NATURAL MOVEMENTS OF SMALLMOUTH BASS AND THEIR RESPONSE TO TOURNAMENT DISPLACEMENT WITHIN THE EASTERN BASIN OF LAKE ONTARIO

by

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A thesis submitted to the Department of Biology
in conformity with the requirements for the
degree of Master of Science

Queen's University
Kingston, Ontario, Canada
(October 2018)

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Abstract

Smallmouth Bass (*Micropterus dolomieu*) are one of the most popular species targeted by angling tournaments in North America, particularly in the Great Lakes region. Tournament anglers target the largest fish in these populations and can transport them across great distances (>100 km), generating concern among scientists and anglers about their ability to return to their established home ranges. Understanding the movement of sport fish by tournament anglers can aid in managing the large recreational fishery that exists in the Great Lakes region. Currently, there is insufficient research examining the natural movements or long-distance displacement of bass within large waterbodies. This study investigates tournament displacement within the Eastern Basin and the natural, non-displaced, movements of these fish. A dataset (2012 – 2016) of externally tagged Smallmouth Bass was used to examine movement, both natural and post-tournament displacement. In addition, acoustic telemetry was used to monitor the movements of an experimentally displaced and non-displaced group. From initial tagging to recapture, experimentally tagged displaced fish travelled an average of 23.4 km, while the control group travelled an average of 2.91 km. Both groups had similar lengths of time between tagging and recapture. The acoustically tagged control group were frequently detected within their initial tagging site, suggesting these fish maintain home ranges similar in size with Smallmouth Bass inhabiting smaller waterbodies. Both experimental groups displayed varying movement throughout the Eastern Basin, suggesting that many of these fish may be searching for pre-established home-ranges. No acoustically tagged fish displaced within the Eastern Basin returned to their original area of capture, suggesting they experienced difficulty navigating. These results have very important implications for fisheries managers, as well as organizers of competitive angling events for bass in the Great Lakes.

Acknowledgements

I would like to thank Dr. Bruce Tufts for providing me with the opportunity to complete my Masters of Science and allowing me to join the Freshwater Fisheries Conservation Lab. I appreciate your advice and patience while helping me to complete my thesis. I have learned a great deal from working in this lab that has helped me to pursue a career in fisheries science. I am truly grateful for this experience. Additionally, I would like to thank Dr. Shelly Arnott and Dr. Mel Robertson for acting as my supervisory committee.

I am extremely grateful to the Greenberg Family Fund at Queen's University who funded this research. Their generosity has allowed many students, including myself, to participate in innovative research in fisheries biology.

I would like to thank all the members of the Freshwater Fisheries Conservation Lab, both past and present, who helped me throughout the completion of this project. I would especially like to thank Rachael Hornsby for her mentorship and guidance throughout my time at Queen's. Your continued help and support throughout this process was invaluable. I would also like to specifically thank Arthur Bonsall, Sean Bridgman, and Mary Hanley for their continued support and encouragement throughout this process. Without your valuable advice, this would not have been possible.

I would like to take this time to thank Maria Ruiz and Dr. Michael Wood who provided invaluable advice and aid throughout the completion of this MSc. Your help was greatly appreciated.

Finally, I would like to thank my wife, family, and friends for their continued love and support throughout this process. I can't thank you enough.

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Chapter 1: Introduction

Recreational angling is widely practiced throughout North America and has a large economic value. Scientific research provides extremely important information to manage and conserve recreational fisheries. Unlike most commercial fishers, recreational anglers are able to target and capture specific individuals within a population. This allows for the selection of specific fish for release or harvest, which is important for the sustainable use of the fishery. This selective harvest helps to ensure that the most ecologically valuable members of the population are released back into the population. Estimates suggest that about 64% of all angled fish in Canada are released, with the remaining 36% being harvested (Cooke and Cowx, 2006).

Canada is home to some of the most valuable recreational freshwater fisheries in the world, with over 2.7 million anglers residing here (Tufts, Holden, and DeMille, 2015). Approximately 10% of Canadians and Americans are anglers. In 2010, recreational fishing in Canada had an economic impact of approximately 2.5 billion dollars, with an additional 3 billion dollars spent on boats, transportation, and other major purchases related to recreational fishing (Tufts, Holden, and DeMille, 2015). The total estimated expenditures for recreational fishing in North America range between $47.3 billion to $56.8 billion dollars (Tufts et al. 2015).

In recent years, competitive angling events (tournaments) have become an important element of recreational fisheries. Competitive recreational fishing events are widespread throughout Canada, with Ontario hosting the greatest number of angling tournaments, particularly the Great Lakes Region (Kerr, 2012). The majority of these competitive angling events target one to two species and usually last anywhere from one to three days. There has been a great deal of research conducted on tournament practices, including the live-release weigh-in procedures, biological impacts, and post-release survival (Ferguson and Tufts, 1992; Booth et al. 1995; Hartley and Moring, 1995; Philipp et al. 1997; Cooke et al. 2002; Shaun and Suski, 2003; Suski et al. 2003; Suski et al. 2004; Cooke and Suski, 2005; Morrissey et al. 2005; Driscoll, Smith, and Myers 2007; Gries, 2009; Maynard et al. 2013). Results from these studies have led to more sustainable competitive angling practices, reducing mortality and the overall stress imposed on tournament caught fish.

High catch-rates during competitive angling events have allowed researchers to obtain valuable information about popular target species during tournament events, such as Smallmouth Bass. These events can provide unique opportunities to study the life history, population dynamics, and movements of these fish. Understanding how Smallmouth Bass move throughout their environment is especially important in areas where recreational fishing is popular, as it helps to identify changes in behaviour that may be caused by fishing pressure. While there is research in this field, the majority of this research focuses on smaller, inland lakes, rivers, and reservoirs. There is currently much less known about the movements of important recreational species in larger waterbodies such as the Great Lakes.

The Smallmouth Bass (*Micropterus dolomieu*) is a member of the Centrarchidae family and commonly grouped under the term Black Bass with other species from the *Micropterus* genus. Smallmouth Bass is a warm-water species, although it is more tolerant of colder waters than other Black Bass, such as Largemouth Bass. Smallmouth Bass inhabit clear, deeper waterbodies and rivers, preferring low turbidity, moderate gradient in rivers, and substrate consisting of rocks and cobbles on which to spawn (Scott and Crossman, 1973; Todd and Rabeni, 1989; Bozek et al. 2002). Smallmouth Bass have been known to associate with cover, which includes woody debris, large boulders, and other structures (Todd and Rabeni, 1989). They prefer cooler waters with optimum growth temperatures approximately 22°C (Whitledge et al. 2002).

Smallmouth Bass are one of the most popular targets for recreational anglers in Canada, particularly in the Great Lakes Region. In addition to traditional fishing, competitive angling tournaments are popular in this region, particularly in Lake Ontario. In the last 10 to 15 years, there has been an increase in catch and release angling events held in Ontario, making it host to the largest number of angling tournaments in North America (Kerr and Kamke, 2003; Kerr, 2012). A study conducted in 2012 found that 49.3% of competitive angling events were held in Southern Ontario and 30.4% were held on the Great Lakes (Kerr, 2012). Black Bass are the most popular target for competitive angling events in Ontario, making up 32.1% of target species (Kerr, 2012).

Fish targeted during these events are some of the largest and most valuable members of the population. Competitive angling tournaments targeting Black Bass require that fish brought

in during the event must meet a minimum size requirement of 300 mm. It is not uncommon for fish between 500 mm and 700 mm to be brought in during competitive angling events on Lake Ontario. These fish are some of the most valuable members of the population in terms of genetics, the quantity and quality of eggs produced, and their spawning success rate. Understanding the impacts of competitive angling on fish targeted during these events is essential for effectively protecting the largest, most mature members of the population.

Previous studies indicate that Smallmouth Bass maintain home ranges throughout the year, restricting their movements to a concentrated area (Todd and Rabeni, 1989; Brown et al. 2009). The information available suggests that home ranges for Smallmouth Bass are roughly 200 – 400 hectares in size (Langhurst and Schoenike, 1990; Ridgway et al. 2002). There is also evidence to suggest that fish can shift their home ranges throughout the summer months, although this has yet to be tested in larger systems (Savitz et al. 1993). Researchers speculate that home range behavior is due to nest site fidelity and successful foraging (Forney, 1961; Langhurst and Schoenik, 1990; Ridgway et al. 1991; Ridgway and Shuter, 1996). To better understand Smallmouth Bass behaviour, previous studies have utilized mark-recapture methods, often in combination with other techniques, including: dispersal (Ridgway and Shuter, 1996; Blunt et al. 2002; Wilde, 2003; Kaintz and Bettoli, 2010; Hornsby, 2016), distribution (Beamesderfer and Rieman 1991; Barthel et al. 2008), migrations (Langhurst and Schoenike, 1990), and site fidelity (Ridgway et al. 1991).

Movement patterns for Smallmouth Bass have been well studied on small - medium sized waterbodies (Forney, 1961; Munther, 1970; Todd and Rabenie, 1989; Langhurst and Schoenike, 1990; Ridgway et al. 2002; Brown et al. 2009). These studies have shown that fish typically migrate in the spring to spawning sites. After spawning, Smallmouth Bass will occupy established home ranges throughout the summer, followed by a fall migration into deeper, colder water where they will overwinter (Todd and Rabeni, 1989; Ridgway et al. 1996; Brown et al. 2009). Although these fish occupy a limited home range throughout the summer months and are relatively inactive throughout the winter, they can display long migrations during the spring and fall (Forney, 1961; Pflug and Pauley, 1984; Langhurst and Schoenike, 1990). Langhurst and Schoenike (1990) found that some Wisconsin Smallmouth Bass were able to navigate distances between 69-87 km during the fall migration. Bass tagged in Chateauguay River, Quebec have

been known to migrate up to 30 miles (48.28 km) (Cuerrier, 1943). Other studies have reported these fish migrating distances of up to 150 km (Kaemingk et al. 2011). Interestingly, Smallmouth Bass in Lake Ontario are considered non-migratory (Gerber and Haynes, 1988).

Research into the movement of fish has expanded our understanding of the navigational strategies used many different species. Fish have several sensory mechanisms with which to take in their environment, including sight, smell, pressure, and sound. Some species rely on more than one sensory mechanism to navigate their environments. Species like Atlantic Salmon utilize the Earth's magnetism, as well as polarized light, to navigate the open ocean. Once these fish have moved into freshwater, it is thought that they employ olfaction to find their initial spawning sites (Ueda, H. 2012). In contrast, some species undergo fairly short migrations, using different navigational strategies. Although our understanding of fish movements has greatly improved in recent years, there is still much to be learned in this area.

At the present time, there is a need to improve our understanding of the movement patterns and navigational abilities of Smallmouth Bass in large waterbodies such as the Great Lakes. Although many studies have examined movement patterns in this species, the vast majority of this research focuses on small, inland lakes, rivers, or reservoirs (Forney, 1961; Munther, 1970; Todd and Rabenie, 1989; Langhurst and Schoenike, 1990; Ridgway et al. 2002; Brown et al. 2009). The growing number of competitive fishing events on large waterbodies such as the Great Lakes has raised concerns about their movements after being caught during competitive angling events.

Angling tournaments typically release fish in one common location after they have been weighed-in, effectively displacing these fish from their initial capture locations. Tournaments held in the Eastern Basin of Lake Ontario, Bay of Quinte, and St. Lawrence River have the potential to displace fish upwards of 100 km due to the size of the waterbody. Although research has investigated the impacts of displacement on Black Bass, the majority of it has been conducted on smaller waterbodies, displacing fish relatively short distances (1 – 45 km) (Forney, 1961; Pflug and Pauley, 1983; Ridgway and Shuter, 1996; Blunt et al. 2002; Kaintz and Bettoli, 2010; Brown et al. 2015).

Research conducted on the impacts of displacement on Black Bass indicate that the return rate of displaced Smallmouth Bass is relatively variable (Ridgway, 2002; Wild and Paulson,

2003; Hornsby, 2016). Forney (1961) found that, in Lake Odeida, New York, 54% of Smallmouth Bass were able to return to their initial capture site after being displaced between 8 and 24 km. Similarly, Ridgway and Shuter (1996) found that 83% of Smallmouth Bass displaced an average distance of 6.7 km were able to return to their initial capture location in Lake Opeongo, Ontario.

Not all studies showed a high rate of return. Blunt et al. (2002) found a lower rate of return (29%) for Smallmouth Bass, displaced 21 km in the Grand River, Ontario. A review by Wilde (2003) reported that, on average, 32% of Smallmouth Bass return to their initial capture sites when displaced. Other studies have reported lower (mean < 30%) return rates, suggesting difficulty in navigation. (Gilliand, 1999; Richardson-Heft et al. 2000). After displacement, Smallmouth Bass have been known to remain at the release site from a few hours to a week (Ridgway and Shuter, 1996; Kaintz and Bettoli, 2010; Hornsby, 2016). Wilde (2003) found that 26% of displaced Smallmouth Bass remain within 1.6 km of the release site. A recent study by Hornsby (2016) found that 17 of 18 Smallmouth Bass displaced into the Bay of Quinte from the surrounding waterbody failed to return to their initial capture location outside of the bay. The one fish that was able to navigate out of the bay travelled approximately 135 km before being detected again around Main Duck Island (Hornsby, 2016). The Eastern Basin of Lake Ontario, Bay of Quinte, and St. Lawrence River are host to a great many competitive angling events each year (Kerr, 2012) and have the potential to displace angled fish long distances from their established home ranges. In order to properly manage and conserve Smallmouth Bass populations in this region, there is an urgent need to better understand whether these fish are able to navigate back to their home ranges after long distance displacement in tournaments.

The purpose of this study is to investigate if Smallmouth Bass are able to return to their initial capture locations after tournament displacement within the Eastern Basin of Lake Ontario. Secondly, this study will investigate the natural (non-displaced) movements of Smallmouth Bass within Lake Ontario. This study will include data from several different sources. Data collected from a long-term mark-recapture study on 5,268 Smallmouth Bass tagged throughout the Bay of Quinte, Kingston and the St. Lawrence River were analyzed. Information was collected from a smaller number of individual Smallmouth Bass that will be surgically implanted with acoustic transmitters. The acoustic telemetry experiment will include a control (non-displaced) group of

fish and an experimental (displaced) group of fish. I hypothesize that the natural home ranges of Smallmouth Bass on Lake Ontario are similar in size to those documented in smaller water bodies. I hypothesize that experimentally displaced Smallmouth Bass will return to their initial capture site after displacement within the Eastern Basin of Lake Ontario. If this occurs, it would suggest that these fish can effectively navigate the open waters of the Eastern Basin of Lake Ontario. Alternatively, if these fish do not navigate back to their initial capture location, this result will have important implications for tournament organizers and fisheries managers, including stockpiling and post-tournament spawning success.

Chapter 2: Methods

Study Site

This study took place within the Eastern Basin of Lake Ontario between July 2016 and September 2017. This area of the lake is approximately 200,000ha in size and is characterized by small, shallow basins, varying depths, and an abundance of shoreline. While Lake Ontario has a max depth of 244m, the average depth of the Eastern Basin is approximately 30m with a max depth of 50m. The numerous bays that make up the shoreline of the Eastern Basin provide suitable habitat for many aquatic species including Northern Pike, Smallmouth Bass, Lake Trout, Brown Trout, Chinook Salmon, Alewife, Cisco, Lake Whitefish, Yellow Perch, and Round Goby (Ontario Ministry of Natural Resources, 2016). Smallmouth Bass are commonly found in the rockier bays and shoals throughout the waterbody.

The Bay of Quinte is a long, narrow bay located on the northern shore of Lake Ontario (Figure 2.1). The bay extends past Trenton, Belleville, and Deseronto before turning south towards Glenora and draining east into Lake Ontario and the St. Lawrence River (Figure 2.2). The Bay of Quinte has an average depth of 5m, although the average depth increases to approximately 24 meters around Adolphus Reach.

The St. Lawrence River originates at the east end of Lake Ontario near Kingston, ON and Cape Vincent, NY. The river flows 1,197 km to the Gulf of St. Lawrence and subsequently the Atlantic Ocean. The river flows in a north-easterly direction, acting as part of the international boundary that separates Canada from the United States.

Mark-Recapture

Mark-recapture techniques involve tagging members of a population and relying on their recapture to generate useful data. This information is useful in investigating movement patterns, survival, and in some cases, size of the target population. This research method requires larger samples sizes, depending on the study system, for the initial tagging in order to effectively gain information from the study population. This approach can be difficult and costly to obtain a representative sample and so studies are often conducted over several years, which was the case in this study. I used this technique to compare the movements of displaced and non-displaced Smallmouth Bass within the Eastern Basin of Lake Ontario.

Tournament Format

Lake Ontario is a popular location for competitive angling events due to the healthy populations of some of the most sought-after game fish in North America, including Northern Pike, Walleye, and Black Bass. Since 2012, Smallmouth Bass have been sampled and tagged from tournaments held in Kingston (11), Morrisburg (2), Gananoque (1), Rockport (3), Belleville (26), Trenton (1) and Deseronto (1) (Figure 2.3). These tournaments generally have a limit of five fish per angling team, which are weighed in at the end of the angling period. The largest weight determines the winner.

Competitive angling events have strict rules to ensure fair play as well as the preservation of the caught fish. There are strict times for when anglers can start and when they need to return for the weigh-in procedure. All competitors are required to start from a common launch point but are usually able to fish throughout any connected waterbody, though some tournaments held within the Bay of Quinte restrict either species or fishing area based on the target species. Anglers commonly compete as teams of two and must abide by legal angling methods. There are size restrictions that prohibit anglers from weighing in any fish less than 300mm (12 inches). These tournaments are live-release, with penalties for any dead fish (0.5lb/dead fish). Competitors are required to possess a boat with a functioning live well.

Scientific research has helped to improve tournament weigh-in proceedures, reducing mortality and overall stress (Siepker, et al. 2007). Most tournaments now incorporate a water weigh-in system where the fish are kept submerged throughout the majority of the weigh-in process. During the weigh-in procedure individuals move fish from their livewell to the stage in water filled bags. Fish are then moved into an aerated holding tank until they ready to be weighed. After the weigh-in, fish are moved to an aerated holding tank where they wait to be moved by trained volunteers to a live release boat. Fish are released offshore immediately after the conclusion of the tournament.

Tagging

The process for tagging Smallmouth Bass at competitive angling events involves several steps and is generally completed by teams of three to four individuals. A tagging team usually

includes one handler, one recorder, and one fish tagger. Multiple tagging teams are often present during larger angling tournaments.

Fish are tagged after the formal weigh-in process for the anglers is complete to allow for the tournament to operate smoothly. Tagging occurs on a measuring board situated near the holding tanks. Before tagging, total length (tip of the mouth to the end of the caudal fin when pinched) and fork length (tip of the mouth to the fork of the caudal fin when open) are recorded for each fish measured. Two yellow floy T-bar tags are then implanted just under the soft dorsal spines on both sides of the fish, each containing a unique tag number as well as contact information for reporting recaptures. Fish are then quickly transported to a live release boat. Any fish that perished before or after the tournament weigh-in proceedure are retained for future processing back in our laboratory at Queen's University.

Smallmouth Bass were sampled and tagged at the Thousand Island Open live-release fishing tournament in August 2016 and 2017. Additional mark-recapture data collected from previous angling tournaments held in the Bay of Quinte, the St. Lawrence River, and the Eastern Basin of Lake Ontario between 2012 and 2017 were also included in the analysis.

In addition to competitive angling events, tagging was also conducted by members of the Freshwater Fisheries Conservation Lab between 2013 and 2017. The purpose of this additional tagging was to create a control group by catching, tagging, and releasing fish in the same location to better understand the natural movements of these fish. Tagging took place during the summer months (May to September) throughout the Eastern Basin of Lake Ontario and the St. Lawrence River (Figure 2.4). All tagging and sampling were done under the Queen's University animal care protocol #2013-040 and within the tournament size restrictions (>300mm total length).

Recaptures

Recaptures were recorded during angling tournaments and from individual anglers fishing throughout the year. Anglers who captured previously tagged fish could report these recaptures through email, phone, Facebook, or our lab website. The unique tag ID, location of recapture, and the status of the fish (released or killed) was recorded. If the fish status was

unclear, it was marked unknown. Locations of recapture were either in the form of GPS coordinates, general site descriptions, or zones illustrated on the lab website.

Statistical Analysis

Time and Distance

For both the experimental and control groups, the time between the initial tagging event and recapture was calculated by subtracting the recapture date from the date of initial tagging. In addition, the total distance travelled was determined for each recapture using the shortest possible route via Google Earth ©.

Shapiro-Wilk was used to determine if the data collected was normally distributed. In the case where the data was not normally distributed, a Kruskal-Wallis test was used to determine any significant differences between 1) time from initial tagging until re-capture and 2) distance travelled in the control and experimental groups. To better understand movements, the experimental (displaced tournament) fish were separated into smaller groups based on where each fish was tagged (Bay of Quinte, Eastern Basin of Lake Ontario, and the St. Lawrence River).

Acoustic Telemetry

Acoustic telemetry has been used in a variety of studies to better understand both broad and fine-scale movements of Black Bass in lakes, rivers, and reservoirs (Ridgway and Shuter, 1996; Ridgway, 2002; Cooke et al. 2004; Suski and Ridgway, 2009; Carter et al. 2012; Brown et al. 2015; Howell et al. 2015; Hornsby, 2016). This study also investigated the movements of displaced and non-displaced Smallmouth Bass in Lake Ontario using acoustic telemetry.

Implanting Transmitters

Study Design

18 tournament size (>300 mm) Smallmouth Bass were implanted with V16-4H coded acoustic transmitters (25g, 16 mm x 68 mm, 69 kHz, 120 s delay, battery life 1825 days, Vemco) on 9 August, 18 August, and 4 October, 2016. Fish were angled from the south side of Main Duck Island. After the fish were angled, they were transported by boat in a livewell to Portsmouth Harbour in Kingston for surgery (~35 km) (Figure 2.5). After undergoing surgery,

these fish were released at Penitentiary Shoal, in the center of a small network of receivers. In 2015, an additional twelve Smallmouth Bass were angled from the south Side of Main Duck Island. These fish were surgically implanted with similar acoustic transmitters and released at the site of capture to serve as a control group (Table 2.1).

Surgery

Prior to surgery, fish were anesthetised in a bath of 60-ppm clove oil / ethanol (1:9) solution (Keen et al. 1998). After the fish displayed a loss of equilibrium (stage four anesthesia (Keen et al. 1998) they were removed from the bath and positioned on a surgery sling. The sling allowed for the fish to be cradled upside down, creating easy access to the incision site. During surgery, a bilge pump was used to pump an aerated solution of 30-ppm clove oil / ethanol solution over the gills of the fish (Keen et al. 1998). An incision of approximately 20 – 25mm long was made using a razorblade off-centre from the midline, anterior to the vent. The transmitter was then activated and inserted into the body cavity. The incision was then sealed using three to four simple, interrupted sutures (Ethicon, FS-1 reverse cutting, 3-0 monofilament). Two pink floy tags containing contact information for the lab (phone, email, website) were attached to the back of the fish on either side of the dorsal fin. Pink tags were used to indicate the presence of an internal transmitter. Fish were then recovered in an aerated bath until they regained equilibrium. Recovery usually took between five and ten minutes. Once they had fully recovered from the surgery, the fish were placed in the livewell of the boat and transported to the release site. All surgery tools were sterilized using 95% ethanol solution prior to surgery. All methods were approved by the Queen's Animal Care and met CCAC requirements (protocol 2013-040).

Receiver Deployment and Retrieval

Prior to deployment, acoustic receivers were activated and programmed with station names and GPS coordinates for each location VUE (2.3.0). Battery life was documented before deployment to ensure active recording throughout the study period.

Seventeen VR2W (69 kHz) acoustic receivers (VR2W, 69 kHz, Vemco) were deployed in the Kingston area and at Main Duck Island in the Eastern Basin of Lake Ontario (Figure 2.6). Six receivers were deployed at Main Duck Island on September 6th, 2016, and 11 in the Kingston

area on July 19th, 2016. Receivers were retrieved in November, 2016, due to the potential interference from ice in the winter months. The receivers stationed at Main Duck Island were redeployed on June 26th, 2017 and retrieved on August 24th, 2017 to determine if any of the experimentally-displaced fish had returned to their initial capture location. Receivers were retrieved using a grappling hook.

Acoustic receivers were anchored using either cinderblocks or smaller cylindrical anchors, depending on receiver location. Anchors were connected with a long rope, which was used as a grappling line for receiver retrieval. Receivers were attached to a second rope that was suspended from one of the anchors; they were attached with five zip ties to the rope approximately half-way up the rope. An orange float was attached to the top of the rope to ensure that the receiver position remained vertical. This float was suspended in the water column and displayed contact information for the lab if the receiver was accidentally pulled up. GPS coordinates for each anchor block were recorded upon deployment (Figure 2.7). Upon retrieval, the data was downloaded and organized based on each receiver and transmitter. Each receiver location was assigned a station code, allowing for data from multiple receivers to be compiled into the single station. Detections for both the experimentally displaced and control groups were compiled throughout the study period.

In addition to the receivers mentioned above, data was also collected from a network of receivers deployed by the Ontario Ministry of Natural Resources and Forestry (OMNRF). These receivers make up two arrays, one covering the Eastern Basin and the other extending from the basin into Lake Ontario proper along the East side of Main Duck Island. These receivers are identical to the ones used in this study, allowing for additional information to be collected (Figure 2.8). Within the Great Lakes, all acoustic telemetry data collected is submitted to the Great Lakes Acoustic Telemetry Observation System (GLATOS). GLATOS represents research conducted in the Great Lakes within the Ocean Tracking Network, and is administered by the Great Lakes Fishery Commission, Michigan State University, U.S. Geological Survey, and the Great Lakes Observation System. This allows for the sharing of telemetry data between researchers and management agencies throughout the Great Lakes region.

Range Test

Range testing was conducted between Simcoe Island and the mainland (44°11'16.26"N 76°33'5.46"W). Testing was conducted from September 12th to September 19th, 2016 using a V16 range testing tag (11s delay, Vemco). The tag was anchored along the line of receivers set up between the mainland and Simcoe Island in approximately nine meters of water, allowing for the previously deployed gate of receivers to monitor detection frequency at distances of 524.7 m, 954.9 m, 1800.6 m, and 3033.6 m (Figure 2.9).

Previous research had conducted range testing in both shallow and deep water at Main Duck Island between May and June of 2015 (Hornsby 2016). This information was used when planning this study.

Statistical Analysis

Statistical analysis was performed using the program R (3.3.2) "Sincere Pumpkin Patch". Shapiro-Wilks tests were used to determine if the data was normally distributed. If the data was not normally distributed, then a Kruskal-Wallis test was used to compare each group.

Time to Leave Release Array

To determine the amount of time that each fish spent at the release site before dispersing, the number of consecutive days where the individual was detected at the release site was calculated. An individual was assumed to have left the release site when they had not been detected for 24 hours or were detected by receivers outside of the release network.

Distance from the Release Site

Distance traveled from the release site was determined using the ruler function in Google Earth Pro ©. The shortest distance between the release site and each receiver that an individual was detected on was used to determine the distance traveled from the release site. Distances were calculated by measuring the path of the individual, allowing for an estimate of total distance travelled.

Residency Index

Residency indices were used to determine where fish were detected most often throughout the study period. By dividing the number of detections by the number of deployment days, differences in lengths of deployment time between individual acoustic receivers was accounted for. This standardized number of detections for each receiver was then divided by the standardized number of total detections to generate a residency index at each receiver location.

Survival

Fish were assigned survival statuses based on interpretations of the data retrieved from the acoustic receivers. Fish in this study were categorized into one of four survival categories: "alive," "presumed alive," "stationary," or "unknown." For an individual to be categorized as "alive," it must have been detected within one week of the retrieval of the receivers (October 26th, 2016 to November 2nd, 2016). If fish did not exhibit movement between receivers during the study period, it was assumed that the fish had likely expired or dropped the acoustic tag. These fish were categorized as "stationary." Fish were categorized as "presumed alive" if they were detected within a month of retrieving the receivers. Fish categorized as "unknown" were not detected within a month of the receiver retrieval date.

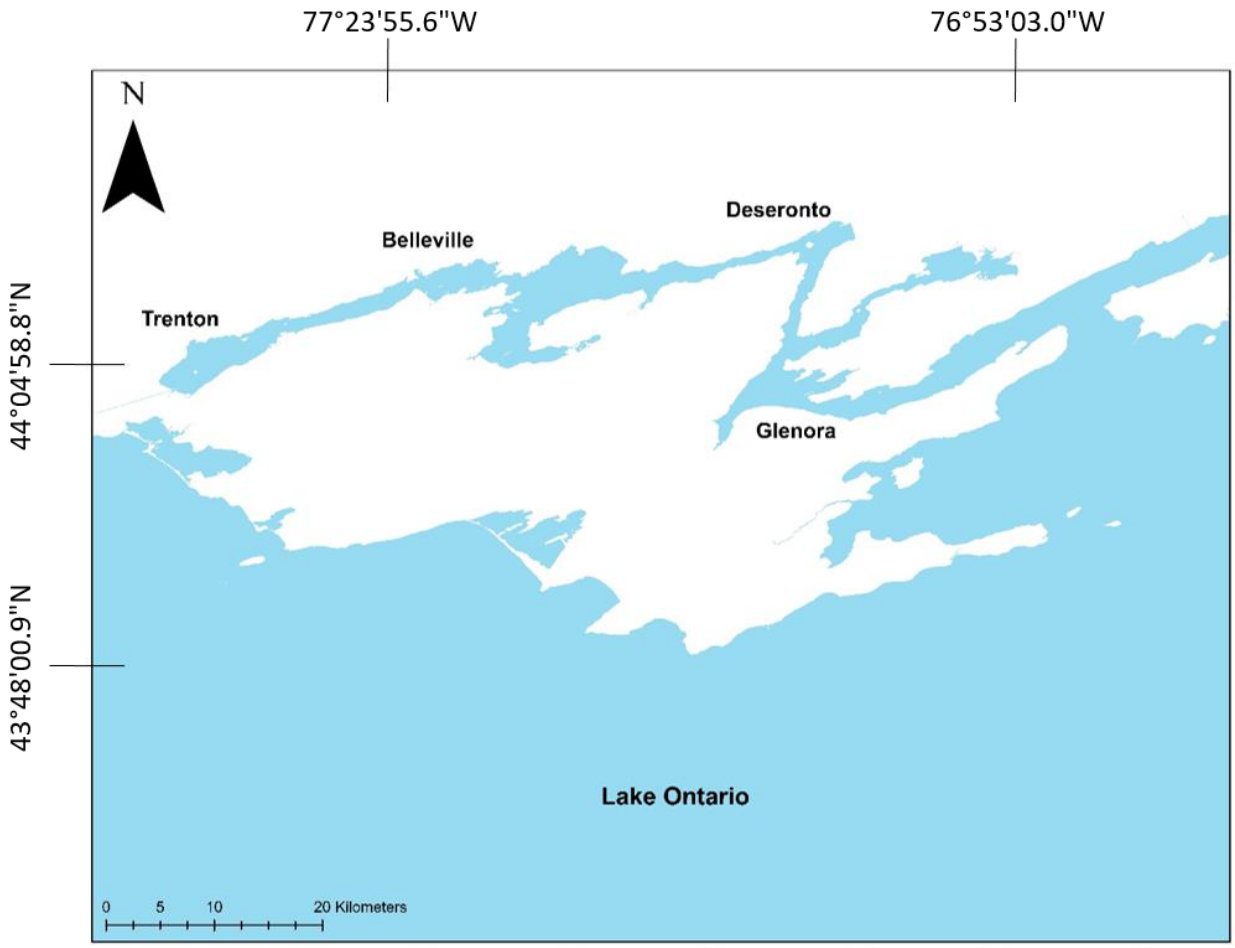

Figure 2.1 Study Site: The Bay of Quinte extends from Trenton to Deseronto before turning south towards Glenora. The bay then turns east out towards Lake Ontario.

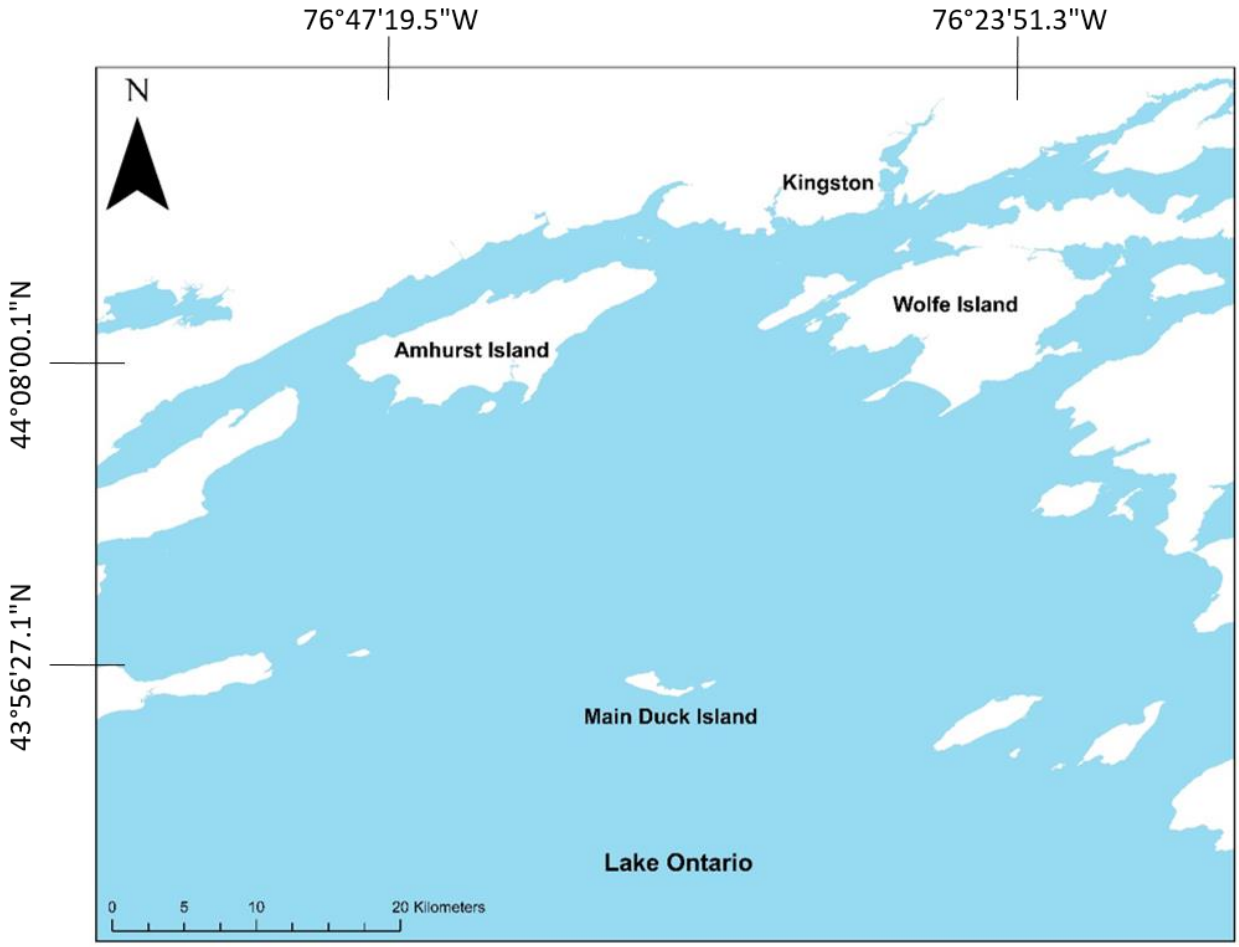

Figure 2.2 Study site: The Eastern Basin of Lake Ontario extends from Kingston in the North, to Main Duck Island in the south, Amherst Island in the west, and the mouth of the St. Lawrence River in the east.

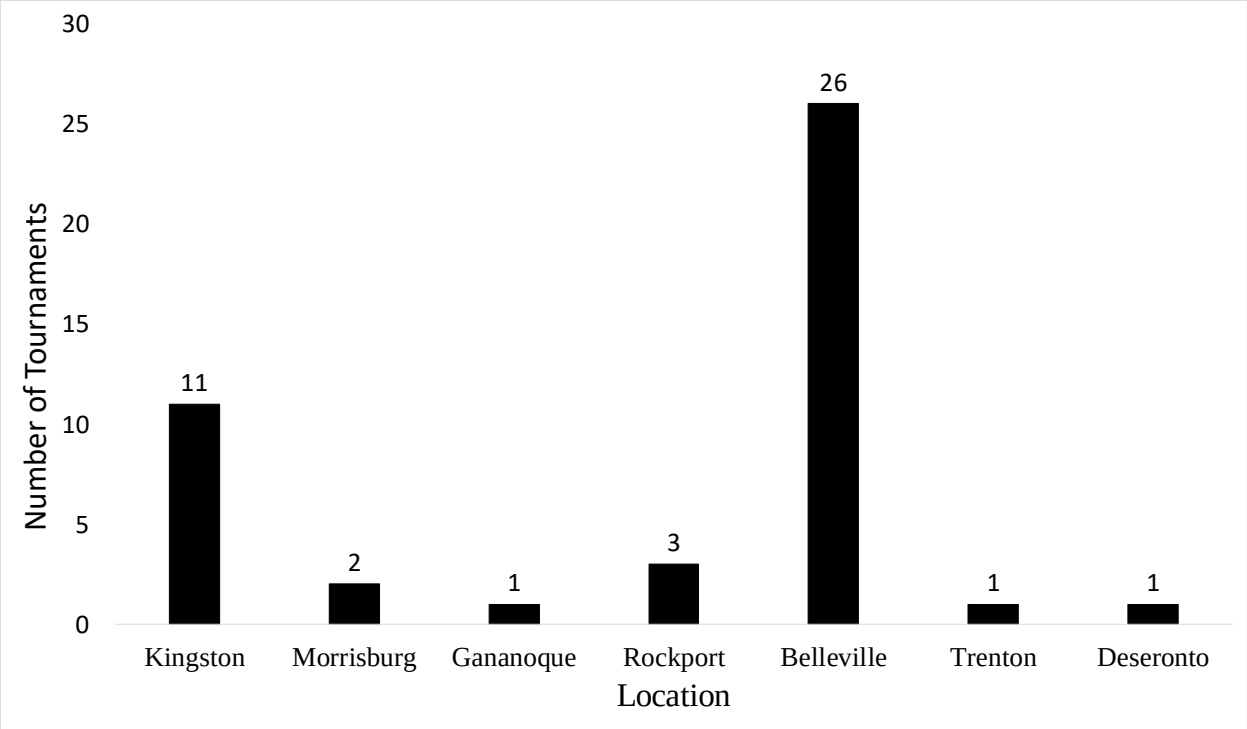

Figure 2.3 The number of competitive angling tournaments between 2012 and 2017 that Smallmouth Bass have been externally tagged with floy tags.

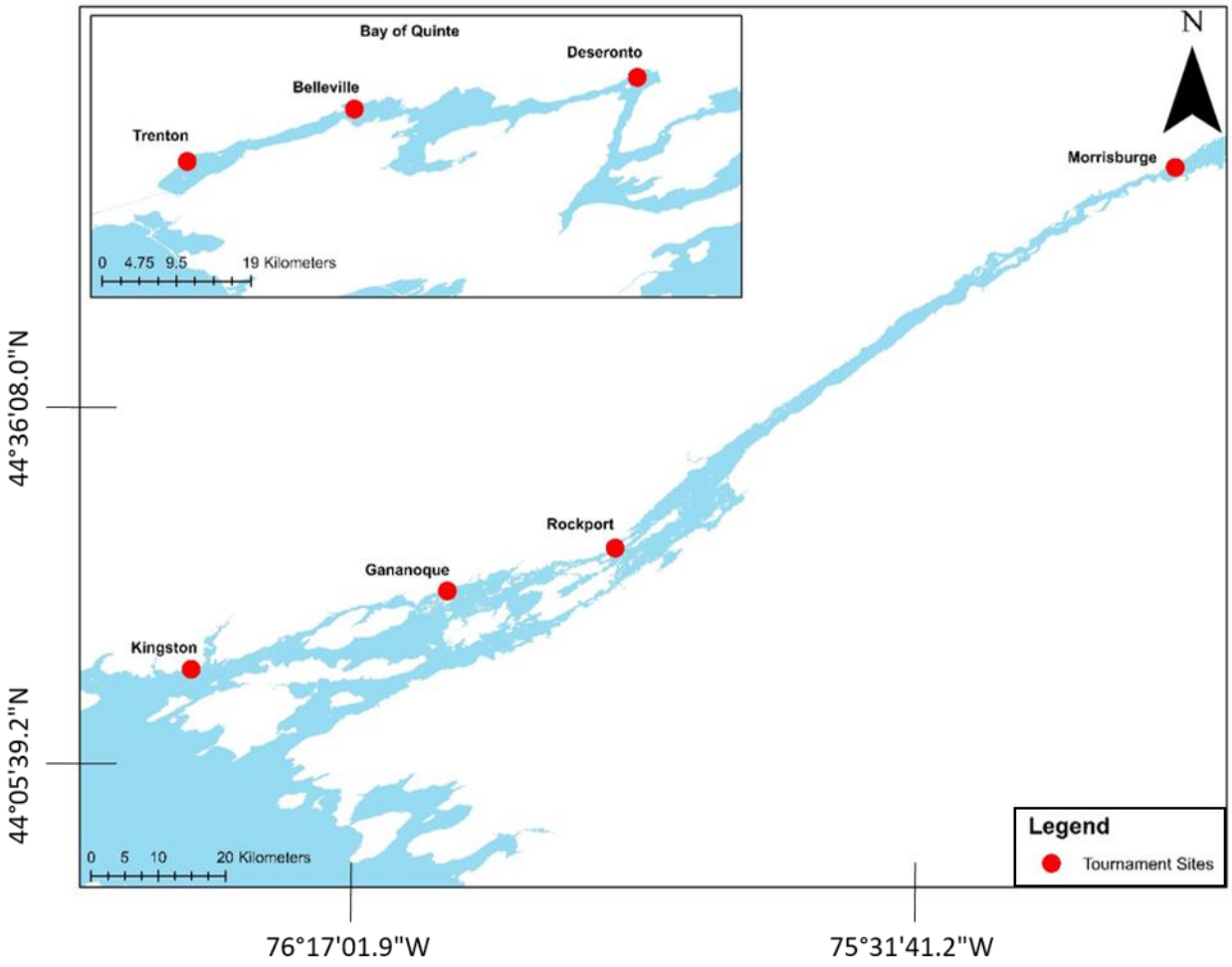

Figure 2.4 The locations of competitive angling tournaments where Smallmouth Bass were tagged between 2012 and 2017.

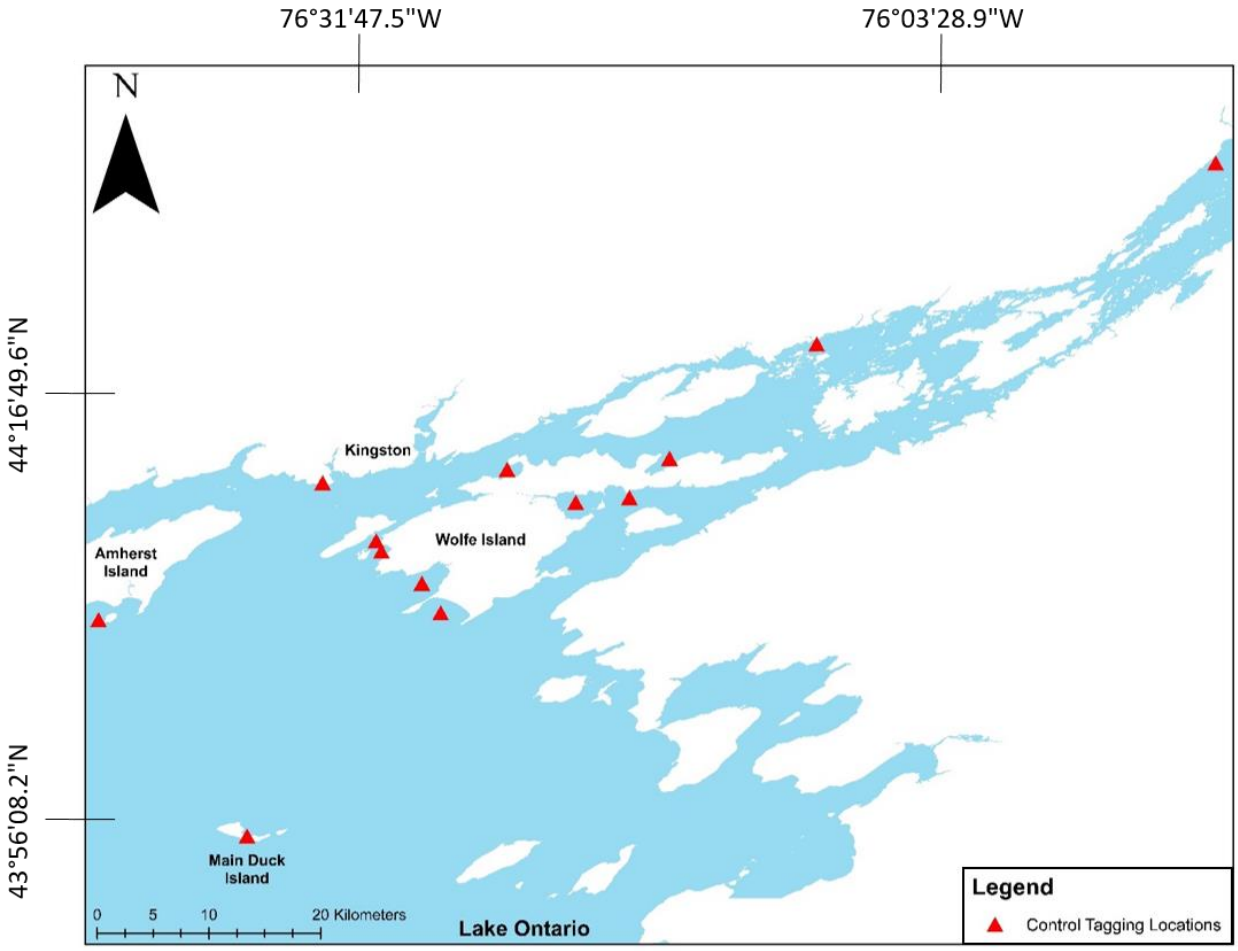

Figure 2.5 The locations where control fish were caught, tagged, and released between 2012 and 2017.

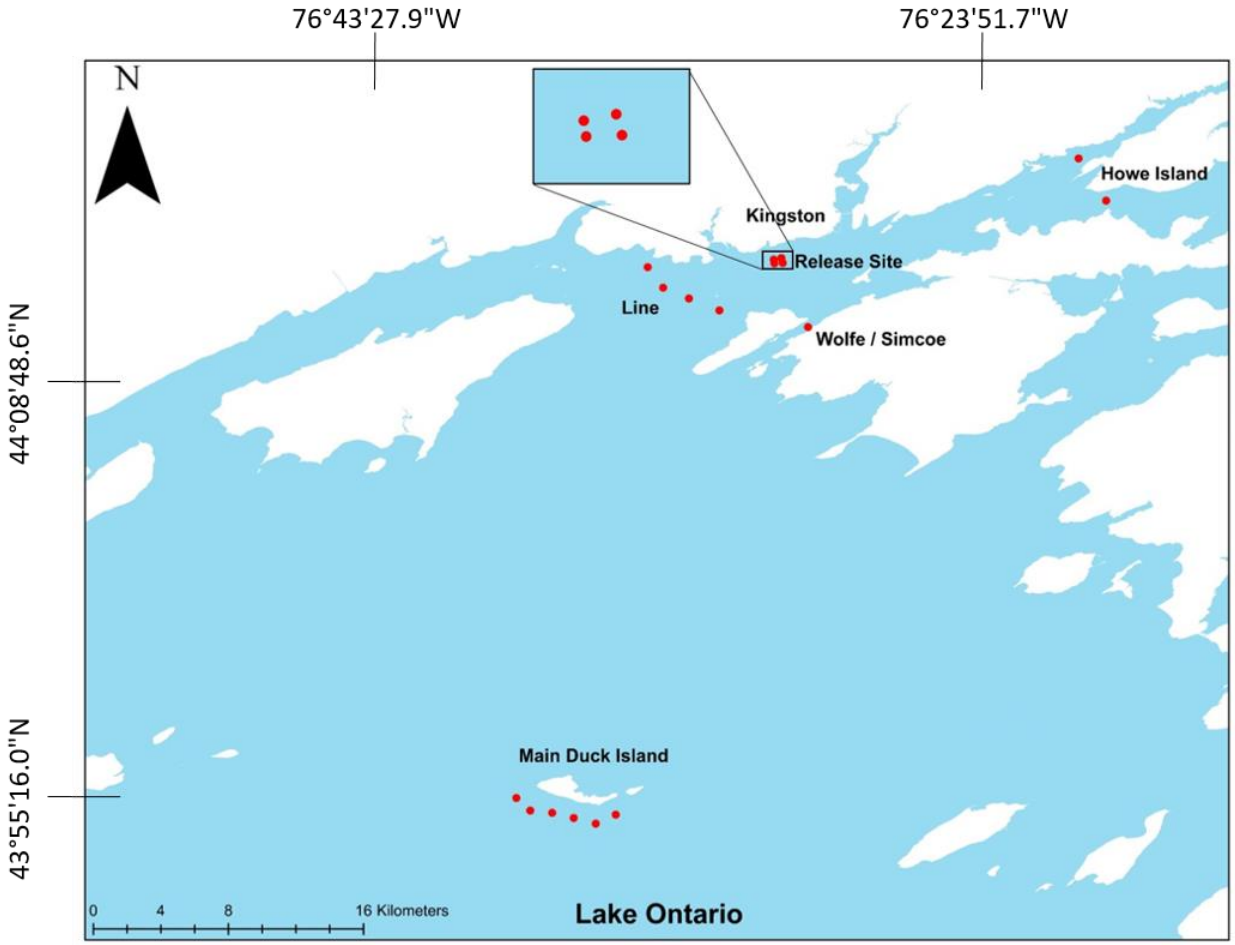

Figure 2.6 Receiver network: VR2W acoustic receiver locations and their station names throughout the Eastern Basin of Lake Ontario. Red circles indicate receiver placement. Receivers were deployed for approximately four months, between July 2016 and November 2016.

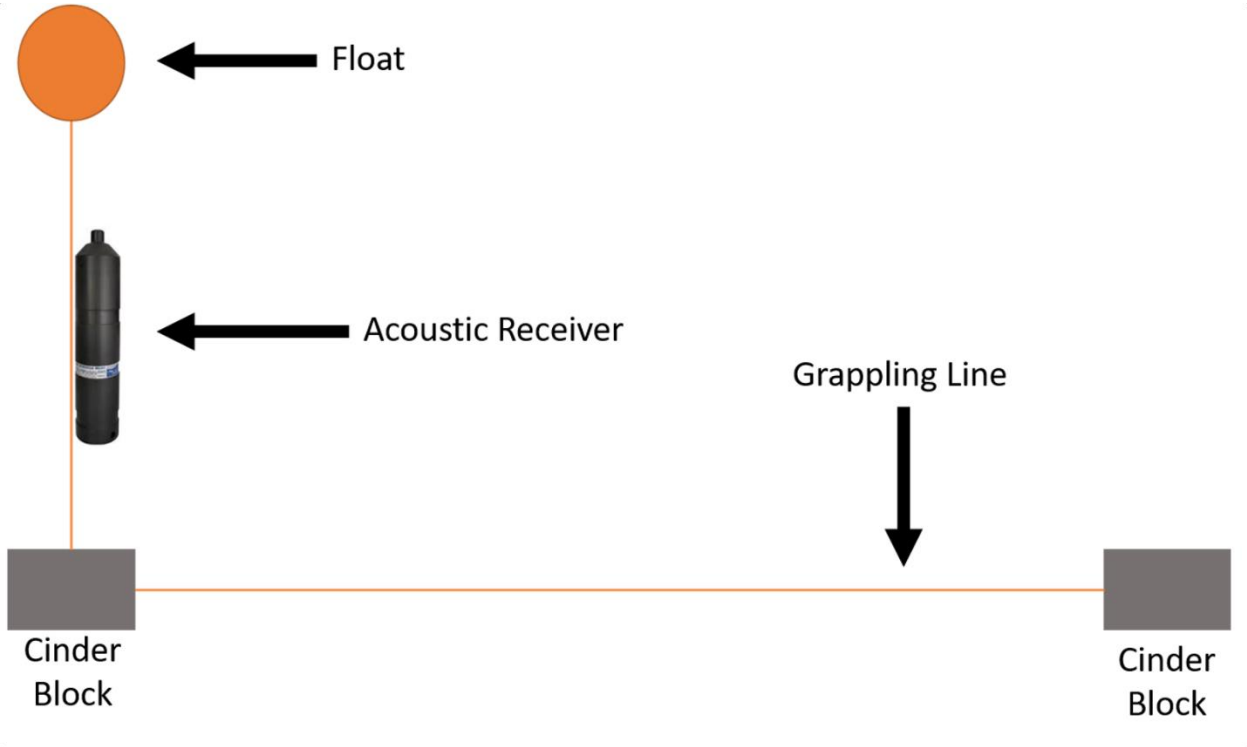

Figure 2.7 The anchoring system for acoustic receivers used in this study. Grappling hooks were used to pull the anchored receiver up by the grappling line. Upon redeployment, GPS coordinates were taken for each cinderblock, allowing for future retrieval. Floats displayed the name of the university and contact information for anyone who accidently pulled up the receiver.

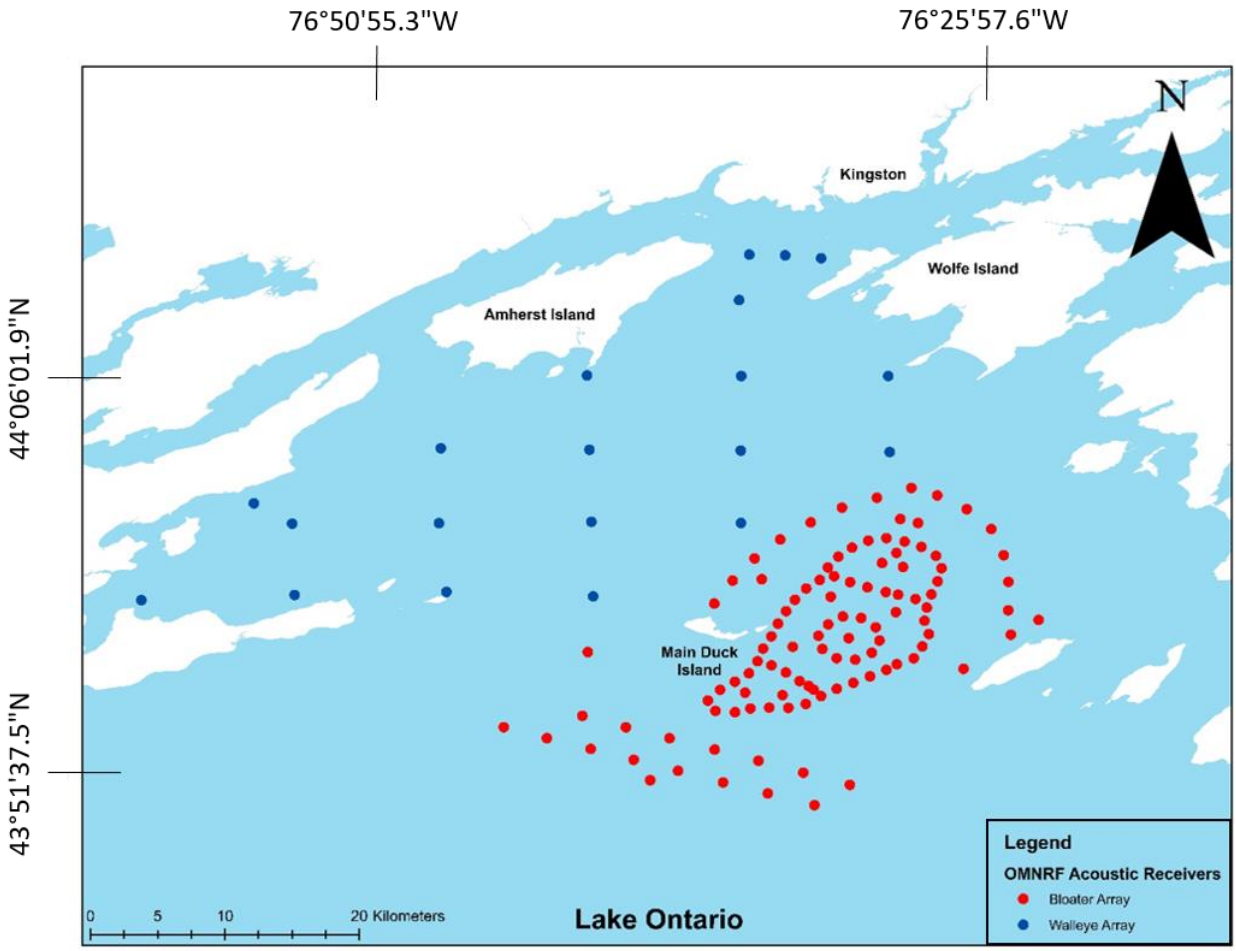

Figure 2.8 A network of VR2W acoustic receivers (Vemco) deployed by the Lake Ontario Management Unit throughout the Eastern Basin of Lake Ontario.

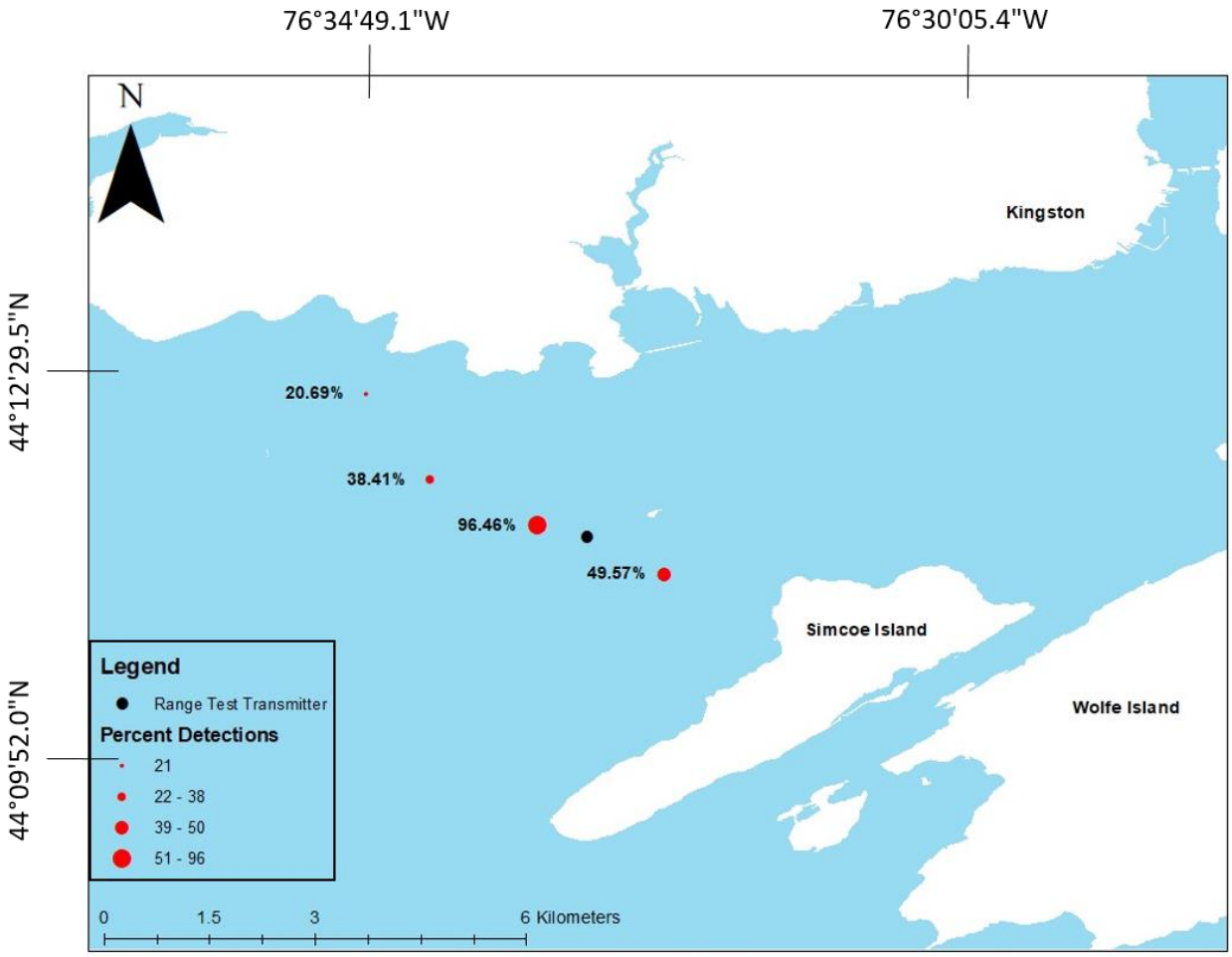

Figure 2.9 Range testing was conducted using the line of receivers between Simcoe Island and the Mainland. The range testing tag was situated at varying distances from each receiver (524.66m, 954.91m, 1800.64m, and 3033.58m). The range testing tag was deployed for approximately one week.

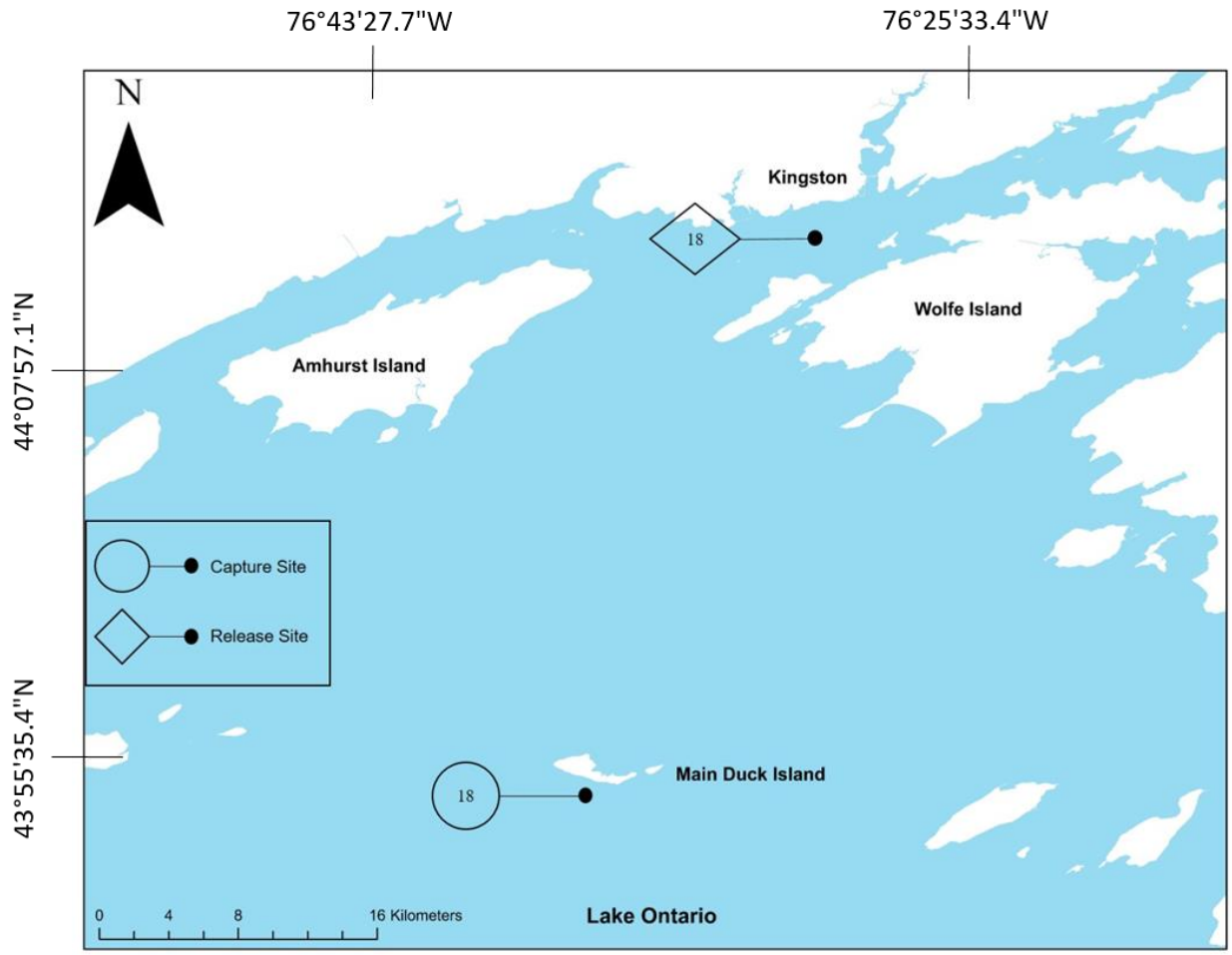

Figure 2.10 Capture and release site for the experimentally displaced fish. Surgeries were performed at Portsmouth Harbor on August 9, August 18, and October 4. Numeric values indicate the number of displaced fish. Displacement distance is approximately 35 km.

Table 2.1 Release dates, displacement locations, and size for Smallmouth Bass implanted with acoustic transmitters.

Tagging Date	Group	Capture Site	Release Site	Approx. Distance (km)	Fork Length (mm)
2016-08-09	Displaced	Main Duck Island	Pen Shoal	35	440
2016-08-09	Displaced	Main Duck Island	Pen Shoal	35	441
2016-08-09	Displaced	Main Duck Island	Pen Shoal	35	406
2016-08-09	Displaced	Main Duck Island	Pen Shoal	35	385
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	444
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	445
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	392
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	398
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	424
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	455
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	411
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	394
2016-08-18	Displaced	Main Duck Island	Pen Shoal	35	464
2016-10-04	Displaced	Main Duck Island	Pen Shoal	35	460
2016-10-04	Displaced	Main Duck Island	Pen Shoal	35	424
2016-10-04	Displaced	Main Duck Island	Pen Shoal	35	425
2016-10-04	Displaced	Main Duck Island	Pen Shoal	35	400
2016-10-04	Displaced	Main Duck Island	Pen Shoal	35	445
2015-09-03	Control	Main Duck Island	Main Duck Island	0	415
2015-09-03	Control	Main Duck Island	Main Duck Island	0	410
2015-09-03	Control	Main Duck Island	Main Duck Island	0	440
2015-09-03	Control	Main Duck Island	Main Duck Island	0	465
2015-09-03	Control	Main Duck Island	Main Duck Island	0	455
2015-09-03	Control	Main Duck Island	Main Duck Island	0	385
2015-09-03	Control	Main Duck Island	Main Duck Island	0	440
2015-09-03	Control	Main Duck Island	Main Duck Island	0	425
2015-09-03	Control	Main Duck Island	Main Duck Island	0	405
2015-09-03	Control	Main Duck Island	Main Duck Island	0	455
2015-09-03	Control	Main Duck Island	Main Duck Island	0	430
2015-09-03	Control	Main Duck Island	Main Duck Island	0	425

Chapter 3: Results

Mark-Recapture

The total number of Smallmouth Bass tagged, as of October 2017, is 5,267, with 4,960 Smallmouth Bass tagged at competitive angling events throughout the Bay of Quinte, the Eastern Basin of Lake Ontario, and the St. Lawrence River. Of these fish, 308 were recaptured. A total number of 307 Smallmouth Bass were tagged outside of angling tournaments by our lab, of which 25 were recaptured (Table 3.1).

Time and Distance

In the control group, average time at liberty between initial tagging and recapture was 227 days. In the experimental group, the time at liberty was 307 days. No significant statistical difference was found between the control (n=25) and experimental groups (n=295) (Kruskal-Wallis, df=1, p=0.86) (Figure 3.1).

The average distance travelled for the control group was determined to be 3 km. The average distance traveled in the experimental group was determined to be 24 km. A significant statistical difference was found between these two groups (Kruskal-Wallis, df=1, $p<0.05$) (Figure 3.2). Results revealed that 92% of control fish were recaptured within ~5 km of the release site whereas 21.5% of tournament fish were recaptured within ~5 km of the release site.

Since many tournament fish are displaced from Lake Ontario to weigh-in/release sites in the Bay of Quinte, an additional analysis was conducted to examine the impact of this displacement. The experimental group was separated based on tagging location: Eastern Basin of Lake Ontario (EBLO) and Bay of Quinte (BOQ). Fish tagged within the Eastern Basin displayed significantly more time at liberty (283.1 days) than those tagged within the Bay of Quinte (170.7 days) (Kruskal-Wallis, df=1, p=0.004) (Figure 3.3). No significant difference was found in distance travelled between the fish tagged in the Kingston / St. Lawrence (23.5 km) and in the Bay of Quinte (27.9 km) (Kruskal-Wallis, df=1, $p>0.05$) (Figure 3.4).

Although no significant difference was found in distance traveled between fish tagged within the Eastern Basin and fish tagged within the Bay of Quinte, fish displaced from Lake Ontario into the bay showed limited dispersal. The vast majority of Smallmouth Bass displaced

into the Bay of Quinte did not return to the Eastern Basin of Lake Ontario. Since 2012, 1,122 Smallmouth Bass have been tagged within the bay. Of the 1,122 Smallmouth Bass tagged within the Bay of Quinte, 40 of these fish were recaptured within the bay. Only seven of these fish were recaptured outside of the bay (Figure 3.5).

Multiple Recaptures

A total of 18 fish were recaptured more than once throughout the study period, with three of these fish being recaptured three times (Table 3.2). Of the 18 fish, 14 were tagged and recaptured within the Eastern Basin of Lake Ontario or the St. Lawrence River. Five fish were recaptured within the same general area as tagging (1-3 km) and are individuals tagged as part of our control group. The remaining 13 fish are part of the experimentally tagged group.

Acoustic Telemetry

Movement and Detections

Control Smallmouth Bass were consistently detected throughout the study period, suggesting they remained within the area along the South side of Main Duck Island, as well as the deeper waters to the East in the winter months. On November 5th, 2016, five control tags expired, leaving 7 functioning control tags. Four of the five fish were detected within a month of the tag expiry date. Throughout the summer months, these fish appeared to have spent most of their time along the south side of Main Duck Island. Control fish were detected moving from one end of the island to the other, spending their time around different receivers (Figure 3.6). During the winter months, these fish were detected on the OMNRF bloater receiver network (Hornsby, 2016). Ten of the twelve control fish were detected at Main Duck Island less than one month before the receivers were retrieved, with seven of those fish detected on the retrieval day. The remaining two fish were last detected on 23 June 2016, 132 days before the receivers were retrieved.

Seven control fish were detected throughout 2017. Six of the seven fish were detected on the OMNRF bloater array during the winter months. These fish appeared to leave this array between May and June 2017. Two of the seven fish were last detected on the Main Duck Island receivers on August 24th, 2017, the day these receivers were retrieved. Two different control fish were detected on the OMNRF bloater array until May 26th and June 1st, 2017. The remaining

three fish were last detected on the OMNRF Walleye array on October 6th, 9th, and 22nd, 2017 respectively. Each fish was detected on a different receiver within the OMNRF Walleye array. Final detections for these fish were approximately 6.5 km, 9.5 km, and 18 km away from the Main Duck Island receiver network (Figure 3.7).

The experimentally displaced Smallmouth Bass displayed varying movement throughout the study period. Two fish were constantly detected at the release site, suggesting that these fish did not survive the surgery procedure, or dropped their acoustic transmitter shortly after release. Nine of the displaced fish were detected throughout the release site and line of receivers approximately 4.7 km away and appeared to be moving in and out of the release site and between the release site and the line network (Figure 2.6). Three fish left the detection range of the receivers at the release site shortly after release and were not detected again throughout the study period. Several fish were detected on the receiver situated between Simcoe Island and Wolfe Island. Four fish exhibited longer distance movements throughout the study area, making their way to the west side of Amherst Island and the west end of Howe Island. Five fish were detected on the OMNRF Walleye array at Melleville Shoal, approximately six kilometers from the release site (Figure 3.8).

One fish traveled extensively throughout the study area. After being released, this fish made two trips to Amherst Island where it was last detected on January 2nd, 2017. It was detected again on April 21st, 2017 making its way toward Melleville Shoal. Thereafter, this fish was most frequently detected in the Melleville Shoal area, although it made several movements to the west end of Amherst Island, east to Long Point on Wolfe Island, and south to about three kilometers north of the OMNRF bloater array. The total estimated distance travelled for this fish is >300 km between initial release and final detection (388 days).

One fish was detected on the OMNRF bloater array, northeast of the island (Figure 3.9). This fish was detected by the OMNRF bloater array on October 15th and on November 15th and 16th, 2016. During the month between these detections, this fish traveled back to the release site and made its way over to Amherst Island. The total estimated distance this fish travelled is approximately 146 km between initial release and final detection. This individual was the closest to reaching its initial capture location, travelling approximately 13.5 km from the capture site at the Main Duck islands.

In July of 2017 a mobile hydrophone was used to determine if any of the experimentally displaced fish had returned to their initial capture site at Main Duck Island. At this time, no displaced fish were detected at their initial capture locations.

Time to Leave Release Array

Experimentally displaced fish took an average of six days to leave the release site. Fish were considered to have left the release site once a 24-hour gap in detections was observed, or they were detected on receivers outside of the release site. The control group of Smallmouth Bass was released on the South side of Main Duck Island, approximately at the acoustic receiver stationed at the center of the island (Hornsby 2016). Of the 12 control Smallmouth Bass, five individuals took 24 hours to leave the release site. The remaining fish left the release site after an average of 23.14 days (Hornsby, 2016). There was no significant difference in time to leave the release site found between the two groups (Kruskal-Wallis, df = 1, p = 0.685) (Figure 3.10).

Distance Travelled

The experimental group had a slightly higher average distance travelled than the control group (12.2 km and 11.6 km respectfully); however, there was no significant difference between the two groups (Kruskal-Wallis, df = 1, p = 0.08). Visually inspecting the data showed that several fish in the experimental group displayed movement “back and forth” from the release site into the surrounding area. This movement was not present in the control fish, indicating that the control group was occupying their established home range. These experimentally displaced fish were detected on receivers between 4.7 km and 31.9 km (average: 10.8 km) from the release site. An estimate of the total distance travelled was calculated, ranging from 6 km to >300 km, with an average of 49.9 km (Figure 3.11). Control fish travelled between 8.7 km and 19.8 km (average: 11.6) from the release site. Individuals from the control group were detected on more than once receiver throughout the study period, making it difficult to determine their exact location. Therefore, an estimate of total distance travelled was not generated for the control group.

Return to Initial Capture Location

Upon retrieving the acoustic receivers stationed at Main Duck Island in July 2017, it was determined that none of the experimentally displaced fish returned to their initial capture

location. None of the experimental fish managed to return to Main Duck Island as of August 9th, 2016 (approximately 439 days from displacement). One individual managed to make it within ~13.5 km of the south side of Main Duck Island. This fish was detected there 409 days after release (Figure 3.12).

Survival

Detections from both the experimental and control groups were visually assessed to estimate survival. Detection data were assessed for gaps between detections that indicated an individual alive and mobile. Individuals that had consistent detections within a localized area were thought to have dropped their tags or died. In the experimental group, two fish were detected constantly at the release site throughout the receiver deployment period. These fish likely did not survive the surgery procedure, or dropped their tag shortly after being released. Ten of the remaining 16 fish were last detected between late August and early November of 2016. It is noteworthy that the acoustic receivers were removed from this area in November 2016. Detection data indicates that these fish are likely still alive, but outside the range of any acoustic receiver. The remaining six fish were detected throughout 2017. These individuals were detected on multiple receivers, indicating that these fish were alive. By dividing the total number of individuals that were assessed to be alive by the total group size, survival for the experimentally displaced fish is estimated at 88%. Hornsby (2016) estimated survival at 100% approximately one year after release. These fish were continuously monitored throughout 2016 and 2017 to assess movement and survival. The number of detections indicate that these fish are alive and moving throughout the area around Main Duck Island. Based on the detection data, it is likely that all the control fish are still alive as of the summer of 2017.

Residency Index

Residency indices were calculated for both the experimental and control groups and a significant difference was found between these groups (Kruskal-Wallis, df=1, $p = 0.01$). The primary residence site used by both control and experimental groups were the release sites. Experimentally displaced fish were found to spend most of their time around the release site, and to a smaller extent, the line of receivers located West of the release site. Control fish were found to reside primarily along the south side of Main Duck Island.

Range Test

The results of the range test performed just north of Simcoe Island indicated significant differences in the hourly detections across the range test period (Kruskal-Wallis, df=1, $p<0.05$). An overall trend of decreasing detections with increasing distance was observed. At the closest receiver (524.6m), the average percent detections were 98.1% with a standard deviation of 2.3. The average percent detections for the farther receivers (954.9 m, 1800.6 m, 3033.5 m) were 47.7%, 39.1% and 21.0% with standard deviations at 26.6, 23.3 and 20.2 respectively (Figure 3.13).

Table 3.1 Number of fish externally tagged in both experimental and control groups throughout the Bay of Quinte and Eastern Basin between 2012 and 2017.

	Total Fish Tagged	Fish Tagged in Bay of Quinte	Fish Tagged in Eastern Basin and St. Lawrence River	Total Recaptures
Control Group	142	0	142	25
Experimental Group	4,960	1122	3838	307
Total	5,102	1122	3980	332

Table 3.2 Externally tagged fish that were recaptured more than once throughout the study period. Initial tagging represents the location where these fish were initially caught and tagged. R1 – R3 indicates the recapture locations. TE1 – TE3 indicates the time elapsed between each recapture in days. D1 – D3 indicates the distance travelled between each recapture in kilometers.

Initial Tagging	R1	R2	R3	TE1	TE2	TE3	D1	D2	D3
Reeds Bay	Reeds Bay	Reeds Bay		2	0		1	1	
Rockport	Zone 06	Alexandria Bay		6	3		43.95	39.38	
Main Duck Island	Main Duck Island	Main Duck Island		10	354		1	1	
South side of Wolfe Island	South Side of Wolfe Island	Unknown		10	52		1	N/A	
Chimney Island	Chimney Island	Chimney Island		12	2		1	1	
Dupont Bay	Sand Bay	Clayton, NY		13	2		2.5	36.61	
Belleville	Zone 03	Big Bay		15	2		34.55	24.94	
Main Duck Island	Main Duck Island	Main Duck Island		17	1		1	1	
Belleville	West end of Big Bay	South End of Big Bay	Belleville	21	0	1	6.05	3.5	9.66
Kingston	Wolfe Island	Kingston		62	1042		4.5	4.5	
Kingston	Kingston	Horsey Bay		69	11		1	6	
Trenton	Zone 03	Big Bay		69	2		51.93	24.94	
Belleville	West of Glenora Ferry	Adolphus Reach		217	47		39.39	15.71	
Kingston	Reeds Bay	Collins Bay		298	75		67	19.18	
Rockport	South of Wolfe Island	South of Wolfe Island	Zone 06	324	3	6	32	1	1
Kingston	Reeds Bay	Collins Bay	Reeds Bay	330	33	1	16.5	17.44	17.44
Kingston	Chimney Island	Mallorytown		331	2		64.05	1.2	
Main Duck Island	Main Duck Island	Main Duck Island		397	415		1	1	

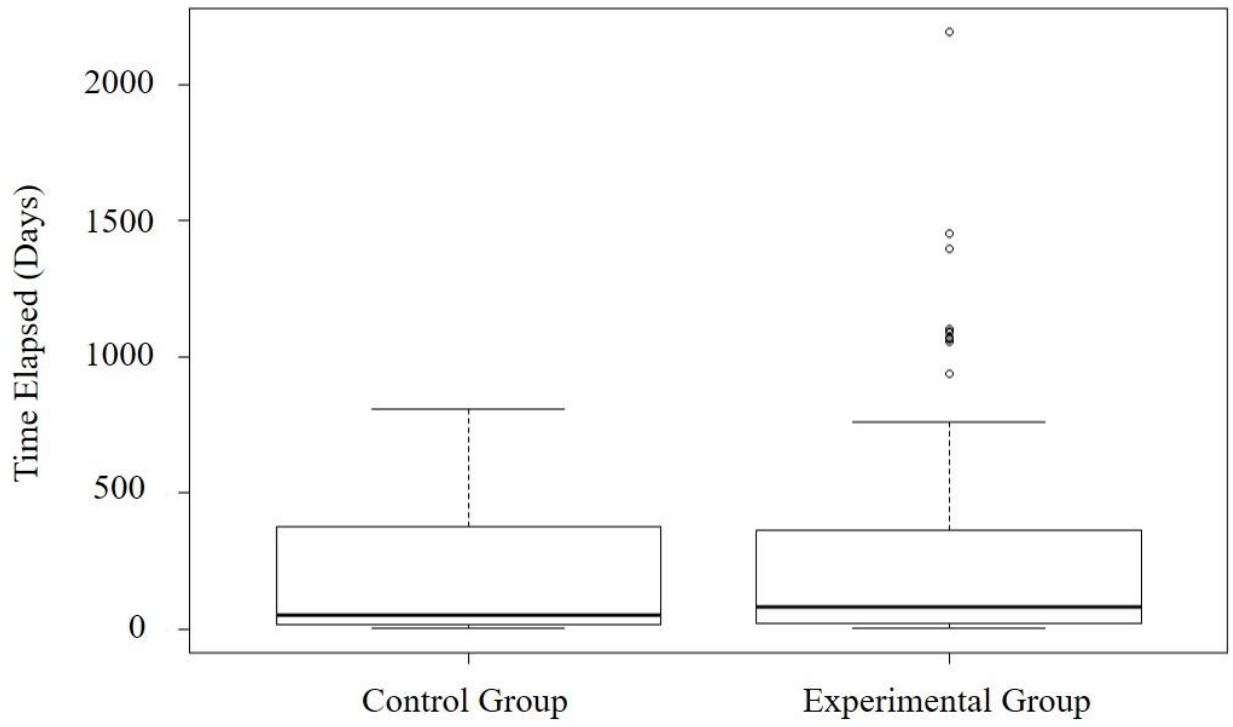

Figure 3.1 Average time at liberty between initial tagging and recapture for both control and experimental groups.

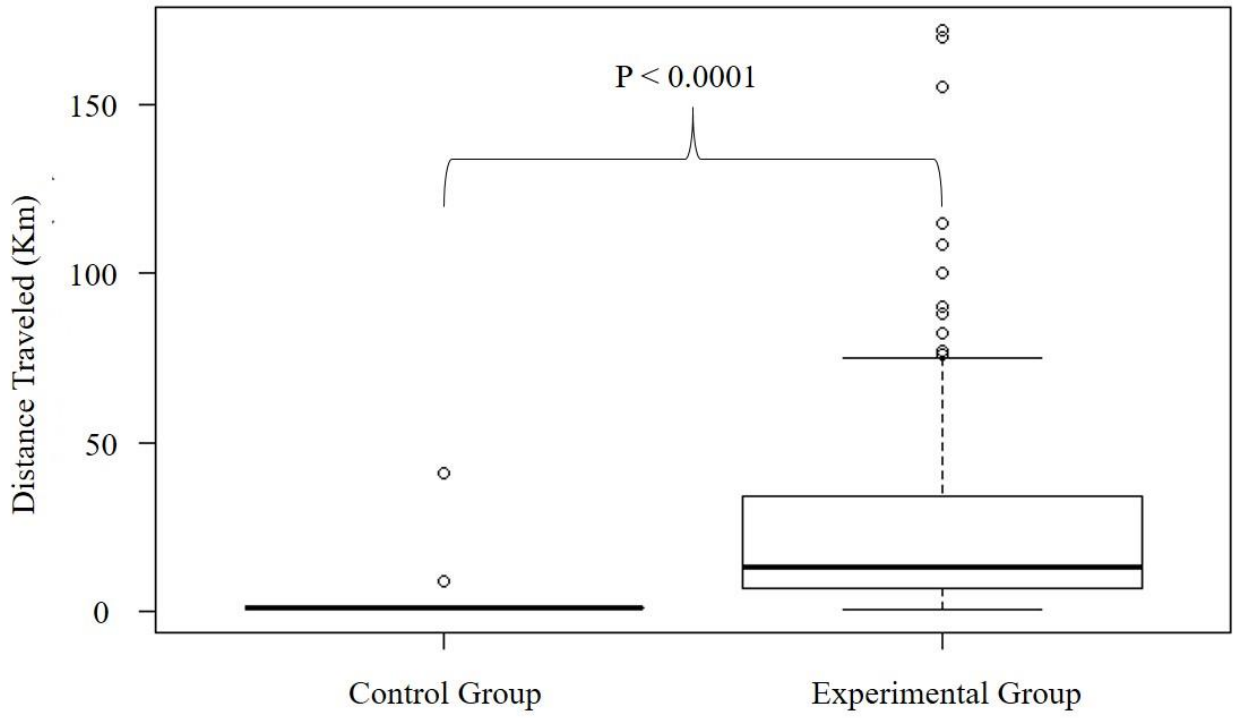

Figure 3.2 Average distance travelled between initial tagging and recapture for both control and experimental groups. Average distance travelled for control fish is 2.91 km while the average for the experimental group is 24.34 km. Experimental Fish travelled significantly further than those within the control group (Kruskal-Wallis, df = 1, p = <0.001).

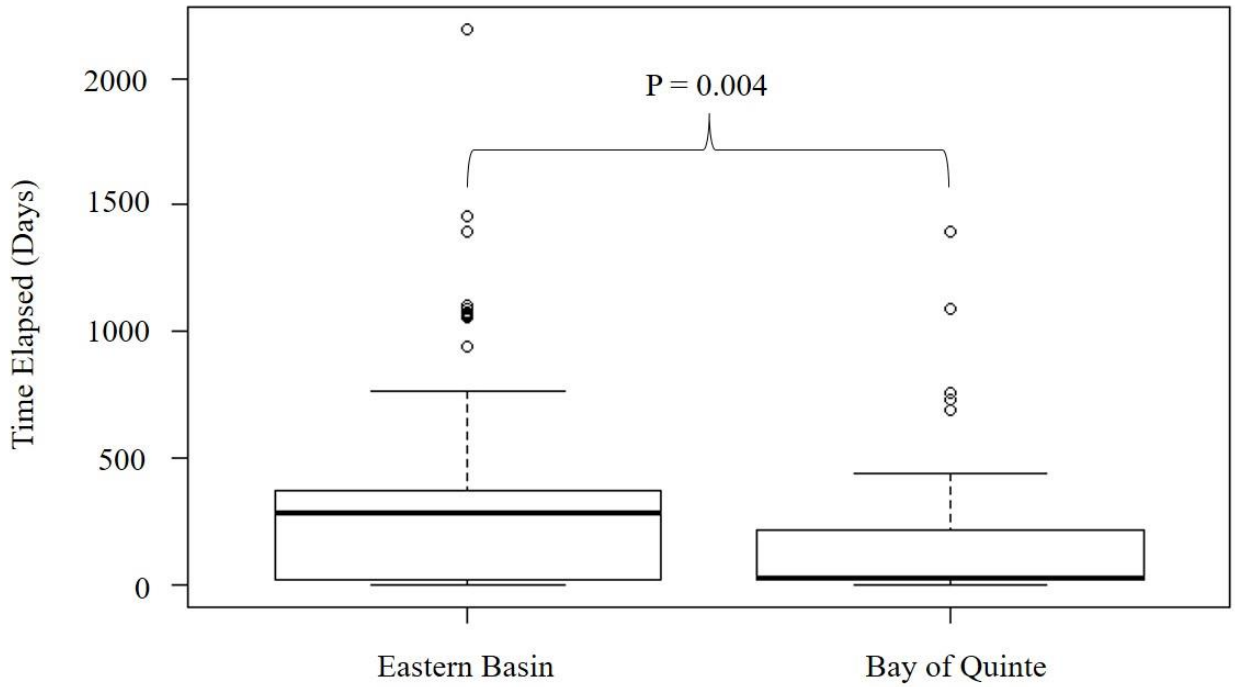

Figure 3.3 Average time at liberty in days between initial tagging and recapture for fish tagged in the Eastern Basin of Lake Ontario and fish tagged in the Bay of Quinte. Average time at liberty for fish in the Eastern Basin is 283.17 days and 170.72 for the fish within the Bay of Quinte. The fish displaced into the Bay of Quinte had significantly less time at liberty than those displaced within the Eastern Basin (Kruskal-Wallis, df = 1, p = 0.004).

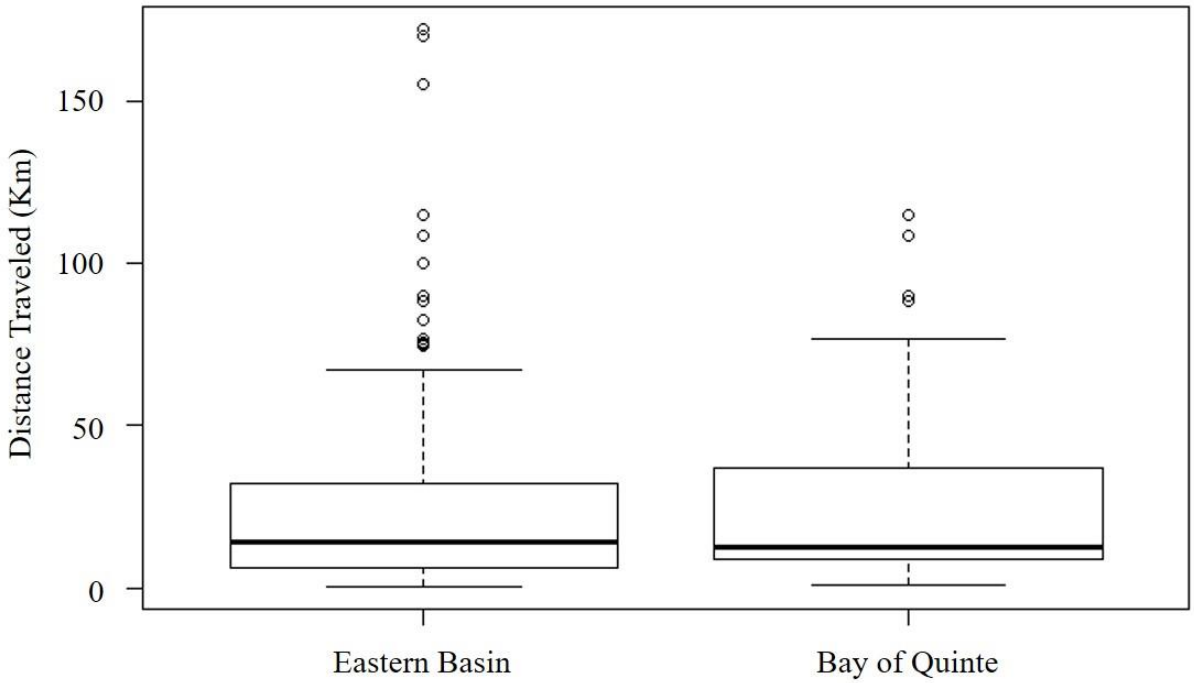

Figure 3.4 Distance travelled in kilometers between initial tagging and recapture in experimental fish. Average distance travelled for fish in the Eastern Basin of Lake Ontario is 23.49 km and 27.93 km for fish in the Bay of Quinte. No significant difference was found between these two groups (Kruskal-Wallis, df = 1, p = 0.567).

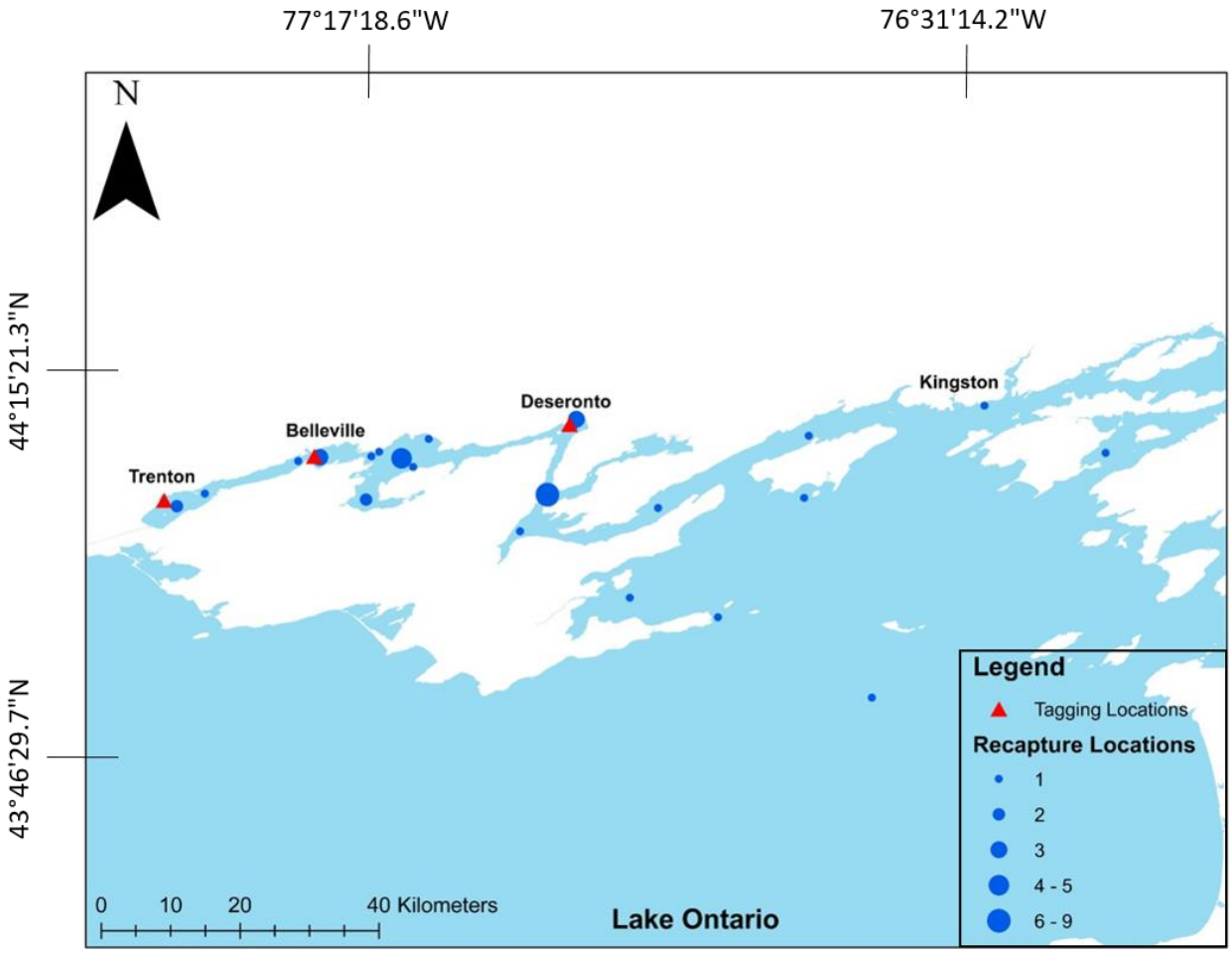

Figure 3.5 Tagging and recapture locations for Smallmouth Bass tagged within the Bay of Quinte. The size of the blue circle reflects the number of fish recaptured in that area. Of the 39 recaptured fish, only 7 managed to leave the bay.

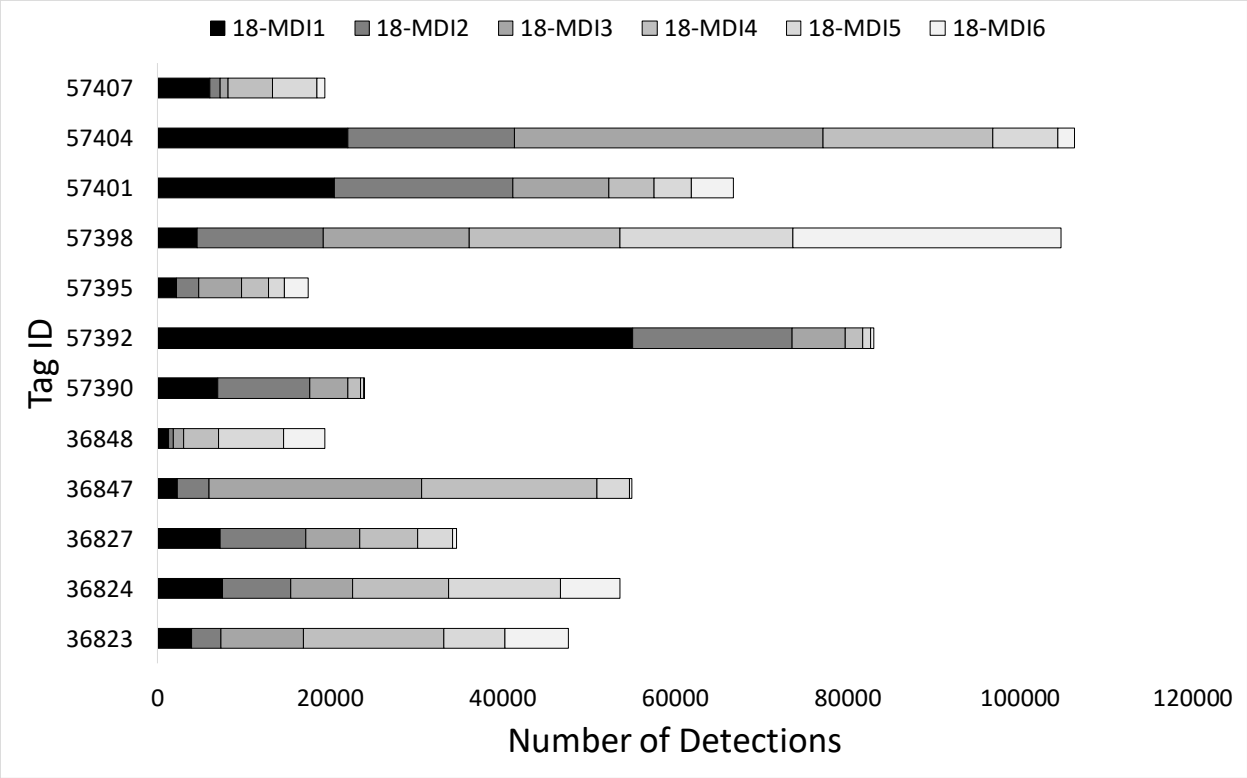

Figure 3.6 Total detections for each control fish on the Main Duck Island receiver network. Receivers are arranged left to right, and colour coded (dark to light) indicating which end of the island they were detected at most often.

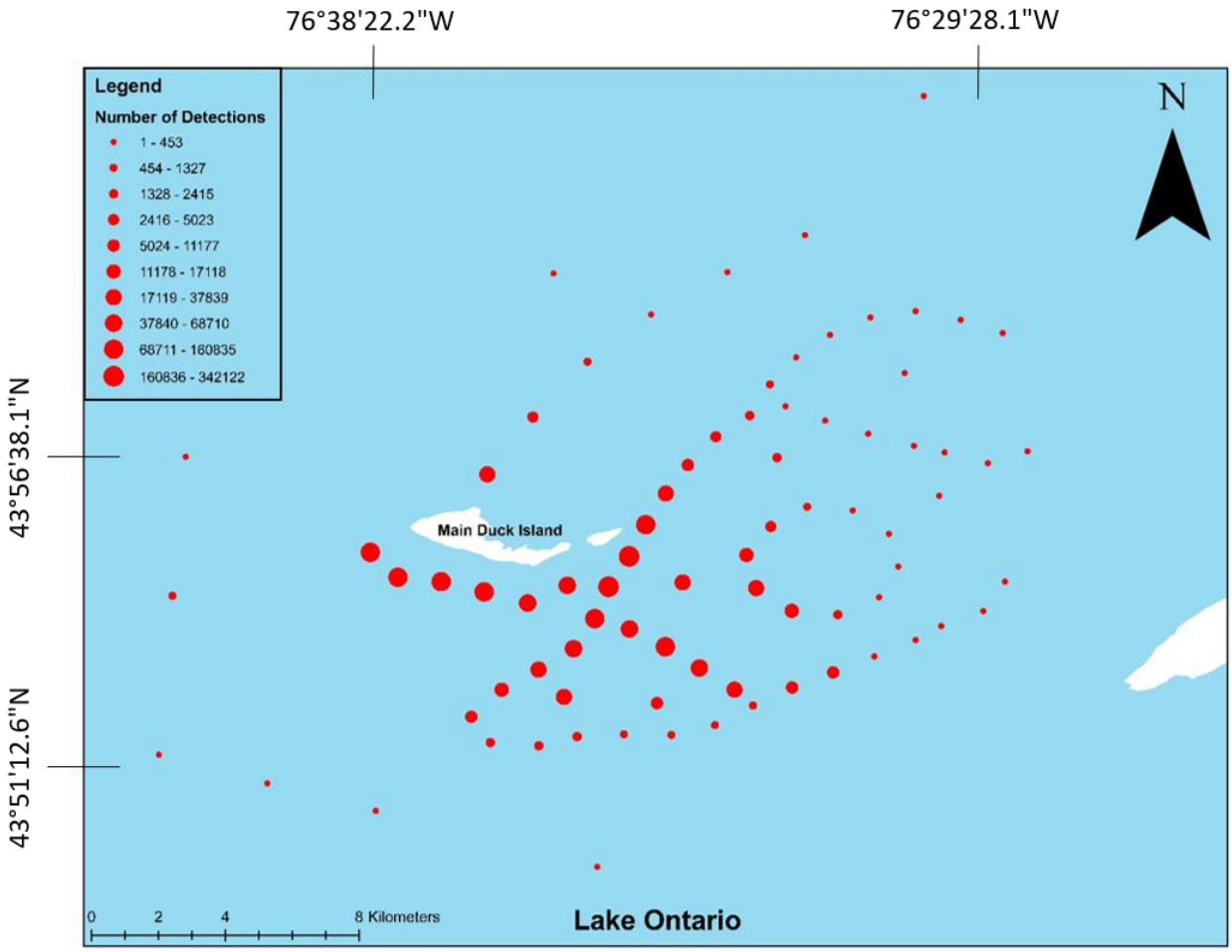

Figure 3.7 The number of detections from control fish between August 9th, 2016 and November 5th, 2017. The majority of the detections from the control fish were along the western portion of the OMNRF acoustic array, suggesting these fish occupy this area throughout the winter months.

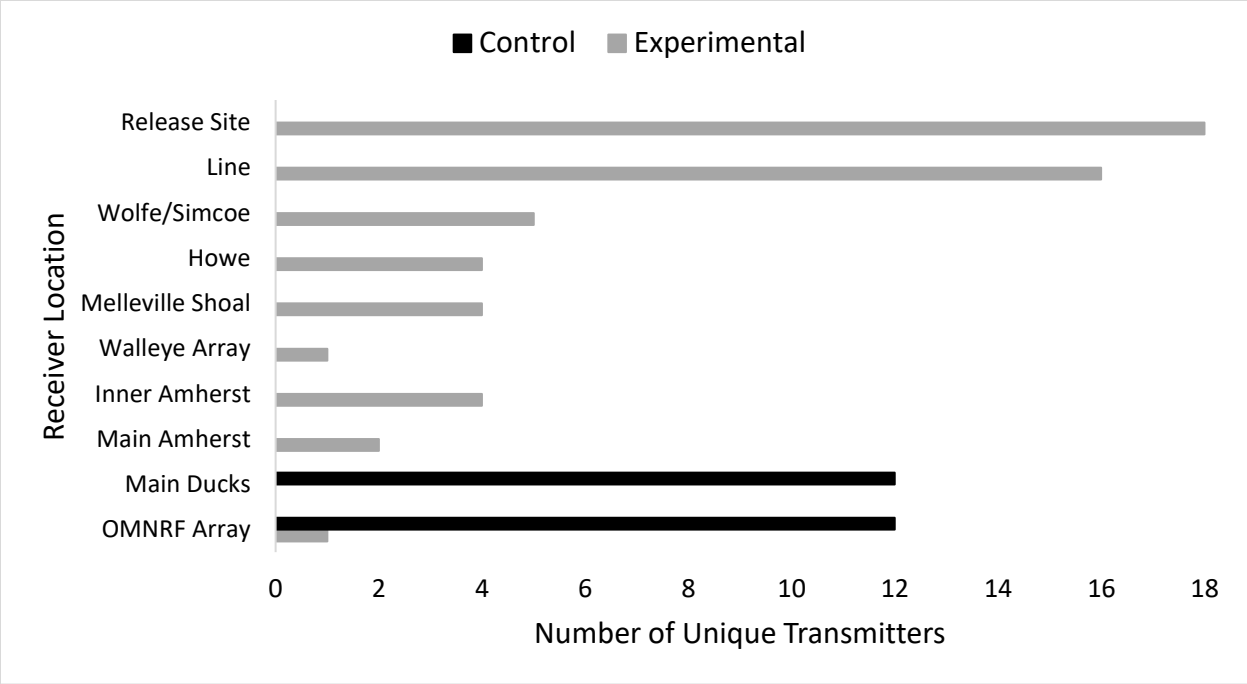

Figure 3.8 The number of unique transmitters detected at receiver locations. Black bars represent the control group while grey bars represent the experimental group.

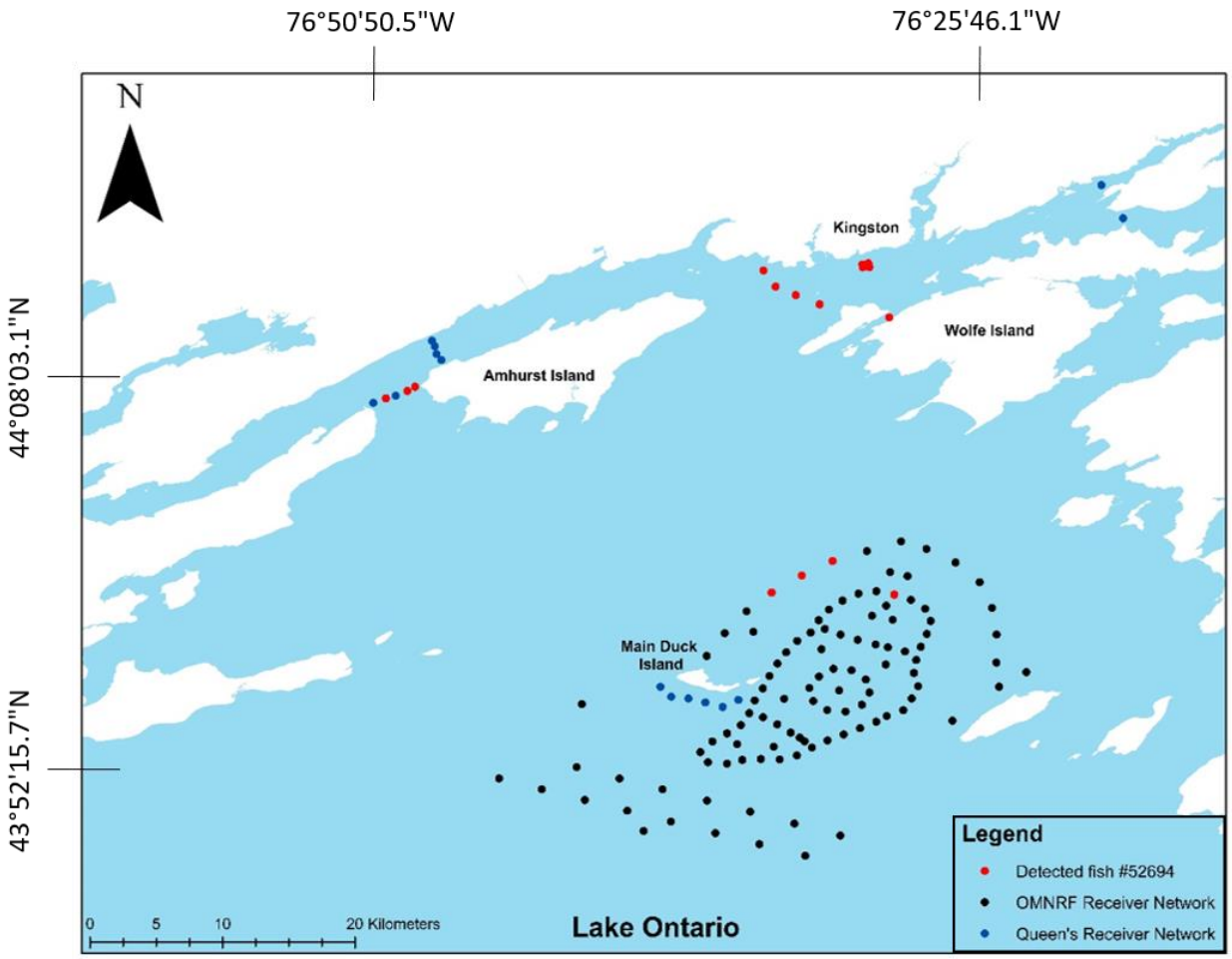

Figure 3.9 Detections for experimentally displaced fish #52694 throughout the study period. Receivers deployed by Queen's University are indicated in blue. Receivers deployed by the OMNRF are indicated in black. This fish travelled a total estimated distance of approximately 145 km between October 4th 2016 and November 16th 2016 (43 days) averaging 3.37 km per day.

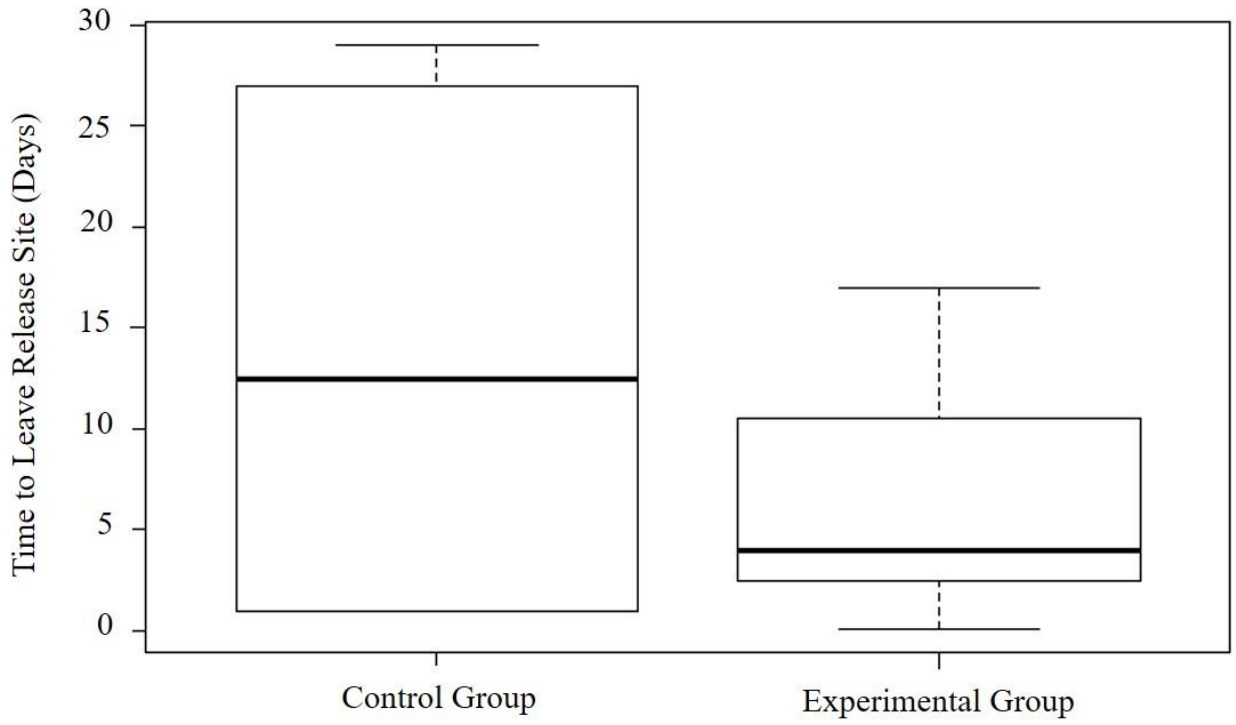

Figure 3.10 Time to leave the release site between control and experimental groups. There was no significant difference in time to leave the release site between the experimentally displaced group and the control group (Kruskal-Wallis, df = 1, p = 0.685).

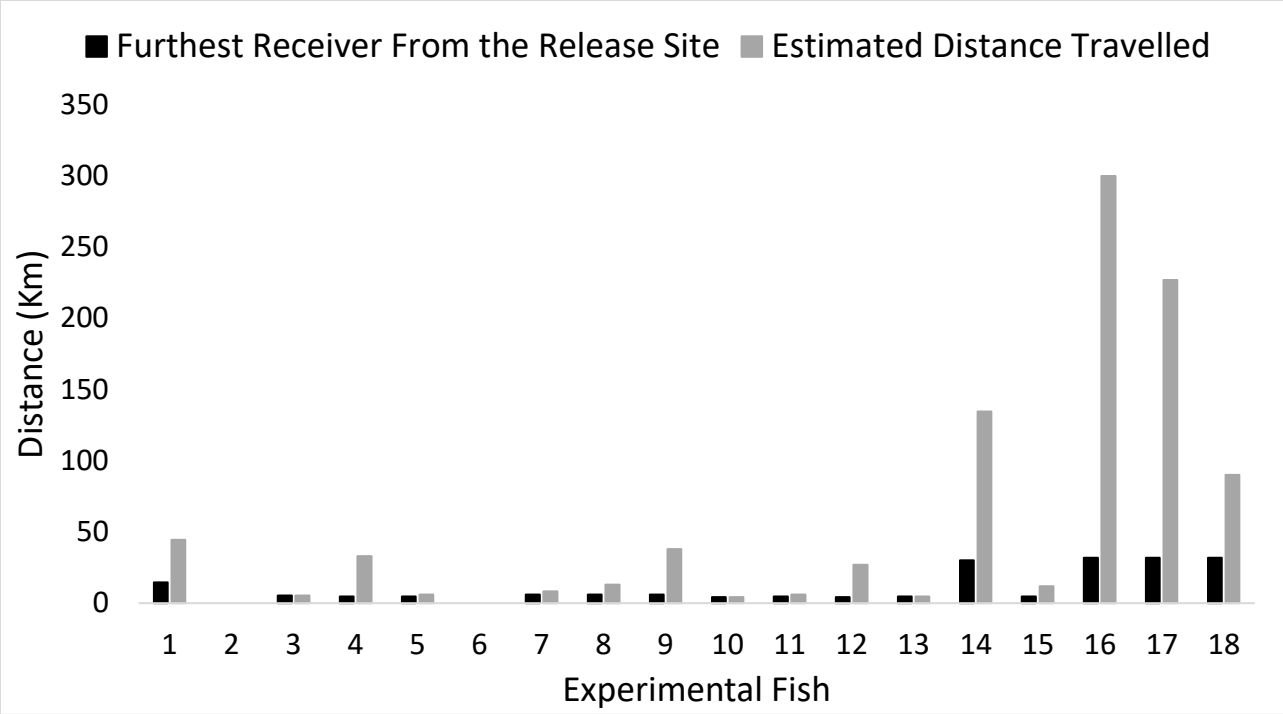

Figure 3.11 Distances travelled by experimentally displaced acoustic fish. Black indicates the maximum distance travelled from the release site. Light grey indicates the estimated total distance travelled by each fish.

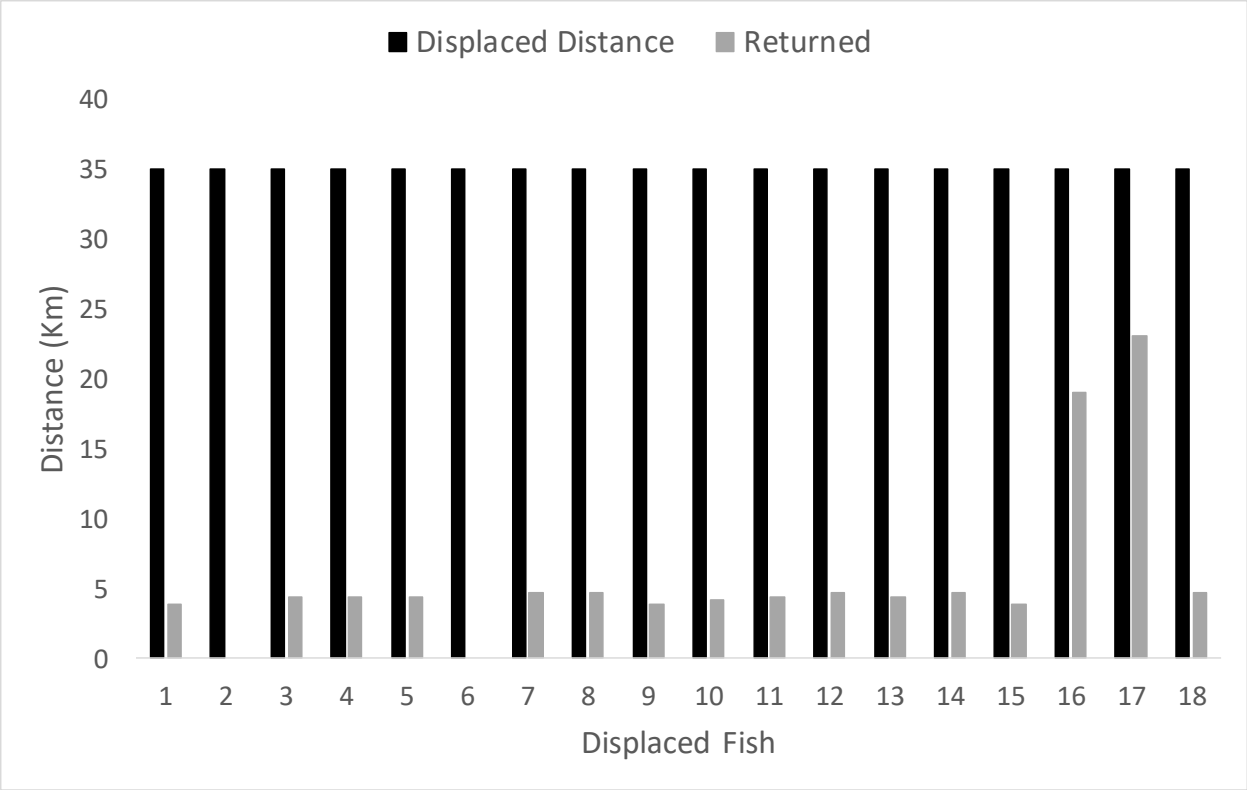

Figure 3.12 Displacement distance, and return distance, of experimentally displaced fish.

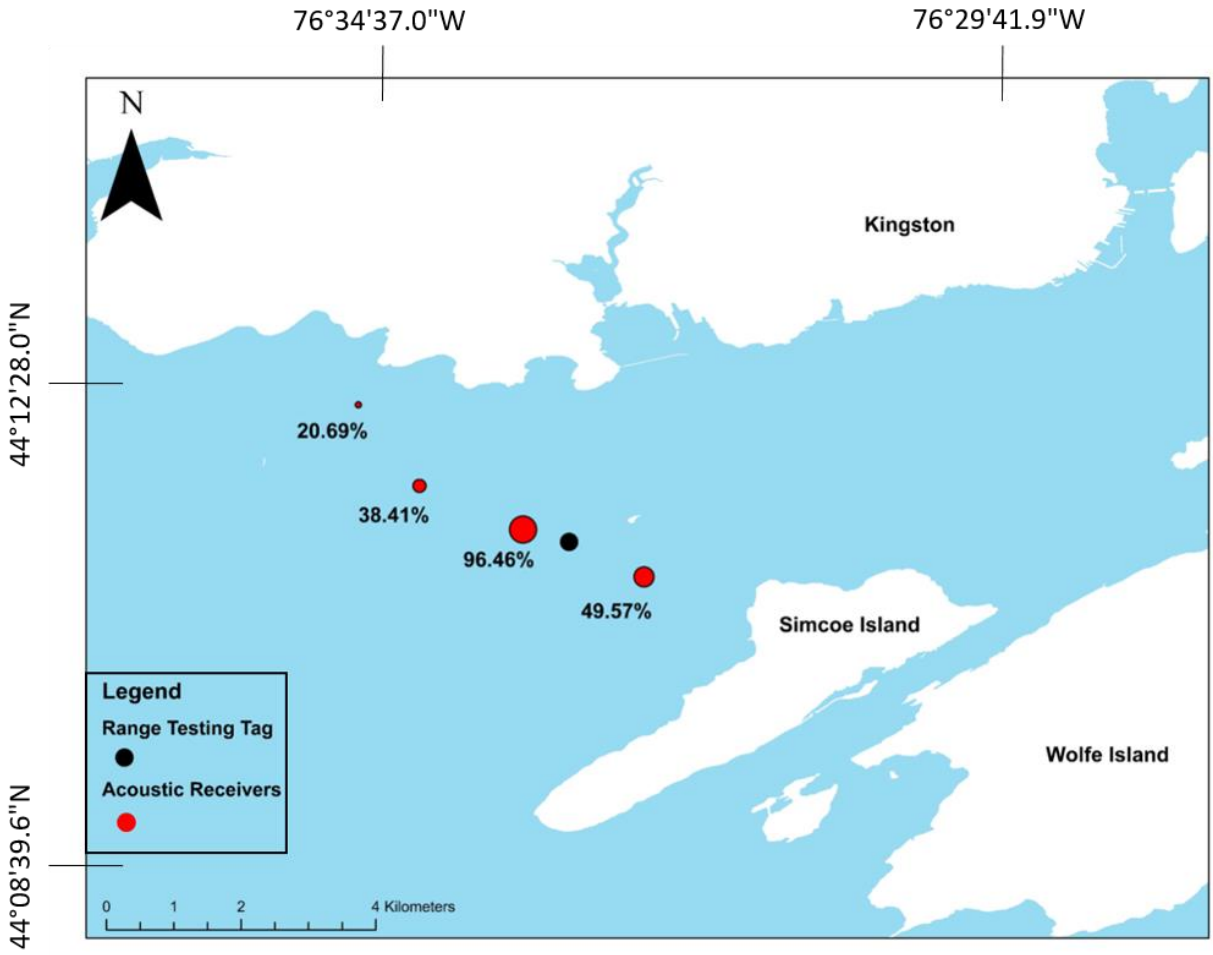

Figure 3.13 Average percent detections for a V16 range test tag (11s delay, Vemco) conducted between September 12 and September 19, 2016. Maximum detection range (>50% detections) was determined to be ~ 900m.

Chapter 4: Discussion

Recreational fishing has a large economic and cultural impact in North America, with expenditures related to recreational fishing exceeding $47.3 billion dollars per year (Tufts et al. 2015). In order to conserve this important resource for future use, it is essential that management decisions are based on the most current scientific information. With the increasing number of angling tournaments held in the Great Lakes Region, there is a need for continued scientific research in this area.

Understanding displacement of fish during competitive fishing events is important in understanding the impacts of angling tournaments, and for developing strategies to reduce stress on targeted species. (Forney, 1961; Pflug and Pauley, 1983; Ridgway and Shuter, 1996; Blunt et al. 2002; Kaintz and Bettoli, 2010; Brown et al. 2015). Although most research in this area has investigated smaller, inland lakes, rivers, and reservoirs, there has been some recent work conducted on these fish in Lake Ontario. Hornsby (2016) investigated the impacts of long distance displacement on both Smallmouth and Largemouth Bass between the Eastern Basin of Lake Ontario and the Bay of Quinte. Hornsby found that all but one Smallmouth Bass displaced into the bay from the Lake were unable to return to their initial capture location within Lake Ontario. To expand upon these results, this study aimed to investigate if Smallmouth Bass are better able to return to areas of capture after tournament displacement within the Eastern Basin of Lake Ontario.

This study found that the externally tagged fish displaced during tournament angling travelled further than those caught and released in the same location. Displaced fish travelled an average distance of 26.8 km between being released and recaptured (Figure 4.1), approximately eight times greater than the control group, which travelled an average distance of approximately 3.2 km (Figure 4.2). This difference in movement may be attributed to the strong site fidelity of Smallmouth Bass. These fish maintain strong affinities for established home ranges and have been shown to return to them over short distances (Wilde, 2003). It is likely that fish displaced during competitive angling events are demonstrating this fidelity by travelling throughout the area in search of their home range. In comparison, non-displaced fish appeared to occupy an established home range, as there was little movement between tagging and recapture. It has been suggested that waterbody size may not influence home range size as much as temperature or

food abundance (Gerber and Hayne, 1988; Kaemingk et al. 2011; Carter et al. 2012; Hornsby, 2016). Given the abundance of food available for Smallmouth Bass in Lake Ontario, it is likely that these fish maintain similar sized home ranges to Smallmouth Bass in smaller waterbodies.

The externally tagged experimental group was separated into two subgroups to better investigate any differences in behaviour based on the location of angling tournament. The first group was composed of fish tagged in the Bay of Quinte and the second group was fish tagged in the Eastern Basin and St. Lawrence River. The results showed that Smallmouth Bass tagged at tournaments in the Bay of Quinte generally have less time at liberty than Smallmouth Bass tagged at tournaments within the Eastern Basin of Lake Ontario and St. Lawrence River. The Bay of Quinte has limited suitable Smallmouth Bass habitat, which could play a role in this faster recapture rate. The lack of suitable habitat may pressure Smallmouth Bass released within the Bay of Quinte to congregate in small patches of adequate habitat after release.

In some cases, tournament angling could cause increased stress, and potential mortality, particularly to those fish that remain near the release site for longer periods of time. Hornsby (2016) demonstrated that acoustically tagged Smallmouth Bass displaced from the Eastern Basin of Lake Ontario into the Bay of Quinte take approximately 14.9 days to leave the release site, approximately twice as long as fish displaced within the Eastern Basin, which took an average of six days to disperse. The slower dispersal could mean that there is a short-term stockpiling of these fish at the release site. This stockpiling may be more of a concern when releasing Smallmouth Bass into suboptimal habitat, such as the Bay of Quinte, as this may slow dispersal. Stockpiling around the release site could influence the local ecology. Studies have suggested that tournament stockpiling can lead to the carrying capacity of the area being exceeded (Richardson-Heft et al. 2000), overuse of the available resources (Wilde, 2003), and an increased vulnerability for recapture by anglers in the area (Blunt et al. 2012). Continued stockpiling could disrupt the ecology of the area, making it less suitable for desirable species.

No significant difference in distance travelled was found between Smallmouth Bass tagged and released within the Bay of Quinte and Smallmouth Bass tagged and released within the Eastern Basin / St. Lawrence River. This was unexpected as previous research has investigated the movement of Smallmouth Bass throughout the Bay of Quinte, suggesting that

the suboptimal Smallmouth Bass habitat may be a reason for reduced movement (Hornsby, 2016).

A total of 18 fish were recaptured more than once throughout the study period, several of them appearing to have returned to their pre-established home ranges between recaptures. While the number of fish recaptured more than once is low, it appears that those tagged within the Eastern Basin and St. Lawrence River can return to their initial capture locations. Only three of the 18 fish recaptured more than once were tagged within the Bay of Quinte, and all three were recaptured within the bay. Future data collection will increase this sample size.

Acoustic telemetry allowed for a more in depth approach to investigating the movements of Smallmouth Bass within Lake Ontario. This study found that experimental fish dispersed from the release site in an average time of six days. Previous work has found similar dispersal times in Smallmouth Bass (Ridgway and Shuter, 1996). However, Hornsby (2016) found that Smallmouth Bass displaced into the Bay of Quinte had an average dispersal time of 14.9 days, approximately twice as long as the fish in this study (Kruskal-Wallis, $df = 1$, $p = 0.01$) (Figure 4.3). A possible explanation for these slower dispersal rates may be habitat differences between the bay and the Eastern Basin. The Bay of Quinte is characterized by an abundance of vegetation, warmer waters, and a sharp "Z" shape. In contrast, the Eastern Basin consists of more rocky substrates, cooler waters, and a more open environment typically favored by Smallmouth Bass. Displaced fish may find the habitat within the Bay of Quinte more difficult to navigate than the Eastern Basin.

After dispersal from the release site, control fish were detected consistently along the south side of Main Duck Island in the Eastern Basin on Lake Ontario throughout the summer months. These fish were initially caught along the South side of the island, making it likely that these fish had already established home ranges within the length of the island (4-5 km long, 200-400 ha), which is consistent with previous literature (Forney, 1961; Ridgway and Shuter, 1996). Detections indicated that several of these fish moved back and forth along the south side of the island throughout the summer months.

Data from acoustic receivers stationed at Main Duck Island, and OMNRF receivers stationed east of the island, indicate that the control group of Smallmouth Bass transition from their summer/early fall home ranges on the south side of the island to deeper waters east of the

island for the winter. This behavior was observed by Hornsby (2016), who suggested that these fish are likely moving into this area due its close proximity and its suitability for overwintering. Post-winter, these fish returned to the south side of Main Duck Island. Hornsby (2016) found that during this time, they were situated in shallower waters during the spawning season. The control group was detected here throughout the spring, although not as consistently as in the summer months (Hornsby, 2016). They were detected throughout the summer of 2016, indicating that after spawning, these fish moved out of the shallows and established their summer home ranges in this area (Figure 4.4). This overlap in home ranges is consistent with results from Ridgway and Shuter (1996), who found that Smallmouth Bass show a 74% overlap in summer home range over consecutive years. It has also been suggested that fidelity associated with areas inhabited post-spawn may be more important than the spawning site itself (Kaemingk et al. 2011). The south side of Main Duck Island is both spawning and summer habitat for Smallmouth in this area, making it especially important for these fish.

Movement of experimentally displaced Smallmouth Bass was variable. Some fish remained close to the release site while others travelled extensively throughout the Eastern Basin. It has been suggested that there may be differences between individuals (sedentary and mobile), of the same species, within the same population (Funk, 1957; Miller, 1975). Kaemingk et al. (2011) found that Smallmouth Bass inhabiting the same waterbody displayed varying levels of movement. He also found that differences in habitat may play a role in movement behaviours. However, the acoustically tagged fish used in this study were caught in the same location on the south side of Main Duck Island, suggesting home range location may not be the only factor influencing movement.

Another possible explanation for the variation in distance travelled is the sex ratio of the sample group. While Smallmouth Bass display strong site fidelity for home ranges, males will also display strong site fidelity to their spawning sites (Scott and Crossman, 1973). Females will not have the same drive to return to the same spawning sites each year as they select mates randomly with little evidence for inbreeding (Franckowiak, Ridgway, and Wilson, 2017). It is impossible for us to know the proportion of males to females that were acoustically tagged in this study without killing the fish. The variability in movement between male and female Smallmouth Bass could be explored further in future research.

Twelve of the experimental fish were detected moving back and forth from the release site to the line of receivers approximately 4.7 km west of the release site. This may indicate an unfamiliarity with their surrounding area. These fish may be using the release site as an area from which they can branch off to explore their surroundings. This increased movement is characteristic of searching behaviour and an attempt to familiarize themselves with their new environment (Richardson-Heft et al. 2002; Ridgway, 2002). Four fish left the array quickly (within three days) and were infrequently detected for the remainder of the study.

It is possible that individuals established new home ranges after displacement. Four individuals were detected in the Melville Shoal area throughout the summer of 2017, suggesting that they may have established a new home range within this area. These fish were detected relatively consistently from April to October 2017. Future monitoring will reveal if these fish return to this area in the Summer of 2018. If they were to return, this would indicate that they likely established a home range in this area during 2017.

While detections for Melville Shoal were relatively consistent, there were some larger gaps in when individuals were detected. These detection gaps may be explained by increased wave action, precipitation, and boat noise throughout this area that may impact detection range. An alternative explanation for the gaps in detection could be that individuals died, or dropped their tag, near the limits of the receiver's detection range. This would create a similar detection pattern where an individual was detected consistently, but due to the distance of the tag, would have gaps in detections. This is unlikely as individuals were detected on days with increased acoustic interference (high winds and waves) and not detected on calmer days with less interference. This suggests that the individuals are alive and moving throughout the area.

Several of the displaced Smallmouth Bass travelled great distances, and multiple directions, throughout the study area. Three displaced fish were detected on acoustic receivers stationed on the west end of Amherst Island, approximately 30 km away from the release site. Movements west to Amherst Island and back to the release site were accomplished within three to seven days, and resulted in some individuals travelling over 130 km. One individual travelled south from the release site and was detected on the OMNRF's Bloater array just east of Main Duck Island. This fish appeared to be traveling towards the island, but turned around and returned to the release site, traveling a total distance of approximately 146 km. This was the

closest any of the displaced fish came to returning to their initial capture location, making it within approximately 13.5 km from the initial capture location.

Studies have investigated the movement of Black Bass, suggesting visual cues may be important to their navigation (Parker and Hasler, 1959; Savitz et al. 1983). Wilde (2003) suggested that the absence of visual landmarks may inhibit fish from returning to capture sites over longer distances. In addition, Maynard et al. (2017) found that radio tagged Smallmouth Bass were unable to return to their initial capture locations after being displaced an average distance of 6.7 km in a larger, more pelagic, lake system. This is in contrast with this study as displaced Smallmouth Bass were able to travel distances up to 146km. They found that Smallmouth Bass preferred shallower waters and were not detected in deep, pelagic zones (>60m). This is consistent with previous research that found Smallmouth Bass dispersing from tournament release sites are rarely found in open-water areas (Kaintz and Bettoli, 2010). The majority of the acoustically tagged, displaced fish in this study moved throughout the Eastern Basin, although they appeared to follow the shoreline while doing so. The Eastern Basin of Lake Ontario has an average depth of approximately 30m with a maximum depth of 50m in select locations. Although previous work has investigated deeper pelagic zones (>60m) it is likely that Smallmouth Bass within the Eastern Basin would avoid deeper waters with few visual landmarks.

A broader visual reference may explain higher return rates in displaced Smallmouth Bass in smaller, inland lakes. Previous research indicates that Smallmouth Bass displaced within a smaller, inland lake are generally able to return to their initial capture location after short distance displacement (<25 km) (Wilde, 2003). A possible explanation for this is that fish within a smaller lake system may have explored more of their surroundings. Smallmouth Bass have been shown to shift their home ranges throughout the summer months, which may have allowed them to increase the number of recognizable landmarks in a smaller lake or river. This increased ability to recognize visual cues and landmarks may aid Smallmouth Bass displaced in smaller waterbodies to navigate back to their initial capture locations more effectively than in larger systems.

No significant differences in the maximum distance travelled were found between acoustically tagged Smallmouth Bass displaced into the Bay of Quinte and the Eastern Basin.

The acoustically tagged control group was found to be significantly different from the fish displaced into the Bay of Quinte (Kruskal-Wallis, df = 1, $p < 0.001$) but not from the fish displaced within the Eastern Basin (Figure 4.5). Fish displaced into the Bay of Quinte reached an average max distance from the release site of 4.8 km, while fish displaced into the Eastern Basin reached an average maximum distance of 12.2 km. The control group (tagged and released at Main Duck Island) reached an average max distance of 11.6 km. This indicates that fish displaced into the Bay of Quinte and those displaced within the Eastern Basin can travel similar distances, though the group displaced within the Eastern Basin has a higher average distance travelled. Smallmouth Bass travel into deeper, warmer waters for the winter months. The winter movements of the acoustically tagged fish were included in this comparison and could influence the comparison of distance travelled from the release site.

Survival for both experimental and control groups was considered high, as detection data indicated that almost all of these fish were alive and mobile. Two of our experimentally displaced fish likely died, or dropped their tags at the release site. Higher survival in this study is consistent with past experiments where Smallmouth Bass were acoustically tagged (Ridgway and Shuter, 1996; Brown et al. 2015; Hornsby, 2016). Tagged individuals were displaced in areas of optimal habitat, which may be a contributing factor to the high survival. Survival was estimated for acoustically tagged fish by assessing the acoustic detection data for signs of movement. Survival was estimated at 72.2% for all acoustically tagged fish.

Range testing of acoustic equipment was conducted to ensure accuracy in detections. Data gathered indicate that the effective range (>50% detections) is approximately 900m. Percent detections at 524.7m ranged from 84% to 100% with an average of 96.46%. At 954.9m, percent detections ranged from 0% to 100% with an average of 49.57%. Previous range tests conducted at Main Duck Island between May 17 and June 23, 2016, show a similar pattern of decreasing percent detection with increasing distance (Hornsby, 2016). Range tests were conducted at two locations, one shallow (~1.5 meters) and one deep (~10 meters). When testing the shallow site, a detection rate of 17.1% was found for a distance of 960m. For the deeper range test, average percent detections were 60.9% at 480m and 28.7% at 750m. The range tests indicate that the effective range (>50% detection) is likely between 480m and 750m. This lower detection range may be due to extreme weather conditions at Main Duck Island as opposed to the

more sheltered waters near the release site. Dispersal of the sound waves over longer distances could be the cause of variability in detections. In addition, inclement or poor weather conditions (high wind, rain, and so on), boat traffic, and biological noise could affect the signals' dispersal at the release site the water (Catipovic, 1990). These results indicate that the placement of acoustic receivers offered wide coverage of the release site and surrounding area, minimizing the chance of acoustically tagged fish from leaving the area undetected.

Additional research should be conducted on Lake Ontario and the St. Lawrence River to better understand the fine scale movements of these fish after tournament displacement. The fish used in this study were angled from a relatively isolated island on the South end of the Eastern Basin of Lake Ontario. Additional research could further explore the navigational abilities of these fish by investigating connected shoreline displacement in Smallmouth Bass throughout the Eastern Basin of Lake Ontario. This would allow for a comparison between Smallmouth Bass populations situated throughout the Eastern Basin. In addition to moored receivers, active tracking may also allow for additional information on movements and survival to be collected. In addition, generating a survival estimate for tournament caught Smallmouth Bass within the Bay of Quinte and Eastern Basin of Lake Ontario would aid in our understanding of mortality associated with tournament displacement. Furthermore, comparing delayed mortality and post-release behaviour as it relates to tournament stress would allow for a better understanding of mortality and dispersal of Smallmouth Bass after post-tournament release and how this differs from other species.

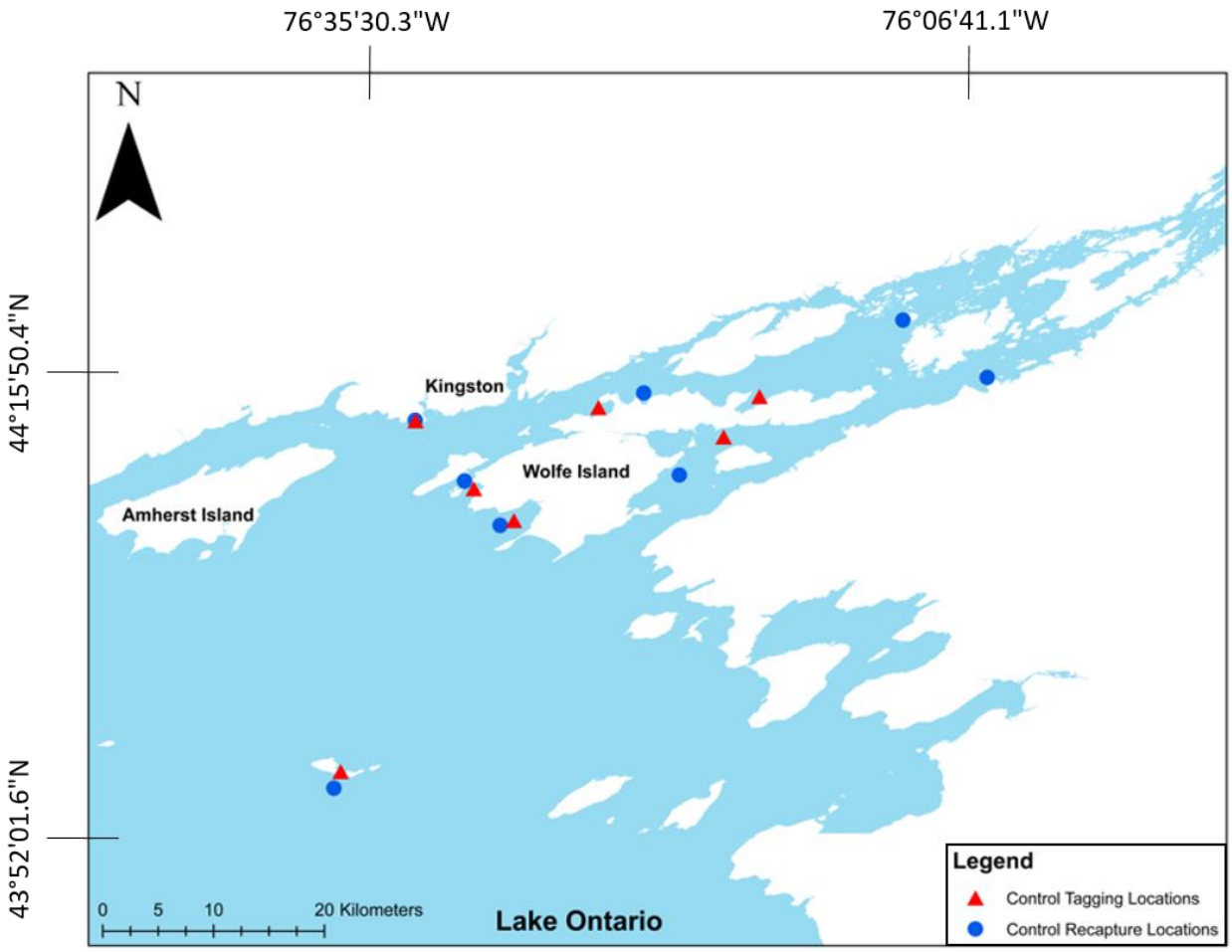

Figure 4.1 The tagging and recapture locations for externally tagged control fish. Control fish travelled an average distance of 3.1 km from their initial capture location.

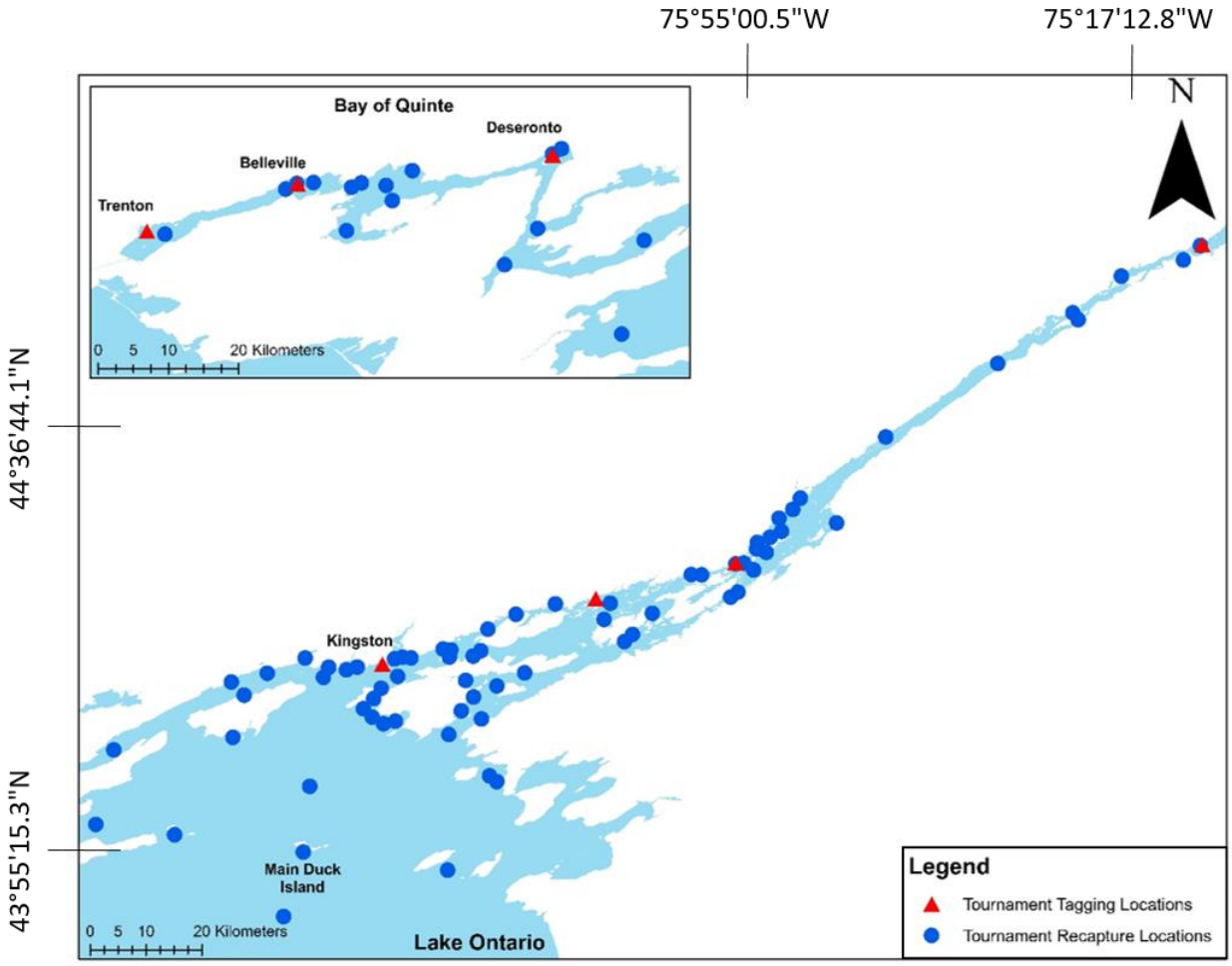

Figure 4.2 The tagging and recapture locations for externally tagged experimental fish. Displaced fish travelled an average distance of 26.86 km from their initial capture location.

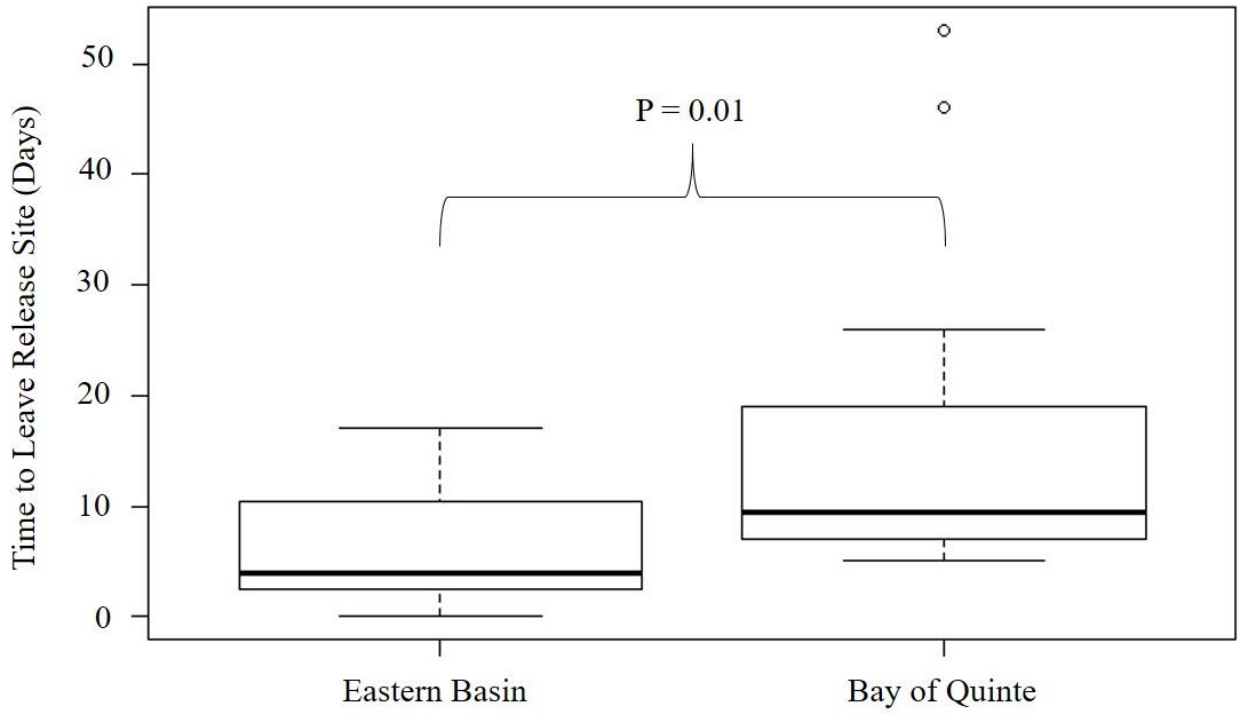

Figure 4.3 Time to leave the release site for tournament displaced Smallmouth Bass in the Eastern Basin of Lake Ontario and the Bay of Quinte. Smallmouth Bass in the Bay of Quinte take significantly longer to disperse from their release site than those displaced in the Eastern Basin (Kruskal-Wallis, df = 1, p = 0.01).

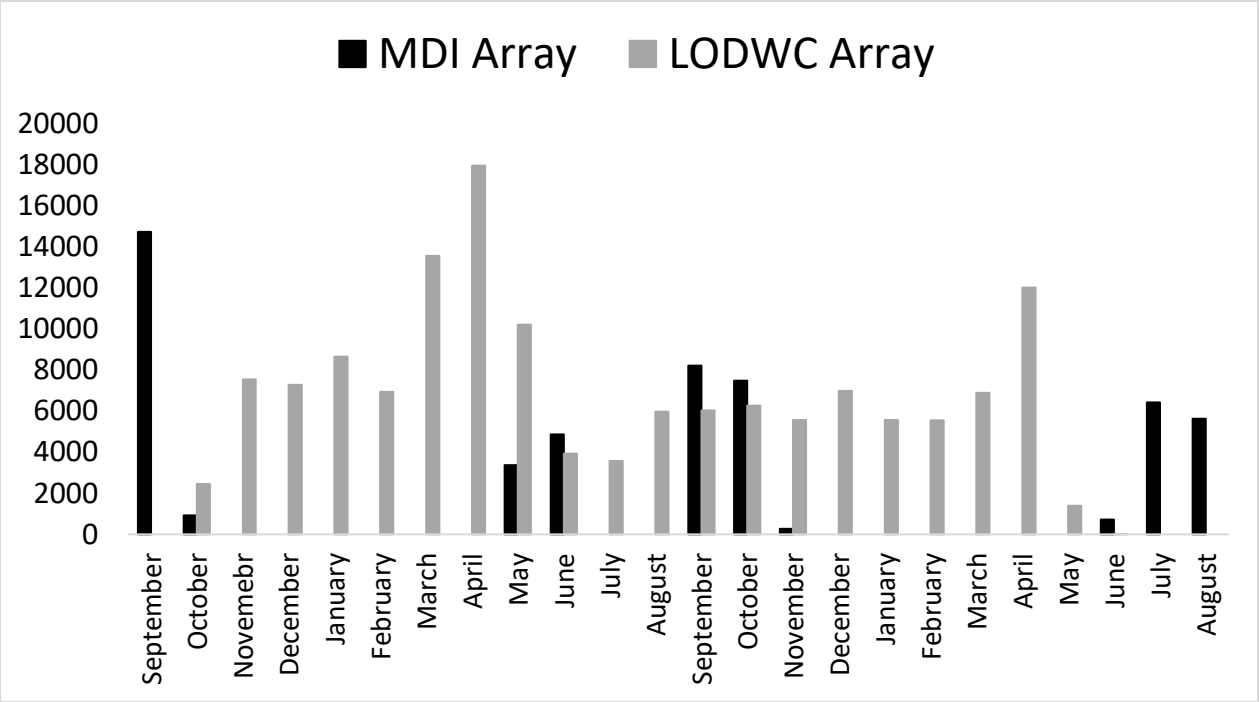

Figure 4.4 Detections of the Smallmouth Bass in the acoustic control group from September 2015 to August 2017. Grey bars indicate detections on the acoustic receivers stationed on the south side of Main Duck Island. The blue line indicates detections on the OMNRF's bloater array east of the island. Receivers at Main Duck Island were deployed in September and October of 2015, May and June of 2016, September to November of 2016, and June to August of 2017. The removal of these receivers was done to avoid ice damage during the winter or to download data.

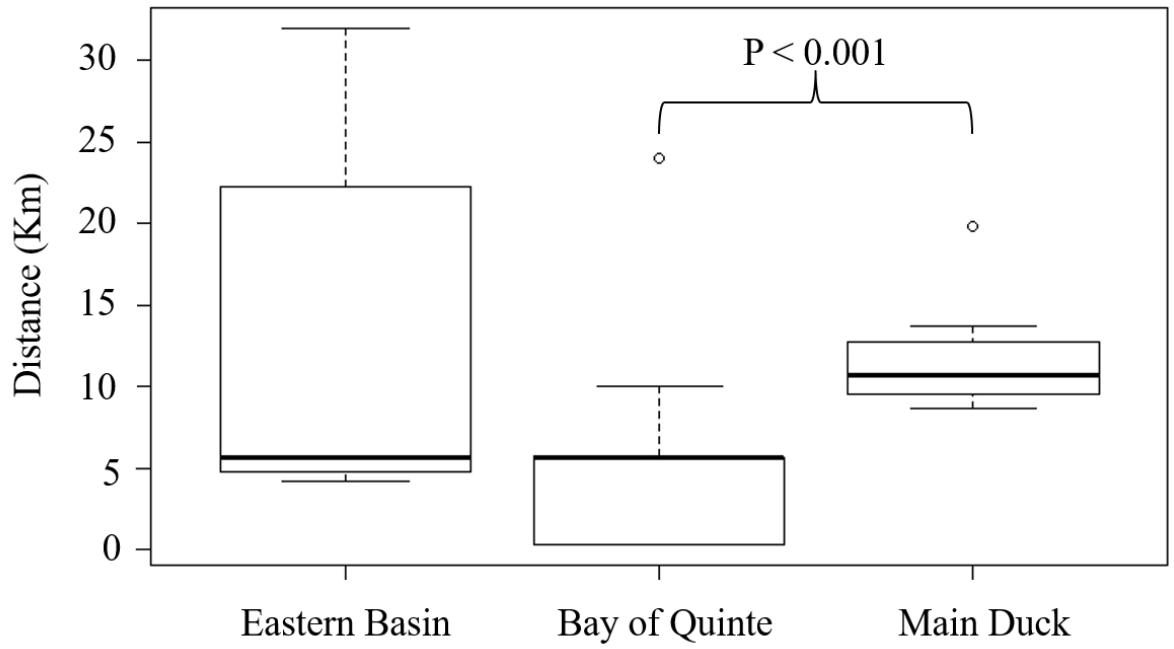

Figure 4.5 The maximum distance from the release site reached by acoustically tagged Smallmouth Bass displaced into the Eastern Basin of Lake Ontario and Bay of Quinte. The control group at Main Duck Island was also included. No significant difference was found between the Eastern Basin and the Bay of Quinte group (Kruskal-Wallis, df = 1, p = 0.07). However, a significant difference was found between the control group and the Bay of Quinte group (Kruskal-Wallis, df = 1, p = < 0.001).

Chapter 5: Conclusion

The purpose of this study was to investigate the natural movements of Smallmouth Bass in a large waterbody, Lake Ontario, and to also examine their response to tournament displacement. This study utilized mark-recapture techniques as well as acoustic telemetry to better understand the movements of these fish on both a broad and fine scale. Thirty tournament sized Smallmouth Bass were surgically implanted with acoustic transmitters and released strategically in order to understand the natural and displaced movements of these fish. Mark-recapture data for over 5,189 externally tagged Smallmouth Bass was also analyzed, spanning 2012 to 2017.

The results of this study suggest that the home range of Smallmouth Bass in Lake Ontario is similar in size to Smallmouth Bass situated in smaller, inland lakes. Our results suggest that these fish remain tied to their established home ranges throughout the season, often with very little movement away from initial tagging sites. These results contrast with fish displaced through simulated tournament angling, which displayed significantly greater movement between tagging and recapture. While these fish were able to swim great distances after release, the instance of tagged individuals returning to their initial capture location are few. The acoustic telemetry data revealed that these fish take approximately six days to disperse from the release site, suggesting that long term stockpiling of these fish in areas with numerous angling tournaments does not appear to be a major concern.

Acoustic telemetry results indicate that displaced fish were able to travel great distances after dispersing from the release site. The behaviour displayed by these fish was repetitive, often repeatedly returning to the release site before venturing out again. This behaviour suggests that these fish are searching for their home ranges, though may be experiencing difficulty navigating. Although there is no consensus on the methods that Smallmouth Bass use to navigate their environment, there is evidence to suggest that sight plays an important role in their movement, which explains the behaviour displayed by the acoustically tagged displaced fish. While these fish are able to travel the required distance back to their initial capture location (~35 km), they experience difficulty due to the lack of navigational landmarks. Future studies investigating populations of Smallmouth Bass throughout the Eastern Basin and St. Lawrence will improve

our understanding of the impact of tournament displacement and will also shed light on their navigational strategies.

This study was limited by the size of the study system and costs associated with equipment. The high cost of acoustic receivers makes it impossible to determine the fate of individuals after they had left the detection range of the receivers with 100% accuracy. Increased use of a mobile hydrophone in future research may improve our total detections and aid in understanding their movement patterns.

The information gathered from this study could be of use to both management agencies and tournament organizers in advising how the species are managed or the format of competitive angling events in this area. Previous research suggests some solutions to the problem of displacement, including implementing satellite release locations (Hornsby 2016). Tournament organizers may consider limiting the allowed fishing areas or the target species to reduce longer distance displacement. While some of these strategies are already being implemented in local events, they are not universally incorporated into the tournament format. Incorporation of these strategies may aid in the effective management of these species, reduce the overall effort required to return to their home range, and potentially improve the image of tournament angling to the general public.

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