Title: Lake Trout Spawning Studies: updates, new survey, and comparison to standard September gillnet survey

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Abstract

In Lake Ontario, lake trout restoration efforts have not established a self-sustaining population. Herein we describe efforts to evaluate standard and new surveys, and to estimate dispersal from stocking locations, to better understand impediments to natural reproduction. In 2019, lake trout egg deposition was sampled at two locations, Stony Island Reef, and Ford Shoals. No eggs were collected at either site. Egg deposition rates at Stony Island Reef, expressed in eggs/net/day, were lower in 2019 (0) and 2017 (0.0004) than in 1987 and 1989 (1.27 and 0.27, respectively). Spawning lake trout were indexed using standard gillnets set at six locations along the southern shore. Sites were fished overnight with two nets, except Youngstown where only one net was set. When comparing the standard September gillnet survey to the spawning survey, the spawning survey caught more and older fish, but had a similar representation of strains. Both gillnet surveys revealed that, during the early to late fall, most lake trout (>72%) are caught as adults near where they were stocked as juveniles. This spawning survey demonstrated that lake trout in spawning condition are aggregating near possible spawning habitat, but the presence of adults alone cannot identify the specific spawning habitat. Egg deposition results suggest lake trout may be depositing eggs in different habitats then they have in the past. Alternatively, our egg collection methods may not be effective when egg abundance is low. Lake Ontario lake trout restoration would benefit from survey approaches that identify specific spawning habitat.

Introduction

Lake trout restoration efforts have been ongoing in Lake Ontario for decades without reaching the ultimate goal of establishing a self-sustaining population. There is renewed interest in broadening the current understanding of the impediments blocking successful natural reproduction. Previously, we reported on a spawning and habitat assessment that was conducted at Stony Island Reef, in the eastern basin of Lake Ontario (Furgal et al. 2019). In 2019, we re-sampled egg deposition at Stony Island Reef and added another site, Ford Shoals, west of Oswego, NY. Updated GPS locations provided by a team of scientific divers indicated that the 2017 egg deposition sample locations were slightly off from the area of high-quality spawning habitat identified by previous studies (Marsden et al. 1988; Marsden and Krueger 1991). In 2019 on Stony Island Reef, egg traps were set both on the previously identified spawning habitat, and repeated on the sites sampled in 2017.

To complement egg trapping, a multi-agency gill netting effort was undertaken by USFWS, USGS and NYSDEC to sample spawning lake trout along the U.S. shore of the lake. The standard Lake Ontario adult lake trout assessment occurs during September (Elrod et al. 1995; Lantry et al. 2020). As this is close in time/season to the lake trout spawning period in late October – early November, the data collected are sometimes used as a proxy for fish that would comprise the local spawning stock (Elrod et al. 1996b; Page et al. 2003). The objectives of the spawning gill net survey were to examine whether lake trout in spawning condition were aggregating near putative spawning habitat; and to compare collections with the annual September gillnet survey by examining abundance, strain representation, age structure, and sex ratio.

The Great Lakes Science Center (GLSC) is committed to complying with the Office of Management and Budget data release requirements and providing the public with high quality scientific data. The USGS research vessel data collected between 1958 and 2019 is publicly available from the GLSC website (http://doi.org/10.5066/F75M63X0). Please direct any immediate questions to our Information Technology Specialist, Scott Nelson, at snelson@usgs.gov. All USGS sampling and handling of fish during research are carried out in accordance with guidelines for the care and use of fishes by the American Fisheries Society (http://fisheries.org/docs/wp/Guidelines-for-Use-of-Fishes.pdf). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Methods

Sample Locations

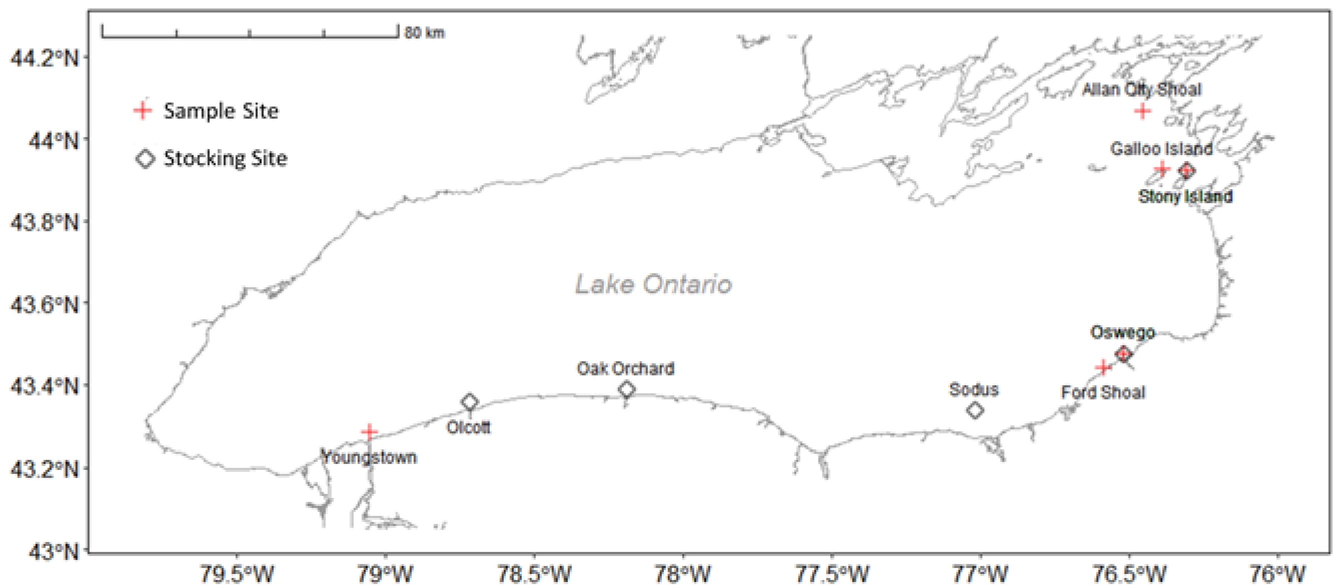

Figure 1. Map showing egg sampling sites (Stony Island Reef and Ford Shoals) gillnet sample sites (all areas shown; red crosses), and stocking sites (black diamonds).

Egg Deposition

Two types of egg collecting gear were used to collect eggs: the Horns et al. (1989) traps used in 2017 (Furgal et al. 2019) and a new metal ring trap. Each metal ring trap was constructed of a 6 in diameter steel ring measuring 3 in in height, which was covered with two layers of rigid plastic screen with 0.39 in mesh. The meshes of the two screens were not aligned with the intent to improve egg retention within the trap. A 24 in long nylon net with 1/16 in mesh was wrapped around the steel ring and secured with a 6.5 in hose clamp. Approximately 14–16 ounces of weight was zip-tied to the bottom of the net. Three strings of tarred twisted nylon twine were used to attached a trap to a long line clip so traps could be deployed on a setline together, and could then be easily removed upon retrieval. During 2019 on Stony Island Reef, 50 Horns traps (5 gangs of 10 nets) were deployed on October 20 and retrieved during November 17 - 19. Three gangs were placed on the habitat identified by Marsden et al. (1991) and two gangs were placed just north of that location where sampling occurred in 2017. On October 28, 20 metal ring nets were deployed on Stony Island Reef adjacent to the Horns traps and on October 29; an additional 20 metal ring traps were deployed on Ford Shoal, near Oswego, NY. After egg traps were retrieved, they were stored in coolers with lake water/ice, then brought into the lab for processing. Trap contents were removed by cutting the zip tie securing the cod end, releasing the weights, then rinsing out trap contents into a 0.039 in mesh sieve. Trap contents were then identified, enumerated, and weighed.

Spawning Adults

During October 28 – November 13, 2019, standard assessment gillnets (for net detail see Lantry et al. 2020), were set overnight, along bottom, at six sites (from west to east): Youngstown, Ford Shoals, Oswego, Galloo Island, Allan Otty Shoal, and Stony Island Reef (Figure 1). Two nets were fished at all sites, except Youngstown, which had one net set. Site-specific catch-per-unit-effort (CPUE) was expressed as the number of lake trout caught per net fished. Lake trout were processed similar to the standard September gillnet survey (Lantry et al. 2020) including recording length, weight, sex, maturity, fin clips, stomach contents, lamprey wounds, and removing coded wire tags (CWTs) when present. Age and strain information was obtained from fish with CWTs, and CPUE was calculated from all fish captured. Comparisons were then made to catches from the same sites fished during the standard September gillnet survey (Lantry et al. 2020). T-tests were done to statistically compare CPUE and age results from the two surveys.

Results and Discussion

Egg Deposition

Five days after deployment, divers examined traps at Stony Island Reef, and observed that approximately half of the Horns traps and about 10% of the metal ring traps were overturned. As these were the same Horns traps that were deployed in 2017 under similar severe environmental conditions (Furgal et al. 2019; Marsden and Krueger 1991), we assumed that the traps behaved similarly during both years sampled.

From October 29 to November 1, 2019, there was a large storm event, with west winds averaging 20.8 mph with gusts in excess of 60 mph, that resulted in the loss of most of the metal ring traps deployed on Ford Shoals. During retrieval, only 6 metal ring traps were found, containing no eggs. The decision was made to abandon trapping at this site. No eggs were collected at Stony Island Reef in 2019. Egg densities observed in 2019 were lower than the 0.00035 eggs/net/day observed in 2017, and both the 2019 and 2017 densities were significantly lower than the egg densities measured in 1987 and 1989 (1.27 eggs/net/day and 0.27 eggs/net/day respectively). These results suggest lake trout may be depositing eggs in different habitats then they have in the past. Alternatively, our egg collection methods may not be effective when egg abundance is low.

Spawning Adults

638 lake trout were collected during the two surveys (326 and 312 for the standard and spawning gillnet surveys respectively). Of the 638 fish collected, 93 (14.5%) were fish that bore fin-clips but lacked a CWT (classified as unknown), and 16 (2.5%) of fish collected lacked both forms of hatchery markings (no fin-clip, no CWT) and were classified as potentially wild in origin (Table 1). Stocking histories, strain, and age could not be calculated for these groups of fish, and they were therefore excluded from those analyses.

Average CPUE for all lake trout collected was greater for the spawning survey (28.4 ± 19.4 *SD*) than for the same sites during the standard September gillnet survey (15.5 ± 8.8 *SD*), indicating that spawning congregations were more densely clustered later in the spawning season. However, this difference was not statistically significant ($t_{12.2}$=2.1, p=0.058), but did represent a medium effect size (r=.51). Similarly, a comparison of CPUE between surveys for each site individually, showed that relative abundance was greater during the spawning survey at all sampling locations, except Oswego (Figure 2). The largest differences were seen at the Youngstown and Galloo Island sampling locations (4.9x, and 3.6x greater receptively). The largest spawning season CPUE was recorded at the Youngstown site, which is located near the mouth of the Niagara River in the western basin of the lake. Due to the fact that only one gill net was set at Youngstown during the spawning survey, site specific statistical analyses were not possible.

The average age of fish caught during the spawning survey (7.8 ± 2.6 *SD*) was significantly greater than those caught during the standard survey (6.3 ± 2.2 *SD;* $t_{510.7}$=6.6, $p < 0.05$). The average age of fish was greater at all six sites during the spawning survey than in September, and unlike the September survey, no fish younger than age-4 were collected during the spawning survey (Table 2). These results support the finding that adult and immature lake trout segregate more completely during the spawning period (Elrod and Schneider 1987; Zimmerman et al. 2009). Males made up a greater proportion of adult lake trout collected during the spawning survey than during the standard survey at four of the six sites (Figure 3). Males comprised over 73% of all adults collected during the spawning survey at all sites except Allan Otty Shoal (66%), similar to previous findings that males arrive earlier and stay longer on spawning sites than females (Gunn 1995).

The individual strains encountered differed between sites, but were similar within sites between the two surveys. For instance, the strains encountered at Youngstown, Galloo Island, Allan Otty Shoal, and Stony Island were the same during both surveys, and only differed by one strain at Ford Shoals and Oswego between surveys. However, the proportion of each strain comprised of the total catch collected at each site differed between surveys (Figure 4). Differences in strains encountered between sites may be due to differences in the number of each strain stocked near a site (Connerton 2020), and/or differential survival of strains between sites (Kornis et al. 2019). Variation in strain composition between surveys at individual sites may also be the result of older fish having the tendency to arrive at spawning sites later than younger fish (Elrod et al. 1996a). Therefore, the fact that fish caught in the spawning survey were sexually mature adults and older on average (Table 2) may account for the difference in strain composition exhibited between surveys.

The coded wire tagged fish captured at a sample site were dominated by those that were stocked as juveniles at nearby stocking locations, with >72% of fish sampled originating from the stocking location nearest to the survey site (Figure 5). This finding is similar to results from previous studies (Elrod et al. 1996b, Pycha et al. 1965, Rybicki and Keller 1978), which generally report lake trout straying of 10-20%. For instance, Youngstown, the westernmost sample location, was composed primarily of fish that were stocked at the nearest stocking site, Olcott (69%). Similarly, the catch at the easternmost location, Stony Island, was primarily composed of fish that were stocked at Stony Island (91%). Proportions of fish from other stocking sites decreased in relation to distance from the netting locations, a trend that holds true for both the standard September gillnet survey and the spawning survey.

Fish without CWTs (unknown or wild) were captured at all sample locations during both surveys, with Allan Otty Shoal and Galloo Island having the greatest proportion of unknown fish (54.5% and 26.9%) during the standard September gillnet survey, and Allan Otty, Oswego, and Galloo Island having the greatest proportion of unknown fish during the spawning survey (39.0%, 23.2%, and 22.2% respectively). Galloo Island had the greatest proportion of wild fish caught during the standard September gillnet survey (19.2%), and Allan Otty and Stony Island had the greatest proportion during the spawning survey at 7.3% and 4.1% (Table 1).

The timing of the standard September gillnet survey in Lake Ontario was chosen in part due to weather conditions during the October-November lake trout spawning season often being unsuitable for sampling.

The 2019 October-November spawning season survey provided an opportunity to test the assumption that data collected during the annual standard September gillnet survey reflect the conditions of the local spawning congregation of the area sampled (Elrod et al. 1996b, Page et al. 2003). The results from the 2019 study seem to confirm this assumption.

This survey revealed that lake trout in spawning condition are aggregating near possible spawning habitat, and that the standard September gillnet survey data is suitable for characterizing the potential spawning population; however, we have yet to thoroughly sample a location with any measurable amount of egg deposition in recent times. Egg deposition was documented in the Niagara River, south of the Youngstown sample site (Gatch et al. in prep.), however environmental conditions in the river (i.e., high river currents) hinder the ability to accurately quantify egg deposition at that location. Future research is needed to locate specific habitats where Lake Ontario lake trout are currently depositing eggs. Acoustic telemetry has proven useful to describe movements of adults during spawning in other Great Lakes (Binder et al. 2017), and can be used to identify spawning habitats that might not have been identified by previous studies (Binder et al. 2018). Locating eggs and fry is another strategy to identify specific spawning sites, which could be sampled alone or in conjunction with acoustic telemetry (Marsden et al. 2016). Identifying spawning sites is an important step in lake-wide restoration efforts and should remain an emphasis for future studies.

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Table 1. Number of lake trout of each strain collected, and the proportion of the catch each strain comprised (Catch %) during the standard September gillnet and spawning surveys in Lake Ontario, 2019. LCD – Lake Champlain Domestic; SEN – Seneca Lake Strain; SAW – Apostle Island Strain; SKW – Superior Klondike Strain; HPW – Huron Parry Sound Strain; UNK – Hatchery fish of unknown origin (fin clip, not CWT); WLD – potentially wild lake trout (lacked all hatchery marks) strain histories are given in Lantry et al. (2020).

	Site																	
	Allan Otty Shoal			**Ford Shoal**			**Gallo Island**			**Oswego**			**Stony Island**			**Youngstown**		
Survey	**Strain**	**N**	**Catch %**	**Strain**	**N**	**Catch %**	**Strain**	**N**	**Catch %**	**Strain**	**N**	**Catch %**	**Strain**	**N**	**Catch %**	**Strain**	**N**	**Catch %**
Standard	LCD	8	36.4	HPW	1	1.6	LCD	6	23.1	HPW	1	1.2	HPW	1	2.5	HPW	10	10.8
	SEN	2	9.1	LCD	13	20.3	SEN	5	19.2	LCD	15	18.5	LCD	10	25.0	LCD	25	26.9
	UNK	12	54.5	SEN	12	18.8	SKW	3	11.5	SEN	12	14.8	SEN	14	35.0	SAW	3	3.2
				SKW	31	48.4	UNK	7	26.9	SKW	48	59.3	SKW	12	30.0	SEN	18	19.4
				UNK	7	10.9	WLD	5	19.2	UNK	5	6.2	UNK	3	7.5	SKW	25	26.9
																UNK	7	7.5
																WLD	5	5.4
Spawning	HPW	1	2.4	HPW	1	1.5	LCD	27	60.0	LCD	11	36.7	LCD	22	44.9	HPW	3	3.8
	LCD	15	36.6	LCD	22	32.4	SEN	7	15.6	SEN	7	23.3	SEN	16	32.7	LCD	26	32.9
	SEN	6	14.6	SAW	1	1.5	SKW	1	2.2	SKW	5	16.7	SKW	5	10.2	SAW	6	7.6
	UNK	16	39.0	SEN	23	33.8	UNK	10	22.2	UNK	7	23.3	UNK	4	8.2	SEN	33	41.8
	WLD	3	7.3	SKW	10	14.7							WLD	2	4.1	SKW	6	7.6
				UNK	10	14.7										UNK	5	6.3
				WLD	1	1.5												

Table 2. Mean age ± standard deviation, and age range, for all CWT lake trout collected the standard September gillnet and spawning surveys in Lake Ontario, 2019.

	Site											
	Allen Otty Shoal		Ford Shoals		Galloo Island		Stony Island		Oswego		Youngstown	
Survey	**Mean Age (±SD)**	**Age Range**	**Mean Age (±SD)**	**Age Range**	**Mean Age (±SD)**	**Age Range**	**Mean Age (±SD)**	**Age Range**	**Mean Age (±SD)**	**Age Range**	**Mean Age (±SD)**	**Age Range**
Spawning	8.8 ±3.0	4-15	7.4 ±2.5	4-13	8.9 ±2.5	4-13	7.7 ±2.6	4-15	7.4 ±3.0	4-15	7.4 ±2.8	4-19
Standard	7.6 ±2.1	5-11	6.4 ±2.2	3-13	8.8 ±3.3	5-15	6.1 ±2.9	2-12	6.4 ±1.9	3-13	5.6 ±2.5	2-13

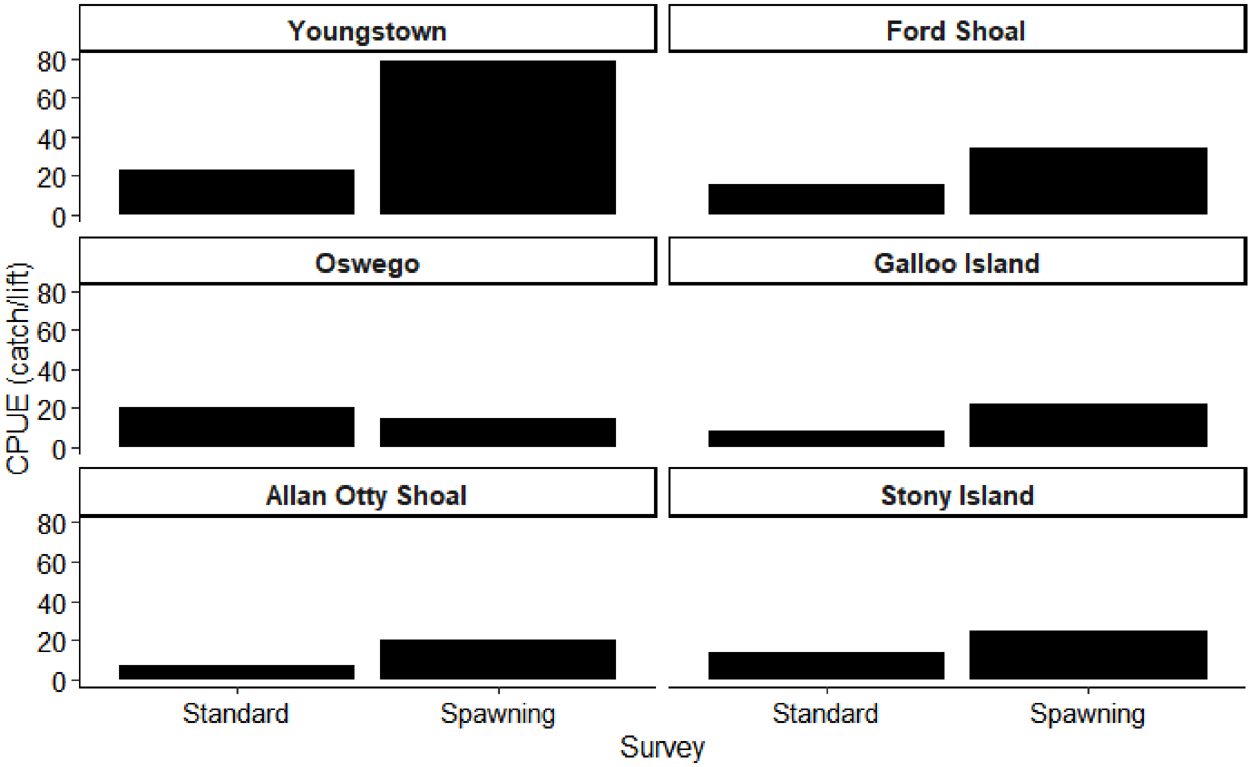

Figure 2. Comparison of catch per unit effort (catch/lift) of all lake trout captured between the standard September gillnet and spawning surveys at six potential spawning sites in Lake Ontario, 2019.

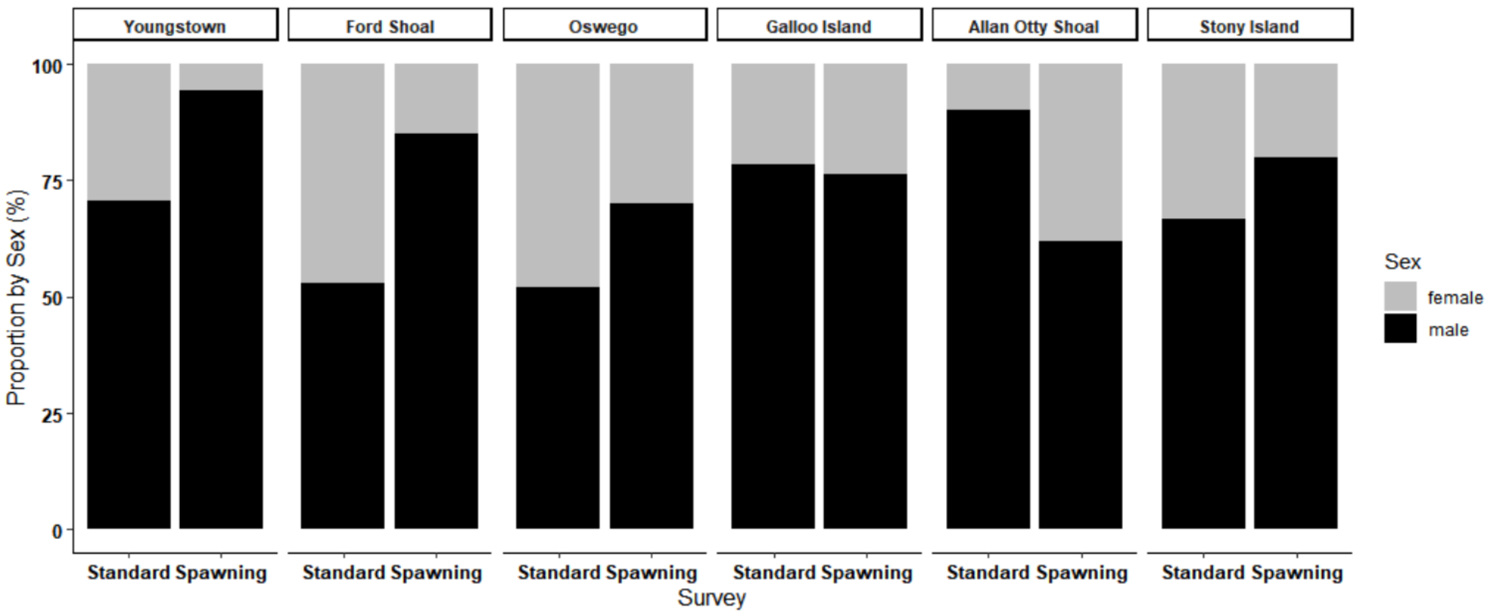

Figure 3. Proportion of sex of all adult CWT lake trout (age 5+) caught between the standard September gillnet and spawning surveys.

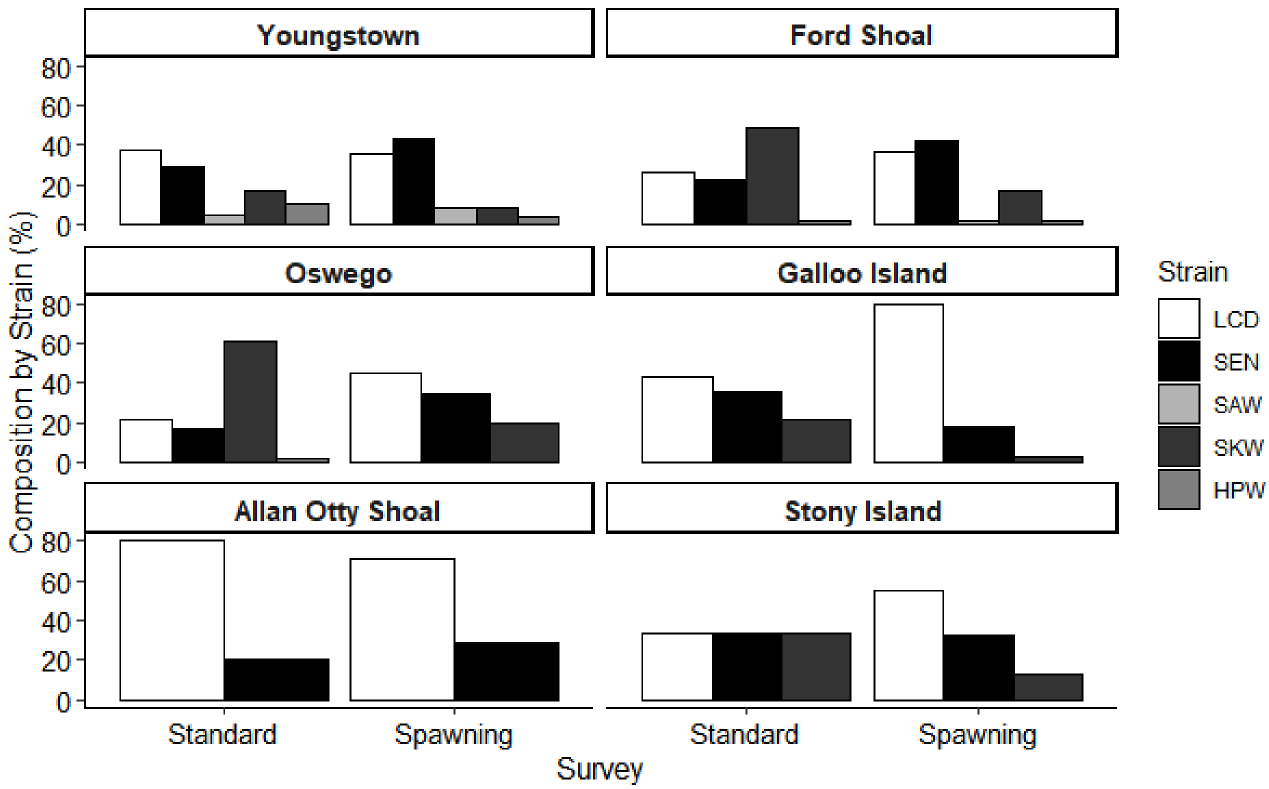

Figure 4. Strain composition of adult CWT lake trout (age 5+) caught during the standard September gill net and spawning surveys at six sampling sites. LCD – Lake Champlain Domestic; SEN – Seneca Lake Strain; SAW – Apostle Island Strain; SKW – Superior Klondike Strain; HPW – Huron Parry Sound Strain, strain histories are given in Lantry et al. (2020).

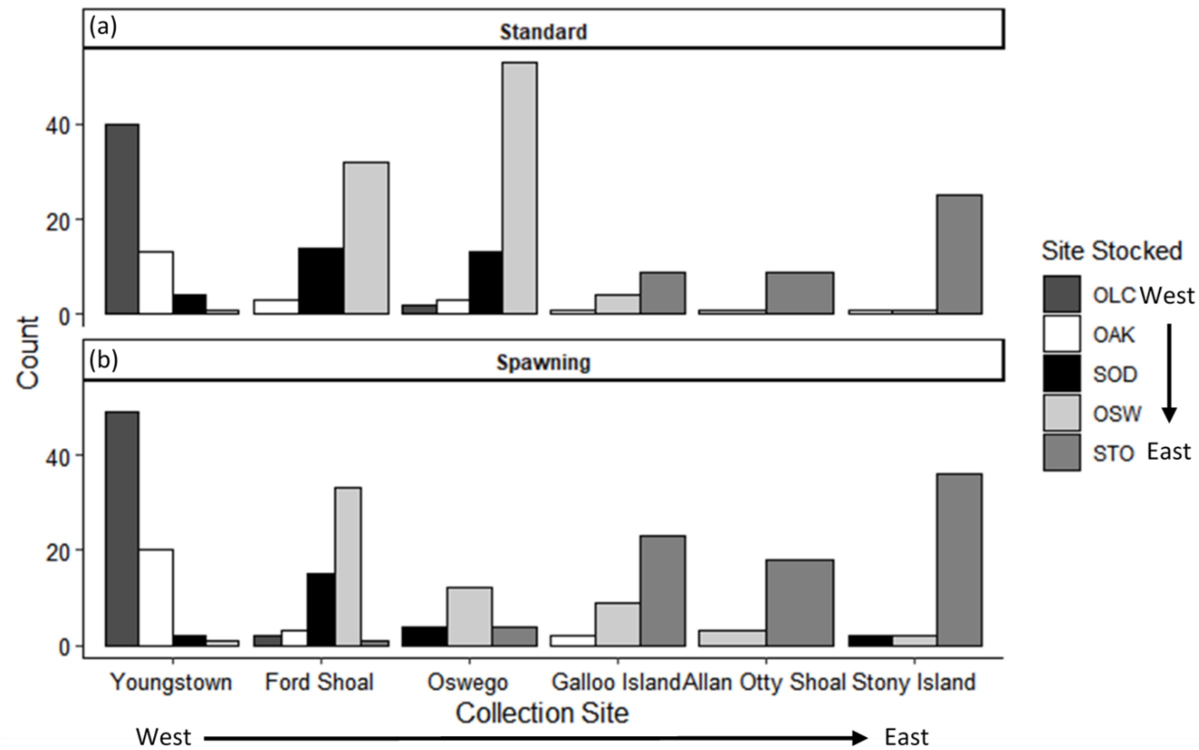

Figure 5. Numbers of mature CWT lake trout (age 5+) captured in gill nets at six sampling sites during the standard September survey (a) and the spawning survey (b), and their original stocking site in Lake Ontario. Stocking and collection sites are shown in Figure 1. OLC – Olcott, OAK – Oak Orchard, SOD – Sodus, OSW – Oswego, STO – Stony Island.