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Spatial segregation of three anadromous salmonids in a northern Labrador (Canada) river during the spawning and over wintering periods

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Abstract

The range of anadromous Atlantic salmon (*Salmo salar*), Arctic charr (*Salvelinus alpinus*) and brook charr (*Salvelinus fontinalis*) overlap in coastal rivers of Labrador, Canada. These species have similarities in both life history characteristics and habitat requirements and it was thus hypothesised that their co-existence would lead to habitat segregation within a given river system. This hypothesis was tested in the English River where returning adults were surgically implanted with radio transmitters during July-August, 2001. The geographic location of these fish was investigated both in early and late October 2001 and again in January 2002 to elucidate spawning and over-wintering habitat utilisation. Additionally, a series of fixed stations, located at significant junctions within the river system, monitored the movement of the tagged fish from August 2001 to July 2002. While habitat utilisation varied within each species, a majority of the tagged individuals within a species exhibited similar behaviours. Although some overlap existed geographically, the three species occupied separate areas during spawning and the subsequent over-wintering periods. A detailed description of the habitat used and the differing behaviours exhibited by the three species are presented and discussed.

Introduction

Good scientifically defensible management of habitat is an important component of viable fisheries management strategies (Auster, 2001; Minns, 2001). Habitat managers however, are often faced with making decisions in absence of the scientific information they require and this increases the uncertainty within the decision making process (Minns and Moore, 2003). Habitat utilisation patterns are an important 'first step' in the habitat management process when trying to determine the potential a development has for harm to fishery resources (e.g. Bradbury *et al.*, 2001). Despite our advanced knowledge in many areas of fishery science, fish habitat associations for many species and geographic locations are still rudimentary (Minns, 2001; Minns and Moore, 2003). This is especially true in remote locations where little research has been conducted and physical and biological conditions can be quite different from areas where the scientific literature has been developed for any particular species.

Industrial development within Labrador has grown exponentially over the past three decades with many of the new projects expected to have significant interactions with freshwater habitats (i.e. mining; hydroelectric development; road building etc.). Despite this activity, very little habitat information for aquatic species has been collected in Labrador freshwater systems, due in large part to the remoteness of the area. The little habitat utilisation information we do have has generally been collected in conjunction with the larger development projects that have undergone environmental assessment (e.g. Ryan, 1980; Beddow *et al*., 1998). Experience gained from these environmental assessments has generally indicated a unique habitat utilisation pattern for most species sampled within the Labrador landscape. The reasons for these differences may be varied but most likely include differences due to colder environmental conditions, from the influence of the Labrador Current, and overall lower fish species diversity. Coastal Labrador systems are generally dominated by salmonids, which have similar life history patterns and overlapping ranges throughout Labrador, and lack predators and competitors from the Esocidae, Cyprinidae and Percidae as compared to other North American locales.

For the reasons cited above there was a need to improve our knowledge on the habitat utilisation patterns within Labrador Rivers. The use of telemetry vastly improves our ability to investigate usage patterns in large watersheds and the English River system supplied a unique opportunity as it contains three of the most valued anadromous salmonids in coexistence (Reddin *et al*., 2001). The three species, Atlantic salmon, brook charr and Arctic charr all are highly valued in commercial, recreational and aboriginal fisheries. Although the coexistence of anadromous populations of these three species may be considered rare throughout the world their ranges overlap throughout Labrador and it is quite common to find them in the same river system. The interaction of these species is poorly understood and a recent review of their freshwater habitat requirements failed to produce any information on the habitat requirements of Arctic charr or from rivers where they co-exist (Scruton *et al*., 2000).

It was thus hypothesised that the coexistence of these three anadromous salmonid species with similar life history patterns would result in distinct habitat use patterns due to competition for available habitat. These habitat use patterns were expected to differ from published reports or from observations made on the island portion of Newfoundland and Labrador where the low fish diversity has been associated with a niche expansion for many species (Gibson *et al*., 1993). Habitat utilisation was investigated for the three species within distinct life history stages (i.e. spawning and over-wintering) which is consistent with ongoing efforts to manage habitat within Newfoundland and Labrador (Bradbury *et al*., 2001).

Materials and methods

Study area

English River is located in northern Labrador with a catchment area of 545 km^2. It flows in an easterly direction into Kaipokok Bay at 54° 58' N 59° 45' W, approximately 8 km northeast of the town of Postville (Anderson, 1985; Fig. 1). The lower mainstem section of the river is characterised by braided channels, created by islands, with a predominance of cobble/gravel substrate. The upper part of the mainstem has a higher gradient with three small falls and larger substrate sizes. The entire mainstem section is only 700 m in length. The lower portion of the catchment is dominated by English River Pond with a surface area of 15.62 km^2. Four tributaries flow into English River Pond (Fig. 1) with the two major tributaries, Goudies Brook and Tilt Cove Brook comprising the majority of the fluvial habitat within the entire catchment.

Goudies Brook is comprised of a series of ponds that are connected by areas of 'classical' salmonid habitat with a good mix of cobble/gravel substrates. There is an impassable falls on Goudies Brook approximately 11 km from the confluence with English River Pond (Fig. 1). Tilt Cove Brook has two sub-tributaries which empty into Deer Pond (Fig 1). The first of these (Tilt 1) is comprised of good salmonid habitat with a mixture of cobble/gravel substrates and moderate gradients. The entrance to the second sub-tributary from Deer Pond has a high gradient with limited areas that would serve as resting areas for migrating salmonids and was thus deemed inaccessible.

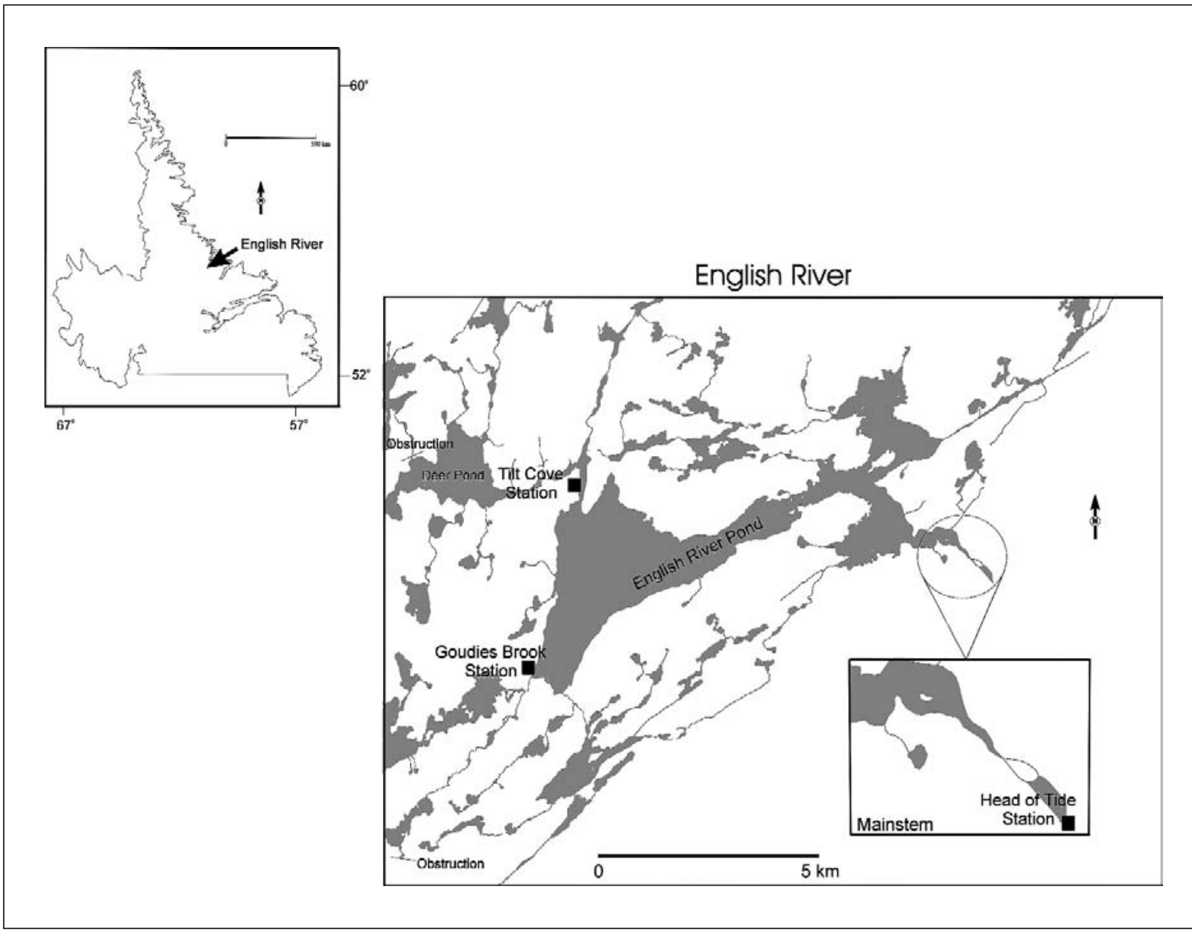

Fig. 1 – Location of the English River system with fixed station monitoring sites highlighted. Inset shows accessible portions of the watershed only.

Tagging and monitoring

Surgery and manual tracking procedures followed those as outlined by Clarke *et al*. (2001). Coded radio transmitters (Lotek model MCFT-3BM; 11x43 mm, 3.7 g in water), with an expected battery life of 278 days, were surgically implanted in twenty three Atlantic salmon, twenty eight Arctic charr and twenty brook charr during two surgery episodes in late summer 2001 (Table 1). Fish were collected from a complete counting fence operated just above head of tide. Fish were immersed in an anaesthetic bath until equilibrium was lost (3-5 minutes), anaesthetic consisted of clove oil (40 ppm) dissolved in ethanol. Fish were then placed on a V-notched table for surgery. During surgery fish were kept moist at all times and fresh water was continually passed over the gills via a small portable pump. Additional anaesthetic was periodically passed over the gills during surgery, ensuring that the fish stayed under the influence of the anaesthetic during handling. After surgery was complete (3-5 minutes), fish were held until the effects of the anaesthetic wore off and equilibrium was restored, at which time the fish were released into a pool just above the counting fence where they could be observed until they resumed their upstream migration.

Table 1 – Characteristics of tagged fish.

Species	July 25-27 N (tagged)	August 28-30 N (tagged)	N (tracked)	Average FL (range); (mm)
Salmo salar	23	0	19	550 (440 – 730)
Salvelinus fontinalis	1	19	18	350 (290 – 475)
Salvelinus alpinus	27	1	22	444 (360 – 560)

FL = Fork length.
N (tracked) = Number of tagged fish detected at least once through monitoring.

Monitoring consisted of both fixed-station sites at significant junctions within the catchment and three separate helicopter trackings. Fixed-station sites consisted of a Lotek SRX 400 receiver capable of detecting the coded tags with a date and time stamp. These stations utilised a 3-element Yagi antennae with an approximate range of 150 meters and were powered by a deep cycle 12 volt battery which was trickle charged by a solar panel. Two stations were set up on July 27, 2001, one at the junction of Tilt Cove Brook and English River Pond and the second at the confluence with Goudies Brook and English River Pond (Fig. 1). The Tilt Cove Brook station was in operation until October 2, 2001 and was subsequently moved to a site just above head of tide to monitor fish migrating out to sea. The Goudies Brook station was removed January 8, 2002. The lower station was installed on October 28, 2001 but did not operate properly for the entire winter, due to extremely cold temperatures. This station did operate properly from October 28 to November 14, 2001; December 12 to December 25, 2001; January 7 to January 23, 2002 and February 4 to July 18, 2002. Additional information about salmon migrating out to sea was derived from two recaptures that occurred within Kaipokok Bay during the aboriginal fishery of 2002. Three manual tracking episodes were conducted to locate fish positions. Two were conducted in the fall of 2001, October 2/3 and October 29, to elucidate spawning locations and one was conducted in mid winter, January 15, 2002 to elucidate over wintering locations. Tracking was conducted from a helicopter, affixed with an H-antenna and a Lotek SRX 400 receiver, moving at a speed of approximately 60-70 kmh^{-1} at an altitude of less than 100 meters above the river, which was well within the range of the transmitters. Once a tag was located its geographic position was recorded using a hand held Global Positioning System (GPS) (model: Garmin III Plus). The receiver was also set to log data during the helicopter flights, which augmented the manual recording of fish positions. Due to the large number of fish located within the mainstem, manual tracking from the ground was also conducted for this area during October 2, 2001. Fish locations were subsequently entered into a Geographic Information Systems (GIS) program (Map Info) and overlaid onto a 1:50,000 map (1:50,000) of the catchment to delineate likely spawning and over wintering areas for the three species within the system.

Results

Two of the tagged brook charr did not have any information collected during the monitoring exercise. One of these was found dead on the mainstem in September, 2001 (Table 1). Of the remaining 18 brook charr the majority (15) stayed within the mainstem area for the entire monitoring period (Fig. 2). The brook charr were located in two main aggregations within the mainstem. Six (6) fish stayed just above head of tide for the entire monitoring period returning to saltwater in June while seven (7) were located in the upper section of the mainstem, these fish also returned to saltwater in June. Two of the brook charr known to have returned to saltwater during the spring of 2001 were observed to re-enter freshwater in late summer 2002 after approximately 3 months in saltwater.

Only three (3) brook charr ventured past the mainstem into English River Pond and beyond (Fig. 2). One of these fish (code 58.1; see table 1) was located in Tilt Cove brook during the spawning season (October 2) and was located at the far end of English River Pond, near the entrance to Goudies Brook, during the winter (December 14, 2001). This fish had returned to the area just above head of tide on the mainstem by June 20, 2002 and remained in this area for one month before re-entering saltwater. One other brook charr entered Tilt Cove Brook on September 17, 2001 and was located in Deer Pond during both the October and January manual trackings. The final brook charr which was tracked successfully was located in a small pond off English River Pond (Fig. 2) during October, 2001 but was not located in subsequent tracking.

Sixty percent (13 of 23) of the tagged salmon passed the Goudies Brook station within a month of their release from the fence site. During the spawning season these fish were located throughout Goudies Brook (Fig. 3), which has a number of suitable spawning areas with good gravel and suitable velocities. The salmon remained in Goudies Brook throughout the winter either near their spawning sites or in one of the small ponds on the system (Fig. 3). Three of the salmon located in Goudies Brook were recorded returning to sea in late June 2002 which was almost two months later than salmon that used the lower part of English River (see below).

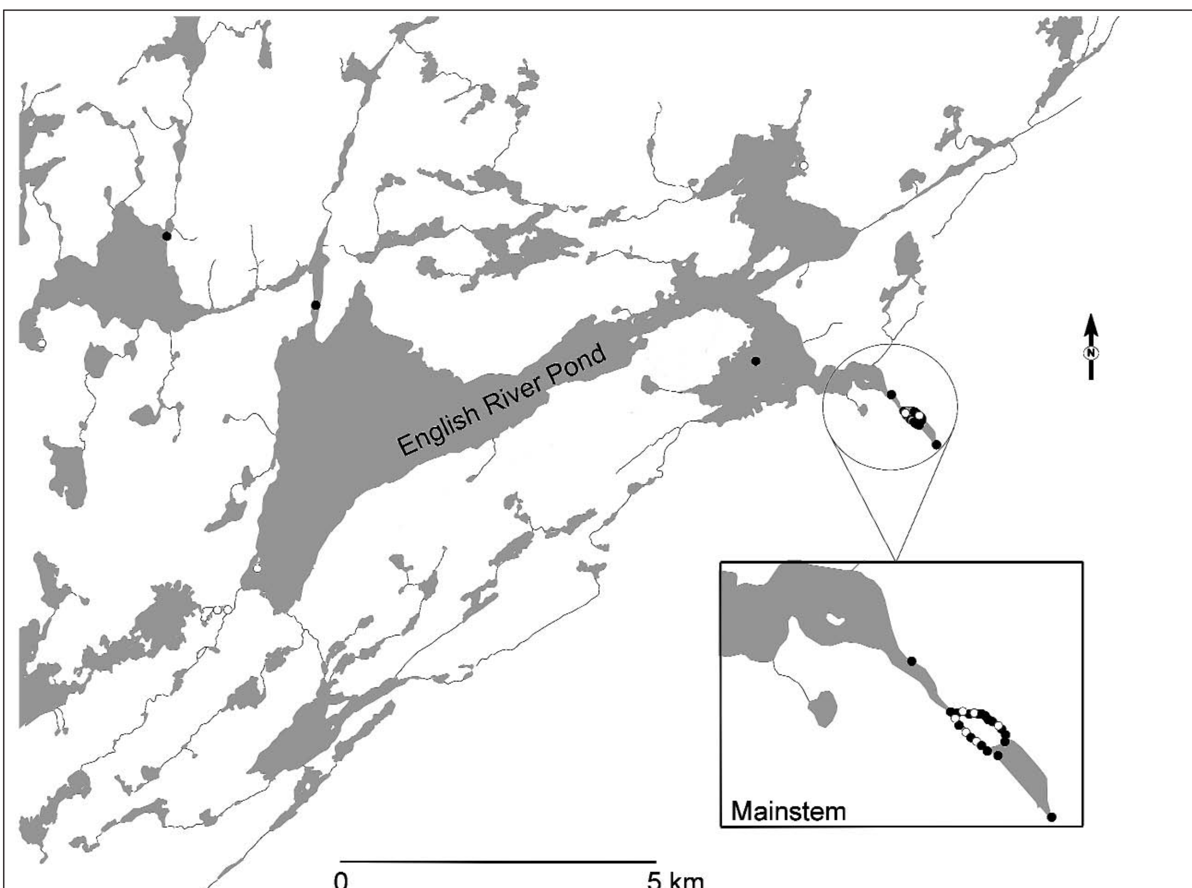

Fig. 2 – Location of brook charr (*S. fontinalis*) during fall (❍) and winter (●) monitoring periods.

A second aggregation of tagged salmon (N=5) used the upper portion of the mainstem just downstream of the English River Pond outlet (Fig. 3). These fish were observed spawning on isolated pockets of suitable substrate that are located in this area. These fish either over wintered in a similar area to their spawning locations or moved up into lower part English River Pond (Fig. 3). Two of the salmon using this area passed the downstream station on their way to sea in late April. Four of the tagged salmon were never located during the monitoring program (Table 1).

The largest aggregation (50%) of Arctic charr was located within English River Pond during both the fall and winter tracking period (Fig. 4). These fish were located at depth as indicated from the transmission power of the tags. Four charr were located over suitable spawning substrate within the mainstem. Five charr entered Tilt Cove Brook, two of which entered the eastern tributary and were located in suitable spawning habitat; the other three fish remained in Deer Pond. One charr entered Goudies Brook on September 23 but returned to English River Pond during the winter (January 15) and one charr was located over suitable spawning substrate in a small tributary off the Northeast coast of English River Pond (Fig. 4).

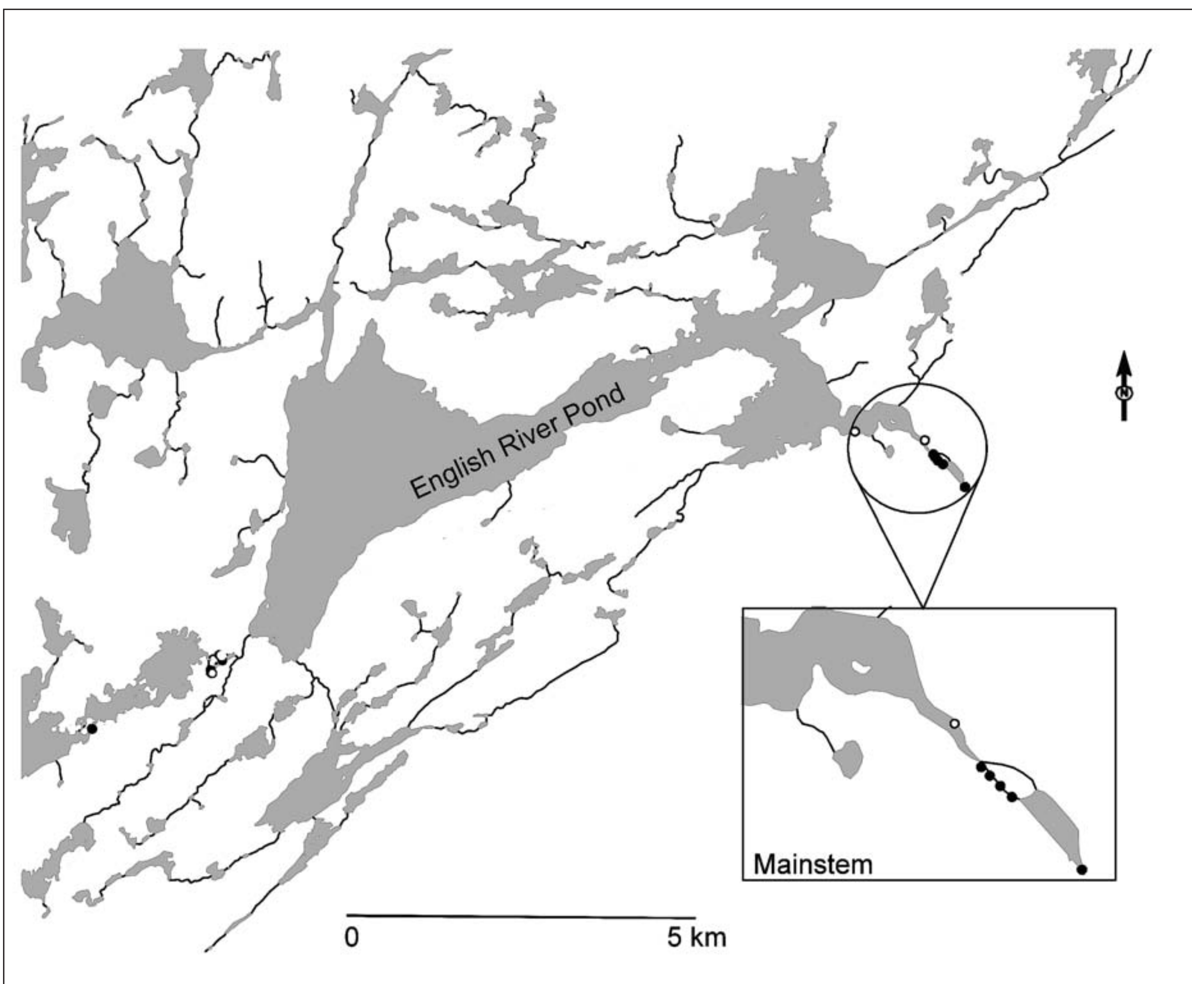

Fig. 3 – Location of Atlantic salmon (*S. salar*) during fall (❍) and winter (●) monitoring periods.

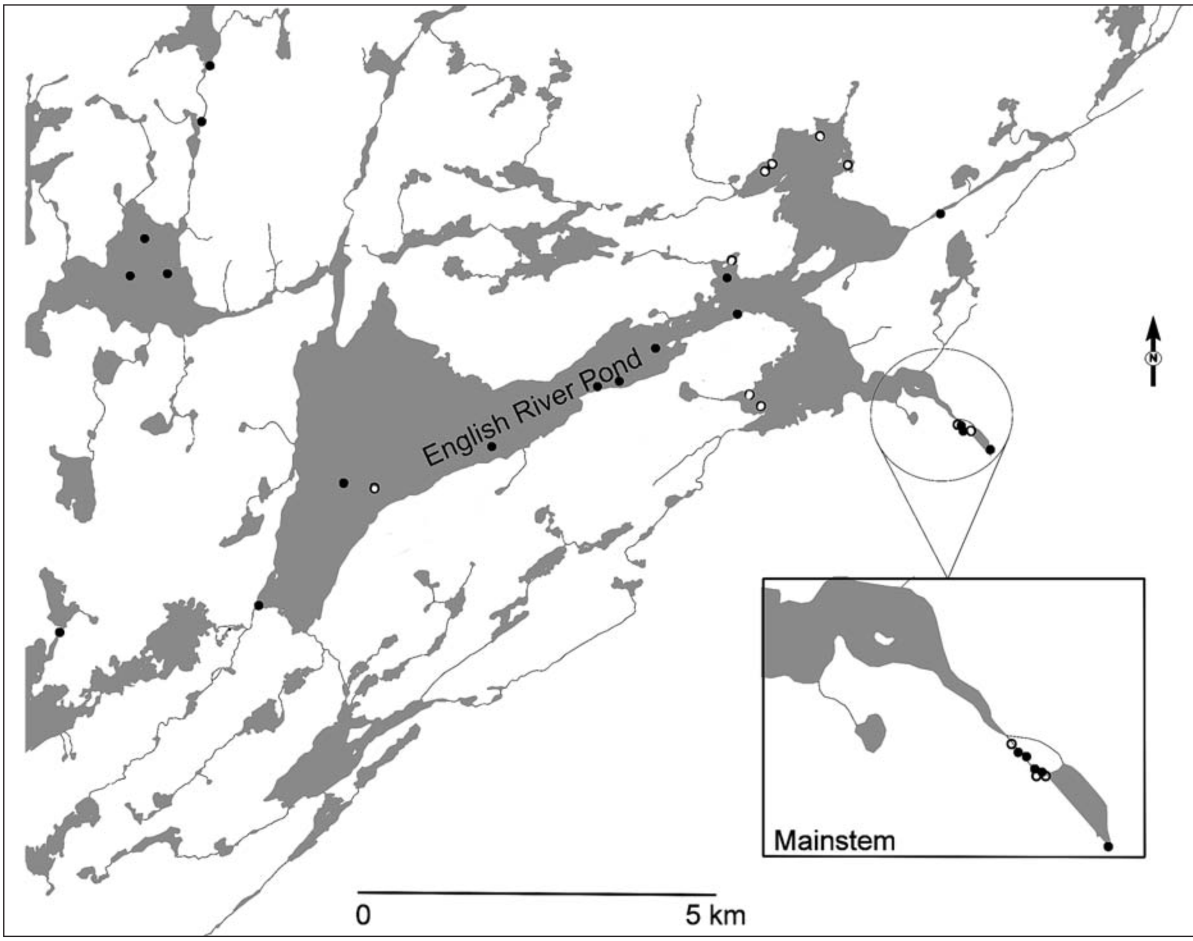

Fig. 4 – Location of Arctic charr (*S. alpinus*) during fall (❍) and winter (●) monitoring periods.

Discussion

The species that had the widest utilisation of the English River system and exhibited the most diverse behaviours was the Arctic charr. Over sixty percent (> 60%) of the charr monitored were located in lacustrine habitats during both tracking episodes in October 2001. These fish were located at depth and were not associated with shoals that may serve as spawning areas for this species (Dempson and Green, 1985). While it is quite possible that these fish moved from English River Pond to a small, unmonitored tributary to spawn either between or after our tracking episodes, previous work has indicated that this species does not spawn every year (Dempson and Green, 1985; see also review in Klemetsen *et al*., 2003) and many migrants move into freshwater to over-winter. Charr associated with spawning habitats were equally divided between those that remained in the mainstem and others that moved into two small tributaries in the upper areas of the watershed.

Both brook charr and Atlantic salmon exhibited fairly limited distributions within English River. Salmon either stayed within the mainstem on isolated pockets of suitable spawning gravel or they moved through English River Pond and entered Goudies Brook to spawn. Salmon that remained in the mainstem tended to use the upper section just downstream of the outlet of English River Pond.

Some of these fish subsequently moved up into the pond to over winter. From a management perspective it appears that Goudies Brook may be the most important producer of Atlantic salmon for the entire watershed and again lacustrine areas may serve as important over wintering areas for post spawned adults.

The brook charr were the most aggregated of the three species and for the most part showed very little migration into the English River system. Anadromy is not a well studied life history strategy for brook charr, but many authors have hypothesised that charr following this strategy make limited migrations between estuarine and freshwater habitats throughout the year (Power, 1980). The fish were located just above the head of tide, which has both areas of suitable spawning substrate and a large pool where fish may over winter. The head of tide area was found to be an important over wintering site for post spawned Atlantic salmon in the Miramchi, New Brunswick (Komadina-Douthwright *et al.*, 1997). The authors hypothesised that this area would supply a relatively stable area with respect to environmental variables due to the influence of the salt water. Recent work on anadromous brook charr movements in eastern Canadian systems has also found that this was an important habitat for the populations studied (R. A. Curry, University of New Brunswick, personal communication). Since the head of tide area of English River, could supply both spawning and over wintering opportunities, and there was limited separation of the tagged individuals, it is difficult to say how many of the fish were using this area for either purpose. It is evident however, that this section of river is an important habitat for the anadromous brook charr of the English River system.

There was little movement by the majority of the fish between their selected spawning areas in October and over wintering sites in January but the manual tracking data was limited in temporal resolution. Salmon tended to move into lacustrine areas adjacent to their spawning sites and the charr species either remained in the lake for Arctic charr or at the head of tide for brook charr. There was some movement within the lake by Arctic charr with an aggregation of fish in the large bay to the Northeast side of English River Pond (Fig. 4). Also, the brook charr, which did migrate into the main catchment, over wintered in an outlet area on the southwest side of the pond (Fig. 3). It is possible that these areas have a preferred thermal habitat, possibly created by groundwater, which has been associated with over wintering sites for other salmonids (Power *et al.*, 1999). The behaviour exhibited by the three species tended to separate them in space throughout the English River system with the most overlap occurring throughout the mainstem. Even within the mainstem salmon and charr used opposite ends of the river stretch but there was little separation between individuals of the two charr species using the lower sections of the river. Individuals that utilized the mainstem tended to return to sea earlier than those that migrated to the upper portions of the system. This behaviour would be expected to increase survival and production for these earlier returning individuals which, is an interesting hypothesis for future research.

It was apparent that a large proportion of the migrating adult charr were not on a spawning run but moving into freshwater to over winter. While not a unique observation for northern populations (Klemetsen *et al.*, 2003; Power, 1980) this has important ramifications for fishery management decisions with respect to stock recruitment relationships and would make environmental assessment descriptions more difficult and time consuming to conduct for these species. Also, this behaviour as well as the post spawning movements of the salmon suggests that over wintering habitats play an important role in the production of these populations.

Although this work was limited in its sample size and temporal coverage of the upstream migration, with only two tagging episodes, it has revealed that the fish species studied exhibit a variety of behaviours. This work is thus, a good first step in the investigation of the habitat associations these species have during coexistence in coastal Labrador systems. Such information is needed by managers, who are faced with decisions regarding habitat alterations and their potential for harm as well as ways to mitigate and compensate for harmful encroachments. The diversity of fish behaviours observed is an important consideration from a management viewpoint. Many of the behaviours were unique to an individual species and may be viewed as differing from the norm for salmonids throughout more temperate climates.

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