WISCONSIN DEPARTMENT OF NATURAL RESOURCES

LAKE SUPERIOR LAKE TROUT SPAWNING SURVEY 2020

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March 25, 2021

INTRODUCTION

Lean Lake Trout populations in Lake Superior declined to historically low numbers during 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 Lake Trout Spawning Survey was crucial in multiple aspects of aiding Lean Lake Trout recovery in Lake Superior. This survey was instrumental for the establishment of both Gull Island (1976) and Devils Island (1981) Fish Refuges and documenting the resurgence of Lean Lake Trout on these spawning shoals within the refuges in the following decades. These two refuges encompass two of the largest Lean Lake Trout spawning shoals in the entire lake, which support the majority of Lean Lake Trout reproduction in the Apostle Islands and contribute to populations in other jurisdictions. Additionally, this survey was the method the Wisconsin Department of Natural Resources (DNR) used to collect Lean 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 initially boost Lean Lake Trout populations and was ceased in 1995 after the population recovered.

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

METHODS

Gill nets were set on the bottom for one night (24 hours) using the R/V Hack Noyes. The 2020 spawning Lake Trout Survey was conducted in the Apostle Islands region of Lake Superior (Figure 1) between October 20 and October 27. Gull Island Shoal (GIS) was sampled with a 823 m monofilament gill net. The net was composed of alternating 140 and 152 mm 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 m gill net that used the following sequence of meshes; 152, 140, 152, 140. Michigan Island was sampled with a 457 m gill net that used the following sequence of meshes; 152, 140, 152, 140, 152. Both GI and MI were combined to generate a single estimate (GI/MI). Sand Cut Reef (SCR) was sampled with a 1,189 m monofilament gill net that was divided between two humps (549 m on the west hump and 640 m 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. This same net was used on Devils Island Shoal (DIS) and Cat Island Shoal (CIS) as one net. *We were not able to sample Devils Island Shoal in 2020.*

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-wide Lake Trout survey and summer small-mesh survey. 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. 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 number of years at large calculated for both the most recent capture (i.e., number of years since most recent capture of that individual) and the original capture event (i.e., number of years since the original capture of that individual). Mean annual growth increment was calculated by grouping individual Lake Trout into 20 mm 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 most recent capture. Growth was also assessed by fitting von Bertalanffy growth functions to length and age data. Lastly, a transition plot was constructed to visualize 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.

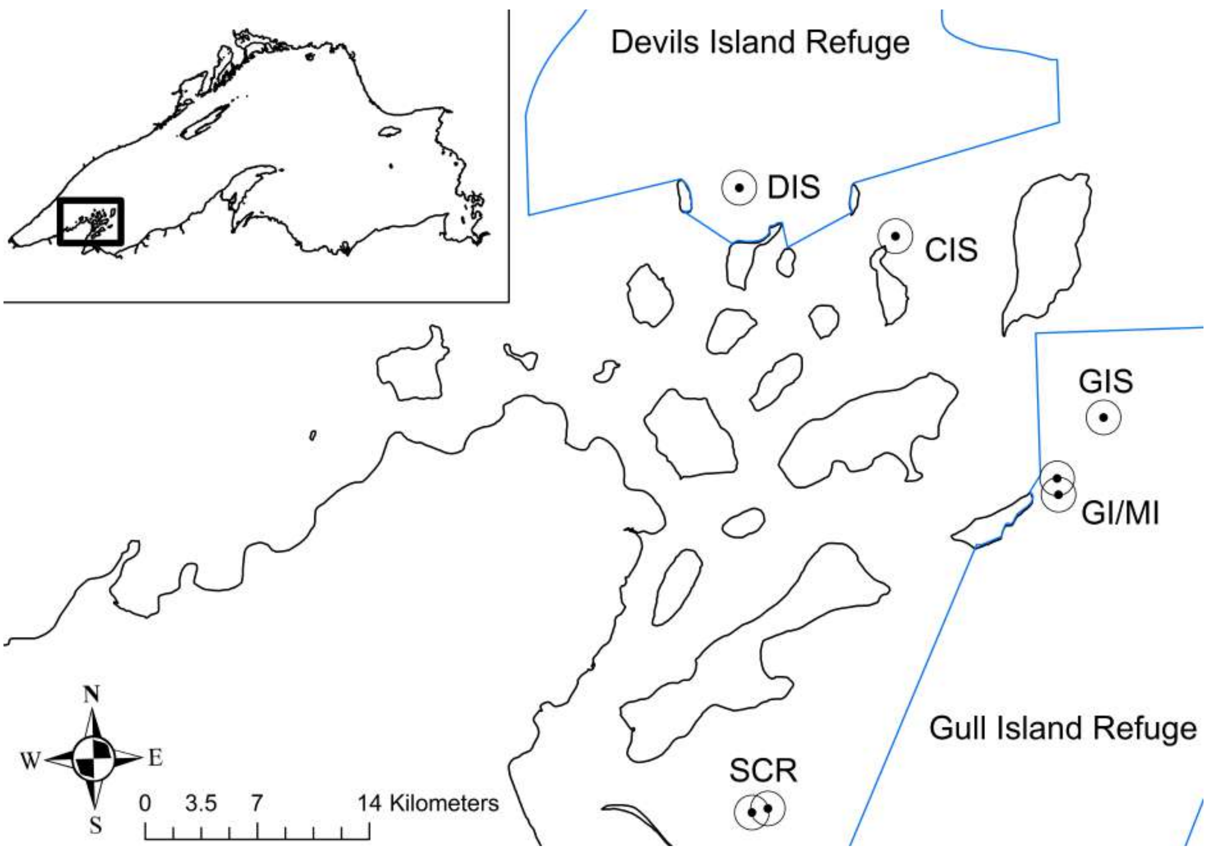

Figure 1. Map of the DNR's fall Lake Trout spawning shoal assessment in the Apostle Islands region of Lake Superior. DIS = Devils Island Shoals, CIS = Cat Island Shoals, GIS = Gull Island Shoals, GI/MI = Gull Island/Michigan Island, SCR = Sand Cut Reef.

RESULTS

The Lake Trout spawning stock at GI/MI and GIS had larger size structure than other spawning shoals, likely due to using larger mesh sizes at these shoals (Figure 2). CIS and SCR were fished using the same gear and are thus comparable. In 2020, SCR had the smallest size structure of the shoals sampled (Figure 2). Median total length of both spawning male and female Lake Trout increased throughout the 1980s and 1990s but has generally declined slightly throughout the 2000s and 2010s at all spawning shoals (Figure 3). The proportion of wild (non-hatchery origin) Lake Trout spawning stock was greater than 99% at all spawning shoals in 2020 (Figure 4). Proportion of wild Lake Trout has increased substantially 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. Generally, males reach sexual maturity (i.e., appear in the spawning stock) one to two years earlier than females (Figure 5). The oldest Lake Trout age estimate from this survey since 2010 was 49 years old (sampled in 2019). Lake Trout spawning stock from SCR had a younger age structure than Lake Trout from CIS and DIS (Figure 5). GIS and GI/MI Lake Trout had much older age structure than the other three spawning shoals, but again this is likely biased due to the use of different gears. SCR and CIS Lake Trout spawning stock also had a smaller median number of years at large since most recent capture and original capture compared to all other spawning shoals (Figure 6). GIS Lake Trout had the largest median number of years at large since recent capture and original capture. These results indicate 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 6) 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 mm) on average grew 31 mm per year, but annual growth declined to an average of 16 mm per year for 620-639 mm male Lake Trout and evened out around an average of 7-10 mm per year for Lake Trout between 680 and 919 mm (Figure 7). On average, female Lake Trout grow slightly faster than male Lake Trout through the first 20 years of life (i.e., higher K value), but average maximum lengths near the growth asymptote are similar (i.e., similar L-inf values; Figure 8, Table 1).

Lake Trout captured on Apostle Islands spawning shoals displayed a relatively large degree of homing back to the same spawning shoal during subsequent recapture events (Figure 9). 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 2010 to 2020. Spawning Lake Trout captured on GI/MI were recaptured on GIS in a subsequent year 28% of the time and vice versa occurring 13% of the time, suggesting the two shoals act more as a "spawning reef complex." Likewise, to a lesser degree, spawning Lake Trout captured on CIS were recaptured on DIS in a subsequent year 11% of the time and vice versa occurring 9% of the time, suggesting these two shoals also act more as a reef complex together. Movement outside of these spawning reef complexes was much more rare; all other transitions occurred 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 complexes.

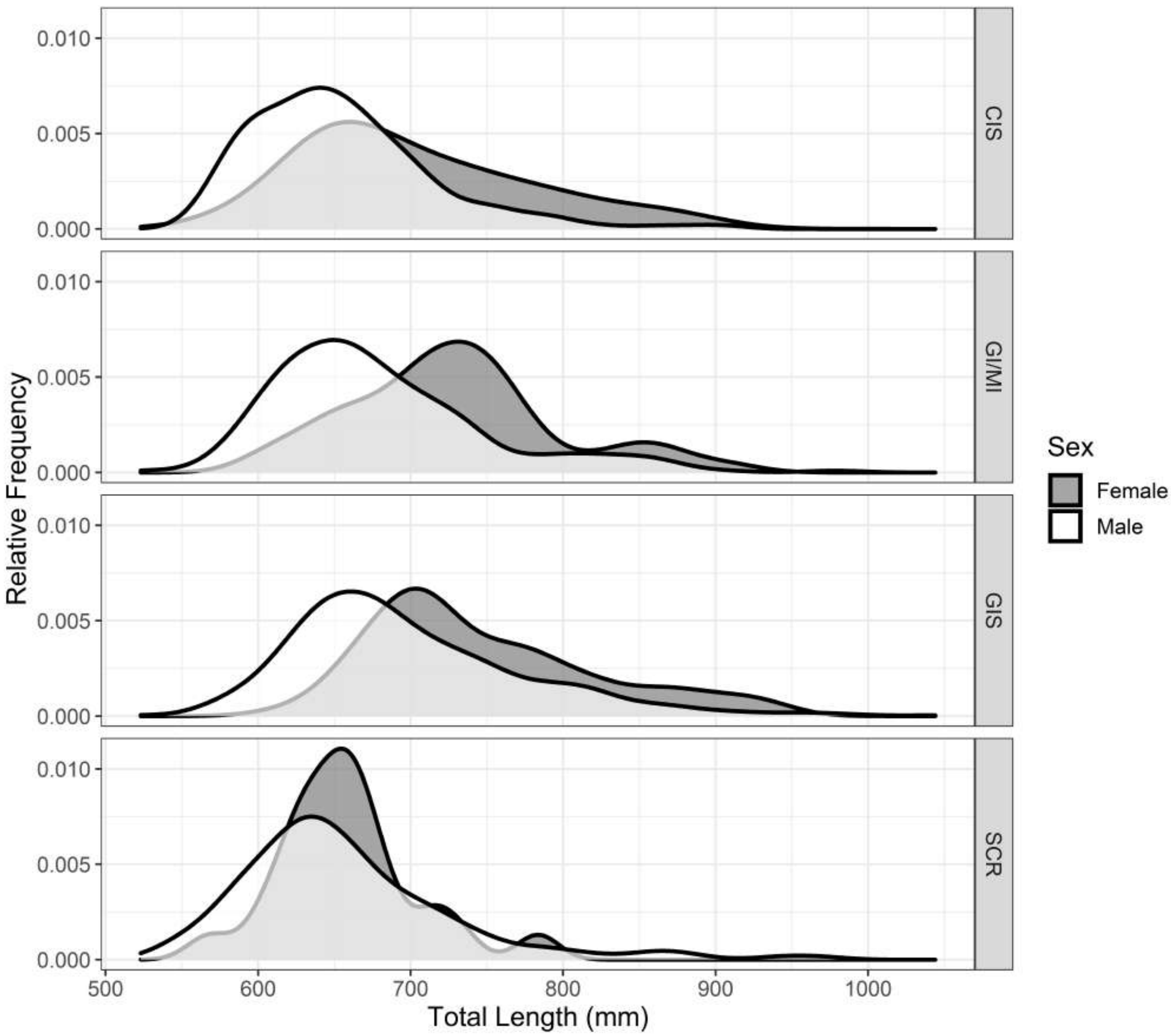

Figure 2. Density plots of male (white) and female (grey) Lake Trout length frequency on four Apostle Islands spawning shoals in 2020.

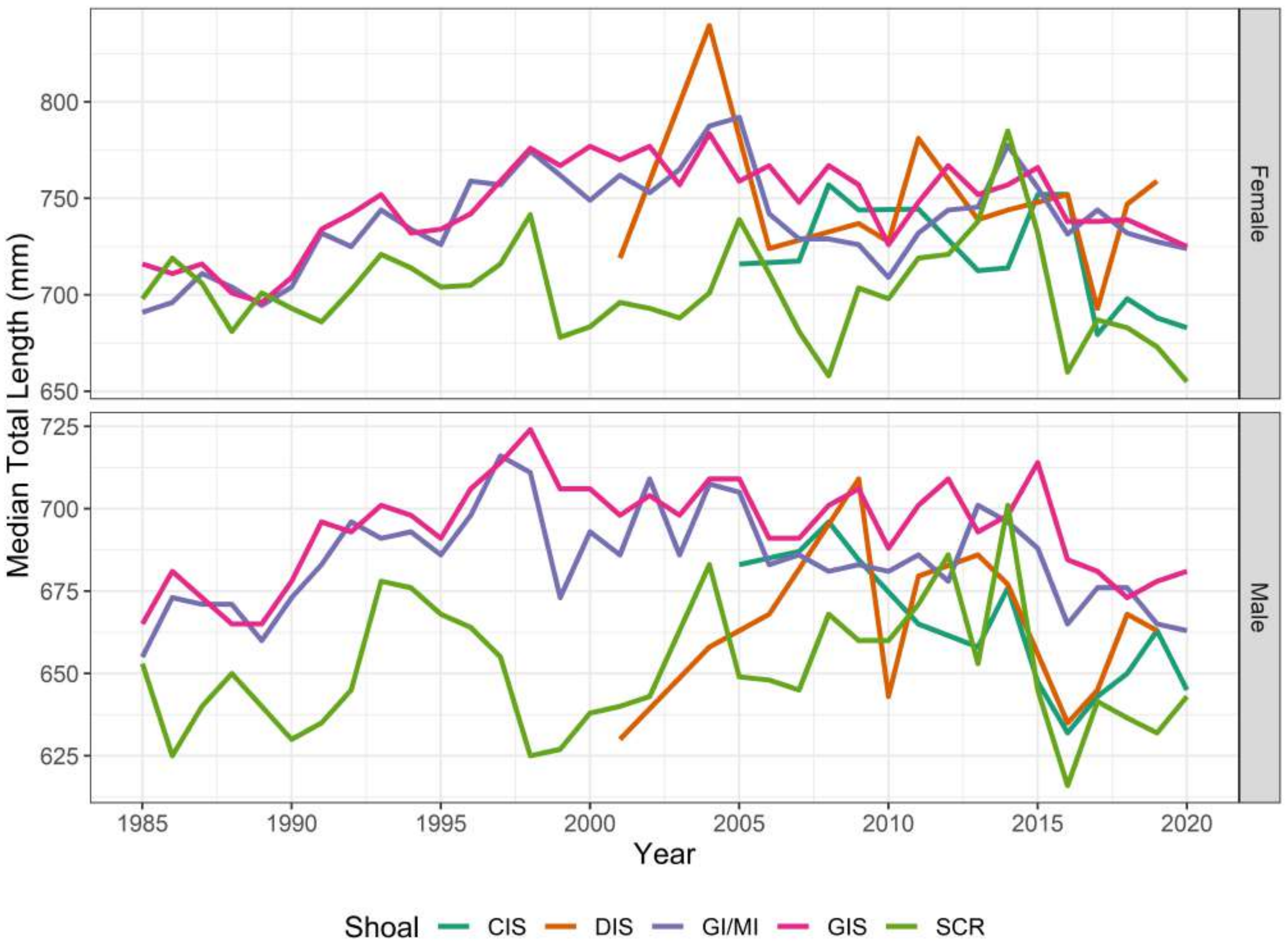

Figure 3. Time series of wild female (top) and male (bottom) Lake Trout median total length (mm) captured on five Apostle Islands spawning shoals from 1985 to 2020. Note the differing y-axis scales among sexes.

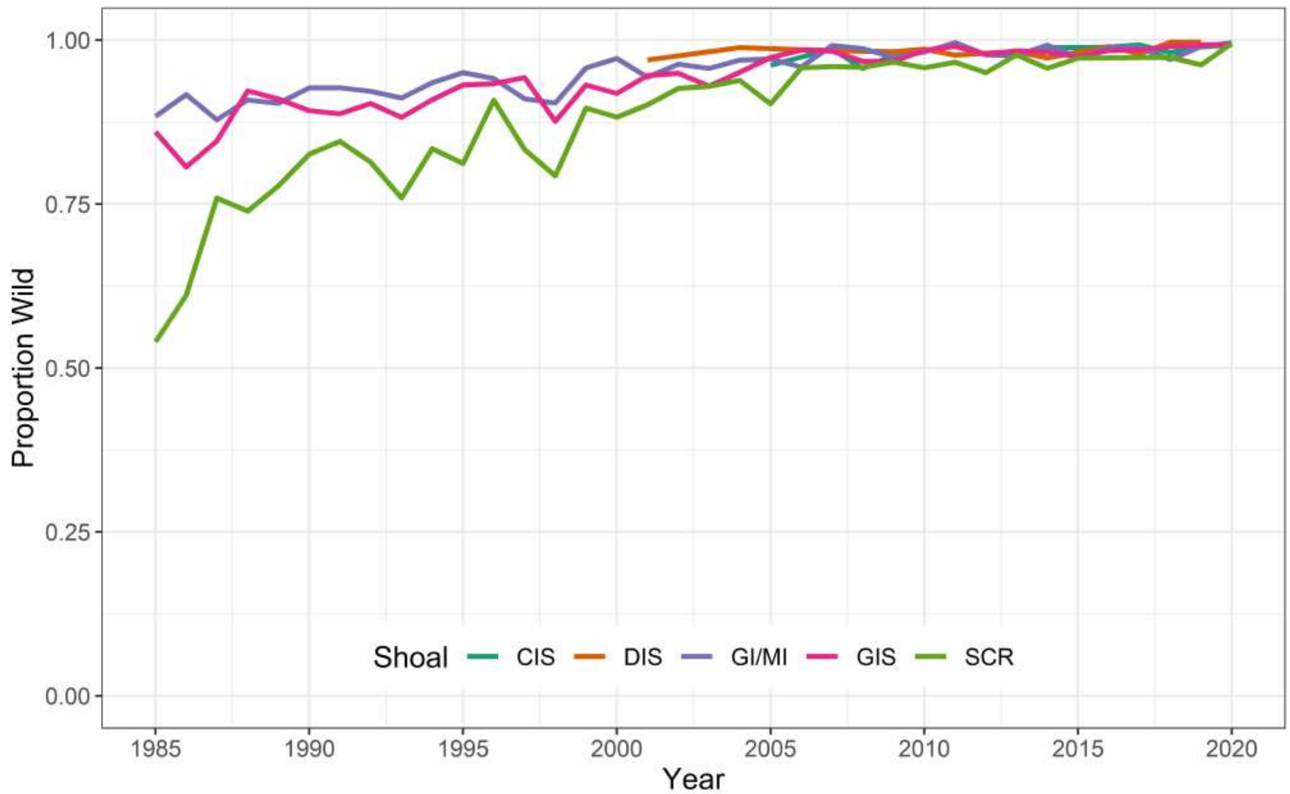

Figure 4. Time series of the proportion of wild (non-hatchery origin) Lake Trout among five Apostle Islands spawning shoals from 1985 to 2020.

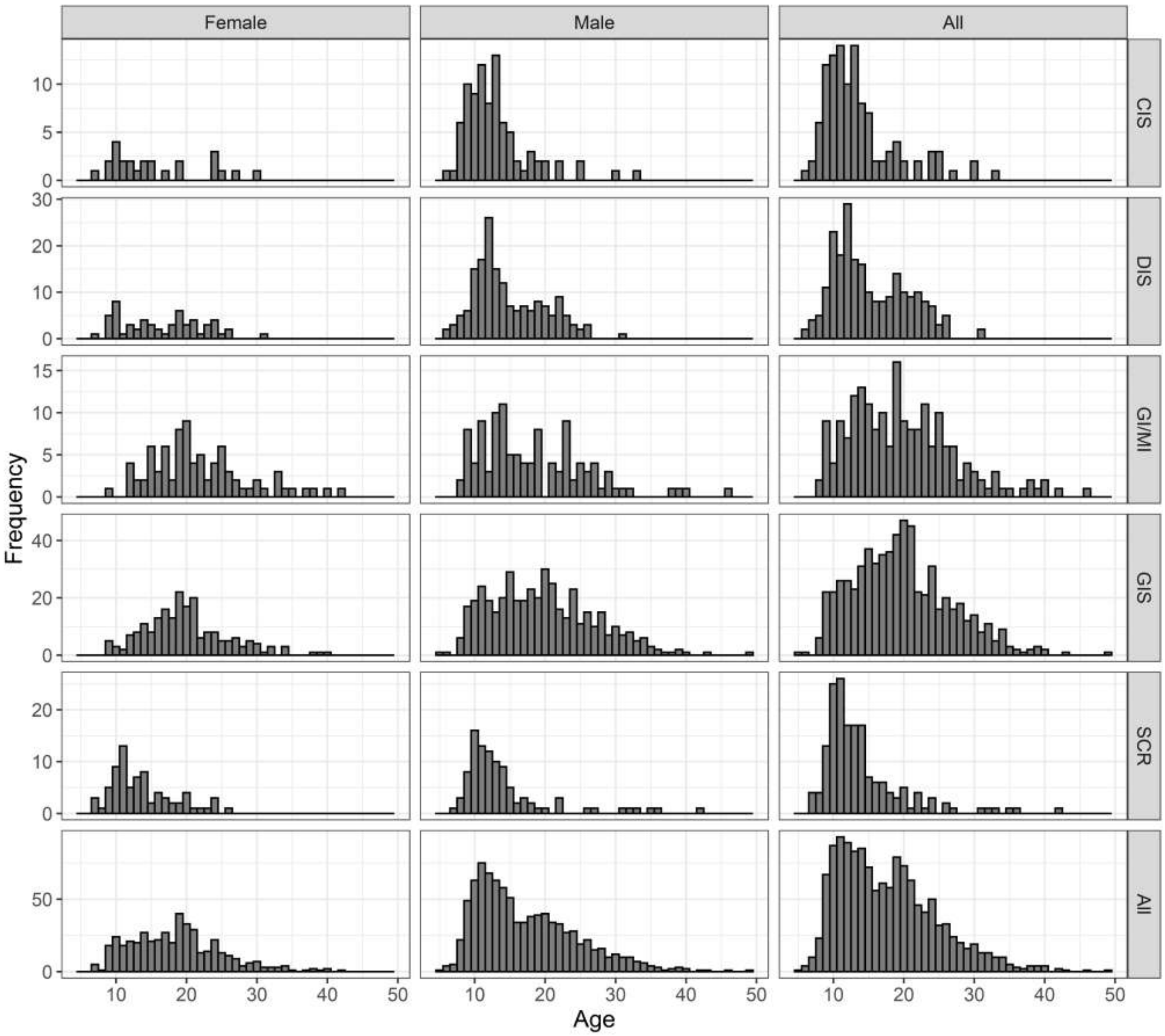

Figure 5. Age frequency plots for male, female and all sexes of Lake Trout combined that were captured among five Apostle Islands spawning shoals. Data include age estimates from the spawning survey from 2010 to 2019. Note the differing y-axis scales among grids.

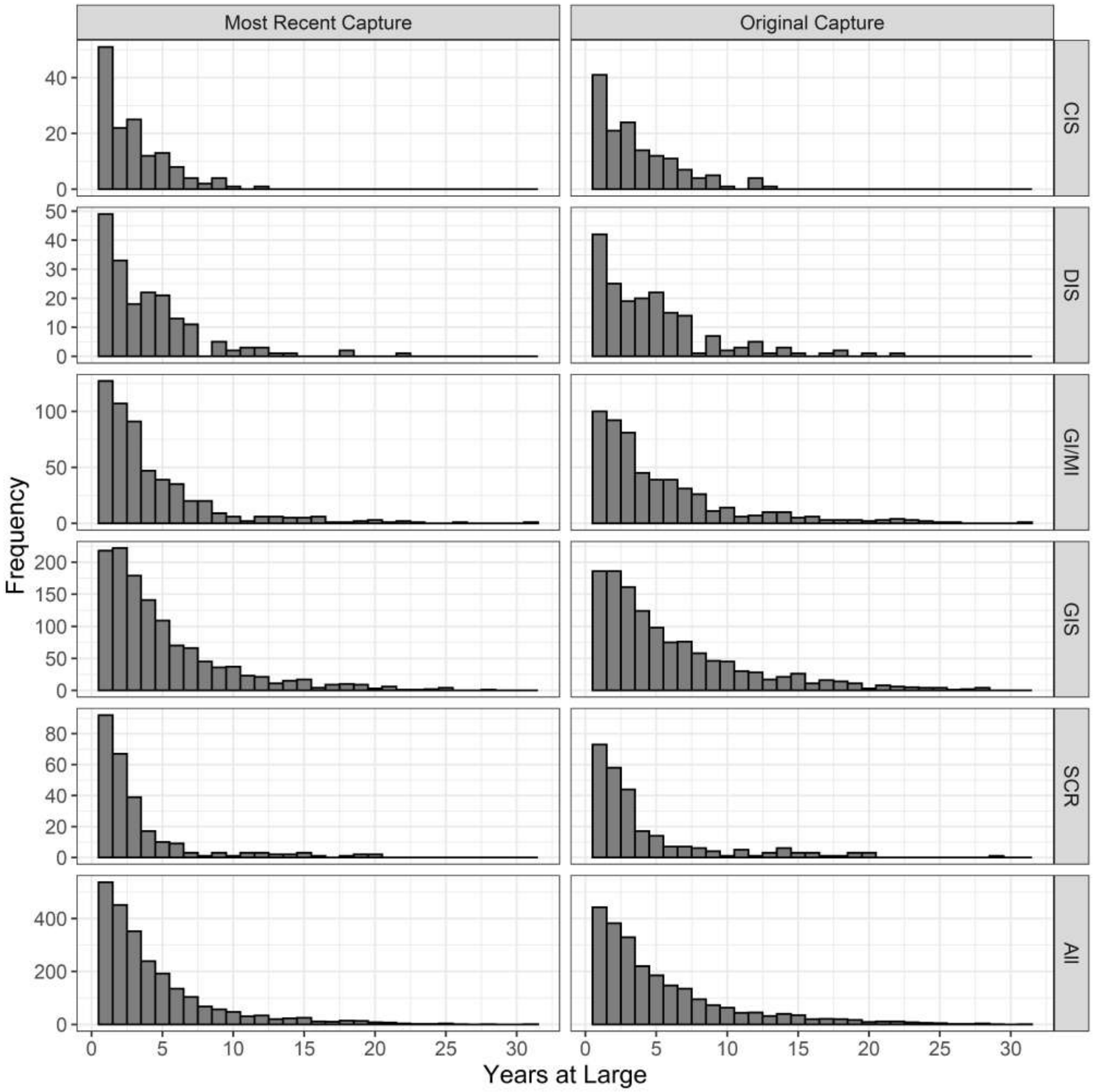

Figure 6. Frequency of the number of years at large since the most recent capture event (left) and the original capture event (right) for all individual recaptured Lake Trout during the fall spawning survey from 2010 to 2020 from each individual spawning shoal and all shoals combined (All).

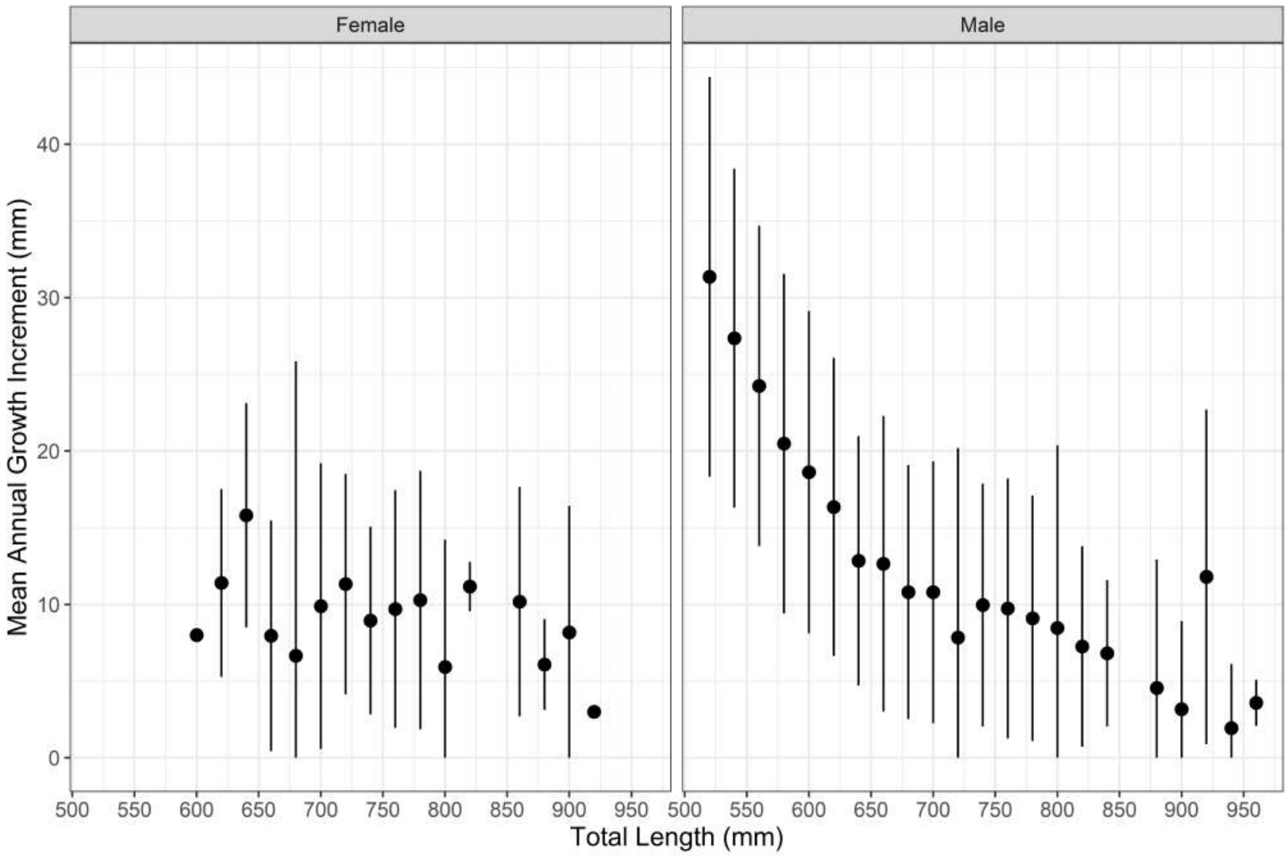

Figure 7. Mean annual growth increment (mm) of female (left) and male (right) recaptured wild Lake Trout during the DNR's spawning survey using data from 2010 to 2019. Vertical bars represent +/- one standard deviation. Individual Lake Trout were grouped into 20 mm length bins based on the observed total 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.

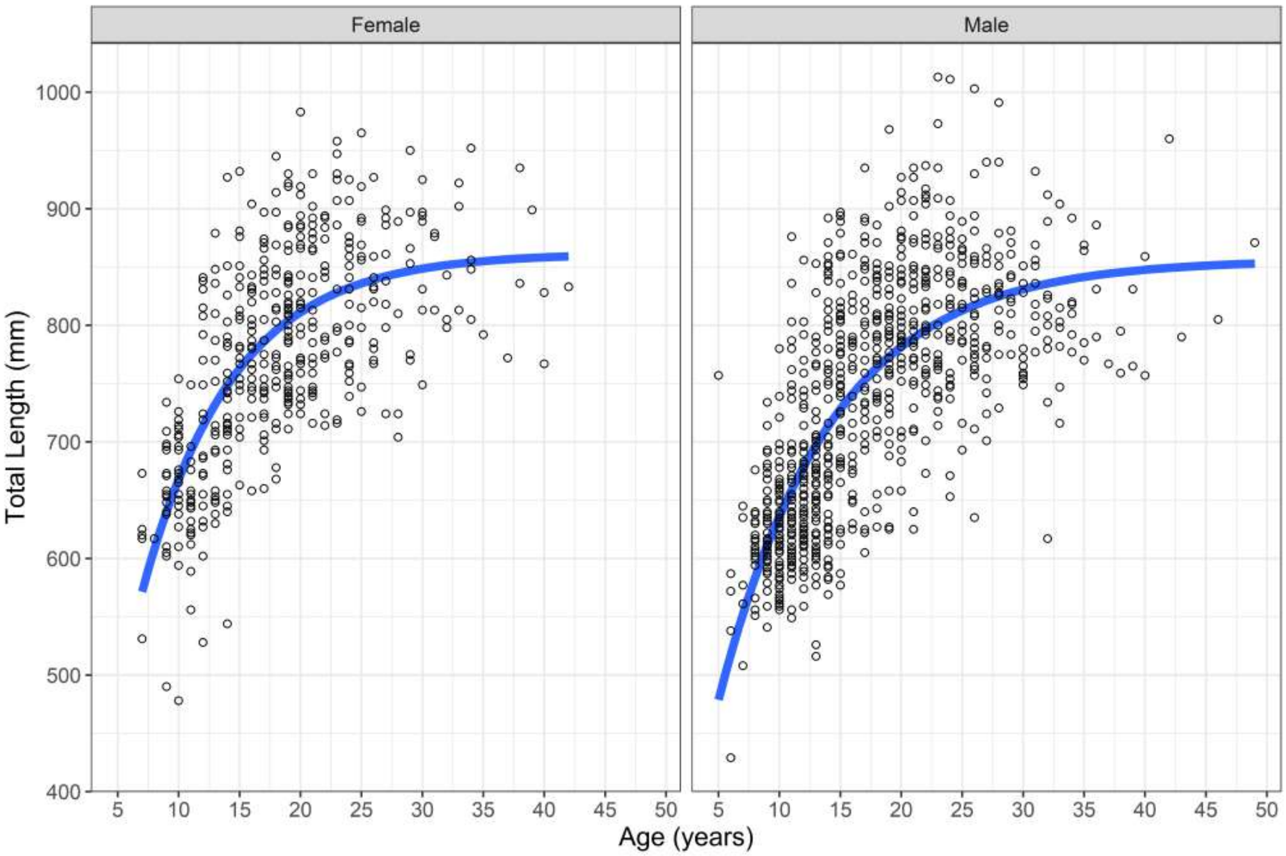

Figure 8. von Bertalanffy growth functions of both female (left) and male (right) Lake Trout from the Spawning Lake Trout Survey from 2010 to 2019.

Table 1. von Bertalanffy growth function coefficients for female and male Lake Trout from the Spawning Lake Trout Survey from 2010 to 2019.

	Female			Male		
	Coefficient	**L 95% CI**	**U 95% CI**	**Coefficient**	**L 95% CI**	**U 95% CI**
Linf	861.736	843.087	886.345	856.190	839.603	876.314
K	0.135	0.104	0.169	0.108	0.091	0.126
t0	-1.084	-3.841	0.880	-2.574	-4.393	-1.119

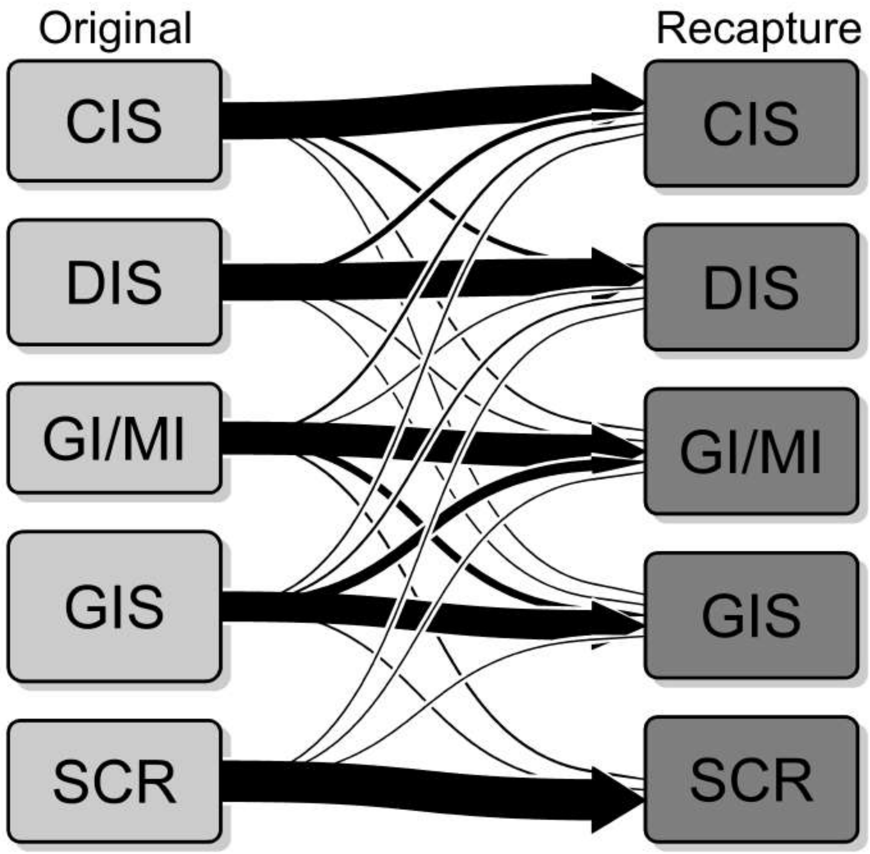

Figure 9. Transition plot representing trends of individual Lake Trout movement from its original capture location (light grey) to its next encounter location (dark grey). Arrow thickness represents proportions of total Lake Trout recaptured within each original capture location. All recaptures from the fall spawning survey from 2010 to 2020 were used in this analysis.