Protecting cisco (*Coregonus artedi* Lesueur) oxythermal habitat from climate change: building resilience in deep lakes using a landscape approach

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with 4 figures

Abstract: Cisco (*Coregonus artedi* Lesueur) was projected to persist in at least 171 deep, clear lakes in a climate-warmed Minnesota, U.S.A. A process-oriented, dynamic, one-dimensional year-round lake water quality model was used to predict coldwater habitat as a function of Secchi depth (a surrogate of lake productivity) and geometry ratio = $A_s^{0.25}/H_{max}$ (a measure of relative depth and strength of stratification) for a series of lake types in Minnesota. Late-summer hypolimnetic oxygen concentrations were predicted to remain sufficiently high to provide coldwater habitat within the refuge lakes even with longer durations of stratification after climate warming. Catchments of refuge lakes were prioritised based on two components: 1) threat (changes in land use) and 2) investment efficiency (total surface area of refuge lakes protected per amount invested). Priority scores were calculated for each refuge lake catchment based on the two components. Conservation strategies can be targeted in critical areas of the prioritised catchments to prevent future degradation of water quality in refuge lakes from changes in land use.

Keywords: Cisco conservation, climate change, catchments, water quality.

Introduction

Coldwater stenotherms such as cisco (*Coregonus artedi* Lesueur) are especially vulnerable to the effects of climate warming (Fang et al. 2004, Jacobson et al. 2010). Extended periods of lake summer stratification from climate warming will reduce hypolimnetic oxygen concentrations in stratified lakes (De Stasio et al. 1996, Stefan et al. 1996). Coldwater habitat will then be reduced for fish such as cisco that remain under the thermocline during summer. Warming of lakes that do not stratify will directly reduce thermal habitat for coldwater fish

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