Great Lakes lake trout thiamine monitoring program annual report

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Abstract

The U.S. Geological Survey's Great Lakes Science Center (GLSC), Eastern Ecological Science Center, and Columbia Environmental Research Center (CERC), and the State University of New York (SUNY) Brockport have conducted in collaboration with partner agencies a cooperative program to monitor thiamine concentrations in lake trout eggs since the late 1990s. In 2021, egg thiamine concentrations were highly variable at each sampling site. No eggs samples with thiamine concentrations less than the 4 nmol/g threshold recommended for successful lake trout reproduction were collected in Lakes Superior, Huron, Erie, and Champlain. In contrast, every site in Lakes Michigan and Ontario and Cayuga Lake had some lake trout eggs below 4 nmol/g. Time series of mean lake trout egg thiamine concentrations showed high temporal and spatial variability within the Great Lakes region.

Introduction

Lake trout *Salvelinus namaycush* were extirpated from Lakes Michigan, Erie, and Ontario and greatly reduced in Lakes Huron and Superior by the 1950s, and rehabilitation efforts have been underway since the 1960s (Krueger et al. 1995; Krueger and Ebener 2004). Very little natural reproduction of lake trout was observed in the Great Lakes outside of Lake Superior until recently (e.g., Riley et al. 2007; Hanson et al. 2013), suggesting that recruitment failure might be limiting rehabilitation. Low early life-stage survival of lake trout was observed in the Great Lakes in the 1960s through the 1990s and was thought to be a potential cause of the lack of natural recruitment of lake trout (Eshenroder et al. 1984; Harder et al. 2018). In the 1990s, it was determined that this mortality could be mitigated by thiamine (vitamin B_1) treatments (Fitzsimons 1995), suggesting that it was caused by insufficient thiamine, an essential nutrient. Subsequent research has demonstrated that low thiamine concentrations are common in Great Lakes lake trout and other salmonines (e.g., Fitzsimons et al. 2007; Futia et al. 2017; Futia and Rinchard 2019). This phenomenon, known as *Thiamine Deficiency Complex* (TDC; Riley and Evans 2008; previously referred to as Early Mortality Syndrome, or EMS), results in early life stage mortality of salmonines in the Great Lakes and may also decrease the performance or survival of adults (Brown et al. 2005; Ketola et al. 2009).

TDC may be an impediment to natural reproduction by lake trout in the Great Lakes presenting a potential obstacle to lake trout restoration programs, and egg thiamine concentrations greater than 4 nmol/g have been recommended for successful lake trout reproduction (Fitzsimons et al. 2007; Bronte et al. 2008). The egg thiamine concentration associated with 20% fry mortality (ED20) for lake trout has been estimated to be 2.63 nmol/g (Fitzsimons et al. 2007), whereas sublethal effects (i.e., 20-50% reductions in foraging and growth rates) of low thiamine on lake trout fry occur when thiamine concentrations are less than approximately 3-8 nmol/g (Fitzsimons et al. 2009). More recently, Futia and Rinchard (2019) determined that the lethal concentration inducing 50% fry mortality was 2.32 nmol/g.

The U.S. Geological Survey's Great Lakes Science Center (GLSC), Eastern Ecological Science Center, and Columbia Environmental Research Center (CERC), and the State University of New York (SUNY) Brockport have conducted a cooperative program to monitor thiamine concentrations in lake trout eggs since the late 1990s. Partner agencies include the Illinois Department of Natural Resources (DNR), Indiana DNR, Michigan DNR, Wisconsin DNR, the

Little Traverse Bay Band of Ottawa Indians, the Grand Traverse Bay Band of Ottawa and Chippewa Indians, the Little River Band of Ottawa Indians, the Illinois History Survey, the US Fish and Wildlife Service, US Geological Survey, New York State Department of Environmental Conservation, University of Vermont, SUNY Brockport, the Chippewa Ottawa Resource Authority, and the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry.

The 2021 data associated with this report are in review and will be released publicly at https://www.sciencebase.gov. Data used in this report collected prior to 2021 are publicly available at https://doi.org/10.5066/P9W3MUTU and https://doi.org/10.5066/P9I4CZI7. All USGS sampling and handling of fish during research are carried out in accordance with guidelines for the care and use of fishes by the American Fisheries Society (http://fisheries.org/docs/wp/Guidelines-for-Use-of-Fishes.pdf). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Methods

In 2021, collections of unfertilized eggs from lake trout took place at sites in Lakes Superior, Michigan, Huron, Erie, Ontario, and Champlain, and Cayuga Lake by partner agencies during fall spawning assessments (Figure 1 and Table 1). Lake trout egg collections from Lake Champlain and Cayuga Lake were included in the analyses because both lakes contain alewives, are sources of lake trout stockings in the Great Lakes, and present contrast with the Great Lakes in terms of lake size, levels of natural reproduction, and strains present. Eggs were frozen soon after collection and shipped to SUNY Brockport for biochemical analysis. Thiamine was extracted following Brown et al. (1998) using 1 g of eggs (about 8-10 eggs) homogenized in a 2% trichloroacetic acid solution. Lake trout egg extracts were then quantified using high-performance liquid chromatography (HPLC) according to Brown et al. (1998) with modifications following Futia et al. (2017). All samples were analyzed in duplicate. Two method blanks were included after every 15 samples for quality insurance. A six-point standard curve with known concentrations of thiamine (0, 1, 2.5, 5, 10, and 30 nmol/g) was generated at the start of each group of samples run. All thiamine concentrations reported here represent total thiamine. Mean thiamine concentrations in lake trout eggs are reported for each site as well as the estimated proportion of eggs samples that were below the threshold of 4 nmol/g thiamine. Long-term changes in thiamine

concentrations are also presented for selected sites in this report (Data courtesy of: Dale Honeyfield - USGS, Stephen Riley - USGS, Donald Tillitt - USGS, Ellen Marsden University of Vermont, and Jacques Rinchard – SUNY Brockport). Note that from 2005 to 2020 thiamine concentrations were measured using the rapid solid phase extraction fluorometric method (RSPE) developed by Zajicek et al. (2005). Thiamine concentrations measured using the RSPE method were not adjusted to be comparable to the HPLC results in the time series presented. However, results from both methods were found to be highly correlated (Zajicek et al. 2005, Riley et al. 2011)

Results and Discussion

Mean egg thiamine concentration in lake trout eggs collected in 2021 ranged from 8.10 to 38.73 nmol/g in Lake Superior, from 2.67 to 30.82 nmol/g in Lake Michigan, from 5.04 to 17.83 nmol/g in Lake Huron, from 8.67 to 36.80 nmol/g in Lake Erie, from 1.76 to 16.06 nmol in Lake Ontario, from 4.05 to 12.90 nmol/g in Lake Champlain, and from 2.81 to 19.59 nmol/g in Cayuga Lake (Figure 2 and Table 1). Egg thiamine concentrations were highly variable at each sampling site (Figure 2). No eggs samples with thiamine concentrations less than the 4 nmol/g threshold recommended for successful lake trout reproduction were collected in Lakes Superior, Huron, Erie, and Champlain (Figure 3). In contrast, every site in Lakes Michigan and Ontario and Cayuga Lake had some eggs below 4 nmol/g ranging from 10 to 40% in Lake Michigan, 10 to 47% in Lake Ontario, and 37% in Cayuga Lake (Figure 3, Table 1).

Time series of mean egg thiamine concentrations (nmol/g) in lake trout eggs collected at selected sites are reported in Figures 4 to 10. These figures showed high temporal and spatial variability in egg thiamine concentrations within the Great Lakes region. Continued annual monitoring will enable evaluation of the effects of TDC on lake trout recruitment.

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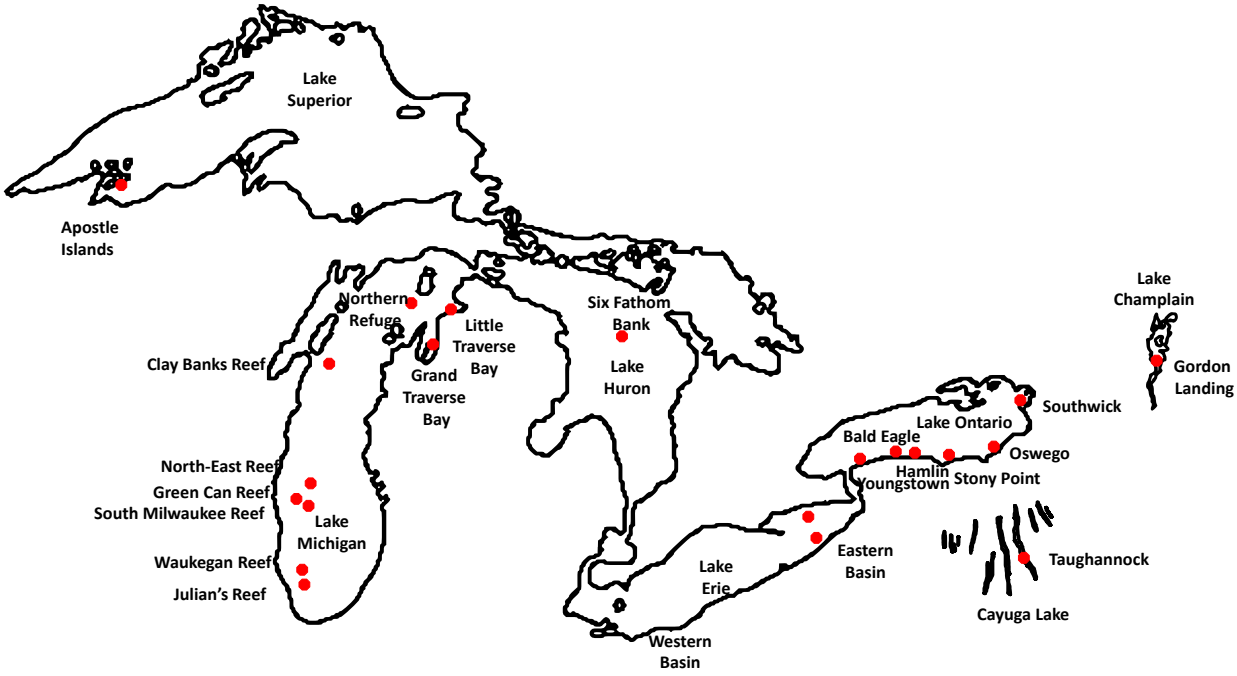

Figure 1: Lake trout egg sampling sites in 2021.

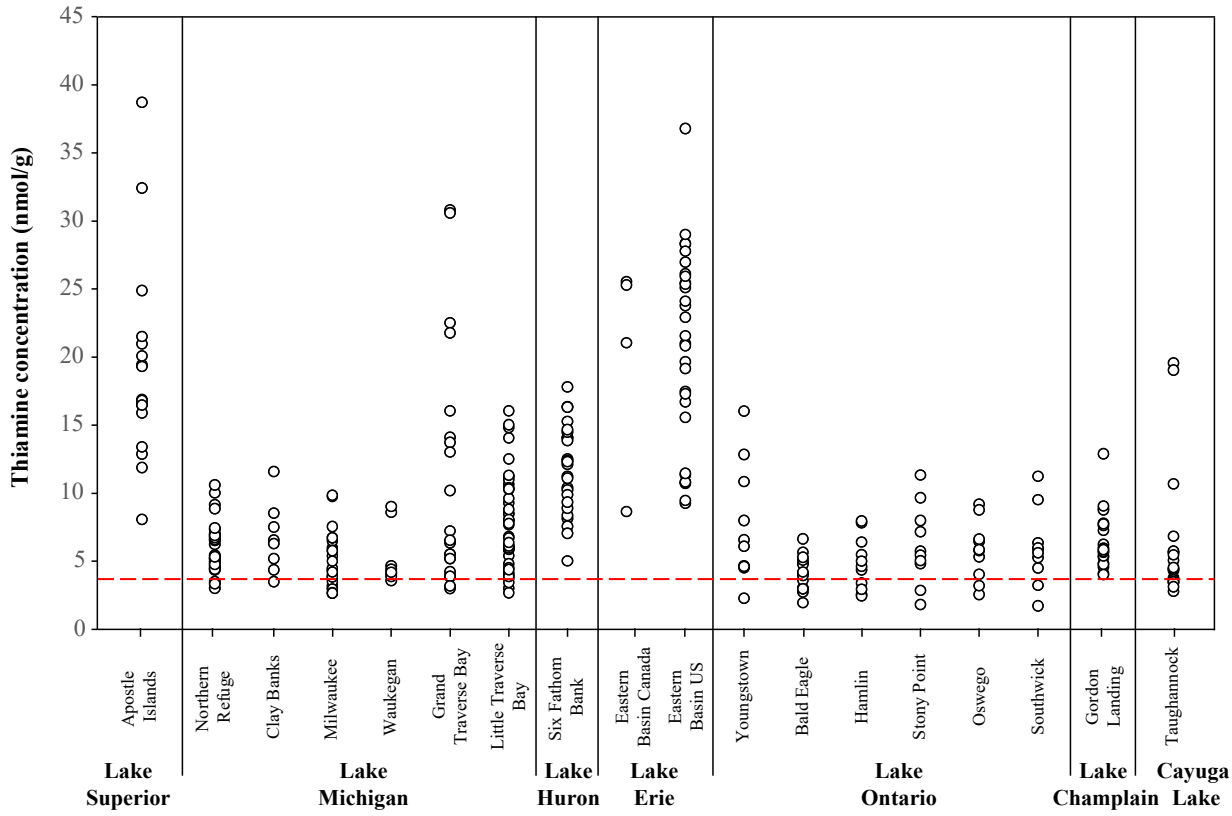

Figure 2: Thiamine concentrations in lake trout eggs (each dot represents a measurement from a separate female) collected in 2022. The dashed red line represents the recommended egg thiamine threshold of 4 nmol/g.

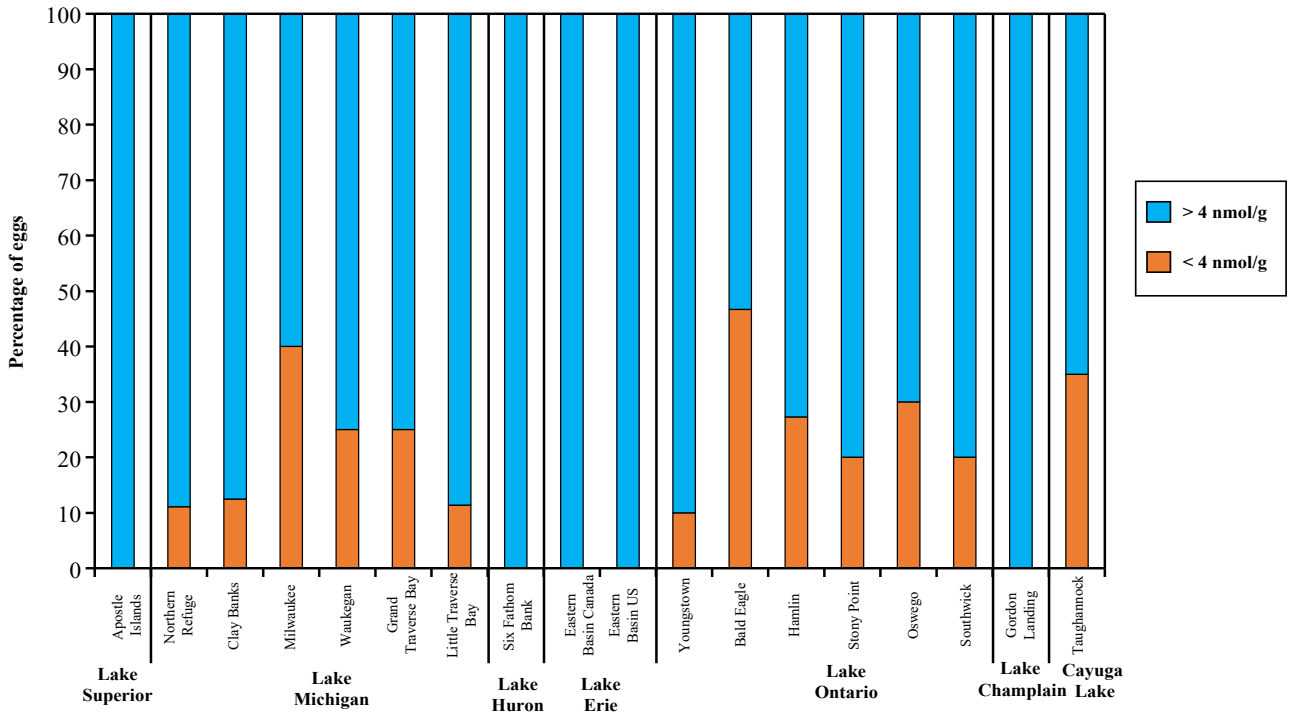

Figure 3: Percentage of females with egg thiamine concentration below (red) or above (green) threshold of 4 nmol/g.

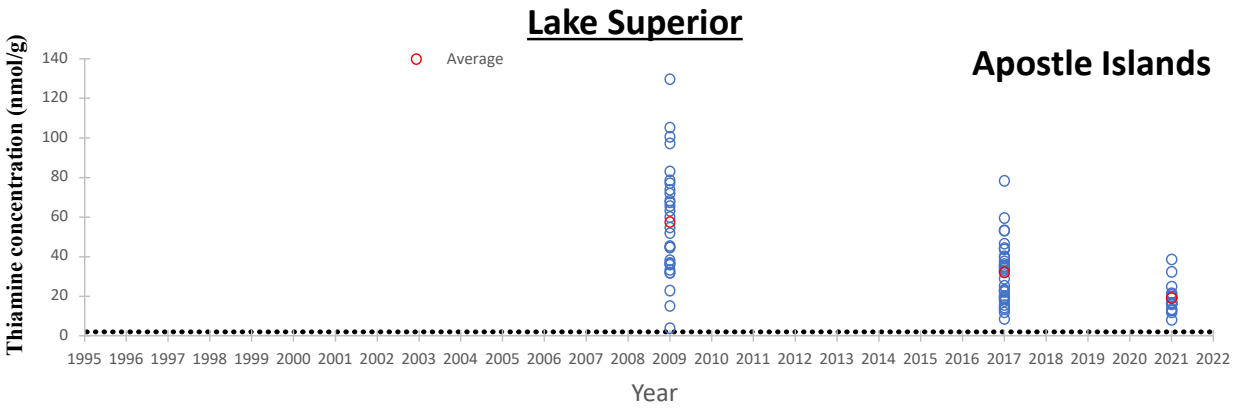

Figure 4: Mean egg thiamine concentration (nmol/g) in lake trout eggs sampling sites in Lake Superior. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g.

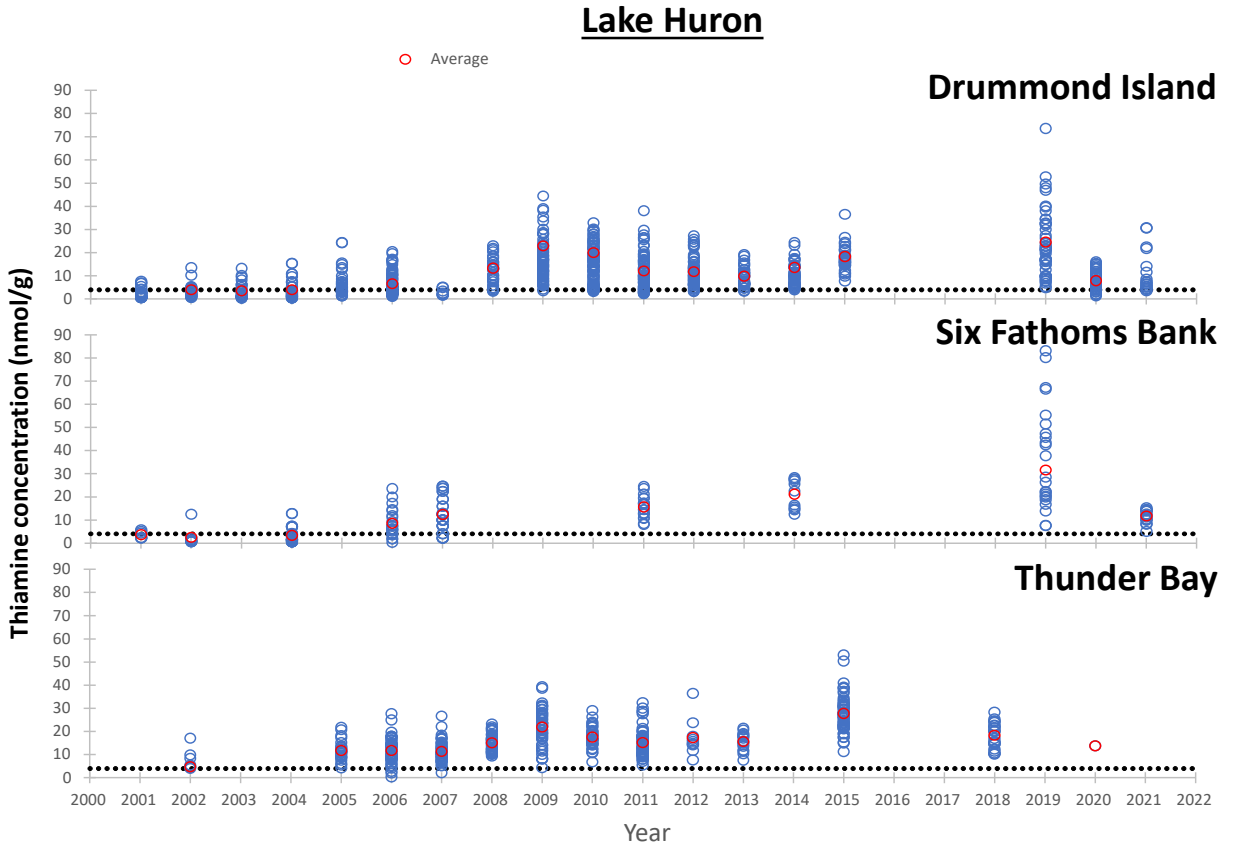

Figure 5: Mean egg thiamine concentration (nmol/g) in lake trout eggs sampling sites in Lake Huron. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g.

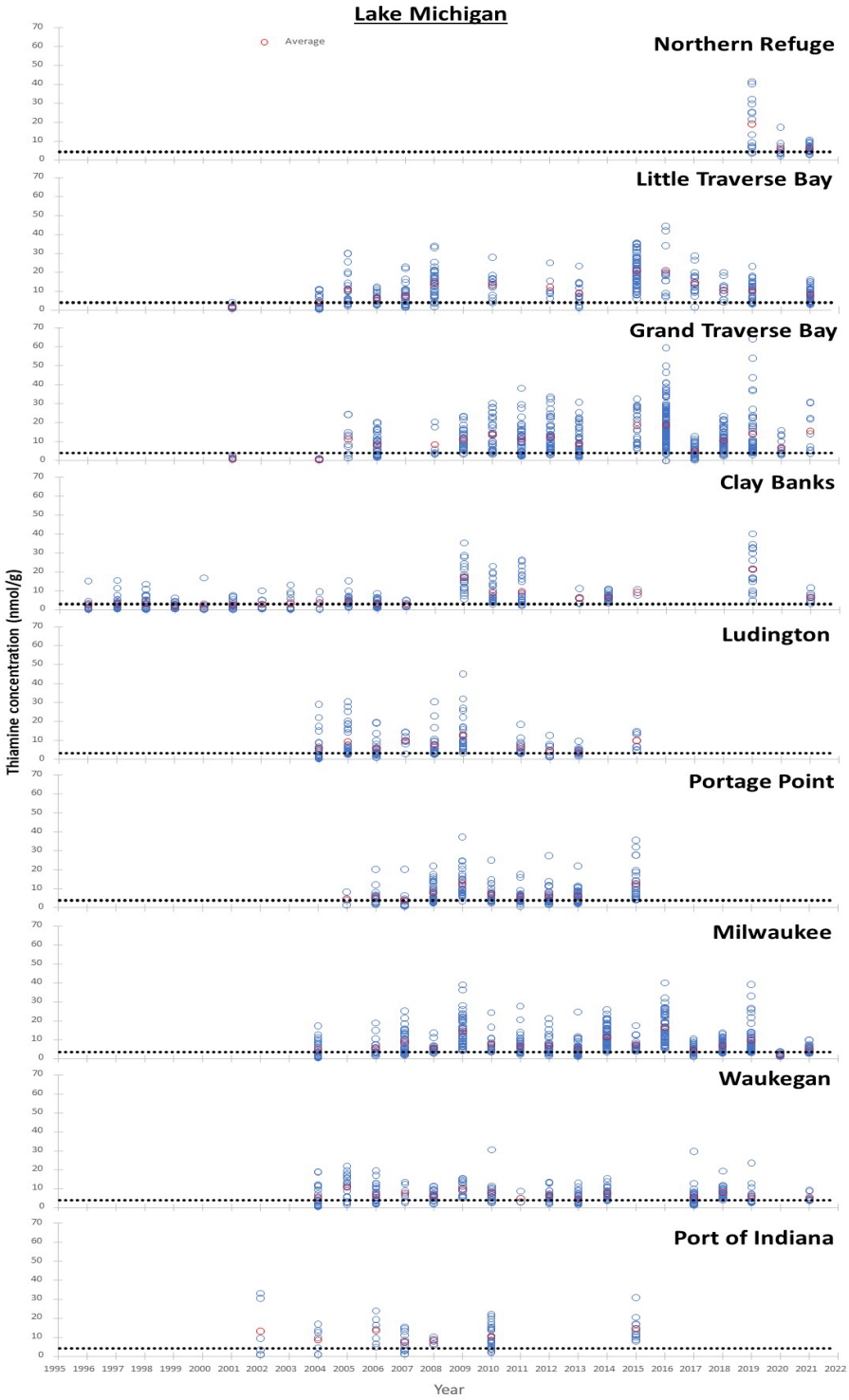

Figure 6: Mean egg thiamine concentration (nmol/g) in lake trout eggs sampling sites in Lake Michigan. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g.

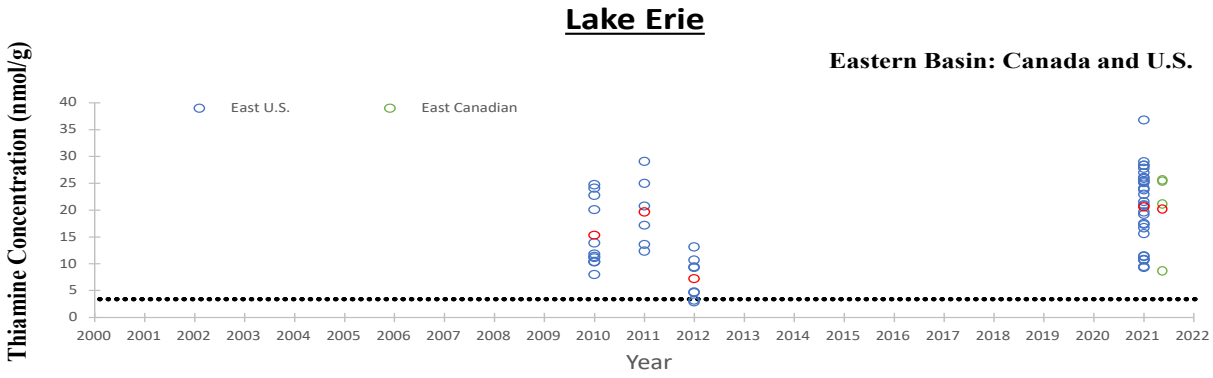

Figure 7: Mean egg thiamine concentration (nmol/g) in lake trout eggs sampling sites in Lake Erie. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g.

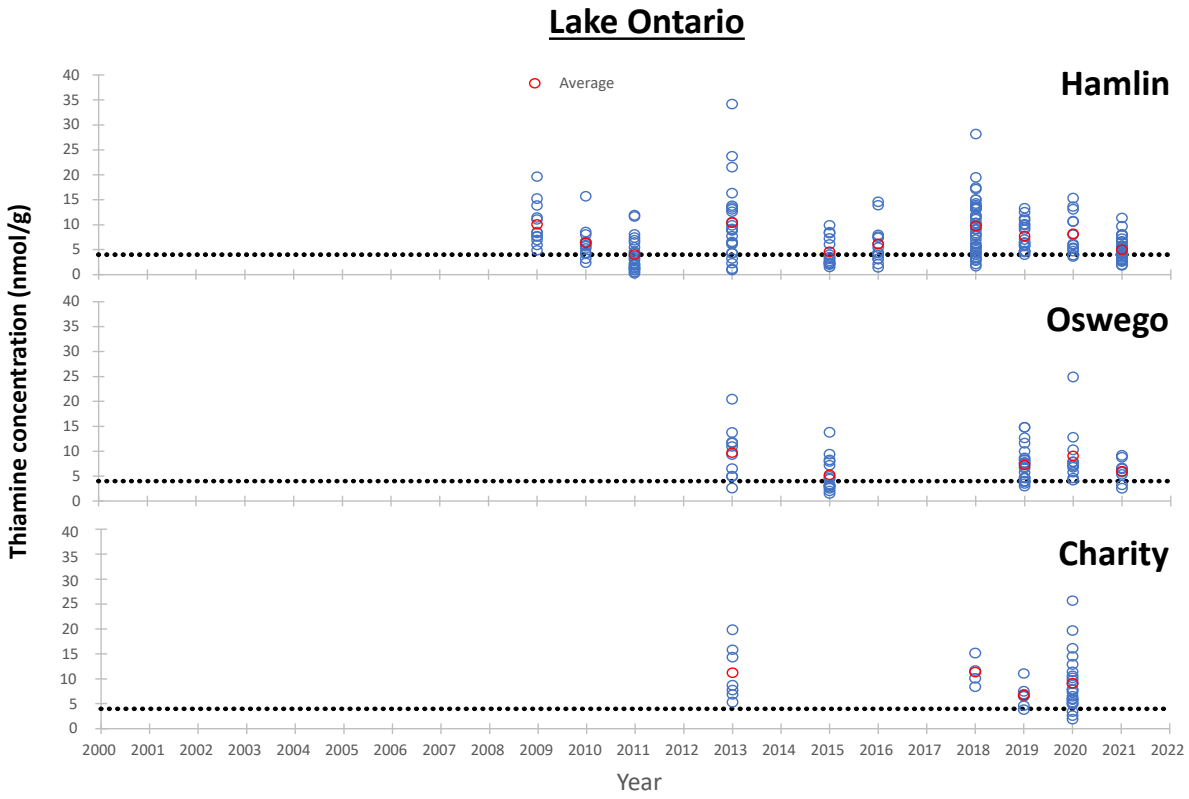

Figure 8: Mean egg thiamine concentration (nmol/g) in lake trout eggs sampling sites in Lake Ontario. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g.

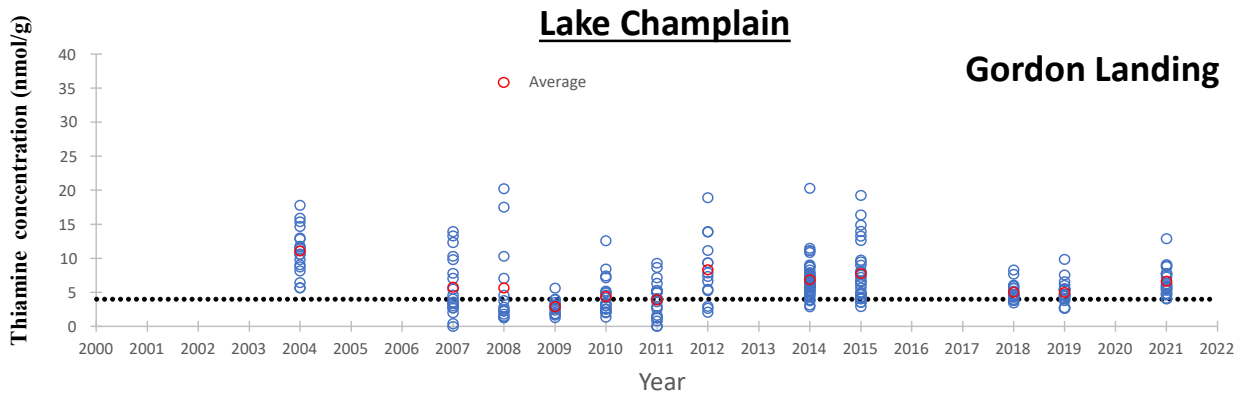

Figure 9: Mean egg thiamine concentration (nmol/g) in lake trout eggs sampling sites in Lake Champlain. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g.

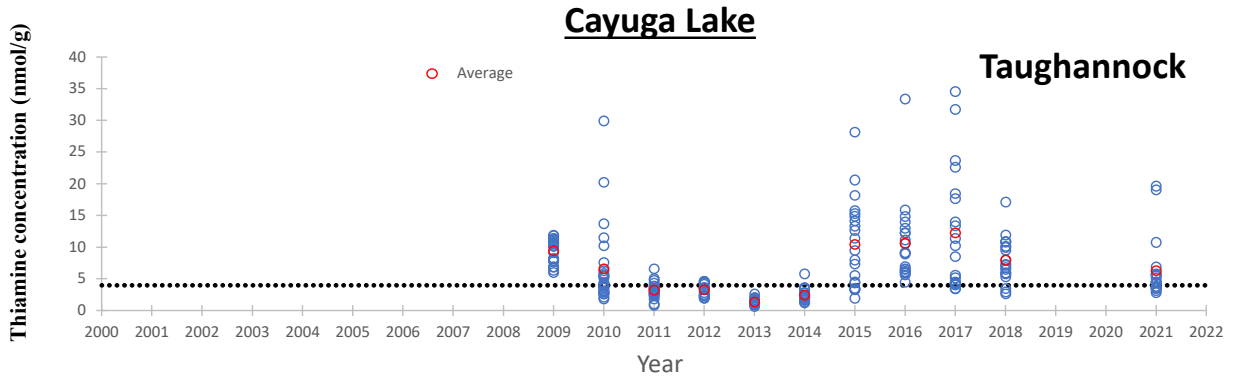

Figure 10: Mean egg thiamine concentration (nmol/g) in lake trout eggs sampling sites in Cayuga Lake. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g.

Table 1: Mean egg thiamine concentration (nmol/g) in lake trout eggs collected in 2022. n = sample size, T = total thiamine concentration, SD = standard deviation, Min = minimum thiamine concentration, Max = maximum thiamine concentration, Below = percentage of egg samples below 4 nmol/g. See Figure 1 for site locations.

Locations	n	T	SD	Min T	Max T	Below
Lake Superior						
Apostle Islands	18	19.05	7.24	8.10	38.73	0
Lake Michigan						
Northern Refuge	27	6.9	1.96	3.04	10.62	11
Clay Banks	8	6.71	2.57	3.51	11.61	13
Milwaukee Reefs	25	5.01	2.03	2.67	9.87	40
Julian and Waukegan Reefs	8	5.32	2.19	3.61	9.04	25
Grand Traverse Bay Band	24	10.27	8.46	3.01	30.82	25
Little Traverse Bay Band	44	7.95	3.42	2.69	16.07	11
Lake Huron						
Six Fathom Bank	25	11.76	3.26	5.04	17.83	0
Lake Erie						
East Canada	4	20.15	7.93	8.67	25.56	0
East US	30	20.65	7.12	9.29	36.80	0
Lake Ontario						
Youngstown	10	7.67	4.32	2.31	16.06	10
Bald Eagle Marina	15	4.14	1.27	1.97	6.66	47
Hamlin	11	4.83	1.96	2.47	7.97	27
Stony Point	10	6.21	2.92	1.85	11.35	20
Oswego	10	5.80	2.16	2.57	9.20	30
Southwick	10	5.95	2.77	1.75	11.26	20
Lake Champlain						
Gordon Landing	20	6.64	2.16	4.05	12.90	0
Cayuga Lake						
Taughannock	20	6.28	4.79	2.81	19.59	35