EVALUATION OF LAKE TROUT SPAWNING HABITAT AND EGG, FRY, AND PREDATOR ABUNDANCE ON LAKE MICHIGAN’S DEEP REEFS

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Study Objectives:
1. Facilitate location of lake trout spawning habitat by making improvements to the ROV based suction sampler to generate microhabitat-specific relative abundances of lake trout eggs and sac-fry at the MLRC.
2. Evaluate egg predator densities.
3. Develop and evaluate deep-water egg traps
4. Beam trawl for post sac-fry to further out knowledge of fry/habitat relationships.

Highlights (matching the Study Objectives):
1. We have evidence that lake trout prefer to spawn at the tops of ridges and humps that are on the Sheboygan Reef Plateau (Janssen et al. in press). At East Reef the spawning habitat is at the dropoffs and we find eggs from about 50 to 60 m depth. Page 5.
2. We have estimates of slimy sculpin densities at lake trout spawning sites (C. Houghton, completing M.S. thesis). Page 9.
3. We have obtained the first quantitative estimates of lake trout egg deposition rates in deep water, with estimates for a site at Sheboygan Reef and East Reef. Page 11.
4. We have successfully collected our first lake trout fry via beam trawl. This included at least one individual with gas in its swim bladder. We have also collected many more lake trout sac fry via ROV-based electroshocking than in previous years. Page 14

Ancillary accomplishments
1. We have developed two inexpensive techniques for electroshocking lake trout fry. Page 16
Study sites.

Fig. 1. The Midlake Reef Complex (MLRC, here called the Midlake Plateau) is bounded by the (counterclockwise) Muskegon, Ludington, and Milwaukee Basins and, to the south, the Southern Basin. Sheboygan Reef is about 43° 20’ N, 87° 09’ W and East Reef is about 43° 02’ N, 87° 21’ W.
Figure 2. 34 km$^2$ multibeam bathymetry of part of Sheboyan Reef. Edsall Ridge is about 1.5 km long with an elevation of 2-3 m and is mostly cobble. Kennedy Hump is a mound of cobble about 2-3 m high.
Figure 3  48 km$^2$ multibeam bathymetry of part of East Reef. The three arrows show where we have successfully collected viable lake trout eggs. Eggs have also been collected at other sites near the three shown. We have also collected, via ROV electroshocking, lake trout sac fry at sites M and S. Site N has not been sampled yet for lake trout fry, but one was collected near there via beam trawling.
Objective 1/Highlight 1: Microhabitat and relative egg deposition densities

We have modified the ROV suction sampler to allow us to estimate the number of eggs collected during individual sampling events. After a suction event, the eggs are viewed by a secondary camera in a Transient Observation Chamber (Fig 4), then flushed to a composite chamber to be brought to the surface. Eggs are then enumerated and either preserved for developmental staging or brought to the lab to incubate for later genetic analysis.

![Figure 4. Lake trout eggs (arrows) collected via ROV and viewed in situ in the transient viewing chamber. After viewing and image recording the eggs are flushed to a composite chamber (exit valve to the left).](image)

For examining the relationship between microhabitat and egg deposition we targeted two sites that were discrete and small enough for one day’s work. The first site was Edsall Ridge and the second was Kennedy Hump, both on Sheboygan Reef (Fig. 2). Both have an elevation above the Sheboygan Reef plateau of about 2-3 m (higher for Kennedy Hump) and the ship’s sonar consistently marks relatively large fish aggregated at these structures in autumn.

At Edsall Ridge and Kennedy Hump and we found that the eggs were most concentrated at the summit, essentially the top meter, of the structures. The transect
across Edsall Ridge is shown in Fig 5 and a composite of egg CPU vs elevation above the plateau for both sites is shown in Fig. 6.

![Graph showing lake trout egg catch per effort for a transect across Edsall Ridge](image)

**Figure 5.** Lake trout egg catch per effort for a transect across Edsall Ridge (Fig. 2). Figure modified from Janssen, Marsden, Bronte, Jude, Sitar, and Goetz, in press, (J. Great Lakes Res.)
Figure 6. Lake trout egg CPU vs elevation above the Sheboygan Reef plateau for Edsall Ridge and Kennedy Hump (Fig. 2). Edsall Ridge has a maximum elevation of about 2.5 m and Kennedy Hump has a maximum elevation of about 3.5 m. At both sites the eggs are primarily at the upper meter of the structure. The correlation between elevation (above the plateau) and egg number is 0.615 (P < 0.001).

These results indicate that the lake trout at Sheboygan Reef select the same type of spawning habitat as they do in shallow water. In shallow water the fish concentrate egg deposition near the tops of similar structures, presumably to maximize ventilation of the eggs.

We also have egg sampling transects for East Reef, particularly the South Tongue Site S (Fig.3), that appear to have more complex results (Fig. 7.) There we have collected eggs (and seen or collected lake trout sac fry) from the summit (about 50 m) to about 60 m, 10 m down slope. The egg densities appear to be about an order of magnitude greater than those for Edsall Ridge or Kennedy Hump. At the South Tongue there are strong currents from 50 to 60 m so we think this range of deposition depths reflects the potential ventilating current rather than elevation per se. We have begun investigating Site N, which is a similar structure, and early indications from suction sampling is that the densities are similar to those for the South Tongue.
Fig. 7. Map of the tip of the South Tongue of East Reef with egg trap, egg suction samples, and sac-fry electroshocking results. The light blue circles with connecting green lines are the locations of the egg traps (data shown in Fig. 9, see below). Circles are ROV-based egg suction sampling sites; the enclosed numbers are the number of eggs per 2-minute sample. The red markers and darker blue markers are sac-fry electroshocking events; this is shown in more detail in Fig. 14.
Objective 2/Highlight 2: Estimate egg predator densities.

The densities and diet of the major lake trout egg predator, slimy sculpin, is being investigated by C. Houghton (2007). Egg numbers per stomach are reported in Janssen et al. (2006, J. Great Lakes Res. 32:749-763). The slimy sculpin density estimates are based on numbers of fish electroshocked in a defined field of view from the ROV (Figs. 8 and 9).

Average slimy sculpin densities ranged from 1.2 m\(^{-2}\) to 8.1 m\(^{-2}\) at Sheboygan Reef (Fig. 8) and 0.9 m\(^{-2}\) to 7.5 m\(^{-2}\) at East Reef (Fig. 9). These numbers are mostly lower than values reported for total number of predators (sculpins, crayfish, round gobies) reported by Jonas et al. (2005, Can J. Fish. Aquat. Sci. 62: 2254-2264) for northern Lake Michigan (7.8 to 25.6 m\(^{-2}\)) and Parry Sound (Lake Huron: 3.6-7.6 m\(^{-2}\)), a site where lake trout are restored.

![Figure 8](image)

Figure 8. Mean and standard deviation of slimy sculpin densities (number per defined field of view) for Sheboygan Reef, Edsall Shoal. The numbers above each date are the variance to mean ratios. These are mostly near 1. indicating a random (Poisson) distribution.
Figure 9. Mean and standard deviation of slimy sculpin densities (number per defined field of view) for East Reef, several sites. The numbers above each date are the variance to mean ratios. These are mostly near 1, indicating a random (Poisson) distribution.
Objective 3/Highlight 3. Estimation of Lake Trout egg deposition densities for Sheboygan Reef and East Reef

Our primary second fall (fall 2006) objective was to develop the means of lake trout quantitative egg trap deployment and recovery in deep water. We chose our best site at Sheboygan Reef (about 40 m, Edsall Ridge, Fig 2) and our best site at East Reef (Site S, the South Tongue, Fig. 3). The traps were initially designed in 2005 and tested in Lake Champlain alongside the conventional egg deposition technology: egg bags. For these trials the traps were positioned by scuba divers. In 2005 and 2006 egg bags and the new egg traps were deployed by scuba divers in Lake Champlain and their estimates of egg deposition densities were comparable. In 2006 we did our first deployments in Lake Michigan. Deployment was by lowering an array of 13-14 traps stretched out along the length of the R/V Neekeay. We subsequently verified their position by ROV. The results are shown in Fig. 10.

![Fig. 10. Raw counts of lake trout eggs caught in egg traps for Sheboygan Reef (2 sites with 13 traps each on Edsall Ridge, see Fig. 2) and East Reef (2 sites with 14 traps), site S (Figs. 3 and 7).](image)

The Sheboygan Reef site, which we call “Edsall Ridge” is a ridge of cobble and boulders about 1.5 km long, 30 m wide, and 2-3 m high. Its long axis is approximately E-SE to W-NW and it is flanked by sand to the north side and sparse boulders to the south. The East Reef site is the southern most tip and the site where we have the highest catch-per effort for ROV-based egg suction sampling (Fig. 12). There is a significantly
greater egg density at the East Reef site than the Sheboygan Reef site \((Z = 2.71, P < 0.01\) Mann Whitney test). At both sites the number of eggs per trap is highly variable.

The egg densities for Sheboygan Reef and East Reef (Same data as for Fig. 10) are compared to Parry Sound (egg bags Jonas et al. 2005. Can. J. Fish. Aquat. Sci, 62:2254-2264) and Lake Champlain (the new egg traps, 2006 data) in Fig. 11. Parry Sound (Lake Huron) has a restored lake trout population with several spawning sites. The egg densities for East Reef are higher than one of the Parry Sound sites, but lower than the rest. The East Reef mean egg density is about the same as the highest density for N. Lake Michigan Reefs reported by Jonas et al. (2005) (LTB-crib, an artificial site with 75.9 eggs \(m^{-2}\)), and much higher than their other N. Lake Michigan sites (range 0.0-2.9 eggs \(m^{-2}\)) The Sheboygan Reef densities (6.9 \(m^{-2}\)) are less than those for all of the Parry Sound sites, but seem to be higher than most of the Northern Lake Michigan sites. Lake Champlain has relatively large egg deposition densities (Jonas et al. 2005 and here), but undetectable recruitment of lake trout.

![Egg Densities, MLRC vs Lake Champlain](image)

Fig. 11. Comparison of egg deposition densities for Sheboygan Reef, East Reef, Lake Champlain, and Parry Sound. The data for Sheboygan Reef and East Reef are the same as in Fig 10, but converted to numbers per square meter. Parry Sound data are taken from Jonas et al. (2005).

The egg trap data also afford us the opportunity to determine whether the ROV-based suction sampling CPU provides us with a reasonable estimate of relative egg density. The ROV-based CPU are given in Fig. 12.
Fig. 12. Catch per effort of ROV suction sampling for East Reef (South Tongue, at the summit) and Sheboygan Reef (summit of Edsall Ridge). For comparison, the mean number of eggs per trap for Sheboygan Reef was 1.23 and for East Reef it was 13.25 (Fig. 10). From this limited data set it would appear that ROV catch per effort does give a reasonable estimate of relative egg density.

**Preliminary conclusion.** The egg deposition densities for East Reef are promising, but probably too low for lake trout restoration at present. This site is where we have seen and collected the most lake trout sac-fry (next section). The Sheboygan Reef egg densities are not particularly promising, but we have collected lake trout sac fry at Sheboygan Reef.
Objective 4/Highlight 4: Collection of lake trout fry via beam trawl and improving ROV-based electroshocking of lake trout sac fry.

We focused our beam trawling effort on East Reef in 2006, after failing to collect any lake trout fry at Sheboygan Reef in 2004. This was based primarily on the ROV-based electroshocking of lake trout sac-fry, which suggested higher densities at East Reef compared to Sheboygan Reef. We felt that a focus on East Reef would more likely collect some lake trout fry.

We collected a total of 4 lake trout fry via beam trawling at East Reef in three dates of sampling (3 on the first date, 1 on the second, and none on the third). Two of the fry had a vestige of yolk while the two largest fry had no yolk. One of these had gas in its swim bladder and the other was too damaged to check for gas. The latter fish did have copepods in its stomach, however.

The electroshocking effort was, by far, the most successful thus far. We collected a total of 17 sac fry (see Fig 13 for a range of sizes collected on Sheboygan Reef). This is much better than our previous seasonal high of 3 in 2004. The fish have all been archived for scheduled genetic analyses. On video we seem to see about four times as many sac fry as we collect.

The reason for the improvement in electroshocking success is likely due to changes in electrode and shocker configurations. There is a possibility that the improved success may also be due to increasing numbers of lake trout sac fry being produced.

As far as we know, the Mid-Lake Reef Complex is the only Lake Michigan site producing lake trout fry. None was found in the Jonas et al. (2005) study of northern Lake Michigan reefs.

Fig. 13. Three lake trout sac-fry collected from Sheboygan Reef by ROV-based electroshocking. April 2006.
At East Reef’s South Tongue we found lake trout sac fry over the entire depth range sampled, from 60 m to 50 m. This is the same depth range in which we found lake trout eggs. Most of the sac fry were near the summit, however, and where we found the highest densities there were about 40 shocking events and 20 sac-fry total seen. We collected 8 sac fry on this dive.

Fig. 14. Detail from Fig. 7 to show the electroshocking events. Red symbols shows electroshock events in which no lake trout sac fry were seen in a single shock event. Solid darker blue symbols show where one (smaller circle) or two (larger circle) lake trout sac fry were seen in one shocking event. Note that lake trout sac fry have been seen to about 60 m deep, but appear to be most concentrated at about 50 m. As in Fig. 7, the circled numbers indicate number of eggs per suction sample.
Ancillary accomplishments 1: Improvements to electroshocking of lake trout fry.

We have made two preliminary efforts in making remote electroshocking of small fishes easily and cheaply available. By “remote” we mean that the electroshocker electrodes are associated with a waterproof video camera and the ensemble is operated from the surface.

The first configuration uses a “drop” video camera that looks into the middle (target) of central electrode surrounded by a square PCV pipe electrode with a chain electrode of opposite polarity (Fig. 15). This was used in Lake Champlain in spring 2006 with great success in visualizing lake trout sac fry. In 46 shock trials 84 lake trout fry were seen with the range per trial being 0-12.

Fig. 15. Drop camera/electroshocker used at Lake Champlain. The frame is PVC pipe. The cathode is a chain at the bottom (square) and the anode is directly beneath the downward-looking camera.
The second configuration is that we have adapted a Massachusetts Institute of Technology “home-made” suction sampling electroshocking ROV (Fig 16. Cost < $200 for all parts, including camera, but not the electroshocker). This is limited to water less than 30 feet deep. We have successfully stunned and collected round gobies with this apparatus and will be testing it in Lake Champlain for collecting lake trout sac fry.

Fig 16. Electroshocked round goby (arrow) being sucked into the collection chamber of a “home-made” $200 ROV, suitable for sampling in shallow water (based on a MIT Ocean Engineering design). Our hope is that a cheap ROV will facilitate sampling on shallow reefs and provide an alternative to the scuba based lake trout fry traps available to non-divers. The device may also facilitate the collection of egg predators, which, in most studies, are collected as “bycatch” in egg bags.

In future work we hope to combine the features of the “drop shocker” and “$200 ROV” into an effective, but inexpensive tool for rapid detection and assessment of lake trout sac fry.
Papers:

