Quantifying a potential mechanism between ice cover and cisco recruitment success: what role does light play in cisco embryonic development?

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**ABSTRACT:**

**INTRODUCTION:**

Freshwater whitefishes, Salmonidae Coregoninae (hereafter coregonines) have played important economic and ecological roles throughout the northern hemisphere (REFS). Over the past 35 years, coregonine populations worldwide have experienced declines due to highly variable and weak year-class strengths (Nyberg et al. 2001, Myers et al. 2015). Historical coregonine declines have been attributed to overfishing, invasive species, habitat alterations, and competition (Stockwell et al. 2009, Rosinski et al. 2020, Lucke et al. 2020). However, actual reasons for contemporary declines remain unknown, but climate-induced changes in early-life stage environments have been hypothesized, and winter ice and water temperature regimes have changed over the past 20 years or more (Austin and Colman 2007, O’Reilly et al. 2015). In the Laurentian Great Lakes, native coregonine conservation and restoration efforts are at the forefront of fisheries management efforts (REFS). Future climate change predictions show that the timing and physical characteristics of winter and ice regimes are likely to drive some of the most important biological changes (REFS).

Year-class strength in most fish species, including coregonines, is thought to be established prior to the end of the first season of growth (Hjort 1914, Cushing 1990). Unlike larvae, embryos are static, leaving this early-life stage vulnerable to predation (Stockwell et al. 2014) and unable to evade inter-annual variation in winter conditions (REFS). Most coregonines are autumn spawners whose embryos incubate under ice throughout the winter and hatch in spring (REFS). Changes in winter severity and ice cover could alter developmental rates, embryo survival, and time of hatching (REFS). Potential mechanisms by which ice cover might influence cisco development include the reduction of physical wave action (REFS), lower and more stable winter and spring water temperatures (REFS), and less sunlight reaching the lake bottom (REFS). Recent changes in ice cover coupled with poor coregoninerecruitment has led to speculation about the relationship between ice cover and embryo survival for more than two decades with limited rectification. In Lake Superior, all known cisco spawning locations are estimated to be covered when lakewide ice cover reaches 15% (Figure 1, Goodyear 1982). Therefore, understanding how variable and declining ice regimes may impact coregonine early-life history is an important aspect of coregonine conservation and restoration efforts in the Great Lakes, and likely beyond.

Changes in ice regimes can have larger ecosystem implications.

* Temp-ice relationship for spring conditions
* Yolk-feeding-survival relationship
* Spring zooplankton phenology

A larger yolk-sac at hatching increases time before exogenous feeding is required, which increases larval survival (Fuiman 2002).

Contrast between Lake Superior and Lake Ontario ice regimes

Why light? Ice-light relationship as experimental proxy

* Ice and snow cover strongly affect the light environment in lakes and can reduce light transmittance from 83% in open water to 62% under ice coverage, and to ≤ 10% under snow and ice coverage (Bolsenga and Vanderploeg 1992).
* Lakes Superior and Ontario provide a contrast in ice cover and subsequent light attenuation.
* Different incubation depths. Look at Lar’s lab for literature. Paufve thesis

We experimentally studied cisco from Lakes Superior and Ontario to measure how cisco embryos responded to different ice regimes. Our objective was to identify to what extent light, as a proxy for ice cover, influences cisco embryo survival, incubation duration, yolk-sac volume and length at hatching. We hypothesized that exposure to elevated light intensity (low ice cover) would accelerate embryogenesis, resulting in smaller yolk-sacs and lower larval survival. Lake Superior cisco are expected to be adapted to lower light levels and thus will experience more negative impacts from increasing light intensity than Lake Ontario cisco. If these results hold up to more rigorous experimentation this would be a significant step towards understanding the recent high variability observed in coregoninerecruitment and help predict what the future of these species may look like under current climate trends to inform restoration efforts.

**METHODS:**

Cisco will be collected from Lake Superior, near Bayfield, Wisconsin, and Lake Ontario, Chaumont Bay, New York, in December 2019 by the Wisconsin DNR and New York DEC, respectively. Eggs and milt will be stripped from 12 females and 16 males and artificially inseminated to create 48 families from each lake. Fertilized eggs will be transported overnight to the University of Vermont (UVM) where all laboratory work will be conducted. Fertilization success will be assessed within 48-hours post-fertilization and unsuccessful families removed. Embryos from successful families ﻿will be divided among three light treatments and individual embryos randomly distributed into three 24-well microplates. Light treatments will represent 90-100, 40-60, and 0-10% ice cover and follow daily photoperiods. Incubation light levels will be based on measured lakebed light intensity data collected by the proposal authors throughout the entirety of Lake Superior’s 2016 and 2017 ice seasons. Embryos will be incubated at a constant temperature of 2.0°C in climate-controlled chambers. This novel incubation method was tested at UVM on Lake Ontario cisco with unrivaled embryo survival (>80%) in 2018-19.

Newly-hatched larvae will be photographed, and the images then used to measure total length-at-hatch (mm) and yolk-sac volume (mm3). The relationship between embryonic life history traits (incubation period, length-at-hatch, yolk-sac volume) and incubation light treatments between lakes will be analyzed using linear mixed models and ANOVAs. A sib analysis (Falconer and Mackay 1996) will be used to assess the relative role heritability (variation within sibling families) and the common environment (light) played in effecting the measured life history traits.

Larvae will be moved from microplates to rearing tanks by lake and incubation light treatment and exposed to the same photoperiod cycle (*i.e.,*12-hr light, 12-hr dark) with gradual sunrise and sunset transitions. Larvae will be reared in 150-L oval recirculating tanks at 10°C and provided dry feed *ad libitum*. At three months post-hatch, total length and weight of all larvae will be measured. Mean daily growth increment will be calculated as (mean final length – mean length-at-hatch)/duration of the larval experiment to assess how incubation light intensity impacted subsequent larval growth.

**RESULTS:**

**DISCUSSION:**

**LITERATURE CITED:**

**TABLES:**

**FIGURES:**