Great Lakes Fishery Trust

Dr. Andrew Muir
Great Lakes Fishery Commission
2100 Commonwealth Blvd., Suite 100
Ann Arbor, MI 48105

Dear Mr. Muir:

According to our records, the grant period for your Great Lakes Fishery Trust (GLFT) project, *Illustrated Field Guide to the Ciscoes of the Laurentian Great Lakes*, ended on January 1, 2016, and $1,800 remains for the purposes of the project. If you have a reasonable need for a project extension, please visit the GLFT website (www.glft.org) for more information about extension requests or contact your grant manager.

As your GLFT-funded project comes to a close, please carefully review your grant agreement to ensure that you have met all the requirements. Please note that the project was approved with two contingencies:

1. The GLFT will be recognized as a funder within the field guide.
2. The Great Lakes Fishery Commission will provide the GLFT at least 20 copies of the field guide for our Scientific Advisory Team members and staff.

Please note that your final project report is due to the GLFT within 60 days following the end of the grant period. Final reports must be submitted through the GLFT website (www.glft.org) according to the attached instructions. The final report must contain:

1. A narrative of what was accomplished by expenditure of the grant funds (guidelines to use in preparing the final narrative report are attached).
2. A financial report (final financial report form and instructions are attached). The financial report should include a statement of expenses according to the line items in the approved bid as submitted to the GLFT and the appropriate financial documentation that verifies payments (e.g., copies of invoices, record of hours expended, standard accounting ledgers used by your organization, and/or copies of canceled checks with descriptions).

Upon receipt of your final report, the GLFT will disburse the total from Column IV in your financial report up to your total grant amount, less funds previously disbursed.

Please let me know if you have any questions.

Sincerely,

Jonathon Beard
Grant Manager

230 N. Washington Square, Suite 300 Lansing, MI 48933
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RESEARCH FINAL REPORT GUIDELINES

PROJECT ABSTRACT

Title: CISCOES (COREGONUS, SUBGENUS LEUCICHTHYS) OF THE LAURENTIAN GREAT LAKES AND LAKE NIPIGON.

Abstract Body: This study of the ciscoes (*Coregonus*, subgenus *Leucichthys*) of the Great Lakes and Lake Nipigon represents a furtherance through 2015 of field research initiated by Walter Koelz in 1917 and continued by Stanford Smith in the mid-1990s—a period spanning nearly a century. Like its predecessor, this work contains information on taxonomy, geographical distribution, ecology, and status of species (here considered forms). Of the seven currently recognized forms (*C. artedi*, *C. hoyi*, *C. johannae*, *C. kiyi*, *C. nigripinnis*, *C. reighardi*, and *C. zenithicus*) described by Koelz as major in his 1929 monograph, two (*C. johannae* and *C. reighardi*) are extinct. In addition, *C. alpenae*, described by Koelz but subsequently synonymized with *C. zenithicus*, though extinct, is recognized as valid making for a new total of eight major forms. Six of these forms, all but *C. artedi* and *C. hoyi*, have been eliminated from Lake Michigan, and seven have been eliminated from Lake Huron, leaving in Lake Huron only *C. artedi* and an introgressed deep-water form. *Coregonus artedi* appears, like its sister form *C. alpenae*, to have been eliminated from Lake Erie. Only *C. artedi* remains extant in Lake Ontario, its three sister forms (*C. hoyi*, *C. kiyi*, and *C. reighardi*) having disappeared long ago. Lakes Superior and Nipigon have retained their original species flocks consisting of four forms each: *C. artedi*, *C. hoyi*, and *C. zenithicus* in both lakes, *C. kiyi* in Lake Superior, and *C. nigripinnis* in Lake Nipigon. Morphological deviations from the forms described by Koelz have been modest in contemporary samples. Overall, *C. kiyi* and *C. artedi* were the most morphologically stable forms while *C. hoyi*, *C. nigripinnis*, and *C. zenithicus* were least stable. Although contemporary populations of *C. artedi* from Lakes Michigan and Huron are highly diverged from the forms described by Koelz, the contemporary samples were of undescribed deep-bodied forms unlikely, because of their association with bays, to have been sampled by Koelz. Of the two intact species flocks, Lake Nipigon's was much-less stable morphologically than Lake Superior's even though Lake Nipigon is far-less disturbed than Lake Superior. Two priorities for research are determining the role of developmental plasticity in morphological divergence, especially

within *C. zenithicus* of Lake Superior, and the morphological diversity of *C. artedi* in Lakes Michigan and Huron.

FINAL NARRATIVE REPORT GUIDELINES

- **Project Title:** *Illustrated Field Guide to the Ciscoes of the Laurentian Great Lakes*
- **Grantee Organization:** Great Lakes Fishery Commission
- **Project Team**

R.L. Eshenroder (Great Lakes Fishery Commission), P. Vecsei (Golder Associates), N.E. Mandrak (University of Toronto Scarborough), D.L. Yule (U.S. Geological Survey), O.T. Gorman (U.S. Geological Survey), T.C. Pratt (Fisheries and Oceans Canada), D.B. Bunnell (U.S., Geological Survey), and A.M. Muir (Great Lakes Fishery Commission)

- **Contact Person**

Andrew Muir, Great Lakes Fishery Commission; amuir@glfc.org; 734-646-6441

- **Grant Amount:** $18,000
- **Start and End Dates:** 04/01/2013–01/01/2016
- **Key Search Words** (native fishes, Coregonus, prey fishes, exploitation, succession)

Background/Overview

1. Briefly summarize the project description as outlined in the original proposal.

Ciscoes are important native prey fishes in the Great Lakes. In response to species extirpations and reductions in population abundance, restoration efforts are underway. Great Lakes ciscoes are notoriously difficult to identify and a field guide does not exist; therefore, we produced a lake-specific, color-illustrated guide to the Great Lakes ciscoes. This multi-agency collaboration addresses a basin-wide need for standardized identification protocols to support identification of morphotypes encountered in monitoring and reestablishment efforts.

2. Briefly summarize any significant changes to the work performed in comparison to the originally proposed and funded plan of work. If changes were made, describe how they affected your ability to achieve the intended outcomes for the work.

The project expanded much beyond what was initially proposed, which is why the original completion date of January 2016 was exceeded. In short, we were able to access and digitize historical data for an additional 1500 specimens collected during 1950-1972. In addition, we digitized all of the tabular data from a 1929 (pre-fishery collapse) monograph on the Coregonid Fishes of the Great Lakes (Koelz 1929). These additional data, involving 9,000 samples, facilitated a comparative approach that allowed us to determine changes (21 in all) in morphotypes occurring over nearly a century. Additionally, several re-discovered populations from Lakes Huron and Michigan were

sampled for the project. These additional contemporary samples led to considerable new insights as described below.

Outcomes

Please characterize key outcomes of the project related to *knowledge*, *training*, *relationships*, and *practice.* Not all projects will have outcomes of all types.

3. To what extent and how (if at all) did this research project advance scientific knowledge of the issue?

The project represents the first detailed treatment of the Great Lakes ciscoes since W. Koelz published his seminal monograph in 1929. In contrast to the Koelz monograph, we present for the first time, user-friendly lake-specific keys that enable users to recognize variation within and among lakes thereby facilitating specimen identification. In addition, the guide presents the first update on the status of ciscoes in the Great Lakes basin in nearly 30 years. The guide will be critical to fishery managers as they begin to consider priorities for cisco re-establishment in Lakes Michigan, Huron, and Erie, and how to further improve efforts in Lake Ontario. For example, lake specific keys will allow biologists to identify with greater certainty cisco forms, which will strengthen assessment data. Additionally, we provide conclusive evidence that remnant *C. artedi* no longer exist in Lake Erie and strong evidence (lacking genetics) that the deepwater ciscoes of Lake Huron have collapsed into a hybrid swarm. These findings have important implications for developing restoration strategies.

4. To what extent and how (if at all) did this project contribute to the education and advancement of graduate or undergraduate students focused on Great Lakes fishery issues?

The project did not involve any students; however, the monograph will be a resource for future fishery students.

5. To what extent and how (if at all) did this work help you or others on your team build new relationships with others in the research or management communities?

The project team brought together many of the Coregonid biologists from Canada and the United States. The project strengthened communications, collaboration, and relationships among experts throughout the basin and generated research questions that will help inform an ongoing science collaboration around cisco restoration.

In sampling newly re-discovered cisco populations from Lakes Huron and Michigan, we trained Chris Olds (U.S. Fish and Wildlife Service) on morphometric and meristic sampling protocols. We worked extensively with Chris to the point where he is comfortable collecting data and teaching others the methods. We are presenting the guide and facilitating training workshops on morphometric techniques to two groups of biologists at the Lake Superior and Lake Huron Technical Committee meetings in July 2016.

6. To what extent and how (if at all) do the findings have action implications for fishery managers? If the research has direct management implications, do you have any knowledge of use of the findings by managers? If the research does *not* have direct management implications at this stage, to what extent did the research advance the process of identifying management responses to critical issues?

The guide will be critical to fishery managers as they begin to consider priorities for cisco re-establishment in Lakes Michigan, Huron, and Erie, and how to further improve efforts on Lake Ontario. For example, lake specific keys will allow biologists to identify with greater certainty cisco forms, which will strengthen assessment data. These data are extremely important for identifying source populations for restoration efforts. Additionally, we provide conclusive evidence that remnant artedi no longer exist in Lake Erie and strong evidence (lacking genetics) that the deepwater ciscoes of Lake Huron have collapsed into a hybrid swarm. These findings have important implications for developing restoration strategies. The information presented in the monograph is too new to be influencing fishery management policy; however, we presented some of the key findings to the Lake Committees during spring 2016, and the Council of Lake Committees will use the guide to inform development of their cisco restoration priorities (workshop to be held Dec 2016).

7. Considering the above or other factors not listed, what do you consider to be the most important benefits or outcomes of the project?

Given the effort and data that went into generating the monograph on Great Lakes ciscoes, it is likely that the document will be useful to fishery biologists and mangers for decades to come. We consider this guide an important contribution to Great Lake fishery biology and management. In terms of tangible outcomes, the ability to identify with more reliability ciscoes of the Great Lakes is an important benefit as lake-specific keys to the ciscoes had never previously existed. The database generated by the project will also benefit future fishery professionals. The database will be made available via the Commission's website.

Related Efforts

8. Was this project a standalone effort, or was there a broader effort beyond the part funded by the GLFT? Have other funders been involved, either during the time of your GLFT grant or subsequently?

The project is stand alone, but it was funded by multiple sources including the Great Lakes Fishery Commission, Great Lakes Fishery Trust, U.S. Geological Survey, Fisheries and Oceans Canada, and the Sea Grants of Michigan, Minnesota, New York, and Wisconsin.

9. Has there been any spinoff work or follow-up work related to this project? Did this work inspire subsequent, related research involving you or others?

As the monograph will be important to cisco restoration efforts, we anticipate that many of the uncertainties raised will become the focus of future research projects. For example, U.S. Geological Survey is leading an effort to develop a science agenda and implement

projects to help fishery managers achieve their Great Lakes cisco restoration objectives (Dec 2016).

Communication/Publication of Findings

10. List publications, presentations, websites, and other forms of formal dissemination of the project deliverables, tools, or results, including those that are *planned* or *in process*.

Eshenroder, R.L., P. Vecsei, N.E. Mandrak, D.L. Yule, O.T. Gorman, T.C. Pratt, D.B. Bunnell, and A.M. Muir. 2016. Ciscoes (*Coregonus*, subgenus *Leucichthys*) of the Laurentian Great Lakes. Great Lakes Fishery Commission Miscellaneous Publication 2016-1, Ann Arbor, Michigan.

11. Please characterize your efforts to share the findings of this research with state, federal, Tribal and interjurisdictional (e.g., Great Lakes Fishery Commission) agencies charged with management responsibilities for the Great Lakes fishery. If other audiences were priority for this research, please characterize your outreach efforts to those audiences as well. (Please note: You may wish to consult midterm reports in which specific audiences for the findings, and means of outreach to these audiences, were identified.)

We presented a summary of the management implications resulting from the project at the upper (https://www.youtube.com/watch?v=MPojC6KElBs&feature=youtu.be) and lower (https://www.youtube.com/watch?v=z5D62Vj2q6k&feature=youtu.be) Lake Committee Meetings during spring 2016.

Eshenroder, R.L., P. Vecsei, N.E. Mandrak, D.L. Yule, O.T. Gorman, T.C. Pratt, D.B. Bunnell, and A.M. Muir. 2016. Ciscoes (*Coregonus*, subgenus *Leucichthys*) of the Laurentian Great Lakes. Upper Lake Committee Meetings. 21-22 March, Milwaukee, WI.

Eshenroder, R.L., P. Vecsei, N.E. Mandrak, D.L. Yule, O.T. Gorman, T.C. Pratt, D.B. Bunnell, and A.M. Muir. 2016. Ciscoes (*Coregonus*, subgenus *Leucichthys*) of the Laurentian Great Lakes. Lower Lake Committee Meetings. 31 March, Niagara Falls, ON.

We also provided a talk on potential source populations and considerations for reintroduction of *Coregonus artedi* in the Great Lakes Basin.

Eshenroder, R.L. and A.M. Muir 2016. Source Populations for Reintroduction of *Coregonus artedi*. International Association for Great Lakes Research, Guelph, Ontario.

Finally, as mentioned above, we will participate in two workshops during summer 2016 hosted by the Lake Huron and Lake Superior Technical Committees of the Great Lakes Fishery Commission.

12. Please identify technical reports and materials attached to this report by name and indicate for each whether you are requesting that GLFT restrict access to the

materials while you seek publication. (Please note that the maximum amount of time during which GLFT will restrict access to the results of funded research is six months, unless notified that more time is needed.)

Eshenroder, R.L., P. Vecsei, N.E. Mandrak, D.L. Yule, O.T. Gorman, T.C. Pratt, D.B. Bunnell, and A.M. Muir. 2016. Ciscoes (*Coregonus*, subgenus *Leucichthys*) of the Laurentian Great Lakes. Great Lakes Fishery Commission Miscellaneous Publication 2016-1, Ann Arbor, Michigan.

The monograph will be published as a Great Lakes Fishery Commission Miscellaneous Publication. Please restrict access to the materials as they are currently being copy edited and formatted for printing. Printing is expected to begin 01 September and 20 copies of the printed document will be provided to the GLFT per contract.

13. Manuscripts. Grantees submitting one or more publications or pending publications in lieu of a standalone technical report must submit a cover memo that confirms that all aspects of the funded research are incorporated in the published work, and in cases of multiple publications, identifies or crosswalks the grant-funded objectives to the published article containing results.

N/A

14. Compilation reports. Grantees working on several related subprojects under a single grant may submit a series of subproject reports rather than a single, integrated report. However, grantees must submit a cover sheet or introduction that outlines and crosswalks grant objectives with the location of the results in the compilation document.

N/A

Discussion

This project was funded under the GLFT's *Healthy Ecosystems and Sustainable Fish Populations* funding stream because a field guide to the Great Lakes ciscoes will "*enhance the ability of managers/agencies to respond to changes in the fishery and ecosystem*" and will "*build research capacity and management expertise needed to understand and manage the Great Lakes ecosystem for sustainable production of valuable species*." Although, a field-guide to the ciscoes has long been desired by agency biologists, it satisfies key management needs related to capacity building under the GLFT *Emerging Issues* focal area. Our project also falls under the GLFT's *Lake Michigan Priority* theme because ciscoes in that lake were most affected by ecosystem change; of the six native species only *C. hoyi* remains abundant, but re-establishment plans are underway.

Our project also relates to the native fish re-establishment research priorities identified by the Council of Lake Committees and supports the GLFT *ecosystem health and sustainable fish populations* initiative. The cisco field guide project promotes partnerships through the communication of information about Great Lakes ecosystems and their fish communities and, therefore, is consistent with the aim of the GLFC Science

Transfer Program and the vision statement on healthy *Great Lakes Ecosystems and Sustainable Fisheries* (Pillar one).

The most important part of the guide is the section on the status of ciscoes, which updates a paper published in 1992. Major changes since then include the following: a deep-bodied form of *C. artedi* not previously known to inhabit Lakes Michigan and Huron is confirmed extant in those lakes, while the form thought to be extant in those lakes is likely extirpated; two forms of deepwater cisco thought to be extant in Lake Huron have introgressed into a hybrid swarm, and a deep-water form of *C. artedi* thought prevalent does not exist nor did it exist in recent times; a form of deepwater cisco, thought to have been misidentified as another form, did in fact exist, but has been extirpated, except that it may be represented genetically in the hybrid swarm of Lake Huron; and *C. artedi* of Lake Erie is extirpated. In addition, the guide presents strong evidence that the ciscoes of Lake Superior, previously thought to have been unaffected morphologically by overfishing, experienced a disturbance such that several forms have become more alike and two forms, formerly common, now rarely express. We were unable to determine whether the forms of *C. artedi* are genetically fixed or arise from polyphenism. Likewise, the three forms of *C. zenithicus* in Lake Superior may or may not arise from polyphenism. But, this problem was defined such that now simple breeding experiments can resolve the question. The guide provides a description and a review of ecology for every extant form of cisco in the Great Lakes and Lake Nipigon. This effort enabled an accounting of how morphology of extant ciscoes has changed since Koelz collected in 1917-1924. Twenty-one such changes have occurred. One of the most intriguing outcomes is that *C. hoyi* of Lake Huron, the subject of many papers, has not existed as formerly described since about 1965. One of the most immediate benefits of this research is that reintroduction programs will not use brood sources that would in effect require one morphotype to change into another, i.e., the brood source and the intended population establishment can now be matched. Lastly, the hybrid swarm in Lake Huron has prospects for reintroduction elsewhere because, although it did not exist in other lakes, it likely contains genetic elements for forms otherwise extinct. The implication here is that although an extinct form cannot be reestablished, some aspects of it can. Moreover, hybridized ciscoes likely have a greater facility to adapt to transplantation than do fixed types, making naturally occurring hybrids attractive.

Final Financial Report Instructions

Reference Number	Instructions
I.	These are the approved expense categories according to the Grant Agreement or most recently approved budget revision. Definitions of these categories are available on the GLFT website (www.glft.org), under the Proposal Resources tab.
II.	These are the approved budget amounts according to the Grant Agreement or most recently approved budget revision.
III.	List the expenditures for the project reporting period for the budget line items in Column II. See V below regarding cash versus accrual basis accounting.
IV.	Subtract Column III from Column II. Line item amounts may be positive (unused) or negative (overspent). If the ***total*** amount in Column IV is positive, please return the unused funds by check made out to the Great Lakes Fishery Trust via the address below.
V.	**Cash basis**: The cost of goods and services is recorded when they are received and paid for within the statement period. **Accrual basis**: The cost of goods and services is recorded when received within the statement period, whether paid for or not. Goods and/or services authorized, ordered, or budgeted, but not yet received before the end of the statement period, should not be included.

The financial report must be accompanied by financial documentation verifying expenditures (e.g., copies of invoices, record of hours expended, standard accounting ledgers used by your organization, and/or copies of canceled checks with descriptions).

Submit the signed form to the GLFT website following the attached instructions.

FINAL FINANCIAL REPORT

GLFT Project Number: # **2013.1286_**
GLFT Grant Manager: (Check one)
Jonathon Beard __X___ Mark Coscarelli _____

Organization Name: Great Lakes Fishery Commission
FOR THE PERIOD: Beginning Date: 04/01/2013 End Date: 01/01/2016

I Expense Categories	II Approved Budget Line Items	III Expenditures of GLFT Funds	IV Difference Between II & III
Salaries	$16,000	$16,000	0
Fringe Benefits	$0	$0	0
Supplies/Materials/Printing	$1,700	$1,700	0
Other Direct Expenses	$300	$300	0
Overhead/Indirect/Admin	$0	$0	0
Contract Services	$0	$0	0
Total	**$18,000**	**$18,000**	0

NOTE: Written explanation should be given for deviations in actual and/or proposed expenditures from originally approved budget items.

V: I hereby certify that this financial report form is prepared on (check the basis that applies) _X__ a cash basis _____ an accrual basis, and the resulting balance is correct.

____Sean Martineau_____ _____ __7/7/2016__
Chief Financial Officer Name and Title (please type) Chief Financial Officer (signature) Date

_____Andrew Muir_____ _____ __7/7/2016__
Project Director Name and Title (please type) Project Director Date