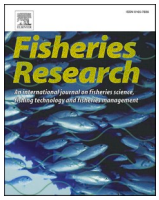
Fisheries Research 288 (2025) 107457

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres



Full length article

Factors affecting short-term post-release survival probability of Lake Trout implanted with acoustic telemetry transmitters

Alexander J. Gatch [a,*], Dimitry Gorsky [b], Kyle T. Morton [b], R. Josephine Johnson [b], Collin J. Farrell [b], Timothy B. Johnson [c], Emma J. Bloomfield [c], Brent Metcalfe [c], Jessica Goretzke [d], Michael Connerton [d], Sarah M. Larocque [e], Jonathan D. Midwood [e], Brian O'Malley [f], Brian Weidel [f], Steven J. Cooke [g], Stacy Furgal [h]

[a] US Geological Survey, Great Lakes Science Center, Tunison Lab of Aquatic Research, 3075 Gracie Road, Cortland, NY 13045, USA
[b] US Fish and Wildlife Service, Lower Great Lakes Fish and Wildlife Conservation Office, 1101 Casey Road, Basom, NY 14013-9730, USA
[c] Ontario Ministry of Natural Resources, Glenora Fisheries Station, 41 Hatchery Lane, Picton, ON K0K 2T0, Canada
[d] New York State Department of Environmental Conservation, Cape Vincent Fisheries Station, 541 Broadway St, Cape Vincent, NY 13618, USA
[e] Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Science, 867 Lakeshore Rd., Burlington, ON L7S 1A1, Canada
[f] US Geological Survey, Great Lakes Science Center, Lake Ontario Biological Station, 17 Lake Street, Oswego, NY 13126, USA
[g] Fish Ecology and Conservation Physiology Laboratory, Department of Biology and Institute of Environmental and Interdisciplinary Science, Carleton University, Ottawa, ON K1S 5B6, Canada
[h] New York Sea Grant, 7060 State Route 104, Oswego, NY 13126, USA

ARTICLE INFO

Handled by A.E. Punt

Keywords:
Lake Trout
Acoustic Telemetry
Great Lakes
Survival
Angling

ABSTRACT

The use of acoustic telemetry is steadily expanding to help answer questions related to habitat use, movement, and behavior of fishes. Significant time and resources are invested to start acoustic telemetry studies; therefore, careful planning is needed to limit post-release mortality of tagged individuals. Deep, cold-water species present additional challenges to acoustic tagging because of changes in temperature and pressure experienced during capture. The objective of our study was to determine if capture method, surface water temperature, water depth, or fish size influenced short-term post-release survival of a deep, cold-water species, Lake Trout *Salvelinus namaycush*. In 2023, 299 Lake Trout were captured with angling or gillnets across Lake Ontario (Laurentian Great Lake – U.S. & CAN) and surgically implanted with acoustic transmitters. We estimated 30-day post-release mortality and 24-h post-release distance traveled for tagged Lake Trout. We used Cox proportional hazards models to identify factors affecting survival probability and multiple linear regression to identify factors affecting post-release distance traveled. Thirty-day post-release mortality was minimal (9.03 %, 27/299 Lake Trout); however, mortality was 6.37 times more likely for Lake Trout captured in gillnets compare to angling ($p = 0.003$). Lake Trout length had a marginally significant effect on mortality ($p = 0.052$) but capture depth and temperature did not ($p > 0.05$). Lake Trout post-release distance traveled was not significantly influenced by capture gear, depth, temperature, or Lake Trout length ($p = 0.61$). Our results indicate that tagging-induced post-release mortality is minimal for Lake Trout tagged in the spring, but survival can be increased by avoiding use of gillnets.

1. Introduction

Increasingly, biologists seek to understand environmental and anthropogenic influences on behavior and movement of wild fishes using advanced technology such as acoustic telemetry. Acoustic telemetry is well suited for a variety of questions involving fisheries management (Brooks et al., 2017; Brownscombe et al., 2022; Crossin et al., 2017; Jacoby and Piper, 2023) but the current high cost of this technology is limiting (Brownscombe et al., 2019; Klinard et al., 2025). The high cost of acoustic telemetry (>$4000 USD/ acoustic receiver and >$400/acoustic tag) reinforces cost saving via operational efficiencies (e.g., fish collection) and requires proper planning and execution to

* Corresponding author.
E-mail address: agatch@usgs.gov (A.J. Gatch).

https://doi.org/10.1016/j.fishres.2025.107457
Received 29 April 2025; Received in revised form 1 July 2025; Accepted 1 July 2025
Available online 11 July 2025

ensure the study's success. Additionally, the success of acoustic telemetry studies, in part, relies on low post-release mortality of tagged fish. If acoustic tagged individuals die from capture and handling shortly after release, data will be of little value and the mortality will be unknown until data are downloaded from acoustic receivers, which typically occurs seasonally or annually. Capture, handling, and surgical techniques can affect post-release behaviors and ultimately, survival of tagged fish, therefore, identifying standard methods that maximize survival are imperative.

Standardization of acoustic tagging surgeries has been well adapted and is commonly required for animal health standards (Bridger and Booth, 2003; Cooke et al., 2013, 2011), but best practices for capture of fish for acoustic tagging is less reported. Factors such as capture gear type, abiotic conditions (e.g., water temperature, and depth), and physiological attributes (e.g., fish size) are important to consider before capturing fish and performing any acoustic tagging surgeries. Many types of fisheries capture gears (e.g., angling, trap nets, electrofishing, and gillnets) and associated handling (e.g., air exposure) are well known sources of sublethal impacts and fishing mortality (reviewed in Davis, 2002 and Brownscombe et al., 2017; Roth et al., 2018). For example, capture gears can negatively affect the health of captured fish by damaging essential structures (e.g., gills) and triggering physiological responses (e.g., changing blood chemistry), which can lead to post-release mortality (Farrell et al., 2000; Manire et al., 2001). Specifically, gillnets can lead to high post-release mortality, and sublethal effects from gillnets can be prolonged, changing fish behaviors (e.g., lethargy) or causing delayed mortality (Bell and Lyle, 2016; Broadhurst and Cullis, 2020; Cook et al., 2019; Ng et al., 2015; and Rulifson, 2007). In comparison, angling (i.e., hook and line) tends to be less harmful, potentially leading to lower short-term post-release mortality and limited delayed mortality (Chopin et al., 1996; Martins et al., 2018). Furthermore, environmental conditions can exacerbate stress in tagged fish, especially at times of the year when water temperatures rise, and dissolved oxygen concentrations decrease (Keretz et al., 2018; Lee and Bergersen, 1996; Robichaud et al., 2024). Limiting changes in depth and temperature experienced by captured fish should also decrease stress and ultimately, mortality (Howell et al., 2024; Madden et al., 2024; Schramm et al., 2010). Finally, fish size influences selection of appropriate acoustic tag size (e.g., see Jepsen et al., 2005 for discussion of the "2 % rule"), but it should also be considered when targeting fish for capture. For example, when angled, larger individuals may have higher post-release mortality and increased stress compared to smaller conspecifics (Howell et al., 2024; Meals and Miranda, 1994), in part because larger fish can take longer to retrieve, increasing the physiological stress response (Meka and McCormick, 2005).

Considerations for capture methods are species and context-specific and will need to be adjusted depending on the physiological constraints of the target species, the gear used, and environmental conditions (Raby et al., 2015). For example, freshwater Lake Trout (*Salvelinus namaycush*) are a deep, cold-water piscivore native to North America that are capable of occupying depths exceeding 300 m (Jasonowicz et al., 2022). The extreme depths and thermal preferences (~4–10°C; Jasonowicz et al., 2022; Ivanova et al., 2024; Raby et al., 2020) of Lake Trout make this species potentially difficult to capture and tag without causing mortality. To limit depth and temperature induced stress, Lake Trout are commonly acoustic tagged by exploiting times of the year when Lake Trout are aggregated in shallow depths (<10 m) and the water column is isothermal (e.g., autumn – spawning season; Gatch et al., 2021; Marsden et al., 2016; Pinheiro et al., 2017). However, some studies necessitate capturing Lake Trout outside of the spawning season depending on study objectives (Funnell et al., 2023), and concerns about tagging Lake Trout in stressful conditions (deep, variable temperatures) may be ameliorated by two factors. First, Lake Trout are physostomous, meaning they can regulate their swim bladder through their gastrointestinal tract, and thus should be able to account for differences in pressure when captured from depth (Howell et al., 2024; Saunders, 1953). Second, Lake Trout commonly make foraging forays above the thermocline, therefore, are somewhat tolerant of warmer water temperatures (e.g., > 15 °C, Gallagher et al., 2018; Jasonowicz et al., 2022).

In this study, we quantified short-term post-release mortality and identified factors that affect survival of acoustic tagged Lake Trout in Lake Ontario, one of the largest freshwater lakes in the world that contains an extensive acoustic receiver array. Specifically, our objectives were to: 1) quantify short-term post-release mortality of acoustic tagged Lake Trout, 2) determine if gear type, water depth, water surface temperature, or Lake Trout length had an effect on short-term post-release survival probability, and 3) determine if gear type, water depth, water surface temperature, or Lake Trout length had an effect on 24-h post-tagging movements. Results from our study can be used by others tagging deep, cold-water fishes to inform capture gear selection and thus, potentially limit capture and tagging related mortality.

2. Methods

2.1. Study location

Lake Trout were captured, acoustic tagged, and monitored in Lake Ontario, a Laurentian Great Lake (surface area ~19,000 km^2, max depth - 244 m) bordered by the United States and Canada (Fig. 1). To monitor tagged Lake Trout, the 2023 Great Lakes Acoustic Telemetry Observation System (GLATOS) acoustic telemetry array was used, and included 545 acoustic receivers (69 kHz Models VR2W, VR2TX, & VR2AR; Innova Sea, Halifax, NS) that were positioned in depths from 0 to 206 m and covered the extent of Lake Ontario (Fig. 1). Spacing between acoustic receivers varied depending on project-specific GLATOS arrays but in general were situated between 6 and 15 km grid spacing (Fig. 1). Receivers were retrieved, data downloaded and redeployed annually. Since no evidence exists to suggest Lake Trout migrate outside of Lake Ontario, the tagged Lake Trout were considered to be from a closed population and removal from the system was assumed to be through recreational harvest.

2.2. Lake Trout tagging

Lake Trout were captured via angling and gillnetting by the Ontario Ministry of Natural Resources (OMNR), U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS), New York State Department of Environmental Conservation (NYSDEC), and Fisheries and Oceans

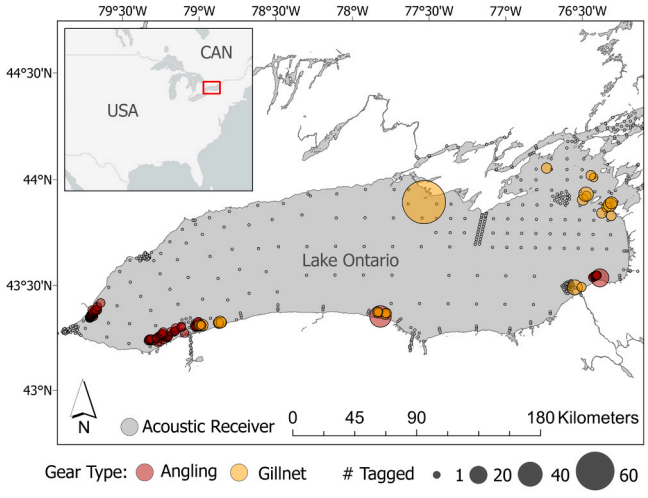


Fig. 1. The 2023 Lake Ontario acoustic telemetry array and Lake Trout tagging locations. Grey points are individual acoustic receivers, and colored points represent the gear type used and the number of Lake Trout (>500 mm TL) tagged in that location.

Canada (DFO) in different regions of Lake Ontario during spring 2023 (Fig. 1). The Lake Ontario Lake Trout population is maintained through a binational stocking program and hatchery-origin Lake Trout account for the majority of the population (~97 % hatchery origin; O'Malley et al., 2023). Tagging occurred from the months of April-June in each year when surface water temperatures were < 18°C. Before Lake Trout were tagged, fish were examined for hatchery fin clips and coded wire tags, a small fin and gill clip were taken and stored in 95 % ethanol for genetic strain identification and sex assignment, and total length (TL) was recorded. A minimum TL of 500 mm was used as a threshold because reproductively mature adult Lake Trout were the target for a separate spawning habitat identification project undescribed in this study.

Angling of Lake Trout occurred on professional fishing charters where Lake Trout were caught using rod and reel attached to downriggers fished 1–2 m above the bottom of the lake (although some fish were caught higher in the water column on occasion). Lake Trout were captured via trolling at ~3 km/hr and the vessel was not slowed to retrieve the Lake Trout. The depth the Lake Trout was captured at was recorded for each fish. Trolling spoons with a single barbed (USA) or barbless (Canada) treble hook were used as lures. Once hooked, retrieval methods were standardized among each agency, Lake Trout were brought to the surface within 5 min with a steady retrieval and netted into the fishing vessel. Lake Trout that were hooked in the gill or esophageal region and bleeding from the gills were not acoustic tagged because hooking in this region significantly reduces survival (Loftus et al., 1988; Sitar et al., 2017). Once landed, angled Lake Trout were sampled as indicated above, and then placed in a surgical sling with water irrigated over the gills, acoustic transmitters were surgically implanted, and an external anchor tag inserted. After tagging and processing, Lake Trout were quickly assessed for recovery to equilibrium in a holding tank (150 L) with fresh aerated water, and then immediately released with minimal holding times (~180 s for sampling and surgeries). Angled Lake Trout were exposed to air during surgery. If Lake Trout showed signs of barotrauma (e.g., bloated gut cavity, loss of equilibrium), fish were 'burped' by gently compressing the abdomen until gas escaped through the esophagus.

Gillnets used to catch Lake Trout were multifilament, contained four 30 m panels, mixed size 65–89 mm mesh (stretch), and fished in overnight sets (~24-h). The use of multifilament with small stretch mesh (65–89 mm) was intended to entangle Lake Trout by the teeth and maxillary structures rather than ensnare and potentially injure the gills of Lake Trout, although some collected Lake Trout did become fully entangled in the gillnet. Any Lake Trout with visible damage to gills or operculum were not tagged (e.g., bleeding or torn operculum). Gillnets were lifted from the water with hydraulic net lifters or by hand. When more than one Lake Trout was captured in a gillnet, all Lake Trout from that individual net were held in aerated tanks (568 L) on the research vessel (up to 1-hr) until each fish could be processed and tagged (~180 s/fish) using the same methods as angled Lake Trout. Holding tank water was directly pumped (flow through) from the surface water of the lake and as such, had the same water temperature. Gillnet collected Lake Trout were exposed to air during disentanglement from gillnets before being placed in holding tanks and during surgery. Lake Trout were immediately returned to holding tanks after surgery and assessed for recovery to equilibrium before being released.

A total of 320 Lake Trout were tagged with surgically implanted acoustic transmitters in 2023 (V16-P (capable of recording pressure/depth) or V16; Innova Sea, Halifax, NS; Table 2). At 50 % detection efficiency, V16 and V16-P acoustic tags had a ~1.5 km detection radius (Klinard et al., 2019), transmitted randomly at intervals of 60–180 s, and had an estimated battery life of 10 years (Innova Sea, Halifax, NS). Tagging of Lake Trout followed procedures similar to Gatch et al. (2022), (2021) and Ivanova et al. (2021) with exception of the method of anesthetization. Briefly, Lake Trout were immobilized using electric fish handling gloves (5–15 mA; Smith-Root, Vancouver, WA), gills were constantly irrigated with water, a 30 mm incision was made adjacent and parallel to the linea alba, an acoustic transmitter was inserted into the coelomic cavity, the incision was closed with 2–3 simple interrupted sutures using absorbable suture material (PDO II, 3–0; Oasis, Mettawa, IL), an external anchor tag (Floy Manufacturing) was inserted in the dorsal musculature just posterior to the dorsal fin, and the fish was released after a brief (<60 s) check for equilibrium in a 150 L holding tank. Tagging was completed in ~ 180 s per Lake Trout. Lake Trout that would not recover after surgery and release (i.e., no swimming vigor, lack of equilibrium) were euthanized, and not used in the study. Because of the expansive distribution of Lake Trout capture locations, not all Lake Trout were released within the detection radius of an acoustic receiver and therefore, detection data were not immediately available for all tagged Lake Trout.

2.3. Fate assignment

Acoustic detections were used to interpret the fate (survival/mortality) and time-to-fate for each tagged Lake Trout. Detection data were available from the period of April 2023 through November 2024. First, detection data were filtered to remove any false detections using the "glatos" package in R (Holbrook et al., 2024), using a minimum lag threshold of 1-h. Next, mortality events were interpreted using the same rules as Gatch et al. (2022), where Lake Trout that had continuous detections on a single or neighboring receiver for more than seven consecutive days were interpreted as a mortality. Additionally, if a Lake Trout was tagged with a V16-P transmitter that recorded depth of fish, and the depth of the Lake Trout did not change ±2.0 m over a seven-day period, that fish was interpreted as a mortality. Any Lake Trout that was detected during the 30-day post-release period, but detections stopped before day-30, and never was detected again over the extent of detection data (April 2023 - November 2024), was also considered a mortality. Finally, any Lake Trout that was never detected in 2023, was interpreted as a mortality. It is important to note that mortality, tag loss, and tag malfunction cannot be differentiated by data analysis, therefore, mortality may be overestimated due to the grouping of these three occurrences.

2.4. Statistical analysis

Nonparametric Mann-Whitney U tests were used to determine if capture depth, surface temperature, or TL of Lake Trout (dependent variables) differed between capture gear types (independent variables) and tested at a significance of $\alpha = 0.05$. A nonparametric Mann-Whitney *U* test was used because dependent variables did not follow a normal distribution and assumptions for parametric tests were violated (e.g., One-Way Analysis of Variance; ANOVA). Survival probability was then estimated over a 30-day period for Lake Trout captured and tagged in 2023 using acoustic telemetry detections. A 30-day period was selected because the objective of the study was to quantify post-release mortality caused by capture gear (i.e., a component of fishing mortality), not by natural causes (e.g., Sea Lamprey *Petromyzon marinus* predation). For the purposes of this study, it was assumed that any mortality after 30 days post-release was likely unrelated to capture. A multivariate Cox proportional hazards model (a time-to-event based model) was used to determine if capture depth, capture gear, surface temperature, acoustic-tagger, and Lake Trout TL had a significant effect on post-release mortality of tagged Lake Trout (Cox, 1972; Koeberle et al., 2023; Paulic et al., 2025; Sauls, 2014). The interaction between surface temperature and depth of capture was also tested since these variables have been reported to significantly increase post-release mortality (Sitar et al., 2017). For gillnet captured Lake Trout, the exact capture depth of an individual fish was not known because gillnets could extend over multiple depths. The average gillnet depth ((min depth + max depth) / 2) was used to account for this discrepancy, but importantly, no gillnets were set across depths with different atmospheric pressure gradients (i.

e., atm's). Capture method and acoustic tagger were correlated because some taggers only used one method of capture, therefore, acoustic tagger was removed from the survival analysis because all taggers were trained experts. Although acoustic detection data was available for more than 30-days post-release, we truncated the data set to only include the first 30-days post-release for each individual Lake Trout. The "survival" package with functions "coxph" and "Surv" were used in R to fit Cox proportional hazards models (Therneau, 2024). A Martingale residual plot was visually assessed on the three continuous variables (depth, TL, & surface temperature) to confirm the linearity assumption for the Cox proportional hazards model. To test for the proportional hazards assumption, a Schoenfeld Test using the R function "cox.zph" was used to test each predictor variable for proportional hazards ratios and all variables had $p > 0.05$, confirming the assumption that hazards ratios are proportional over time. Model selection was determined by ranking all combinations of individual variables in the Cox proportional hazards model with Akaike's Information Criterion corrected for small samples sizes (AIC_c) using the "aictab" function in the "AICcmodavr" package in R (Mazerolle, 2023). Only models with $\Delta AICc < 4$ were reported for brevity. All models were tested at a significance of $\alpha = 0.05$. Survival probabilities were visualized using a Kaplan-Meier time-to-event curve generated in R using the "ggsurvfit" and "survival" packages (Sjoberg et al., 2025; Therneau, 2024).

Distance traveled by Lake Trout 24-h after tagging was evaluated to determine if capture conditions affected behavior. The straight-line distance between the capture location, and the receiver with the first detection after 24-h at large, was calculated for each fish using GPS location. If a Lake Trout was not detected between 24 and 48 h of release, it was not used for the analysis. A multiple linear regression was used to determine if 24-h distance traveled (dependent variable) was related to capture gear, depth, surface temperature, or TL (independent variables) and tested at a significance of $\alpha = 0.05$. All statistical analyses were conducted using R statistical software (v4.4.0; R Core Team 2024).

3. Results

3.1. 30-day survival probability

A total of 320 adult Lake Trout were tagged in 2023 with 299 of those Lake Trout containing enough data to model survival probability in the first 30-days after release (Table 1). The 21 Lake Trout excluded from analysis were missing capture data (e.g., water temperature or depth) and were removed from the dataset rather than censoring. Over the 30-day post-release period, 693,671 detections were collected from the 299 Lake Trout. Lake Trout captured by angling or in gillnets had significantly different TL ($W = 12524$, $p = 0.035$), collection surface temperatures ($W = 4874$, $p < 0.001$) and collection depths ($W = 17987$, $p < 0.001$). Lake Trout captured with angling were slightly larger (angling: 751.8 ± 116.3 mm, gillnet: 733.6 ± 89.0 mm; mean ± sd), collected from deeper depths (angling: 34.9 ± 12.1 m, gillnet: 21.4 ± 7.0 m; mean ± sd), and colder surface temperatures (angling: 7.8 ± 3.2 °C, gillnet: 9.4 ± 2.6 °C; mean ± sd) compared to gillnet captured Lake Trout (Fig. 3). Collection of angled Lake Trout was more efficient 8.6 fish/day (129 fish/15 days) compared to gillnet captured Lake Trout 5.2 fish/day (170 fish /33 days). After 30-days post release, 9.03 % (27 of 299) of Lake Trout were interpreted as mortalities. Mortality of tagged Lake Trout over the 30-day period was not consistent between capture gear (2.3 % 3/129 angling, 14.1 % 24/170 gillnet). Of the lake trout that died, the highest single-day mortality, occurred on the day of tagging (n = 2/3, 66.7 % angling, n = 9/24, 37.5 % gillnet; Fig. 4).

Table 1
Mean ± 1 sd and total length (TL;mm) of Lake Trout by collection method and transmitter model (Innova Sea) tagged in Lake Ontario in 2023.

Tagging Date	Gear Type	Tag Model	TL (mm)	*n*
4/21/2023 – 6/01/2023	Angling	V16	757.4 ± 127.8	68
		V16P	745.4 ± 102.3	61
4/21/2023 – 5/09/2023	Gillnet	V16	726.6 ± 85.5	97
		V16P	743.1 ± 93.3	73
		Total		299

When identifying factors that affected post-release mortality, the most parsimonious Cox proportional hazards model included collection gear type and TL as covariates (AICc = 291.39, AICcWt = 40 %; Table 2). Cox proportional hazards models with $\Delta AICc < 2$ included covariates 1) collection gear, TL, and depth, and 2) collection gear, but these models accounted for smaller AICc weights compared to the most parsimonious model (AICcWt = 23 % and AICcWt = 17 %, respectively; Table 2). In the highest ranked model (Survival ~ Gear + TL; Table 2), capture gear had a significant effect on Lake Trout survival probability and indicated that post-release mortality of Lake Trout captured in gillnets was 6.37 times more likely compared to angling (Cox proportional hazards: hazard ratio = 6.37, 95 % CI:1.98–21.19, $p = 0.003$) and TL had a near-significant effect on Lake Trout survival probability indicating that post-release mortality decreased with Lake Trout length (Cox proportional hazards: hazard ratio = 0.99, 95 % CI: 0.99, 1.00, $p = 0.054$). Depth, surface temperature, and the interaction between

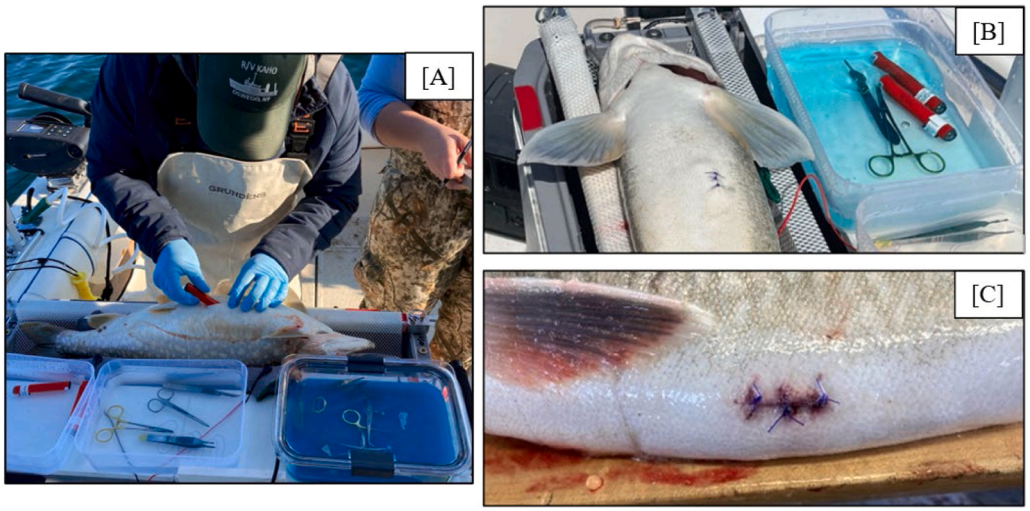


Fig. 2. Incision site for acoustic transmitter surgically implanted in Lake Trout captured from Lake Ontario. Panel [A] shows a Lake Trout being tagged, [B] a newly tagged Lake Trout, and [C] represents the healing process of a Lake Trout recaptured 84 days after tagging (Panels A, B, and C are not same fish).

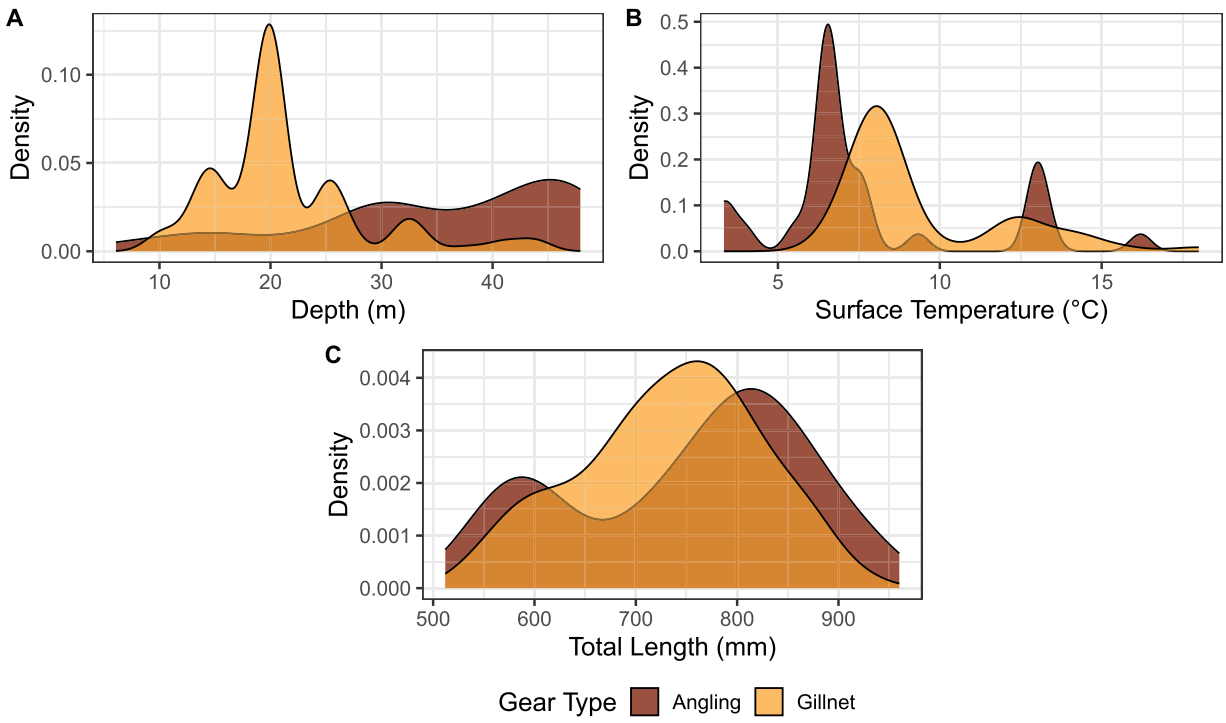


Fig. 3. Density plots for capture depth [A], surface temperature [B], and total length at capture [C] of acoustic tagged Lake Trout (n = 299) caught with angling or gillnets in Lake Ontario 2023.

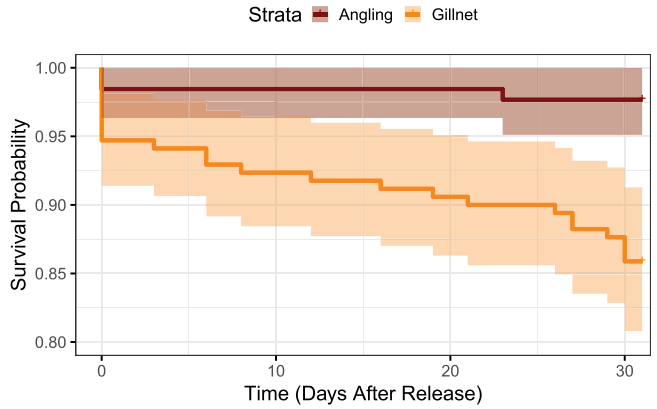


Fig. 4. Kaplan-Meier survival curve with 95 % CI representing the probability of survival over 30-days for post-release Lake Trout (n = 299) captured with either angling or gillnets from Lake Ontario in 2023.

Table 2
Model validation using Akaike's Information Criterion adjusted for small sample sizes (AICc) on Lake Ontario acoustic tagged Lake Trout time-to-event multivariate Cox proportional hazards models. Variables include 'Gear' = capture gear, 'TL' = total length, 'Depth' = capture depth, and 'Temp' = surface water temperature. Models with ΔAICc > 4 are not shown.

Cox Proportional Hazards Model	k	AICc	ΔAICc	AICcWt	Cum. Wt	Log-likelihood
Gear + TL	2	291.39	0.00	0.40	0.40	−143.67
Gear + TL + Depth	3	292.52	1.13	0.23	0.63	−143.22
Gear	1	293.13	1.75	0.17	0.79	−145.56
Gear + TL + Depth + Temp	4	294.41	3.02	0.09	0.88	−143.14
Gear + Depth	2	294.76	3.38	0.07	0.95	−145.36

depth and surface temperature were not included in the highest ranked model, and when tested in a Cox proportional hazards model, none of these covariates had a significant effect on Lake Trout survival ($p > 0.05$).

3.2. 24-h post-tagging movements

Days to first detection ranged from 0 to 26 days (mean = 1.6 days), and a total of 171 Lake Trout had detections within 24–48 h of release. The average straight-line distance 24-h after release was 6.3 ± 3.6 km (mean ± sd) for angling and 7.2 ± 4.7 km for gillnet captured Lake Trout. The two covariates which significantly affected survival probability (gear type and TL), did not have a significant effect on total straight-line distance traveled after release (Fig. 5) nor did capture depth or surface temperature ($R^2 = 0.017$, $F_{(4154)} = 0.67$, $p = 0.61$).

3.3. Recaptures

Recapture and release of tagged lake trout by recreational anglers occurred twice in this study. Interestingly, one Lake Trout (ID: 201) was originally captured with a gillnet, tagged, and 343 days later, was recaptured by an angler at ~10 m depth and released (tagged 04/26/2023 & recaptured 04/03/2024; Fig. 6). Lake Trout ID:201 survived capture events with both gear types. Similarly, Lake Trout (ID:105) was captured with angling, tagged, and 64 days later, recaptured by an angler at 22.9 m depth and released (tagged 05/30/2023 & recaptured 08/02/2023). Both Lake Trout 201 and 105 survived two known capture events and continued to be detected in Lake Ontario in 2024, which supports the position that Lake Trout are capable of being captured and released with relatively low post-release mortality.

4. Discussion

Short-term post-release survival of acoustic tagged Lake Trout was high in this study (97.7 % angling and 85.9 % gillnet captured), however, Lake Trout captured in gillnets were over six times more likely to

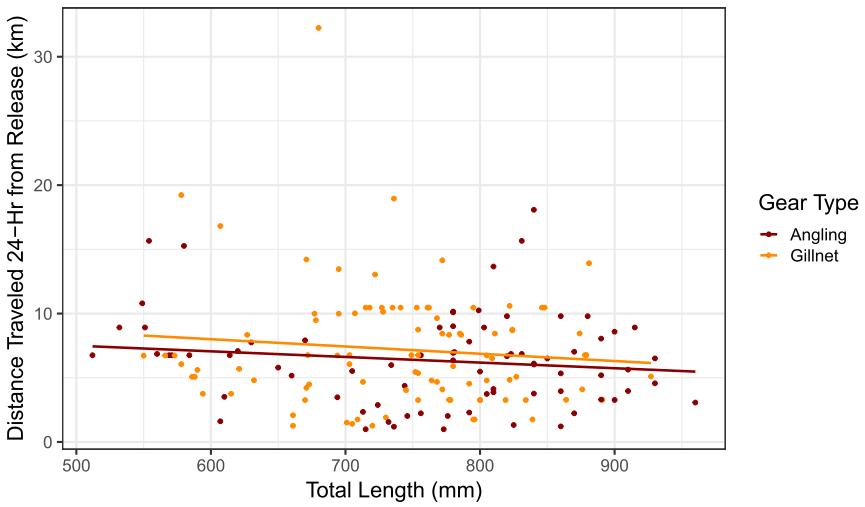


Fig. 5. Straight-line distance traveled 24-h after release by acoustic tagged Lake Trout (n = 171) in Lake Ontario given total length and capture gear type. Regression lines represent the line-of-best-fit for each gear type. Overall model (Distance ~ TL + Gear) is non-significant (R2 = 0.024, F(2168) = 2.04, p = 0.13).

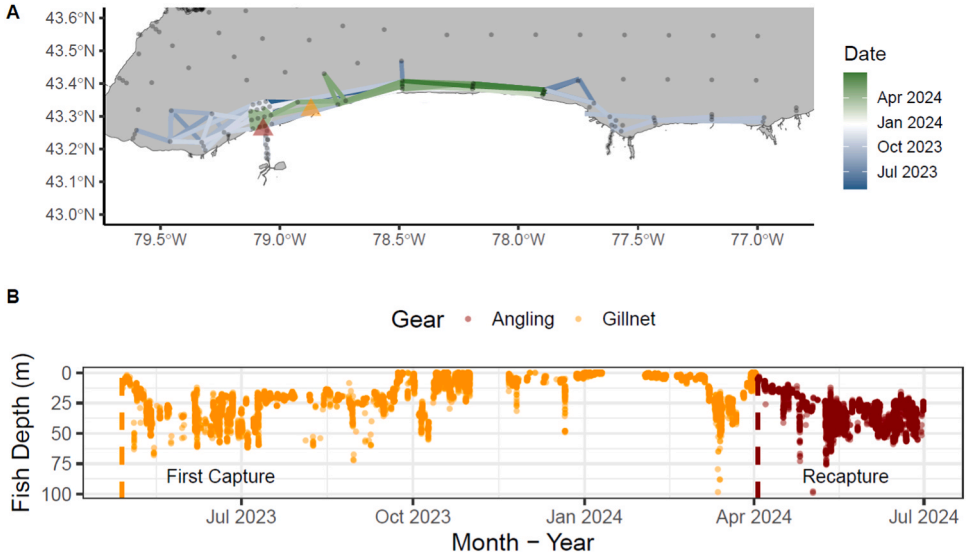


Fig. 6. Movements [A] and depth distribution [B] of a single acoustic-tagged Lake Trout in Lake Ontario (Lake Trout ID: 201) that was captured with a gillnet and tagged in 2023 (orange) and recaptured in 2024 by a recreational angler (red). The path of Lake Trout 201 increases in green color as time from tagging increases [A]. Gillnet capture/tagging location and date are represented by orange triangle [A] and orange dotted line [B] and angler recaptured location and date are represented by dark red triangle [A] and dark red dotted line [B]. Points (black) represent acoustic receivers capable of detecting Lake Trout in Lake Ontario [A] and points (red & orange) represent single depth detections of Lake Trout 201 [B].

die after release compared to angled Lake Trout. The added stressors and increased holding time of gillnet captured Lake Trout may explain the difference in survival probability compared to angled fish. For example, gillnets can cause acute injuries (e.g., gill damage and blood loss) and physiological disruption (e.g., hypoxia, acidosis) leading to rapid death or chronic injuries (e.g., constriction of internal organs and stripping of skin-mucus), which may cause delayed mortality (Cook et al., 2019; Ng et al., 2015). Also, Lake Trout may have been entangled in gillnets for up to 24 h before tagging, and injury to fish as well as physiological disturbance increases with entanglement time (Buchanan et al., 2002; Frick et al., 2010; Savina et al., 2016; Veneranta et al., 2018). In this study, Lake Trout with acute gillnet injuries were not tagged, however rapid mortality (i.e., mortality within the first day post-release) still occurred (n = 9/24 gillnet Lake Trout). Exhaustion of fish in nets as well as reduced oxygen availability in instances where gillnets impeded respiration, may be an important factor leading to stress and post-release mortality, therefore, minimizing duration of capture (soak length) and handling should reduce the magnitude of detrimental capture stress and ultimately, mortality (Cook et al., 2019, Ganias et al., 2023; Ng et al., 2015).

In comparison to gillnet captured Lake Trout, angled Lake Trout were reeled in for <5 min, tagged immediately upon capture, and were not subject to the same capture and holding stressors as gillnet captured Lake Trout. A steady rate in mortality after the first day post release (0.5 Lake Trout/day; 15/29 days) occurred over the next consecutive 29-day post-release time with gillnet captured Lake Trout compared to angled fish (0.03 Lake Trout/day; 1/29 days), supporting the supposition that gillnets caused delayed mortality. Another source of stress experienced by gillnet captured Lake Trout is that gillnet captures were held in tanks on research vessels until tagging occurred (see Methods), unlike angled fish. Although holding tanks were aerated and continuously supplied with lake water, gillnet captured Lake Trout still could be held for 30–60 min before being tagged depending on the number of trout that were collected in a gillnet. Stress associated with short-term holding of

fish can cause exhaustion, decreased efficiency of the immune system, and loss of physiological homeostasis, all of which can lead to delayed mortality after release (Portz et al., 2006). Although holding exhausted fish in on-board recovery tanks has also been used as a method to facilitate physiological recovery of Pacific salmon *Oncorhynchus* sp. (Farrell et al., 2001), the type of tanks used in our study have been determined to be of little benefit (Farrell et al., 2000). There were also significant differences between temperature and depth of Lake Trout caught between the gillnets (warmer/shallower) and angling (colder/-deeper), however, neither temperature nor depth were significant predictors of lake trout survival and thus, are less likely to explain the difference in survival between gear types.

Lake Trout body size (TL) had a marginally significant effect on Lake Trout survival probability suggesting larger Lake Trout may provide better post-release survival. Increased post-release survival of larger size classes of Lake Trout compared to smaller size classes was also observed by Loftus et al. (1988) in Lake Trout from Lakes Michigan, Huron, and Superior (Laurentian Great Lakes), but this is contrary to other freshwater species where larger fish have lower post-release survival (e.g., Largemouth Bass *Micropterus nigricans*, Meals and Miranda, 1994; Rainbow Trout *Oncorhynchus mykiss*, Meka and McCormick, 2005). Smaller Lake Trout caught in gillnets may have been more likely to become entangled and suffer injury in gillnets compared to larger fish. The discrepancy in survival by size may also be explained by the fact that Lake Trout tagged in this study were selected based on a minimum size (>500 mm). Inclusion of smaller sizes of Lake Trout may better clarify the relationship between size and post-release survival. However, if larger Lake Trout do in fact have better post-release survival, targeting size classes may be possible as Lake Trout have been shown to segregate spatially with juveniles (i.e., smaller individuals) inhabiting deeper water in part to avoid predation by adults (Elrod and Schneider, 1987; Zimmerman et al., 2009).

Although Lake Trout are a deep, cold-water species, rapid changes in depth and water temperatures did not influence survival probability during April-June. Since Lake Trout are physostomes, it was suspected that capture depth would have little effect on mortality. In fact, results from this study are supported by Loftus et al. (1988), Sitar et al. (2017), and Howell et al. (2024) that determined capture depth had no effect on Lake Trout post-release mortality. Observationally, when Lake Trout experienced barotrauma, as determined by body cavity bloat, Lake Trout could typically be compressed by hand to 'burp' air from the swim bladder returning Lake Trout to a normal state of buoyancy. Conversely, the lack of an effect of surface temperature on Lake Trout post-release mortality is surprising given the results of others. For example, Sitar et al. (2017) found that post-release mortality of Lake Trout in Lakes Huron and Superior (Laurentian Great Lakes) significantly increased with surface water temperatures, with mortality being as high as 76.4 % when temperatures were greater than 16°C. Similarly, Howell et al. (2024) noted that short-term mortality of released Lake Trout was 18.4 % during summer months (mean water temperature 18.6°C) but fell to 0 % in the autumn (mean water temperature 13.2°C); conditions that were more comparable to our study in which both gear treatments averaged less than 10°C. Finally, Lee and Bergersen (1996) found that Lake Trout post-release mortality was as high as 87.5 % during summer months when dissolved oxygen was below 3 mg/L in water less than 12°C. Dissolved oxygen was not measured in this study, however, the majority of Lake Trout were captured when surface water temperatures were less than 10°C (75.9 % 227/299), and for those captured between 10°C and 18°C (24.1 % 72/299), the thermocline had yet to fully develop. When surface temperatures rise in the summer and the depth of the thermocline increases, mortality of released Lake Trout may increase in Lake Ontario.

Lake Trout post-release distance traveled did not appear to be related to any factors measured in this study and were no different than random. Because stress inducing events (capture) can affect swimming behavior, cardiovascular, and metabolic rates (Howell et al., 2024; LaRochelle et al., 2022; Madden et al., 2024; Portz et al., 2006), post-release distance traveled may be an indicator of stress or injury. For instance, Wilson et al. (2017) found that Walleye (*Sander vitreus*) that were captured and acoustic tagged had different behaviors and swimming speeds compared to Walleye that had been acoustic tagged 1–2 years earlier, suggesting that the capture stress and invasiveness of the tagging procedure caused a difference in swimming behavior. However, in a different telemetry study conducted by Eberts et al. (2018), post-release Walleye movements at the end of a fishing tournament were variable and not related to capture or handling techniques. In our study, 24-h straight-line distance traveled was used instead of total cumulative distance traveled due to the expanses of Lake Ontario and the lack of high-density acoustic receiver coverage. With a 50 % detection radius of ~1.5 km and lack of multiple receiver detections to better estimate GPS position, the straight-line distance between release location and first detection after 24-h at large may not have the precision to detect tangible differences in Lake Trout movement. If Lake Trout had 1) all been released in the same location or 2) been released in a fine-scale acoustic telemetry array, post-release behaviors by individuals may have been easier to discern.

Mortality due to catch and release angling has not been previously quantified in Lake Ontario, but results from this study suggest that short-term post-release mortality of angled Lake Trout is negligible in April-June given 'best-case' scenario of catch and release. Only 2.3 % (3/129) of Lake Trout angled and released were classified as a mortality during the 30-day post-release monitoring period. Importantly, these angled Lake Trout also underwent surgery, acoustic tag implantation, and were held out of water for ~180 s (while water was irrigated over gills), which is likely more invasive than most catch and release events. In other studies from the Great Lakes, average post-release mortality after angling ranged from 13.6 % to 15.6 % in Lakes Michigan, Huron, and Superior (Loftus et al., 1988) and between 15.0 % and 76.4 % in Lakes Huron and Superior (Sitar et al., 2017). Loftus et al. (1988) quantified hooking mortality by tethering angled Lake Trout and observing survival/mortality over 48 h, while Sitar et al. (2017) modeled post-release mortality rates based on recaptures of loop-tagged Lake Trout caught and released by recreational anglers over a period of 6-years. Compared to Loftus et al. (1988) and Sitar et al. (2017), estimates of short-term post-release mortality in our study were based on more than 680,000 acoustic detections, which allowed for fine-scale temporal analysis based on individual fish, albeit results were only quantified over 30-days. Remarkably, two tagged Lake Trout in our study were also recaptured after tagging and released again; both Lake Trout survived multiple capture events, supporting our results that Lake Trout short-term post-release mortality is negligible in spring months. However, Lake Trout tagged in this study were quickly retrieved, not 'played', and were also tagged based on the best-case scenario for capture and release (e.g., not foul-hooked, maintained equilibrium after release). The fate of angled, released, but not tagged Lake Trout is unknown and went unrecorded in our study; however, foul-hooked and injured Lake Trout rarely occurred while sampling in 2023. Additionally, differences in post-release mortality between our study and those described above are likely due to time of year, as we did not sample in summer months when increased surface temperatures and decreased dissolved oxygen concentrations might affect survival (Lee and Bergersen, 1996; Sitar et al., 2017). By tagging Lake Trout in the spring, air temperatures and water temperatures were cooler, which likely reduced stress compared to capture and tagging during warmer summer months (Lee and Bergersen, 1996). Lastly, our sample period was 30 days post-release, which is significantly less than the 6-year study by Sitar et al. (2017), and there is the potential that we did not capture latent mortality past 30 days experienced by angled Lake Trout.

5. Conclusion

Mitigating post-release survival of acoustic tagged fish is paramount

to the success of most behavioral studies or those interested in quantifying natural or fishing mortality independent of the tagging session. Although 30-day post-release mortality was minimal in this study (9.03 %; 27/299), the value of losing acoustic transmitters and data from 27 Lake Trout, especially with 10-year battery life, is substantial. Limiting post-release survival of tagged Lake Trout and therefore, maximizing value of data, can be partially achieved with use of angling instead of gillnets. Angling was also more efficient than gillnetting (8.6 fish/day vs. 5.2 fish/day, respectively), which created a more cost-effective method of capture. Additionally, when Lake Trout were tagged in spring months (nearly isothermal water conditions), capture depth and surface temperature did not affect survival probability, which may be useful for other deep, cold-water species. Results from this study may help guide capture methods for acoustic telemetry studies and it also serves to establish an estimate of hooking mortality for spring angled Lake Trout in Lake Ontario.

CRediT authorship contribution statement

Emma J. Bloomfield: Writing – review & editing, Investigation. **Brent Metcalfe:** Investigation. **Jessica Goretzke:** Investigation. **Michael Connerton:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Steven J. Cooke:** Writing – review & editing, Conceptualization. **Stacy Furgal:** Writing – review & editing, Investigation. **Collin J. Farrell:** Writing – review & editing, Investigation. **Timothy B. Johnson:** Writing – original draft, Investigation, Funding acquisition, Conceptualization. **R. Josephine Johnson:** Writing – review & editing, Investigation. **Sarah M. Larocque:** Writing – review & editing, Investigation. **Jonathan D. Midwood:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Gatch Alexander James:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Brian O'Malley:** Investigation. **Dimitry Gorsky:** Writing – review & editing, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Brian Weidel:** Funding acquisition, Conceptualization. **Kyle T. Morton:** Writing – review & editing, Investigation.

Funding

Funding for this project came from the U.S. Environmental Protection Agency's Cooperative Science and Monitoring Initiative efforts in the Great Lakes, the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, and in-kind support from individual government agencies. Funding for DFO's contributions to this project came from DFO's Freshwater Habitat Initiative.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank the many scientists and crew members from the U.S. and Canada that helped collect and tag Lake Trout in 2023, including Captain Alan Fairbanks, Russell Moore, Captain Terry Lewchanin, Lucas Le Tarte, Matt Nguyen, Greg Kronisch, Kevin Campbell, Taylor Huff, Ben Maynard, Tyson Scholz, Kurtis Winter, Cody Anderson, Alexa Davis, Lucas Lagoon, Isabella Mustafa, Captain Nick Foxcroft, Melanie Croft-White, Nicole Turner, Captain Casey Prisco, and the Dirty Goose Sportfishing crew. We would also like to thank the many agencies (OMNR, USFWS, NYSDEC, DFO, USGS) and individuals that maintain the Lake Ontario GLATOS acoustic telemetry array and manage the GLATOS database. We thank Tyler Funnell (USGS) for internal peer-reviews of the manuscript. We thank the U.S. Environmental Protection Agency's Cooperative Science and Monitoring Initiative efforts in the Great Lakes, the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, DFO's Freshwater Habitat Initiative, and in-kind support from individual government agencies for funding this study. Any use of the trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service. This paper is contribution 151 of the Great Lakes Acoustic Telemetry Observation System (GLATOS).

Data Availability

Data are freely available from the USGS Science Base website (Gatch and Gorsky, 2025). https://www.sciencebase.gov/catalog/item/6819f8f3d4be022177538c1a

References

Bell, J.D., Lyle, J.M., 2016. Post-capture survival and implications for by-catch in a multi-species coastal gillnet fishery. PLoS One 11 (11), e0166632.
Bridger, C.J., Booth, R.K., 2003. The effects of biotelemetry transmitter presence and attachment procedures on fish physiology and behavior. Rev. Fish. Sci. 11 (1), 13–34.
Broadhurst, M.K., Cullis, B.R., 2020. Mitigating the discard mortality of non-target, threatened elasmobranchs in bather-protection gillnets. Fish. Res. 222, 105435.
Brooks, J.L., Boston, C., Doka, S., Gorsky, D., Gustavson, K., Hondorp, D., Isermann, D., Midwood, J.D., Pratt, T.C., Rous, A.M., Withers, J.L., 2017. Use of fish telemetry in rehabilitation planning, management, and monitoring in areas of concern in the Laurentian Great Lakes. Environ. Manag. 60, 1139–1154.
Brownscombe, J.W., Danylchuk, A.J., Chapman, J.M., Gutowsky, L.F., Cooke, S.J., 2017. Best practices for catch-and-release recreational fisheries–angling tools and tactics. Fish. Res. 186, 693–705.
Brownscombe, J.W., Griffin, L.P., Brooks, J.L., Danylchuk, A.J., Cooke, S.J., Midwood, J. D., 2022. Applications of telemetry to fish habitat science and management. Can. J. Fish. Aquat. Sci. 79 (8), 1347–1359.
Brownscombe, J.W., Lédée, E.J., Raby, G.D., Struthers, D.P., Gutowsky, L.F., Nguyen, V. M., Young, N., Stokesbury, M.J., Holbrook, C.M., Brenden, T.O., Vandergoot, C.S., 2019. Conducting and interpreting fish telemetry studies: considerations for researchers and resource managers. Rev. Fish. Biol. Fish. 29, 369–400.
Buchanan, S., Farrell, A.P., Fraser, J., Gallaugher, P., Joy, R., Routledge, R., 2002. Reducing gill-net mortality of incidentally caught Coho Salmon. North Am. J. Fish. Manag. 22 (4), 1270–1275.
Chopin, F.S., Arimoto, T., Inoue, Y., 1996. A comparison of the stress response and mortality of sea bream *Pagrus* major captured by hook and line and trammel net. Fish. Res. 28 (3), 277–289.
Cook, K.V., Reid, A.J., Patterson, D.A., Robinson, K.A., Chapman, J.M., Hinch, S.G., Cooke, S.J., 2019. A synthesis to understand responses to capture stressors among fish discarded from commercial fisheries and options for mitigating their severity. Fish Fish 20 (1), 25–43.
Cooke, S.J., Nguyen, V.M., Murchie, K.J., Thiem, J.D., Donaldson, M.R., Hinch, S.G., Brown, R.S., Fisk, A., 2013. To tag or not to tag: Animal welfare, conservation, and stakeholder considerations in fish tracking studies that use electronic tags. J. Int. Wildl. Law Policy 16 (4), 352–374.
Cooke, S.J., Woodley, C.M., Brad Eppard, M., Brown, R.S., Nielsen, J.L., 2011. Advancing the surgical implantation of electronic tags in fish: a gap analysis and research agenda based on a review of trends in intracoelomic tagging effects studies. Rev. Fish. Biol. Fish. 21, 127–151.
Cox, D.R., 1972. Regression models and life-tables. J. R. Stat. Soc. Ser. B (Methodol. 34 (2), 187–202.
Crossin, G.T., Heupel, M.R., Holbrook, C.M., Hussey, N.E., Lowerre-Barbieri, S.K., Nguyen, V.M., Raby, G.D., Cooke, S.J., 2017. Acoustic telemetry and fisheries management. Ecol. Appl. 27 (4), 1031–1049.
Davis, M.W., 2002. Key principles for understanding fish bycatch discard mortality. Can. J. Fish. Aquat. Sci. 59 (11), 1834–1843.
Eberts, R.L., Butt, J.C., Somers, C.M., 2018. Unexplained variation in movement by Walleye and Sauger after catch-and-release angling tournaments. North Am. J. Fish. Manag. 38 (6), 1350–1366.
Elrod, J.H., Schneider, C.P., 1987. Seasonal bathythermal distribution of juvenile lake trout in Lake Ontario. J. Gt. Lakes Res. 13 (2), 121–134.
Farrell, A.P., Gallaugher, P., Clarke, C., DeLury, N., Kreiberg, H., Parkhouse, W., Routledge, R., 2000. Physiological status of coho salmon (*Oncorhynchus kisutch*) captured in commercial nonretention fisheries. Can. J. Fish. Aquat. Sci. 57 (8), 1668–1678.
Farrell, A.P., Gallaugher, P.E., Fraser, J., Pike, D., Bowering, P., Hadwin, A.K., Parkhouse, W., Routledge, R., 2001. Successful recovery of the physiological status of coho salmon on board a commercial gillnet vessel by means of a newly designed revival box. Can. J. Fish. Aquat. Sci. 58 (10), 1932–1946.
Frick, L.H., Reina, R.D., Walker, T.I., 2010. Stress related physiological changes and post-release survival of Port Jackson sharks (*Heterodontus portusjacksoni*) and gummy

sharks (*Mustelus antarcticus*) following gill-net and longline capture in captivity. J. Exp. Mar. Biol. Ecol. 385 (1-2), 29–37.
Funnell, T.R., Brenden, T.O., Kraus, R., MacDougall, T., Markham, J., Murray, C., Robinson, J., Vandergoot, C.S., 2023. Seasonal spatial ecology of lake trout in Lake Erie. Trans. Am. Fish. Soc. 152 (5), 672–693.
Gallagher, C.P., Guzzo, M.M., Dick, T.A., 2018. Seasonal depth and temperature use, and diel movements of lake trout (*Salvelinus namaycush*) in a subarctic lake. Arct. Sci. 5 (2), 71–89.
Ganias, K., Malioufa, G., Kaloyanni, M., 2023. Evaluating the levels of capture-related stress and physical injury in métiers that use gillnets and trammel nets. Fish. Res. 267, 106814.
Gatch, A.J., Furgal, S.L., Gorsky, D., Marsden, J.E., Biesinger, Z.F., Lantry, B.F., 2022. Evaluation of post-stocking dispersal and mortality of juvenile lake trout *Salvelinus namaycush* in Lake Ontario using acoustic telemetry. J. Gt. Lakes Res. 48 (2), 572–580.
Gatch, A., Gorsky, D., Biesinger, Z., Bruestle, E., Lee, K., Karboski, C., Bartron, M.L., Wagner, T., 2021. Evidence of successful river spawning by lake trout (*Salvelinus namaycush*) in the Lower Niagara River, Lake Ontario. J. Gt. Lakes Res. 47 (2), 486–493.
Gatch, A.J. and Gorsky, D. 2025, Acoustic detection and biological data for Lake Trout, *Salvelinus namaycush*, in Lake Ontario: US Geological Survey data release, https://doi.org/10.5066/P19H76DM.
Holbrook, C., Hayden, T., Binder, T., Pye, J., 2024. glatos: a package for the Great Lakes acoustic telemetry observation system. R. Package Version 0. 8. 0. Retrieved from. ⟨https://github.com/ocean-tracking-network/glatos⟩.
Howell, B.E., Navarroli, G., DePasquale, S.W., Cooke, S.J., Hasler, C.T., 2024. Sex and season influence behaviour and physiology of lake trout following angling. Conserv. Physiol. 12 (1), coae041.
Ivanova, S.V., Fisk, A.T., Johnson, T.B., 2024. Realized thermal niche approach eliminates temperature bias in bioenergetic model estimates. Ecol. Evol. 14 (2), e10974.
Ivanova, S.V., Johnson, T.B., Metcalfe, B., Fisk, A.T., 2021. Spatial distribution of lake trout (*Salvelinus namaycush*) across seasonal thermal cycles in a large lake. Freshw. Biol. 66 (4), 615–627.
Jacoby, D.M., Piper, A.T., 2023. What acoustic telemetry can and cannot tell us about fish biology. J. Fish. Biol.
Jasonowicz, A., Sitar, S., Seider, M., Goetz, F., 2022. Depth and temperature selection of lake charr (*Salvelinus namaycush*) ecotypes in Lake Superior revealed by popup satellite archival tags. J. Gt. Lakes Res. 48 (4), 1050–1066.
Jepsen, N., Schreck, C., Clements, S., Thorstad, E.B., 2005. A brief discussion on the 2% tag/bodymass rule of thumb. Aquat. Telem. Adv. Appl. 255–259.
Keretz, K.R., Dinken, C.P., Allen, P.J., Colvin, M.E., Schramm Jr, H.L., 2018. The effect of water temperature, angling time, and dissolved oxygen on the survival of Largemouth Bass subjected to simulated angling and tournament handling procedures. North Am. J. Fish. Manag. 38 (3), 606–622.
Klinard, N.V., Halfyard, E.A., Matley, J.K., Fisk, A.T., Johnson, T.B., 2019. The influence of dynamic environmental interactions on detection efficiency of acoustic transmitters in a large, deep, freshwater lake. Anim. Biotelemetry 7 (1), 1–17.
Klinard, N.V., Vandergoot, C.S., Briggs, A., Elliott, C., Faust, M., Fielder, D.G., Gorsky, D., Hartman, T., Holbrook, C.M., Isermann, D.A., Midwood, J.D., 2025. Integrating acoustic telemetry research into management: successes and challenges in the Laurentian Great Lakes. Can. J. Fish. Aquat. Sci. ja.
Koeberle, A.L., Pearsall, W., Hammers, B.E., Mulhall, D., McKenna Jr, J.E., Chalupnicki, M., Sethi, S.A., 2023. Whole-lake acoustic telemetry to evaluate survival of stocked juvenile fish. Sci. Rep. 13 (1), 18956.
LaRochelle, L., Trahan, A., Brownscombe, J.W., Danylchuk, A.J., Cooke, S.J., 2022. A Comparison of different tournament weigh-in formats on the short-term postrelease behavior of black bass assessed with biologgers. North Am. J. Fish. Manag. 42 (2), 250–259.
Lee, W.C., Bergersen, E.P., 1996. Influence of thermal and oxygen stratification on lake trout hooking mortality. North Am. J. Fish. Manag. 16 (1), 175–181.
Loftus, A.J., Taylor, W.W., Keller, M., 1988. An evaluation of lake trout (*Salvelinus namaycush*) hooking mortality in the upper Great Lakes. Can. J. Fish. Aquat. Sci. 45 (8), 1473–1479.
Madden, J.C., LaRochelle, L., Burton, D., Danylchuk, S.C., Danylchuk, A.J., Cooke, S.J., 2024. Biologgers reveal unanticipated issues with descending angled walleye with barotrauma symptoms. Can. J. Fish. Aquat. Sci. 81 (2), 212–222.
Manire, C., Hueter, R., Hull, E., Spieler, R., 2001. Serological changes associated with gill-net capture and restraint in three species of sharks. Trans. Am. Fish. Soc. 130 (6), 1038–1048.
Marsden, J.E., Binder, T.R., Johnson, J., He, J., Dingledine, N., Adams, J., Johnson, N.S., Buchinger, T.J., Krueger, C.C., 2016. Five-year evaluation of habitat remediation in Thunder Bay, Lake Huron: comparison of constructed reef characteristics that attract spawning lake trout. Fish. Res. 183, 275–286.
Martins, C.L., Walker, T.I., Reina, R.D., 2018. Stress-related physiological changes and post-release survival of elephant fish (*Callorhinchus milii*) after longlining, gillnetting, angling and handling in a controlled setting. Fish. Res. 204, 116–124.
Mazerolle, M.J., 2023. AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c). R package version 2.3.3. Retrieved from. ⟨https://cran.r-project.org/package=AICcmodavg⟩.
Meals, K.O., Miranda, L.E., 1994. Size-related mortality of tournament-caught largemouth bass. North Am. J. Fish. Manag. 14 (2), 460–463.
Meka, J.M., McCormick, S.D., 2005. Physiological response of wild rainbow trout to angling: impact of angling duration, fish size, body condition, and temperature. Fish. Res. 72 (2-3), 311–322.
Ng, E.L., Fredericks, J.P., Quist, M.C., 2015. Effects of gill-net trauma, barotrauma, and deep release on postrelease mortality of lake trout. J. Fish. Wildl. Manag. 6 (2), 265–277.
O'Malley, B.P., Lantry, B.F., Minihkeim, S.P., McKenna, J., Goretzke, J.A., Gatch, A.J., Gorsky, D., 2023. Lake Ontario August gillnet survey and Lake Trout assessment, 2022 USGS Rep. 11. Retrieved from. ⟨https://www.glfc.org/pubs/lake_committees/common_docs/Ontario_2022_LakeTroutReport.pdf⟩.
Paulic, L.L., Ivanova, S.V., Morton, K., Johnson, R.J., Gorsky, D., Farrell, C., Sweka, J., Johnson, T.B., Fisk, A.T., 2025. Evaluation of post-stocking survival and movement of hatchery-reared juvenile bloater (*Coregonus hoyi*) stocked across bathymetric depths in Lake Ontario. Can. J. Fish. Aquat. Sci. 82, 1–14.
Pinheiro, V.M., Stockwell, J.D., Marsden, J.E., 2017. Lake trout (*Salvelinus namaycush*) spawning site use in Lake Champlain. J. Gt. Lakes Res. 43 (2), 345–351.
Portz, D.E., Woodley, C.M., Cech, J.J., 2006. Stress-associated impacts of short-term holding on fishes. Rev. Fish. Biol. Fish. 16, 125–170.
Raby, G.D., Donaldson, M.R., Hinch, S.G., Clark, T.D., Eliason, E.J., Jeffries, K.M., et al., 2015. Fishing for effective conservation: context and biotic variation are keys to understanding the survival of Pacific salmon after catch-and-release. Integr. Comp. Biol. 55 (4), 554–576.
Raby, G.D., Johnson, T.B., Kessel, S.T., Stewart, T.J., Fisk, A.T., 2020. Pop-off data storage tags reveal niche partitioning between native and non-native predators in a novel ecosystem. J. Appl. Ecol. 57 (1), 181–191.
Robichaud, J.A., Piczak, M.L., LaRochelle, L., Reid, J.L., Chhor, A.D., Holder, P.E., Nowell, L.B., Brownscombe, J.W., Danylchuk, A.J., Cooke, S.J., 2024. Interactive effects of fish handling and water temperature on reflex impairment of angled rainbow trout. Fish. Res. 274, 106993.
Roth, C.J., Schill, D.J., Quist, M.C., High, B., 2018. Effects of air exposure in summer on the survival of caught-and-released salmonids. North Am. J. Fish. Manag. 38 (4), 886–895.
Rulifson, R.A., 2007. Spiny dogfish mortality induced by gill-net and trawl capture and tag and release. North Am. J. Fish. Manag. 27 (1), 279–285.
Sauls, B., 2014. Relative survival of gags *Mycteroperca microlepis* released within a recreational hook-and-line fishery: Application of the Cox Regression Model to control for heterogeneity in a large-scale mark-recapture study. Fish. Res. 150, 18–27.
Saunders, R.L., 1953. The swimbladder gas content of some freshwater fish with particular reference to the physostomes. Can. J. Zool. 31 (6), 547–560.
Savina, E., Karlsen, J.D., Frandsen, R.P., Krag, L.A., Kristensen, K., Madsen, N., 2016. Testing the effect of soak time on catch damage in a coastal gillnetter and the consequences on processed fish quality. Food Control 70, 310–317.
Schramm Jr, H.L., Vondracek, B., French, W.E., Gerard, P.D., 2010. Factors associated with mortality of walleyes and saugers caught in live-release tournaments. North Am. J. Fish. Manag. 30 (1), 238–253.
Sitar, S.P., Brenden, T.O., He, J.X., Johnson, J.E., 2017. Recreational postrelease mortality of lake trout in lakes Superior and Huron. North Am. J. Fish. Manag. 37 (4), 789–808.
Sjoberg, D., Baillie, M., Fruechtenicht, C., Haesendonckx, S., Treis, T., 2025. ggsurvfit: Flexible Time-to-Event Figures. R. Package Version 1 (1).
Therneau, T., 2024. A Package Surviv. Anal. R. R. Package Version 3. 0, 7. Retrieved from. ⟨https://CRAN.R-project.org/package=survival⟩.
Veneranta, L., Pakarinen, T., Jokikokko, E., Kallio-Nyberg, I., Harjunpää, H., 2018. Mortality of Baltic sea trout (*Salmo trutta*) after release from gillnets. J. Appl. Ichthyol. 34 (1), 49–57 (Feb).
Wilson, A.D., Hayden, T.A., Vandergoot, C.S., Kraus, R.T., Dettmers, J.M., Cooke, S.J., Krueger, C.C., 2017. Do intracoelomic telemetry transmitters alter the post-release behaviour of migratory fish? Ecol. Freshw. Fish. 26 (2), 292–300.
Zimmerman, M.S., Schmidt, S.N., Krueger, C.C., Vander Zanden, M.J., Eshenroder, R.L., 2009. Ontogenetic niche shifts and resource partitioning of lake trout morphotypes. Can. J. Fish. Aquat. Sci. 66 (6), 1007–1018.