Migratory behaviour of brook charr (*Salvelinus fontinalis*) in Gros Morne National Park, Newfoundland, and the potential for co-management of the recreational fishery

By

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Abstract

Charr (*Salvelinus* spp.) exhibit a variety of migration strategies, whereby some individuals venture to sea (anadromous) while others spend the entirety of their lives in freshwater (residents). The anadromous individuals are of particular interest as their behaviours may shape life history and affect population dynamics through increased exposure to fishery exploitation. Here, I explore the migratory behaviour at sea of brook charr (*S. fontinalis*) from two distinct populations in Gros Morne National Park (GMNP), Newfoundland; one where the river enters a protected fjord and the other, open ocean. An interdisciplinary approach is used, integrating acoustic telemetry, otolith microchemistry, and fishermen surveys to quantify and contrast migratory behaviours, and to characterize the recreational fishery. Acoustic telemetry of 17 brook charr from one population (in the Bonne Bay fjord), and otolith microchemistry from two populations (Bonne Bay fjord, where N=23, and Western Brook, where N=82) show age and habitat specific movements of brook charr. Brook charr make their first seaward migration at age 2+, often with previous movements to brackish environment between ages 1-2. At sea, charr frequent areas close to river mouths during the beginning and end of migratory period, venturing further away during the mid period of their marine residency. Results indicate that estuarine habitat may be important to anadromous individuals. After first seaward migration at 2+, there was no significant age-specific pattern for subsequent migrations. Fishermen surveys from two charr fisheries in western Newfoundland (the brook charr fishery of GMNP, and the Arctic charr [*S.alpinus*]) fishery of Pistolet Bay) provided some evidence that sea-run charr are at increased risk of fisheries interactions. Surveys revealed the usefulness of fishermen's knowledge to managers, especially to rural communities where local fishermen are the primary resource user and have historical knowledge of the fishery. In both cases, fishermen identified decreases in stock health, but where fishermen were more engaged, in Pistolet Bay, resource users supported increased management efforts to improve stock health. By comparing the GMNP fishery with the Pistolet Bay fishery, I emphasized the effectiveness of fishermen engagement in management regimes and highlight opportunities for comanagement in recreational fisheries to protect stock health where necessary. My results provide insight into the complexity of migratory strategies exhibited by charr species and the opportunities in management of charr recreational fisheries.

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1.0. Chapter 1 – Introduction

1.0.1 Partial Migration

Partial migration is a life history strategy consisting of two alternative tactics, whereby an individual may migrate seasonally or remain resident (Jonsson and Jonsson 1993, Kaitala et al. 1993, Chapman et al. 2011a, Chapman et al. 2011b). This strategy is important as it provides information on migratory adaptation and the evolution of migratory behaviour; however, this importance has only been highlighted recently, with past research focusing on other areas of migratory behaviour (Jonsson and Jonsson 1993, Kaitala et al. 1993, Brodersen et al. 2008, Cooke et al. 2008, Chapman et al. 2011a, Chapman et al. 2011b). The prevalence of partial migration in nature and its potential ecological importance have encouraged recent studies, despite associated logistic difficulties which have made this area of migration research difficult (e.g. distinguishing resident from migratory animals, tracking animals long distances) (Kalish 1990, Rieman et al. 1994, Veinott and Porter 2005, Chapman et al. 2011a). These studies suggest that partial migration may be condition dependent and shaped by both environment and genetics (Jonsson and Jonsson 1993, Brodersen et al. 2008, Chapman et al. 2011a, Chapman et al. 2011b). Environmental factors affecting migration in these populations may include food availability and preferences (Jardine et al. 2005, Chapman et al. 2011b).

In fishes, partial migration is often manifested in the form of some individuals within a population migrating to sea while others remain in natal rivers and/or lakes (Doyon et al. 1991, Jonsson and Jonsson 1993, Kaitala et al.1993). Anadromous fish, those that go to sea and later return to breed, benefit from the increase in food quality and/or quantity but face many potential consequences, including an increased possibility of mortality due to predators and to interactions with fisheries (Jonsson and Jonsson 1993). In areas with high fishing pressure, migratory fish populations may be particularly at risk to target fisheries and as bycatch, and sustainable management of such populations will be dependent on an understanding of the potential for such interactions.

Costs and benefits of migration, as well as frequency of anadromy, are topics widely studied in salmonid research (e.g. Jardine et al. 2005, Brodersen et al. 2008). Rounsefell (1958) outlined key aspects of anadromy that should be studied for salmonid species because of the associated costs and benefits, such as extent of migration, time at sea, maturation at sea, spawning activities, and occurrence of freshwater individuals. The migratory behaviour of an individual is considered to be driven by genetics, environment, and condition of the fish (Jonsson and Jonsson 1993, Brodersen et al. 2008), with a clear advantage of increased food abundance at sea for migrant fish (Jardine et al. 2005). Increased food abundance implies increased growth rates for anadromous individuals, which would result in higher fecundity and mating success (Gross et al. 1988, Fleming and Reynolds 2004). However, the costs associated with migratory behaviour, may give a reproductive advantage to non-anadromous members of a population, based on their increased survival (Gross et al. 1988). Costs include the large energetic inputs required for the trip to sea, as well as for osmoregulation during the transition from fresh to salt water, and increased potential for mortality from interactions with, for example predatory fishes, marine mammals, seabirds, and fisheries (Jonsson and Jonnson 1993).

Migratory behavior, as well as the cost and benefits of anadromy, have been studied in a number of species; but with char (*Salvelinus spp*.) anadromy has been largely unstudied because of the variability in frequency of seaward runs across and among populations (Quinn and Myers 2004). Yet, this variability is intriguing because it suggests that there is considerable plasticity in the behaviour and that its evolution is complex. Lack of research may stem from the difficulties in capturing anadromous individuals and tracking their migratory behavior, as it relates to habitat and environmental factors. Because of these difficulties, migration studies, for many different species, including charr, often have low sample sizes by which to draw more generalized observations about movement and habitat use (Brenkman, Hubley et al. 2008, Curry et al. 2002, Anras et al.1999). Recently, researchers have highlighted the benefits of combining methods, such as telemetry and otolith microchemistry, to provide a more complete picture of migratory behavior (Cooke et al. 2008).

One important challenge for migratory fish, mentioned above, is the potential for susceptibility to fisheries, both as a targeted species and as bycatch. Often anadromous fish are exposed to a variety of different fishing pressures at sea, including commercial fishing, fishermen targeting physical bottlenecks along migratory routes, and an increased variety of fishing gear (Jonsson and Jonsson 1993). These pressures may increase the mortality risk for anadromous fish, leading to selection for residency (Thériault et al. 2008). It is therefore important to understand the pressures on anadromous species in order to protect them, when necessary, where they are most vulnerable.

Brook charr (*Salvelinus fontinalis*) are the most widely fished species by recreational fishermen in Newfoundland and Labrador, in terms of number of participants and catch, (DFO 2010) and represent a species with both anadromous and non-anadromous members within many populations, as well as populations that are solely non-anadromous (Curry et al., 2010). There is a lack of knowledge on the anadromous members of brook charr populations as their migratory behaviour is considered to be less obligate and predictable than in other salmonid species (e.g. the Pacific and Atlantic salmons). Current data on brook charr anadromy in Newfoundland is limited and somewhat vague, suggesting that charr from 200-500 mm in fork length will migrate in May-June and return from sea by August, that they travel 2-20km from the river mouth, and that they are expected to migrate to highly productive areas for access to food resources (O'Connell 1983). Additionally, stock sizes and catch rates for brook charr in Newfoundland and Labrador are largely non-existent, leaving a large gap in our knowledge (DFO 2010).

1.0.2. Local Ecological Knowledge

Recreational fisheries are common pool resources where users have access to the same resources, have short-term outlooks, and operate at highly variable spatial and temporal scales, which makes monitoring stock status difficult and increases risk of overexploitation. These factors make recreational fisheries susceptible to Hardin's (1968) "Tragedy of the Commons" (Berkes 1999). In "tragedy of the commons," users will exploit resources to maximize their personal benefit without interest in the good for the resource or the community (Hardin 1968). Often managers attempt to counteract this tragedy by having centralized management of resources by the government (Plummer and Fitzgibbon 2004). However, this approach is often disputed by those who provide examples from traditional management regimes, as well as fisheries forums, which have proven effective in maintaining sustainable stocks (McCay and Acheson 1987, Ostrom et al. 1999, McClanahan et al. 2009). As there is an increasing awareness of the importance of monitoring recreational fisheries (Post et al. 2002, Myers and Worm 2003, Sutinen and Johnston 2003, Cooke and Cowx 2004, Lewin et al. 2006), development of management regimes for these fisheries is becoming increasingly important.

Recreational fisheries in Newfoundland are the most popular with the largest take for this sector in Canada (DFO 2005), with brook charr being the most widely fished species (DFO 2005). Management of brook charr and other charr resources is centralized in the hands of government, which generally uses seasonal closures and bag limits to manage the resource (DFO 2010). Additionally, there are conflicting situations, with highly motivated fishermen in some recreational fisheries, and others with conflicting views about the need for fisheries management, meaning that a province wide management regime may not be appropriate for all fisheries. In light of historical fisheries management issues in the province of Newfoundland and Labrador (NL), engaging fishermen in science and management in order to tap their knowledge and to allow them to voice their opinions about their remaining fisheries may be key if managers hope to gain trust, maximize the information they have available for management and ensure compliance with management regimes (Neis and Felt 2000, Murray et al. 2006)

In order to gain information on current recreational fisheries in Newfoundland and Labrador, managers should consider using local ecological knowledge (LEK). As defined by Berkes (1999), local ecological knowledge is knowledge and practices that evolve and adapt over time, which is provided by people about their interaction with other people and local resources. Local ecological knowledge can be used for management of many different natural resources that are exploited both commercially and recreationally (Berkes 1999, Olsson et al. 2004, Plummer and Fitzgibbon, 2004). In the case of recreational fisheries, local fishermen would provide the knowledge in the form of their experiences with the local resources and with other users of the resources. It is widely accepted that this knowledge is an important source of data to be combined with science for co-management regimes (Berkes 1999, Neis and Felt 2000, Maurstad 2002, Holm 2003, Bruckmeler et al. 2005, Gerhardinger et al. 2009). However, there is much discussion on how the knowledge should be used, shared, and how much we can rely on knowledge over scientific data (Maurstad et al. 2002, Holm 2003).

Recreational fishermen in NL are a potentially useful source of local ecological knowledge, especially from small-scale fisheries, which are common in the province, where fishermen have likely interacted with the resource for many years, giving them historical knowledge of fishery dynamics. The knowledge gathered from this group can expand ecological databases and, when combined with science, can provide a more complete picture of fisheries (Sutton 2006). Knowledge is an important tool in the recreational sector as stock assessments are done less frequently in inshore or coastal areas where these fisheries are most common, than in offshore areas (Arlinghaus 2006).

Recreational fishermen have a vested interest in the stock health, though this may not be recognized by the resources users, and therefore may be more likely to provide information to maintain healthy stocks (Arlinghaus 2006, Granek et al. 2008). Additionally, engaging fishermen in the management process can increase fishermen's sense of responsibility for stock health, promoting cooperation with management regimes.

1.0.3. Purpose and Objectives

The aim of this study was to quantify the migratory behaviour of brook charr from two rivers within Gros Morne National Park (GMNP), Newfoundland, and to evaluate whether co-management regimes would be effective in this area, as compared to other recreational charr fisheries (specifically the Arctic charr fishery of Pistolet Bay) both within the province and globally. This study employs a novel approach, combining the study of biological and social sciences aspects of a fish species and its associated fishery.

In order to develop a wider understanding of charr migratory behaviour and how fisheries might select for anadromous individuals, my research focused on three objectives: 1) quantify aspects of the marine migratory behaviour over a season by tracking anadromous individuals from a river system using acoustic telemetry, 2) determine life history patterns of marine migration using otolith microchemistry and 3) assess the current state of the brook charr fishery, as well as the Arctic charr fishery of Pistolet Bay, and determine the potential for co-management regimes using fishermen surveys.

The first objective was to determine spatial and temporal migratory behaviour during one season. Short-term charr migratory behaviour was tracked to determine whether the charr utilize productive estuary habitat during seaward migration, as has been documented previously (Currie 2009) and to assess habitat use and distribution at sea. The study site for the tracking research, the Bonne Bay fjord, presents an excellent opportunity to determine the extent of migratory behaviour because the Eastern Arm of this fjord is largely protected from the harsh open sea environment (Fig. 2.1). This allows an investigation as to whether charr prefer more protected environments close to their natal brook, including estuaries, to the harsher conditions in the open sea, giving managers a better understanding of migratory behaviour in order to protect important habitat if stock health is at risk. As well, this part of the study provides basic information on migratory behaviour, such as timing, distance travelled, and habitat usage.

The second objective is to gain information on lifelong migratory behaviour of brook charr. This provides a better understanding of migratory patterns in terms of timing of first seaward migration for anadromous fishes and frequency of these migrations during a fish's lifetime.

The third objective is to gather fishermen's knowledge from two charr fisheries (brook charr in GMNP and Arctic charr in Pistolet Bay) in order to understand how fishermen interact with the resource, and to provide information for managers on the current health of the fish stock, and support for management regimes. The effectiveness of co-management, defined as a management system, which incorporates interests and opinions from both government and resource users (specifically in areas where stocks are at risk of collapse or already collapsed), in recreational fisheries is evaluated.

Furthermore, I examine whether a co-management system would be effective in this area or whether current management regimes are sufficient to protect stock health.

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Statement of co-authorship

The author of this thesis, Michelle Caputo, designed field sampling protocols, collected, processed and analyzed the data, and wrote the subsequent manuscripts. Dr. Ian Fleming made substantial contributions to the design of the study and aided in the collection and interpretation of data, and also provided editorial reviews of all the chapters.

2.0. Chapter 2 – Spatial and temporal marine migratory patterns of brook charr (*Salvelinus fontinalis*) in Gros Morne National Park, Newfoundland

2.1. Introduction

Partial migration, which is characterized by a mixture of resident and migratory individuals within a population, is widespread in nature (Chapman et al. 2011). It is particularly common in fishes (Kerr et al. 2009) and especially so among salmonid species (Dutil and Power 1980, Berg and Berg 1989, Doyon et al. 1991, Berg and Berg 1993, Whalen et al. 1999, Gulseth and Nilssen 2000, Jardine et al. 2005). In salmonids, it is exemplified by migrations to saline or brackish environments in order to access areas of increased food abundance and return migrations to fresh water for breeding (i.e. anadromy). This benefits fish by increased growth, which improves fecundity, mating success and ultimately reproductive success (Gross 1987, Fleming and Reynolds 2004, Quinn and Myers 2004, Jardine et al. 2005). Costs associated with migratory behaviour include an increased potential for mortality from a variety of factors such as predation, parasites, injury and human interactions. Thus, the occurrence of partial migration and evolution of this strategy in salmonids is an interesting and complex area of research, which involves trade-offs between the various costs and benefits (Dodson et al. 2013).

Brook charr (*Salvelinus fontinalis*) is a salmonid species that is native to eastern North America and is often characterized as having a freshwater life history. Yet, populations showing a degree of anadromy can found from Maine in the USA to Labrador in Canada (reviewed in Curry et al. 2010). Brook charr is one of the most widely fished species in Canada, with particular importance for recreational fishermen in

Newfoundland and Labrador where anadromy is an important life history strategy of these fishes (DFO 2005). Current studies suggest that brook charr move downstream in the spring (May-June) and spend approximately one month in a brackish environment, accessing rich food sources, before returning to rivers for fall (August) (Dutil and Power 1980, Castonguay et al. 1982, O'Connell and Dempson 1996, Curry et al. 2002, 2006, 2010). Evidence suggests that these migrations first take place in fish ages 3-6 (Dutil and Power 1980, Castonguay et al. 1982, McCormick et al. 1985, O'Connell and Dempson 1996, Curry et al. 2010), with one study showing that charr spend some time in earlier years in estuarine environments before venturing five to six kilometres out into the fully saline environment (Dutil and Power 1980). This seaward migration may increase fishing pressure on charr populations, especially when fish leave the natal brook in large numbers (Palmisano 1997, Theriault et al. 2008).

Current evidence is limited as it is derived from a few populations studied using contemporary techniques. These studies indicate that brook charr can show a diversity of migratory patterns (reviewed in Curry et al. 2010). The generality of such patterns, however, remains unknown, particularly for unstudied regions in Newfoundland. Moreover, the mechanisms driving charr migration remain somewhat unclear, with evidence that this seaward migration out of the natal brook is actually passive and that fish growth is independent of the length of marine residency (Doyon et al. 1991), contrasted by evidence that fish size and environmental factors, such as tide, motivate migration for increased food abundance at sea (Dutil and Power 1980, Castonguay et al. 1982, Curry et al. 2002, Curry et al. 2010). Curry et al. (2010) suggest that the river environment dictates whether migratory behaviour will exist and how predominant it will be. Additionally, there is a lack of knowledge of charr distribution at sea and use of productive habitats during that period. Long-term trends in migratory behaviour of brook charr appear complex, with studies suggesting variable ages of first seaward migration, timing of subsequent migrations, and use of estuary habitats (Curry et al. 2010). With advances in tracking technology and accessibility of otolith microchemical analyses, this variability and associated gaps in knowledge may be further addressed (Zimmerman 2005, Cooke et al. 2008).

The purpose of this study was to determine both the short and long term migratory behaviour of brook charr from two systems in Gros Morne National Park (GMNP), Newfoundland (Fig. 2.1), and identify factors that influence these behaviours. The Bonne Bay fjord, contained within GMNP, provides a unique opportunity for tracking studies as it is made up of two arms, separated by a shallow sill, which provides a protected saline environment in the Eastern Arm of the fjord. As this area contains rich sea grass beds, and limits exposure to potential threats, fish were predicted to remain in the Eastern Arm throughout their time at sea, which would support previous research which suggests that fish remain close to natal brooks and do not make extensive, long distance migrations (Dutil and Power 1980, Castonguay et al. 1982, Currie 2009, Curry et al. 2006). Based on previous evidence, charr were predicted to leave the natal brook during late May and return in August or late July, in coordination with tidal events (i.e. moving outward on an ebbing tide and inward on a flowing tide). Otolith microchemistry was used to determine frequency of anadromy and age at first seaward migrations from two populations displaying anadromy in GMNP - one representing a more closed in, protected environment (Bonne Bay Fjord), and the other an open, harsher marine environment (Western Brook). This analysis allowed us to test whether migration events are predictable in brook charr populations (Volk et al. 2000, Veinott and Porter 2005, Zimmerman 2005). Based on evidence from previous studies and similar species, it was predicted that charr would make yearly trips to sea starting at age 2, with potential for fish to be non-migratory in subsequent years, and that differences in environmental conditions may cause differences in frequency of anadromy (O'Connell and Dempson 1996).

2.2. Methods

2.2.1. Study Sites

Two systems in GMNP, Bonne Bay Fjord and Western Brook, on the west coast of the Island of Newfoundland were studied (Fig. 2.1). Acoustic tagging and hydrophone deployment were focused in the Bonne Bay Fjord, an open system with two arms: the South Arm and the Eastern Arm. The Eastern Arm is separated from the rest of the fjord by a shallow sill, which protects it from harsh oceanic conditions. The biotelemetry study was focused on charr entering the Eastern Arm from Deer Arm Brook, a river flowing from the Northern section of the Eastern Arm (Fig. 2.1). Hydrophones were all placed within the Eastern Arm, with one at the sill to monitor movement out of the Eastern Arm. Another large river, potentially used by brook charr in the Eastern Arm system, is Lomond River, at the southern tip of the Eastern Arm.

Otoliths were also collected from fish in the Bonne Bay Fjord, as well as fish from the Western Brook system, north of Bonne Bay along the coast. In the Bonne Bay region, fish heads were collected from fishermen fishing the Bay, with no specific information on the location of catches. The Western Brook system consists of a deep freshwater fjord called Western Brook Pond that connects to the ocean by Western Brook, a wide flowing river. Western Brook winds several kilometres to the ocean and has a narrow opening at the mouth that empties directly into the Gulf of St. Lawrence in contrast to Deer Arm Brook that empties into a large, protected saltwater fjord. Otoliths were collected predominantly from the mouth of Western Brook where fishing is permitted. Ten fish were sampled from Western Brook Pond in late July (with eight otoliths used for analyses), where fishing is prohibited. The differing natures of the two study systems provides a means of comparing migratory strategies between two populations living in relatively close proximity to one another, but with different conditions in the marine environment.

2.2.2. Acoustic Telemetry Tagging and Tracking

2.2.2.1. Surgical Implantation of Acoustic Transmitters

Brook charr were captured (angled) on their outward migration to the Bonne Bay fjord (Fig. 2.1) between May 25 and June 7, 2009 at the mouth of Deer Arm Brook as they moved from freshwater to saltwater. After capture, the fish (n=17; Table 2.1) were anesthetized in an induction bath of clove oil emulsified in ethanol (approximately 50 mg L^{-1}) and measured for fork length (mm) and weight (g) in order to determine if they were the appropriate size for surgery. We abided by the "2 %" rule (Brown et al. 1999) for transmitter size in fish and ensured that there was adequate room within the abdominal cavity for the device such that there was no pressure on viscera or the body wall which could lead to problems with feeding or pressure necrosis. We also collected fin clips and scales from fish prior to surgery. For all occasions, fish were implanted using standard surgical procedures (Cooke et al. 2003). Briefly, fish were placed on a foam surgery table and, during the surgery, the gills were continuously irrigated with re-circulating water containing a maintenance dose of clove oil in ethanol. A small incision (~ 1.5 cm) was made on the ventral side of the fish using a sterilized scalpel. A Vemco V9-2L ~ 120 seconds acoustic transmitter (diameter: 9 mm, length: 29 mm, and weight: 2.9 g in water) (www.vemco.com) was then inserted into the intraperitoneal cavity, and the incision closed using 2-3 independent absorbable monofilament sutures. Measures were taken to ensure a near-sterile environment, including the use of surgical gloves and disinfection of all surgical instruments using ethanol. After surgery, the fish were placed in a recovery bath of water and released upon regaining equilibrium (10-20 min). One experienced surgeon performed all surgeries in order to reduce risk to fish health and to maintain consistency in surgical method (Cooke et al. 2003). A hydrophone was placed close to the release area to get an initial position of the fish and ensure that tracking was successful. All 17 fish were successfully tagged and tracked using this procedure.

2.2.2.2. Hydrophone Deployment

In order to track the tagged fish, an array of seven hydrophones was deployed in the Eastern Arm of Bonne Bay, with one hydrophone placed at the shallow sill, which separates the Southern Arm from the Eastern Arm (Fig. 2.2; Table 2.2). Hydrophone 6 could not be retrieved and therefore data from this hydrophone were lost. The hydrophones were arranged in the Eastern Arm to track migration to areas of known sea grass beds or where potential fish prey is abundant, and to target nearshore environments, as previous studies suggest that fish preferentially use these areas (Currie et al. 2010). Hydrophones were deployed by floating the receiver 10 feet above a grapnel hook using a buoy. The grapnel was attached to a cinder block with 90 metres of rope running perpendicular to the shore, which had small buoys attached every 10 feet to raise the rope off the bottom of the seabed. The cinder block was equipped with a white buoy for identification and in case of uprooting of the hydrophone (see Appendix I for a detailed description of the deployment method). The location of each hydrophone was recorded using a GPS unit and the distance between each hydrophone and the distance from each hydrophone to the natal brook were calculated. Hydrophones were retrieved in October 2009 by dragging an anchor from the back of a boat, parallel to the shore (and therefore perpendicular to the 90m rope) until the anchor caught on the rope at which point the apparatus was pulled in manually.

2.2.2.3. Data Analysis

Data were analyzed using JMP v. 9.0.2. and Systat 13. Fork length was used to determine the effect of fish size on date of out/in travel from hydrophone 1 (H1) at the mouth of Deer Arm Brook (H7 in cases where fish appeared to enter Lomond River rather than Deer Arm Brook) and the effect of size on the time fish left the protected Eastern Arm environment (leaving H4 and returning to H4).

Proportion of time spent at each receiver location (1-5, 7) was calculated by determining the number of detections per hydrophone, dividing this by total time on the array, and comparing these results for each by time period starting on the first day fish appear on array (May 14) and ending on the last (July19) (early: May 14-June 4, middle: June 5-27, and late: June 28-July 19) and overall during the marine residency period (Kruskal-Wallis tests). The median number of tags detected at each hydrophone for the three time periods was calculated by determining the number of individual fish that were detected at a hydrophone for each time period as well as for the overall marine residency period. This was also compared between time periods (Kruskal-Wallis), as well as for the overall marine residency period (Kruskal-Wallis). The diel periodicity (day or night) of migration events (when a fish leaves a hydrophone) was determined and the number of migrations (in and out of the natal brook) occurring at day and night was compared (ANOVA).

The effects of tide and diel period on charr migration out of the natal brook in the spring and back in the summer were examined by determining tide height, flow direction, and time of day. Tidal height and diel period were recorded at the time of the last detection of fish at Deer Arm Brook (H1) following tagging and at the last detection upon return to the brook at the end of the migratory cycle. These were compared between out and in events (t-test), and the tide height was compared between fish leaving in the night and the day. In order to reveal patterns, the effect of tide on exit from and entrance into the natal brook was calculated by giving an angular value to the time of last detection at natal brook both in and out of the natal brook (Lefevre 2011). Similarly, an angular value was assigned to time fish left the natal brook and time fish returned to natal brook. Angular values for tide were based on (1) ebbing (time after high tide = t_h) or (2) flowing tides (time after low tide = t_l) as follows:

1) $x^o = 180^o(t/E)$

2) $x^o = 180^o(t/F)+180^o$

where x^o is the angular value of tidal cycle, t is the time after low or high tide, calculated as $t = d-t_h$ for ebbing tide, and $t = d-t_l$ for flowing tide, E is the duration of ebb tide and F is the duration of flow tide

Angular values for time were based on (1) AM or (2) PM as follows:

1) $x^o = 180^o(t/12)$

2) $x^o = 180^o(t/12) + 180^o$

where x^o is the angular value of diel cycle, t is the time fish left in hours based on a twelve hour clock.

2.2.3. Otolith Collection and Analysis

The majority of fish heads collected for otolith microchemistry were collected from fishermen in the GMNP area who fished both in the Bonne Bay fjord and in the short, tidally influenced section of Western Brook before it emptied into the ocean. Additional heads were collected from Western Brook Pond to compare with estuary caught fish; these fish were euthanized with an overdose of buffered clove oil in ethanol (100 mg L^{-1}). Fork length and weight were recorded for as many fish as possible (some fish were donated by fishermen and no size data were available). Otoliths were removed subsequently and polished, before being mounted on slides for microchemical analysis.

Laser ablation plasma-mass spectrometry was used to determine the strontium to calcium ratio (Sr/Ca) throughout the life history of each fish using a laser transect starting at the core of the otolith (beginning of the fish's life) and travelling outward to the edge of the otolith (i.e. following the fish's life cycle). In total, 104 otoliths were analyzed at the MAFIIC lab housed in the INCO Center at Memorial University of Newfoundland (MUN) (22 from Bonne Bay, 82 from Western Brook estuary, and 10 from Western Brook Pond). The analytical system is a Finnigan ELEMENT XR, a high-resolution double focusing magnetic sector inductively coupled plasma mass spectrometer (HR-ICPMS) coupled to a GEOLAS 193 nm excimer laser system. A helium flow rate of 0.9 to 1.0 l/min was used to carry ablated material from the ablation cell to the HR-ICPMS, with an additional 0.75 l/min argon gas added after the ablation cell. The laser was rastered across the otoliths at 15 um/sec to produce profiles across the otolith growth lines. Laser energy was approximately 3 J/cm^2 and the laser repetition rate was 10 Hz. Time resolved intensity data were acquired by peak-jumping in a combination of pulse-counting and analog modes, depending on signal strength, with one point measured per peak for masses. The ICPMS was tuned each day for maximum sensitivity using a reference material (National Institute of Standards Technology NIST 612). Oxides ThO/Th were monitored and were less than 0.5%. Data were calibrated with the NIST 612 glass. Calcium oxide (CaO) was used as an internal standard to deal with differences in ablation yields and matrix effects between the unknown otoliths and the calibration materials (NIST glasses). The CaO concentrations of the unknowns were assumed to be homogeneous at 55.0%. Approximately 30 seconds of gas background data were collected prior to each laser ablation of both standards and unknowns.

The data acquisition methodology employed an analytical sequence of two analyses of the NIST 612 standard and one of MACS1 reference material with analyses of up to 14 unknown otoliths, closing with a repetition of the same standards in reverse order. The MACS1, a similar matrix to the otoliths, was treated as an unknown and data were acquired to allow the monitoring of accuracy and precision of the dataset and the technique in general. The error for the method when measuring homogeneous materials is estimated to be better than 5% relative based on the reproducibility of results for various reference materials measured from day to day over several months in the MUN laboratory.

Data were reduced using MUN's in-house CONVERT and LAMTRACE spreadsheet programs, which employ procedures described by Longerich et al. (1996). LAMTRACE was used for selection of representative signal intervals, background subtraction, internal standard correction for ablation yield differences, instrument sensitivity drift during the analytical session, and calculations to convert count rates into concentrations by reference to the standards.

Raw counts of Sr and Ca were plotted, and transect start and end points and the point of Sr inflection were recorded. These points of interest on the chemical output were then related to actual location on the otolith to determine age at first seaward migration and age at subsequent migration events. This was done by determining the position of events on the otolith from the elapsed time of the transect multiplied by the rate of blast (5μm/s) (e.g. Fig. 2.3). Age was calculated from photographs by counting annuli (Secor, Henderson-Arzapalo and Piccoli 1995), where the first ring represented "Age 1" or one year after birth (Fig. 2.3). Low values of Sr/Ca found during the early stages of juvenile development served as a benchmark freshwater (salinity <0.5 ppt) signal (Type 1) and values which exceeded this benchmark were considered to represent saltwater residency (Volk et al. 2000, Brenkman, Corbett and Volk 2007). Peaks were considered separate events when a decrease in Sr/Ca by at least half the peak-height was observed. Two forms of elevated peaks were observed (Campbell 2010) a moderate signal (Type 2), which is presumed to represent shorter trips to brackish environments, and a more pronounced elevation of Sr/Ca concentration (Type 3), which represent extended trips to the ocean environment (35 ppt). Based on this information, the number of Type 2 and Type 3 peaks were calculated per fish and fish age at the time of these trips was determined.

2.2.3.1. Data Analysis

Data were analyzed to determine frequency of anadromy and effect of age and size on this frequency, as well as to determine age of first seaward migration, using JMP v. 9.0.2. and Systat 13. The effect of age on number of extended trips (Type 3) and brackish trips (Type 2) was determined using Spearman Rank correlations for both study sites. The median age of first and second migrations were compared between the two study sites using Mann-Whitney Rank Sums. Additionally, the effect of location (BB or WB) and age on the number of total trips to the brackish environment (number Type 2 +

number of Type 3) was determined (ANOVA). The median number of Type 2 and Type 3 trips was calculated for fish from Western Brook estuary (WB), and Bonne Bay (BB). These were compared between the two sites using Mann-Whitney Rank Sum tests for fish aged 1 to 4 years (as BB fish were maximum age 4). The effect of age on number of migrations was tested for Western Brook Pond (WBP) fish (Spearman Rank correlation). Subsequently, Western Brook Pond (WBP) fish were size and/or age matched with WB fish and compared for number of Type 2, Type 3 and total migrations (Mann-Whitney test).

2.3. Results

2.3.1. Acoustic Telemetry

The average time (± S.D.) spent by charr in the marine environment, including all areas with tidal influence, was 51.6 ± 15.2 days (N=14), with two fish never being detected beyond the Deer Arm Brook hydrophone (H1) and one never returning. Seven brook charr left H1 in the last week of May (25^{th} – 31^{st}) and eight left during the first week of June (1^{st} – 7^{th}) (Fig. 2.4 and 2.5 for individual charr migrations). Fork length (Table 2.1) had no significant effect on date of migration out of the brook (p=0.546, N=15) nor on the date of return to the natal brook at the end of seaward migration period (p=0.918, N=15).

The proportion of time spent at each hydrophone was significantly different (ANOVA, p<0.001) (Fig. 2.6). There was also a significant difference in the number of individual fish detected at each hydrophone, with more fish being detected at H1 and H5 than the other receivers (Kruskal-Wallis, p<0.01) (Fig. 2.7). When divided into the three time periods (Early, Middle and End), there was no significant difference in median proportion of time charr spent on the array among the different time periods (Kruskal-Wallis, $p=0.138$) (Fig. 2.8). There was, however, a significant difference in the median number of tags detected at each hydrophone between the three time periods (Kruskal-Wallis, $p<0.001$), with the end period differing significantly from the early and middle periods ($p<0.001$), which did not differ from one and other ($p=0.505$) (Fig. 2.9). During the early time period, there was a significant difference in the median proportion of time spent at each hydrophone (Kruskal-Wallis, $p<0.001$), with fish spending the most time at H1. During the middle time period there was no significant difference in the median proportion of time spent at each hydrophone (Kruskal-Wallis, $p=0.505$). The late time period had significantly more time spent at H2 and H1 than the other hydrophones (Kruskal Wallis, $p<0.001$).

Tidal period differed significantly between fish on the outward and inward migrations, with outward migration appearing to occur independent of tidal period and inward migration occurring during ebbing tides (Fisher Exact Test, $p=0.017$, $N=15$) (Figs. 2.10 and 2.11). Outward migrations appeared to occur randomly with respect to tide as nine took place on an ebbing tide, and six on a flowing tide, (no meaningful vector for this analysis) (Fig. 2.10). The majority of inward migrations took place during an ebbing tide after high tide, with a mean vector of 1.8 hours after high tide (Fig. 2.11). Outward migrations occurred primarily between 12am and 12pm, with the majority of movement between 12am and a mean time of 7:04am (Fig. 2.12). Inward migrations occurred primarily in the hours of sunrise, between 12am and 6am, with a mean time of 5:25am (Fig. 2.13).

2.3.2. Otolith Microchemistry

The otolith analyses from Western Brook estuary (WB) and Bonne Bay (BB) showed three signatures: Type 1, Type 2, and Type 3 (Fig. 2.14). These signatures are higher for BB than they are for WB. There is no significant difference in the age of charr captured in WB (range = 1-4, median = 3, N=24) versus BB (range = 2-4, median = 2, N=83; Mann—Whitney Rank Sum, p=0.654). The age at first seaward migration did not differ between charr from WB and BB (Mann Whitney Rank Sum, p=0.777, medians were 2.0; Table 2.3). Nor was there a difference in the age at second seaward migration between charr from WB and BB (Mann Whitney Rank Sum, p=0.694, BB median=3.0, WB median=3.5; Table 2.3). For the effect of age and location (ie. BB or WB) on total number of migrations (Type 2 + Type 3), location was the only factor that had an effect (ANOVA, p=0.012, N=95) with BB fish migrating significantly more. Age and the interaction between age and location had no significant effect on the total number of migrations (ANOVA, p=0.110 and p=0.380, respectively, N=95).

When comparing fish of similar ages, the median number (25^{th} percentile, 75^{th} percentile) of migrations (both estuary and saltwater) for fish from WB was 1 (0.25, 2) and for BB 1 (1, 2). Brook charr from both WB and BB make between zero and three migrations. In WB, an increase in age causes an increase in number of Type 3 trips to sea (Spearman Rank Correlation, p<0.001, N=82) (Fig. 2.15); however, number of Type 2 trips appears to be independent of age (Spearman Rank Correlation, p=0.556, N=82)

(Fig. 2.16). In BB, there is no relation between age and number of Type 3 (Spearman Rank Correlation, p=0.789, N=22) (Fig. 2.15) or Type 2 migrations (Spearman Rank Correlation, p=0.156, N=22) (Fig. 2.16). The median number of total Type 2 and Type 3 migrations (for fish age 1 to 4) differs between WB and BB (Mann-Whitney Rank Sum, p=0.021), with more migrations at BB. The number of Type 2 migrations (for fish age 1 to 4) does not differ between BB and WB (Mann-Whitney Rank Sum, p=0.471); however the number of Type 3 migrations (for fish age 1 to 4) does differ significantly (Mann-Whitney Rank Sum, p=0.001), with more shown in BB fish. For Western Brook Pond (WBP) fish, age had no effect on number of migrations (Spearman Rank correlation, p=0.341, N=7). When compared fish of the same ages from WB, there was no difference in the number of Type 3 migrations (Mann-Whitney Rank Sum, p=0.094 (median of WB=0, and WBP=0) and no signficant difference in the number of Type 2 migrations (Mann-Whitney Rank Sum, p=0.324, median of WB=0, and WBP=0).

2.3. Discussion

2.3.1. Brook Charr Migratory Behaviour

Combining acoustic telemetry and otolith microchemistry allowed for the investigation of both short- and long-term migratory behaviour in brook charr, and provided age and habitat specific movement patterns. Based on these two analytic approaches, a general life history pattern emerges for anadromous brook charr in Gros Morne National Park, Newfoundland, with behaviour varying both within and between the two populations studied. From patterns of Type 2 and Type 3 migrations by age, it appears anadromous juveniles inhabit the freshwater environment for their first 1-2 years, venturing to sea at age 2+, often having made prior short trips to brackish environments, as demonstrated by Type 2 trips prior to saltwater signatures. Based on the telemetry data from Deer Arm Brook, they spend 1-2 months at sea, from the end of May to mid July, and spend the beginning of their time at sea close to the brook, before moving further away during the mid part of their marine period, and then return to fresh water. At sea, brook charr from Deer Arm Brook move througout the Eastern Arm of Bonne Bay (minimum distances travelled ranged from 11-93 km), with the majority of fish venturing out of the Eastern Arm for indeterminate distances. Migration behaviour was not affected by fish size or by diel period; however, tide may have an effect on movement into fresh water at the end of the migration season. Estuary habitat is used extensively by brook charr, as they spend a large proportion of time in these areas (Currie 2009). Otolith microchemistry suggests that after the initial migration at age 2+, fish may make subsequent migrations at age 3-4, moving seaward once every 1-2 years after their first seaward migration. However, in Bonne Bay, otoliths were derived mostly from fish 2-3 years old, which limits the insights that can be drawn about the frequency of anadromy in this area.

The migratory behaviour of anadromous brook charr in Gros Morne National Park is consistent in some respects with previous research on the species, but does differ in others, highlighting the diversity of life history strategies of brook charr. Date of migrations inward and outward of river and length of stay in the brackish environment are consistent with previous studies, with fish leaving in late winter and early spring and returning in mid to late summer, staying at sea just over a month depending on environmental conditions (Dutil and Power 1980, Castonguay et al. 1982, McCormick et al. 1985, Doyon et al. 1991, Curry et al. 2002, Curry et al. 2010). Age at first migration (2+), as well as distance travelled at sea are consistent with a study from Saint-Jean, QC (Castonguay et al. 1982), but differs from Lac Guillame, QC, where fish were found not leaving the natal brook until age 4+ and travelling only 5-6 km away from it (Dutil and Power 1980). Other studies have found fish size and tidal/diel influences to affect the timing of migration, with bigger fish leaving the rivers earlier and a very strong tidal influence on movement (Dutil and Power 1980, Castonguay et al. 1982, Doyon et al. 1991, Curry et al. 2002), but in Bonne Bay there was no effect of fish size on the timing of diel and tidal patterns of inward or outward migration. Moreover, outward migration of brook charr from Bonne Bay appeared to be independent of tidal cycle, whereas inward migration occurred most frequently during high ebbing tides. Diel period appeared to influence both outward and inward migration, with most fish moving during night, dawn and early morning and the pattern being somewhat stronger with regards to inward than outward migrations. As summarized in Curry et al. (2010), brook charr may be repeat spawners but the mechanisms for this are unclear. This is consistent with otolith results, which indicate that some individuals make multiple migrations to sea during their lifetime. Additionally, Curry et al. (2010) note that the behaviour of brook charr at sea is variable within and amongst size groups, confirming the results obtained in this study. The differences between brook charr populations in terms of migratory behaviour, suggest that habitat and study location affect charr life history, specifically in the timing and frequency of migrations.

Patterns of brook charr migratory behaviour are also comparable with other salmonid species, showing consistency with Arctic charr (*Salvelinus alpinus*) in age at first seaward migration (1-8 years), yearly timing of migration (end of May to July), and length of stay at sea 1-2 months) (Berg and Berg 1989, Berg and Berg 1993, Staurnes et al. 1994, Gulseth and Nilssen 2000). Dolly Varden (*Salvelinus malma*) have also been observed to leave their natal brook around age 2, with a range from 2-6 (Randall, Healey and Dempsey 1987); however, anadromous whitespotted char (*Salvelinus leucomaenis*) appear to leave later, at age 3 (Morita 2001) and a sample of far north Norwegian Arctic charr showed a much higher age at first seaward migration (4-13 years) (Radtke et al. 1996). Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) parr can migrate to brackish environments as early as age one (Jonsson and Jonsson 2011). Much of this likely reflects differences in growth during juvenile freshwater residency, with age at first migration increasing latitudinally as a reflection of slower juvenile growth rates (Jonsson and Jonsson 1993).

2.3.2. Use of Estuary Habitat by Gros Morne National Park Brook Charr

Habitat mapping from Gros Morne National Park provides evidence that locations used by charr during seaward migration are highly productive and provide food resources. Currie (2009) performed seine sampling in the Eastern Arm of the Bonne Bay Fjord and described the habitat sampled, which is similar habitat to that used by brook charr in this study. Currie (2009) found brook charr from multi-year sampling in areas of hydrophones 2, 3, 4, and 7, especially during the month of June. Based on tracking data from the current study and on observations from Currie's (2009) seine data, charr spent the majority of their time in sites which were described as having lower salinity due to freshwater imputs from rivers, substrates of cobble, pebbles, and boulders, and areas with extensive vegetation, which in some cases were eelgrass beds (Currie 2009). These areas are also the sites of the highest richness in fish assemblages, as well as used by snails, amphipods, and other prey species of brook charr. This provides further evidence that anadromy provides fish with access to areas of high prey availability and abundance that may not be found in estuaries.

The importance of estuary habitat to anadromous brook charr is highlighted by the current study, which has also been found for other anadromous salmonids (Simenstad et al. 1982, McCabe Jr. et al. 1983, Krentz 2008). Previously, estuary habitat was considered to be important for transition as fish moved into saline environments from freshwater; however, as highlighted by Krentz (2008), estuaries can also provide fish with essential habitat at sea for accessing abundant and diverse forms of prey, and finding protection from the increased stressors of seaward migration (Brenkman and Corbett 2005, Quinn 2005, Krentz 2008). A large proportion of the time brook charr spent at sea was in estuary type habitat, specifically in May and July. Possible estuary signatures were also visible in otolith microchemical analysis, including some trips in which fish made only a short trip during a year, as indicated by Type 2 trips. The extent of the importance of estuaries to anadromous brook charr populations remains unclear, however in Gros Morne National Park, they are highly frequented by charr.

2.3.3. Partial Migration, Conservation Implications, and Future Research

The presence of anadromous individuals in brook charr populations is a management concern with respect to maintaining biodiversity of aquatic species and socio-economic value for recreational fisheries (Curry et al., 2010, Thériault et al., 2008). A recent study by Curry et al. (2010) theorizes on the mechanism of partial migration in brook charr, suggesting that the expression of anadromy in brook charr results from the dispersal characteristics of this species which are influenced by density (i.e. over-production of juveniles) and avoidance of intra- and interspecific interactions, the tolerance to saline conditions, and the presence of critical habitats for larger sea-run members of populations. In the case of Gros Morne National Park, the freshwater habitats are large and deep enough to accommodate sea-run individuals and are protected from fishing activities during the spawning season. Curry et al. (2010) suggest that protection of critical habitats is key for maintaining sea-run individuals and that other management strategies (e.g. fish stocking) are not effective.

In the case of Gros Morne brook charr, as found in many other studies (Dutil and Power, 1980, Naiman et al., 1987, Curry et al., 2010), estuary habitat is used extensively by charr, most likely for foraging. In Western Brook, fishing is restricted to salt water and brackish environments during the months of anadromous activity to prevent fishing in rivers, which puts pressure on anadromous individuals, and may select for resident charr (Thériault et al. 2008). During this stage of their life history, fish in these highly fished estuary habitats (see Chapter 3) may not have contributed genetically to populations (as observed in the present study where many individuals were subadults), are vulnerable to increased mortality (e.g. predation), and have incurred energetic costs due to migration (though this could be negligible as they do not venture far from the brook). If managers observe declines in brook charr populations, they may consider protection of estuary habitat in this region to aid in recovery of anadromous brook charr.

Using otolith microchemistry and acoustic telemetry in unision has provided increased detail of migratory behaviour in brook charr; however, much research remains to fill in the gaps of our understanding (Cooke et al. 2008). Future studies should incorporate multi-year acoustic tagging data to improve research on spatial distribution of brook charr at sea, and compliment this with seine data like that from Currie (2009). Additionally, increasing the number of hydrophones in the area between hydrophones 4 and 2 may provide finer scale movement data and increase understanding of estuary use. As fish do migrate out of the Eastern Arm of the Bonne Bay Fjord, it would be useful to determine the distance they will travel outside of the Eastern Arm and the habitats frequented. Also, while we have some data on tidal and diel effects on migratory behaviour, further investigation of the environmental triggers of down and upstream migration of charr is warranted.

In order to improve our understanding, additional research may prove useful. An attempt to capture brook charr of an older age group for otolith microchemistry would provide greater insight into longer term patterns of seaward migration. Also, a comparison of resident and anadromous fish could be useful in further understanding the patterns of partial migration. Additionally, otoliths could be analysed for maternal anadromy (Veinott et al. 2012) to indicate the effect of maternal history on migratory behaviour. Increasing understanding of both short- and long-term migratory behaviour is important in improving management decisions for anadromous fish. Here we identify the age at first seaward migration, and highlight that fish are entering the sea before reaching age at maturity. We also suggest that estuary habitat and places with a freshwater influence may be key habitats during the marine residency of brook charr, but also highlight the diversity in brook charr spatial distribution at sea.

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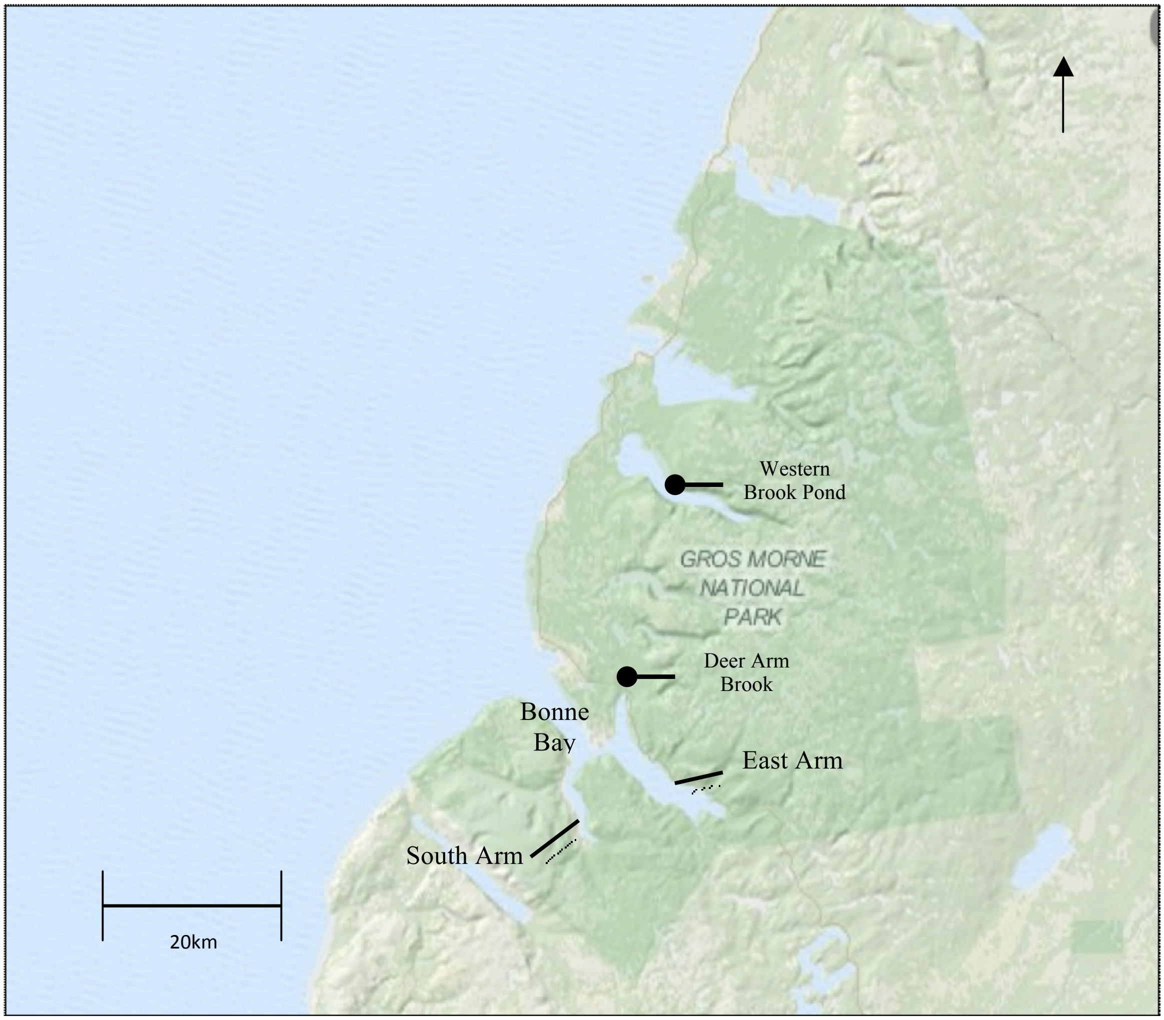

Fig. 2.1: Location of the study sites, Deer Arm Brook and Western Brook Pond, within Gros Morne National Park, Newfoundland, Canada.

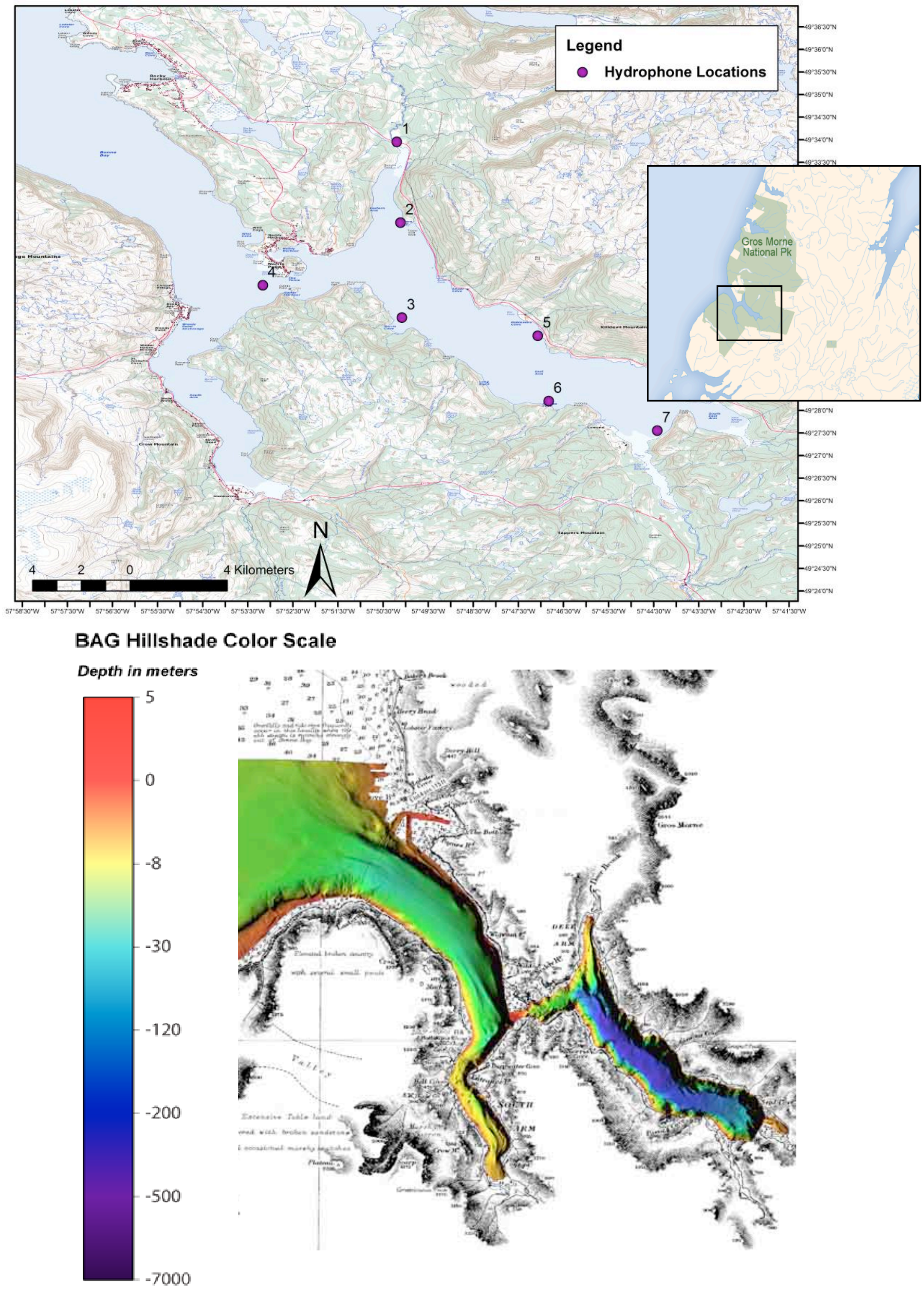

Fig. 2.2: Location of seven hydrophones deployed in the Bonne Bay fjord, Gros Morne National Park, Newfoundland, including the one that was lost (number 6) and a multi-beam bathymetric depth profile of the fjord (NRCAN 2013).

Table 2.1: Fork length (mm) of brook charr tagged at Deer Arm Brook for acoustic telemetry tracking (N=17).

Fish ID	Fork Length (mm)
1	467.5
2	479
3	441
4	403
5	382
6	438
7	411
8	487
9	447
10	394
11	321
12	309
13	416
14	320
15	490
16	294
17	268

Table 2.2: Distance (km) from H1 (Deer Arm Brook) and GPS location of hydrophones in Bonne Bay.

Hydrophone	Location		Distance from H1 (km)
1	-57.8366	49.5659	0
2	-57.8352	49.5360	3.32
3	-57.8347	49.5009	7.22
4	-57.8861	49.5129	6.89
5	-57.7845	49.4943	8.81
6	-57.7804	49.4701	11.39
7	-57.7403	49.4592	13.74

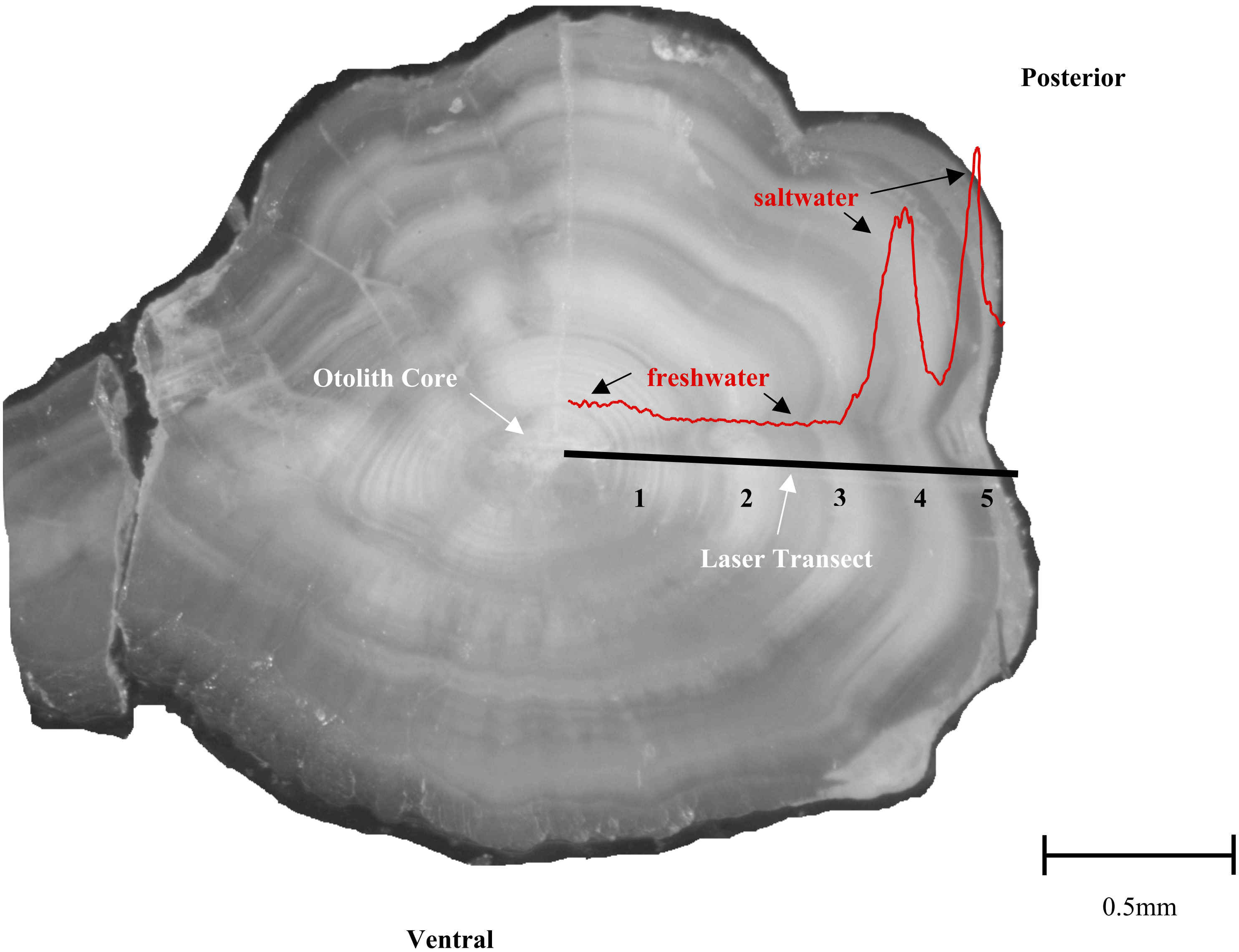

Fig. 2.3: Laser transect of a brook charr otolith from Western Brook showing the age rings as indicated by the numbers and Sr/Ca signal (red line) found using otolith microchemical analysis.

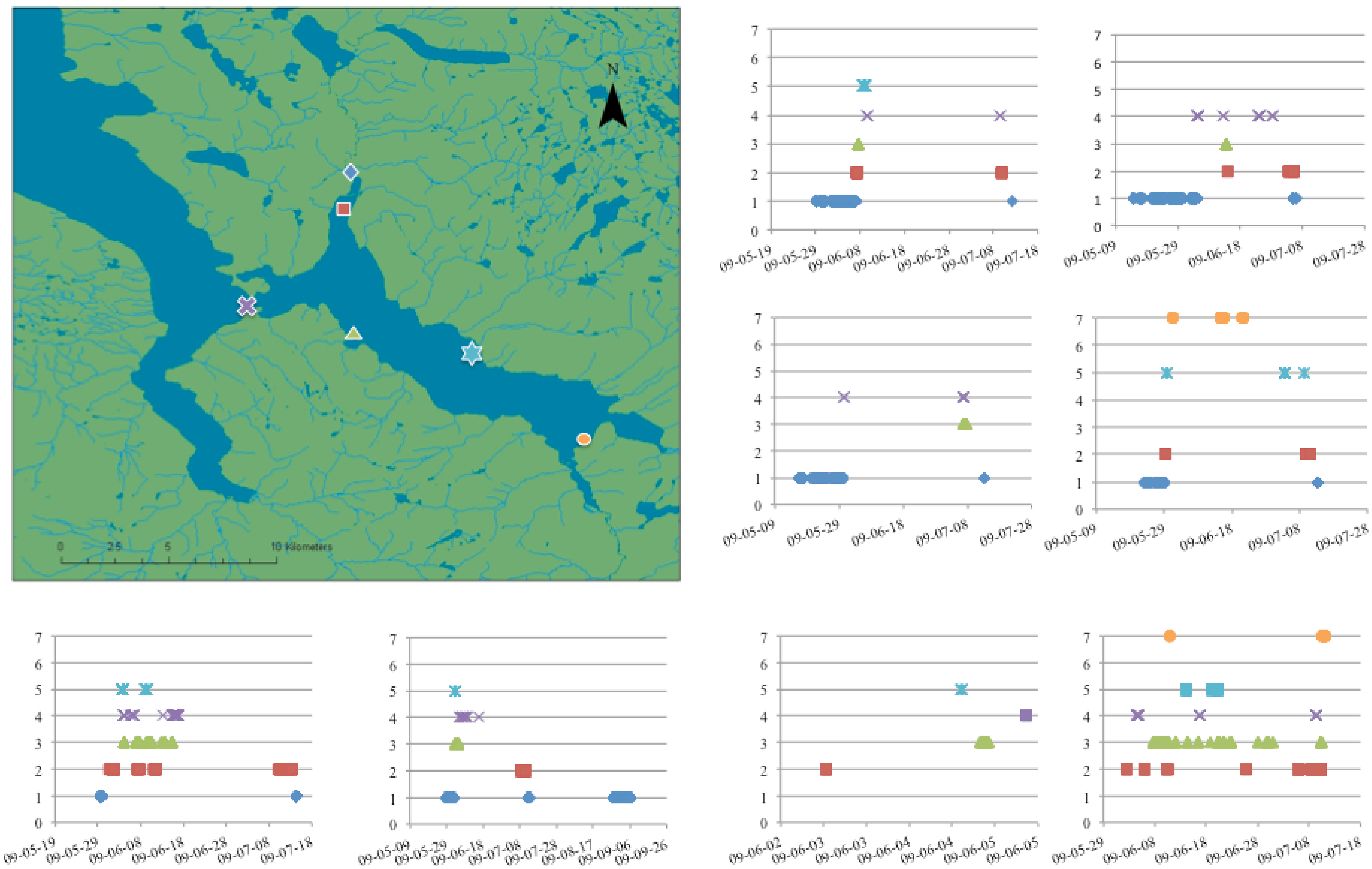

Fig. 2.4: Individual trips for brook charr (fish 1-8) in Gros Morne National Park, Newfoundland, during their migratory season (time on the x-axis), where symbols on the map represent hydrophones (y-axis) and each graph is an individual fish.

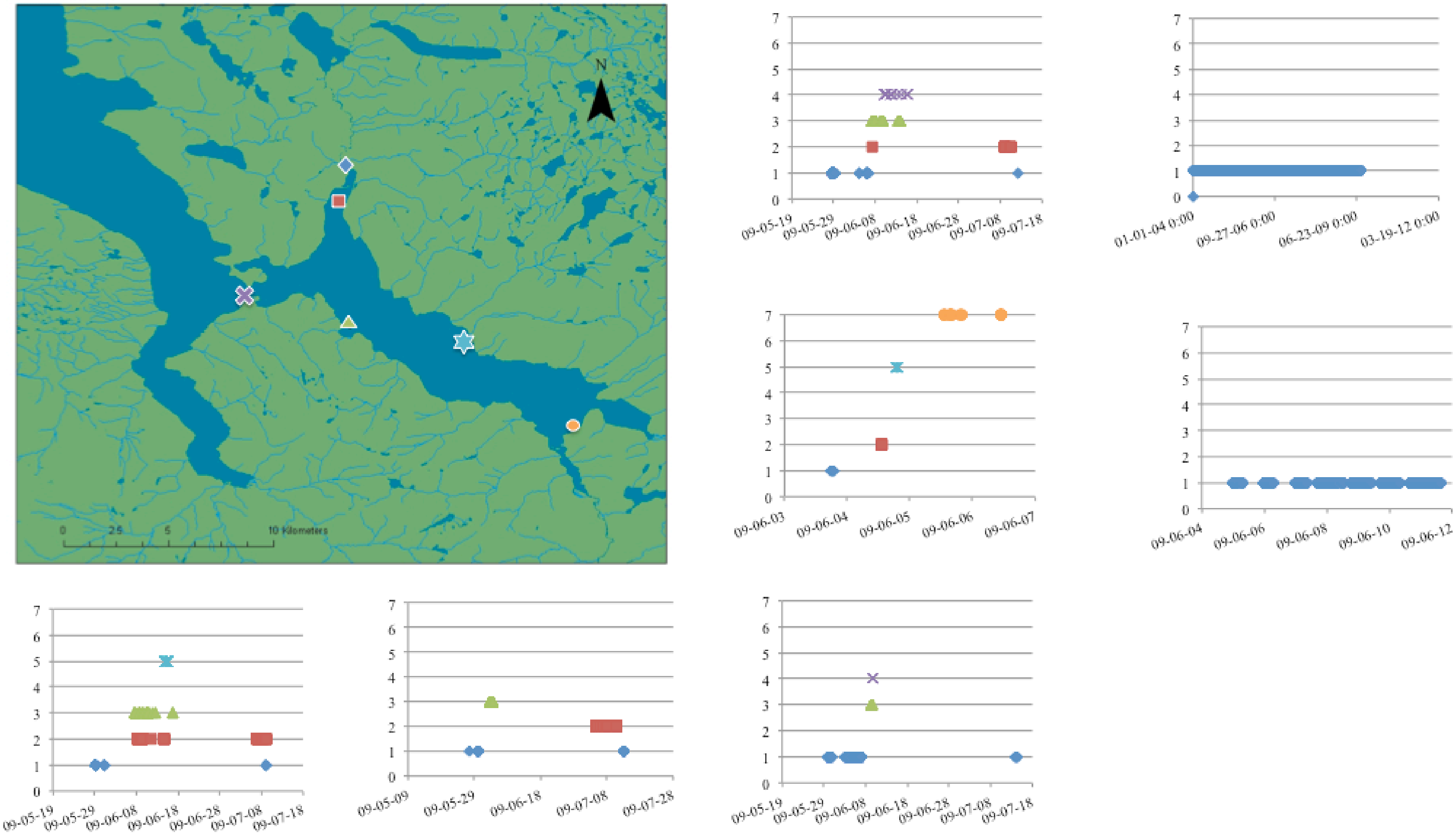

Fig. 2.5: Individual trips for brook charr (fish 9-13, 15, and 17) in Gros Morne National Park Newfoundland during their migratory season (time on the x-axis), where symbols on the map represent hydrophones (y-axis) and each graph is an individual fish.

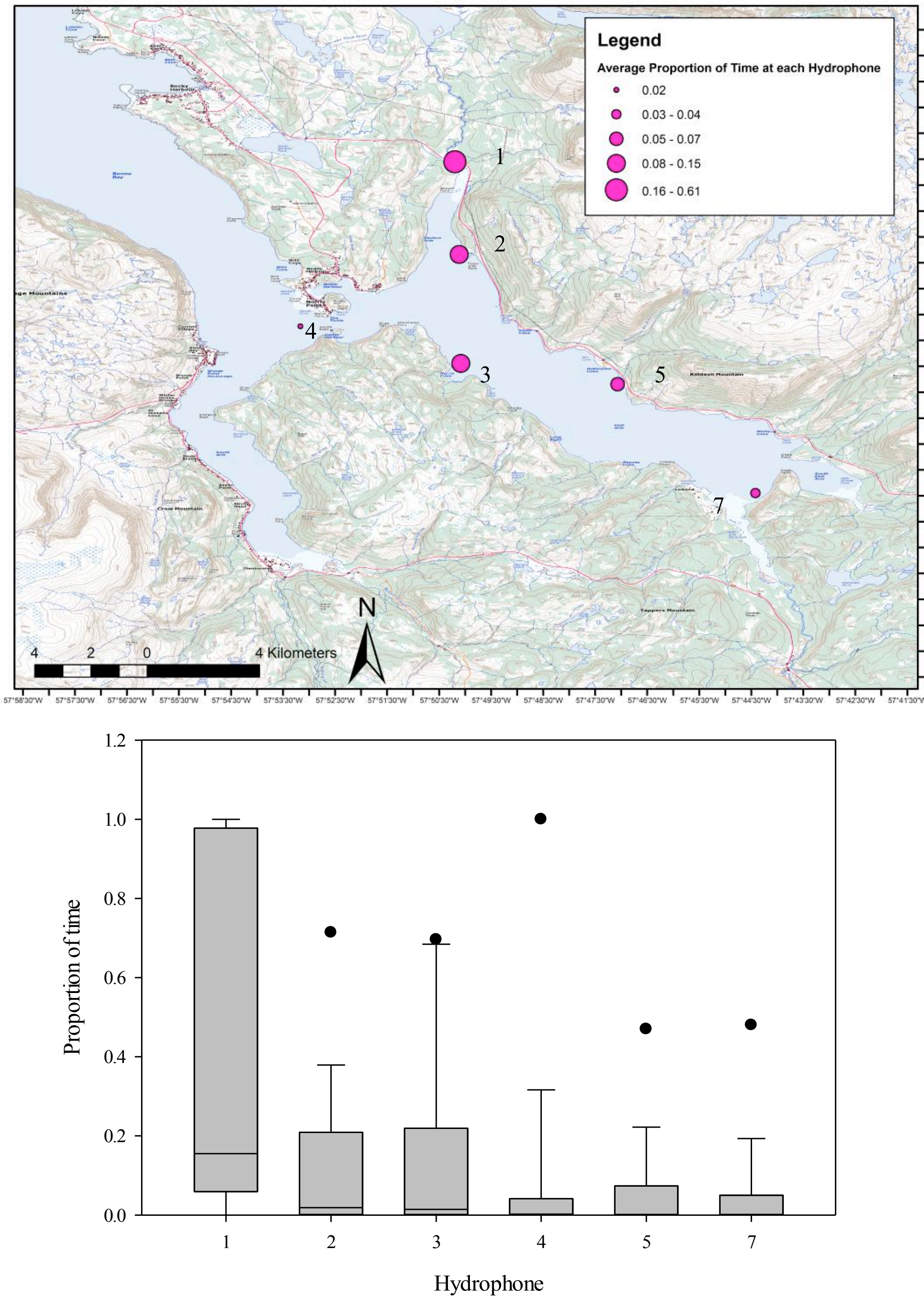

Fig. 2.6: Proportion of time spent by brook charr at each hydrophone in the Bonne Bay Fjord over the study period, where the mid-line represents the median (note: midline is at 0 if not visible), the box is the 25th-75th percentiles, the whiskers are the 10th and 90th percentiles, and the dots are the outliers ($p<0.001$). Map shows the average proportion of time spent at each hydrophone.

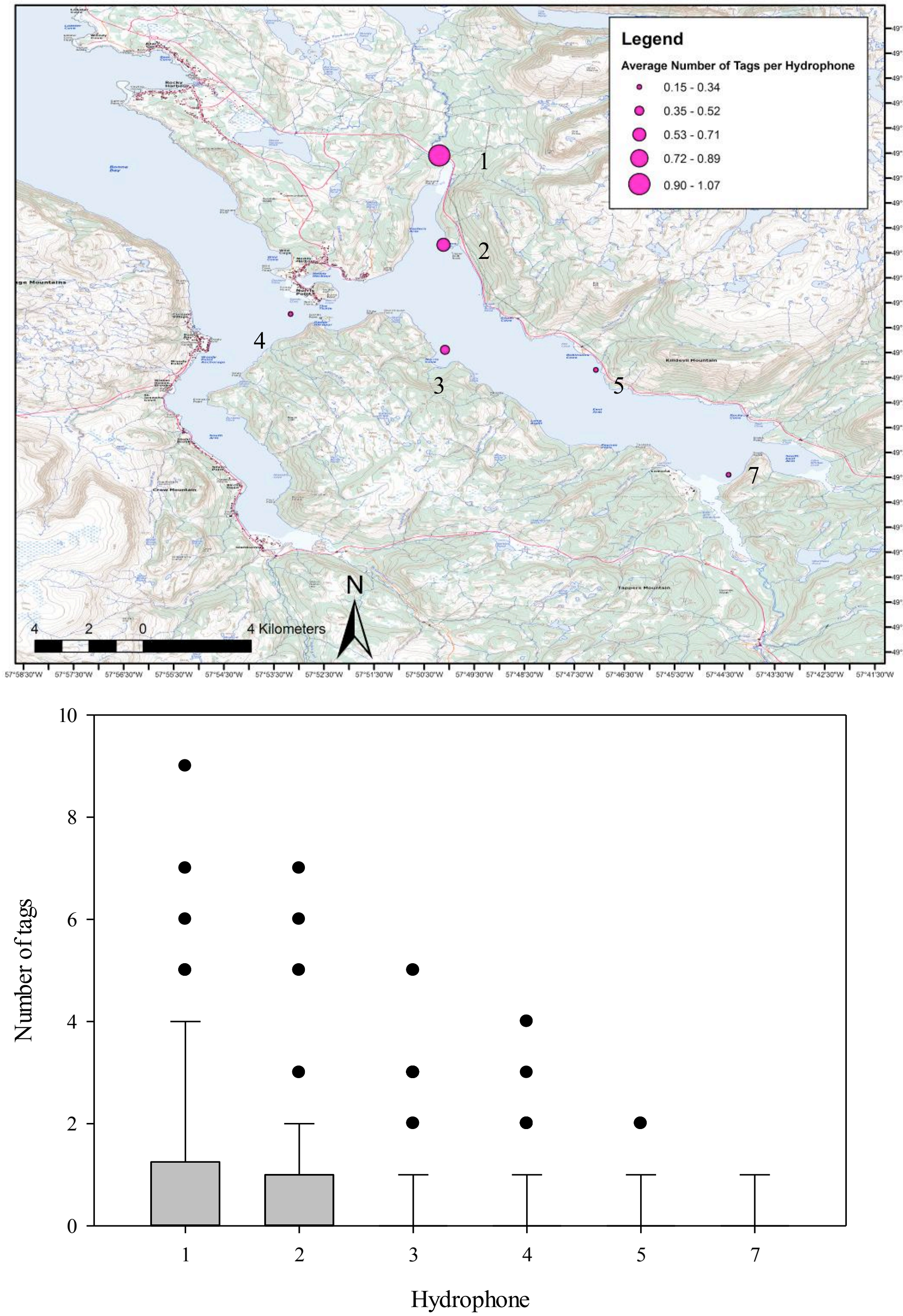

Fig. 2.7: Number of individual fish recorded at each hydrophone in the Bonne Bay Fjord over the study period, where the mid-line represents the median (note: midline is at 0 if not visible), the box is the 25th-75th percentiles, the whiskers are the 10th and 90th percentiles, and the dots are the outliers ($p<0.001$). Map shows the average number of tags detected at each hydrophone.

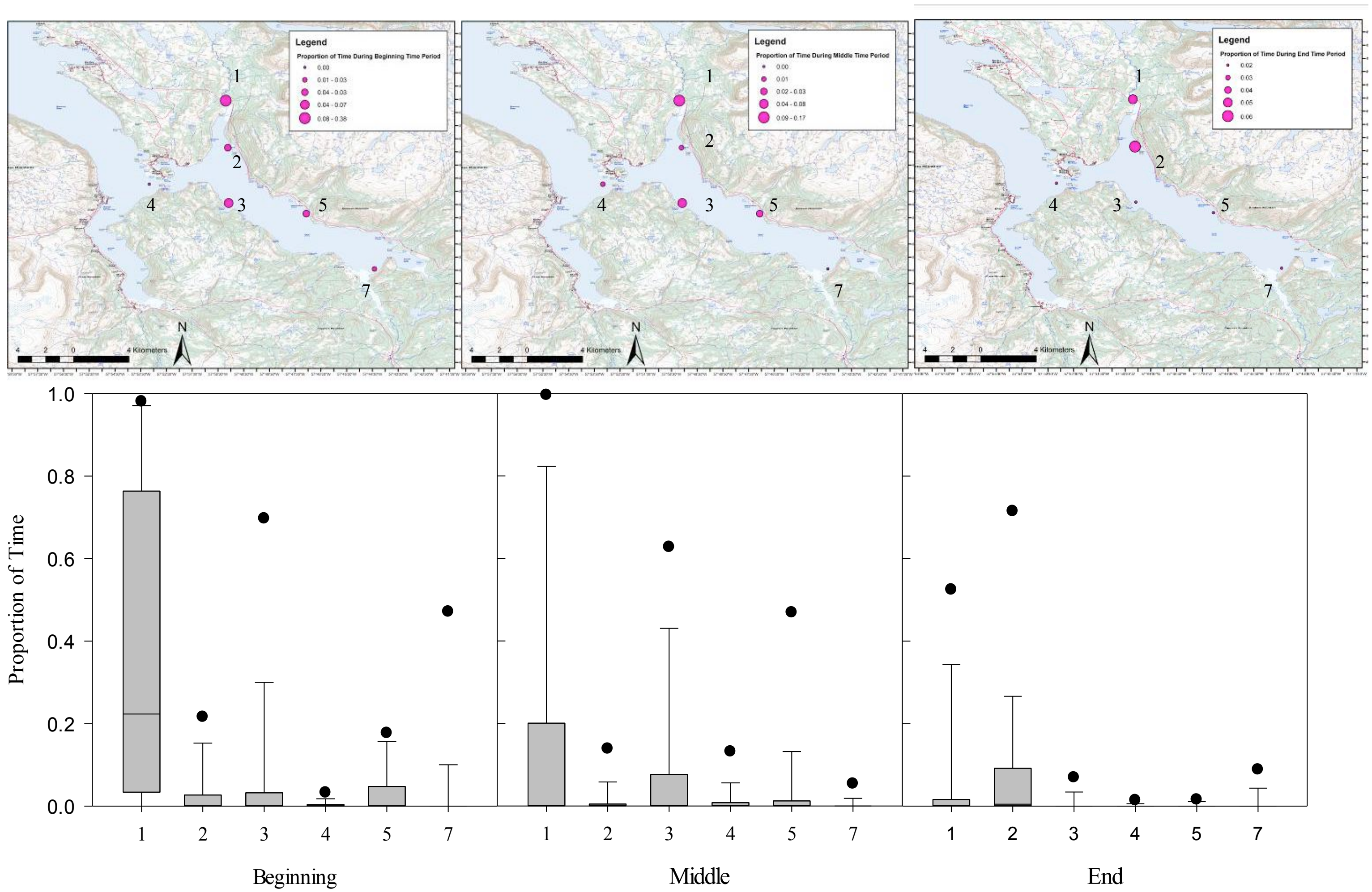

Fig. 2.8: Proportion of time spent by brook charr at each hydrophone for three time periods: Early (May 25-June 4), Middle (June 5 – June 28), and Late (June 29-July 17), where the mid-line represents the median (note: midline is at 0 if not visible), the box is the 25th-75th percentiles, the whiskers are the 10th and 90th percentiles, and the dots are the outliers (N=17). Maps show average proportion of time for each time period.

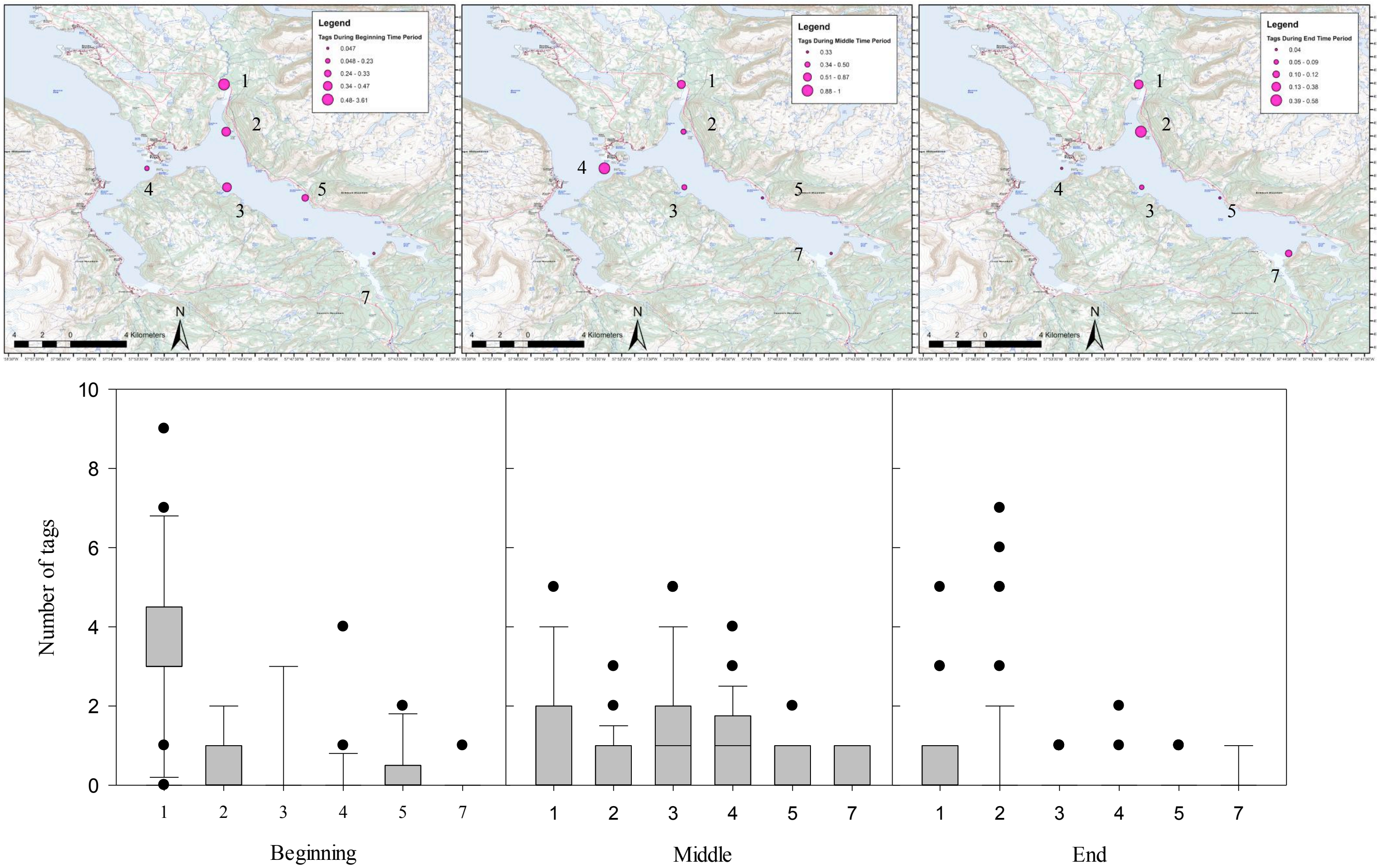

Fig. 2.9: Number of tags at each hydrophone for three time periods: Beginning (May 25-June 4), Middle (June 5 – June 28), and End (June 29-July 17), where the mid-line represents the median (note: midline is at 0 if not visible), the box is the 25th-75th percentiles, the whiskers are the 10th and 90th percentiles, and the dots are the outliers (N=17). Maps show average number of tags per hydrophone in each time period.

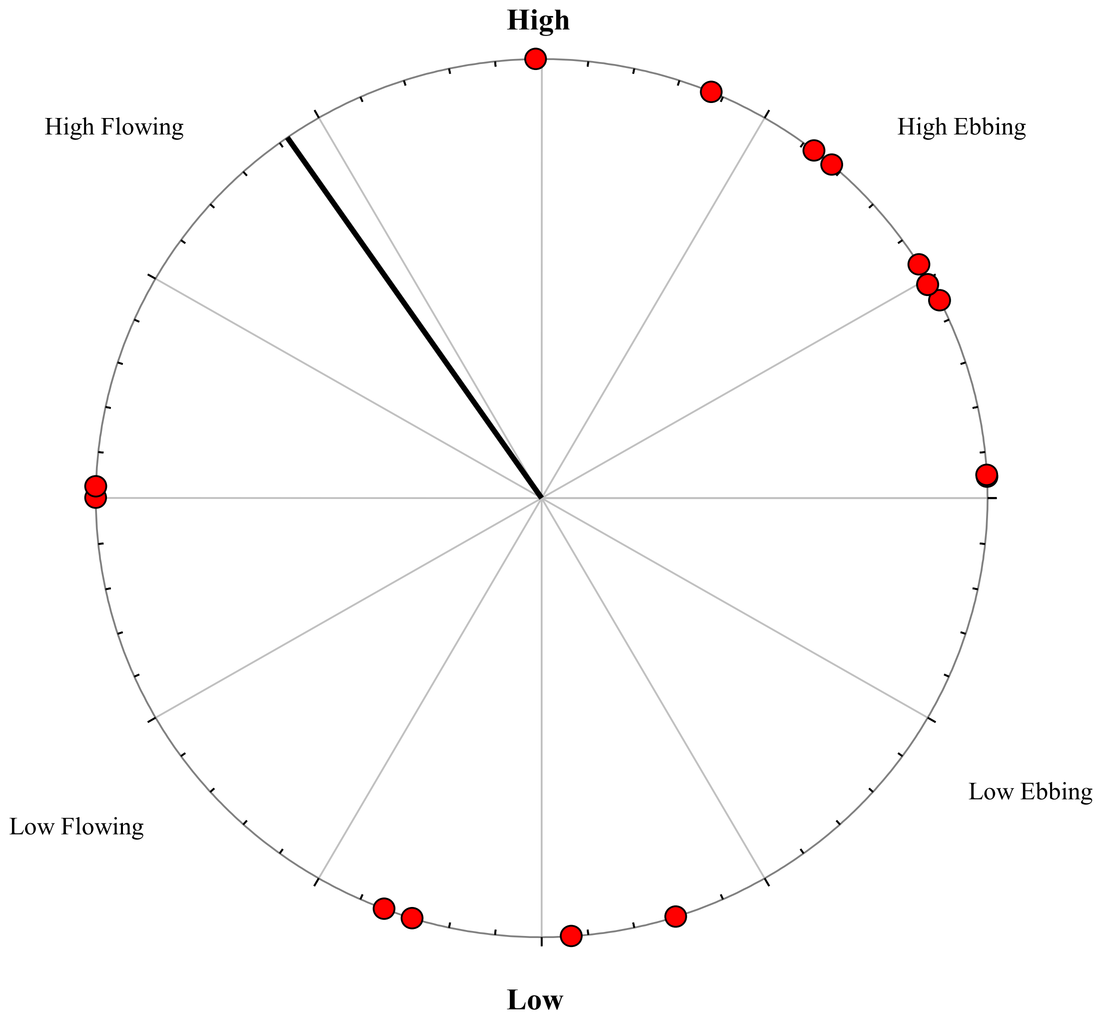

Fig. 2.10: Tidal influence on outward migration (leaving H1) for brook charr (red dots) entering Bonne Bay, with a mean vector (indicated by a thick black line) of 124.79º (2.19 hours before high tide on a flowing tide) (N=15, as two fish never left H1).

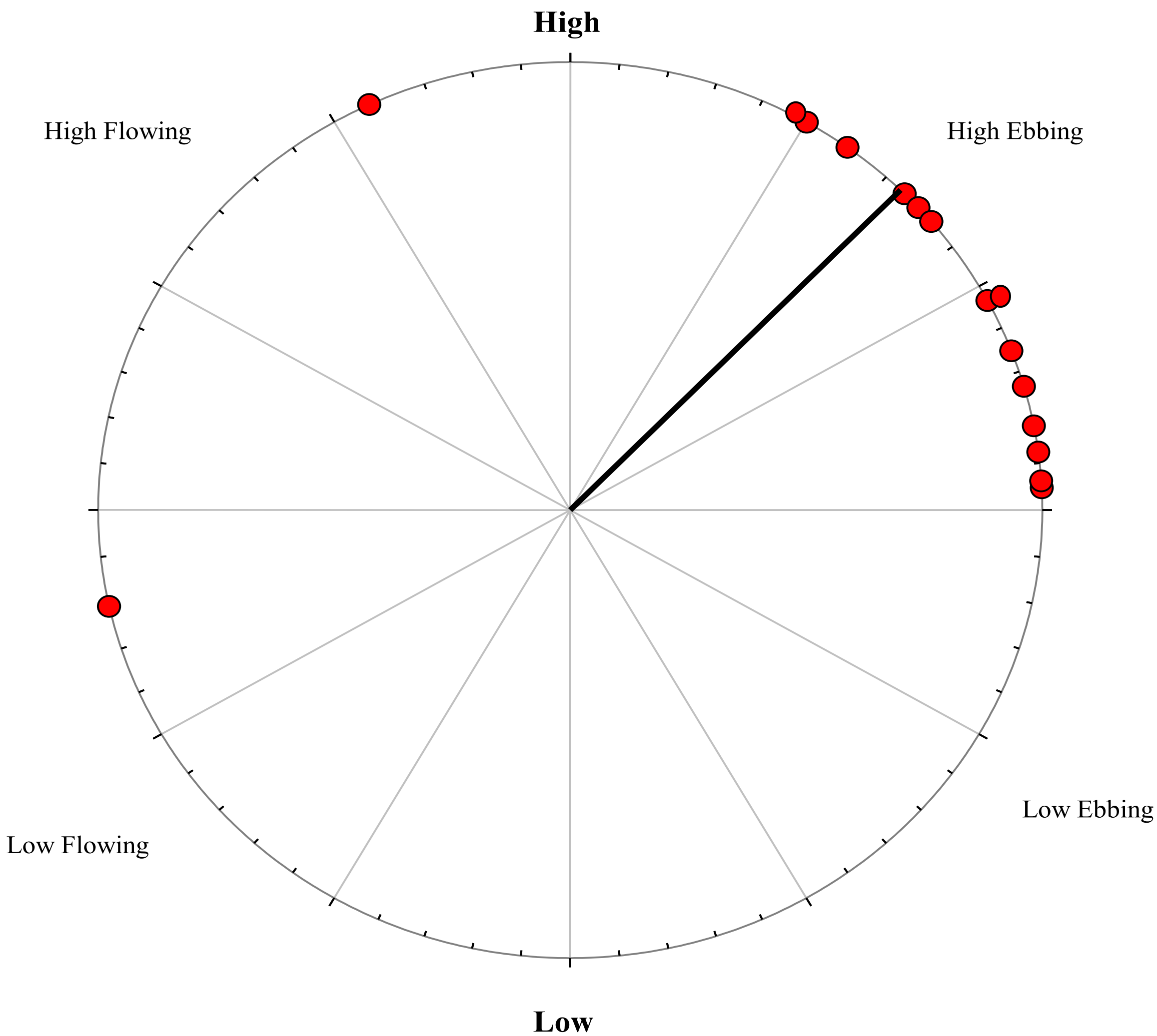

Fig. 2.11: Tidal influence on migration inward migration (leaving H1) for brook charr (red dots) in Bonne Bay, with a mean vector (indicated by a thick black line) of 45.59º (1.80 hours after high tide on an ebbing tide) (N=16, one fish was lost at sea).

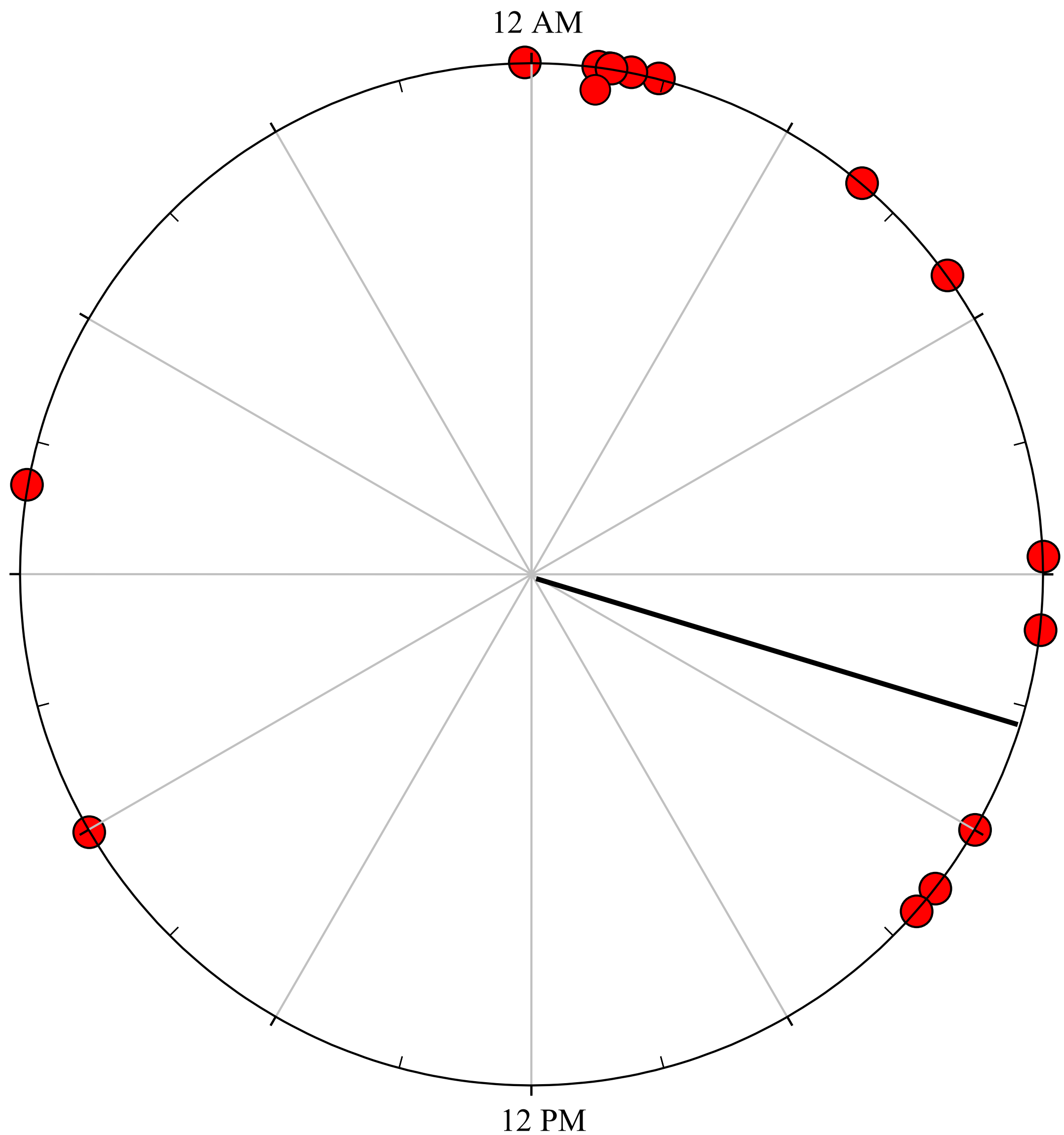

Fig. 2.12: Diel influence on outward migration of brook charr from Deer Arm Brook on a 24 hour scale (mean time is 105.86, which is 7:04am) (N=15 as two fish never left H1).

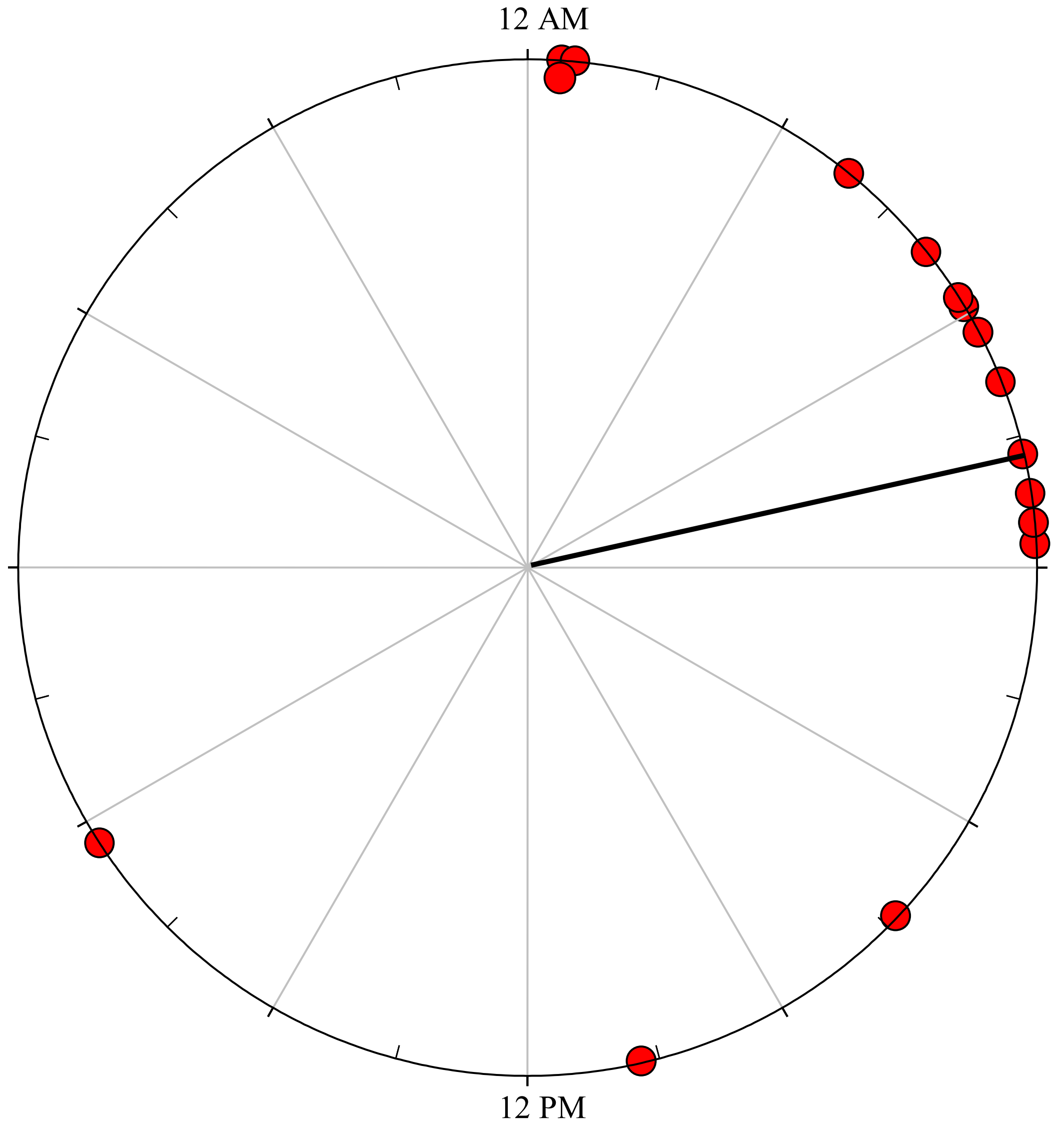

Fig. 2.13: Diel influence on inward migration of brook charr into Deer Arm Brook on a 24 hour scale (mean is 81.20 or 5:25am)(N=16, one fish was lost at sea).

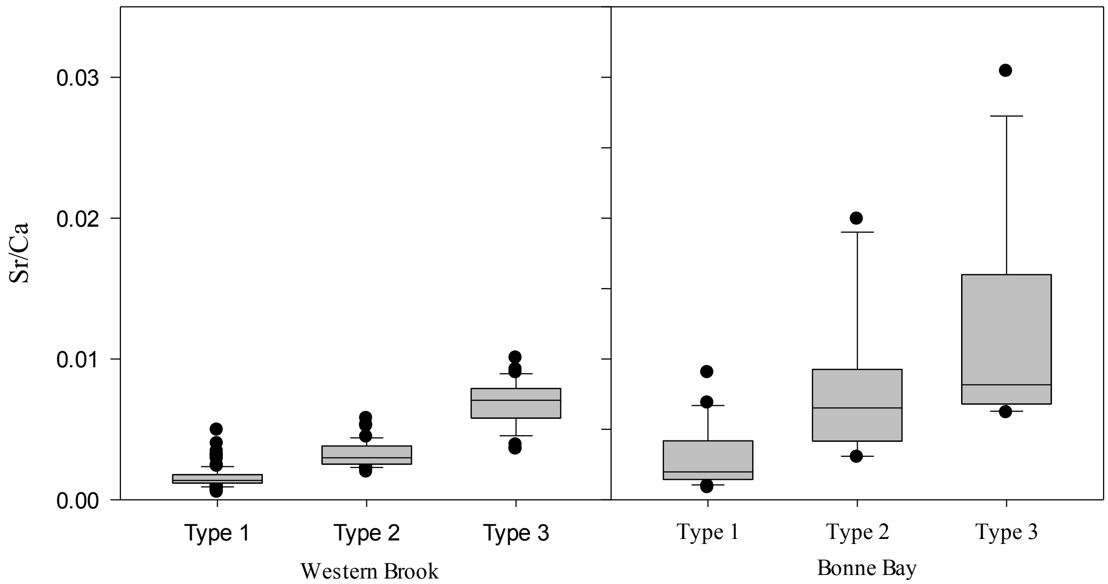

Fig. 2.14: Strontium-calcium ratio for Western Brook and Bonne Bay brook charr otolith transects showing Type 1 (freshwater), Type 2 (estuary), and Type 3 (saltwater) signatures, where the mid-line represents the median, the box is the 25th-75th percentiles, the whiskers are the 10th and 90th percentiles, and the dots are the outliers.

Table 2.3: Age at first and second migration for brook charr from Western Brook and Bonne Bay, with no significant difference for first (t-test, p=0.282) and second migration (t-test, p=0.254), where 2 equals time between second and third annual ring.

		Age at first migration	Age at second migration
WB	Median	2	3.5
	25th percentile	2	3
	75th percentile	3	4
	Range	2 – 4	3 – 4
BB	Median	2	3
	25th percentile	2	3
	75th percentile	3	4
	Range	2 – 4	2 – 4

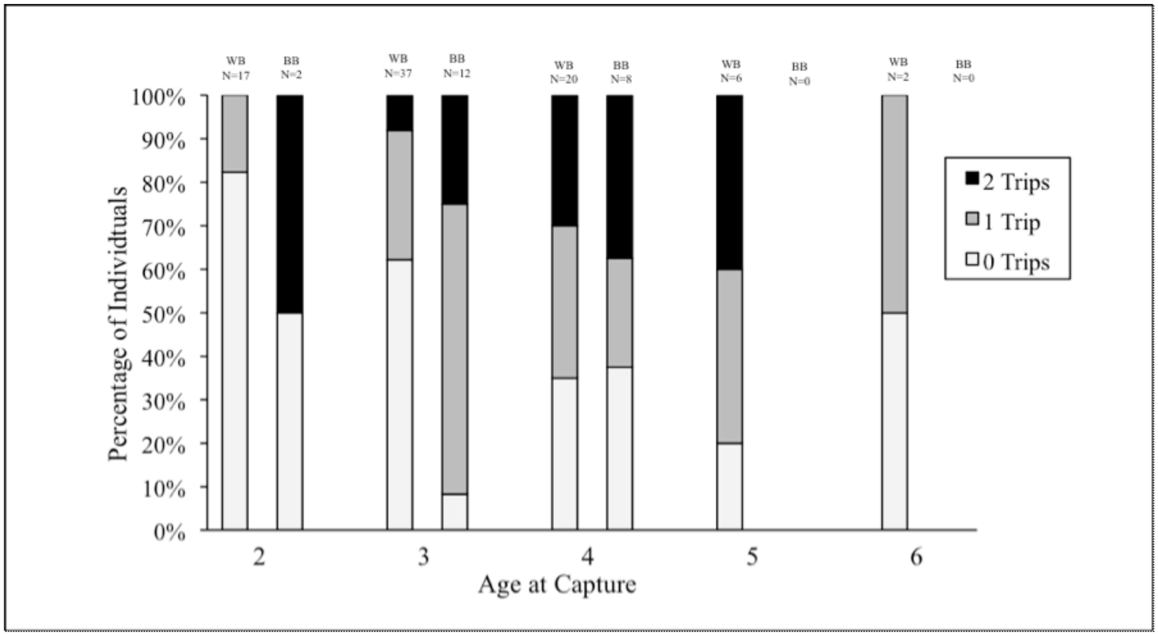

Fig. 2.15: Average percentage of WB and BB brook charr making 0, 1, and 2 Type 3 (saltwater) migrations as age at capture increases (p<0.001, N=82; p=0.900, N=23).

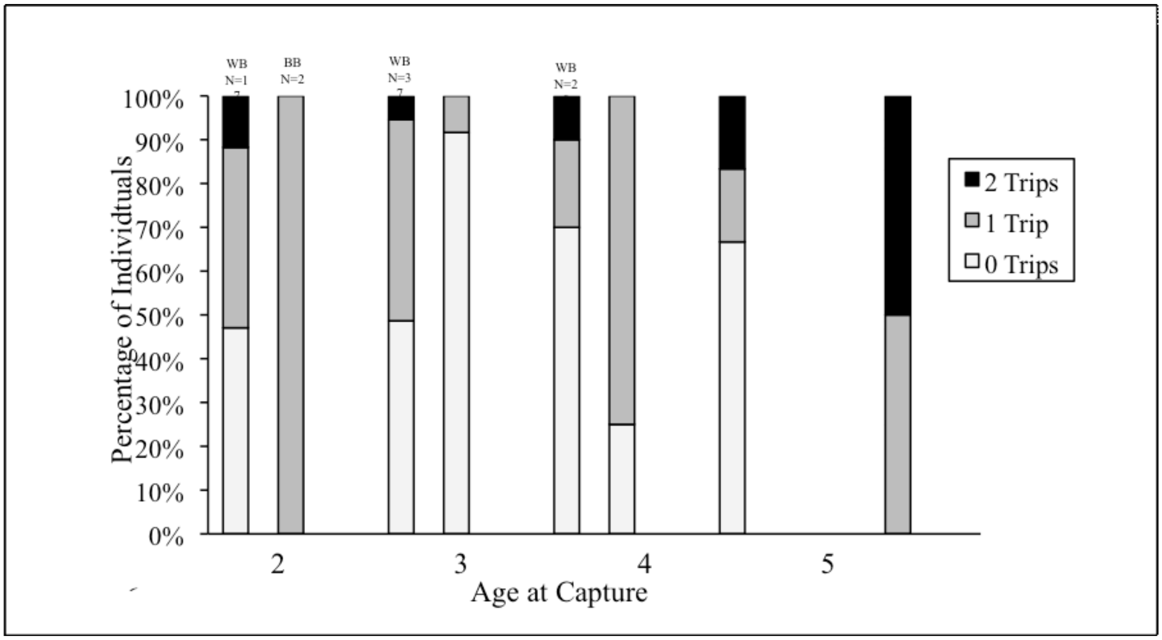

Fig. 2.16: Average percentage of WB and BB brook charr making 0, 1, and 2 Type 2 (estuarine) migrations as age at capture increases (p=0.556, N=82; p=0.156, N=22).

3.0. Chapter 3 – Co-management of recreational fisheries: Case studies from two charr (*Salvelinus spp.*) fisheries in western Newfoundland

3.1. Introduction

Recreational fisheries are popular worldwide and, in many coastal and inshore communities, they are the only user of fish resources (Sutinen and Johnston 2003, Arlinghaus 2006, Arlinghaus and Cooke 2008). They account for approximately 12% of worldwide take for all fish (FAO 2008) and contribute approximately 8.3 billion dollars to Canada's economy per year (DFO 2005) (Cooke and Cowx 2004, Arlinghaus and Cooke 2005, Nussman 2005, Cooke and Cowx 2006, Arlinghaus and Cooke 2008). Despite prominence globally, recreational fisheries are largely undermanaged or managed with generic regimes that are not site specific (such as bag limits and seasonal closures) (Post et al. 2002, Pereira and Hansen 2003, Nussman 2005). It is becoming increasingly apparent that a lack of adequate management in the recreational fisheries sector may result in habitat degradation (Lewin et al. 2006), over exploitation of stocks (Post et al. 2002, Myers and Worm 2003, Sutinen and Johnston 2003, Cooke and Cowx 2004, Lewin et al. 2006), as well as increasing competition among commercial and recreational fishermen (Sutinen and Johnston 2003, Nussman 2005).

In order to protect recreationally fished species, it is important to develop management regimes that are specific, adaptable, and incorporate the interests of all stakeholders to reduce fisheries impacts while maintaining the economic viability of the resource (Plummer and Fitzgibbon 2004, Olsson et al. 2004, Bruckmeier et al. 2005, Davis and Ruddle 2010). As such, co-management has been identified as a possible regime for recreational fisheries management. Co-management has many different definitions with the same basic principles; it is a type of adaptable management system or rights regime that extends responsibility to the users, nongovernmental agencies, and the government, recognizing the need to manage the resource and human users (Berkes 1999, Olsson et al. 2004, Plummer and Fitzgibbon 2004). Central to this definition is the sharing of power between many different stakeholder groups, which is contrary to many current practices in recreational fisheries, which are managed by centralized government or by users in the traditional ways (Berkes 1999, Plummer and Fitzgibbon 2004).

Experts have not only recognized the need for co-management regimes in the recreational fisheries sector, but have identified fishermen's knowledge as a key component for the success of co-management of commercial and, in some cases, recreational fisheries (Neis and Felt 2000, Maurstad 2002, Holm 2003, Bruckmeier et al. 2005, Bruckmeier and Neuman 2005, Murray et al. 2006, Berkes 2009, Gerhardinger et al. 2009). Despite recognizing the usefulness of fishermen's knowledge, many fisheries scientists have identified the challenges that are faced when trying to incorporate the needs of a variety of different stakeholders and in interpreting different kinds of knowledge and incorporating insights from them into management regimes (Pinkerton 1994, Sutinen and Johnston 2003, Arlinghaus 2006, Gelcich et al. 2006, Van Wyk et al. 2008). The potential for success in the use of local ecological knowledge is highlighted in *Sacred Ecology*, by Berkes (1999), where he presents a case study of Cree fishermen who have maintained a sustainable fishery based on their traditional practices, which are passed on between generations. Similarly, in the lobster fishery of Maine, fishermen enforce regulations without government intervention based on community efforts (McCay and Acheson 1987). However, the challenges are also widely discussed in the literature, as in a study on use of local ecological knowledge in marine protected area management in Brazil, where researchers identified major challenges to the use of local knowledge in this country because of government and community structures (Gerhardinger et al. 2009). In British Colombia, communities also had low success in incorporating local ecological knowledge into management decisions despite having highly structured and organized community groups (Pinkerton 1994). These examples demonstrate the complexities of using knowledge in fisheries science and in the practical application of co-management regimes.

In Newfoundland and Labrador, recreational fisheries are often overlooked by resource managers (Post et al. 2002, Cooke and Cowx 2004), despite having the highest participation rate in this sector for all of Canada (25.5%) and the largest percentage of kept catch nationally (76%) (Post et al. 2002, Cooke and Cowx 2004, DFO 2005). Brook char or charr (*Salvelinus fontinalis*) are the most widely fished species in Newfoundland and Labrador in the recreational fisheries sector (DFO 2005); however, there is a lack of research concerning this important species in terms of both stock numbers and fishery intensity. In a study by Keefe and Perry (2010), fishermen surveys and fisheries data to assess stocks health in a watershed of Newfoundland, and suggested that implementing size regulation would benefit the stock. Arctic charr (*S. alpinus*) have been widely fished recreationally in the northern parts of Newfoundland and in Labrador, but the fishery may be at risk of decline due to commercial fishery by-catch in some regions (DFO, 2010).

Currently, provincial brook charr and Arctic charr fisheries are regulated by the Department of Fisheries and Oceans, with general strategies such as bag limits and seasonal closures (DFO 2005). These regimes do not account for differences between fish populations, opinions of resource users, or scientific capture data (Sutton 1997, DFO 2005).

Recently, the use of local ecological knowledge in fisheries management has been identified as an important area of research for Newfoundland and Labrador; however, most current studies are focused on commercial fisheries, as these have greater economic value (Sutton 1997, Murray et al. 2006, Davis and Ruddle 2010). Scientists lack vital information about many recreational fisheries that could shed light on conditions of current stocks and health of fisheries, as well as fishermen's views of management (Sutton 1997). As identified by many previous studies, stakeholders, such as fishermen, are vital to the success of management regimes as they are the direct users, and compliance with regulations is at the heart of fishery management (Pinkerton 1994, Sutinen and Johnston 2003, Plummer and Fitzgibbon 2004, Bruckmeier et al. 2005, Arlinghaus 2006, Granek et al. 2008, Gelcich et al. 2009, Gerhardinger et al. 2009, McClanahan et al. 2009, Silvano and Begossi 2010).

The purpose of this study is to identify the benefits and challenges of using fishermen's knowledge for co-management in Newfoundland. Included here are two case studies, one in which the majority of fishermen have limited interest in fishery health and lack motivation to conserve the resource, and another where fishermen are both highly motivated and involved. The first is the brook charr (*Salvelinus fontinalis*) fishery on the western coast of Newfoundland in Gros Morne National Park (Fig. 3.1a), and the second is the Parkers Brook Arctic charr (*Salvelinus alpinus*) fishery on the Northern Peninsula of Newfoundland in Pistolet Bay (Fig. 3.1b). In both these contexts, fishermen surveys were used to determine fishery health and assess current management regimes both in terms of effectiveness (i.e. health of stocks) and their opinions about fishing conditions, in terms of their catch rates and size of fish caught.

Here, we will use their local knowledge to determine how the fisheries have changed over time in the view of the users, the key factors which affect the health of the fishery, and what users want for the future management of the fisheries. These two case studies attempt to demonstrate where local knowledge can be used effectively and to provide insight for future researchers wishing to incorporate local knowledge into recreational fisheries co-management regimes in Newfoundland and other parts of the world.

3.2. Methods

3.2.1. Case 1: Brook charr in Gros Morne National Park

Brook charr fisherman surveys were conducted between June 18 and November 1, 2009 in Gros Morne National Park (GMNP) area (Fig. 3.1a). Fishermen were surveyed using two methods, as approved by the Interdisciplinary Committee on Ethics in Human Research at Memorial University of Newfoundland (ICEHR Proposal No. 2008/09-145-SC), either in person at fishing grounds during the fishing season in May-August 2009 (n = 16) or by telephone surveys (n = 14) after the fishing season was over from August to

October, 2009. During in person surveying efforts, fishermen were approached at the fishing grounds of Western Brook estuary and asked to participate in the survey. An attempt was made to contact every fisherman observed fishing during sampling times (June– October 2009) and those who were not able to complete the survey at that time, were asked to mail-in a copy of the completed survey. For the telephone surveys, fishermen from all areas of Gros Morne National Park were identified by snowball sampling, whereby respondents were asked to name others who would be willing to participate in the research. In total 20 potential fishermen were called, with four responding that they do not participate in the brook charr fishery, two refusing to do a survey, and 14 completing a survey. Survey questions were separated into four sections: 1) demographics, 2) charr life history, 3) catch information, and 4) fisheries management (adapted from Sutton, 1997). Fishermen were asked to respond specifically for the GMNP area, including all places they fish in the park (in all cases they only fished one location).

Fishermen who agreed to participate, were first asked questions related to their fishing experience and background. These questions were aimed at identifying the approximate age and location of residence of fishermen in GMNP, average length of a charr fishing career in GMNP, the preferred fishing areas, and the targeted species in GMNP. Next, fishermen were asked to identify the timing of their recreational fishing activity, which indicated whether they were fishing for anadromous (sea going) or resident (freshwater only) brook charr. They were also asked to compare the current catch rates, fish sizes, and number of fishermen to those from 10 years ago in order to assess changes in the fishery over time. Finally, fishermen were asked to rank the importance of bag limits, season length, effectiveness of enforcement, amount of poaching, and commercial fisheries in terms of their impact on the recreational fishery on a scale from 0 – 6, where 0 was not important and 6 was very important. This section also included several open-ended questions in which fishermen were asked to suggest areas for improvement in the management of the recreational brook charr fishery (see Appendix II for full survey).

3.2.2. Case 2: Arctic charr in Pistolet Bay

The Save Our Char Committee was formed in 2007 as an initiative to monitor and preserve Arctic charr stocks in Pistolet Bay, Newfoundland. In conjunction with the current research, a survey was created in 2009 to gather local fishermen's knowledge in this area to provide insight into changes in the stock from the users viewpoint and user opinion of current management regimes and improvements for the future. Arctic charr recreational fishermen were surveyed between June and December 2009. The target group included fishermen who fished recreationally in the Pistolet Bay area of Newfoundland and Labrador (Fig. 3.1b). Information about the survey was disseminated via radio advertisements. In those advertisements, fishermen were told where they could pick up surveys and asked to mail completed surveys to the Save Our Char Committee. Each respondent participated anonymously and voluntarily.

Survey questions were similar to those used in the brook charr survey and were separated into four sections: 1) demographics; 2) char life history; 3) catch information;

and 4) questions about fisheries management. The survey also included some questions on charr and Atlantic salmon stock statuses. Surveys were self-administered and the survey took no longer than 20 minutes to complete.

Fishermen participated were first asked questions related to their fishing experience and background. These questions provided information on the age range and communities of origin of fishermen, trends in the average length of Arctic charr caught over their fishing careers in the St. Anthony area, as well as information on their preferred fishing areas and targeted species. Next, fisherman were asked to discuss the timing (season) of their recreational fishery and to compare their current catch rates, fish sizes, and the number of fishermen in recent years to those from 10 years ago in order to assess changes in the fishery over time. Finally, fishermen were asked to rank on a scale from 0 – 6, where 0 was not important and 6 was very important, the importance of bag limits, season length, effectiveness of enforcement, amount of poaching and commercial fisheries in terms of their impact on the recreational fishery. This last section of the survey also included several open-ended questions in which fishermen were asked to suggest areas for improvement in the management of the recreational Arctic charr fishery in the area (see Appendix III for full survey).

3.2.3. Data Analysis

All distribution data were analyzed using Systat 13 and JMP IN v. 9.0.2., part of the SAS Institute of products. Normality was checked and data were transformed to satisfy this condition where it was violated.

3.3. Results

3.3.1. Case 1: Brook charr in Gros Morne National Park

3.3.1.1. Demographics

In the five months of survey sampling, 30 fishermen agreed to participate in the survey. The average age of participants was 46 ± 14 (± SD), with the oldest participant being 76 and the youngest being 20 (note only 26 fishermen agreed to answer this question). The most frequent age group was 36-45 with 50% (N=13) of participants falling into this category. The distribution of the remaining age categories was: less than 25 with 8% (n=2), 26-35 with 8% (n=2), 46-55 with 15% (n=4), 56-65 with 4% (n=1), and over 65 with 15% (n=4). The average fishing experience for the participants within the GMNP area was 23 years, with a maximum of 53 years and a minimum of three (N=30). Of the 30 fishermen surveyed, 27 take part in the spring/summer fishery for anadromous charr and 10 participate in the winter fishery for freshwater charr; only three participants were solely winter fishermen.

The large majority of fishing for brook charr in the GMNP area is done by residents, with 84% of respondents living within the park (N=25), and all of the remaining respondents living within Newfoundland. All of the respondents target brook charr in GMNP, but only one fishes solely for charr. Sixty-nine percent of respondents reported fishing for mackerel and/or salmon, as well as brook charr, and 46% reported also fishing for cod (Fig. 3.2).

3.3.1.2.Responses Regarding Catches

Based on responses from 30 fisherman, the spring and summer fishery for brook charr in GMNP begins in the middle of May and ends in the middle of August, whereas the winter fishery begins in February and goes until the middle of April, which both fall within the open season for the fishery (summer: May 1 to first week of September, winter: February 1 to April 15). In the spring/summer fishery, fishermen reported fishing in fresh, estuary, and marine waters, which differs from the winter fishery, which takes place exclusively in fresh water. For both of these fisheries, the majority of fishermen in the GMNP area will keep all of their catch if fish are large enough to eat (68% of respondents).

When asked how the fishery has changed over time, over half of fishermen reported that there had been no change in the number of charr fishermen in the area, as well as no change in the size of fish they catch (Fig.3.3). However, the majority of fishermen reported that there were fewer fish in the area, making their catch rates per day lower than they were 10 years ago (Fig.3.3).

3.3.1.3. Responses Regarding Management

The large majority of fishermen in GMNP (77%) indicated that the bag limit (2.2kg or 12 fish +1) imposed on the fishery is appropriate (Table 3.1). Similarly, all but one of the respondents considered the seasonal closure (open Jun. 15 – Sep. 7) of the fishery to be appropriate, with only one respondent suggesting that the closure is unnecessary (Table 3.1). This response was reiterated by fishermen when rating the importance of bag limit and season length for the health of the fishery (Fig. 3.4), where respondents considered both to be of high importance. Additionally, the majority of fishermen believed that monitoring and enforcement were very important (scored as 6) to fishery health (65.4%), and all of these respondents commented that there is a lack of enforcement in the area; however, only half of respondents (50%) considered poaching to be a very important issue (scored as 6) in GMNP (Fig.3.4). Finally, the most frequent response from fishermen (38.5%) regarding the effect of commercial fisheries (by-catch) in GMNP on the brook charr fishery was that it was not important, while the second most frequent response (26.9%) was that it was very important to the health of the brook charr fishery (Fig.3.4). When asked what commercial fisheries may have brook charr as by-catch, fishermen named the purse seine and gillnet fisheries.

The largest number of fishermen did not have any suggestions for improvement of the management of the brook charr fishery in GMNP (36%; Fig.3.5). Several respondents suggested limiting access to the fishery by increasing the number of no-fishing zones (28%) and 24% respondents suggested increased enforcement/monitoring (Fig.3.5). Another suggestion was to decrease the bag limit to reduce the amount of fish being taken out of rivers in GMNP (Fig.3.5).

3.3.2. Case 2: Arctic charr in Pistolet Bay

3.3.2.1. Demographics

During the 5 months when the survey was available to recreational fishermen, 17 fishermen completed the survey. The average age of participants was 59 ± 13 (± SD), with the oldest participant being 76 and the youngest being 32. The largest age group was 46-55 years of age, with 29% of participants falling into this category. The distribution of the remaining age categories was: <25 (0%); 26-35 (12%), 36-45 (18%), 56-65 (24%), and over 65 (18%) (N=17). The median number of years of fishing experience within the St. Anthony area for the participants was 33 (upper quartile = 41, lower quartile = 20), with a maximum of 60 years and a minimum of 15 years of experience (N=17). Of the 17 fishermen surveyed, 71% were from St. Anthony and all but one of the remaining fishermen were from the Northern Peninsula. The one exception was from Goose Bay, Labrador. All participants indicated that the Northern Peninsula was their preferred fishing location.

3.3.2.2. Responses Regarding Catches

The targeted species for survey respondents were salmon (15/17 respondents), brook charr (all respondents) and Arctic charr (15/17 respondents), with cod, lobster, mackerel, and others, including cunner and smelt, being caught/sought after less frequently. Fishermen in the area keep the fish they catch on average 79% of the time, with the majority reporting that mid-sized fish are kept, which is in line with fishing regulations that limit the take of large fish.

Survey results indicate that respondents start fishing for Arctic charr in the Parkers Brook area (Fig. 3.1a) in July, but some start as early as mid-May or as late as mid-July. The fishing season is over by August/September, which is in line with fishing regulations (open until first week of September). Fishermen were asked where they fish in each season from three categories: 1) freshwater (Parker's and other brooks), which are brooks/rivers leading into the open marine bay; 2) headwaters (Western Brook and/or

Stock Pond), which are upstream areas of freshwater that feed rivers to the sea; or 3) marine waters (e.g. Cooks Harbour, Raleigh) (Fig. 3.1a). In the spring, fishing takes place mainly in fresh and salt water, with only one respondent reporting fishing in headwaters during this time. The summer season is similar to the spring, with most respondents reporting fishing in the fresh waters, marine waters, and few fishing in all three areas. In the fall, the majority of participants report fishing in fresh water; however, in winter they fish more often in the headwaters than in either fresh or marine waters.

When asked how the fishery has changed over time, the large majority of fishermen reported that fish are both smaller now and less numerous than they were 10 or more years ago (7/10 and 16/17, respectively) (Fig.3.6). Fishermen attribute this change to a variety of factors including commercial seine vessels (6), overfishing (6), seals (3), poaching (1), and commercial vessels (2) (participants could suggest more than one factor). Additionally, the majority of participants believe that the number of fishermen in their area targeting Arctic charr has decreased by 50% over time, with few respondents suggesting that the number has increased by 50% (10/17 versus 4/17, respectively); the remaining three respondents saw no change in the number of fishermen in the area (Fig. 3.6).

3.3.2.3. Responses Regarding Management

Half of the fishermen in the Pistolet Bay area indicated that the bag limit (2.2 kg total weight or 12 fish with +1 fish for each condition) imposed on the fishery was too high, indicating that these respondents would support the lowering of the limit. The other half of the fishermen responded that the bag limit was appropriate (Table 3.2). Similarly, a large majority of respondents believe that the year-round closure of the area of Parkers Brook from the highway to the mouth of the river, is appropriate, with few respondents considering this closure inappropriate based on a lack of fishing in that area (Table 3.2).

When asked to rank the importance of several management requirements from 0 to 6 (0 being not important and 6 being very important), the majority of fishermen did not believe that either the bag limit or the seasonal closure were "very important," but rather felt that the negative effects of commercial fisheries was the most important factor affecting the Arctic charr fishery (Fig. 3.7). When asked which commercial fisheries may have Arctic charr as by-catch, fishermen identified mainly the purse seine fisheries (12), with a few respondents identifying the gillnet fisheries (10). Moreover, the majority of survey respondents indicated that the effects of the purse seine fisheries on char in the area are great and that further monitoring and enforcement are necessary in order to preserve the species and the fishery, as is additional scientific research (Fig. 3.7).

3.4. Discussion

3.4.1. Recreational Fishermen Surveys – Case Studies from Two Char Fisheries in Newfoundland

The results of this study shed light on the current state and historical changes for the two fisheries studied, as well as a means of gauging resource user opinion of current management regimes. In both cases, the sample sizes were not large; however, they reflect the small human populations in these rural areas, and thus, the samples are likely reflective of general opinion. As Newfoundland has the highest percentage of resident fishermen, as opposed to non-resident fishermen, and the highest percentage of fish caught and kept in Canada (DFO 2010), these fisheries are potentially at increased risk to over-exploitation, as compared to catch-and-release fisheries, which predominate in other provinces (Cooke and Schramm 2007). Fishermen surveyed largely target sea-run members of the char populations, which already face increased risks associated with anadromy, including the energetic costs of migration and increased exposure to predation, disease and commercial fishery by-catch (Copes 1977, Arnesen et al. 1993, Jonsson and Jonsson 1993, Due and Curtis 1995). In both case studies, fishermen's knowledge could likely be advantageous for management, but each fishery has unique characteristics in terms of location, species, and fishermen in the area.

The fishermen surveyed in Gros Morne National Park regarding the brook charr fishery were, on average, experienced brook charr fishermen in the area; therefore, the information gathered should reflect current conditions, as well as changes they have seen in the fishery. The survey indicated that fishing is primarily conducted by resident fishermen and not noticeably affected by tourism. This is further supported by their assessment that the number of fishermen has not been increasing over the past 10 years. As for the most part, all fishermen observed at the two study sites during biological sampling (see Chapter 2) were surveyed, we have confidence that results come from the primary resources users.

Overall, these resident fishermen in GMNP feel that current management regimes are appropriate despite the decrease in the number of fish in the area that they have observed. This is paralleled in a study done on brook charr angler attitudes from the Avalon Peninsula of Newfoundland, where they reported a decline in the fishery but did not think it warranted a change in regulations (Perry et al. 2010). In the case of the Avalon Peninsula, fishermen also suggest that lack of enforcement is the problem and not inappropriate regulations (Perry et al. 2010), which was also observed by fishermen in the GMNP area as they also approve of current regulations and agree that more enforcement is the key for management. In GMNP, this is conflicting, as they do not consider poaching to be a problem in the area. The fishermen also do not appear to be concerned about the stock health or motivated to improve fishery practices, for example by switching to catch-and-release angling. Since the fishermen largely keep all fish caught, as evident from official records (DFO, 2005) and from our results, the fishery could be at risk of overexploitation, which is supported by fishermen's view of decreasing numbers of charr. Despite this risk, it is important to consider that this is a subsistence fishery and may be an important source of food for rural populations. Stock assessments conducted using existing Parks Canada fish fence counts would be necessary to provide biological data to compliment surveys and confirm stock status. If the fishery were overexploited, the effect of migratory bottlenecks where sea-going fish are known to pass could be an area for future research as they may increase fish vulnerability.

Results from Arctic charr fishermen surveys indicate that fishery health is decreasing in terms of both size and number of fish. They also indicate a decrease in the number of fishermen, which may benefit recovery of the Arctic charr population, or could simply be a result of fishermen's perception of the health of the fishery (i.e. lack of fish resource or self-imposed management). The decrease in numbers of fishermen may also be attributed to a decrease in fishing in Newfoundland in general (DFO 2010) as opposed to a fishery-specific decrease; however, this was not reflected in the brook charr fishery survey. The results also highlight the changes in Arctic charr fishermen's effort depending on season, which may be useful for future studies and management decisions.

Arctic charr fishermen in the Pistolet Bay area are increasingly concerned about the health of the fishery. The most predominant opinion is that commercial seine vessels fishing for pelagics in the Pistolet Bay area are the main factor in the decrease in char numbers, and that more monitoring and enforcement is needed for the fishery. Further research, including by-catch assessment, is necessary to determine the extent of fishery decline, which is clearly visible to fishermen in the area, but without historical data it may be difficult to quantify. Research focused on the potential threats to the fishery and avenues for reducing these threats may be essential for ensuring persistence of the char population in the area.

Sampling methods used for surveys in this study differed somewhat between the two study sites, with the Gros Morne fishermen being approached in person or by telephone via snowball sampling and the Pistolet Bay fishermen being self-selected respondents. This may have affected the responses obtained. In person surveys may be different than self-directed surveys in terms of the detail of information and the content, since the interviewer can prompt for more information or the fishermen may feel less comfortable providing information. For self-selected surveys, there is no opportunity to ask for additional information or clarification from respondents, but they are also more likely to be more candid in their responses, as they are fully anonymous.

Despite sampling differences, the results shed light on changes in the fisheries in the regions over time, as well as highlighting the importance of continuing to monitor these systems. Fishermen from both fisheries identified some form of decline in either numbers and/or size of fish, which may be incentive to begin stock monitoring programs to give scientists a better understanding of current conditions. Brook charr fishermen also supported current management regimes, suggesting that there is not a need for improved regimes. By contrast, Arctic charr fishermen in Pistolet Bay are highly motivated to implement change and increase stock numbers. Both groups, however, support the idea of increased enforcement and monitoring.

3.4.2. Recreational Fisheries – Insights from Newfoundland.

A key aspect to recreational fisheries management, reported in previous studies and highlighted by the case studies from Newfoundland presented here, is both the potential importance of stakeholder involvement and benefits of formal institutions to serve as a forum for fishermen generated ideas and knowledge (Sutinen and Johnston 2003, Hilborn et al. 2005, Nussman 2005. Gelcich et al. 2006, Gelcich et al. 2009, Gerhardinger et al. 2009, McClanahan et al. 2009, Keefe and Perry 2010). As resource users, fishermen have insights into not only current stock health, but also historical changes in stock numbers and fishing practices (Salas and Gaertner 2004, Nussman 2005, Granek et al. 2008, Keefe and Perry 2010, Silvano and Begossi 2010). Their knowledge can be key in setting up relevant monitoring or management regimes, which are both site and population specific. Additionally, motivated and engaged fishermen are more likely to make informed decisions when it comes to fishing practices, and having fishermen support for management regimes is essential in helping to ensure compliance (Arlinghaus 2006, Granek et al. 2008). However, without organized structures to gather knowledge and gauge resource user opinions of management strategies, these important stakeholders with valuable knowledge may be overlooked.

In Pistolet Bay, a group of concerned community members and fishermen have joined together to protect the Arctic charr recreational fishery in a formal committee, the Save Our Char Committee (SOCC); this type of institution is lacking in the brook charr fishery in Gros Morne National Park. The differences in fishermen's involvement and interest in the health of the fishery is apparent in the survey responses, specifically in the support for new management measures. As brook charr fishermen in the Gros Morne area are often targeting other species and catching charr opportunistically, their interest in this recreational fishery was much lower, proven by conflicting answers and satisfaction with current management regimes despite decreasing fish numbers. Conversely, the fishermen in Pistolet Bay support the listing of Arctic charr in that area as a species at risk, and, in a large majority, considered purse seine practices to be the cause of decreasing stock size. They also are engaged in management and monitoring of the char fishery, and support and encourage future research and monitoring. Having a motivated fishermen's institution can not only provide support for management objectives, but manpower and funding for science and monitoring programs; therefore, managers should continue attempts to engage fishermen in management, collect fishermen's knowledge, and communicate with fishermen (Sutinen and Johnston 2003, Bruckmeier et al. 2005, Hilborn et al. 2005, Granek et al. 2008, McClanahan et al. 2009).

3.4.3. Co-management in Recreational Fisheries – Challenges and Future Directions

Needless to say, co-management may not be the best management regime in all cases, therefore, several researchers have attempted to identify the preconditions and essential components of co-management (Gelcich et al. 2006). As summarized by many researchers in the field, preconditions for co-management include a precursor, such as stock collapse, environmental degradation, or another indicator of increased exploitation that may lead to collapse, willingness for both the local user and government to participate in management, opportunity for negotiation, formal institutions to generate ideas, educational opportunities to inform of risks, leadership, and a common vision or networking system (Sutinen and Johnston 2003, Plummer and Fitzgibbon 2004, Granek et al. 2008, McClanahan et al. 2009). Once preconditions have been met, co-management regimes should allow for diverse interests to be taken into account, networking and communication between interest groups with decisions made based on this dialogue, transfer of knowledge between interest groups, and shared action taken by all user groups (see Olsson et al. 2004, Plummer and Fitzgibbon et al. 2004). These steps can provide the framework for creating co-management regimes.

Recreational fisheries may provide a good opportunity for co-management regimes due to the participants' interest in the health of specific fish stocks. Recreational fishermen are globally diverse; where in some areas they fish for pleasure and others they fish for subsistence (Arlinghaus and Cooke 2005, Granek et al. 2008, Gelcich et al. 2009). In the case of subsistence fishing, fishermen are usually found exploiting resources in their local communities and require this resource for survival, giving them a vested interest in the health of their fish stock (Arlinghaus 2006, Granek et al. 2008). There is a similar interest for recreational fishermen who fish for pleasure as their leisure activity depends upon healthy fish stocks (Arlinghaus 2006, Granek et al. 2008). With such strong interests in the fish stock, recreational fishermen are likely to participate in co-management regimes willingly and their participation can be necessary in some cases if resources are to be maintained (Granek et al. 2008, Eden 2012).

Due to the diverse and varied interests of recreational fishermen, co-management in the recreational fisheries sector must be more decentralized than current management practices by having local organizations sharing responsibilities with government in order to maintain community interest (Sutinen and Johnston, 2003). If members are made to feel a part of the process and the solution, they will be more likely to continue to lend support and participate in discussions that will lead to successful co-management (Sutinen and Johnston, 2009). Additionally, they will gain knowledge of fishery conditions and dynamics, giving the possibility of a change in behaviour to improve conditions, outside of management regimes (Salas and Gaertner 2004). These conditions and mechanisms should be used in the recreational sector to implement co-management.

Despite the advantages identified above, there are still obstacles to overcome in co-management of recreational fisheries. In a review by Arlinghaus (2006), he identifies nine obstacles to co-management which are 1) lack of social priority, 2) lack of integrated approaches, 3) lack of cooperative linkages, 4) lack of system thinking, 5) lack of monitoring, 6) lack of shared values and dominance of stereotyped perceptions, 7) lack of consideration for regional fish-angler dynamics, 8) lack of objective communication of scientific findings, and 9) lack of critical self-reflection among individual anglers. These obstacles are not without solutions and can be overcome by facilitating interactions between stakeholders, increasing communication of science, applying active management regimes, fostering common interests, and detailed evaluation of socioeconomic value of angling (Arlinghaus, 2006).

Other obstacles include those highlighted here, which showed the difficulty in implementing co-management in fisheries without engaged fishermen. In order to overcome this obstacle, managers must foster a sense of responsibility and interest in fishermen by public outreach, which includes education as this important resource user is necessary to the effective management of recreational fisheries (Pereira and Hansen 2003, Salas and Gaertner 2004, Arlinghaus 2006). By understanding the preconditions, diverse stakeholder interests, and overcoming the challenges, recreational fishery co-management regimes can be effective ways of conserving at risk biologically and socio-economically important resources.

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Fig. 3.1. Locations of the study sites on the island of Newfoundland, Canada, (a) Northern Peninsula and Pistolet Bay, and (b) Gros Morne National Park.

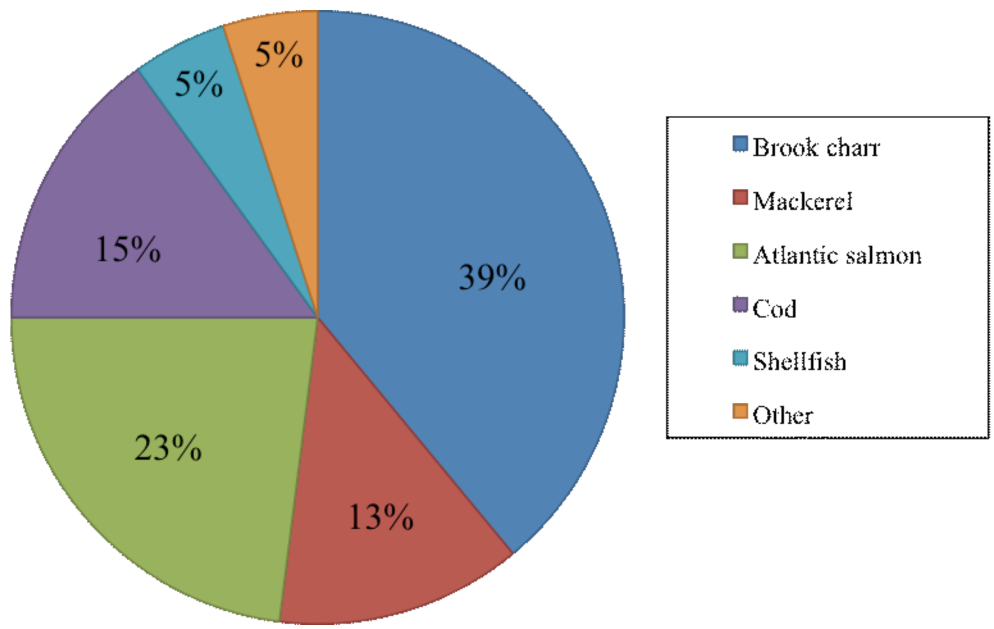

Fig. 3.2: Species targetted in Gros Morne National Park, Newfoundland, as reported by surveyed fishermen in the area (N=30).

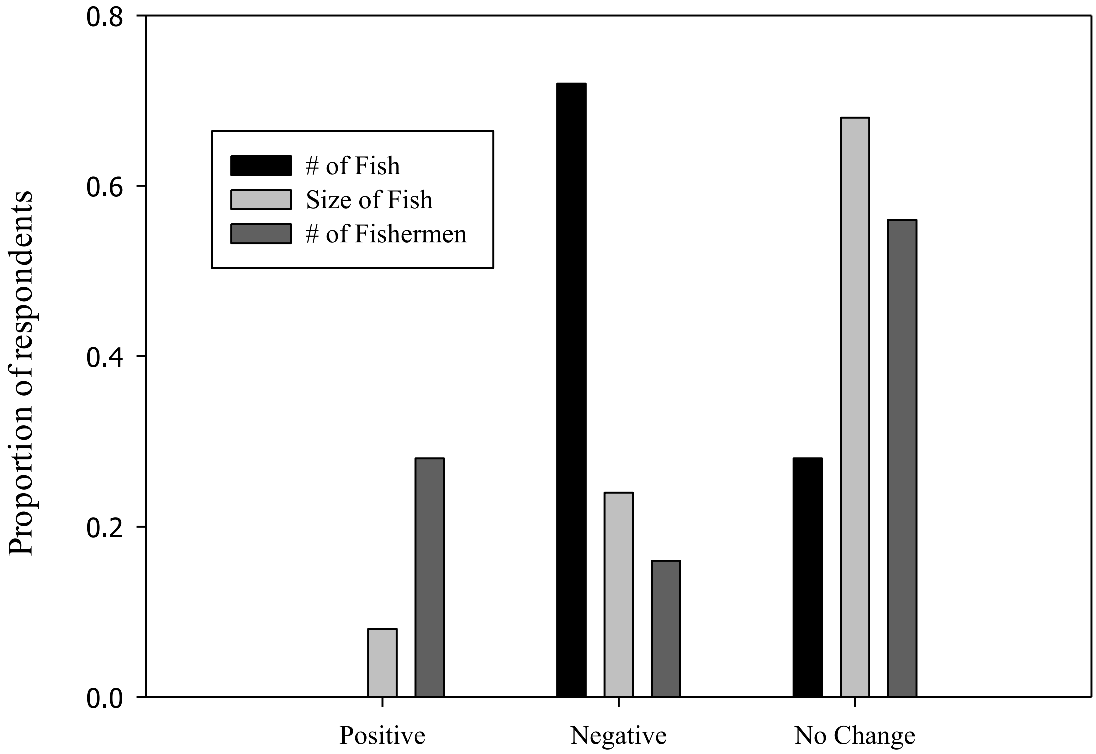

Fig. 3.3: Changes in fishery over time as observed by brook charr fishermen in Gros Morne National Park, reported as a proportion of respondents (N=25).

Table 3.1. : Approval of management measures currently in effect in Gros Morne National Park, reported as the frequency of each response (N=30).

Management	Response	Frequency
Bag limit	Too high	5
(2.2 kg or 12 fish +1)	Appropriate	23
	Too low	2
Season closure	Appropriate	29
(open Jun. 15 – Sep. 7)	Inappropriate	0
	Other: no effect	1

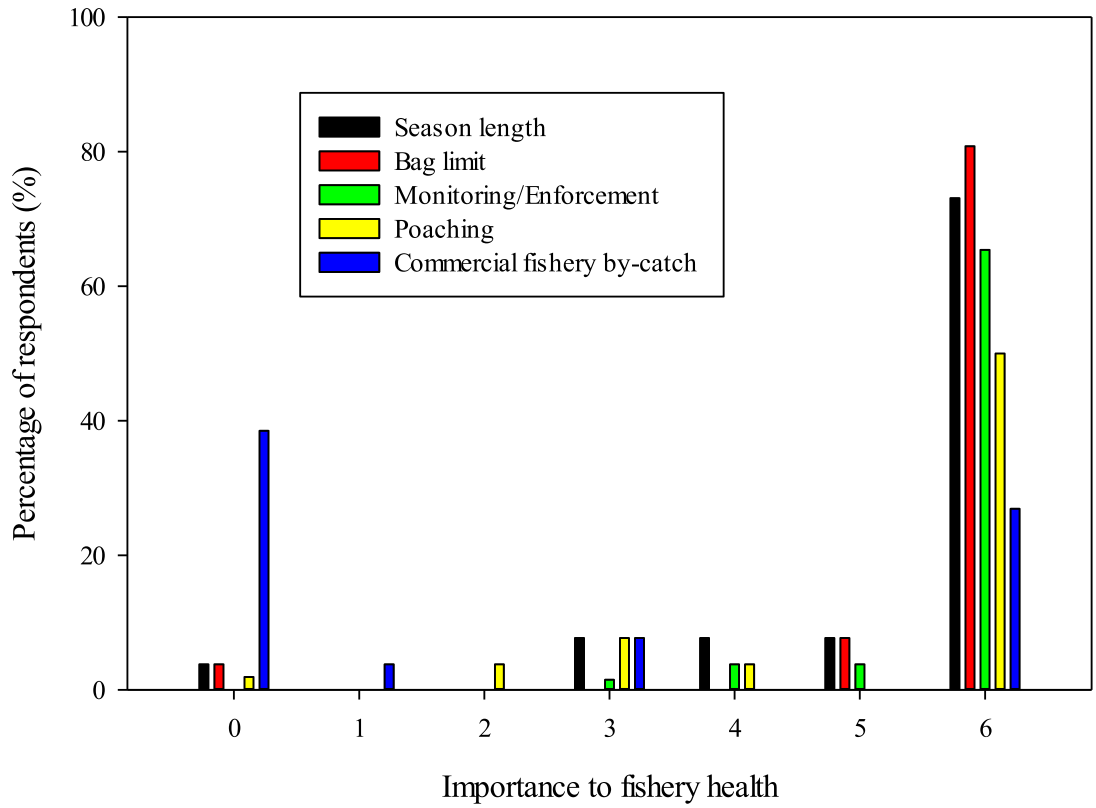

Fig. 3.4: The importance of various measures on the brook charr fishery in Gros Morne National Park as identified by fishermen in the area, reported as a percentage of each response (N=28).

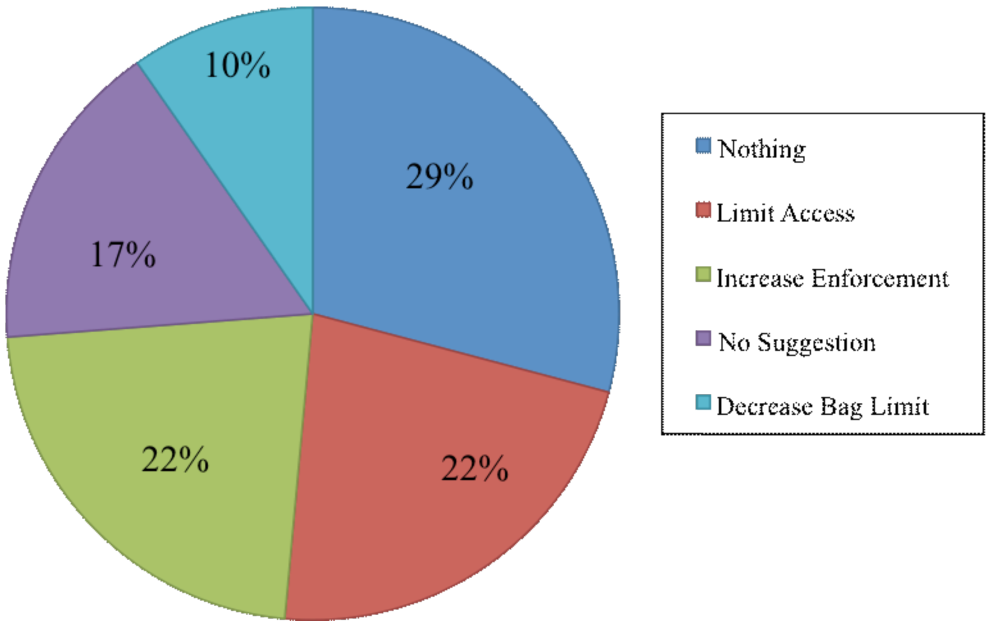

Fig. 3.5: Fishermen's suggestions for improving brook charr fishery health in Gros Morne National Park, Newfoundland (N=25).

Table 3.2: Approval rating of management measures for the Arctic charr fishery currently in effect in the Pistolet Bay area, reported as the frequency of respondents (N=17).

Management	Response	Frequency
Bag limit (N=16)	Too high	8
(2.2 kg or 12 fish +1)	Appropriate	8
	Too low	0
Season closure	Appropriate	14
(N=17)	Inappropriate	3
(all year)	Other	0

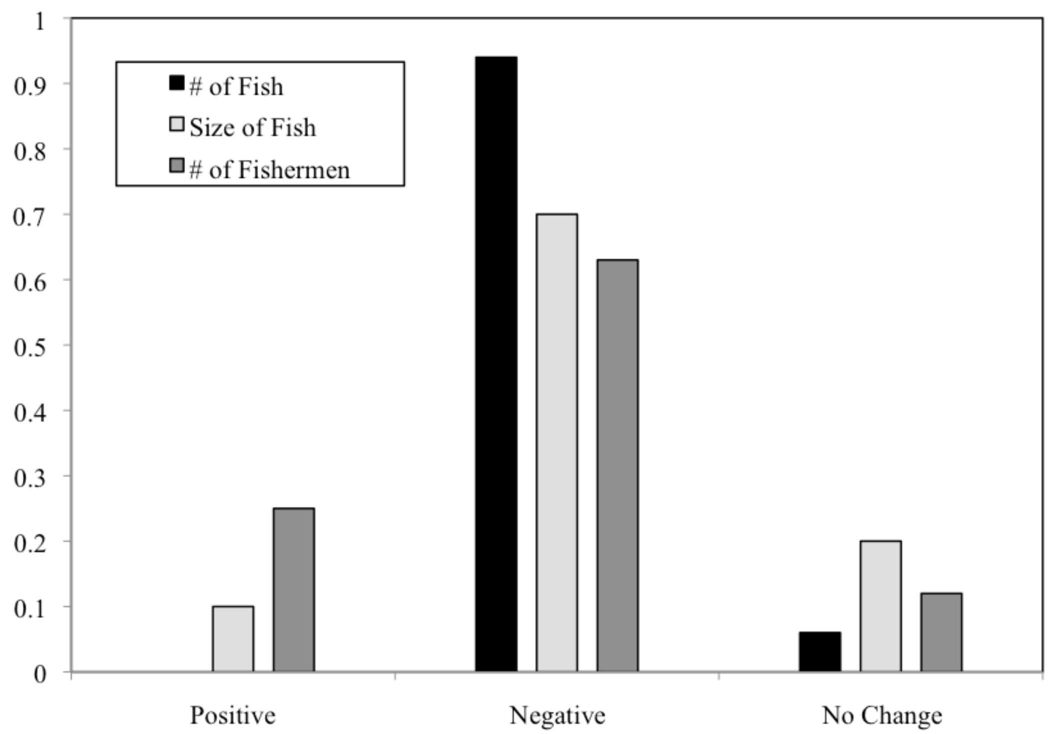

Fig.3.6: Changes in the Arctic charr fishery over time as observed by fishermen in the Pistolet Bay area, reported as the proportion of respondents (N=17).

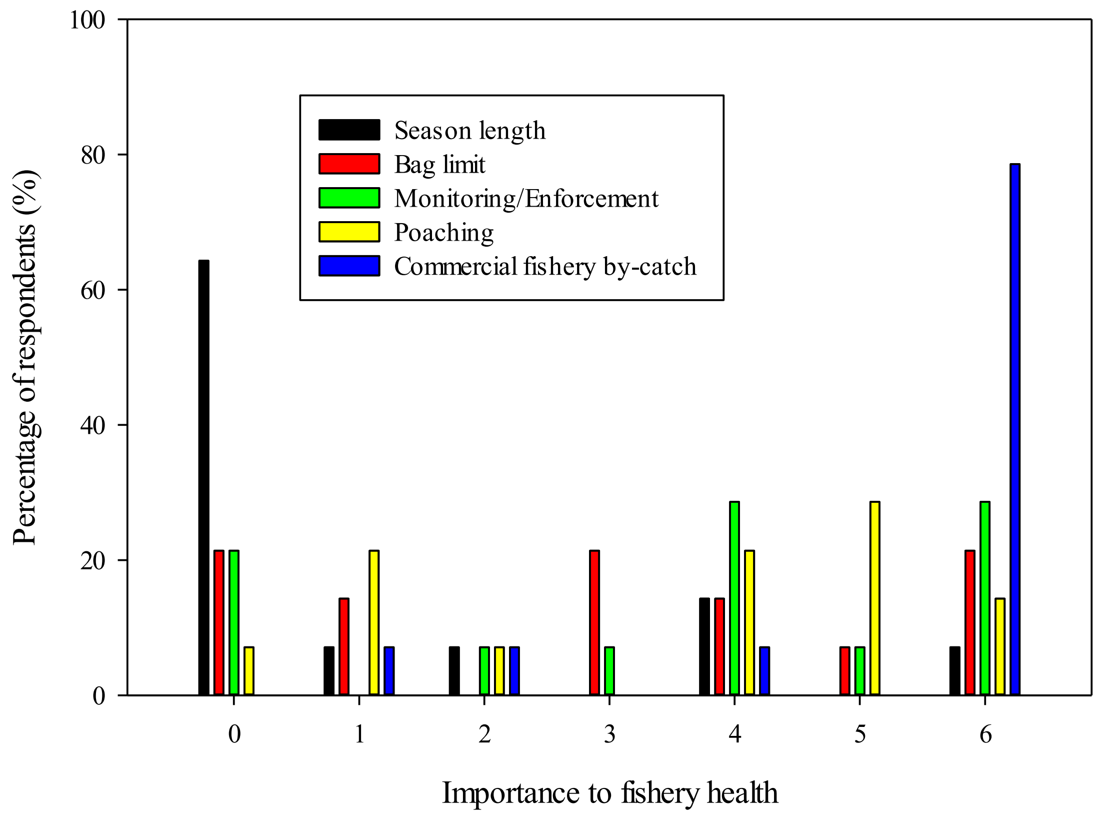

Fig. 3.7: The importance of various measures on the health of the Arctic charr fishery, as identified by fishermen in the Pistolet Bay area (ranked from 0-6, with 0=not important and 6=very important). Percentage of fishermen who selected each ranking is shown (N=17).

Chapter 4.0. Summary and Conclusions

Charr are targeted by recreational fisheries across Canada (DFO 2010). Some populations of char can display partial migration, with some individuals migrating to sea and others remaining resident in freshwater environments. Often recreational fisheries target the anadromous (sea-going) individuals, making them at higher risk to human influences. As such, more attention is required to ensure fish populations that exhibit partial migration are managed in such a way as to ensure stocks remain healthy for fisheries activities (Jonsson and Jonsson 2003). In cases where there is risk of overexploitation and collapse, comprehensive co-management regimes may be employed, with both biological and sociological factors considered.

Local ecological knowledge can be a useful tool in developing the sociological component for co-management. Knowledge can be used and combined with scientific data to provide information on fish biology and stock health, to identify past and present trends in catchability, to inform future science, and to increase awareness of the stock size and fishery interactions (see Berkes, 1999). Furthermore, Holm (2003) describes the use of local ecological knowledge as either hypotheses used to predict what will be found by science, or as data, suggesting that collecting knowledge can serve as a first step in research programs. Incorporating these two factors gives a more complete picture of current conditions and a better way of predicting change in the future.

In the current study on brook charr in Gros Morne National Park, Newfoundland, biological data on fish distribution and both short and long term migratory behaviour were collected, along with knowledge from local fishermen regarding changes in the fishery over time. These data provide a better understanding of the migratory behaviour of brook charr and how the recreational fishery in Gros Morne National Park impacts these fish. Migration data and previous research indicate that fish spend the majority of their time in a brackish environment, close to the mouths of rivers, taking advantage of rich food sources in that area (Currie 2009, Curry et al. 2010). Despite the data showing that the majority of tagged fish ventured out of more protected waters, these migrations were for a proportionally smaller amount of time than was spent within the protected area (Chapter 2, Fig.2.5). This can be compared with fishermen's knowledge for our study sites in that the majority of fishermen participate in a spring-summer fishery, when they focus their attention on charr at river mouths, estuaries, and in the sea (often due to restrictions), indicating that anadromous members of the population are at greater risk to fishing mortality than resident members in the Park.

From migration patterns (Chapter 2), the majority of fish make short trips to the estuary habitats and back to the mouth of the river, never entering the open ocean for the duration of their time in the saline environment, which makes them highly susceptible to fishermen focusing in those areas. The majority of fishermen approached for this study were encountered while fishing at the mouth of Western Brook (22/30). Given that fishermen report a decrease in numbers of fish (Chapter 3, Fig. 3.3), understanding the effect of their activities at migratory bottlenecks is a key next step for further research.

Otolith microchemistry provides long-term migratory trends for anadromous charr. From this analysis, the median age of first seaward migration is two years and subsequent migrations do not demonstrate a specific pattern. As previously mentioned, fishermen are targeting bottlenecks at the mouth of rivers as freshwater habitats are protected by Parks Canada in Western Brook during the summer months, which makes fish leaving susceptible to fishing pressures. At age two, fish have likely not yet contributed genetically to the population, but as they are smaller fish they are likely not targeted by the fishery (O'Connell 1983, Curry et al. 2010). However, the average age of fish caught for this study was three, which could suggest that fish have only had the opportunity for one spawning season before being caught (O'Connell 1983). Further research could focus on determining the effect of this fishing pressure on the proportion of anadromous individuals in a population, as anadromy is thought to be partially driven by genetics (Jonsson and Jonsson 1993, Brodersen et al. 2008).

Recreational fisheries survey data from our two case studies in Newfoundland have emphasized the importance of fishermen involvement in generating knowledge, and encouraging compliance and participation in management regimes. The numbers of fish from both the brook charr and the Arctic charr populations have decreased over the last 10 years, according to the majority of fishermen surveyed (Chapter 3, Fig. 3.3 & 3.6, respectively); however, Arctic charr fishermen have remained motivated to improve their fishery and through a formal institution, the Save Our Char Committee, have started a fishermen supported research program. Brook charr fishermen in the Park have no such institution; however, during our study, 30 fishermen participated in a survey, and many donated charr heads for otolith analyses, suggesting that when engaged they are interested in participating in fisheries research. This is encouraging for future fisheries research in Gros Morne National Park, and indicates to managers that if fishermen are not forming an institution on their own, they may still be willing to provide knowledge for comanagement of the brook charr fishery.

Further research should focus on gathering more information on the interaction of fish and fishermen. At the Gros Morne National Park sites studied here, there is an opportunity for future study in that Parks Canada constructs a fish counting fence at the mouth of Western Brook every year, and Deer Arm Brook during some years to monitor Atlantic salmon populations. As brook charr are generally smaller in size than salmon, in the future, Parks Canada could consider decreasing the spacing of the fencing rods and thus reduce the size of fish that can pass through the fence, generating a more complete dataset on timing and size of fish at migration. Researchers could also use it for a variety of projects, such as growth measurements and further tracking studies. Additional information should be collected on the number of anadromous fish leaving the brook and the returns, to generate mortality at sea estimates, along with an assessment of the number of fish caught and removed during a fishing season. More work could also focus on comparing the anadromous individuals to the residents in terms of overall condition, fecundity, and survival (i.e. fitness and their contribution to population dynamics).

With the growing understanding of the potential impacts of recreational fisheries on fish stocks, it becomes imperative to develop new and adaptable ways to manage and maintain these fisheries (Post et al. 2002). Here we highlight the importance of understanding the life history of species in order to protect them in their vulnerable states, whether that is during spawning season or migration. Also, the use of co-management may be appropriate for some recreational fisheries and having an engaged and active fishermen group will facilitate this management strategy, and ensure that it is effective in maintaining healthy stocks.

4.1. References

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APPENDIX I: Hydrophone Deployment

Fig. Example of a hydrophone from **www.vemco.com**.

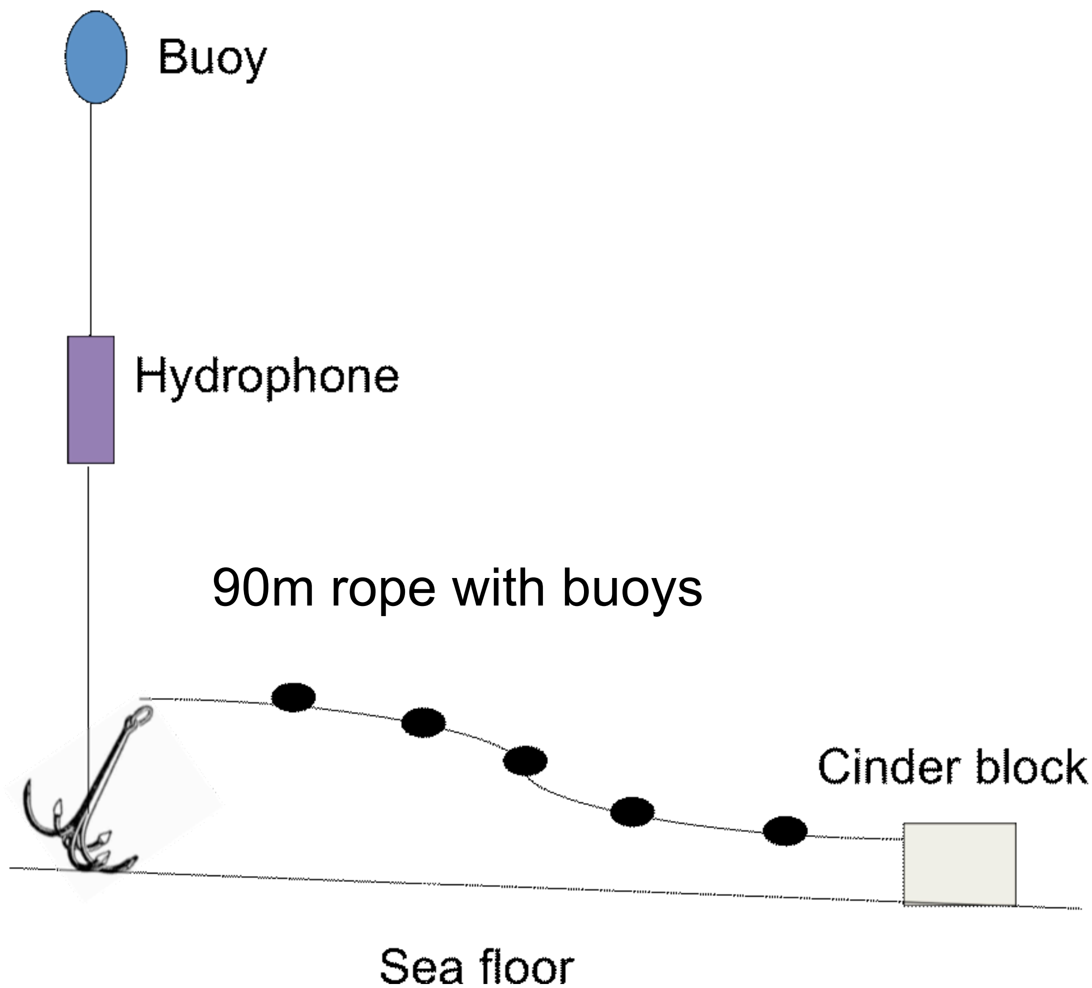

Fig. Hydrophone deployment method

APPENDIX II: Gros Morne National Park Fishermen Survey

Recreational Fishermen Survey – Gros Morne National Park

Fisher Surveys – Introduction

The following survey is being conducted by researchers from Memorial University of Newfoundland in conjunction with the Community University Research for Recovery Alliance (CURRA) in partnership with Parks Canada. The purpose of this survey is to gather local ecological knowledge regarding brook trout (see pamphlet for a picture and more information) life history for populations in Gros Morne National Park. The research is also aimed at gaining a better understanding of commercial and recreational fisheries in the area in order to assess potential impacts on brook trout populations. The results of this research will be combined with biological assessments in the area in order to increase general knowledge of the area and help with fisheries management. We will make results of the survey accessible on the CURRA website (http://www.bonnebay.mun.ca/curra/curra_home.htm) and will present findings at town meetings in communities of Gros Morne National Park.

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University 's ethics policy. If you have ethical concerns about the research (such as the way you have been treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 737-8368. The supervisor for this research is Dr. Ian Fleming. Dr. Fleming can be contacted at …

Participation in this survey is free and voluntary and participants are free to withdraw at any time or to refuse to answer any questions without explanation. Participants will remain anonymous and no names will be used in any reports or publications from this work.

Completed surveys should be returned in person to the researcher or by mail using the enclosed self addressed stamped envelope addressed to:

Michelle Caputo
Bonne Bay Marine Station
P.O. Box 69
Norris Point, NL
A0K 3V0

Demographics:

1. How old are you?

____

2. What community do you live in?

____

3. Where is your preferred spot to fish in Newfoundland?

____

4. How many years have you fished

   recreationally?__________________________________

5. How long have you fished recreationally in the Gros Morne

   area?____________________

6. What species do you fish for in this area? (check all that apply)

   _____ salmon
   _____ brook trout (mud trout, sea trout, brookies, trout, etc.)
   _____ brown trout
   _____ rainbow trout
   _____ cod
   _____ mackerel
   _____ other: ____________________________

Questions pertaining to brook trout catches in the Gros Morne area:

NOTE: For the following questions, trout/sea trout will be referred to as brook trout

1. What date do you start fishing for brook trout in (If you only fish in one of these times, leave the other option blank):

   a. Winter _______________ b. Spring/Summer _________________

2. What date do you stop fishing for brook trout in:

   a. Winter _______________ b. Spring/Summer _________________

3. Where do you fish for brook trout in:

Spring: (check all that apply)

_____ Freshwater (e.g. lakes, brooks, streams, etc.)
_____ Estuaries
_____ Marine

Summer: (check all that apply)

_____ Freshwater (e.g. lakes, brooks, streams, etc.)
_____ Estuaries
_____ Marine

Fall: (check all that apply)

_____ Freshwater (e.g. lakes, brooks, streams, etc.)
_____ Estuaries
_____ Marine

Winter: (check all that apply)

_____ Freshwater (e.g. lakes, brooks, streams, etc.)
_____ Estuaries
_____ Marine

4. When you first started fishing for brook trout in the Gros Morne area, what was the average size of fish you caught?

5. In the past two years that you have been fishing for brook trout in the Gros Morne area, what was the average size of fish caught in:

6. Have you seen a change in the size of fish you catch over your fishing career?

7. When you first started fishing for brook trout in the Gros Morne area, what was a good number of fish/day to catch?

8. In the last two years in the Gros Morne area, what was a good number of fish/day to catch?

9. Have you seen a change in the number of fish you catch over your fishing career?

10. If you've seen changes in the size of the brook trout you catch over your fishing career in this area, what do you think is responsible?

____

11. Do you fish brook trout to keep, for catch and release angling, or both?

____

12. If both: what percentage of the time do you keep the fish you catch?

____

13. What kind of gear do you use to catch brook trout in the Gros Morne area?

____

14. What kinds of gear have you seen used to catch brook trout in the Gros Morne area?

____

15. What is the best tide for catching brook trout in estuaries and marine environments in the Gros Morne area?

____

16. When fishing for brook trout in the Gros Morne area, what other types of fish do you catch?

Questions pertaining to brook trout life history:

NOTE: If you don't know the answer to any/all of the questions, just leave them blank

1. What characteristics do you use to distinguish between brook trout and other species of fish?

____

2. In what kind of bottom habitat (muddy, rocky, grassy…) do you expect to find brook trout in the Gros Morne area?

____

In what kind of water habitat (rapids, pools, estuary…) do you expect to find brook trout in this area?

____

3. Do you have any thoughts about what might trigger brook trout migrations to the sea in this area (water temperature, tides, currents)? What makes you think these things are important?

____

4. In your opinion, roughly what percentage of brook trout in the Gros Morne area rivers go to sea? Do you think all trout in the area are sea-run or only some?

____

5. What sizes of brook trout tend to migrate to sea? A range of sizes or only small/large ones?

____

6. What months do brook trout spend in:

   a. Freshwater:___________________________
   b. Estuaries: ___________________________
   c. Marine: ______________________________

7. What do brook trout feed on in:

   a. Freshwater:___________________________
   b. Estuaries: ___________________________
   c. Marine: ______________________________

8. Do you have any idea when brook trout spawn? What makes you think they spawn around that time?

____

Questions pertaining to fisheries management:

1. How has the number of fishers in your area changed over time? (circle the one that applies)
    a. Increased by 50%
    b. Stayed the same
    c. Decreased by 50%
    d. Other:

The current fisheries regulations for brook trout in the Gros Morne National Park area state that fishing for brook trout is open between: February 1 – April 15, and May 15 – September 7. The bag limit for all trout is 12 trout or 5 lbs round weight (2.27 kg) + 1 fish, whichever limit is reached first of all species (brook trout, brown trout, speckled trout, and ouananiche) combined.

2. What do you think of the seasonal closures?

    a. Appropriate
    b. Inappropriate
    Comments:
    ____

3. What do you think of the bag limit? (circle the one that applies)
    a. Too high
    b. Good
    c. Too low
    Comments:____

4. If you were the minister of fisheries and had a chance to improve things for the recreational brook trout fishery in the Gros Morne area, what would you change and why?

    ____

5. Rank the following in terms of your assessment of their relative contribution to changes in the fisher of the Gros Morne area over your career (0-6 with 0 [not important], 1 least important and 6 most important (if you have not seen a change in this aspect of the fishery leave blank). Let me know how important you think these things are in either managing the fishery or causing changes in the number of fish.

___ season length
___ bag limits
___ monitoring
___ poaching
___ commercial fisheries bycatches (please rank each of the gears in terms of their relative importance to brook trout mortality)

- ___ gillnet
- ___cod trap
- ___ lobster
- ___ purse seine
- ___ etc. (please give us an example):

___ other:

We would like to do in depth interviews with recreational fishermen in the Gros Morne area who, in the opinion of their peers, are local experts with extensive experience in this recreational brook trout fishery. Would you be willing to suggest the names of 3 fishers in the area who are, in your opinion, local experts and who might be willing to participate in these in depth interviews?

Name 1:

Name 2:

Name 3:

Many thanks for participating in this survey.

Remember – if you want to learn about the results from our research, follow the progress of this study and watch for updates on our results at http://www.bonnebay.mun.ca/curra/curra_home.htm

APPENDIX III: Pistolet Bay Arctic Charr Fishermen Survey

Angler Survey – Introduction

The following survey is being conducted by researchers from the Save Our Char Committee in conjunction with the Community University Research for Recovery Alliance (CURRA) in partnership with MUN. The research is aimed at gaining a better understanding of commercial and recreational fisheries in order to assess potential impacts on Arctic char populations in the Pistolet Bay area. The Pistolet Bay area includes all inland waters flowing into Pistolet Bay and the ocean from Cape Norman to Cape Onion. The results of this research will be combined with biological assessments in the area in order to increase general knowledge of the area and help with fisheries management. We will make results of the survey accessible on the NORDIC website (www.nedc.nf.ca/SOCC.asp) and will present findings at town meetings in the adjacent Pistolet Bay area communities.

Participation in this survey is free and voluntary and participants are free to withdraw at any time or to refuse to answer any questions without explanation. Participants will remain anonymous and no names will be used in any reports or publications from this work.

Completed surveys should be returned in person to the researcher or by mail using the enclosed self addressed stamped envelope addressed to:

Carla Hedderson
Save Our Char Committee
c/o Department of Fisheries and Oceans
P.O. Box 5
St. Anthony, NL
A0K 4S0

Demographics:

7. How old are you?

    ____

8. What community do you live in?

    ____

9. Where is your preferred spot to fish in Newfoundland?

    ____

10. How many years have you fished

    recreationally?____________________________________

11. How long have you fished recreationally in the Pistolet Bay

    area?_____________________

12. What species did you catch in this area? (check all that apply)

    ______ salmon
    ______ brook trout (mud trout, sea trout, brookies, trout, etc.)
    ______ Arctic Char
    ______ american eel
    ______ cod
    ______ mackerel
    ______ other: ______________________________

Questions pertaining to Arctic Char catches in the Pistolet Bay area:

17. What date do you usually start fishing for Arctic Char in:

    a. Winter ________________ b. Spring/Summer __________________

18. What date do you usually stop fishing for Arctic Char in:

    a. Winter ________________ b. Spring/Summer __________________

19. Where do you normally fish for Arctic Char in:

Spring: (check all that apply)
_____ Freshwater (Parkers and other brooks)
_____ Headwaters (Western Brook/Stock Pond)
_____ Marine (Cooks Hr/ Raleigh/ Billy's Hr)

Summer: (check all that apply)
_____ Freshwater (Parkers and other brooks)
_____ Headwaters (Western Brook/Stock Pond)
_____ Marine (Cooks Hr/ Raleigh/ Billy's Hr)

Fall: (check all that apply)
_____ Freshwater (Parkers and other brooks)
_____ Headwaters (Western Brook/Stock Pond)
_____ Marine (Cooks Hr/ Raleigh/ Billy's Hr)

Winter: (check all that apply)
_____ Freshwater (Parkers and other brooks)
_____ Headwaters (Western Brook/Stock Pond)
_____ Marine (Cooks Hr/ Raleigh/ Billy's Hr)

20. If you've seen changes in the size of your Arctic Char catches in this area during your fishing career, what do you think is responsible?

____

21. When you first started fishing for Arctic Char in the Pistolet Bay area, what was the average size (lbs) of fish you caught in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

22. In the past two years that you have been fishing for Arctic Char in the Pistolet Bay area, what was the average size (lbs) of fish caught in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

23. When you first started fishing for Arctic Char in the Pistolet Bay area, what was a(n):

Good catch (fish/day) in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

Average catch (fish/day) in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

Poor catch (fish/day) in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

24. In the last two years in the Pistolet Bay area, what was a:

Good catch (fish/day) in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

Average catch (fish/day) in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

Poor catch (fish/day) in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

25. If you've seen changes in the size of the Arctic Char you catch during your fishing career in this area, what do you think is responsible?

____

_

26. Do you fish Arctic Char to keep, for catch and release angling, or both?

____

27. If both: what percentage of the time do you keep the fish you catch?

____

28. What kind of gear do you use to catch Arctic Char in the Pistolet Bay area (i.e. Artificial Flies, Lures, etc.)?

____

29. What kinds of gear have you seen used to catch Arctic Char in the Pistolet Bay area?

____

30. What is the best tide for catching Arctic Char in Headwaters and marine environments in the Pistolet Bay area?

____

31. When fishing for Arctic Char in the Pistolet Bay area, what other types of fish do you catch in:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

Questions pertaining to Arctic Char life history:

9. What characteristics do you use to distinguish between Arctic Char and other species of fish?

____

10. In what kind of bottom habitat (muddy, rocky, grassy…) do you expect to find Arctic Char in the Pistolet Bay area?

____

In what kind of water habitat (rapids, pools, estuary…) do you expect to find Arctic Char in this area?

____

11. Do you have any thoughts about what might trigger Arctic Char migrations to the sea in this area (water temperature, tides, currents)? What makes you think these things are important?

____

12. In your opinion, roughly what percentage of Arctic Char in the Pistolet Bay area rivers go to sea?

____

13. What sizes of Arctic Char tend to migrate to sea?

____

14. What months do Arctic Char spend in:

d. Freshwater:____________________________
e. Headwaters: _____________________________
f. Marine: _______________________________

15. What do Arctic Char feed on in:

d. Freshwater:____________________________
e. Headwaters: _____________________________
f. Marine: _______________________________

16. Do you have any idea when Arctic Char spawn? What makes you think they spawn around that time?

____

Questions pertaining to fisheries management:

6. How has the number of fishers in your area changed over time? (circle the one that applies)
   e. Increased by 50%
   f. Stayed the same
   g. Decreased by 50%
   h. Other:

The current fisheries regulations for Arctic Char in the Parkers Brook state that the area or the river from the highway to the mouth of the river is closed year round.

7. What do you think about this regulation?

   c. Appropriate
   d. Inappropriate
   Comments:

   ____

8. The bag limit for Arctic Char in the Pistolet Bay area is 12 Arctic Char or 5lbs + 1 fish, which ever limit is reached first of all species (brook trout, Arctic Char, speckled trout, and ouananiche) combined. What do you think of the bag limit?
   d. Too high
   e. Good
   f. Too low
   Comments:

   ____

9. If you were the minister of fisheries and oceans and had a chance to improve things for the recreational Arctic Char fishery in the Pistolet Bay area, what would you change and why?

   ____

10. In terms of changes in the fishery over time, rank the following as increased, decreased, or no change:

	Spring	Summer	Fall	Winter
Freshwater				
Headwaters				
Marine				

11. Rank the following in terms of your assessment of their relative contribution to changes in the size of fish caught in the Pistolet Bay area during your career (0-6 with 0 [not important], 1 least important and 6 most important (if you have not seen a change in this aspect of the fishery leave blank)

___ season length
___ bag limits
___ monitoring
___ poaching
___ commercial fisheries by-catches (please rank each of the gears in terms of their relative importance to Arctic Char mortality)

- ___ gillnet
- ___cod trap
- ___ lobster
- ___ purse seine
- ___ etc. (please give us an example):

___ other:

12. Rank the following in terms of your assessment of their relative contribution to changes in the size of daily catches in the Pistolet Bay area during your career (0-6 with 0 [not important], 1 least important and 6 most important (if you have not seen a change in this aspect of the fishery leave blank)

___ season length
___ bag limits
___ monitoring
___ poaching
___ commercial fisheries bycatches (please rank each of the gears in terms of their relative importance to Arctic Char mortality)

- ___ gillnet
- ___cod trap
- ___ lobster
- ___ purse seine
- ___ etc. (please give us an example):

___ other:

THE FOLLOWING WERE NOT INCLUDED IN ANALYSIS:

13. The committee placed a counting fence at Parker's River from late June to early September. The purpose of the counting fence was to give the committee some idea of the number of fish migrating up the river. Listed below are the numbers we observed:

    274 Arctic Char
    189 Atlantic Salmon

224 Brook Trout

a. What do these numbers mean to you?

Arctic Char

____

Atlantic Salmon

____

Brook Trout

____

b. Did you think that this number would be more or less?

Arctic Char

____

Atlantic Salmon

____

Brook Trout

____

c. Do you agree with the Committee applying to have this unique population of Arctic Char placed on the S.A.R.A. registry? (*The purpose of the Species at Risk Act (S.A.R.A.) is to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk.*)

Circle one of the following

Yes or **No**

Many thanks for participating in this survey.

Remember – if you want to learn about the results from our research, follow the progress of this study and watch for updates on our results at: www.nedc.nf.ca/SOCC

If you have any questions regarding the survey or have anything you would like contribute that wasn't asked, contact me at the previous contact information on the front page or by email:
carla_hedderson@hotmail.com

Thank-you for contributing to our research,

Carla Hedderson
SOCC Coordinator