

**Great Lakes lake trout (*Salvelinus namaycush*) thiamine monitoring  
program annual report**

**Report prepared for the Great Lakes Fishery Health Committee, facilitated by the Great  
Lakes Fishery Commission**

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## **Abstract**

Thiamine deficiency in lake trout (*Salvelinus namaycush*) eggs has been linked to early life-stage mortality in the Great Lakes since the 1960s and has likely contributed to reduced recruitment in some populations. In response, the U.S. Geological Survey's Great Lakes Science Center (GLSC), Eastern Ecological Science Center (EESC), and Columbia Environmental Research Center (CERC), together with the State University of New York (SUNY) Brockport and numerous partner agencies, initiated a cooperative monitoring program in the late 1990s to assess thiamine concentrations in lake trout eggs throughout the Great Lakes region. In 2025, a total of 416 lake trout egg samples were collected from 33 locations across the Great Lakes, Lake Champlain, and the Finger Lakes. Egg thiamine concentrations continued to exhibit substantial spatial variability among lakes and spawning locations. Lake Superior maintained consistently high egg thiamine concentrations, and no females sampled from any site had concentrations below the 4 nmol/g threshold recommended for successful lake trout reproduction. Similarly, all females sampled from Lake Erie exceeded the threshold, although these samples were collected early in oocyte development and likely overestimate concentrations present at spawning. In contrast, varying proportions of females with egg thiamine concentrations below the threshold were observed in Lakes Michigan, Huron, Ontario, Champlain, and the Finger Lakes. The highest prevalence of deficient females occurred in Cayuga and Canandaigua lakes (74–76%), followed by several Lake Michigan spawning locations, including Southern Refuge (50%), Ludington Reef (36%), and Arcadia (32%). In Lake Huron, 35% of females sampled from Parry Sound were below the threshold, representing the first occurrence of deficient females in the monitoring program after several years during which no deficient females were detected in the lake. Lake Ontario exhibited moderate thiamine concentrations overall, but sampling of spawning females at Hamlin revealed

substantially lower concentrations than those observed in fish collected earlier in the season, suggesting that thiamine deficiency risk at spawning may be greater than indicated by summer collections. Long-term monitoring data continue to reveal substantial temporal and spatial variation in lake trout egg thiamine concentrations across the Great Lakes region, emphasizing the importance of continued monitoring to evaluate trends in thiamine status and potential risks to lake trout reproduction and recruitment.

## **Introduction**

Lake trout (*Salvelinus namaycush*) were extirpated from Lakes Michigan, Erie, and Ontario and experienced severe population declines in Lakes Huron and Superior by the 1950s (Muir et al. 2013). In response, extensive rehabilitation efforts have been implemented throughout the Great Lakes since the 1960s (Krueger et al. 1995; Krueger and Ebener 2004). Until recently, natural reproduction of lake trout outside of Lake Superior remained uncommon (e.g., Riley et al. 2007; Hanson et al. 2013; Roseman et al. 2020), suggesting that recruitment failure was a major impediment to recovery. Low survival during early life-stages was documented from the 1960s through the 1990s and was identified as a likely factor limiting successful recruitment (Eshenroder et al. 1984; Harder et al. 2018).

During the 1990s, researchers demonstrated that this early-life mortality could be substantially reduced through thiamine (vitamin B1) supplementation (Fitzsimons 1995), implicating thiamine deficiency as a primary cause. Subsequent studies confirmed that low thiamine concentrations are widespread among lake trout and other salmonines throughout the Great Lakes (e.g., Fitzsimons et al. 2007; Futia et al. 2017; Futia and Rinchard 2019). This condition, known as Thiamine Deficiency Complex (TDC; Riley and Evans 2008) and formerly referred to as Early Mortality Syndrome (EMS), causes mortality during early developmental stages and may also impair growth, performance, and survival of juvenile and adult fish (Brown et al. 2005; Ketola et al. 2009).

Numerous studies have linked TDC to diets dominated by alewife (*Alosa pseudoharengus*), which are rich in both thiaminase and lipids, two dietary characteristics that can contribute to thiamine deficiency in salmonines. Correlative field studies have shown that high alewife consumption is associated with the occurrence of TDC in salmonines (Fitzsimons et al. 2010; Riley

et al. 2011), while laboratory experiments have demonstrated that alewife-rich diets can directly induce thiamine deficiency (Honeyfield et al. 2005). The strongest evidence for this relationship comes from Lake Huron, where the collapse of the alewife population was followed by increased thiamine concentrations in lake trout eggs and a substantial increase in natural recruitment of wild lake trout (Fitzsimons et al. 2010; Riley et al. 2011). These findings support the hypothesis that consumption of alewife, through their high thiaminase activity and lipid content, can contribute to TDC in salmonine populations.

Thiamine Deficiency Complex remains a potential barrier to the successful restoration and natural recruitment of lake trout throughout the Great Lakes. Egg thiamine concentrations greater than 4 nmol/g have been recommended to support successful reproduction and recruitment (Fitzsimons et al. 2007; Bronte et al. 2008). The egg thiamine concentration associated with 20% fry mortality ( $ED_{20}$ ) has been estimated at 2.63 nmol/g (Fitzsimons et al. 2007), whereas sublethal effects, including 20–50% reductions in foraging efficiency and growth, have been observed at egg thiamine concentrations between approximately 3 and 8 nmol/g (Fitzsimons et al. 2009). More recently, Futia and Rinhard (2019) estimated the concentration associated with 50% fry mortality ( $LC_{50}$ ) at 2.32 nmol/g.

To assess the prevalence and severity of thiamine deficiency in Great Lakes lake trout populations, a long-term cooperative monitoring program was established in the late 1990s by the U.S. Geological Survey's Great Lakes Science Center (GLSC), Eastern Ecological Science Center (EESC), Columbia Environmental Research Center (CERC), and the State University of New York (SUNY) Brockport. This effort has involved extensive collaboration among federal, state, provincial, tribal, and academic partners, including the Illinois Department of Natural Resources, Indiana Department of Natural Resources, Michigan Department of Natural Resources, Minnesota

Department of Natural Resources, Wisconsin Department of Natural Resources, Little Traverse Bay Bands of Odawa Indians, Grand Traverse Band of Ottawa and Chippewa Indians, Little River Band of Ottawa Indians, Illinois Natural History Survey, Great Lakes Indian Fish and Wildlife Commission, U.S. Fish and Wildlife Service, New York State Department of Environmental Conservation, University of Vermont, Vermont Fish and Wildlife Department, Chippewa Ottawa Resource Authority, Chippewas of Nawash Unceded First Nation, and the Ontario Ministry of Natural Resources and Forestry. This collaborative program provides a critical foundation for evaluating temporal and spatial trends in lake trout thiamine status and informing restoration and management efforts throughout the Great Lakes basin.

The 2025 data associated with this report are publicly at <https://doi.10.5066/P13KJU8V>. Data used in this report collected prior to 2025 are publicly available (Honeyfield et al. 2020, Tillitt et al. 2021, O'Malley et al. 2024, O'Malley and Rinchar, 2026). 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 (Use of Fishes in Research Committee 2014 <https://fisheries.org/wp-content/uploads/2015/05/Guidelines-for-the-Use-of-Fishes-in-Research-PDF.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 2025, unfertilized lake trout egg samples were collected during fall spawning assessments by partner agencies from sites in Lakes Superior, Michigan, Huron, Erie, Ontario, and Champlain, as well as Cayuga Lake (Figure 1 and Table 1). Egg collections from Lake Champlain and Cayuga Lake are included because both systems contain alewife populations, serve as sources of lake trout for stocking programs in the Great Lakes, and provide useful contrasts to the Great

Lakes with respect to lake size, productivity, natural reproduction, and lake trout strains. This year additional egg samples were also collected from Canandaigua and Keuka lakes.

Eggs collected from individual females at each site were frozen and shipped to SUNY Brockport for thiamine analysis. Free thiamine (TH), thiamine monophosphate (TMP), and thiamine pyrophosphate (TPP) were extracted following the methods of Brown et al. (1998). Briefly, approximately 1 g of eggs (8-10 eggs) was homogenized in a 2% trichloroacetic acid solution. Thiamine vitamers were subsequently quantified using high-performance liquid chromatography (HPLC) according to Brown et al. (1998), with modifications described by Futia et al. (2017). All samples were analyzed in duplicate. For quality assurance and quality control, two method blanks were included after every 15 samples, and a six-point calibration curve (0, 1, 2.5, 5, 10, and 30 nmol/g) was prepared at the beginning of each analytical run.

All thiamine concentrations reported in this report represent total thiamine (TH + TMP + TPP). Results are presented for each sampling site as individual observations, summary statistics (mean, median, minimum, maximum, first quartile, and third quartile), and the estimated proportion of egg samples with total thiamine concentrations below the recommended threshold of 4 nmol/g. Long-term trends in egg thiamine concentrations are also presented for selected sites.

Historical data included in this report were provided by Dale Honeyfield (USGS Eastern Ecological Science Center), Stephen Riley (USGS Great Lakes Science Center), Donald Tillitt (USGS Columbia Environmental Research Center), Ellen Marsden (University of Vermont), and Jacques Rinhard (SUNY Brockport). From 2005 through 2020, thiamine concentrations were measured using the rapid solid-phase extraction fluorometric (RSPE) method developed by Zajicek et al. (2005). Although RSPE-derived concentrations were not adjusted to match HPLC-

derived concentrations in the time-series analyses presented here, the two methods have been shown to be highly correlated (Zajicek et al. 2005; Riley et al. 2011).

## **Results and Discussion**

A total of 416 lake trout egg samples were collected from 33 locations in 2025. Egg thiamine concentrations varied substantially among lakes and sampling locations across the Great Lakes region, Lake Champlain, and the Finger Lakes (Figure 2, Table 1). Concentrations ranged from 4.1–36.4 nmol/g in Lake Superior, 1.4–21.9 nmol/g in Lake Michigan, 2.0–28.5 nmol/g in Lake Huron, 13.9–42.6 nmol/g in Lake Erie, 2.5–23.8 nmol/g in Lake Ontario, 3.7–21.3 nmol/g in Lake Champlain, and 1.2–29.3 nmol/g in the Finger Lakes.

Lake Superior exhibited consistently high thiamine concentrations in lake trout eggs, with site means ranging from 7.4 to 21.7 nmol/g (Figure 2, Table 1). No females sampled from any Lake Superior site had egg thiamine concentrations below the 4 nmol/g threshold recommended for successful lake trout reproduction, indicating a low risk of thiamine deficiency throughout the lake (Figure 3, Table 1). The consistently high thiamine concentrations observed in Lake Superior are likely related, at least in part, to the limited abundance of alewife, a thiaminase and lipid rich prey species strongly associated with thiamine deficiency in salmonids.

Lake Huron exhibited intermediate to high thiamine concentrations in lake trout eggs, with site means ranging from 10.0 to 16.2 nmol/g (Figure 2, Table 1). No females sampled from South Bay or Thunder Bay had egg thiamine concentrations below the deficiency threshold. However, 35% of females collected from Parry Sound were below 4 nmol/g (Figure 3, Table 1). This represents a notable departure from recent years, during which no females sampled from Lake Huron through the monitoring program fell below the deficiency threshold. Although mean thiamine concentrations remained relatively high, the occurrence of deficient females in 2025

suggests that thiamine deficiency risk may be re-emerging in portions of Lake Huron and warrants continued monitoring. The relatively favorable thiamine status observed in lake trout eggs throughout most of Lake Huron is consistent with the collapse of the alewife population that began in 2003, which has been associated with improved thiamine status in salmonines throughout the lake.

Lake Michigan generally exhibited lower thiamine concentrations in lake trout eggs than Lake Superior, with site means ranging from 5.6 to 8.9 nmol/g (Figure 2, Table 1). Several locations contained a substantial proportion of females below the 4 nmol/g threshold, including Southern Refuge (50%), Ludington Reef (36%), and Arcadia (32%), suggesting an elevated risk of thiamine deficiency in portions of the lake (Figure 3, Table 1). Unlike Lake Superior and Lake Huron, alewife continue to be an important component of the forage fish community in Lake Michigan, which may contribute to the lower thiamine concentrations observed in lake trout eggs.

Lake Erie had the highest thiamine concentrations in lake trout eggs observed in 2025 (Figure 2, Table 1). Females collected from the Eastern Basin had a mean egg thiamine concentration of 25.7 nmol/g, and all samples exceeded the 4 nmol/g deficiency threshold (Figure 3, Table 1). The high thiamine concentrations observed in these eggs may, at least in part, reflect differences in the lake trout prey community. Rainbow smelt (*Osmerus mordax*) remains an important prey resource for lake trout in Lake Erie, whereas alewife abundance is comparatively low, which could contribute to higher thiamine availability to lake trout. However, the timing of sampling should also be considered when interpreting these results. Sampling occurred relatively early in the reproductive cycle (late July to early August), and the eggs collected were largely undeveloped. If thiamine is deposited into oocytes early during development, subsequent egg growth and accumulation of yolk constituents could dilute thiamine concentrations on a mass

basis. Consequently, measured thiamine concentrations (nmol/g) may decline as eggs increase in size during vitellogenesis, even if the total amount of thiamine per egg remains relatively unchanged. Consistent with this possibility, thiamine concentrations measured in eggs at spawning were substantially higher than those reported several months earlier, suggesting that egg developmental stage and associated changes in egg composition may influence thiamine concentrations on a mass basis. Thus, although the high thiamine concentrations observed in Lake Erie eggs may reflect favorable prey availability, they may also be influenced by the early developmental stage of the eggs and the timing of sampling. Direct comparisons with samples collected closer to spawning in other lakes should therefore be interpreted with caution.

Lake Ontario exhibited moderate egg thiamine concentrations in lake trout eggs, with site means ranging from 6.0 to 10.6 nmol/g (Figure 2, Table 1). Similar to Lake Erie, most samples were collected in August, well before spawning, when eggs were still relatively undeveloped. If thiamine is deposited into oocytes early during development, subsequent egg growth and accumulation of yolk constituents could dilute thiamine concentrations on a mass basis. Consequently, thiamine concentrations measured in these samples may overestimate concentrations present at spawning if dilution occurs during egg maturation. Alewife remains an important component of the forage fish community in Lake Ontario and may contribute to the relatively low thiamine concentrations observed in lake trout eggs. Considerable variation was observed among lake trout eggs collected from Lake Ontario sites. Eggs collected from females at Hamlin exhibited one of the widest ranges in thiamine concentrations (2.6–17.6 nmol/g), likely reflecting, at least in part, differences in the timing of sample collection. While most females were sampled in August, six females were collected during the spawning season. Among these spawning females, three (50%) had egg thiamine concentrations below the 4 nmol/g threshold, and the mean

concentration was only  $3.8 \pm 1.2$  nmol/g. These values were substantially lower than the overall site mean of  $8.1 \pm 5.1$  nmol/g and suggest that thiamine status at spawning may be considerably poorer than indicated by samples collected earlier in oocyte development. This observation is consistent with the hypothesis that egg thiamine concentrations may decline during egg maturation and highlights the importance of sampling fish as close to spawning as possible when assessing thiamine deficiency risk.

Lake Champlain lake trout eggs had a mean thiamine concentration of 7.7 nmol/g, with 9% of females below the deficiency threshold (Figures 2 and 3, Table 1). The moderate thiamine levels observed in Lake Champlain are also consistent with lake trout diet composition in this system, where alewife represents an important component of the forage base.

The Finger Lakes exhibited some of the lowest thiamine concentrations in lake trout eggs observed in the study. Mean concentrations in Cayuga Lake and Canandaigua Lake were 4.7 and 4.0 nmol/g, respectively, and 74–76% of females had egg thiamine concentrations below the 4 nmol/g deficiency threshold, indicating a high risk of thiamine deficiency in these populations (Figures 2 and 3, Table 1). In contrast, lake trout eggs from Keuka Lake exhibited substantially higher thiamine concentrations, with a mean concentration of 20.3 nmol/g and no females below the deficiency threshold (Figures 2 and 3, Table 1). The elevated thiamine concentrations observed in Keuka Lake may be related to recent changes in the forage fish community. Specifically, a collapse of the alewife population has been documented in Keuka Lake in recent years. Because alewife is a thiaminase and lipid rich prey species strongly associated with thiamine deficiency in salmonids, the reduced availability of alewife may have decreased dietary thiaminase exposure for lake trout, resulting in improved thiamine status. However, it is important to note that lake trout populations in Keuka Lake have not consistently exhibited low egg thiamine concentrations when

alewife were present (Fitzsimons et al., 2005). Consequently, while the decline of alewife in Keuka Lake is a plausible contributing factor, it may not be the sole driver of the elevated egg thiamine concentrations observed. In contrast, alewife remain the dominant forage fish in both Cayuga and Canandaigua lakes, where lake trout continue to exhibit low egg thiamine concentrations and a high prevalence of females below the deficiency threshold. These observations are consistent with the long-established relationship between alewife consumption and thiamine deficiency in salmonid populations and suggest that forage fish community composition remains an important driver of lake trout thiamine status in the Finger Lakes.

Figures 4 through 9 present time series of egg thiamine concentrations (nmol/g), including individual observations and site-level means for lake trout collected from selected locations in Lakes Michigan, Erie, Ontario, Champlain, and Cayuga. Together, these figures highlight pronounced spatial and temporal variability in thiamine status across the Great Lakes basin. Continued annual monitoring remains essential to evaluate trends in egg thiamine concentrations and to assess potential implications of TDC for lake trout recruitment dynamics.

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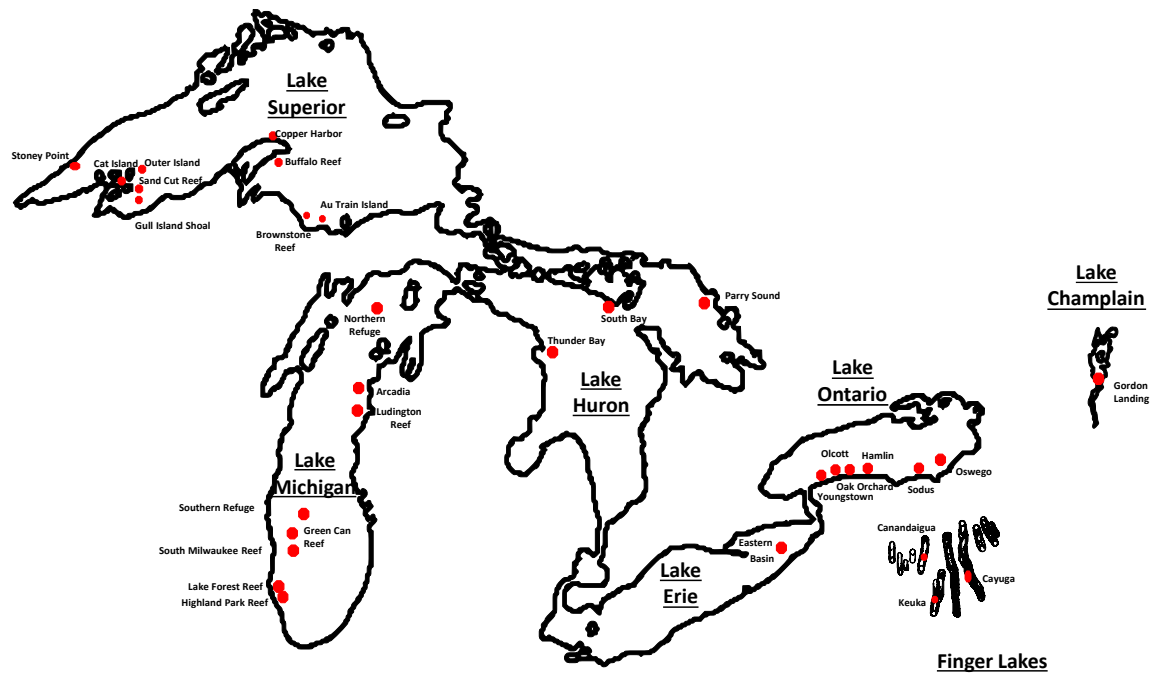


Figure 1: Lake trout (*Salvelinus namaycush*) egg sampling sites in 2025. A total of 416 egg samples were collected in 2025 throughout the Great Lakes region.

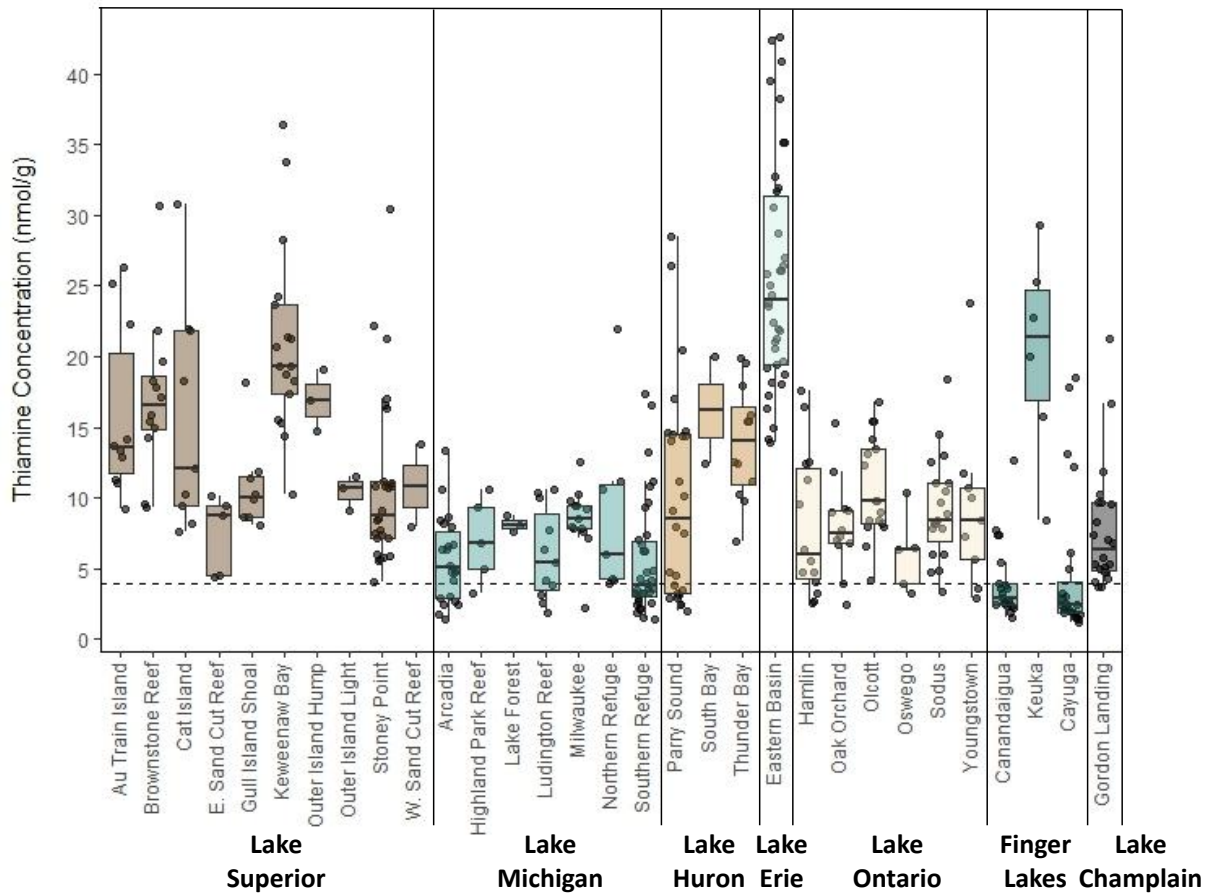


Figure 2: Thiamine concentrations in lake trout (*Salvelinus namaycush*) eggs (each color dot represents a measurement from a separate female, box plot with minimum, maximum, median, first and third quartiles) collected in 2025 at 33 locations across 9 lakes within the Great Lakes region. Milwaukee includes Green Can Reef and South Milwaukee Reef. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008).

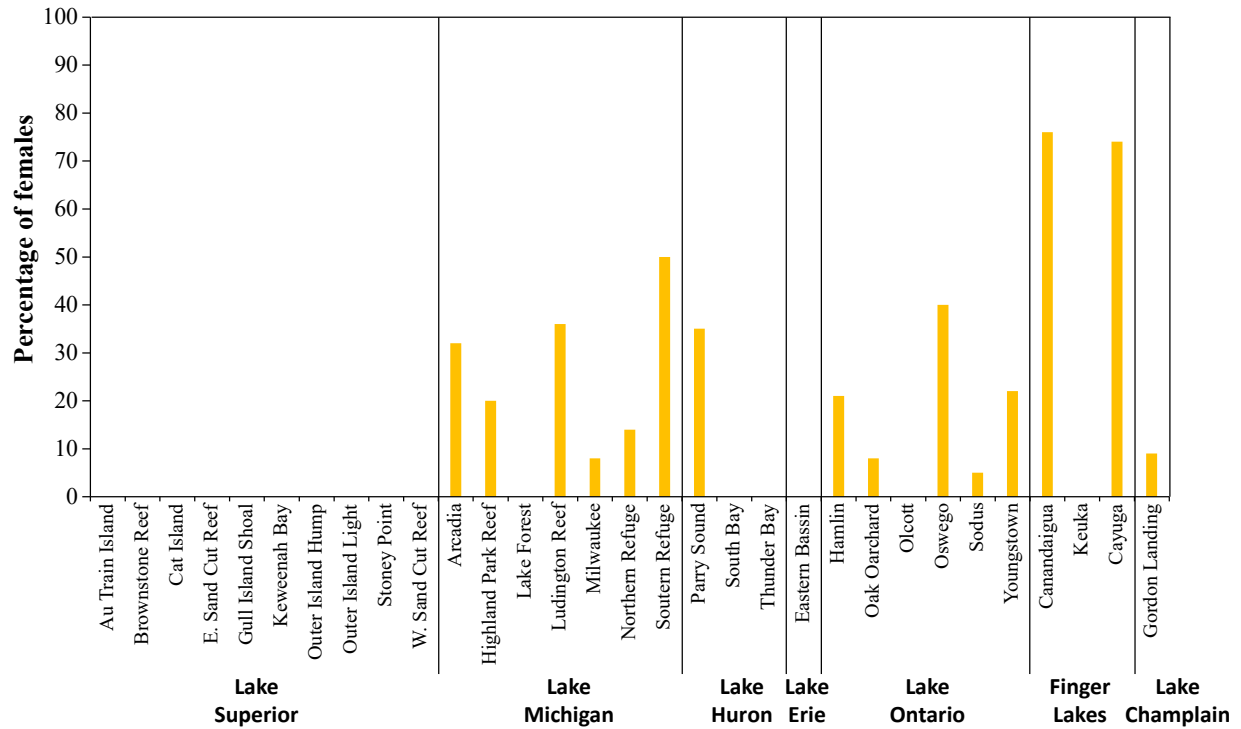


Figure 3: Percentage of lake trout (*Salvelinus namaycush*) females collected in 2025 at 33 locations across 9 lakes within the Great Lakes region with egg thiamine concentration below the recommended threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008). Milwaukee includes Green Can Reef and South Milwaukee Reef.

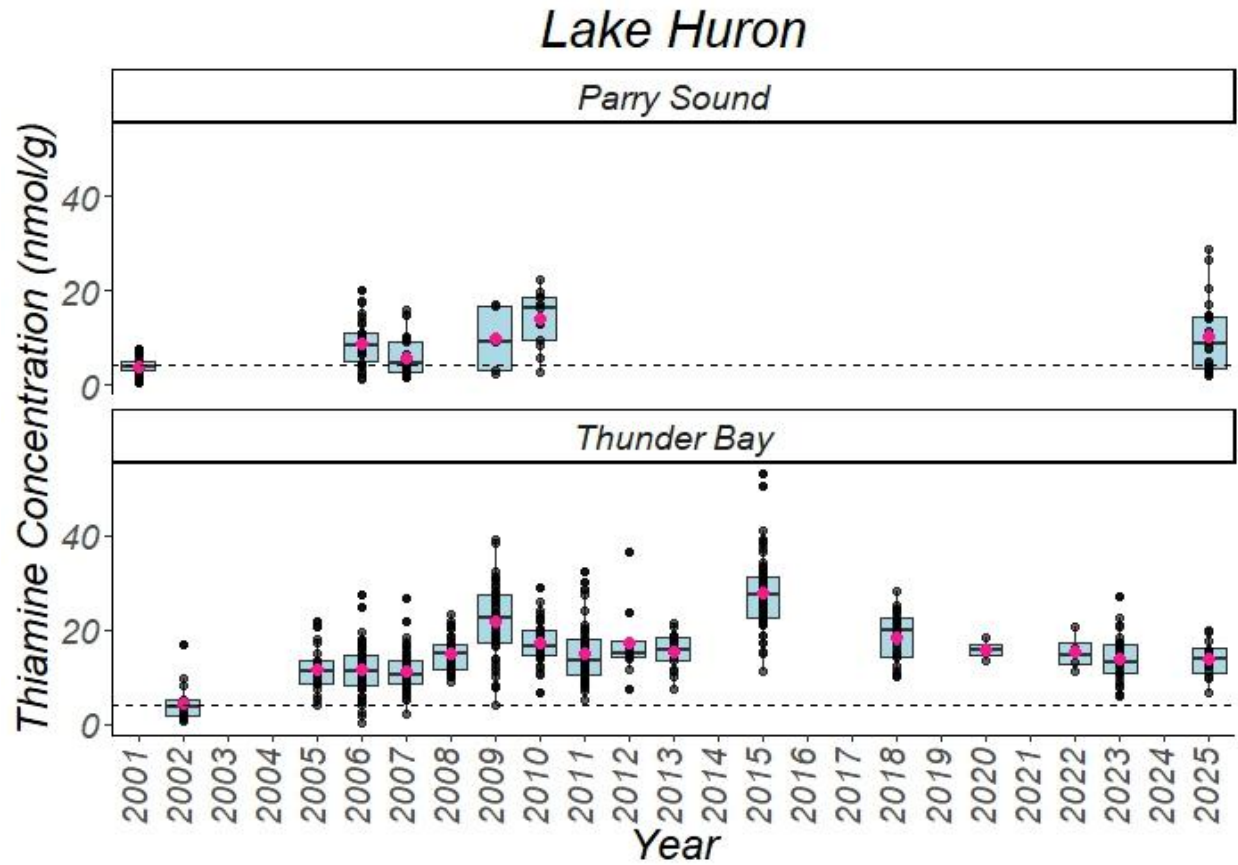


Figure 4: Thiamine concentrations in lake trout (*Salvelinus namaycush*) eggs (each black dot represents a measurement from a separate female, box plot with mean (pink dot), minimum, maximum, median, first and third quartiles) at 2 sampling sites in Lake Huron from 2001 to 2025. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008).

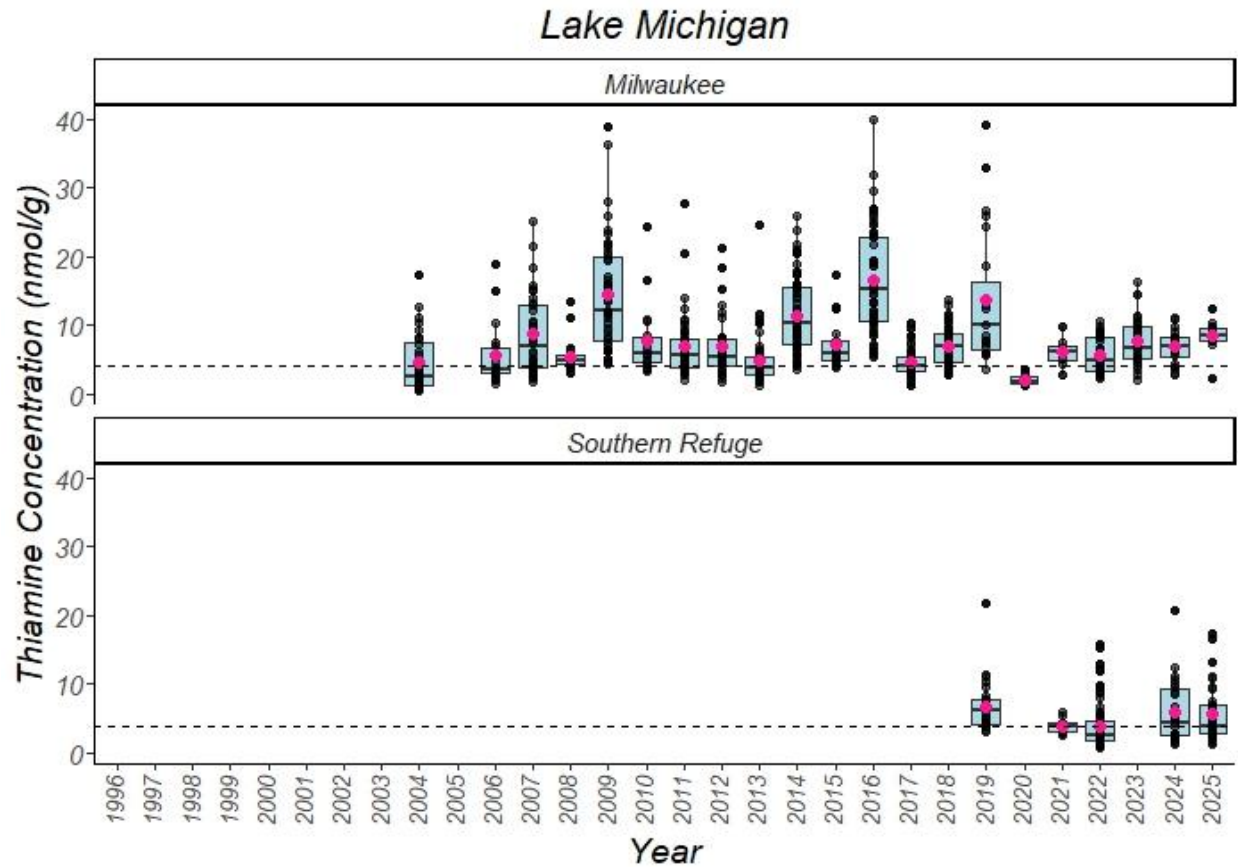


Figure 5: Thiamine concentrations in lake trout (*Salvelinus namaycush*) eggs (each black dot represents a measurement from a separate female, box plot with mean (pink dot), minimum, maximum, median, first and third quartiles) at 2 sampling sites in Lake Michigan from 1996 to 2025. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008).

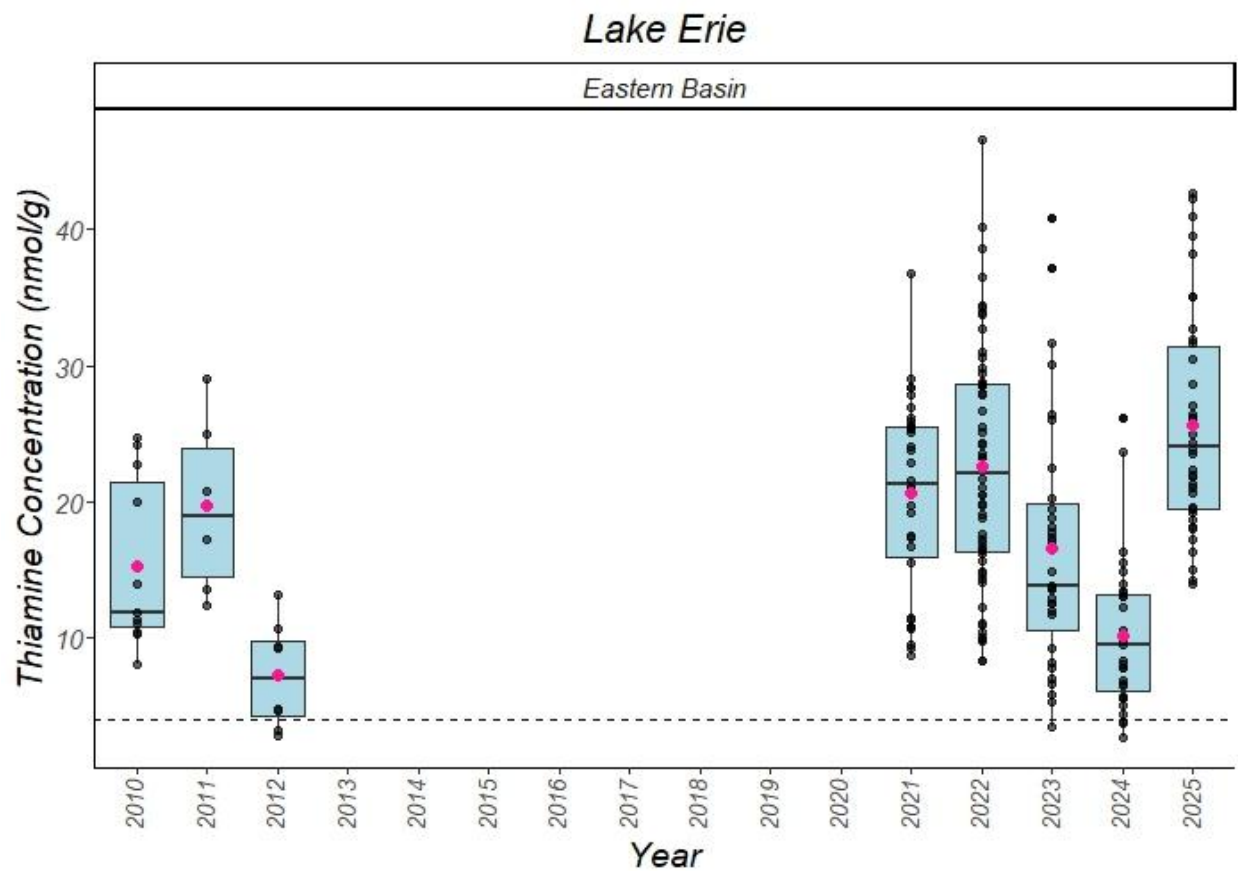


Figure 6: Thiamine concentrations in lake trout (*Salvelinus namaycush*) eggs (each black dot represents a measurement from a separate female, box plot with mean (pink dot), minimum, maximum, median, first and third quartiles) in the eastern basin of Lake Erie from 2010 to 2025. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008).

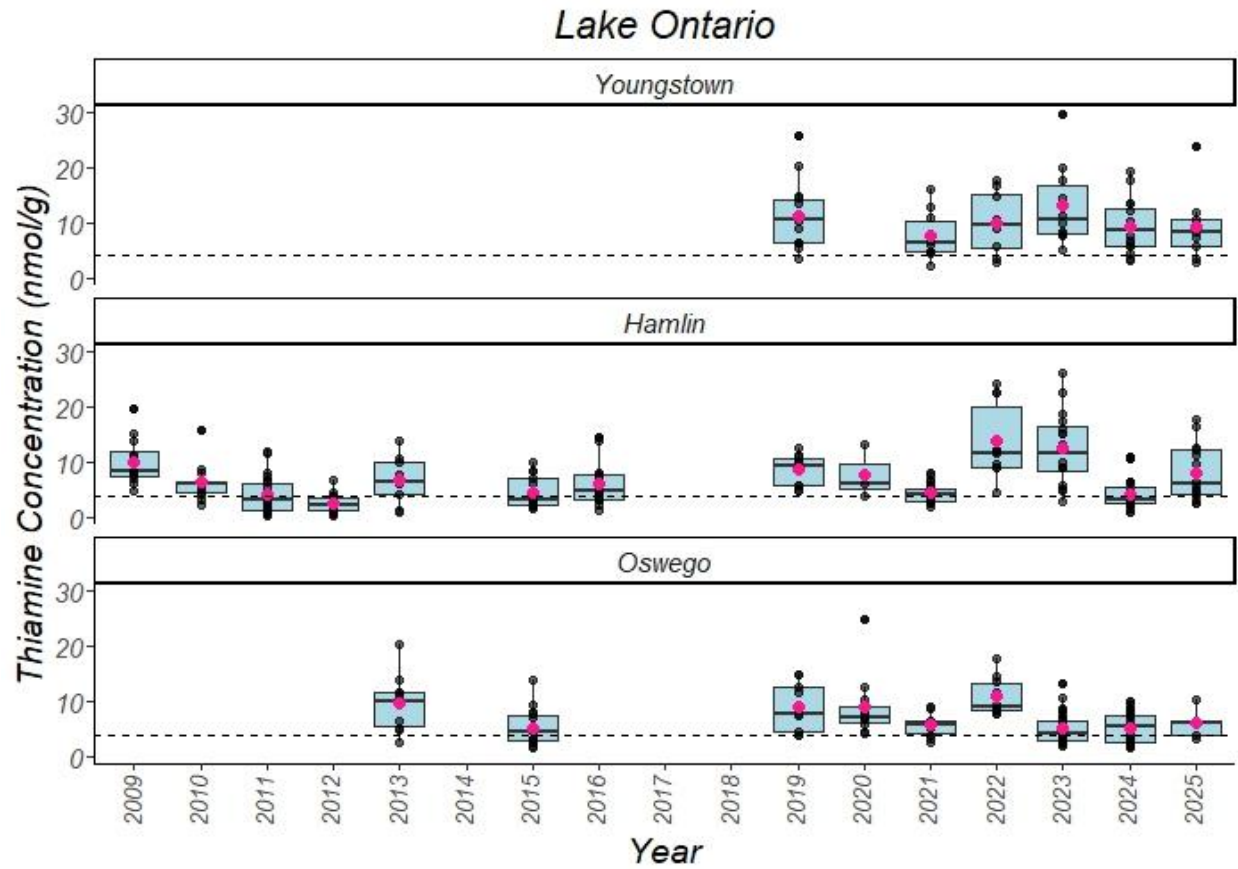


Figure 7: Thiamine concentrations in lake trout (*Salvelinus namaycush*) eggs (each black dot represents a measurement from a separate female, box plot with mean (pink dot), minimum, maximum, median, first and third quartiles) at 3 sampling sites in Lake Ontario from 2009 to 2025. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008).

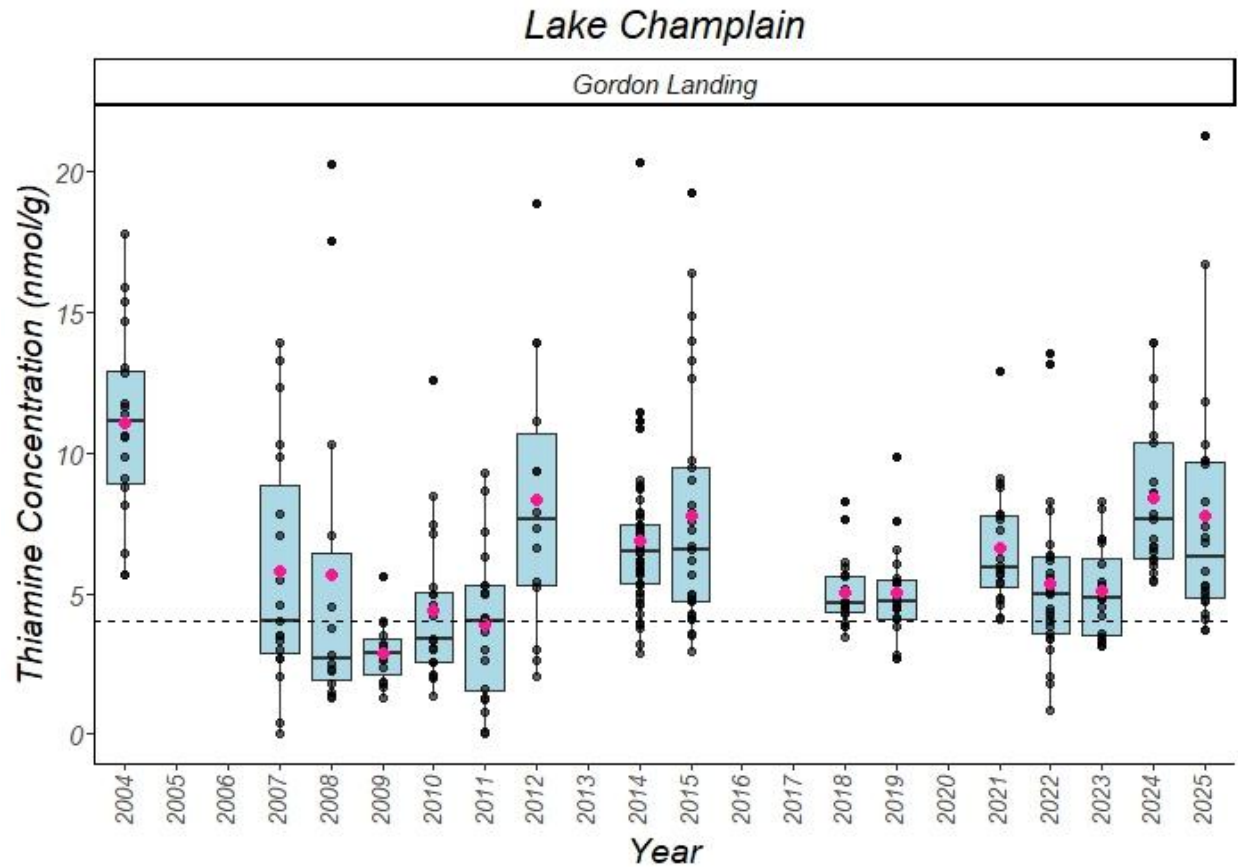


Figure 8: Thiamine concentrations in lake trout (*Salvelinus namaycush*) eggs (each black dot represents a measurement from a separate female, box plot with mean (pink dot), minimum, maximum, median, first and third quartiles) at 1 sampling site in Lake Champlain from 2004 to 2025. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008).

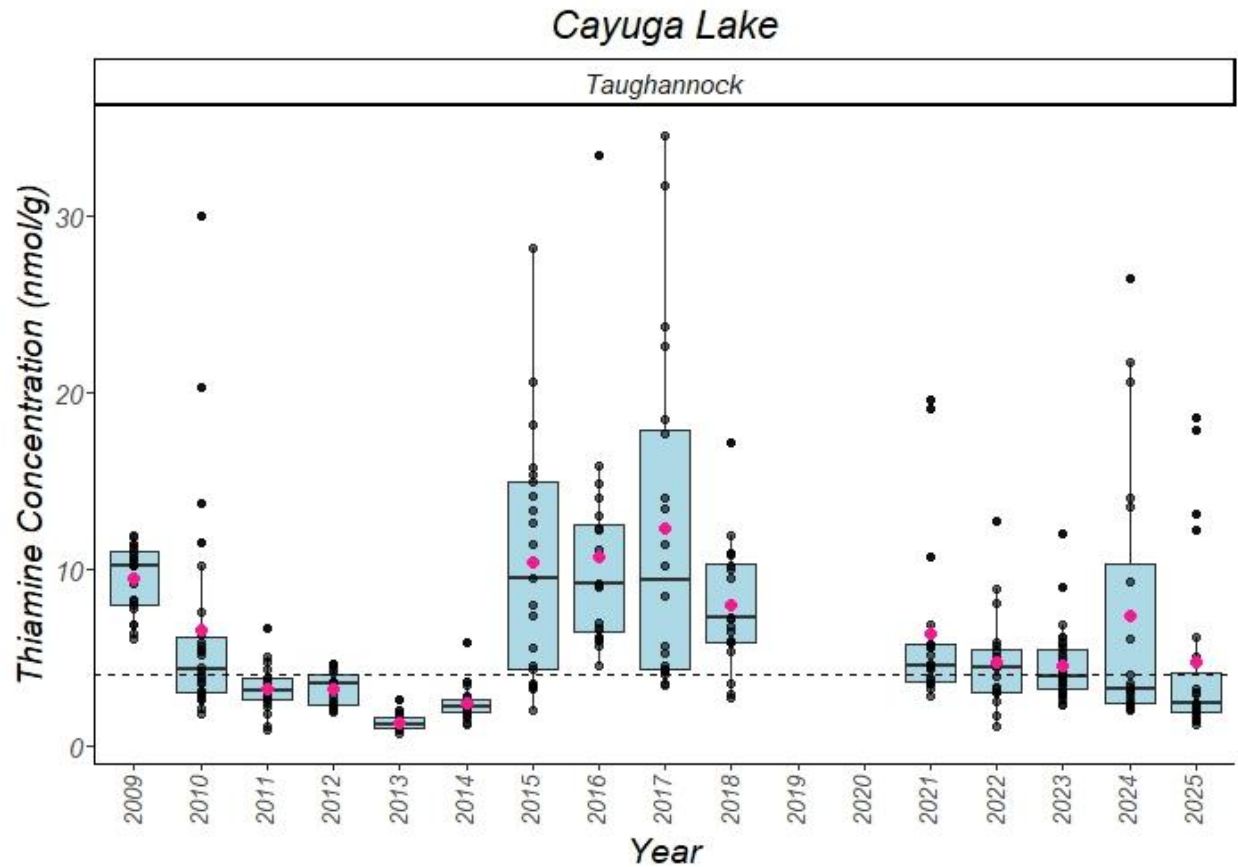


Figure 9: Thiamine concentrations in lake trout (*Salvelinus namaycush*) eggs (each black dot represents a measurement from a separate female, box plot with mean (pink dot), minimum, maximum, median, first and third quartiles) at 1 sampling site in Cayuga Lake from 2009 to 2025. The dashed black line represents the recommended egg thiamine threshold of 4 nmol/g for successful lake trout recruitment (Bronte et al. 2008).

Table 1: Lake trout (*Salvelinus namaycush*) mean egg thiamine concentration (nmol/g) collected in 2025 at 33 sampling sites across 9 lakes within the Great Lakes region. n = sample size, T = mean total thiamine concentration, SD = standard deviation, Min T = minimum thiamine concentration, Max T = maximum thiamine concentration. Refer to Figure 1 for site locations.

| Locations                                      | n  | T    | SD  | Min T | Max T | % Females<br>< 4 nmol/g |
|------------------------------------------------|----|------|-----|-------|-------|-------------------------|
| <u>Lake Superior</u>                           |    |      |     |       |       |                         |
| Stoney Point                                   | 26 | 11.0 | 6.2 | 4.1   | 30.4  | 0                       |
| Buffalo Reef (Keweenaw Bay)                    | 13 | 20.9 | 7.6 | 10.3  | 36.4  | 0                       |
| Copper Harbor (Keweenaw Bay)                   | 4  | 21.7 | 2.8 | 18.3  | 24.2  | 0                       |
| E. Sand Cut Reef                               | 5  | 7.4  | 2.8 | 4.3   | 10.2  | 0                       |
| W. Sand Cut Reef                               | 2  | 10.9 | 4.2 | 7.9   | 13.8  | 0                       |
| Cat Island                                     | 9  | 15.6 | 8.0 | 7.7   | 30.7  | 0                       |
| Outer Island Hump                              | 3  | 17.6 | 6.2 | 14.7  | 19.1  | 0                       |
| Outer Island Light                             | 3  | 13.1 | 4.3 | 9.1   | 11.5  | 0                       |
| Gull Island Shoal                              | 8  | 10.8 | 3.2 | 8.0   | 18.1  | 0                       |
| Au Train Island                                | 10 | 15.9 | 6.2 | 9.2   | 26.3  | 0                       |
| Brownstone Reef                                | 12 | 17.1 | 5.6 | 9.3   | 30.7  | 0                       |
| <u>Lake Michigan</u>                           |    |      |     |       |       |                         |
| Northern Refuge (Boulder Reef and High Island) | 7  | 8.9  | 6.5 | 3.9   | 21.9  | 14                      |
| Milwaukee (Green Can/South Milwaukee Reefs)    | 13 | 8.4  | 2.4 | 2.2   | 12.5  | 8                       |
| Southern Refuge (East Reef)                    | 34 | 5.6  | 4.1 | 1.4   | 17.4  | 50                      |
| Lake Forest                                    | 3  | 8.2  | 0.6 | 7.6   | 8.8   | 0                       |
| Highland Park Reef                             | 5  | 7.0  | 3.0 | 3.3   | 10.6  | 20                      |
| Ludington Reef                                 | 11 | 6.0  | 3.2 | 1.9   | 10.6  | 36                      |
| Arcadia                                        | 22 | 5.6  | 3.1 | 1.4   | 13.4  | 32                      |
| <u>Lake Huron</u>                              |    |      |     |       |       |                         |
| Parry Sound                                    | 26 | 10.0 | 7.5 | 2.0   | 28.5  | 35                      |
| South Bay                                      | 2  | 16.2 | 5.3 | 12.4  | 20.0  | 0                       |
| Thunder Bay                                    | 12 | 14.0 | 4.1 | 6.9   | 19.9  | 0                       |
| <u>Lake Erie</u>                               |    |      |     |       |       |                         |
| Eastern Basin                                  | 38 | 25.7 | 8.1 | 13.9  | 42.6  | 0                       |
| <u>Lake Ontario</u>                            |    |      |     |       |       |                         |
| Youngstown                                     | 9  | 9.3  | 6.2 | 2.9   | 23.8  | 22                      |
| Olcott                                         | 17 | 10.6 | 3.6 | 4.2   | 16.8  | 0                       |
| Oak Orchard                                    | 12 | 8.0  | 3.3 | 2.5   | 15.3  | 8                       |
| Hamlin                                         | 14 | 8.1  | 5.1 | 2.6   | 17.6  | 21                      |
| Sodus                                          | 19 | 9.2  | 3.7 | 3.4   | 18.4  | 5                       |
| Oswego                                         | 5  | 6.0  | 2.8 | 3.2   | 10.4  | 40                      |
| <u>Lake Champlain</u>                          |    |      |     |       |       |                         |
| Gordon Landing                                 | 22 | 7.7  | 4.4 | 3.7   | 21.3  | 9                       |
| <u>Finger Lakes</u>                            |    |      |     |       |       |                         |
| Cayuga Lake                                    | 23 | 4.7  | 5.3 | 1.2   | 18.5  | 74                      |
| Canandaigua Lake                               | 21 | 4.0  | 2.7 | 1.5   | 12.7  | 76                      |
| Keuka Lake                                     | 6  | 20.3 | 7.4 | 8.4   | 29.3  | 0                       |