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Egg Thiamine Status of Lake Ontario Salmonines 1995–2004 with Emphasis on Lake Trout

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ABSTRACT: *Alewives* (Alosa pseudoharengus)*, the major prey fish for Lake Ontario, contain thiaminase. They are associated with development of a thiamine deficiency in salmonines which greatly increases the potential for developing an early mortality syndrome (EMS). To assess the possible effects of thiamine deficiency on salmonine reproduction we measured egg thiamine concentrations for five species of Lake Ontario salmonines. From this we estimated the proportion of families susceptible to EMS based on whether they were below the ED20, the egg thiamine concentration associated with 20% mortality due to EMS. The ED20s were 1.52, 2.63, and 2.99 nmol/g egg for Chinook salmon* (Oncorhynchus tshawytscha)*, lake trout* (Salvelinus namaycush)*, and coho salmon* (Oncorhynchus kisutch)*, respectively. Based on the proportion of fish having egg thiamine concentrations falling below the ED20, the risk of developing EMS in Lake Ontario was highest for lake trout, followed by coho* (O. kisutch)*, and Chinook salmon, with the least risk for rainbow trout* (O. mykiss)*. For lake trout from western Lake Ontario, mean egg thiamine concentration showed significant annual variability during 1994 to 2003, when the proportion of lake trout at risk of developing EMS based on ED20 ranged between 77 and 100%. Variation in the annual mean egg thiamine concentration for western Lake Ontario lake trout was positively related ($p < 0.001$, $r^2 = 0.94$) with indices of annual adult alewife biomass. While suggesting*

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the possible involvement of density-dependent changes in alewives, the changes are small relative to egg thiamine concentrations when alewife are not part of the diet and are of insufficient magnitude to allow for natural reproduction by lake trout.

INDEX WORDS: *Thiamine, EMS, alewives, lake trout, Lake Ontario.*

INTRODUCTION

A diet containing a high proportion of alewives (*Alosa pseudoharengus*) has been implicated in development of a thiamine deficiency in salmonines (Fisher *et al.* 1998, Fitzsimons *et al.* 1999, Honeyfield *et al.* 2005). A thiamine deficiency is of concern because it leads to a greater propensity to develop early mortality syndrome (EMS) in the progeny of affected adults and appears to be a major impediment to restoration of lake trout in some Great Lakes (Brown *et al.* 1998a, 2005b; Fitzsimons 1995; Fitzsimons *et al.* 1999, 2003). The deficiency is due to the high thiaminase content of alewives (Fitzsimons and Brown 1998; Fitzsimons *et al.* 1999, 2005a; Honeyfield *et al.* 2005; Tillitt *et al.* 2005) that likely results in thiamine destruction in the gut of an alewife predator leading to insufficient thiamine absorption. As a consequence, maternal egg reserves of thiamine are inadequate to meet the thiamine requirements for embryological development during the sac-fry stage before the onset of exogenous feeding (Fitzsimons *et al.* 1999, Honeyfield *et al.* 2005). Recently, thiamine deficiency has also been associated with increased mortality of adult coho salmon and reduced swimming ability of rainbow trout (Brown *et al.* 2005c, Fitzsimons *et al.* 2005b, Ketola *et al.* 2005).

During the 1990s, alewives dominated both the diets of Lake Ontario salmonines and the prey fish community (Owens and Bergstedt 1994, Owens *et al.* 2003, Casselman and Scott 2004). For example in 1998, adult alewives comprised from 65 to almost 100% of the summer diet of salmonines in Lake Ontario (Lantry 2001). Owing to the overwhelming dominance of the prey fish community by alewives and low abundance of almost every other prey fish species (Mills *et al.* 2003, Owens *et al.* 2003), salmonines in Lake Ontario are more likely to develop a thiamine deficiency than in any other Great Lake. However, the only available published information is for lake trout in 1991 (Fisher *et al.* 1996) and 1994 (Brown *et al.* 1998a) during a period of relatively stable alewife abundance. Since 1991, abundance of alewives has generally been in decline (Owens *et al.* 2003).

We compared thiamine levels among salmonines and assessed annual variability by analyzing eggs from five salmonines in Lake Ontario (lake trout, coho salmon, Chinook salmon, brown trout (*Salmo trutta*), and rainbow trout) in at least 1 year for all species between 1994 and 2004. In lake trout, we examined annual variability over a 10-year period (1994-2004). To determine risk or the potential of low egg thiamine levels to cause EMS, we estimated egg thiamine concentrations associated with 20% EMS (i.e., ED20) for each species from the dose-response relationship between EMS and egg thiamine. We then estimated the proportion of families for each species and year that had egg thiamine concentrations below the ED20. For lake trout we also examined the overall association between the annual mean egg thiamine concentrations and an index of alewife abundance.

METHODS

Egg Collection and Thiamine Analysis

Fish were collected using a variety of methods from several locations over the period 1994–2004 (Table 1). From each female fish a sub-sample of eggs was collected and placed on ice until frozen (–20°C) and analyzed for thiamine. Thiamine was measured using an HPLC procedure that separated total thiamine into three vitamers: free thiamine, thiamine monophosphate, and thiamine pyrophosphate (Brown *et al.* 1998b). Concentrations were reported as the sum of the three vitamers. To assess differences in egg thiamine concentrations among brown, lake and rainbow trout and coho salmon collected in 1997, 1-way analysis of variance (ANOVA) was used. To assess differences among years within Lake Ontario we also used 1-way ANOVA. If the overall ANOVA proved significant ($p < 0.05$) for differences among group means, a Bonferroni multiple comparison test was used to locate these differences. For comparisons of Chinook salmon and lake trout that were collected in 1995 and 1999 we used 2-way ANOVA to assess the effect of species, year, and species x year interaction. All data were log transformed before analysis to achieve normality and homogeneity of variance.