Rheotactic Responses of Two Age Groups and Two Strains of Coaster Brook Trout Fry.

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Abstract

Rheotactic response was studied between two age groups and two strains of coaster brook trout *Salvelinus fontinalis* to determine if there are life history differences between the strains and differences in rheotactic behaviors at different ages. An inlet-spawning strain (Siskiwit Bay) and a shoreline-spawning strain (Tobin Harbor) were compared in identical artificial stream environments. The two strains were compared as "sac-fry" and again as "swim-up fry." Fish were left in the stream channels for a period of 24 hours, then their movements were categorized as upstream, downstream, or neither. The "sac-fry" of both strains did not exhibit much movement in the tanks, but there was a significant statistical difference in the rheotactic responses between the two strains of the older "swim-up fry." Between 12.4 and 33.5 percent more Tobin Harbor "swim-up fry" than Siskiwit Bay "swim-up fry" moved downstream. These differences may imply that there are variations in life history between strains, and that discretion should be used when choosing a strain for management purposes.

Introduction

Coaster brook trout *Salvelinus fontinalis* are a migratory form of brook trout that spend part of their lives in the Great Lakes. Over the last century the abundance of coaster brook trout in Lake Superior has declined dramatically, and only remnant stocks remain (Schreiner et al. 2008). Currently, there are only four self-sustaining populations on the U.S. side of Lake Superior. Tobin Harbor, Siskiwit Bay, and Washington Harbor populations are all located near Isle Royale, MI, and the Salmon-Trout River population is located in the Huron Mountains of the upper peninsula of Michigan. Resource management agencies are now working towards restoring and maintaining self-sustaining populations of coaster brook trout and the habitat they need to survive. Research into the life history of coaster brook trout is underway to better understand this once abundant native fish.

Rheotactic response is a fish's directional response to water current. A positive response is seen when a fish orientates or moves upstream and a negative rheotactic response would be when a fish orientates or moves downstream. In this study, the rheotactic response that will be observed is an actual movement up or downstream. Rheotactic response can be used as an indicator of differences between two strains or populations. Understanding a fish's rheotactic response can also be used to improve management or stocking decisions for a particular fish and area.

The coaster brook trout examined in this study were from two populations near Isle Royale, MI. Isle Royale is found in the northwest part of Lake Superior, and is an archipelago of islands which encompass about 850 square miles. Isle Royale, because of its isolation, is considered biologically and ecologically unique, and was named as an

International Biosphere Reserve in 1980. The influence of Lake Superior on the composition, structure and function of the habitat, and protection from human alterations makes Isle Royale an ideal location for some of the last surviving coaster brook trout populations in Lake Superior. Captive brood stocks developed from these populations are being used for stocking restoration efforts throughout the Lake Superior Basin.

Tobin Harbor and Siskiwit Bay strains of coaster brook trout were used in this study. Tobin Harbor is located on the northeast side of Isle Royale (Figure 1), and is a long narrow bay with several small inlet streams. Brook trout are not known to use these streams to spawn, but rather spawn along the shoreline of the harbor. Therefore this population is classified as "shoreline-spawners." Siskiwit Bay is found on the southeast side of the island, and has several tributaries including the Big and Little Siskiwit Rivers. The Siskiwit Bay population is comprised of brook trout that spawn in these rivers, and is therefore classified as "inlet-spawners."

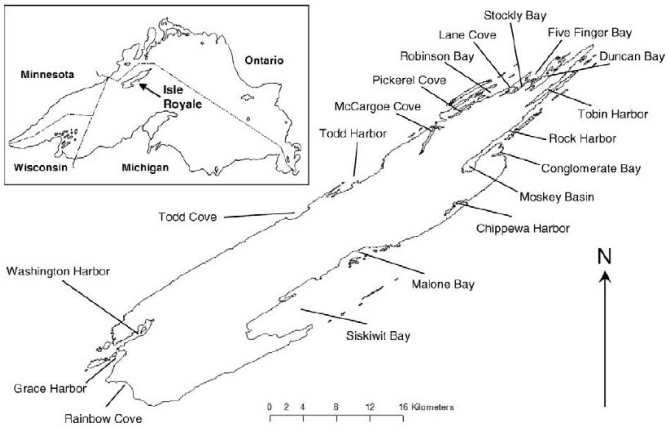

Figure 1. Isle Royale, MI showing the locations of the two populations of coaster brook trout used in this study, Tobin Harbor and Siskiwit Bay.

Baird (2000) examined the rheotactic responses of four wild strains of juvenile brook trout. The fish used in her study were much older than those was used in this study (age-0 fingerlings). Rheotactic responses of younger brook trout have never been studied: thus, I believe it is important to know the rheotactic behaviors of younger fish, and how these behaviors change as the fish grow older.

Hypotheses

Two age-groups of brook trout from both the inlet-spawning Siskiwit Bay strain and the shoreline-spawning Tobin Harbor strain were studied in identical artificial environments at the Iron River National Fish Hatchery. I hypothesized that there would be a significant difference in rheotactic response between the two strains of fish. Specifically, I tested the hypotheses that the Siskiwit Bay strain would have a negative rheotactic response because these fish would need to move downstream in order to reach their adult habitat (Siskiwit Bay), and the Tobin Harbor strain would show no rheotactic response because these fish spawn in a lake environment (Tobin Harbor) and do not need to move up or downstream to reach adult habitat. In addition, I hypothesized that there would be

differences in rheotactic response due to the age of the fish ("sac-fry" and "swim-up fry").

Methods

Eggs from each strain were collected and fertilized by brood stock fish at the Iron River National Fish Hatchery. The eggs developed in hatching trays until most were free-swimming. Fish were observed at two different ages: a "sac-fry" stage ranging from 0 (hatch) to first feeding (20-30 days) and a "swim-up fry" stage ranging from first feeding to approximately 3 weeks after. Fish for the "sac-fry" stage were indiscriminately taken directly from the hatching trays. Once fish were ready to be placed on feed (20-30 days post hatch), they were transferred to a larger rearing tank. Fish for the "swim-up fry" stage were indiscriminately taken directly from the rearing tank and taken off of feed for the duration of the trial.

Fry movements were observed in artificial stream channels that were approximately 3 meters long by 0.5 meters wide and 20 centimeters deep (water depth was 13 cm). There were a total of six stream channels, arranged in a two wide and three high formation in a single room. Each stream channel had screened "trap doors" on both the downstream and upstream ends that were 40.5 cm from the ends of the channel. These trap doors consisted of a funnel with a 1 cm opening that allowed fish to pass through but not back out. Water flowing through the channels was kept at a constant temperature (approx. 6°C) and flow (approx. 4.5 cm per second). The stream channels were lined with small pea gravel (0.5 cm diameter) and two bricks (25x10x5 cm), one on each end, to provide cover and simulate natural stream conditions. The gravel was just deep enough to cover the bottom of the channel. Trials were conducted with a constant water velocity, temperature, and fish density (50 fish per tank). Four lamps were placed in the tank room, two on each side of the tank structure, and angled so that each tank received as close to the same amount of light as possible. Lights were put on a timer so that light duration was similar to that of natural light at first emergence (lights on 30 minutes after sunrise, and off 30 minutes before sunset).

Fish were indiscriminately assigned to one of the paired channels and were then held in round holding pens (approx. 10 cm in diameter) in the center of the channels for a period of 6 to 8 hours to allow the fish to acclimate to their new environment. A trial began by releasing the fish from the holding pens, and allowing them to disperse throughout the channel. Once fish had been released from their holding pens and "free" in the tanks for 24 hours, the fish in the upstream and downstream traps and in the channel between the traps were counted. Dead or dying fish were not counted (four dead in the sac-fry trial, and three dead in the swim-up fry trial with no more than one per tank). Each age group trial was conducted six times simultaneously for each strain. Silt and other materials were brushed out of the channels at the end of each trial to ensure that there was no influence on movement of the next group of fish being put in the tanks.

To quantify fish movement, the percentage of fish that moved upstream, downstream, and neither was calculated for each tank. Significant differences in the mean percentage that moved downstream was compared between strains with a one-way analysis of variance (ANOVA). This analysis was repeated for the percentages that moved

downstream or did not move. I did not statistically compare among strains for the "sac-fry" stage or between age-groups within a strain because very few "sac-fry" moved within the tank. A statistical significance level of 0.05 and the statistical program R (R Development Core Team 2008) was used for all analyses.

Results

The "sac-fry" stage exhibited no rheotactic response in the sense that they did not move into either the upstream or downstream traps. However, movements between the traps were observed for Siskiwit Bay strain "sac-fry" where between nine and fifteen fish per tank were found on the upstream end of the tank either against or within a few centimeters of the trap screen. Similar movements were not observed for the Tobin Harbor strain "sac-fry."

A more substantial rheotactic response was seen with the "swim-up fry" fish. (Figure 2). A significant difference in the mean proportion of fish that moved downstream (a negative rheotactic response) between the Tobin and Siskiwit strains of fish was found ($p=0.0007$; Table 1, Figure 3). Specifically, between 12.4 and 33.5 percent more Tobin Harbor "swim-up fry" than Siskiwit Bay "swim-up fry" moved downstream.

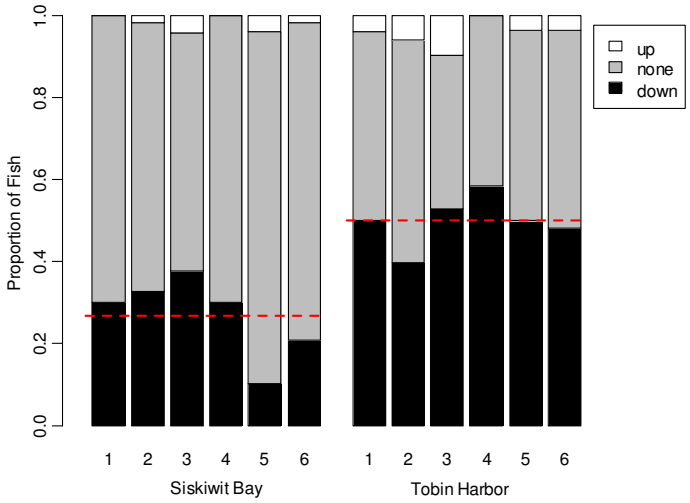

Figure 2. Proportion of Tobin Harbor and Siskiwit Bay "swim-up fry" movements in each direction and in each tank (tank numbers along x-axis). The dashed horizontal lines represent the mean proportion of fish that moved downstream for each strain.

Table 1. ANOVA table testing for a difference in the proportions of fish that moved downstream between "swim-up fry" stage Tobin Harbor and Siskiwit Bay strains.

	df	SS	MS	F	p
Strain	1	0.158293	0.158293	23.580	0.0006654
Residuals	10	0.067129	0.006713		
Total	11	0.2254			

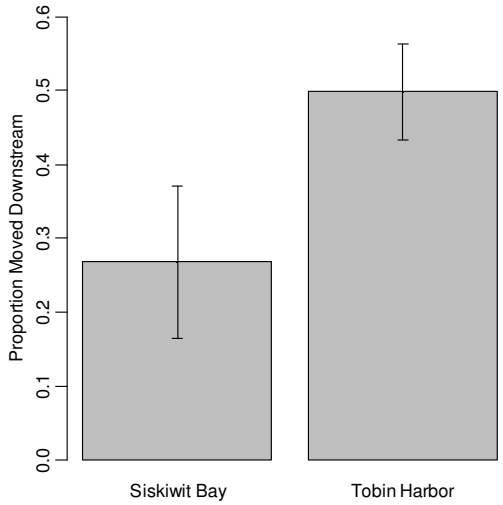

Figure 3. Mean proportion of fish that moved downstream of "swim-up fry" separated by strain with 95% confidence intervals.

Discussion

Coaster brook trout do not show a substantial rheotactic response as "sac-fry." This result could be due to the tanks being too large. Further studies using smaller tanks for "sac-fry" or allowing a longer period for the fish to respond (more than 24 hours) may show different results.

Coaster brook trout do begin to show a negative rheotactic response as "swim-up fry." This suggests that the tanks are more appropriately sized for these fish or rheotactic response becomes stronger with increasing age. Further studies similar to what Baird (2000) did using older fish (smolts and fingerlings) may provide more answers to the changes in rheotactic response due to the age of fish. A study done using Atlantic salmon (*Salmo salar*) (Nemeth et al. 2003) showed changes in rheotactic response with age. Inlet strains of landlocked salmon fry at age 0-21 days post swim up showed a stronger upstream response versus downstream response. However, at an older stage (22-56 days post swim up), these fry reversed their responses and showed a stronger downstream response than upstream. The coaster brook trout used in my study have already begun to show a downstream response. This leads to a question of whether or not their response will change with age or stay the same.

It is a question whether or not the fish were actually "moving" downstream, or just getting pushed downstream because they were not able to maintain position in the current. In previous studies, however, it was said that downstream movements may be less representative of innate rheotactic behavior because downstream is also the direction that fish that are unable to maintain position in the current would move, and it is the easiest route of escape. If indeed these fish were pushed downstream involuntarily, they probably would have been held against the screen by the current and appeared distressed or tired. At the end of trials while fish were being removed and counted from their respective positions in the tank, it was observed that all fish were upright and swimming,

and in no way did it seem as though the fish in the downstream trap were "tired" or otherwise distressed.

The negative rheotactic response was significantly stronger in Tobin Harbor strain "swim-up fry", which was in contrast to what I expected. I had expected to see more downstream movement in Siskiwit Bay strain fish because downstream is the direction in which these fish would need to travel to reach their adult location (Siskiwit Bay, Lake Superior). However, it is unknown exactly when these fish choose to move from their stream habitat to lake habitat. Our results tentatively suggest that this movement does not happen as "sac-fry" but may begin as "swim-up fry." It is also possible that they do not exhibit a rheotactic response to "swim" to the lake, but perhaps wait for a high water event or fast current to be "flushed" out.

Previous similar rheotactic studies using Arctic grayling (*Thymallus arcticus*) have been done using inlet and outlet populations (Kaya, 1989). The results from this study show that "swim-up fry" inlet grayling had a stronger downstream response versus an upstream response, which is consistent with our findings on the Siskiwit Bay (inlet) "swim-up fry."

In contrast, one wonders why there was more downstream movement seen in the Tobin Harbor strain when these fish are not hatched into a stream environment. It is possible that this is a response to the seiche effects seen on Isle Royale that can often cause dramatic and swift currents in the lake's water column. Perhaps Tobin Harbor fish are adapted to "following" these currents.

As mentioned earlier, a study on the rheotactic behaviors of older brook trout (Baird 2000) showed outcomes similar to what was seen in this study. The inlet spawning strain had more downstream movement than upstream, while the outlet spawning strain showed more upstream movement. The rheotactic behaviors of two shoal spawning populations, which would be similar to our Tobin Harbor population, were also observed. She expected to see little directional response, or possibly an upstream response. The results indicated more upstream movement in both strains. This was attributed to predator avoidance and to access food resources. Although our Tobin Harbor strain did not exhibit significant upstream movement, we may be able to conclude that their significant downstream movement is attributed to the instinct of eluding predators or gaining access to food resources.

Conclusions from this study can now be used towards further research and management decisions. Matching a fish's rheotactic behavior with the environment it is being placed into may provide for more successful results. For example, stocking a downstream migrating fish into an outlet environment may cause the fish to move downstream over barriers such as dams and waterfalls, in which they would then be lost to the fishery. However, if downstream migrating fish are stocked into tributaries, this should increase the number of fish accessing the lake, and subsequently reaching maturity and reproducing, which would then increase recruitment to the fishery (Nemeth et al. 2003). Based on the significant downstream movement seen with both Siskiwit Bay and Tobin

Harbor strains, and until further studies are conducted to determine if there is a change in rheotactic response with age, we can suggest that stocking both Siskiwit Bay and Tobin Harbor strains into inlet environments may produce more successful results than stocking them in outlet environments.

Acknowledgments

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