Dynamics of Great Lakes Ecosystems" was added during this reporting period to address shifts in the food webs of the lower Great Lakes. The new Science Transfer Program is being refined continually and is gaining momentum—by the end of the decade, a thorough evaluation of its effectiveness will be possible. The Science Transfer Program has created a searchable database of completed projects with links to management decisions. This database will be used during the second half of the decade to assess the program's contribution to Great Lakes science and to confront emerging challenges to sustaining fisheries. Although the Convention and current strategic vision speak to the role of the GLFC in fishery research, there is risk that the research program for fisheries may wither away if program-funding enhancements being sought from Canada and the U.S. are not provided.

PILLAR TWO: INTEGRATED SEA LAMPREY CONTROL

The Great Lakes Fishery Commission will suppress sea lamprey populations to levels that permit achievement of fish community objectives for each Great Lake.

Goal 1: Suppress Lamprey Populations to Target Levels

Strategy 1: Implement lampricide treatment strategies to suppress sea lamprey populations to target levels in each Great Lake.

Outcome: Sea lamprey abundance and wounding rates on lake trout will be at, or below, target levels in each Great Lake.

Status: The basinwide abundance of adult sea lamprey and wounding rate on lake trout for the first half of the decade are significantly lower than in the previous decade. These declines are a result of increases in chemical treatments and in treatment effectiveness.

Performance: Meets expectations. Abundance targets for adult sea lamprey are being met in Lakes Michigan, Huron, and Ontario and are slightly exceeded in Lakes Superior and Erie. Wounding-rate targets for lake trout are being met in Lakes Superior, Michigan, Huron, and Ontario and are slightly exceeded in Lake Erie.

Prognosis: Lampricide treatment strategies deployed over the first half of this reporting decade have reduced dramatically the abundance of adult sea lamprey and the wounding rate on lake trout. Future challenges include increasing treatments to further the suppression of sea lamprey populations and the diminishment of wounding rates on lake trout, to minimize impacts on non-target organisms, to meet permitting requirements, and to educate agency staff and the public regarding the role of lampricides in maintaining ecosystem health.

Strategy 2: Conduct detection and distribution surveys to identify all sources of larval sea lampreys.

Outcome: Sources of sea lamprey will be delineated and control efforts will be more effectively prioritized among streams.

Status: Larval detection and distribution surveys were conducted annually via electrofishing and granular Bayluscide application, resulting in identification of 18 additional streams requiring treatment. Larval assessments in large (high-flow or deep) tributaries and in connecting channels remain challenging. Alternative assessment techniques, including detection of eDNA and pheromones are being explored.

Performance: Meets expectations. Better assessments have resulted in improved control, resulting in declining abundance of adult sea lamprey and in lake trout wounding rates.

Prognosis: Future challenges include expanding the number of surveys to more of the 5,000 Great Lakes tributaries. Larval assessment in large rivers and connecting channels, however, remains difficult, indicating a need for better methods.

Strategy 3: Measure the effectiveness of lampricide applications and account for its variation among streams.

Outcome: New treatment protocols that result in more-effective application of lampricides will be developed and implemented.

Status: Lampricide concentrations and water chemistries were closely monitored throughout individual treatments and were correlated to treatment efficacy. Refinement of TFM/Bayluscide applications based on larval surveys, water chemistry analyses, and physiological research is ongoing. Host resistance to lampricides and the development of the next generation of lampricides are being explored.

Performance: Above expectations. Post-treatment assessments identified the need to re-treat tributaries and these re-treatments led to reduced sea lamprey abundance and wounding rates on lake trout. New treatment protocols, such as "interrupted" and "long and low" treatment, are being explored. The influence of alkalinity on the toxicity of lampricides also is being reinvestigated.

Prognosis: During the first half of this reporting decade, post-treatment assessments and monitoring of water chemistries during treatment resulted in improved treatment protocols. In addition, alkalinity and pH are being further scrutinized for their impacts on treatment effectiveness. The potential for lamprey resistance to lampricides is being explored. Future challenges include development of even-more effective treatments; determination of the physiological mechanisms involved in lampricide toxicity, including its relationship to water chemistry; and identification of new lampricides.

Strategy 4: Quantify the relationship between the abundance of spawning-phase sea lampreys, lake trout abundance, and wounding rates on lake trout.

Outcome: Inconsistencies between estimates of sea lamprey abundance and observed changes in lake trout wounding rates will be accounted for.

Status: Regional lake trout abundance and wounding data were collected from management agencies and used to calculate lakewide estimates, but the relationship between lake trout abundance and wounding and sea lamprey abundance could not be quantified because of uncertainty around the number of attacks on other suitable hosts. Surveys of wounding on other hosts are not as robust as those for lake trout. Therefore, additional survey effort is needed to reconcile inconsistencies in these relationships.

Performance: Below expectations. Lakewide sea lamprey wounding rates on lake trout were estimated and used to assess the success of the control program. Accounting for the inconsistencies between the estimates of sea lamprey abundance and wounding rates on lake trout was not possible with existing data.

Prognosis: Insufficient data on suitable hosts besides lake trout confounds the relationship between sea lamprey abundance, lake trout abundance, and wounding rates on lake trout. In fact, wounding data on hosts other than lake trout are lacking in most areas and are unlikely to be collected anytime soon by management agencies. The Sea Lamprey Control Board has initiated a "FishLamp" work group to focus analytical capacity on a model intended to relate adult sea lamprey abundance to lake trout abundance and lake trout wounding rates for each of the Great Lakes.

Strategy 5: Construct and maintain a network of barriers to limit sea lamprey access to spawning habitats.

Outcome: Sea lampreys will have reduced access to spawning habitats.

Status: Three new barriers were added to the network, and planning is in progress for five additional barrier construction/reconstruction projects. Conventional dams built for other purposes, but that also block sea lampreys, were inventoried and inspected for their ability to block sea lampreys.

Performance: Meets expectations. New barriers were constructed on three tributaries. Planning began or continued on construction of five additional barriers, and inspections were conducted to ensure adult sea lampreys remained blocked at conventional dams.

Prognosis: Challenges include aging conventional dams (some are nearly a century old) that would be costly to repair, sustained funding for new barriers, involvement with dam removals, and the growing insistence on connectivity between lakes and their tributaries. Special funding is being requested for infrastructure through revised Program Requirements and Cost Estimates.

Strategy 6: Deploy trapping methods to increase capture of spawning-phase and recently metamorphosed sea lampreys.

Outcome: Effective and efficient trapping techniques will be developed and implemented.

Status: Methods to increase the efficiency of adult traps, such as use of pheromones and alarm cues; low voltage electrical guidance systems; eel-ladder-style trap designs; fish wheels; and redesigned traps are in the research and development stage. Additionally, behavioral studies on the out-migration of recently metamorphosed sea lampreys are being conducted to make placement of fyke nets more effective. A trapping-for-control strategy is under development to guide research and development in this area.

Performance: Not meeting expectations. New trapping methods that increase capture of adult and recently metamorphosed sea lampreys have not been fully developed or implemented. Implementation of pheromone-mediated trapping, low-voltage electrical-guidance trapping, and the use of eel-ladder-style trap designs are all being researched, but more research and development is needed.

Prognosis: Capture efficiencies of adult traps are not high enough to affect sea lamprey recruitment and are therefore not considered a control technique. Fyke nets are deployed only on an as-needed basis when streams that cannot be treated before the end of the field season are found to have high numbers of large larvae. Research aimed at increasing trapping efficiencies for both adult and recently metamorphosed sea lampreys is in progress and several methods (listed above) are being explored. Challenges include aging barrier infrastructure (where many adult sea lamprey traps are located) and the costs for their repair, funding for research to advance trapping as a control method, and determining the level of adult trapping needed to make it effective. In addition, a conceptual model for research and development was lacking but is being developed.

Goal 2: Increase the Effectiveness and Efficiency of Sea Lamprey Control to Further Reduce Sea Lamprey Populations in Each Great Lake

Strategy 1: Increase the capture of sea lampreys by developing cost-effective trapping methods, including those based on release of pheromones.

Outcome: One new cost-effective trapping method will be deployed.

Status: The male sex-pheromone component 3kPZS has been shown to increase trapping efficiency by up to 25%, and modeling suggests its use would be cost effective for sea lamprey control in Lake Michigan. See also Goal 1, Strategy 6.

Performance: Not meeting expectations. Despite positive results from large-scale field trials of 3kPZS, more research and development are needed to refine the models necessary for formulating a cost-effective management strategy. Further, additional sea lamprey pheromone components have been identified but not field tested.

Prognosis: Pheromones potentially could be used to increase adult trapping, but expectations are curbed as pheromones have not proved to be the "silver bullet" they were once thought to be. During the first years of this decade, research projects focusing on pheromone-induced sea lamprey behavior and pheromone-mediated trapping were initiated. No new trapping methods have been developed or advanced to the point of being ready for inclusion in the control program, but trapping using 3kPZS or trapping using additional pheromone components remain promising and could be ready for use by 2020. Challenges include securing increased funding for research, even though the prospects for efficacy have been dampened by results observed to date, and expanding the conceptual model for research and development so as to better integrate all possible methods of enhanced trapping. Goal 1, Strategy 6, and Goal 2, Strategy 2, directly relate to these challenges.

Strategy 2: Evaluate a repellent-based control method to deter sea lampreys from reaching spawning areas.

Outcome: The efficacy of a repellent-based control method will be assessed in field trials.

Status: The use of repellents as "chemical" dams and in push-pull redistribution studies was explored, but repellants were not tested in a large-scale field trial. A trapping-for-control strategy and revised chemosensory research and development strategy are in development.

Performance: Not meeting expectations. The necessary research needed to conduct a field trial is underway and a large-scale field trial could be undertaken in the second half of this reporting decade. Behavioral research aimed at improved use of repellents is ongoing. Alarm substances released by dead sea lampreys were field tested as a "chemical" barrier to adult migration and in push-pull redistribution studies. A predatory cue, PEA, was also tested and found to be a repellent in lab experiments, but the responses could not be replicated in the field.

Prognosis: Repellent-based sea lamprey control remains a promising line of research. Repellents could be used as "chemical" barriers to sea lamprey migrations, as behavioral guidance agents to improve trapping, or as a means to guide lampreys into areas that lack suitable spawning or larval-rearing habitat or that are more effectively treated with lampricides. During the first half of this decade, six research projects focusing on behavioral responses of sea lampreys to repellents and on the use of repellents and pheromones, combined as agents to promote trapping, were initiated. Nevertheless, no new methods using repellents have advanced to the point of being ready for implementation. More priority needs to be given to field testing by 2020 a combination of tactics, including repellents; pheromones; and electrical guidance. The immediate challenge is to maintain the research funding stream and to communicate reasonable expectations from the research.

Strategy 3: Improve existing and develop new rapid-assessment methods to determine the distribution and relative abundance of larval sea lamprey populations.

Outcome: The effectiveness of assessing the distribution and abundance of larval sea lampreys will be increased.

Status: Existing larval assessment techniques were improved and new techniques were explored. The use of remote sensing to classify larval habitat continued. Novel assessment techniques are in development.

Performance: Meets expectations. Protocols for surveying the distribution of larvae were improved. Use of remote sensing (RoxAnn) to classify larval habitat continued, and novel assessment techniques based on eDNA and pheromones are being explored.

Prognosis: During the first half of this reporting decade, existing electrofishing and granular-Bayluscide-larval-assessment protocols were revised, resulting in improved effectiveness. Additionally, research began on the use of eDNA and pheromones for assessment. No new larval assessment methods have advanced to the point of implementation, but the research is promising and both tactics could be ready for use by 2020. The challenge here is to initiate research on other technologies in the event that eDNA and pheromones are unsuitable for larval assessment.

Strategy 4: Implement integrated sea lamprey control strategies for each lake and evaluate their effectiveness.

Outcome: Existing and newly developed methods of sea lamprey control will be used in concert and sea lamprey abundance will be further reduced in each Great Lake.

Status: The abundance of sea lampreys and wounding rates on lake trout were reduced as a result of integrated control. Large-scale lampricide treatments and an effective barrier network were the primary drivers behind these declines, but decision-analysis tools and the development of control plans were also factors important in achieving integrated control.

Performance: Meets expectations. Control plans for each lake were developed to allow for an integrated approach across the Great Lakes basin. Decision-analysis tools were used to implement a control strategy on the St. Marys River, and large-scale lampricide treatments were deployed elsewhere. Adult sea lamprey abundance and wounding rates on lake trout have declined dramatically.

Prognosis: During the first half of the decade, control plans were developed for each lake as a prelude to implementing integrated control across the Great Lakes basin, decision analysis tools were used to produce a control strategy for the St. Marys River (most notably leading to the discontinuation of the sterile-male-release technique), and large-scale lampricide treatment strategies were implemented. In response to these efforts, adult abundance and wounding rates on lake trout declined dramatically. Future challenges include securing funding to maintain and increase lampricide applications, improving the use of barriers, and securing research into alternative control and assessment.

PILLAR THREE: STRATEGIC ALLIANCES AND PARTNERSHIPS

The Great Lakes Fishery Commission (GLFC) will build and maintain effective strategic alliances to promote sustainable fisheries and a healthy Great Lakes ecosystem.

Goal 1: Strengthen Interjurisdictional Fisheries Management

Strategy 1: Facilitate implementation of *A Joint Strategic Plan for Management of Great Lakes Fisheries* (Joint Strategic Plan) (GLFC 2007).

Outcome 1: Agencies signatory to the Joint Strategic Plan will have met regularly to coordinate management.

Status: Agencies signatory to the Joint Strategic Plan have met biannually at all levels to coordinate management.

Performance: Meets expectations. Committees at all levels met regularly to coordinate management. The Council of Great Lakes Fishery Agencies in 2013 welcomed the 1854 Treaty Authority as the most-recent signatory.

Prognosis: The secretariat facilitated the continuing implementation of the Joint Strategic Plan during the first half of this reporting period. All Joint Strategic Plan committees met regularly and produced the necessary products to guide coordinated fishery management across the Great Lakes basin. Nevertheless, political pressures within jurisdictions are potential threats to this consensus (nonbinding) approach to fishery management. Continued support from the GLFC will be required to maintain facilitation and continued success.

Outcome 2: Lake committees will have developed, revised, and implemented Joint Strategic Plan products—such as fish community objectives, environmental objectives, total allowable catches, annual lake committee reports, and state-of-the-lake reports—to evaluate progress on achievement of fish community, environmental, and law enforcement objectives.

Status: Lake committees have developed Joint Strategic Plan products.

Performance: Above expectations. Lake committees produced oral and written state-of-the-lake reports on schedule. The Law Enforcement Committee was responsible for promulgating regulations requiring Asian carps to be eviscerated before transport across state lines. The Council of Lake Committees (CLC) actively supported important basinwide programs to enhance cooperative fishery management.

Prognosis: Lake committees continue to evaluate and revise important documents that support cooperative fishery management. Lake committee turnover, lack of familiarity with the Joint Strategic Plan, outdated and non-measurable fish community objectives, and the current political climate will make facilitation of cooperative fishery management more difficult in the future.

Strategy 2: Facilitate the marking of all trout and salmon stocked into the Great Lakes to improve lakewide assessment.

Outcome 1: Mass-marking equipment will have been acquired and used throughout the Great Lakes basin.

Status: Mass-marking equipment has been acquired and is in use throughout the Great Lakes basin.

Performance: Meets expectations. Hatchery produced Chinook salmon (*Oncorhynchus tshawytscha*) and lake trout have been marked basinwide. The results from mass marking have considerably improved decision making by fishery-management agencies. The outlook, however, is not positive, as required equipment has not been purchased, and a permanent source of operational funds has not been identified.

Prognosis: The mass-marking program is well received by the lake committees and is providing useful information for managers and decision makers, such as the proportion of the Chinook salmon population in Lakes Michigan and Ontario that is of wild origin, a finding that is used to make adjustments in stocking. Base funding, however, is a significant obstacle to the future of this program despite extensive briefings by secretariat staff to congressional and U.S. Fish and Wildlife Service (USFWS) officials.

Outcome 2: The CLC will have developed and overseen a coordinated process to collect, maintain, and analyze marking data.

Status: This outcome as written does not capture the need for cooperating agencies to provide funding. The CLC has developed and overseen a coordinated process to collect, maintain, and analyze data, but this process is not sustainable and requires a stronger commitment from the USFWS.

Performance: Meets expectations. The CLC determined initial priorities for marking Chinook salmon and lake trout, which are being successfully implemented. The USFWS Great Lakes Fish Tag and Recovery Laboratory provides vital data to lake committees, including proportion wild, movement patterns, catch locations of marked fish, and survivability by lake region.

Prognosis: To date, the process to identify projects has worked well. However, insufficient base funding threatens implementation of the CLC's full strategy, which calls for marking all stocked salmon and trout. The prognosis for expanded tagging and for critical services provided by the Fish Tag and Recovery Laboratory is uncertain given the inability to get this program into the USFWS base budget. The secretariat has been very active in obtaining full funding, but the desired results have not been forthcoming. A change in status during the second reporting period seems unlikely at this time.

Outcome 3: The extent of natural reproduction will have been determined and the effectiveness of stocking programs and methods known.

Status: The extent of natural production has been determined for Chinook salmon in Lakes Michigan, Huron, and Ontario. Stocking levels have been adjusted downward as a result.

Performance: Meets expectations. Only Chinook salmon and lake trout have been tagged to date because of limited funding. The extent of natural reproduction by lake trout should be known by the end of the decadal reporting period. The ability to tag additional species will depend on the ability to fully fund the program in both the U.S. and Canada.

Prognosis: To date, only two species of stocked salmon and trout have been tagged on a large scale. The information generated from mass marking for these species has enabled agencies to make changes in stocking levels that otherwise would be difficult to justify. The future ability of Joint Strategic Plan agencies to take advantage of the results from mass marking will depend on their ability, and that of the secretariat, to convince the USFWS to base-fund this program and to attract funding in Canada.

Goal 2: Integrate Environmental and Fishery Management

Strategy 1: Assist the lake committees with communicating to environmental agencies the biological, physical, and chemical requirements necessary to achieve each lake's environmental and fish community objectives.

Outcome 1: Environmental objectives for all lakes will have been developed, and progress in their achievement will have been monitored.

Status: Environmental objectives exist for Lakes Huron, Michigan, and Erie; however, they are more than a decade old. Updated objectives remain to be fully developed, and their drafting is now viewed as being impractical.

Performance: Below expectations. The process for implementation of this strategy has changed since it was written making it impossible to achieve the original outcome. Instead, the secretariat and the lake committees have embarked on a replacement process based on the development of environmental principles, and it is proceeding well.

Prognosis: The CLC has developed basinwide environmental principles that replace the need for individual-lake environmental objectives. Using these environmental principles, the CLC is currently identifying priority areas for habitat improvement. This approach has been well received by environmental agencies. Based on progress to date, no course correction appears necessary.

Outcome 2: Lakewide management plans, remedial action plans, and the Great Lakes Water Quality Agreement will reflect fishery-management priorities.

Status: Fishery-management priorities being developed under the environmental-principles approach are in the process of being incorporated into the framework of the Great Lakes Water Quality Agreement (GLWQA), including its lake ecosystem objectives.

Performance: Meets expectations. The CLC's environmental principles have been incorporated into the nearshore framework and the baseline assessments for GLWQA Annexes 2 and 7, respectively. Fishery managers are currently working to incorporate their management priorities into the lake ecosystem objectives being developed under the GLWQA. Once incorporated into these objectives, the path will be clear to incorporate them into lakewide management and remedial action plans.

Prognosis: Progress toward incorporating fishery-management priorities into the GLWQA is proceeding well. The exact time frame for fully accomplishing this goal remains uncertain due to decisions that must be made internal to the GLWQA framework and to fishery-management priorities that also are under development. Given even these uncertainties, the secretariat expects that substantial progress toward this outcome will materialize by the end of the decadal reporting period. No course correction is suggested.

Strategy 2: The GLFC will facilitate implementation of cooperative fishery and ecosystem restoration based on the Joint Strategic Plan.

Outcome 1: The U.S. Army Corps of Engineers will have implemented the Great Lakes Fishery and Ecosystem Restoration Program (GLFER) based on input and support from partner agencies.

Status: Based on input from the CLC, the U.S. Army Corps of Engineers is implementing the GLFER program in a satisfactory manner.

Performance: Meets expectations. The CLC provides regular input to the GLFER program concerning fundable projects. Thanks to Great Lakes Restoration Initiative (GLRI) funding, the GLFER program has completed 10 projects since 2006 with another 11 expected to be under construction by the end of 2016.

Prognosis: Prognosis: The GLFER program has benefitted from the GLRI, which provided a financial opportunity to begin construction on and to complete many needed projects, such as fish passage on the Frankenmuth River in Michigan; aquatic and terrestrial rehabilitation of several plots in Chicago, including Northerly Island and 63rd Street Beach; and reconstruction in Indiana of the linkage between Red Mill Pond and the Little Calumet River watershed. The future of GLFER rests on key legislative and budgetary needs, including reauthorization (Section 506, Water Resources Development Act) and ensuring a stable funding source. The CLC, perhaps working with technical committees, could better identify and promote suitable projects. Base funding for the program remains uncommitted, despite extensive briefings by secretariat staff to the assistant secretary of the army's office, congressional officials, and to the Office of Management and Budget.

Outcome 2: The federal and provincial governments of Canada will have implemented the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem so as to support restoration and protection of the Great Lakes basin ecosystem.

Status: The Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA) continues to be implemented by the federal and provincial governments.

Performance: Meets expectations. In the first half of this reporting period, work involving rehabilitation of native species was conducted. For the latter half of this reporting period, a sharper focus on American eel is needed.

Prognosis: Canada and Ontario are cooperating to improve fish populations through the COA. No course correction is suggested.

Goal 3: Strengthen Advisor Relationships

Strategy 1: The GLFC will support its Canadian and U.S. advisory committees of advisors.

Strategy 2: The GLFC will actively seek advice on policy matters from its committee of advisors.

Strategy 3: The GLFC will consult on a regular basis with its committees of advisors to review and amend as necessary their terms of reference.

Outcome (all): Canadian and U.S. advisors will have attended GLFC meetings regularly and have provided counsel on topics identified by the GLFC and themselves.

Status: The GLFC hosts two major advisor meetings and several between-meeting conference calls annually. Advisor attendance has been robust during this reporting period, and interactions between advisors and the GLFC have increased on several important issues.

Performance: Above expectations. During this reporting period, advisors in both Canada and the U.S. have reviewed their terms of reference, improved the conduct of their meetings, and produced for the GLFC more resolutions and statements of higher quality than at any time in the past.

Prognosis: A longstanding committee of advisors was created under the U.S. Great Lakes Fishery Act of 1956. Much later, in 1999, a Canadian Committee of Advisors was created, as authorized by the Convention on Great Lakes Fisheries. Advisors are expected to consider issues of interest to the Great Lakes fishery and make relevant recommendations to the GLFC. The GLFC greatly values the committees' input and has been pleased with the high level of participation at advisor meetings. The quantity and quality of advisor resolutions and policy statements has improved steadily over time, commensurate with greater secretariat support. Advisors have considered how to improve their meetings, and Commissioners and advisors have, after careful review, implemented important changes. The GLFC remains committed to well-functioning advisory committees through secretariat support and travel funds. The GLFC should consider whether reviewing the terms of reference for Canadian advisors is warranted, including whether membership should be expanded beyond six.

Goal 4: Leverage Resources to Enhance GLFC and Partner Programs

Strategy 1: Forge and maintain strategic alliances to address priority fishery-research and management issues.

Outcome: Strategic alliances among the GLFC and other agencies will have continued to address effectively priority fishery-research and management issues.

Status: Strategic alliances are being maintained and increased to address effectively fishery-management and research priorities.

Performance: Above expectations. The secretariat actively participates in numerous partnerships that lead to improved fishery management. The Fishery and Sea Lamprey Research Programs currently have contracted with over 150 partner agencies and institutions. The GLFC has been a leader in developing the new Aquatic Habitat Connectivity Collaborative and in developing its Selective Fish Passage research theme. The GLFC maintains ongoing relationships with legislators and specialized groups to advance its objectives.

Prognosis: The GLFC has been very active during this portion of the reporting period and has jump-started two very-important strategic projects, the Selective Fish Passage project and the Aquatic Habitat Connectivity Collaborative. Both projects are examples of the high regard with which the GLFC is held and of its ability to foster meaningful partnerships to accomplish goals. The decades-long collaboration among the jurisdictions, facilitated through the Joint Strategic Plan, is the stimulus behind these and other successes. The secretariat continues to nourish and participate in many other cooperative programs that enhance fishery management and research throughout the basin.

Strategy 2: The GLFC will assist its partners in tracking and advocating funding for key Great Lakes programs in Canada and the United States.

Outcome: The GLFC will have contributed to the success of other agencies in maintaining or enhancing the resources needed to deliver effective fishery programs.

Status: In both Canada and the U.S., the GLFC tracks relevant policies and legislation. Working with partners inside and outside of government, the GLFC helps in developing priorities and advocating for their implementation.

Performance: Meets expectations. The GLFC, on a daily basis, tracks legislation and policies, reports to sister agencies regarding the status of initiatives, helps draft policies and legislation, and advocates for passage and implementation.

Prognosis: Legislation, policies, and funding in both Canada and the U.S. are essential if the GLFC and its partner agencies are to fulfill their mandates. The enactment of key initiatives with commensurate funding often depends on speaking with a unified voice that expresses consensus and support. The Great Lakes community is fortunate to have relatively strong lines of communication among myriad government and nongovernmental organizations. The secretariat devotes considerable staff time and energy to advocating for policies and laws that will help all agencies achieve their objectives. Individual directorates within the GLFC regularly provide letters of support aimed at leveraging funding and have been successful in securing funds to support critical initiatives and programs, such as the U.S. Geological Survey Deepwater Science Program, University of Guelph's award of the Canadian First Research Excellence Fund, the Great Lakes Fishery and Ecosystem Restoration Act, the Fish and Wildlife Restoration Act, and the GLRI. These programs are critical to the collective achievement of the fishery- and ecosystem-restoration objectives identified in the GLFC's strategic vision. These efforts require continued communications with the Council of Great Lakes Fishery Agencies, the CLC, sister organizations, elected officials, sister commissions, advisors, and nongovernmental organizations.

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