A Plan to Support Lake Trout Rehabilitation in Lake Erie, 2021-2030

Lake Erie Committee
Great Lakes Fishery Commission
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Table of Contents

1 **Introduction**

Lake Erie is a cool-water lake dominated by a percid fish community (Francis et al. 2020). Historically, native cold-water fishes such as Lake Trout (*Salvelinus namaycush*), Lake Whitefish (*Coregonus clupeaformis*) and Cisco (*Coregonus artedi*) supported commercial fisheries (Hartman 1972) and were important components of the ecosystem. Lake Trout were the dominant cold-water predator in the eastern basin and utilized both benthic and pelagic resources, providing a stabilizing influence on the fish community (Bronte et al. 2007). By 1965, commercial fishing, eutrophication and exotic species invasions are thought to have led to the extirpation of native Lake Trout from Lake Erie (Cornelius et al. 1995; Hartman 1972).

Lake Trout are an excellent indicator of overall ecosystem health (Edwards et al. 1990) and can provide a stabilizing effect which can ultimately improve ecosystem resilience (Ritchie et al. 2012). Lake Trout rehabilitation efforts began on Lake Erie in 1969, were formalized in 1985 (Lake Trout Task Group 1985a) and continue to be a priority (Francis et al. 2020). In the Fish Community Objectives for the Lake Erie Basin (Francis et al. 2020), the Lake Erie Committee (LEC) states the following rehabilitation objective: Establish a Lake Trout population consistent with a functional cold-water ecosystem that maintains a fishery in the eastern and central basins. The status indicator is to maintain viable adult spawning-stock biomass, as measured by survey catch per effort (see Markham et al. 2008) while maintaining and expanding existing fishing opportunities with a goal of documenting evidence of natural reproduction (Francis et al. 2020). The LEC coordinates rehabilitation efforts through the Coldwater Task Group (CWTG), in support of the LEC Fish Community Objectives. Lake Trout rehabilitation is an ambitious goal because the species is long-lived (20+ years), matures at a late age (5-10 years) and has narrow spawning requirements (Bronte et al. 2007; Scott and Crossman 1998). In addition, Lake Erie is at the southern extent of Lake Trout's native range. Increases in annual average temperature and precipitation, and reduced ice cover as a result of climate change could exacerbate the stress on the population impeding Lake Trout rehabilitation (Hayhoe et al. 2010; Kling et al. 2017).

The current management plan for Lake Trout, *A Strategic Plan for the Rehabilitation of Lake Trout in Lake Erie, 2008-2020* (Markham et al. 2008) has led to the recent achievements of (1) desired spawning stock abundance of stocked Lake Trout (i.e. adult (age 5+) and large (>4500g) adult females) and (2) Lake Trout demographics (i.e. >10 age classes present) (Appendix , Table 1). While the overall Lake Trout abundance target was not met, a recent evaluation of the targets revealed that this metric was not strictly measurable in the Coldwater Assessment Survey (CWA) due to younger Lake Trout being underrepresented in fisheries assessment surveys. Targets associated with egg densities and wild yearling production were not assessed over the duration of the plan (Appendix, Table 1). Natural reproduction had not been detected until 2021 when a small number of YOY fish were captured in a spring survey. Since 2008, 58 untagged/unclipped Lake Trout of unknown origin have been caught in assessment gillnets.

The reintroduction trajectory for Lake Trout in Lake Erie is a series of transitions through life stages, each with unique limitations that may impede rehabilitation efforts (Figure 1). Understanding bottlenecks (if any) at each transition will provide the LEC with the opportunity to address/remove the impediment or adjust the management objectives and actions.

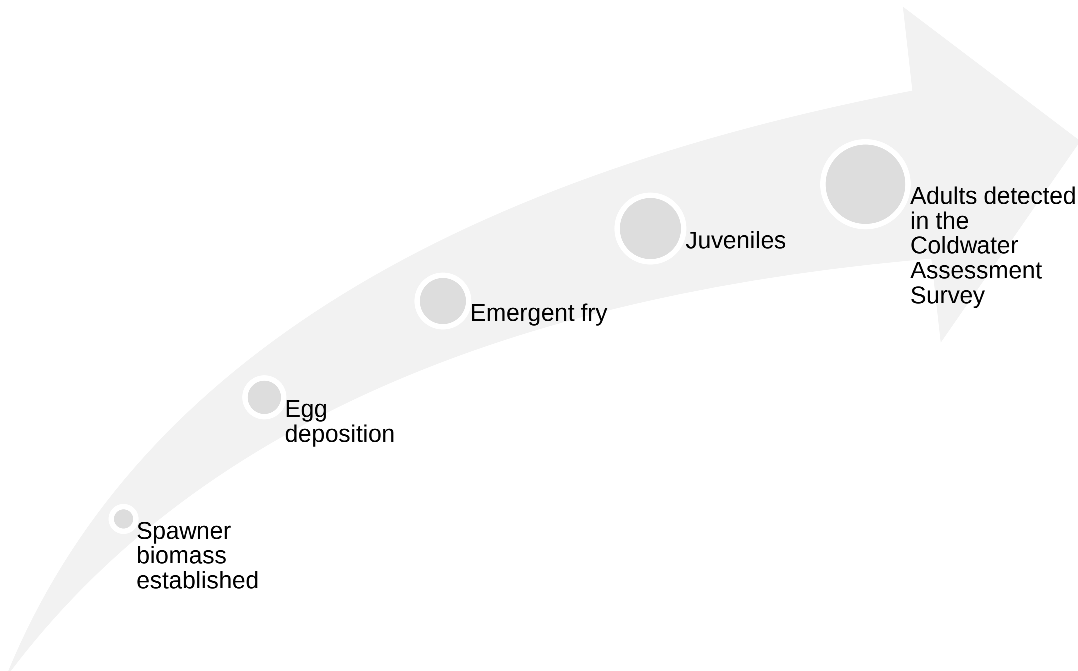

Figure 1: Reintroduction trajectory for Lake Trout in Lake Erie. When the first generation (F1) of naturally produced adults are detected at the last step, this trajectory will repeat, starting with F1 spawners instead of stocked Lake Trout.

This plan (2021-2030) will: (1) use information from previous work to maintain desired stocked adult Lake Trout abundance (i.e., support the first step in the reintroduction trajectory), and (2) provide guidance to better identify life history bottlenecks to the achievement of long-term rehabilitation goals.

2 Management Actions for Continued Maintenance of Stocked Lake Trout Abundance

Insights and approaches developed during thirty-five years of Lake Trout rehabilitation efforts on Lake Erie have been successful in the achievement of desired stocked adult Lake Trout abundance. Therefore, the over arching goal as described by Markham et al. (2008) has been met. The objective of maintaining stocked Lake Trout abundance is to establish a sufficient density of spawning aged fish to initiate natural reproduction. This section describes management actions for maintaining the adult abundance of stocked Lake Trout and establishes key, measurable performance indicators.

A. <u>Consistent and effective Sea Lamprey control</u>

Excessive mortality of adults inhibits the re-establishment of populations of long-lived species such as Lake Trout (Bronte et al. 2007; Mills et al. 2002). Sea Lamprey (*Petromyzon marinus*) control began on Lake Erie in 1986 (Lake Trout Task Group 1985b), and the Lake Trout abundance changes associated with changes in the Sea Lamprey Control Program indicate the importance of a targeted and consistent treatment schedule for reducing mortality in the adult Lake Trout population (Markham et al. 2008).

The Great Lakes Fishery Commission (GLFC), with its agents in the United States Fish and Wildlife Service (USFWS) and the Department of Fisheries and Oceans Canada (DFO) are responsible for Sea Lamprey control. The Coldwater Task Group (CWTG) provides a forum for communication among agencies managing the cold-water fish community and those that are responsible for Sea Lamprey control.

Management Action: Work with GLFC and Sea Lamprey Control agencies to ensure that levels specified in the Sea Lamprey management plan are supportive of Lake Trout rehabilitation.

B. <u>Stock Lake Trout strains with the greatest recovery potential</u>

Lake Trout rehabilitation programs are advised to stock the progeny of remnant populations of native fish to improve the chance of successful rehabilitation (i.e. higher post stocking survival of native vs. introduced strains and propensity to use existing spawning habitat (Haskell et al. 1952; MacLean et al. 1981; Plosila 1977; Powell and Carl 2003)). However, the lack of availability of native strains from Lake Erie, the obvious vulnerability of native strains to sea lamprey predation, and the impacts to historic spawning habitat by dreissenid mussels necessitate the use of non-native strains for rehabilitation efforts. If original Lake Erie strain Lake Trout become available, experimentation to determine their performance under current conditions would be required before switching stocked strains.

Strains of Lake Trout that were stocked during the last plan period were evaluated for their relative survival (Markham et al. 2008; Rogers et al. 2019). Two of the strains (Finger Lakes (Seneca) and Lake Champlain) exhibited higher survival and lower Sea Lamprey wounding rates, indicating they are currently the best available candidates for stocking in Lake Erie (Coldwater Task Group 2021).

Management Action: Standardize stocked strains to the Finger Lakes (i.e., Seneca) or Lake Champlain strains.

Long-Term Goal: Identify and evaluate the feasibility and performance of stocking a native Lake Erie Lake Trout strain.

C. **Maintain annual stocking to support achievement of adult Lake Trout target**

After 30 years of stocking, adult (age 5+) spawning stock abundances have (on average) met rehabilitation targets in the last six years (Appendix, Table 1). Planned increases in stocking numbers (*Ontario increases from 55,000 to 80,000 yearlings annually in 2022) and standardization of strains is hypothesized to further support meeting this target.

In Lake Ontario and Lake Superior, the highest survival for stocked Lake Trout occurred early in the rehabilitation program (Elrod et al. 1995; Hansen et al. 1994), a trend they attributed to increased cannibalism of stocked yearlings by adult, hatchery origin, Lake Trout. Pulse stocking (i.e. creating a gap in stocking in space and/or time) has been recommended to reduce competition and cannibalism in stocked Lake Trout (Kerr and Lasenby 2001; Krueger and Ebener 2004; Powell and Carl 2003).

Management Action: Implement a pulse stocking program to alternate stocking intensity among sites on a rotational basis (Appendix, Table 3).

Management Action: Adjust stocking numbers to maintain a target of 2 adult fish/lift in the 3-year running average of the CWA (Appendix, Figure 4):

- *CWA target <u>within</u> the 95% confidence interval = maintain annual stocking target from previous year*
- *CWA target <u>outside</u> the 95% confidence interval = increase/decrease stocking by 80,000 yearlings (40,000 North shore, 40,000 South shore)*

3 Measuring success: The *Coldwater* Assessment survey

The Coldwater Assessment (CWA) survey is a stratified, random deep-water gill net program that has been conducted during August in the eastern basin of Lake Erie since 1986. This survey annually assesses the Lake Trout population, determines sea lamprey wounding rates on Lake Trout, and looks for evidence of naturally produced fish. The following CWA targets set out in Markham et al. (2008) are used to evaluate success at maintaining stocked Lake Trout abundance:

- Adult Lake Trout (Age 5+) abundance – 2 fish/lift
- Minimum of 10 year-classes

These targets are thought to be indicative of a spawner biomass that can initiate natural reproduction. However, these targets do not draw from supporting literature or successes in other jurisdictions because there are no directly comparable reintroduction efforts. Potential wild fish (i.e., unmarked and unclipped) are evaluated based on the probability of a hatchery fish not having a clip or a tag (i.e. tagging and clipping error).

4 **Identifying Life-history Bottlenecks**

The goal of a self-sustaining Lake Trout population in Lake Erie has not been achieved. As stocked spawner biomass is being maintained at a level that is expected to support reproduction, this section of the plan will focus on identifying bottlenecks that are thought to impede rehabilitation success. The Coldwater Task Group (CWTG) members ranked potential impediments to Lake Trout rehabilitation in Lake Erie according to their perceived magnitude (Appendix, Table 2). The top perceived impediments identified during this exercise are presented with objectives to support potential or planned targeted studies, assessment, and research efforts.

A. <u>Spawning Habitat Availability and Quality</u>

Lake Trout spawning habitat quality is defined by the biophysical environment (e.g., olfactory cues, depth, temperature, substrate size and predation; Marsden et al. 1995). The availability of suitable spawning habitat in Lake Erie has not been thoroughly explored. Since 1992, dreissenid mussels have drastically altered potential spawning habitat in Lake Erie through loss of interstitial spaces (Makarewicz et al. 2000; Marsden and Chotkowski 2001). In Lake Michigan, the greatest natural Lake Trout egg deposition was observed at shallow depths, relatively free of dreissenids and *Cladophora* compared to greater depths (Claramunt et al. 2005).

Objective 1: Identify and describe potential spawning areas and evaluate habitat quality.

Objective 2: Develop a standard operating procedure (SOP) for assessing Lake Trout early life history stages in Lake Erie (e.g., egg pumps, fry traps).

Objective 3: Evaluate prospective spawning areas (Objective One) using the early life history investigations outlined in the SOP (Objective Two).

Objective 4: Develop and propose an action plan to improve, restore, or construct spawning habitat if appropriate (e.g., reef cleaning, optimal depths, constructed reefs).

B. <u>Early Life History Survival</u>

Excessive mortality between egg deposition and late alevin stage has been identified as an early-life stage bottleneck for Great Lakes Lake Trout (Eshenroder et al. 1999). Poor food supply, competition and predation, including cannibalism, have been identified as the primary sources of mortality (Jonas et al. 2005; Marsden et al. 1995). Lake Erie is productive but also has an abundance of pelagic (i.e., Rainbow Smelt, Rainbow Trout) and benthic (i.e., Round Goby, Yellow Perch) predators that may limit Lake Trout egg and fry survival either through direct (predation) or indirect (competition) processes.

Thiaminase, which destroys thiamine (potentially resulting in vitamin B deficiencies that impair reproduction in fish), is present in the fish community (Honeyfield et al. 2005). Early mortality syndrome (EMS) has not been considered a major impediment to Lake Trout rehabilitation in Lake Erie because thiamine levels have been above the 2 nmol/g threshold (15.3, 19.7 and 7.3 nmol/g in 2010, 2011 and 2012, respectively). However, thiaminase activity varies among different species of prey and recent changes in prey composition observed in diets of Lake Erie Lake Trout could alter thiamine levels in the future (Coldwater Task Group 2020; Tillitt et al. 2005). The drop in thiamine levels from 2011 to 2012 warrants further investigation.

Objective 5: Identify direct (predation) and indirect (competitive interaction) sources of mortality i.e., diet, Rainbow Trout stocking, Rainbow Smelt abundance.

Objective 6: Monitor thiamine levels in Lake Trout eggs on a 5-year basis to continue to rule out EMS as an impediment to Lake Trout rehabilitation.

C. **Defining desired population size**

The 2 adults/lift Coldwater Assessment (CWA) target has been achieved (on average) for the years 2014-2020. It is thought that this level of abundance is indicative of spawner biomass sufficient for natural reproduction. Evidence of mature males and females on or near spawning locations has been documented (e.g., acoustic receivers, angler reports, drop cameras) along with a limited number of wild fry. During this phase of rehabilitation where the numbers of Lake Trout in Lake Erie's east basin are increasing, it is necessary to understand the dynamics of the adult population. Defining desired population size targets for stocked and naturally reproducing Lake Trout will support the improvement of future management objectives.

Objective 7: Develop quantitative targets for relevant life stages that indicate successful natural reproduction (e.g., egg deposition, fry/juveniles, adults in CWA) and associated stocking actions (i.e., Lake Trout rehabilitation programs often reduce or stop stocking when recruitment of wild individuals becomes substantial)

Objective 8: Develop a CWA target that would indicate that Lake Trout abundance is sufficient to establish them as an apex predator in the cold-water ecosystems of Lake Erie, in consideration of forage availability and competitive interactions. This will also provide context for the ecosystem impacts of sustained stocking at current levels in a rehabilitation objective. Also see Objective 5.

5 Plan Timelines

The Coldwater Task Group continues to work towards achieving the ultimate goal of Lake Trout Rehabilitation in Lake Erie by implementing management actions (Section 2) and supporting research and assessment to identify early life history bottlenecks (Section 4) outlined in this plan. The CWTG will report to the Lake Erie Committee annually on plan performance indicators.

Timing	Action
Annual	• Collaboration of all jurisdictions on Coldwater Assessment (CWA) design and implementation • Management strategies to maintain stocked Lake Trout abundance are implemented • CWA targets reported
2021	• Pulse stocking in US waters initiated as outlined in Plan (3-yr cycle) • Eggs collected from November LT aggregations in Pennsylvania for thiaminase testing (working with USGS)
2022	• Pulse stocking in ON waters initiated as outlined in Plan (2-yr cycle) • Stocking strains standardized across the basin • Working draft of standard operating procedure (SOP) for assessing Lake Trout (LT) early life history and habitat suitability in Lake Erie (e.g., egg pumps; fry traps; substrate assessment) • Research community engaged to explore adult Lake Trout biomass needs relative to ecosystem dynamics • Evaluate origin of potential wild adults (e.g., tagging error rates, otolith chemistry)
2023	• Draft SOP for early life history and habitat assessment at locations of known spawning aggregations refined • Develop quantitative target that signals successful natural reproduction and associated stocking action • Research on ecosystem dynamics initiated • Continue evaluation of origin of potential wild adults (e.g., tagging error rates, otolith chemistry)
2024	• Additional potential spawning areas outlined based on acoustic telemetry and previous habitat surveys • Draft SOP for early life history and habitat assessment at locations of known spawning aggregations finalized • Research on ecosystem dynamics ongoing
2025	• Eggs collected for thiaminase testing • SOP for early life history and habitat assessment at locations of known spawning aggregations implemented • Research on ecosystem dynamics finalized and reported
2026	• SOP for early life history and habitat assessment at locations of known spawning aggregations continued • Action plan to improve spawning reefs (if limiting factor) is proposed
2027 - 2029	• Continue work on early life history and habitat assessment

	• Continue assessment of spawning habitat and measures for improvement of existing habitat or creation of new habitat
2030	• Eggs collected for thiaminase testing • Evaluate performance of pulse stocking • Status and recommendations related to early life history bottlenecks reported • Targets developed for sustainable adult Lake Trout population (and recommended management actions) • Evaluate progress towards and feasibility of acquiring and implementing culture of historic Lake Erie strain Lake Trout

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Appendix:

Table 1: Performance review of Management Plan Objectives and Targets from Markham et al. 2008. Green cells indicate values which meet or exceed rehabilitation targets. Yellow cells indicate values which approach rehabilitation targets. Red cells indicate values which did not meet rehabilitation targets. Orange cells indicate rehabilitation targets that were not assessed.

Lake Trout Management Plan Objectives	Target	Pre-plan Average (2001-2007)	Plan Average (2008-2019)	Last 5 years (2015-2019)
Lake Trout Abundance (All Ages)	8 fish/lift	2.11 Fish/Lift	**3.64 Fish/Lift**	**3.67 Fish/Lift**
Lake Trout Abundance (Age 5+)	2 fish/lift	0.79 Fish/Lift	**1.88 Fish/Lift**	**2.46 Fish/Lift**
Mature Female Population (+4500g) represent 25% of Adult Population	0.5 fish/lift	0.25 Fish/Lift	**0.48 Fish/Lift**	**0.71 Fish/Lift**
Number of Year Classes	10+	17	**18**	**18**
Egg densities	4 spawning locations	**Not Assessed**		
Natural recruitment	Consistent contribution of Age-1 Lake Trout	**Number of Unclipped & Untagged fish does not exceed tag retention estimates provided by hatchery**		

Adult Abundance Target and Trigger

Adult (Age 5+) Lake Trout abundance is currently at its highest level since stocking began in 1986. Members of the Coldwater Task Group (CWTG) agree that to accomplish the ultimate goal of this rehabilitation plan, spawning stock biomass must be maintained at its current higher levels. Since natural reproduction is not occurring at detectible levels in Lake Erie and adult Lake Trout abundance shows a positive linear relationship with the number of Lake Trout stocked (Coldwater Task Group 2021), managers may respond to declines in adult Lake Trout abundance by increasing annual stocking numbers. To direct this response the CWTG has developed a trigger which, when reached, prompts a stocking response. A stocking increase is triggered when the upper 95% confidence limit around a 3-year running average of adult Lake Trout CPE drops below the target (2 fish/lift).

Confidence limits are generated by bootstrap resampling of the annual Coldwater Assessment (CWA) data using R statistical software. The number of adult Lake Trout caught in each lift are summarized for each spatial area (A1-A8) (Figure 2). Each area is resampled with replacement

1000 times to produce a matrix of values representative of the number of Lake Trout caught in each lift on a given year. 1000 area weighted averages are then produced by calculating the mean CPE for each area, applying a weighting factor equal to the surface area of the cold-water habitat (>20m) in each area divided by the total surface area of the cold-water habitat, and calculating the sum of all the weighted averages from each area. This is completed for each resample. This produces 1000 spatially weighted means for each year, the distribution of those means approximates the variability in the data set (Figure 3). From this distribution confidence intervals can be built (DiCiccio and Efron 1996). The R function "quantile" from the "stats v3.6.2" package of core R functions was then used to define the upper and lower confidence intervals. This function produces sample quantiles based on the underlying distribution of the data by applying the "Type 7" algorithm defined by Hyndman and Fan (1996). Lastly, 3-year running averages are calculated for both upper and lower confidence limits using the arithmetic mean of the confidence intervals from the three most recent years (Figure 4).

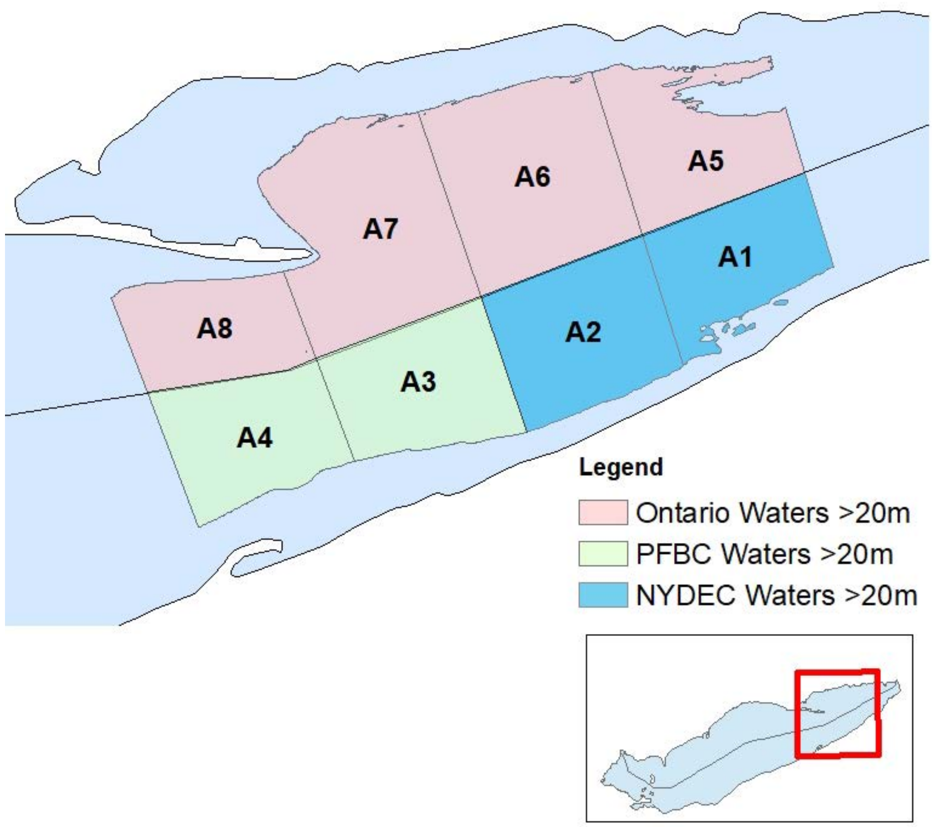


Figure 2: Coldwater Task Group sampling areas in the eastern basin of Lake Erie.

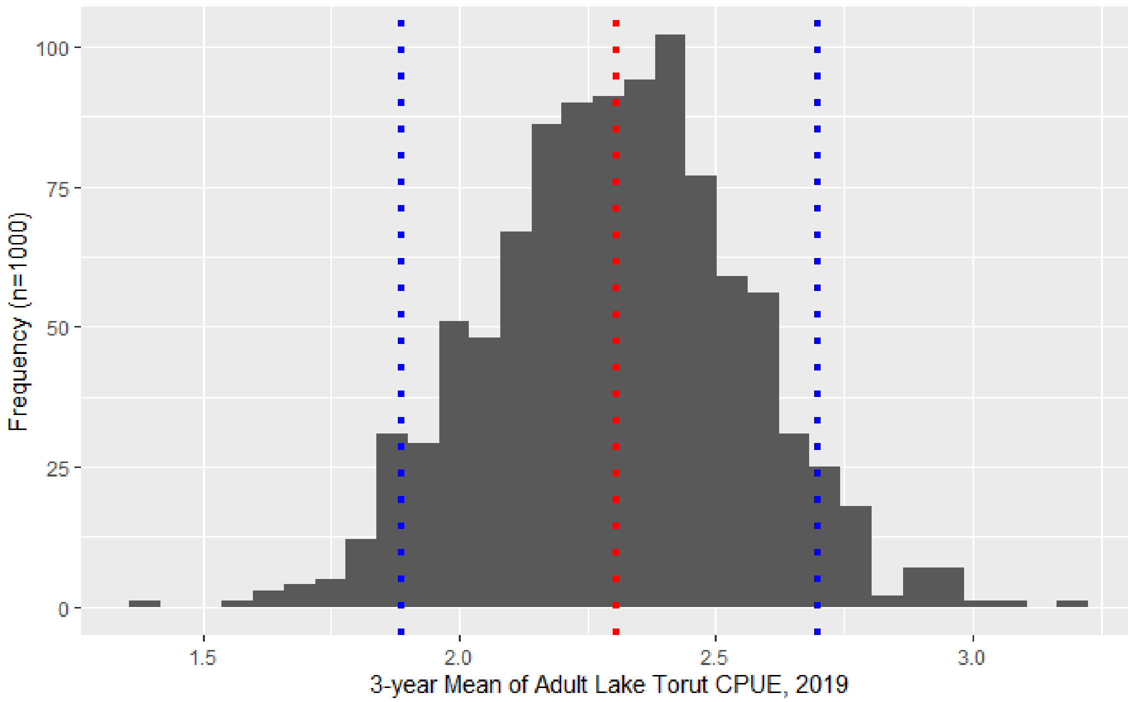


Figure 3: An example of the distribution of the bootstrapped estimates for the 3-year average adult (Age 5+) Lake Trout CPE from 2019. Blue dotted lines represent bootstrap estimates of the 95% confidence intervals. Red dotted line represents the mean. N=1000

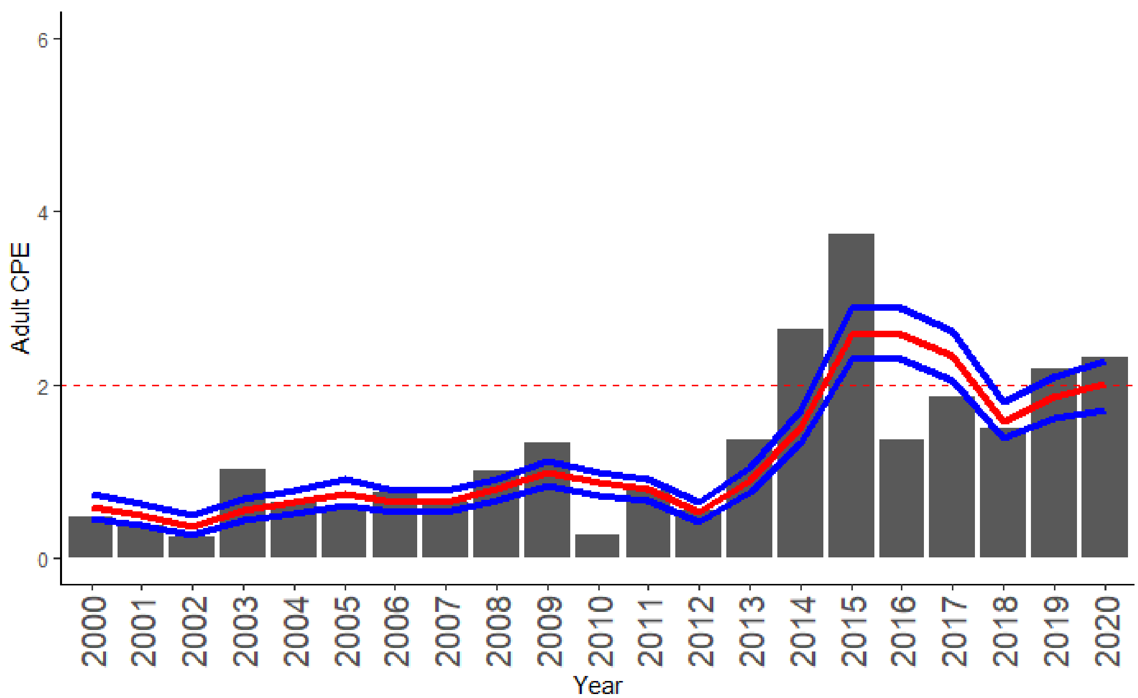


Figure 4 Grey bars: Annual mean adult (Age5+) Lake Trout CPE. Red dotted line: Target adult Lake Trout CPE (2 fish/lift). Red solid line: 3-year running average of Adult Lake Trout CPE. Blue solid lines: Bootstrap estimates of the 95% confidence intervals.

*Table 2: Summary of results from a survey of members of the Coldwater Task Group. Members were asked to rate, from 1 to 3 with 3 indicating high magnitude, each impediment based on the perceived magnitude of the impact of that impediment on rehabilitation success. Members were also asked to rank each impediment from highest to lowest with the lowest number indicating the impediment with the highest perceived influence on rehabilitation and the highest number indicating the least influence. Responses were summarized in this table using the mean of the values assigned by the respondents. * indicates a tie.*

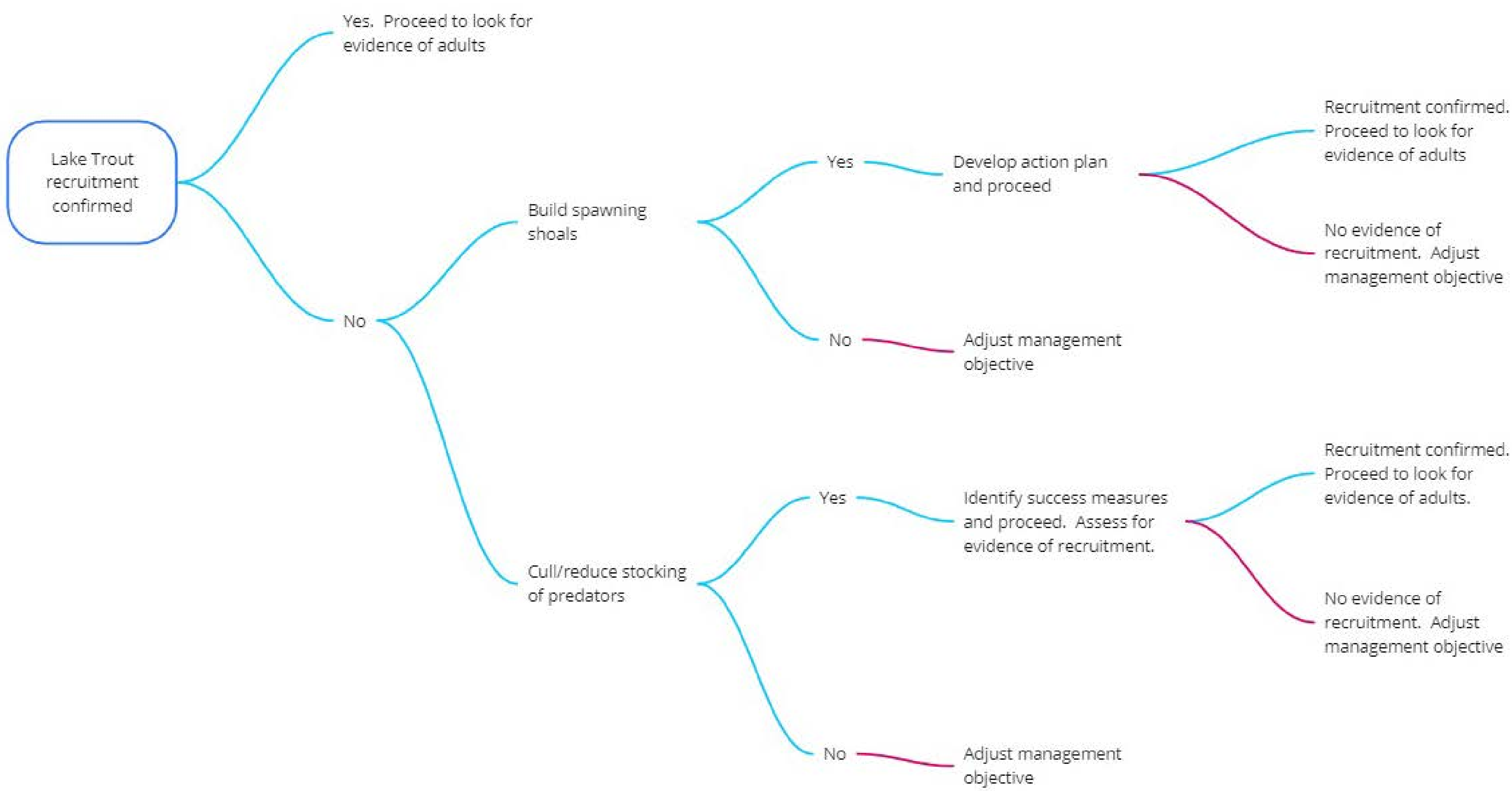
Category	Major Factor	Magnitude of impact on rehabilitation success Mean	Overall Ranking Mean	Rank of Means
Habitat	Spawning habitat	3.0	3.0	1
Survival	Early life stages	3.0	4.0	2
Natural Reproduction	Spawner Biomass	2.2	5.3	3
Stocking	Locations	2.7	6.5	4
Stocking	Strains	2.2	8.3	5
Habitat	Partitioning	2.0	8.5	6
Stocking	Numbers vs desired density	2.3	9.5	7
Habitat	Environmental constraints	1.5	9.6	8
Natural Reproduction	Viability of gametes	2.2	10.3	9
Survival	Sea Lamprey control	1.8	10.8	10
Forage	Fry/juvenile	2.2	11.0	11*
Stocking	Life stage at stocking	2.3	11.2	12
Survival	Rainbow Trout (indirect effect)	2.0	11.3	13
Natural Reproduction	Early mortality syndrome	1.8	11.5	14
Survival	Strain specific	2.3	12.0	15*
Survival	what level required?	1.8	13.8	16
Forage	Adult Lake Trout	1.8	14.3	17
Natural Reproduction	Contaminants	1.0	16.0	18
Survival	Bycatch	1.2	16.0	18
Stocking	Domestication	1.7	16.7	20
Stocking	Hatchery density and survival	1.2	18.0	21
Stocking	Infrastructure	1.0	19.4	22

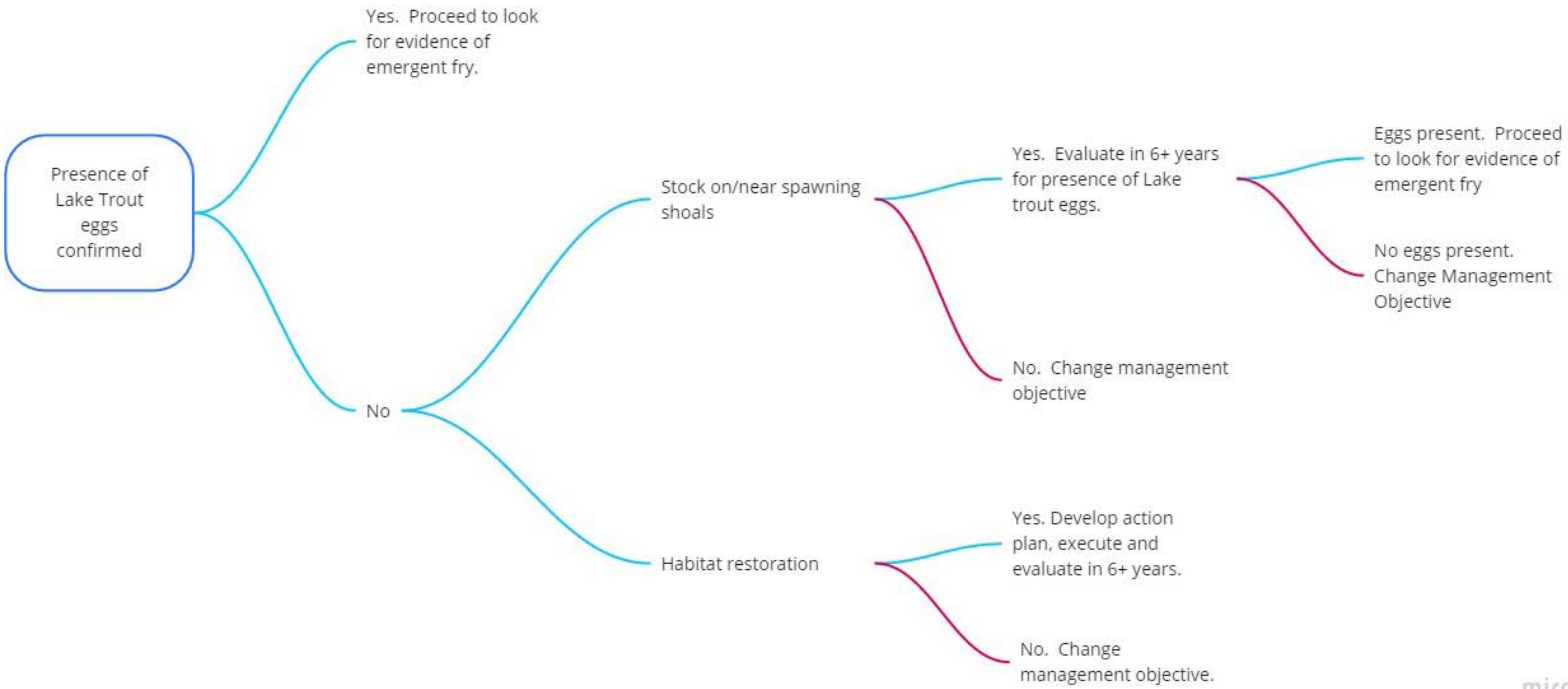
Table 3: Rotational stocking strategy, 2021-2026.

Year	New York Dunkirk	Pennsylvania Erie	Ohio Fairport	Ontario Nanticoke Shoal	Ontario Tecumseh Reef
2021	0	80K	120K	50K	0
2022	120K	0	80K	0	50K
2023	80K	120K	0	80K	0
2024	0	80K	120K	0	80K
2025	120K	0	80K	80K	0
2026	80K	120K	0	0	80K

Management Objective Decision Framework

The objective of identifying life history bottlenecks is to determine the feasibility of long-term rehabilitation goals. At each bottleneck that is identified, the Lake Erie Committee will be presented with an opportunity to address the bottleneck (with recommendations from the Coldwater Task Group) or change the management objective.




Presence of Lake Trout eggs confirmed
Yes. Proceed to look for evidence of emergent fry.
No
Stock on/near spawning shoals
Yes. Evaluate in 6+ years for presence of Lake trout eggs.
Eggs present. Proceed to look for evidence of emergent fry
No eggs present. Change Management Objective
No. Change management objective
Habitat restoration
Yes. Develop action plan, execute and evaluate in 6+ years.
No. Change management objective.
miro