WISCONSIN DEPARTMENT OF NATURAL RESOURCES

LAKE SUPERIOR FALL LAKE TROUT ASSESSMENT REPORT 2022

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INTRODUCTION

Lean Lake Trout populations in Lake Superior declined to historically low numbers from the 1930s to the 1950s due to the invasion of a new predator, Sea Lamprey, and overfishing. By the early 1960s, spawning activity had ceased at nearly all traditional spawning sites in the Apostle Islands. The Fall Lake Trout Assessment was crucial in multiple aspects of aiding Lake Trout recovery in Lake Superior. This survey was instrumental in identifying and establishing both the Gull Island (1976) and Devils Island (1981) fish refuges surrounding critical spawning habitats in the Apostle Islands. The survey was then used to monitor the resurgence of Lake Trout on these spawning shoals within the refuges in the following decades. These two refuges encompass two of the largest Lake Trout spawning shoals in the entire lake, which support the majority of Lake Trout reproduction in the Apostle Islands and substantially contribute to other Lake Trout stocks in Lake Superior. Additionally, this survey was the method the Wisconsin Department of Natural Resources (DNR) used to collect Lake Trout eggs, raise them at the Bayfield State Fish Hatchery and provide supplemental stocking in the Apostle Islands. This stocking program was a tool used to help boost Lake Trout populations and ceased in 1995 after the population was fully recovered.

Today our management team does not face the same problems with Lake Trout management, but this assessment is still a useful management tool and has three main objectives. First, we monitor the size, age and sex structure of the Lake Trout spawning stocks on multiple shoals. Managers agree that maintaining or continuing to increase spawner biomass is essential to a self-sustaining Lake Trout population that supports both commercial and recreational fishery interests. Second, Lake Trout eggs are still collected to raise in the hatchery for supplemental Lake Trout stocking in the Western Arm (WI-1), and Splake (a cross between female Lake Trout and male Brook Trout) are raised in the hatchery and stocked into management unit WI-2 for an additional sport fishing opportunity. Third, during this assessment, we capture hundreds of fish each day, and the conditions of the survey (i.e., shallow sets, cool water temperature) allow a better than 95% survival rate. This allows us to tag and recapture thousands of individual Lake Trout (identified with a unique number on a tag) each year to monitor growth, movement and other dynamics of Lake Trout in Wisconsin waters.

METHODS

Gill nets were set on the bottom of the lake bed on targeted Lake Trout spawning areas for one net-night (24 hours) using the R/V Hack Noyes. The 2022 Fall Lake Trout Assessment was conducted in the Apostle Islands region of Lake Superior (Figure 1) between Oct. 20 and Oct. 31. Gull Island Shoal (GIS) was sampled with a 823-meter monofilament gill net. The net was composed of alternating 140 and 152 millimeter mesh (stretch measure) panels arranged using the following sequence: 152, 140, 152, 140, 152, 140, 152, 140, 152. Both Gull Island (GI) and Michigan Island (MI) were sampled by dividing the standard GIS gill net. Gull Island was sampled with a 366-meter gill net that used the following sequence of meshes: 152, 140, 152, 140. Michigan Island was sampled with a 457-meter gill net that used the following sequence of meshes: 152, 140, 152, 140, 152. Both GI and MI were combined for these analyses (GI/MI). Sand Cut Reef (SCR) was sampled with a 1,189-meter monofilament gill net that was divided between two humps (i.e., 549 meters on the west hump and 640 meters on the east hump). The meshes were arranged using the following sequence: 152, 140, 178, 114, 165, 127, 152, 127, 165, 114, 178, 140, 152. These same nets were used on Devils Island Shoal (DIS) and Cat Island Shoal (CIS) combined as one net.

Biological information (e.g., total length, weight, sex, gonad status, fin clips, etc.) was collected from fish using standardized protocols. Otoliths were extracted from deceased individuals, and ages were estimated using cross-sections. All live Lake Trout were given external Floy tags with unique numbers, and tag information was recorded from all recaptured fish.

Assessing relative abundance (CPE) during spawning assessments is not recommended due to the variable nature of sampling spawning aggregations, and CPE trends in this assessment do not reflect other surveys/estimates (e.g., stock assessment model estimates, Spring Lake Trout Survey, etc.). Thus, relative abundance was not assessed with this survey; however, numerous other population characteristics were summarized. This survey consistently provides information from larger and older Lake Trout compared with the Spring Lake Trout Assessment and Summer Community Assessment. Length and age frequency plots were used to compare size and age structure among the five Apostle Islands spawning shoals, and median length was used to look at trends in size structure through time. The presence or absence of a fin clip was used to determine wild (i.e., not hatchery-origin) and hatchery origins through time. Recapture histories were assessed with the number of years at large calculated for both the most recent capture (i.e., the number of years since the most recent capture of that individual) and the original capture event (i.e., the number of years since the original capture of that individual). Mean annual growth increment was calculated by grouping individual Lake Trout into 20-millimeter length bins based on the observed total length at the most recent capture. Growth increment was then computed as the difference between the observed total length and the total length at the most recent capture event divided by the number of years at large since the most recent capture. Growth was also assessed by fitting von Bertalanffy growth functions to length and age data. Lastly, a transition matrix was constructed to assess Lake Trout movement patterns among the five Apostle Islands spawning shoals sampled in this survey. Analyses were conducted using Program R, and this report was formatted with the package RMarkdown.

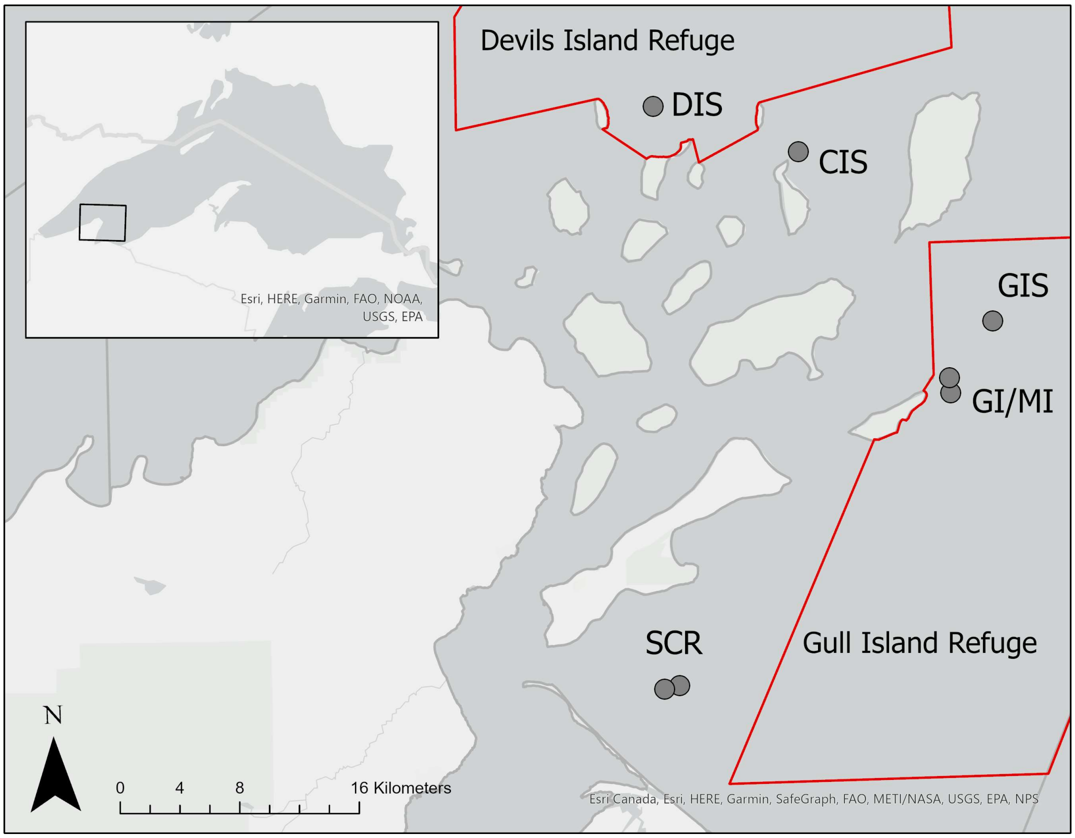

Figure 1. Map of DNR Fall Lake Trout Assessment in the Apostle Islands region of Lake Superior. DIS = Devils Island Shoals, CIS = Cat Island Shoals, GIS = Gull Island Shoals, GI/MI = Gull Island/Michigan Island, SCR = Sand Cut Reef.

RESULTS

The Lake Trout spawning stock at GI/MI and GIS had a larger size structure than other spawning shoals, likely due to using larger mesh sizes at these shoals (Figure 2). CIS, DIS and SCR were fished using the same gear and are comparable. In 2022, SCR had the smallest size structure of the shoals sampled (Figure 2). The median total length of both spawning male and female Lake Trout increased throughout the 1980s and 1990s but has generally declined since about 2000 at all spawning shoals (Figure 3). The proportion of wild (non-hatchery origin) Lake Trout spawning stock was greater than 98% at all spawning shoals in 2022 (Figure 4). The proportion of wild Lake Trout has increased in the Apostle Islands since restoration efforts began and the DNR ceased stocking Lake Trout in WI-2 (Figure 4).

On average, Lake Trout appear in the spawning stock between ages 8 and 10 (Figure 5). Generally, males reach sexual maturity (i.e., appear in the spawning stock) one to two years earlier than females (Figure 5). Lake Trout spawning stock from SCR had a younger age structure than Lake Trout from CIS and DIS, and DIS Lake Trout had an older age structure than CIS (Figure 5). GIS and GI/MI Lake Trout had much older age structures than the other three spawning shoals, but this is likely due to the larger mesh sizes used on those shoals. The oldest Lake Trout age estimate from this survey was 49 years old (sampled in 2019). Most recaptured fish in the 2022 assessment were originally captured and tagged in 2013 or later (Figure 6). Zero Lake Trout were recaptured that were originally encountered 20 or more years ago (i.e., originally captured and tagged prior to 2002). The longest at-large fish detected in the 2022 survey was 19 years. The number of male Lake Trout recaptured in a given year had an exponential decay relationship with the number of years individual fish had been at large since its last detection, but female Lake Trout did not exhibit the same type of relationship, suggesting detection probability differs between male and female Lake Trout on Apostle Islands spawning shoals from year to year (Figure 7). I speculate this could be caused by a higher frequency of skipped spawning by female Lake Trout in the Apostle Islands.

SCR and CIS Lake Trout spawning stocks had a smaller median number of years at large since the most recent capture and original capture compared to the other spawning shoals (Figure 8). GIS Lake Trout had the largest median number of years at large since recent capture and original capture. In summary, Lake Trout captured on spawning shoals outside the two refuges (SCR and CIS; Figure 1) have smaller size structure (Figure 2), younger age structure (Figure 5) and shorter recapture histories (Figure 8) than those inside the refuges, suggesting a higher mortality rate within these population subsets (especially SCR) due to sport and commercial harvest allowances.

Subsequent recaptures of tagged Lake Trout allowed us to measure growth with a known number of years between the original capture event and recapture events. Smaller male Lake Trout (520-539 millimeters) on average grew 28 millimeters per year, but annual growth declined to an average of 15 millimeters per year for 620-639 millimeters male Lake Trout and evened out around an average of 7-11 millimeters per year for Lake Trout between 680 and 840 millimeters (Figure 9). Male Lake Trout greater than 860 millimeters on average grew less than 5 millimeters per year. On average, female Lake Trout reached their asymptotic length slightly faster than male Lake Trout (i.e., higher von Bertalanffy K value), but average maximum lengths near the growth asymptote were similar (i.e., similar von Bertalanffy L-inf values; Figure 10, Table 1).

Lake Trout captured on Apostle Islands spawning shoals had relatively high spawning site fidelity (spatially) during subsequent recapture events in recent years (Figure 11). In other words, a Lake Trout tagged on a particular spawning shoal was likely recaptured on the same shoal. However, there was some degree of mixing among the five spawning shoals assessed from 2000 to 2022. Spawning Lake Trout captured on GI/MI were recaptured on GIS in a subsequent year 31/44% of the time and vice versa 12/15% of the time for males/females, suggesting the two shoals act more as a "spawning reef complex." Likewise, but to a lesser degree, spawning Lake Trout captured on CIS were recaptured on DIS in a subsequent year 12/20% of the time and vice versa 7/6% of the time for males/females, suggesting these two shoals also act more as a reef complex together. Movement outside of these spawning reef complexes was much more rare, as all other transitions occured less than 3% of the time. CIS-DIS spawning Lake Trout were rarely captured in the GIS-GI/MI complex and vice versa, and SCR was relatively isolated from both of the other spawning areas. Interestingly, male Lake Trout appeared to have slightly higher site fidelity than female Lake Trout.

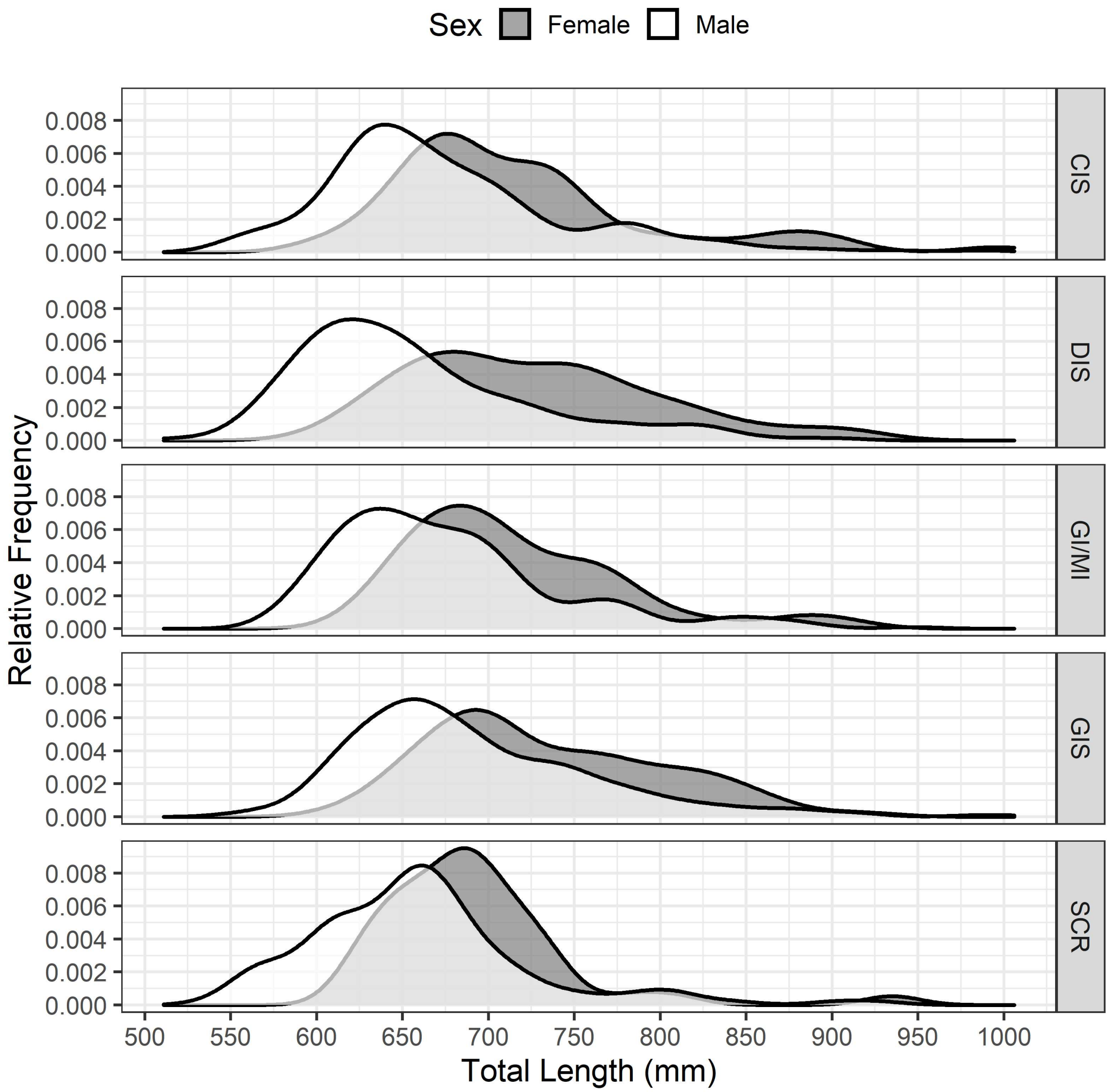

Figure 2. Density plots of male (white) and female (grey) Lake Trout total lengths on five Apostle Islands spawning shoals in 2022.

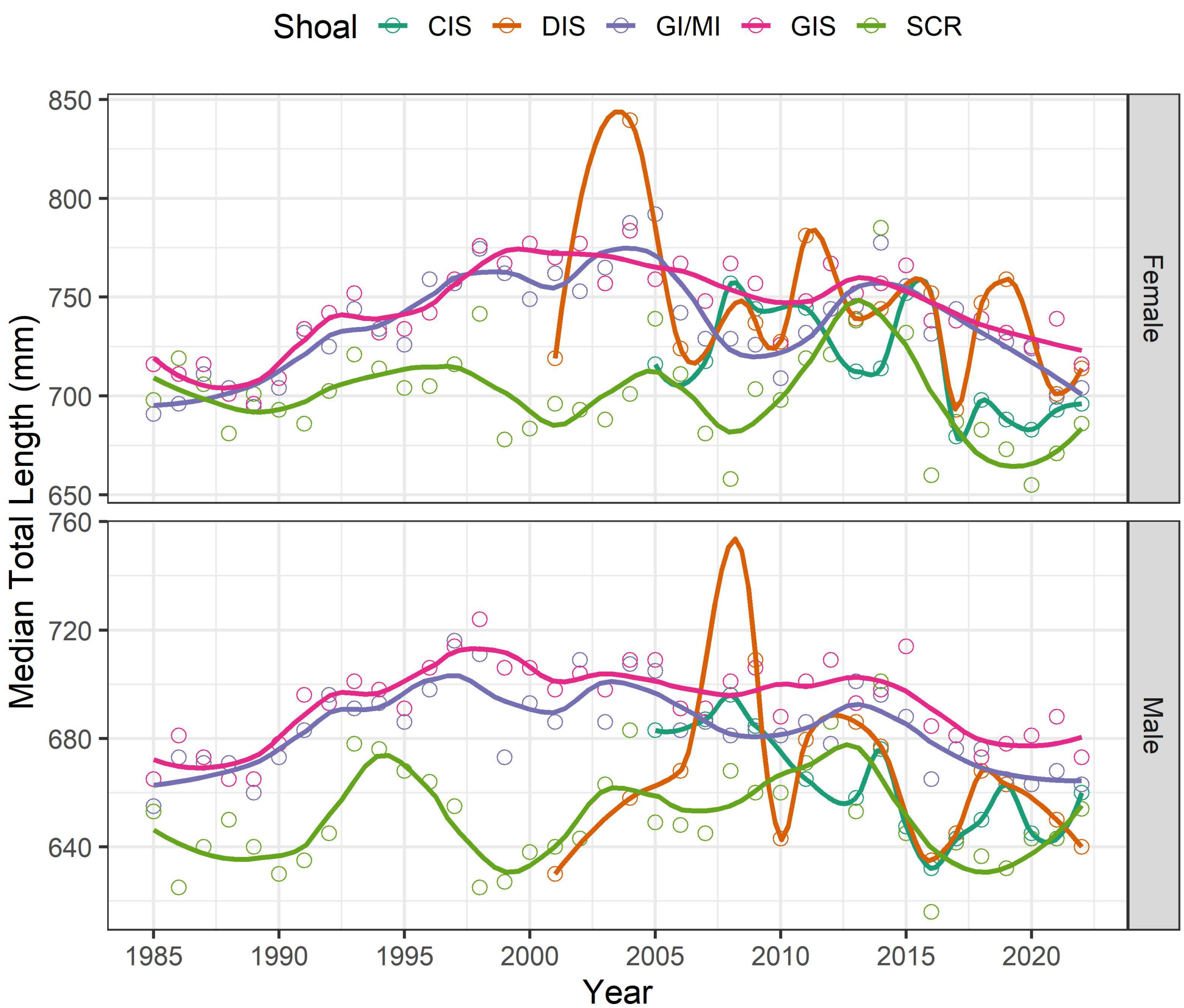

Figure 3. Time series of wild female (top) and male (bottom) Lake Trout median total length (mm) captured on five Apostle Islands spawning shoals from 1985 to 2022. Trend lines were fit using loess regression. Note the differing y-axis scales between sexes.

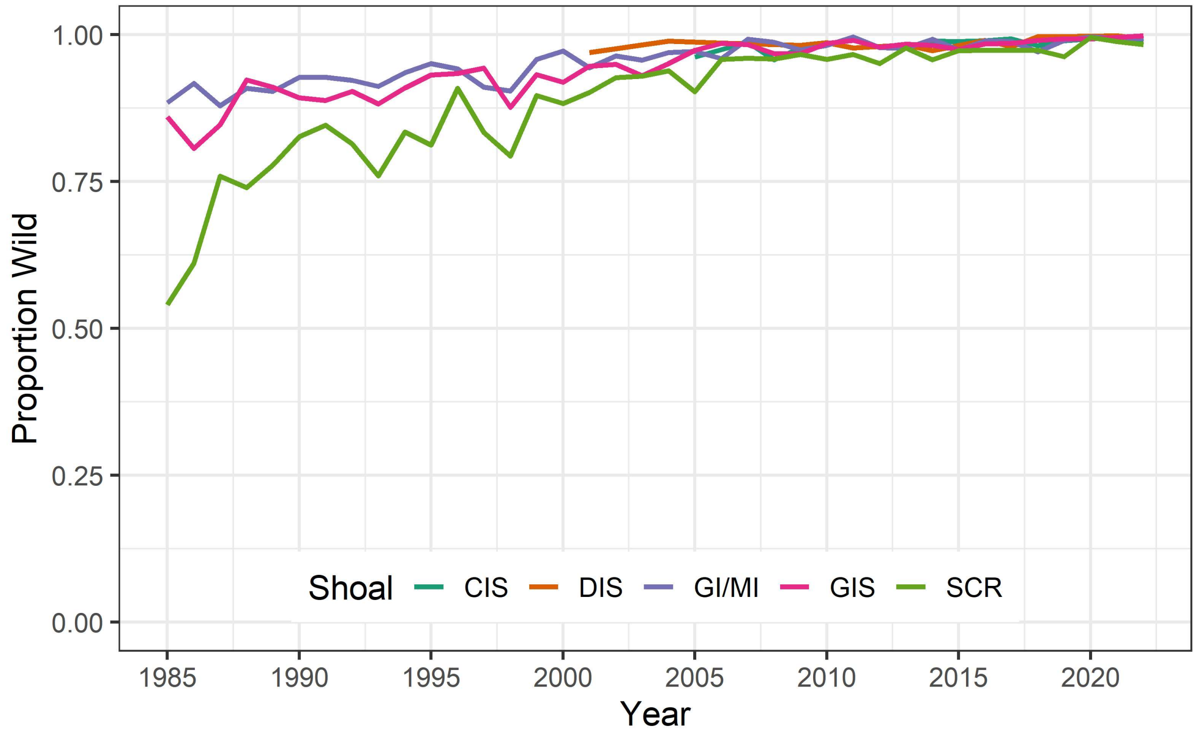

Figure 4. Time series of the proportion of wild (non-hatchery origin) Lake Trout among five Apostle Islands spawning shoals from 1985 to 2022.

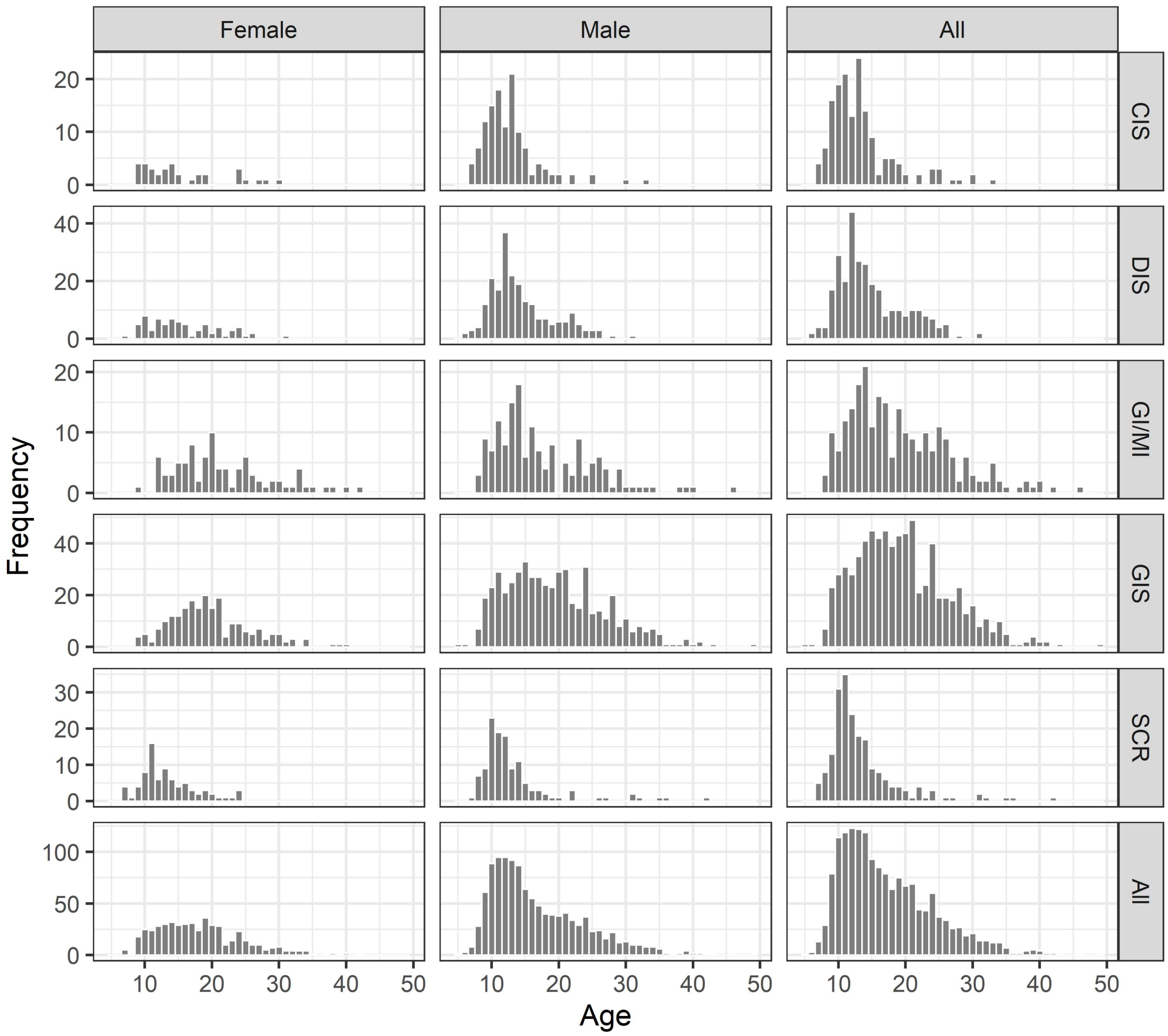

Figure 5. Age frequency plots for male, female and all sexes of Lake Trout combined that were captured among five Apostle Islands spawning shoals. Data include age estimates from the Fall Lake Trout Assessment from 2011 to 2022. Note the differing y-axis scales among grids.

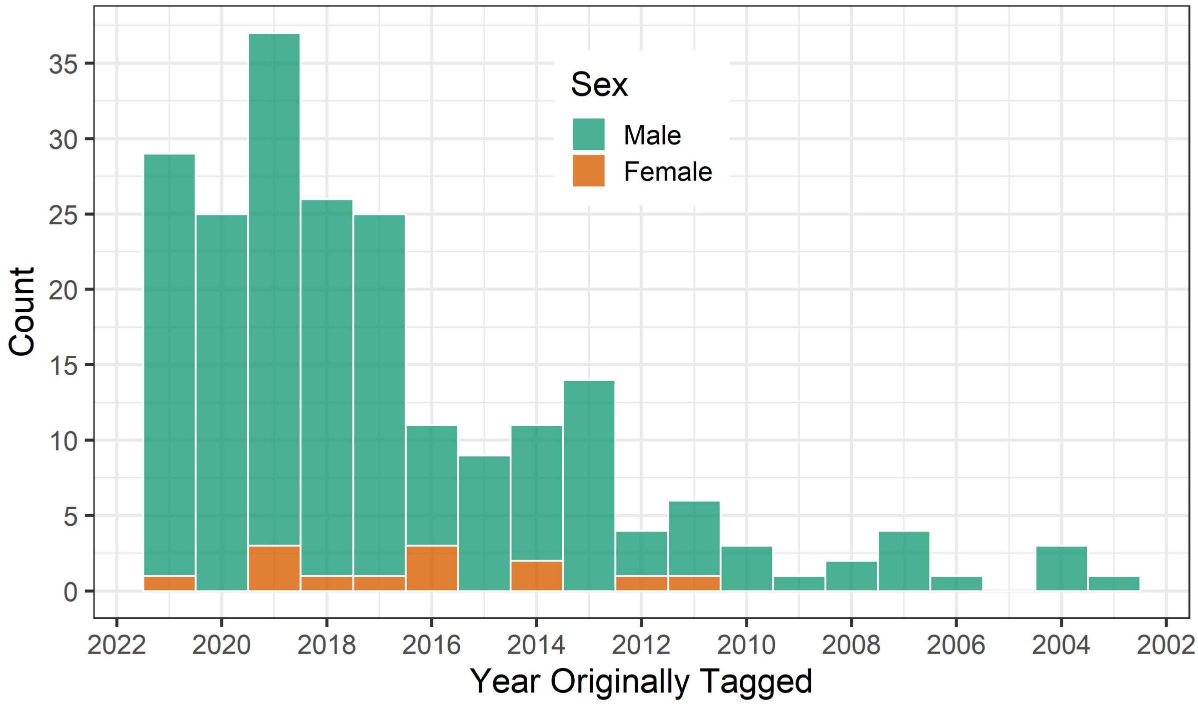

Figure 6. Number of fish captured in the 2022 Fall Lake Trout Assessment per year the fish was originally tagged (male = green, female = orange).

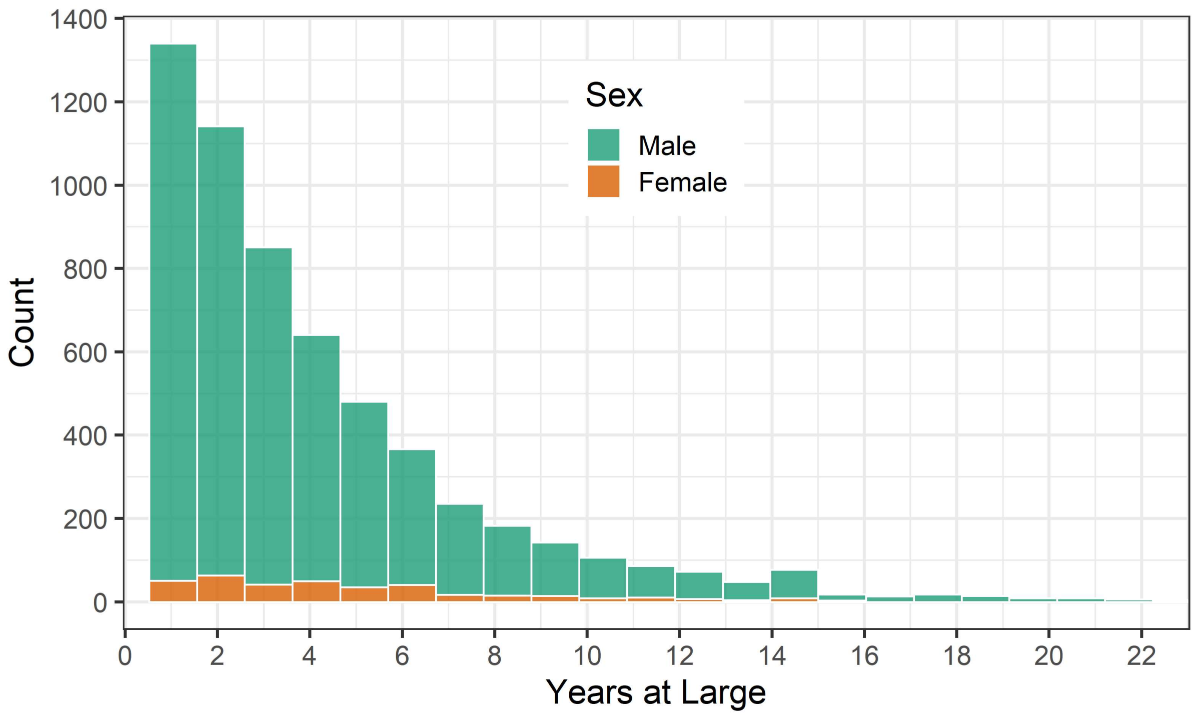

Figure 7. Frequency of the number of years at large since the most recent capture event for all individual recaptured Lake Trout during the Fall Lake Trout Assessment from 1990 to 2022 with males in green and females in orange.

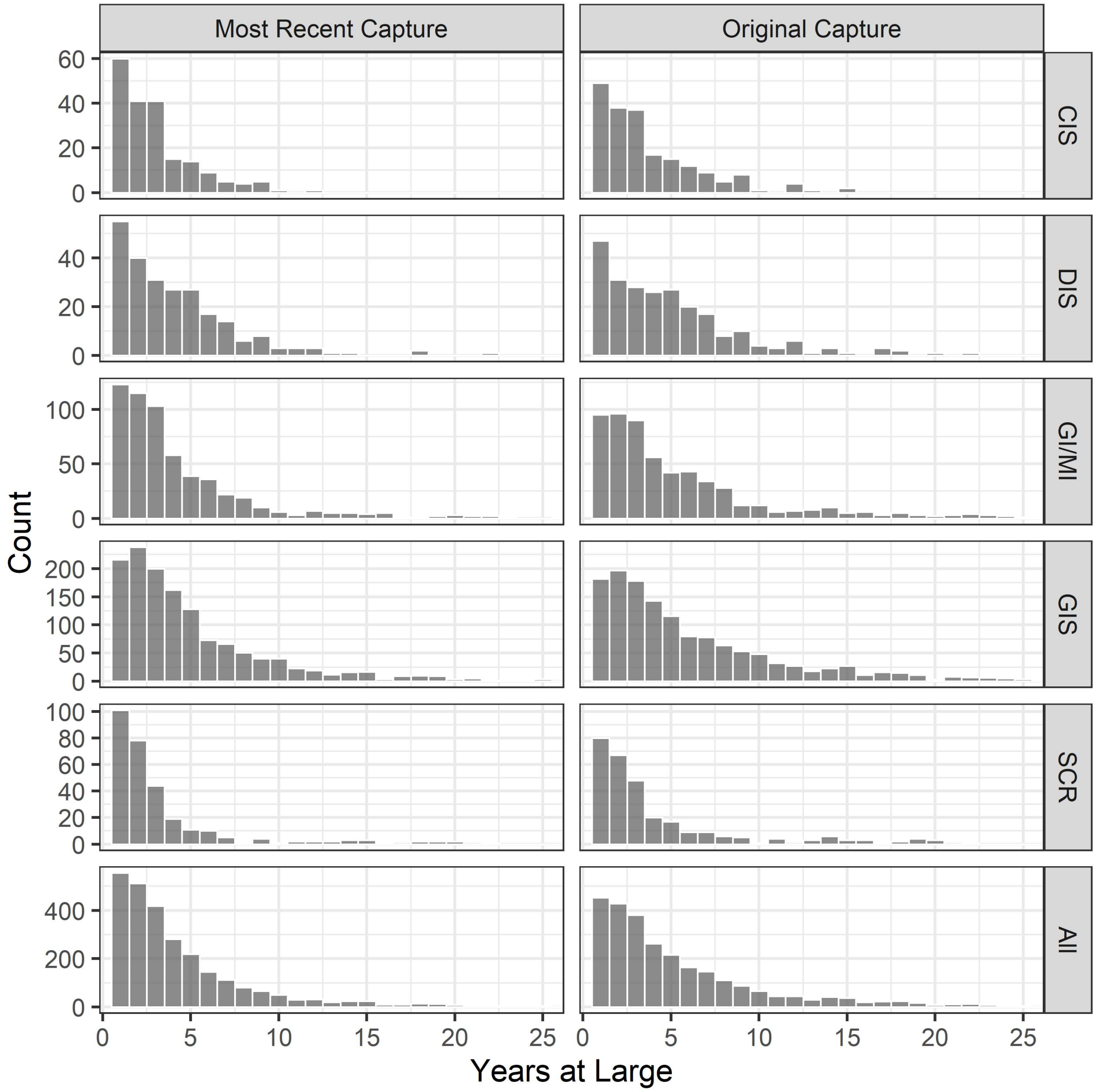

Figure 8. Frequency of the number of years at large since the most recent capture event (left) and the original capture event (right) for all individual recaptured Lake Trout during the Fall Lake Trout Assessment from 2011 to 2022 from each individual spawning shoal and all shoals combined (All).

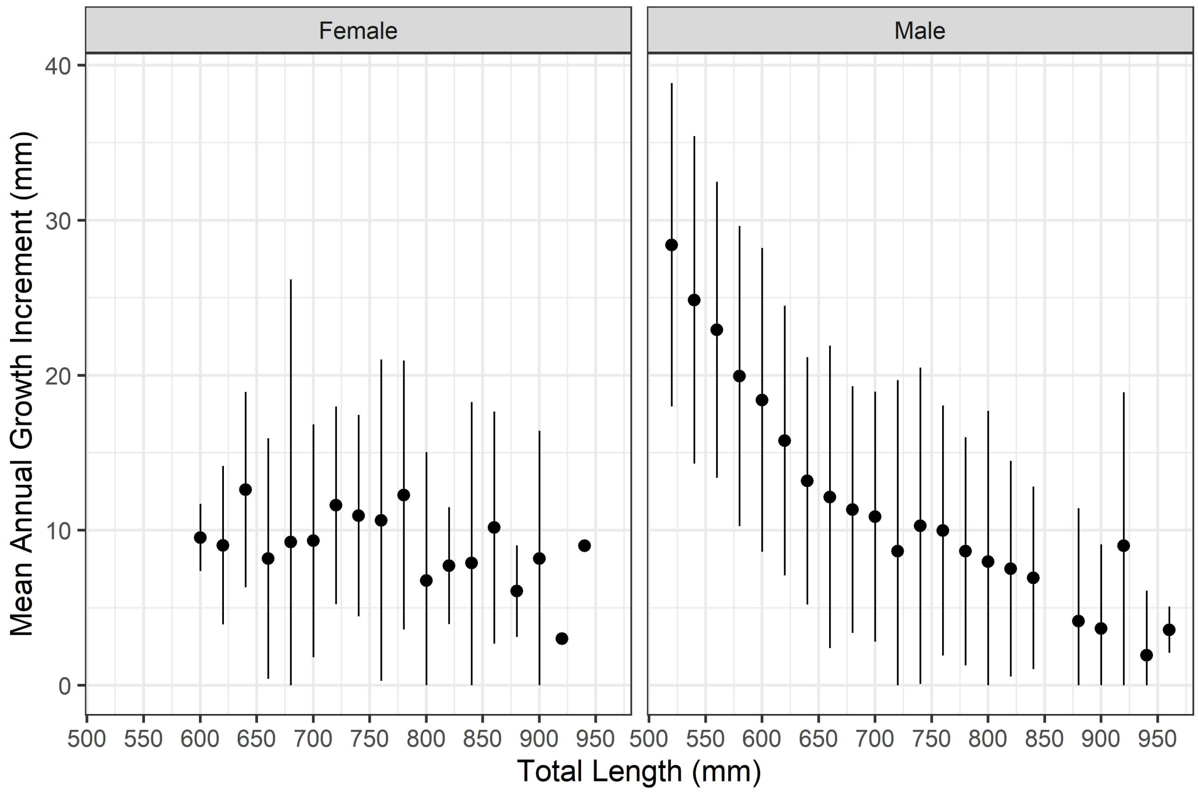

Figure 9. Mean annual growth increment (millimeters) of female (left) and male (right) recaptured wild Lake Trout during the Fall Lake Trout Assessment using data from 2000 to 2022. Vertical bars represent +/- one standard deviation. Individual Lake Trout were grouped into 20 millimeters length bins based on the observed total length at the most recent capture. Growth increment was computed as the difference between the observed total length and the total length at the most recent capture event divided by the number of years since the most recent capture event.

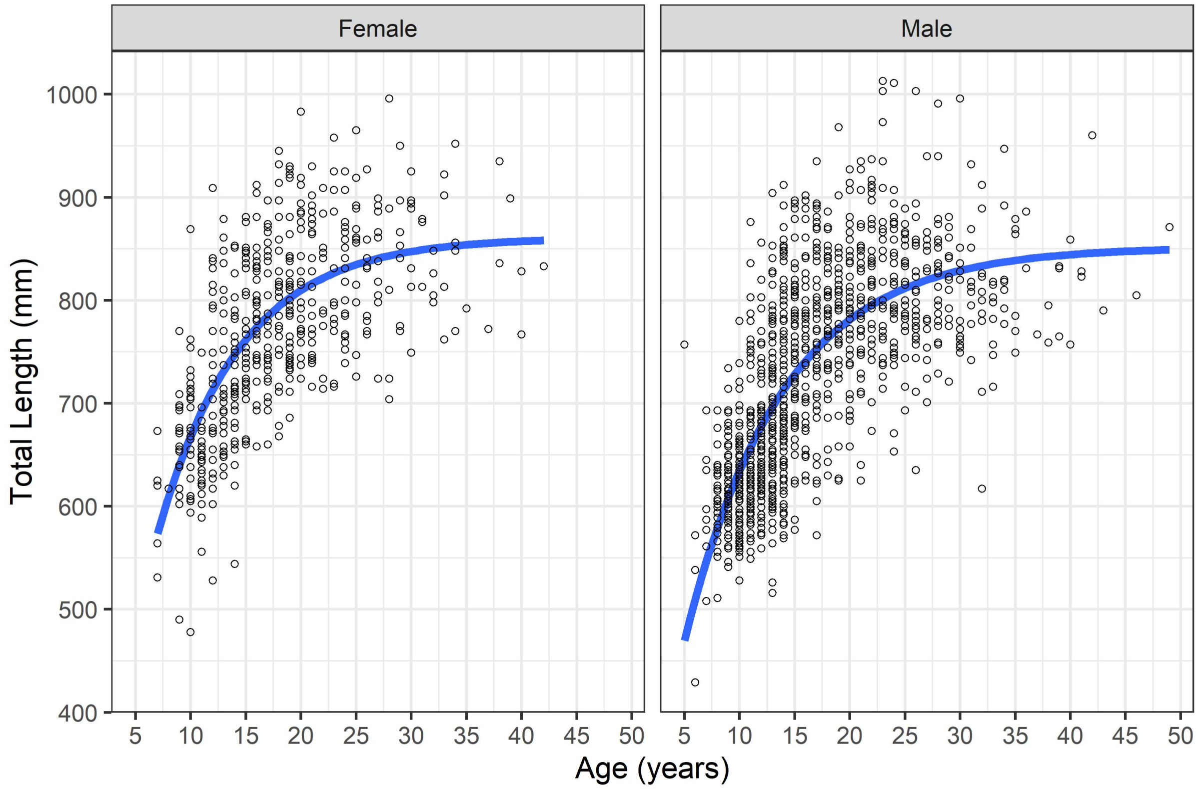

Figure 10. von Bertalanffy growth functions of both female (left) and male (right) Lake Trout from the Fall Lake Trout Assessment from 2011 to 2021.

Table 1. von Bertalanffy growth function coefficients for female and male Lake Trout from the Fall Lake Trout Assessment from 2011 to 2021.

	Female			Male		
	Coefficient	**L 95% CI**	**U 95% CI**	**Coefficient**	**L 95% CI**	**U 95% CI**
Linf	860.988	842.350	885.450	851.773	836.994	869.205
K	0.133	0.102	0.166	0.113	0.097	0.129
t0	-1.269	-4.107	0.740	-2.105	-3.660	-0.834

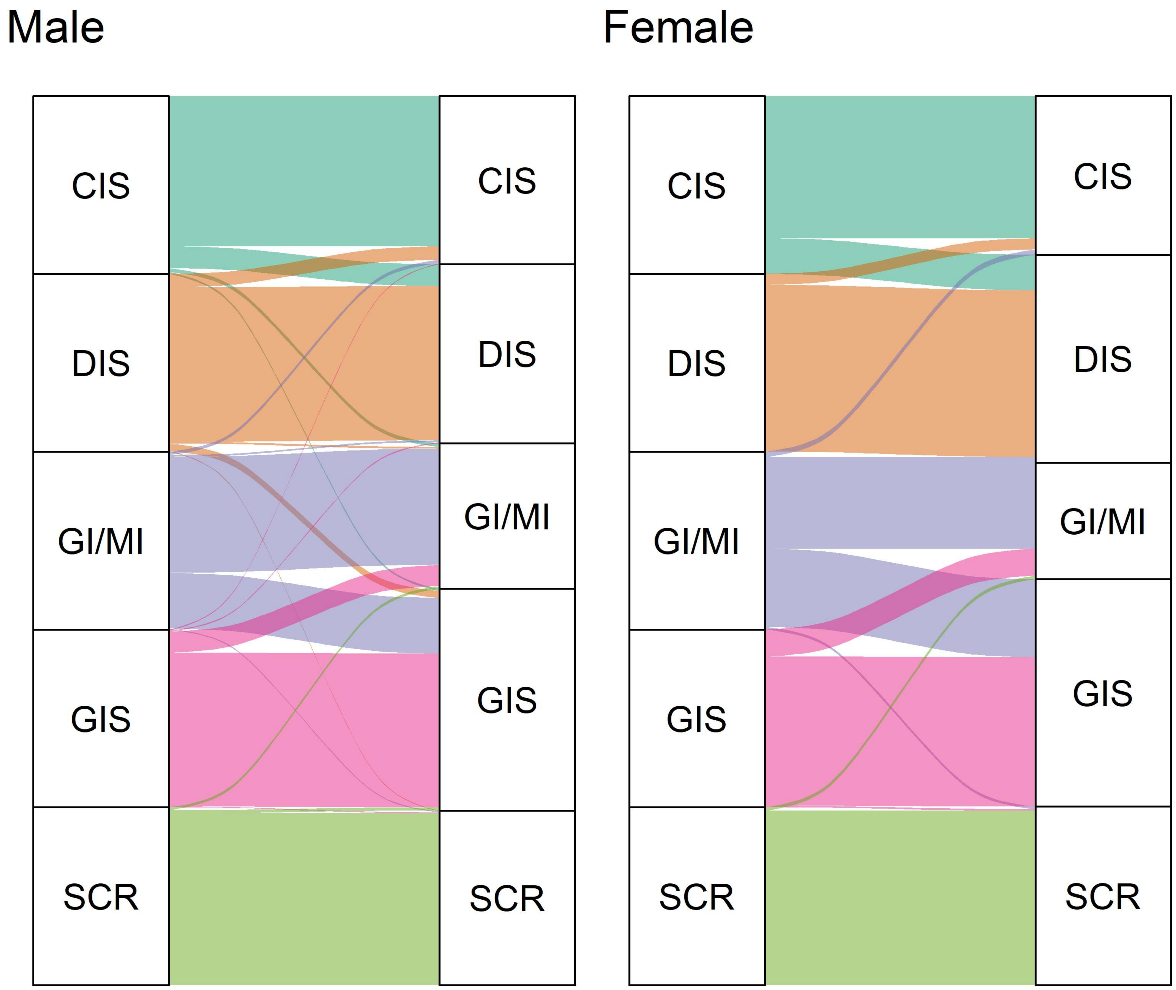

Figure 11. Transition plot representing trends of individual fish movement from its original capture location (left) to its next encounter location (right) for male (left panel) and female (right panel) Lake Trout. Thickness of transitions represents proportion of total Lake Trout recaptured within each original capture location. All recaptures from the fall spawning survey from 2000 to 2022 were used in this analysis.