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A compilation of fisheries research in ponds of Terra Nova National Park 1997-2003

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Terra Nova National Park (TNNP) protects representative examples of the Central and Northshore Forest ecoregions of Newfoundland and includes over 206 bodies of water (Table A). These standing waterbodies make up 6% of the park's area and are used for drinking water, are a focus of recreational activities and support wildlife including harvested populations of fish. Research began in park waters as early as the late 1960's and these findings indicated waters of low productivity; a characteristic leaving them more vulnerable to overharvesting. To understand and protect these systems considerable inventory work has been undertaken in TNNP – in part to monitor the health of fish populations and in part, to gather information for use in predictive management models. The following components outline work conducted from 1997 to 2003. Components 1 and 2 highlight inventory work undertaken to identify fish communities (namely Arctic char populations) in the Wing's Pond and Big Pond watersheds. Component 3 defines the reference condition for High and Hancock's Pond trout populations in anticipation of increased fishing pressure from trail development. Preliminary investigations of using "off-the-shelf" acoustic sounding systems as a means of fish population monitoring are examined in Component 4 while the change in fish population structure of Trout and Yudle Pond over two decades of fishing is examined in Component 5.

Le parc national du Canada Terra-Nova protège des exemples représentatifs des régions écologiques des forêts du Centre et de la Côte nord de Terre-Neuve. On y dénombre plus de 206 plans d'eau calme (tableau 1), qui occupent jusqu'à 6 % de la superficie du parc; ces plans d'eau servent de sources d'eau potable et de lieux de loisirs, en plus de soutenir une faune locale, notamment les populations de poisson récoltées. Les études sur les eaux du parc menées depuis la fin des années 1960 mentionnent leur faible productivité, qui les rend particulièrement vulnérables à la surpêche. Pour mieux comprendre et protéger ce système, d'importants travaux d'inventaire ont été effectués parc national Terra-Nova, notamment sur l'état de santé des populations de poissons et sur les données nécessaires à l'établissement de modèles de gestion prospective. Les éléments suivants décrivent les travaux menés entre 1997 et 2003. Les éléments 1 et 2 décrivent les travaux d'inventaire menés pour décrire les populations de poissons (dans ce cas, les populations d'ombles de l'Arctique) dans les bassins des étangs Wing et Big. L'élément 3 définit les conditions de référence des populations de truite des étangs High et Hancock, en prévision des pressions additionnelles résultant de l'ouverture de nouveaux sentiers. L'élément 4 présente les résultats d'études préliminaires de surveillance des populations de poissons au moyen de systèmes d'échosondage commerciaux. Enfin, l'élément 5 décrit les variations de distribution des populations de poissons dans les étangs Trout et Yudle au fil de vingt années de pêche.

Table A: The distribution of ponds within Terra Nova National Park of Canada with respect to size class. Note: only ponds greater than or equal to 1 ha are represented (ponds < 1 ha represent 4.9% of the total lacustrine area).

Size Class	*No. of Ponds*	*% of Ponds*	*Combined Area (ha)*	*% of Total Pond Area*
1-10 ha	155	81.6	578.8	23.1
10.1-100 ha	30	15.8	709.4	28.3
>100 ha	5	2.6	1220.8	48.6
Total	**190**	**100**	**2510**	**100**

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Component 1: An examination of the fish species inhabiting the Wing's Pond watershed of Terra Nova National Park

ABSTRACT

Three ponds in the Wing's Pond watershed were sampled to document fish diversity, species interactions and population structure. The largest pond, Wing's (121 ha), had the greatest fish diversity of the three ponds and contained brook trout, Atlantic salmon, threespine and fourspine sticklebacks, rainbow smelt and American eels. Little Wing's Pond (20.2 ha) had a similar fish community. In contrast, Little Broad Cove Pond (8.1 ha) was dominated by brook trout and other species found in Wing's Pond were either absent or at low abundance. Arctic char were not detected in any of the ponds despite their presence elsewhere in the watershed.

Trout in Wing's and in Little Wing's lived longer and grew to greater sizes than in Little Broad Cove; characteristics that may be related to the presence of baitfish species. Densities of trout were negatively correlated with pond area; with Little Broad Cove Pond having densities of trout approximately 22 times greater than Wing's or Little Wing's. Size structure and high densities of trout in Little Broad Cove Pond suggests the population is stunted.

Based on stomach contents, feeding was most intense early in the season and declined as water temperatures increased. Analysis of prey occurrence did not indicate significant differences between salmonid species in Wing's Pond or between brook trout populations of the three ponds. Dipterans occurred most frequently in stomachs of both parr and trout. Other prey types, such as sticklebacks and smelt, occurred only in Wing's Pond (though only in small numbers).

INTRODUCTION

The primary resource management objective for Parks Canada is to protect and manage natural resources so as to perpetuate naturally evolving land and water environments and their associated species (Anonymous 1997). Terra Nova National Park (TNNP) protects a representative example of the eastern Newfoundland Atlantic Terrestrial region. Oligotrophic ponds and low species diversity characterize the aquatic systems of the region and anadromous and nonanadromous brook trout and/or Atlantic salmon are the predominant fish species. Although less ubiquitous than brook trout and Atlantic salmon, nonanadromous Arctic char are also widespread in Newfoundland (O'Connell and Dempson 2002). In 1996 research was initiated to determine the distribution of Arctic char populations within the Park. In the first year of this work, Arctic char were reported to inhabit Bluehill Pond (Fraser 1996) – a relatively large (125 ha) and deep pond (max depth = 22.6 m; mean depth = 9.2 m) within the Wing's Pond watershed. These findings prompted further examination of the remaining three major ponds in the watershed, Wing's Pond, Little Broad Cove Pond and Little Wing's Pond.

The objectives of the field study were to: 1) document the distribution of Arctic char and their interactions with other species within the lake; 2) determine whether Arctic char exhibit anadromous or non-anadromous life histories; 3) evaluate the size structure, age composition and population size of the salmonid species inhabiting the ponds; and 4) study feeding habits of the salmonid species.

METHODS

STUDY AREA

The Wing's Pond watershed lies within the Eastport peninsula on the northeast coast of Newfoundland. The watershed has two main tributaries – one that contains Bluehill Pond and a second that contains Wing's Pond, and several other small feeder ponds including Little Broad Cove Pond and Little Wing's Pond (Figure 1). Wing's Brook is a relatively low gradient stream (average = 1.5%, max = 1.9%) that is joined by Bluehill Brook as it flows from Wing's Pond to Southwest Arm; a deep ($depth_{max}$ = > 34.0 m) and expansive (372 ha) estuary (Hutchings 1985). The Wing's Pond feeder brooks that drain Little Broad Cove and Little Wing's Pond are characterized by steeper gradients (Little Broad Cove: average = 4.6%, max = 7.4%; Little Wing's: average = 7.2%, max = 8.8%).

The morphometry of Wing's, Little Wing's and Little Broad Cove ponds are provided in Table 1. Wing's Pond and Little Wing's Pond have singular-basins, and are rectangular with bottoms that deepen gradually. Little Broad Cove Pond is a double-basin pond and is almost entirely littoral in character. The shoreline of Wing's and Little Wing's Pond are boulder strewn with the exception of the southwestern and southeastern shores of Wing's Pond where there are sandy beaches. A predominantly silty bottom characterizes Little Broad Cove Pond. The terrestrial landscape within the watershed is dominated by black spruce (*Picea mariana*) forest and bog (Hutchings 1985).

Table 1: Morphometry of Wing’s, Little Wing’s and Little Broad Cove ponds.

Pond	Location	Area (ha)	Mean depth (m)	Maximum depth (m)	Elevation (m)
Wing’s	48^{o} 37' N, 53^{o} 53' W	121.2	7.2	19.5	23
Little Wing’s	48º 37' N, 53º 54' W	20.2	1.7	9.0	43
Little Broad Cove	48° 37' N, 53° 52' W	8.1	0.9	4.0	40

FISH CAPTURE METHODS

Field sampling was conducted between May 19, 1997 and August 29, 1997 in Wing’s Pond, May 26, 1998 to July 7, 1998 in Little Wing’s Pond and May 26, 1998 to August 27, 1998 in Little Broad Cove Pond. Fish were sampled weekly using a variety of capture techniques involving fyke nets (all ponds), Takvatn baited funnel trap (Wing’s and Little Wing’s Pond), electroshocking (Wing’s Pond only), and angling (Wing’s Pond only). Fixed gear (traps and fyke nets) was set at random locations throughout the system (Figure 1). All fixed gear was deployed on Mondays and hauled once every 24 hours for 3 consecutive days. After the third haul, the gear was removed from the water and stored on shore. On five different occasions

(July 30, 31, August 7, 26, 28 1997) schooling brook trout were sampled with barrier and dip nets in Wing's Pond near the outflow of Jay Pond Brook.

Fyke nets

Littoral zone sampling was conducted with fyke nets. Nets were set parallel to the shore in shallow water (< 3 m). In Wing's Pond, a total of nine nets were deployed; two square framed nets with a 1 m x 1.7 m opening (stretched mesh size of 12.5 mm) and seven circular nets with a 60 cm diameter opening (3 with 7 mm stretched mesh, 4 with 20 mm stretched mesh). Only 5 nets were initially deployed but 4 more were added on July 21 to increase fishing effort. Eleven nets (all with stretched mesh between 7 - 20 mm) were deployed in Little Wing's Pond and Little Broad Cove Pond in 1998. Initially, six of 11 were set in Little Wing's Pond, however 5 of these were transferred to Little Broad Cove Pond on July 14 because water temperatures became too high to safely sample fish in Little Wing's Pond.

Baited Funnel Traps

The funnel traps were constructed of 12.5 x 12.5 mm aluminum mesh and were 90 cm long and 50 cm in diameter. These traps were used to sample the deepest sections of the Wing's Pond and Little Wing's Pond. Since depths in Little Broad Cove Pond did not exceed 3 m, baited funnel traps were not used. In Wing's Pond, six traps were set individually on the substrate (i.e. a single trap attached to a length of polypropylene rope with a buoy) and three were set in a stacked formation to allow for an examination of vertical distribution of actively foraging fish (e.g. Fraser 1996). The stacked traps were attached to a single float/line so they would fish on the bottom, 5 m off the bottom, and 10 m off the bottom. In Little Wing's Pond one funnel trap was set in the deepest part of the pond. The funnel traps were baited with salted herring and capelin.

Angling

Angling effort was conducted opportunistically (after fixed gear was hauled and redeployed) in Wing's Pond. Various baits and lures were used with barbless hooks.

Electroshocking

To monitor for spring sea migrations of Arctic char, a gas powered, backpack electroshocker (Coffelt variable voltage pulsator, model Mark-10 CPS™) was employed on May 23 to sample a 50 m section of upper Wing's Brook starting at the outflow of Wing's Pond. This section was barricaded with upstream and downstream nets and sampled in an upstream direction.

BATHYMETRY

Hammond (1987) surveyed most of the navigable (1+ ha) ponds within the park however; Little Wing's Pond and Little Broad Cove Pond were not included. Therefore, a survey of these two ponds was included in this study.

Transects were surveyed with a depth sounder (model) mounted on a canoe. Depths were recorded at approximately 5 m intervals along with differentially corrected UTM coordinates. This data was then interpolated to generate a bathymetric relief map using SPANS Explorer 7.0.

FISH DATA COLLECTION

Captured fish were held in large tubs of lake water at ambient temperature. All fish were identified to species. Juvenile Atlantic salmon were classified as either parr, smolt, or ouananiche. Salmonids were measured for standard length (SL), fork length (FL), and total length (TL) to the nearest 0.1 cm, and weighed to the nearest gram. Fish (> 6 cm) were marked by clipping the adipose fin then released near the centre of the lake to allow for dispersal. Three randomly selected fish/week of each salmonid species were kept for laboratory analysis. Subsampled fish were aged with scales and otoliths and preserved (fixed in 5-10% formalin for approximately 1 week then transferred to 95% ethanol) for stomach content analysis.

For each specimen, stomach fullness was recorded as either empty, little (less than 50% full), full (greater than 50% full), or distended. Prey items were then identified to order with the aid of taxonomic keys (Needham 1962) and enumerated. Frequency of occurrence (%) was then calculated for each prey taxa.

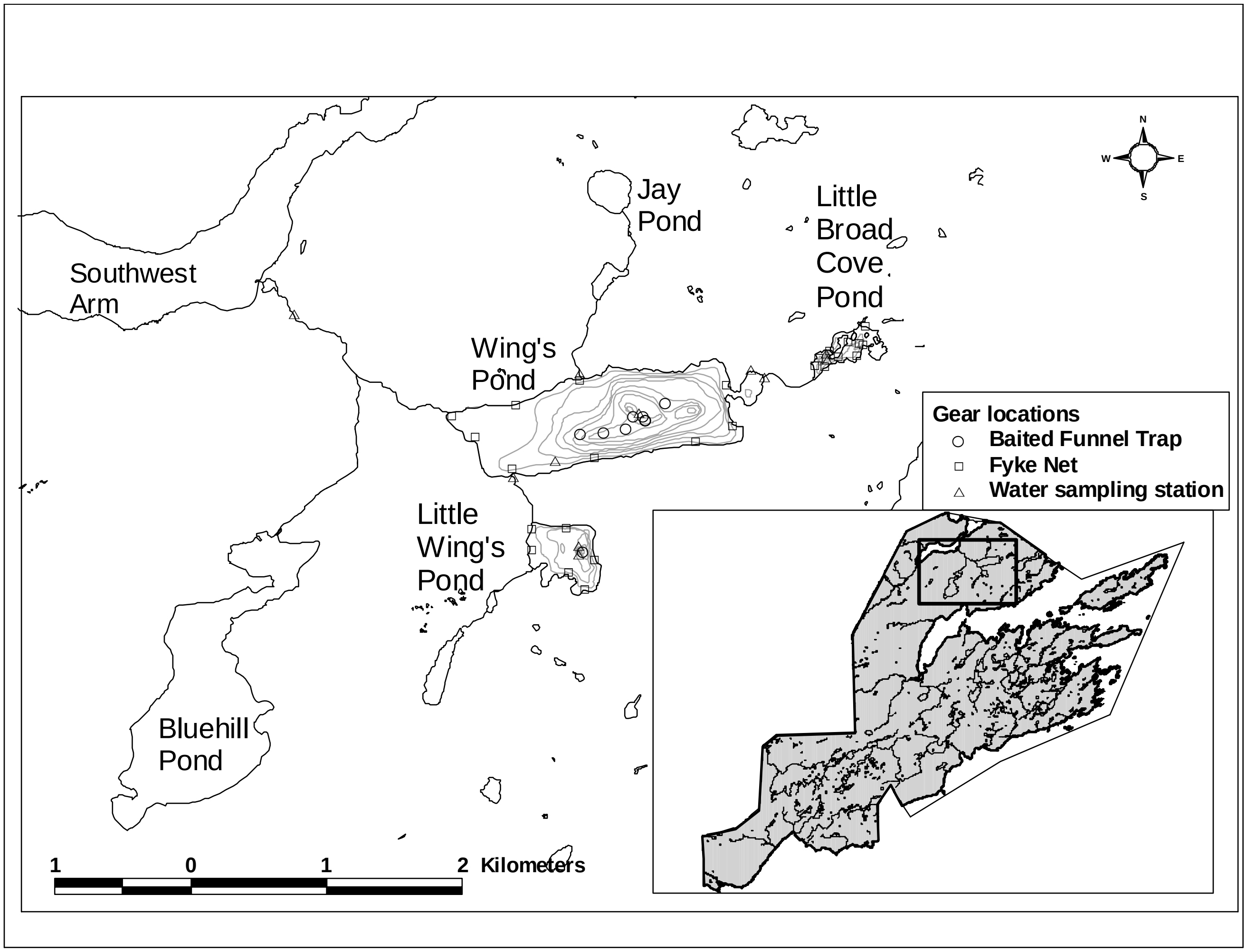

Figure 1: The Wing’s Pond watershed, showing bathymetry, gear locations and water sampling stations. Bathymetric lines represent 2 m intervals. Inset: location of Wing’s Pond watershed in Terra Nova National Park.

ABIOTIC MONITORING

Surface water and air temperatures were collected daily at abiotic sampling sites (Figure 1) with a mercury thermometer. Also, a thermograph (Ryan Instruments model RL-100) was deployed at a depth of 3 m to record hourly temperatures for the duration of the study. On August 6, a vertical temperature profile was determined at the deepest section of Wing's Pond. Measurements were recorded using a Vemco Sealog™ TD probe.

Water samples were collected for chemical analysis during the field study from both riverine and lacustrine waters (Figure 1). Surface water samples were collected from Wing's Pond, Wing's Brook, and all inlet streams flowing into Wing's Pond in 1997 and in Little Broad Cove and Little Wing's Pond in 1998. Concentrations of sulfate, silica, phosphate, nitrate, nitrite, and chloride were monitored in addition to total hardness, specific conductivity, turbidity, total alkalinity, and pH. Water samples were collected in 500 ml, plastic Nalgene bottles and processed using a LaMotte DC1600 Colorimetric test kit (pH was determined on site).

RESULTS

ENVIRONMENTAL CONDITIONS

Wing's Pond surface water temperatures ranged from 7.0 ^{o}C (May 27) to 22.0 ^{o}C (July 9) and temperatures at 3 m ranged from 7.0 ^{o}C (May 27) to 20.5 ^{o}C (July 9) in 1997 (Figure 2). A summer thermocline was observed on August 7 at a depth of ~ 12 m with a decline > 3.0 ^{o}C/m. Bottom temperature (18.5 m) at this time was 10.1 ^{o}C (Figure 3). Water chemistry data (Table 2) show that surface water of Wing's Pond and its inlet streams are very soft and low in dissolved constituents. In 1998, surface water, and temperatures at a depth of 3 m were similar in Little Wing's and Little Broad Cove at the beginning of the field season (Figure 3). Water temperature extremes were observed in Little Broad Cove Pond on August 11 (surface water: 23.5 $^{\circ}$C, 3 m: 19.0 $^{\circ}$C). Fishing was terminated at this time because of high water temperatures to prevent stress-related mortalities. Nets were deployed again on August 17, 1998 when temperatures declined. Temperature extremes of 21.0 $^{\circ}$C (surface water) and 19.5 $^{\circ}$C (3 m) were observed in Little Wing's Pond during the last week of the sample period (July 6-12, 1998). Water chemistry data is provided in Table 2.

SPECIES DIVERSITY

Arctic char were not detected in any of the surveyed ponds or in Wing's Brook. Wing's Pond showed the greatest fish species diversity, supporting populations of anadromous and nonanadromous brook trout (*Salvelinus fontinalis*), anadromous and non-anadromous Atlantic salmon (*Salmo salar*), anadromous rainbow smelt (*Osmerus mordax*), American eel (*Anguilla rostrata*), threespine stickleback (*Gasterosteus aculeatus*), and fourspine stickleback (*Apeltes quadracus*). A similar species assemblage was found in Little Wing's Pond, although rainbow smelt and American eel were not detected. Only brook trout and Atlantic salmon were observed in Little Broad Cove Pond.

Fyke netting was the most successful capture method producing ~ 93 % of the total catch in Wing's Pond and all but one fish in Little Wing's Pond. The baited funnel traps were least successful, catching a total of 7 brook trout. Catches were the highest in June (Figures 4, 5, 6). The low catches in May are attributed to the lack of sampling days in that month (n=4). Catch rates were the highest at the beginning of the study period (Figures 5,6) and decreased as the summer progressed (although, high catch rates in Little Broad Cove Pond occurred sporadically in August (August 11: n = 83; August 25, 26: n = 77)).

In Wing's Pond, a total of 4767 fish were captured (Table 3), threespine stickleback being the most predominant species. Of this total, 1043 salmonids (brook trout and juvenile Atlantic salmon) were sampled though only 730 of sufficient size to be marked (> 6 cm). A subsample of these (39 brook trout, 39 juvenile Atlantic salmon) were kept for laboratory analysis (i.e. aging and stomach content analysis). Salmonid population estimates were conducted by the Schnabel multiple mark-recapture technique (Ricker 1975). Captures of smoltified parr lasted until mid June but as there were no recaptures of any marked smolt, an estimate of smolt density was not attempted. It was estimated that 1238 (95% C.I.: 1013 -1513) brook trout inhabit Wing's Pond; equating to 10.2 trout/ha (Table 3). Most of these fish were between 9.0 - 9.9 cm (SL)(Figure 7); a length which corresponds to age 1+. In total, 7 age classes were represented (Table 4).

The estimated population size of the parr lifestage of Atlantic salmon was 2030 (95% C.I.: 1415 - 3034) and is equal to 17 parr/ha. Most of these fish were between 6.0 - 6.9 cm (SL)(Figure 7) and correspond to the 1+ age-class (Table 4, Figure 7). The estimate of 20 (95% C.I.: 12 - 195) ouananiche is relatively low compared to other species/lifestages and equates to only 0.17 ouananiche/ha. Most of these fish were 14.0 - 16.9 cm (SL); lengths typical of the 4+ age-class. Although there was no estimate for smolt density, most in this lifestage were found to be of the 4+ age-class as well. In combination, age classes of juvenile Atlantic salmon were well represented in the catch. Salmon aged 4+ or greater were present but their proportion of the stock was much lower reflecting the low captures of ouananiche, and indicating that parr smoltify and emigrate from the lake at this age.

One thousand and seventy-three fish were captured at Little Wing's Pond; threespine sticklebacks being the most numerous species (Table 3). Of this total, 276 salmonids (brook trout and juvenile Atlantic salmon) were sampled with only 202 fish of sufficient size to be marked. Twenty trout and 10 juvenile Atlantic salmon were kept for analysis of stomach contents.

A population of 226 trout (95% C.I.: 180-285) was estimated for Little Wing's Pond (Table 3). This abundance equates to 11.2 trout/ha. Most of these fish were between 14-14.9 cm (SL)

(Figure 7) and corresponded to the 2+ age-class. In total, 6 age-classes were represented (Figure 7).

All fish captured in Little Broad Cove Pond were salmonids (brook trout and juvenile Atlantic salmon) (Table 3); trout being the predominant species. Thirty-seven trout were kept for analysis of stomach contents. The abundance of trout in Little Broad Cove Pond was estimated to be 1861 (95% C.I.: 1480-2339); equivalent to 230 trout /ha. Most of these fish were between 13 -14.9 cm (Figure 7) and corresponded to fish of age 2+. Five age classes were represented.

Do to the poor representation of juvenile Atlantic salmon in Little Wing's Pond and Little Broad Cove Pond (Table 5) data pertaining to the population structure of this species were not analysed further.

Frequency of occurrences calculated for stomach fullness and prey items were restricted to the period between June and August. May was eliminated from analysis due to the low number of samples collected. Stomach volumes were highest at the beginning of the summer and decreased as the summer progressed (Figure 8). Most prey items were common to salmon parr in Wing's Pond and to trout amongst all ponds (Figure 9) - dipterans occurring most frequently. Multi-dimensional scaling analysis of Bray-Curtis similarity values using a 2-way ANOSIM test (Clarke and Gorley 2001) indicated non-significant differences in diet for ponds and species ($p < 0.05$). However, Hirudinea, sticklebacks, and smelt were only found in brook trout of Wing's Pond and Bilvalvia and Amphipoda were exclusive to trout in Little Broad Cove Pond.

Table 2: Water chemical parameters measured at Wing's Brook, Wing's Pond and it's inflows during 1997 and Little Wing's and Little Broad Cove Ponds during 1998.

	Wing's Pond	Wing's Brook	Jay Pond Brook	Little Wing's Pond Brook	Little Wing's Pond	Little Broad Pond Brook	Little Broad Cove Pond	Unnamed Brook
Sulfate (mg/l)	6.04±0.19 (n=2)	4.83±0.37 (n=2)	6.18±0.39 (n=2)	6.17 (n=2)	5.64±0.86 (n=7)	6.04±0.19 (n=2)	5.14±0.78 (n=7)	6.73±0.39 (n=2)
Silica (mg/l)	2.34±0.23 (n=2)	2.24±0.78 (n=2)	1.37±1.14 (n=2)	0.44±0.04 (n=2)	0.57±0.32 (n=7)	0.3±0.12 (n=2)	0.61±0.47 (n=7)	1.23±1.16 (n=2)
Phosphate (mg/l orthophosphate)	0.07±0.08 (n=2)	0.08±0.09 (n=2)	0.14 (n=2)	0.03 (n=2)	0.12±0.07 (n=7)	0.05±0.03 (n=2)	0.07±0.06 (n=7)	0.38±0.44 (n=2)
Turbidity (FTU)	12.95±3.89 (n=2)	14.35±3.32 (n=2)	22.55±11.1 (n=2)	15.35±4.74 (n=2)	22.5±9.96 (n=7)	19.75±1.48 (n=2)	27.3±9.41 (n=7)	12.55±4.45 (n=2)
Chloride (mg/l)	9.0 (n=2)	9.75±0.35 (n=2)	9.5±2.12 (n=2)	8.5±2.12 (n=2)	12.0±2.89 (n=7)	9.5±2.12 (n=2)	11.86±2.54 (n=7)	7.5±0.71 (n=2)
Total Alkalinity (mg/l $CaCO_3$)	16.0±1.41 (n=2)	14.25±1.06 (n=2)	16.0±4.24 (n=2)	15.75±2.47 (n=2)	21.29±4.42 (n=7)	16.5±3.54 (n=2)	21.1±4.1 (n=7)	14.75±1.06 (n=2)
Total Hardness (mg/l $CaCO_3$)	5.5±0.71 (n=2)	6.5±0.71 (n=2)	9.0±2.83 (n=2)	8.0±2.83 (n=2)	7.17±3.0 (n=6)	7.0±1.41 (n=2)	6.67±2.5 (n=6)	10.25±3.89 (n=2)
Nitrite (mg/l NO_2)	<0.001 (n=2)	<0.001 (n=2)	<0.001 (n=2)	<0.001 (n=2)	<0.001 (n=7)	<0.001 (n=2)	<0.001 (n=7)	<0.001 (n=2)
Nitrate (mg/l NO_2)	<0.02 (n=2)	<0.02 (n=2)	<0.02 (n=2)	<0.02 (n=2)	<0.02 (n=7)	<0.02 (n=2)	<0.02 (n=7)	<0.02 (n=2)
pH	6.05±0.35 (n=2)	6.35±0.35 (n=2)	6.03±0.53 (n=2)	6.2±0.14 (n=2)	7.02±0.20 (n=6)	6.1±0.71 (n=2)	6.68±0.29 (n=5)	6.1±0.57 (n=2)
Conductivity @ 25 ^oC (micromhos/cm)	29.25±10.9 (n=2)	26.0±2.12 (n=2)	28.5±7.78 (n=2)	24.25±1.06 (n=2)	17.9±1.42 (n=7)	23.75±3.89 (n=2)	17.6±1.6 (n=7)	29.25±3.89 (n=2)

Table 3: Catches and abundance/biomass estimates for fish in Wing's, Little Wing's and Little Broad Cove.

Pond	Species	No. captured	% of catch	No. marked (recaptured)	Population estimate (LCL-UCL)	fish/ha	Mean weight (g)	Fish Biomass (kg)	Fish biomass (kg/ha)
Wing's	Brook trout	557	11.8	363 (94)	1238 (1013 –1513)	10.2	70.9	87.77	0.72
	Atlantic salmon parr	391	8.3	292 (28)	2030 (1415 – 3034)	17	14.2	28.83	0.24
	smolt	35	0.7	28 (0)	N/A	N/A	52.5		
	ouananiche	12	0.3	12 (1)	N/A	N/A	50.1		
	Threespine stickleback	3543	74.9	-	N/A	N/A	-		
	Rainbow smelt	55	1.2	-	N/A	N/A	43.0		
	Fourspine stickleback	133	2.8	-	N/A	N/A	-		
	American eel	2	0.04	-	N/A	N/A	-		
Little Wing's	Brook trout	231	21.5	143 (71)	226 trout (180-285)	11.2	90.3	20.41	1.01
	Atlantic salmon parr	25	2.3	14 (0)	N/A		32.0		
	smolt	14	1.3	11 (0)	N/A	N/A	82.1		
	Ouananiche	5	0.5	3 (0)	N/A	N/A	29.0		
	Anadromous adult	1	0.1	-	N/A	N/A	-		
	Threespine stickleback	792	73.8	-	N/A	N/A	-		
	Fourspine stickleback	4	0.3	-	N/A	N/A	-		
Little Broad Cove	Brook trout	594	98.1	501 (72)	1861 (1480-2339)	230	52.7	98.07	12.1
	Atlantic salmon parr	10	1.6	3 (0)	N/A	N/A	18.0		
	Smolt	1	0.2	2 (0)	N/A	N/A	79.0		
	Ouananiche	1	0.2	1 (0)	N/A	N/A	-		

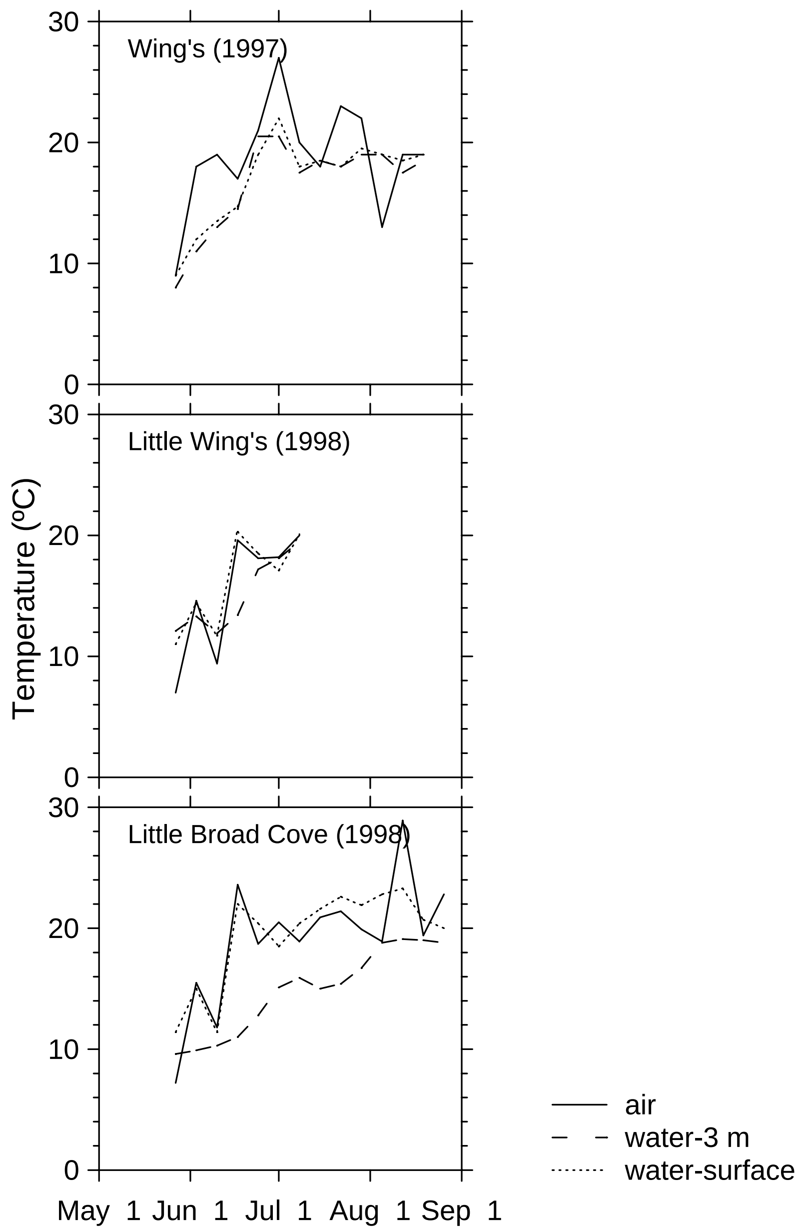

Figure 2: Mean weekly temperature in Wing's, Little Wing's and Little Broad Cove Ponds.

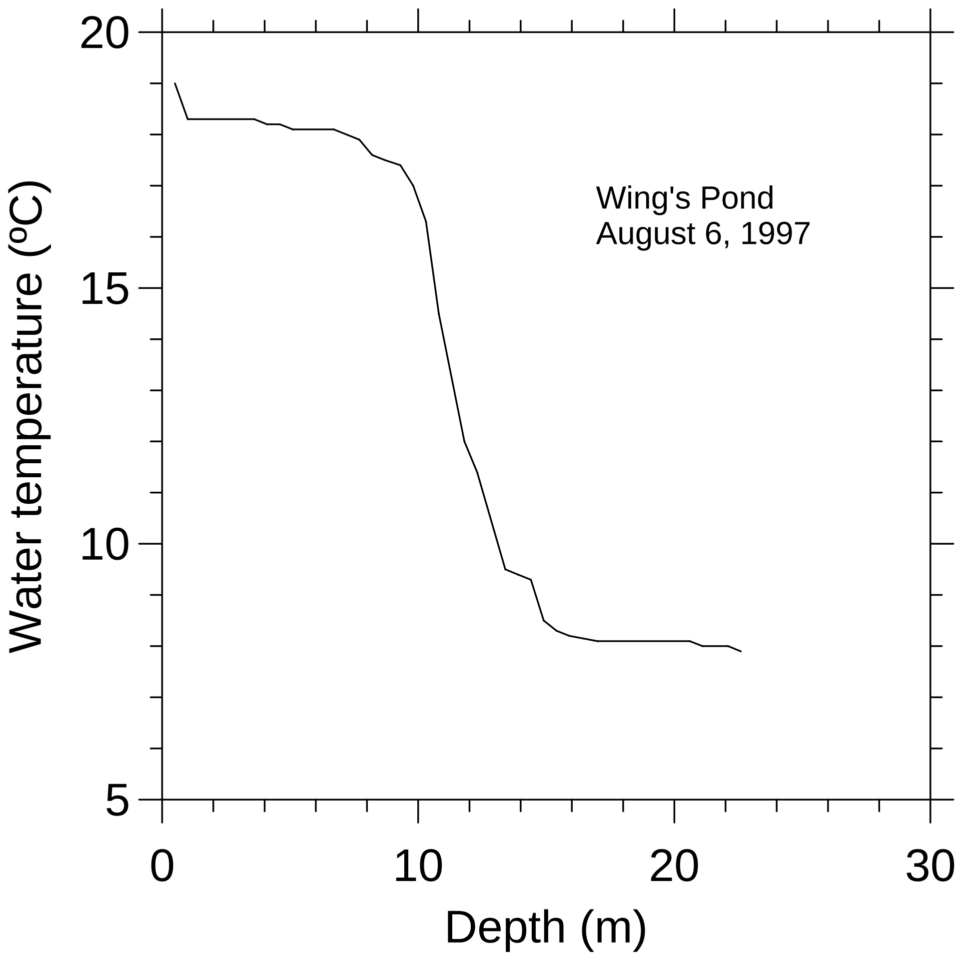

Figure 3: Thermal stratification in Wing’s Pond, August 6, 1997.

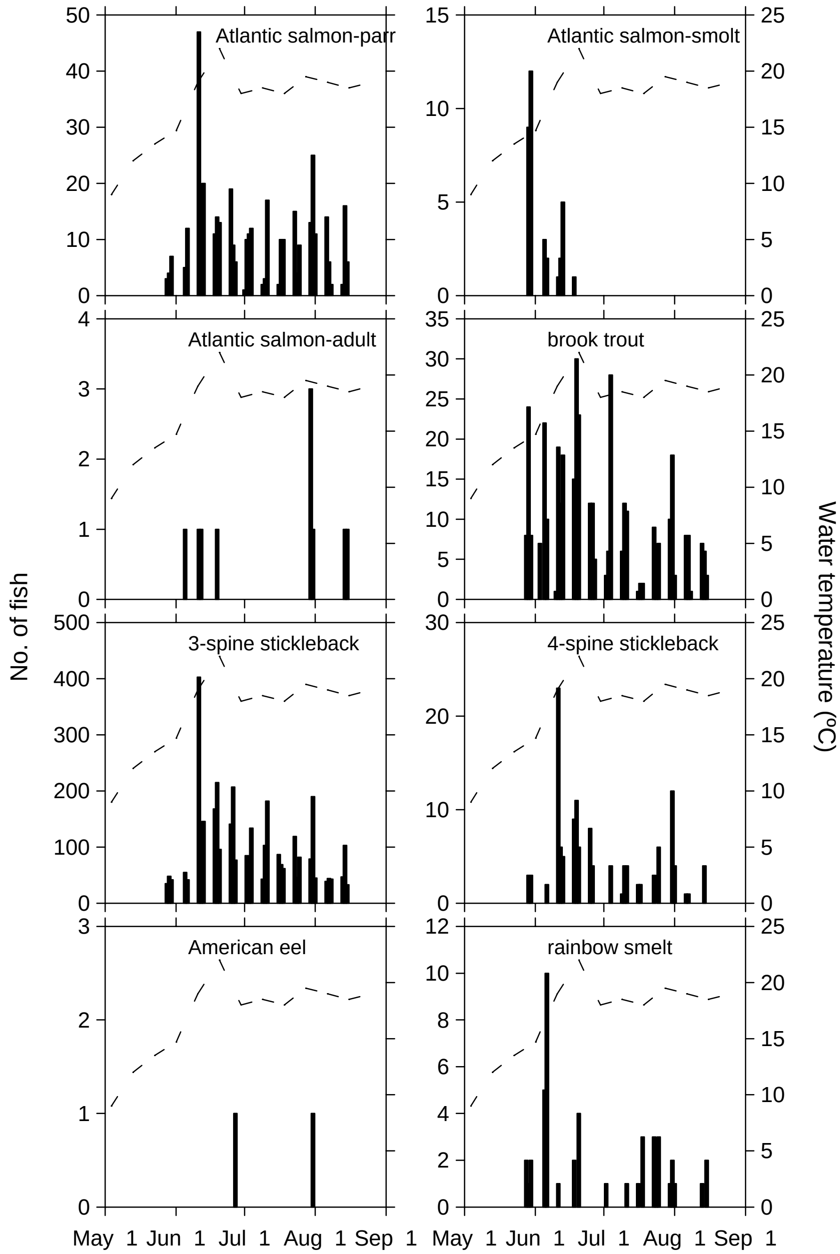

Figure 4: Seasonal variation in fish catch (bars) and surface water temperature (line) in Wing's Pond, 1997. Catches from opportunistic beach seines are not included.

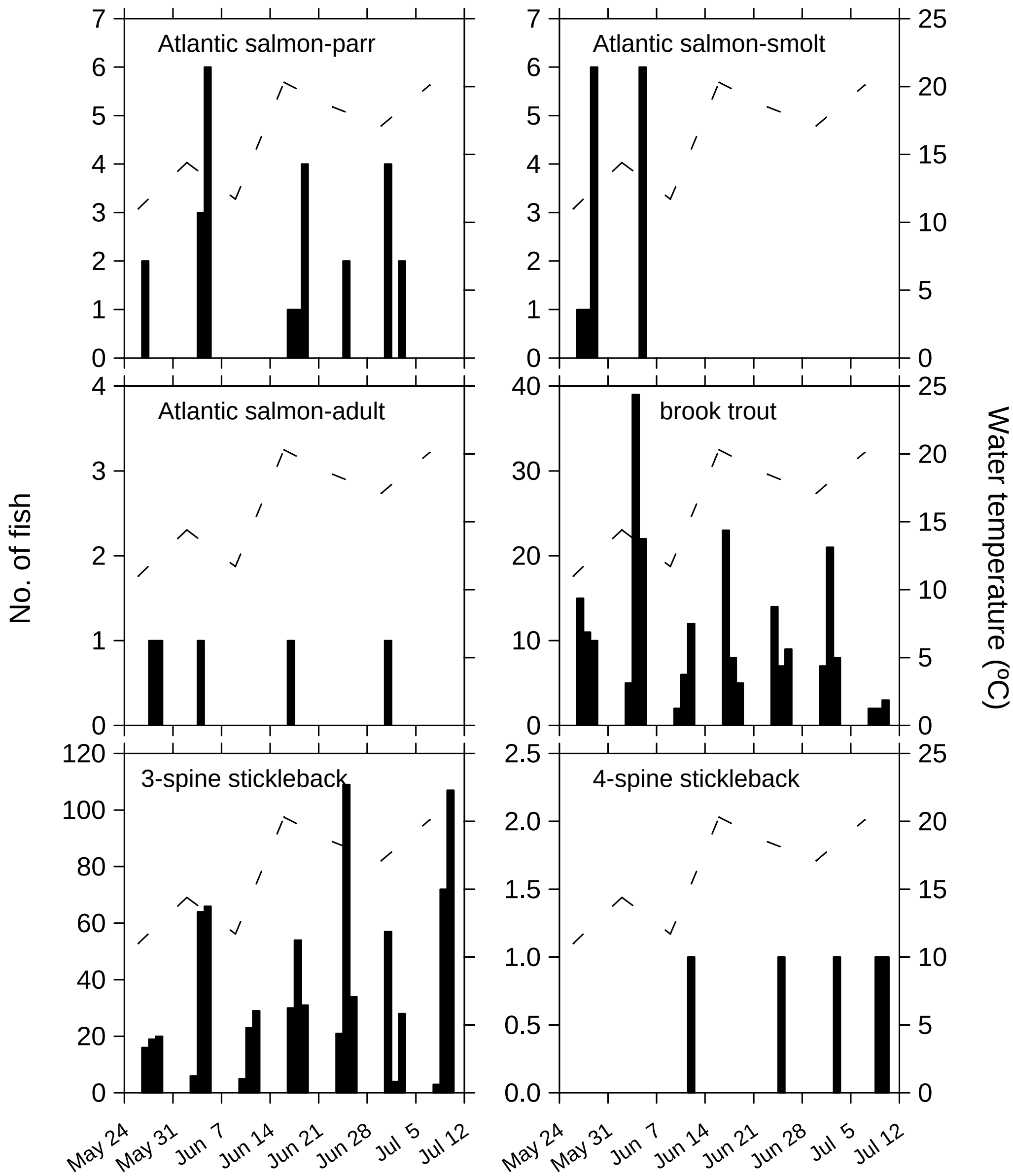

Figure 5: Seasonal variation in fish catch (bars) and surface water temperature (line) in Little Wing's Pond, 1998.

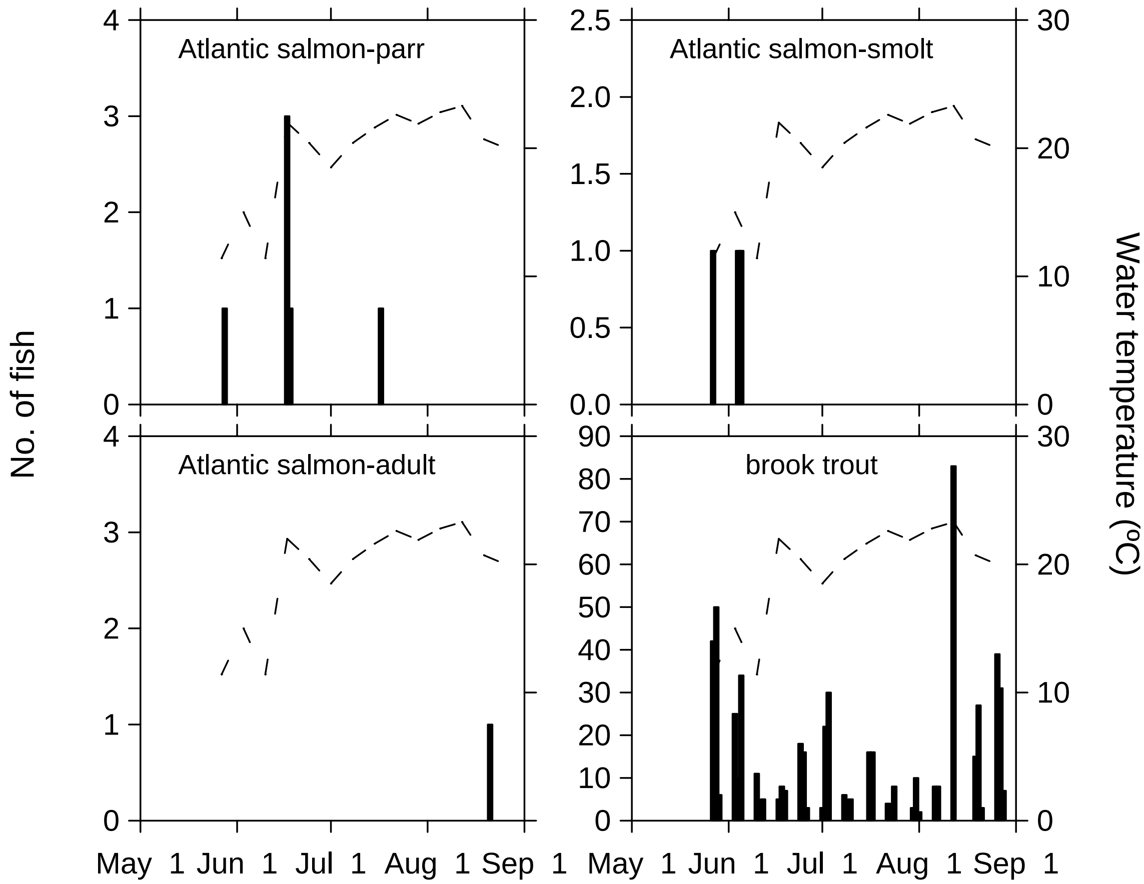

Figure 6: Seasonal variation in fish catch (bars) and surface water temperature (line) in Little Broad Cove Pond, 1997.

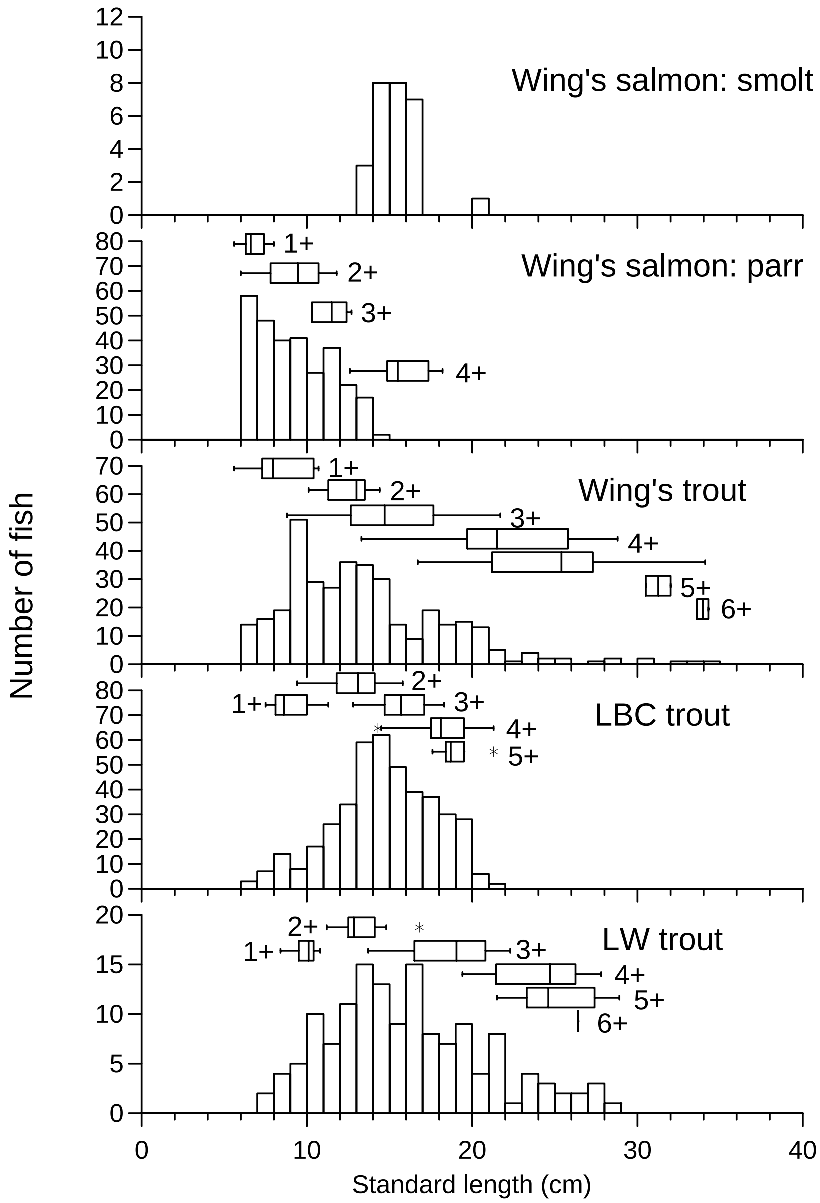

Figure 7: The size distribution of salmonids in Wing's (1997), Little Wing's (LW; 1998) and Little Broad Cove Pond (LBC; 1998). Parr (LBC and LW), smolt (LBC and LW) and adults (all ponds) were not included due to low sample sizes.

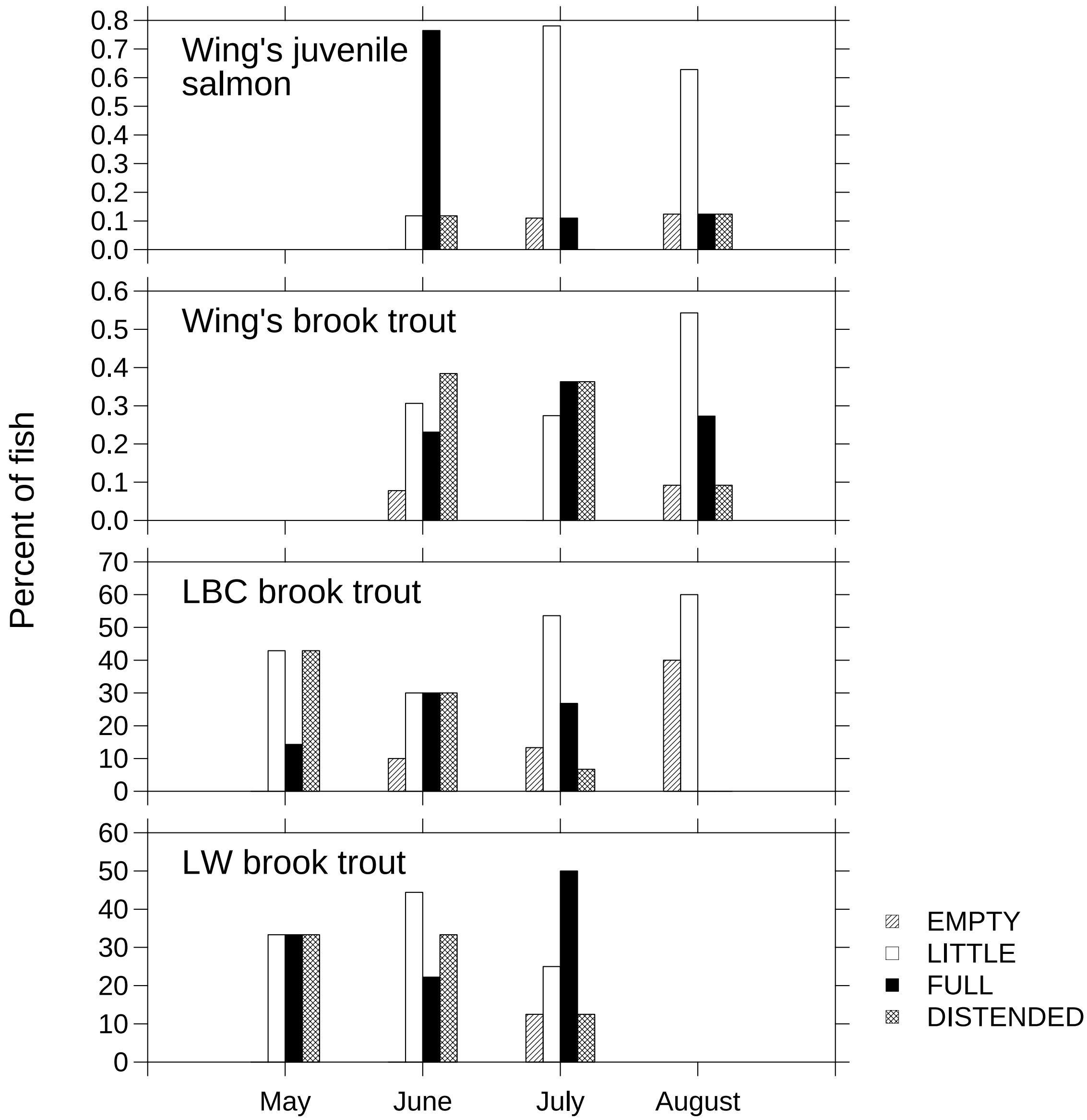

Figure 8: Stomach fullness of juvenile salmon (Wing's 1997) and brook trout (Wing's 1997; Little Broad Cove (LBC) 1998; Little Wing's (LW) 1998).

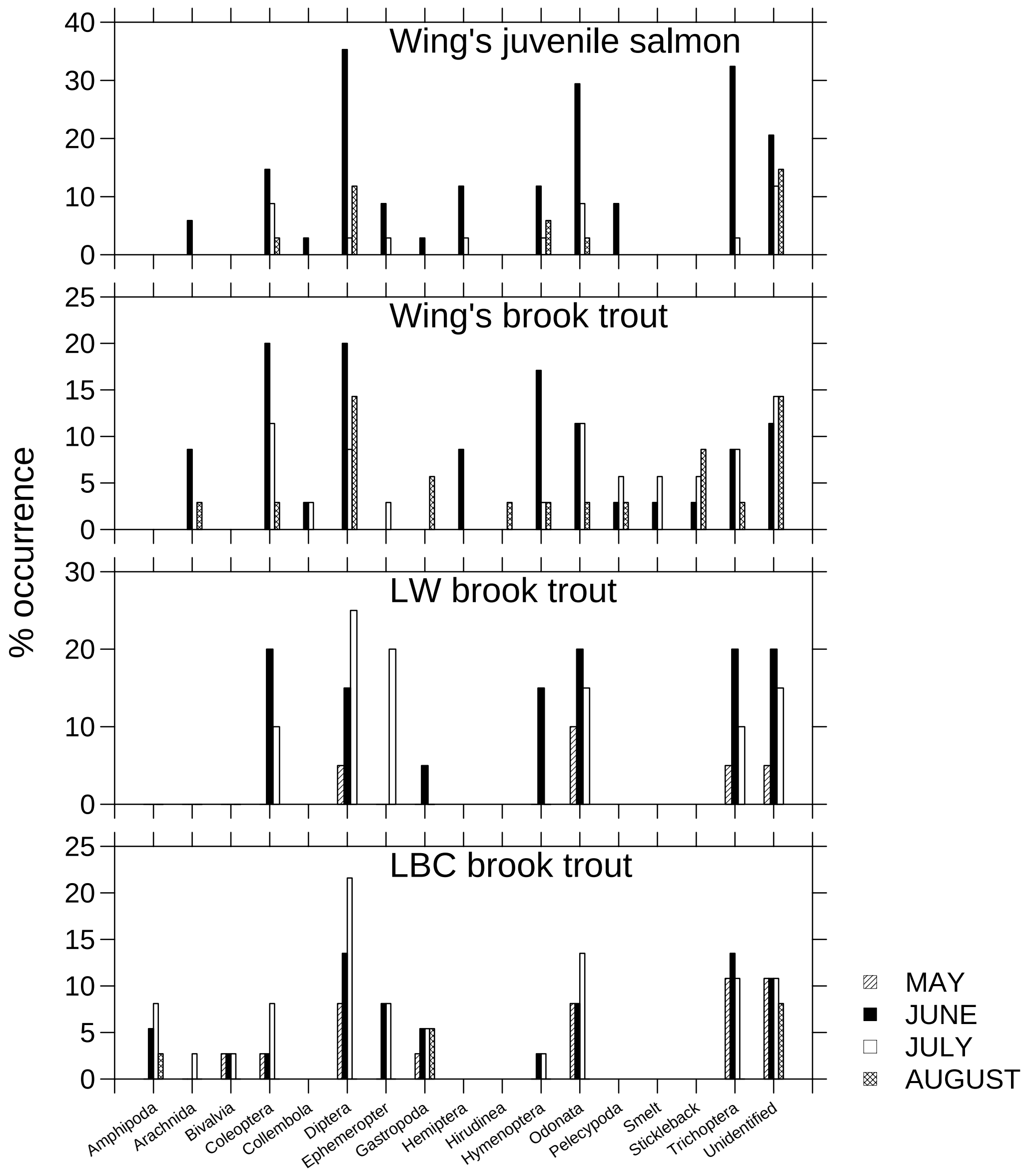

Figure 9: Occurrence of prey items in stomachs of brook trout (Wing's Pond 1997, Little Wing's Pond (LW) and Little Broad Cove Pond (LBC), 1998) and Atlantic salmon parr (Wing's Pond, 1997).

Table 4: Brook trout length $_{SL}$-at-age [SE] for Wing's (1997), Little Wing's (1998) and Little Broad Cove (1998) ponds.

	Wing's		Little Wing's		Little Broad Cove	
AGE CLASS	MEAN LENGTH$_{SL}$ (cm) [SE]	n	MEAN LENGTH$_{SL}$ (cm) [SE]	n	MEAN LENGTH$_{SL}$ (cm) [SE]	n
1+	8.3 [0.79]	6	9.8 [0.42]	5	8.9 [0.38]	10
2+	12.5[0.78]	5	13.3 [0.43]	12	13.1 [0.40]	18
3+	15.2[1.20]	11	18.6 [0.53]	22	15.7 [0.35]	21
4+	22.3[1.12]	15	24.0 [1.11]	8	18.1 [0.29]	33
5+	24.8 [1.87]	8	25.1 [1.34]	5	19.0 [0.52]	6
6+	31.30.75]	2	26.4 []	1		
7+	34.0.35]	2				

Table 5: Length $_{SL}$ -at-age [standard error] for juvenile Atlantic salmon in Wing's (1997), Little Wing's (1998) and Little Broad Cove (1998).

	Wing's		Little Wing's		Little Broad Cove	
AGE CLASS	n	MEAN LENGTH$_{SL}$ (cm) [SE]	n	MEAN LENGTH$_{SL}$ (cm) [SE]	n	MEAN LENGTH$_{SL}$ (cm) [SE]
1+	6	6.8 [0.35]	1	10.0		
2+	14	9.2 [0.47]	6	10.2 [0.19]	1	11.0
3+	6	11.5 [0.43]	4	13.3 [0.64]		

DISCUSSION

Arctic char were not detected in any of the ponds surveyed in this study despite occurring abundantly in the profundal zone of Bluehill Pond – a water body in the same watershed and of similar size and depth as Wing's Pond (Kerekes 1974). Captures of Bluehill Pond Arctic char were most frequent in September (Fraser 1996), a period not sampled in this study. Nonetheless, angling and funnel traps were an effective means of capture of char in Bluehill Pond during summer yet still did not yield specimens from Wing's Pond in that season. In Gander Lake, char were caught in water 1-100 m deep but tended to move to deeper water as the upper water column warmed during summer (O'Connell and Dempson 2002). Wing's Pond was of sufficient depth to exhibit thermal stratification during summer (above 11 m temperature: ~18ºC below 12 m temperature: ~11ºC), but the relatively shallow nature of Little Wing's (maximum depth = 10 m) and Little Broad Cove (maximum depth = 3 m) ponds may not provide suitable thermal refugia through the summer. Alternatively, because char are less aggressive (Halvorsen and Jørgensen 1996), they may not be able to compete with other salmonids (Johnson 1980) where shallow littoral zones are the only available habitat. While all three species prefer shallow littoral habitat, char tend to utilize deeper areas in lakes (Kerekes 1968) more so than do trout or salmon (Halvorsen and Jørgensen 1996). In these deep areas they are thought to have a competitive advantage because they are not obligate visual feeders (Langeland et al. 1991). Water chemistry data (Table 2) show that the surface water of both ponds was very soft and low in dissolved minerals and acid precipitation. Limnological conditions of the Wing's Pond watershed are similar to that of other lakes in TNNP (see Kerekes 1974) – characterized by low productivity and often highly coloured water. Its moderate epilimnetic and high hypolimnetic temperatures are caused by the windy, cool, oceanic climate of the area. Observed pH levels support the findings of Clair et al. (1997) who state that lake chemistry in the eastern region of Newfoundland may show seasonal trends in acidification but no long-term changes. Correspondingly pHs were well above the acid tolerance of brook trout (pH = 5.2, Mount et al. 1988, Ingersoll et al. 1990) and Atlantic salmon (pH = 5.0, Farmer 2000).

In all three ponds, both brook trout and Atlantic salmon demonstrate similar habitat use - the littoral zone being preferred. This conclusion is contingent on the assumption that both sampling methodologies are effective and do not have habitat specific biases. The preferred salmonid (brook trout, Atlantic salmon and Arctic char) habitats observed in this study are in accordance with O'Connell and Dempson (1996) who used the same sampling method (gill nets) for all habitats. Similar prey items in stomachs of both salmonid species observed in the Wing's Pond watershed also corroborate conclusions of similar habitat use. Both species select similar prey items, benthic as well as open water prey, and are likely to be opportunistic feeders. Stomach volumes were greatest at the beginning of the summer and decreased as the summer progressed; likely a reflection of seasonal abundance of insect larvae. Such an interpretation should be considered with caution however, because seasonal changes in water temperature impact gastric evacuation rates and result in underestimates of food consumption (Cunjak et al. 1987). Willers (1991), however, generalizes that salmonids do not feed much, if at all, at temperatures above 18.9°C.

Temperature also appeared to influence the distribution of fish in the water column. Brook trout have a preferred temperature range between 6.0º and 18.0ºC and an upper lethal temperature of 25.3ºC (Garside & Kerekes 1969). In 1997, Wing's Pond temperatures reached a maximum on July 9 ranging from 22.0 ºC at the surface to 20.5ºC at a depth of 3 m. This coincided with declining catch rates in the littoral zone and the first captures of fish in the baited funnel traps, indicating a migration to deeper, cooler water. Other behavioural responses were observed during warm water temperatures as trout were observed to school at the outflow of Jay Pond Brook, likely using this microhabitat as a thermal retreat. Flick (1991) indicated that, where possible, brook trout respond to high water temperatures by finding cool upwelling zones rather than moving to deeper water. Declining capture rates at increased temperatures were also observed in Little Wing's Pond and Little Broad Cove Pond. In Little Broad Cove, where depths do not exceed 3 m, reduced catch rates from fixed gear suggest a reduction in movement at high water temperatures.

The population estimates and size distributions demonstrate that both salmonid species are well established, but low in number. The density of trout in Wing's and Little Wing's (10.0 and 11.2 trout/ha respectively) was low compared to that of other ponds in TNNP but in Little Broad Cove Pond the density was much higher (220 trout/ha). Hick's (1992) study of three small lakes reported densities between 77 trout/ha (Trout Pond) and 118 trout/ha (Davey Ann's Pond). Fish production in TNNP waterbodies is likely low due to their nutrient poor nature (Kerekes 1974) relative to other Canadian lakes (see Hanson and Leggett 1982).

Juvenile Atlantic salmon were present in Little Wing's and Little Broad Cove ponds, but the poor representation indicates that few anadromous Atlantic salmon actually migrate beyond Wing's Pond within this watershed. The gradients of the brooks flowing out of Little Wing's and Little Broad Cove Pond are relatively steep (5-10% in some sections vs. 1-2% in Wing's Brook) and, combined with their shallow nature may make these brooks less accessible to anadromous populations.

Little Broad Cove Pond appears less favourable for brook trout growth compared to Wing's and Little Wing's ponds. More intense intraspecific competition (e.g. Donald and Alger 1989) may play a role in the stunted size distribution since trout densities were considerably higher (~22 times) than in the other ponds. Piscivory was observed in Wing's trout, which was expected given their relatively large maximum size, but was not detected in either of the smaller ponds. Though small trout sizes and an absence of prey species in Little Broad Cove prevented piscivory, the absence of this behaviour in Little Wing's, a pond with large fish and relatively high numbers of sticklebacks, is unclear.

Brook trout live to an age of 5+ in Little Broad Cove Pond, 6+ in Little Wing's Pond and 7+ in Wing's Pond. No obvious reason for the difference in maximum age between ponds is evident as there is no appreciable angling pressure in any of the ponds (pers. obs.). Possibly larger/deeper ponds provide conditions (i.e. thermal) that are more favourable to large trout, which in turn enable them to survive longer. Another possibility is that older individuals may emmigrate from neighbouring ponds if the habitat is more suitable elsewhere. Wild trout seldom live beyond 5 years and do not exceed 8 years (Scott and Crossman 1990), therefore it is likely that these ages represent the natural age of physiological senescence. The degree of overlap in brook trout size-at-age is high. According to Johnson (1976), variability in population structure can occur over a wide variety of ages, depending on the size of the juveniles and the opportunities presented to them. Hutchings (1985) reported that a portion of the salmonid population in Wing's Pond undertake distinct seasonal movements between lacustrine, riverine, and estuarine habitats. Growth rates differ significantly between these habitats (Hutchings 1985) and immigration/emigration to different habitat may explain this overlap. Seasonal movements of this sort may also bias population estimates. Mark-recapture techniques are based on the assumption that emigration and immigration are negligible at the time of the study (Ricker 1975). Previous work on Wing's Pond (Hutchings 1985; Potter 1989) indicates that both salmon and trout violate this assumption as trout tend to be moving from the pond to the brook during the time sampling took place and salmon tend to be moving into the pond from the brook. Extrapolating Wing's Pond trout migration rates from Potter (1989), it is estimated that up to 15% of the Wing's Pond population are migrants (in the worst case scenario where emigrants and immigrants are mutually exclusive). Migratory salmon parr would comprise approximately 10% of the Wing's Pond population. Given these violations, it is probable that the populations in Wing's Pond have been overestimated at least to some degree. However, since migratory behaviour was not widespread through the population, inaccuracies in the population estimate were most likely minor.

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Component 2: Fish community structure of the Big Pond watershed, Terra Nova National Park of Canada

ABSTRACT

Salmonids in the Big Pond watershed, Terra Nova National Park (TNNP) were assessed in terms of species diversity, population abundance and age structure. Additional work was conducted to assess the occurrence and extent of anadromy. Lacustrine environments were sampled from May 17 to August 12, 1999 with fyke nets and Takvatn traps while anadromous salmonids were monitored at a counting fence on Minchin Brook that operated from May 31 to September 20, 1999. The fish community of Big Pond had similar species richness as other large ponds in TNNP and included threespine sticklebacks, Atlantic salmon, brook trout, Arctic char, rainbow smelt and American eels. Threespine sticklebacks were the most abundant and accounted for 75% of the catch. Amongst the salmonids, Atlantic salmon, primarily of the parr lifestage were the most abundant and contributed the most to standing biomass. Brook trout and Arctic char were the least abundant salmonids. Anadromy occurred for both Atlantic salmon and brook trout based on the occurrence of individuals moving through the counting fence – though only one anadromous sea trout was counted. Twenty-nine anadromous salmon (22 small, 7 large) returned to Minchin Brook and run timing corresponded to increased water depth at the counting fence suggesting that water flows limit movement up this small stream. Based upon the Canadian Department of Fisheries and Oceans (DFO) production models used for Atlantic salmon management in Newfoundland, the Big Pond watershed requires egg deposition rates one would expect of a population of approximately 34 small salmon. Based on the achieved returns of small and large

salmon, the estimated anadromous salmon egg deposition was 99.7% of the conservation target. Nonanadromous life history forms, for which the estimated population was 178 (95% confidence intervals were 61 – 890), only contributed an additional 10% (3.4 – 49.4%) of the conservation target, suggesting that salmon production in Big Pond is driven by the anadromous life history form.

INTRODUCTION

Terra Nova National Park (TNNP) is mandated to protect and manage natural resources and their underlying processes. As part of an aquatic habitat management regime, research was initiated in ponds that were thought to contain relic populations of Arctic char (*Salvelinus alpinus*). Arctic char were reported to inhabit Bluehill Pond (see Fraser 1996), which prompted further scrutiny of the remaining ponds in the watershed. Research was initiated at Wing's Pond in 1997 and Little Wing's Pond and Little Broad Cove Pond in 1998, though char were not detected in those waterbodies.

Accounts of Arctic char in Big Pond and Minchin Pond (Kerekes 1974) subsequently lead us to focus efforts on the Big Pond watershed. Baseline data was gathered on all salmonid species inhabiting Big Pond and Minchin Pond for future monitoring and management efforts.

The objectives of this field study were to document the salmonid population structure (size, age, abundance) of these ponds in addition to the life history as it relates to anadromy.

METHODS

STUDY AREA

Big Pond

Big Pond (48° 32'N, 53° 55'W) is the second largest pond in the park (Figure 1). It has a surface area of 173 ha and a maximum depth of 38 meters (mean depth = 5.4 m). The lake is long and narrow, has an axial length of 4.5 km, a maximum width of 0.9 km, and is divided into three basins that are connected by narrow channels. The shores are rocky with interspersed sandy beaches. The pond is fed by five small brooks and is drained by Minchin Brook; a third order stream with low gradient (1.7%). Minchin Brook flows 1.2 km before it enters into Minchin Pond.

Minchin Pond

Minchin Pond (48° 33'N, 53° 53'W)(Figure 1) has a surface area of 6.4 hectares and a maximum depth of 14 meters (mean depth = 6.8 m). The pond bottom drops rapidly from shore except on the northeast end near the inlet of Minchin Brook where it slopes gradually and is very shallow. The shallow end is silted and overgrown by rooted aquatic vegetation. The remaining shoreline is rocky. The lake is drained by the continuation of Minchin Brook, which flows 0.3 km before it enters the ocean at Minchin Cove.

Fish Capture Methods

The field study was conducted over 13 weeks (May 17 - August 12) in 1999. Fish were sampled using a variety of capture techniques involving fyke nets, Takvatn models of the baited funnel trap, angling and a fish counting fence established at Minchin Brook. Fixed gear in the lakes (traps and fyke nets) was set at locations throughout the system. All fixed gear was deployed and hauled once every 24 hours for 3 consecutive days. After the third haul, all gear was removed from the water and stored on shore. The counting fence was established in Minchin Brook and fished from May 31, 1999 until September 20, 1999, at which point it was destroyed by high water flow. When in operation, the counting fence was cleaned of debris and checked for fish on a daily basis.

Fyke nets

Fyke nets were used to sample fish in the littoral zone. They were set parallel to the shore in shallow water (< 3 m). A total of fourteen nets were deployed in Big Pond; each of which had a 60 cm opening and a stretched-mesh-size that varied between 7 and 20 mm.

Baited funnel (Takvatn) Traps

The funnel traps, constructed of 12.5 x 12.5 mm aluminum mesh, were cylindrical in shape (length: 90 cm; diameter: 50 cm) and were marked and hauled with an attached float and line. These traps were set on the bottom of Big Pond (N=13) and Minchin Pond (N=2) in areas beyond the reach of fyke nets. Salted herring or squid was used to bait the traps.

Angling

Angling was conducted opportunistically throughout the study period (i.e. after the gear had been re-set for the day). Various baits and lures were used with barbless hooks.

Fish Counting Fence

The counting fence was installed to establish the numbers of anadromous salmonids returning to the watershed. The apparatus was located approximately 200 m below Minchin Pond and consisted of a wooden holding box with aluminum conduit walls. The holding box had a wooden top but no bottom due to the shallow depth of the brook. A v-shaped conduit fence was attached, on the downstream side, which guided fish into the holding box through a 10 cm wide opening. The conduit was spaced approximately 3 cm apart to allow for water flow and the downstream passage of smaller fish (e.g. smolt).

FISH DATA COLLECTION

Ponds

Captured fish were held in large tubs of pond water at ambient temperature. All fish were identified to species and counted. Juvenile Atlantic salmon were further classified as parr, smolt, or ouananiche (nonanadromous adults). Salmonids were measured for length (SL) to the nearest 0.1 cm and weighed to the nearest 1.0 g. Scales samples were also collected from a subset of the population for aging. Fish greater than 6 cm were marked by clipping the adipose fin and released near the center of the pond to allow for dispersal.

Adult counting fence

All fish species were identified and counted. Captured Atlantic salmon were classified as either small (< 63 cm) or large (>63 cm). Size was estimated with a meter stick held next to the free-swimming fish.

Smolt counting fence

From 5 May to 6 July, 2004, a smolt fence was operated on Minchin Brook, between Minchin Pond and the outflow into Newman Sound. Initially the fence was situated approximately 30 m below the outflow of Minchin Pond but due to unexpectedly low smolt captures, the fence was moved approximately 100 m farther downstream on 14 June. Fish of all species were identified and enumerated. To reduce handling related mortality for Atlantic salmon smolts, only every fifth individual was measured for forklength and weight and scales were removed from every thirtieth. Length and weight were measured and scales taken on adult salmon (anadromous and nonanadromous) and lengths and weights were taken for all other salmonid species.

ABIOTIC MONITORING

Surface water and air temperatures were collected with a handheld thermometer at monitoring sites each sampling week. Thermographs (Ryan Instruments model RL-100) were also deployed at a depth of 3 m in each pond, and in the counting fence holding box. These instruments recorded hourly temperatures for the duration of the study. Water samples were collected for chemical analysis during the field study from lacustrine waters. Total hardness, specific conductivity, turbidity, total alkalinity, and pH were measured as were concentrations of sulfate, silica, phosphate, nitrate, nitrite, and chloride. With the exception of pH, which was measured in-situ, water chemistry was determined from samples collected in 500 ml Nalgene bottles and processed using a LaMotte DC1600 Colorimetric test kit.

ATLANTIC SALMON EGG DEPOSITION

The Department of Fisheries and Oceans (DFO) has established adult return targets for many Atlantic salmon rivers in Newfoundland as a management measure. These conservation requirements do not represent a carrying capacity (maximum sustainable population) for a river but the number of adults required to maintain levels of smolt production characteristic of Newfoundland watersheds, given the available habitat for rearing juvenile salmon (O'Connell et al. 1991; O'Connell and Dempson 1995). With this approach, habitat is characterized as lacustrine or fluvial and quantified by surface area. Habitat-specific smolt production estimates are applied to each habitat type with which, based on estimates of egg-to-smolt survival, fecundity, and sex ratios, the number of adults required to achieve the conservation target can be calculated. For the Big Pond watershed, the paucity of abiotic and biological data required that values from other nearby systems be used as estimates. For biological data on anadromous salmon, estimates came from data acquired in Northwest River, TNNP (approximately 30 km distant), while for nonanadromous salmon, data from the Indian Bay watershed was used (approximately ~40 km distant). Lacustrine area and stream length were available from the Park's 1996 forest classification database. Average stream width from Minchin Cove to Minchin Pond and from Minchin Pond to Big Pond was estimated from monitoring sites previously established on those sections (sampled at mid to low flows). No stream width data was available for headwater streams flowing into Big Pond. Therefore they were estimated from monitoring sites situated on other 1st order brooks in the park.

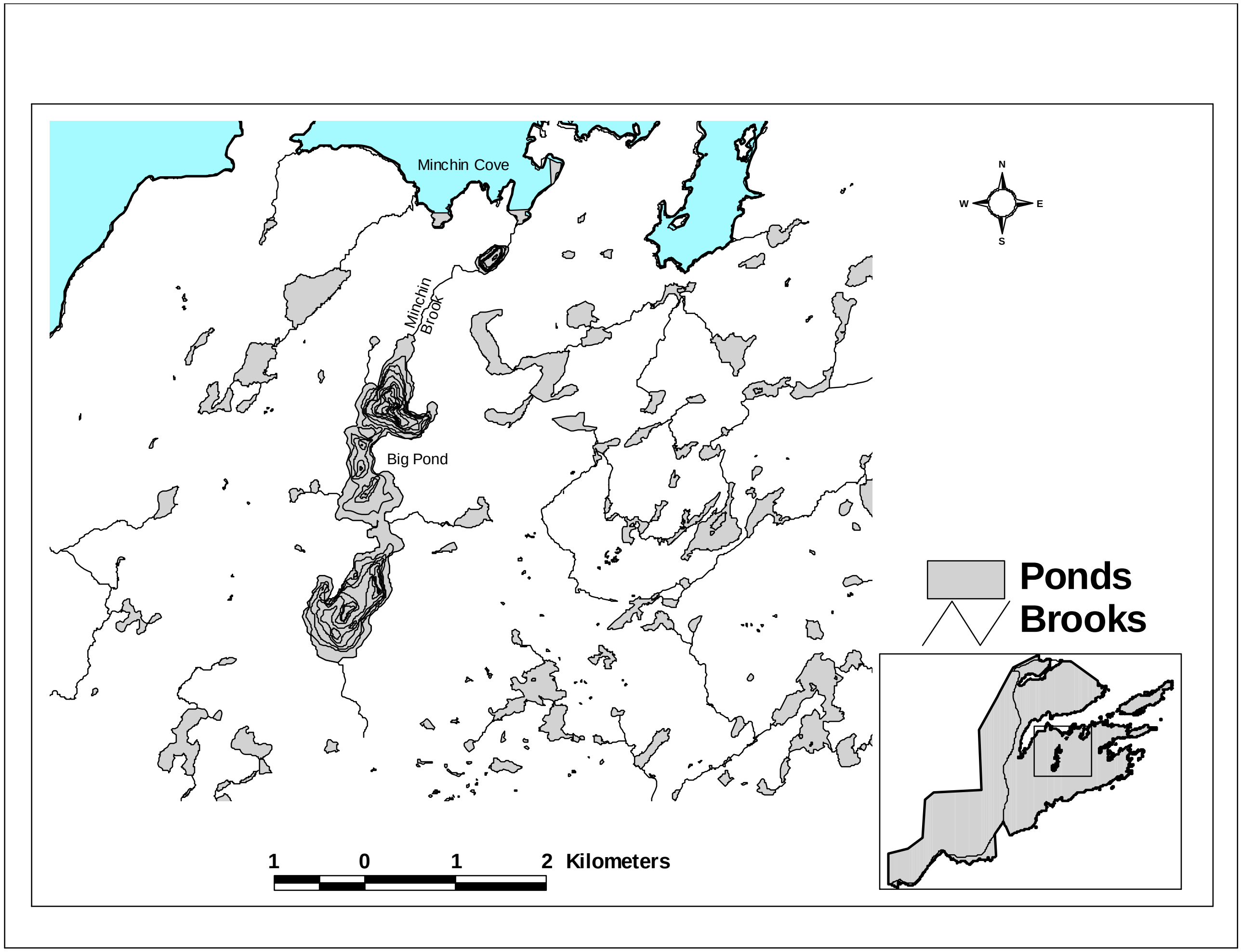

Figure 1: The Big Pond watershed.

RESULTS

BIG POND

Catch rates were the highest at the beginning of the study period and decreased as the summer progressed (Figure 2). A total of 8924 fish were captured at Big Pond; threespine sticklebacks being the predominant species (n = 6687). Of this total, 1978 salmonids (brook trout, Arctic char and juvenile Atlantic salmon) were sampled. Other species worth noting, but present at low abundance, were American eel and rainbow smelt.

Salmonid population estimates were conducted by the Schnabel multiple mark-recapture technique (Ricker 1975). There were 206 brook trout (21 recaptures) and 15 Arctic char (0 recaptures) used to estimate the population size of these species in Big Pond. Furthermore, there were 1774 parr (149 recaptures) and 38 ouananiche (2 recaptures) used to calculate the population sizes of these respective Atlantic salmon life stages. Captures of smoltified parr (n = 150) lasted until June 3. An estimate of smolt density was not attempted.

Based on data collected from all capture techniques it is estimated that 343 (95% C.I.: 227 - 547) brook trout inhabit Big Pond (Table 1). Most of these fish were 10.0 - 11.9 cm (SL) with the maximum size recorded being 19.5 cm. The last brook trout was captured on June 10. Unfortunately, insufficient scales were collected prior to this date to determine a size-at-age relationship. The estimated population size of the parr stage of Atlantic salmon was 8182 (95% C.I: 6973 - 9603), equating to 44.7 parr/ha. Most of these fish were between 9.0 - 11.9 cm (SL)(Figure 3), lengths which correspond to the 2+ age-class. Nonanadromous 4+ and 5+ salmon were present but their abundance was much lower 178 (95% C.I.: 61 - 890) than the younger parr age-classes; indicating that many parr smoltify and emigrate from the pond. Most of these adult fish were 15.0 - 19.9 cm (SL); a length which corresponds to age 4+ fish. Although there was no estimate for smolt density, most of this group were in the 4+ age-class as well. Of the total catch, all parr age-classes (age 1-3+) were well represented (Figure 3; Table 2). Captures of Arctic char (n =15) lasted until June 10. It was estimated that 72 (95% C.I.: 13 - 720) Arctic char inhabit Big Pond. The largest Arctic char captured was 17.0 cm (SL). Scale analysis determined this fish to be in the 4+ age-class. In terms of biomass, Atlantic salmon dominated with 96% of the biomass (parr = 94.8%; ouananiche = 1.2%), followed by brook trout (3.7%) and Arctic char (0.4%).

Fish captures declined considerably after surface temperatures exceeded 17ºC (in late May / early June) except for Atlantic salmon parr and threespine sticklebacks; species for which catch rates stayed relatively high until surface temperatures exceeded approximately 20ºC (late June) (Figure 2).

Table 1: Population estimates for brook trout, Atlantic salmon and Arctic char in Big Pond, 1999.

Species	Captured	Recaptures	Population estimate	95% confidence intervals	Fish / ha
Threespine sticklebacks	6687	NA	NA	NA	NA
Rainbow smelt	30	NA	NA	NA	NA
Brook trout	206	21	343	227-547	2.0
Arctic char	15	0	NA	NA	0.4
Atlantic salmon					
Parr	1774	149	8182	6973 - 9603	44.7
Smolt	150	NA	NA	NA	NA
Nonanadromous adults	38	2	178	61 - 890	1.0
Anadromous adults	22 small 7 large	NA	22 small 7 large	NA (total count)	

Table 2: Age composition for Atlantic salmon life stages in Big Pond, 1999 compared to that for Bluehill Pond (Fraser 1996).

		Bluehill Pond	Big Pond
Lifestage	Age-class	Proportion (n)	
parr	1	0.31 (4)	0.31 (22)
	2	0.38 (5)	0.56 (40)
	3	0.15 (2)	0.13 (9)
	4	0.15 (2)	0
Ouananiche	2	0.21 (5)	0
	3	0.25 (6)	0.09 (1)
	4	0.29 (7)	0.73 (8)
	5	0.21 (5)	0.18 (2)
	6	0.04 (1)	0

Minchin Pond

Two baited funnel traps were deployed at Minchin Pond to establish the presence of Arctic char. Only one individual was captured during the field study (May 19). This fish was 21 cm (SL) in length and scale analysis determined it to be in the 5+ age-class.

Counting Fence (Minchin Brook 1999)

Twenty small (< 63 cm) and 7 large (≥63 cm) anadromous Atlantic salmon passed upstream through the Minchin Brook counting facility with peaks occurring July 15, July 30, and August 17. Pulses in the salmon run loosely correspond to peaks in the tidal cycle but more closely followed peaks in water depth measured at the trap (Figure 4). Only one anadromous trout was counted (July 15).

Smolt counting fence (Minchin Brook 2004)

Three hundred and forty-three smolt were captured between 6 May and 1 July as they left the Big Pond Watershed. The peak of the run occurred on the day following the relocation of the trap (15 June) when 145 passed through the trap. The dominant age-class in the 2004 run was age 3+ (76%), individuals spawned in 2000. The remainder of the aged smolts (24%) originated from the adults counted in 1999. Other species / lifestages captured, in order of abundance, were threespine stickleback (n=346), Atlantic salmon parr (n=116), rainbow smelt (n=21), brook trout (n=3), an Atlantic salmon kelt, an Atlantic salmon post-smolt (age 5+), and an Arctic char (age 2+).

Egg deposition

Juvenile Atlantic salmon rearing units were enumerated at 179.4 for lacustrine habitats and 88 for fluvial habitats. Based on the habitat specific smolt production values (Table

3), the target smolt production for all fluvial habitat was estimated at 264 smolts, which requires 13, 895 eggs or less than 6 small anadromous salmon. For lacustrine habitat the estimated smolt production was 1256 smolt, which requires 66,095 eggs or 28 small anadromous salmon (Table 4).

Small anadromous salmon (N=22) passing through the counting fence contributed approximately 51, 896 eggs (68.9% of the total egg deposition target), while large salmon (N=7) contributed 27, 830 (34.8% of the target), totalling 99.7%% of the total egg deposition requirements (Table 4).

It was estimated that Big Pond ouananiche contributed (95% confidence intervals) 7,933 eggs (2,708 – 39,516) or 9.9% (3.4 – 49.4%) of the target (Table 4). In total, the total egg deposition (non anadromous + anadromous) in 1999 was estimated to be 110% of the habitat-based target.

Table 3: Population parameters for anadromous and nonanadromous Atlantic salmon used in the egg deposition calculation.

	anadromous	nonanadromous
Population	29 (22 small, 7 large)	178 (95% C.I.: 61 - 890)*
Egg-to-smolt survival	0.019[a]	0.019 [a]
Average weight (kg)	1.78 (small) [b] 3.0 (large) [b]	0.069
Fecundity (eggs/kg)	1767[b]	1286[c]
Proportion female	0.75[b]	0.50[c]

*Big Pond only
[a]Estimated with O'Connell et al. 1991 (data collected from Newfoundland systems)
[b]Estimated Linehan and O'Connell unpubl. data collected from Northwest River anadromous salmon)
[c]Estimated with Adams unpubl. data (collected from Indian Bay nonanadromous salmon).

Table 4: Estimated egg deposition of Atlantic salmon in the Big Pond system, 1999.

	Lacustrine units (1 unit = 1 ha)	Fluvial Units (1 unit = 0.01 ha)	Total
Rearing Units			
Minchin Cove to Minchin Pond		10	
Minchin Pond to Big Pond		49	
Big Pond feeder brooks		29	
Big Pond	173		
Minchin Pond	6.4		
Total	179.4	88	
Smolt produced / unit	7[a]	3[b]	
Target smolt production	1256	264	1520
Target egg deposition	66,095	13,895	79,990
Anadromous small salmon required to achieve target	28	6	34
Achieved egg deposition (% of target)			
anadromous small salmon			51,896 (64.9%)
anadromous large salmon			27,830 (34.8%)
Total anadromous			79,726 (99.7%)
Big Pond nonanadromous salmon			7,933 (9.9%) 95% CI: 2,708 – 39,516 (3.4 – 49.4%)
Anadromous + nonanadromous			87,659 (110%)

[a]O'Connell et al. 1991
[b]Elson 1975

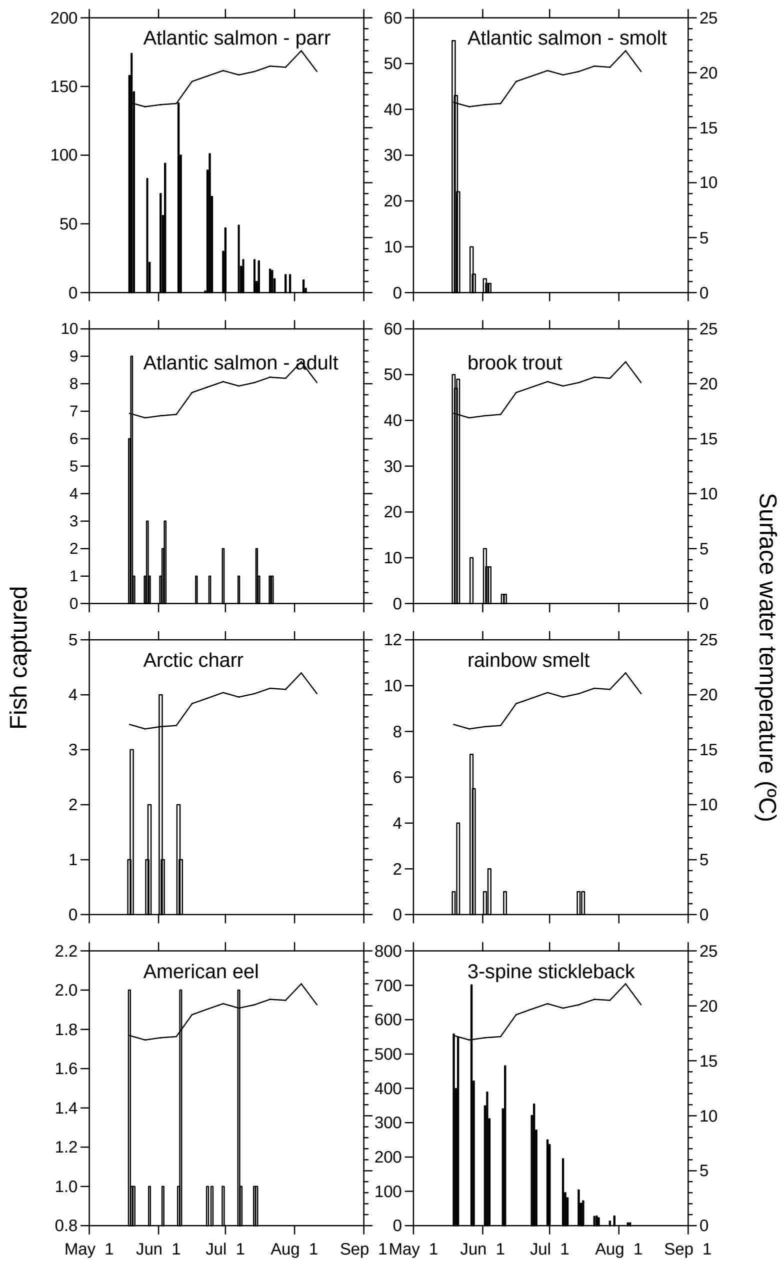

Figure 2: Catches of freshwater fish species and surface water temperature over the sampling period in Big Pond in 1999.

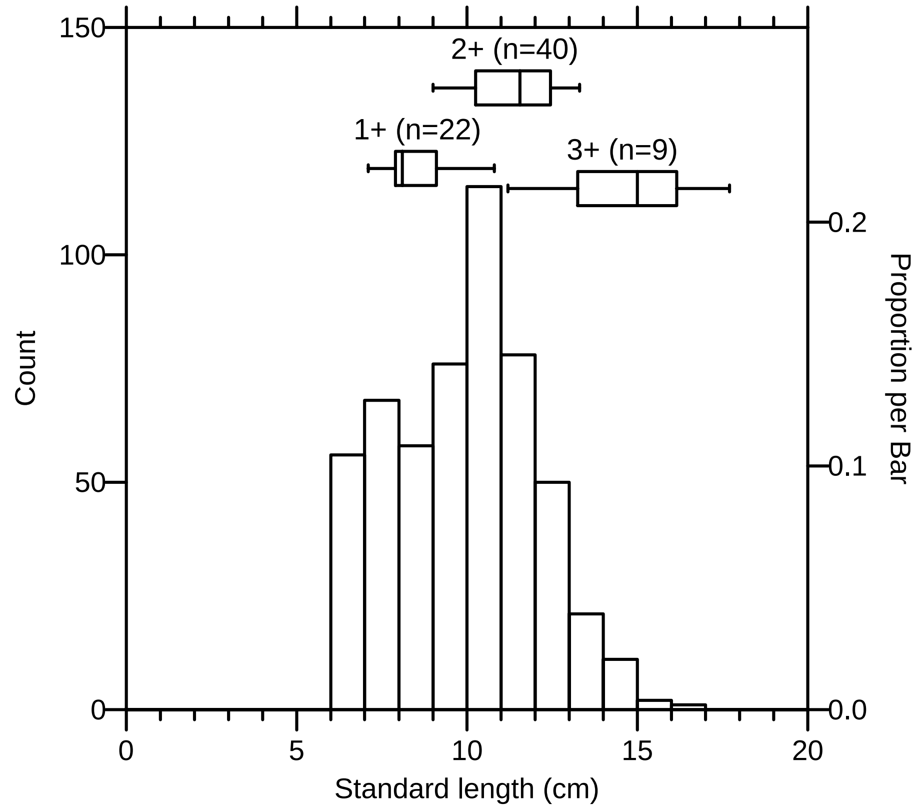

Figure 3: Length distribution (bars) and size-at-age (box and whiskers) of Atlantic salmon parr captured in Big Pond, 1999. Ages are based on scale analysis. Boxes represent 2nd and 3rd quartiles, midline indicates the median and whiskers represent the range of age data.

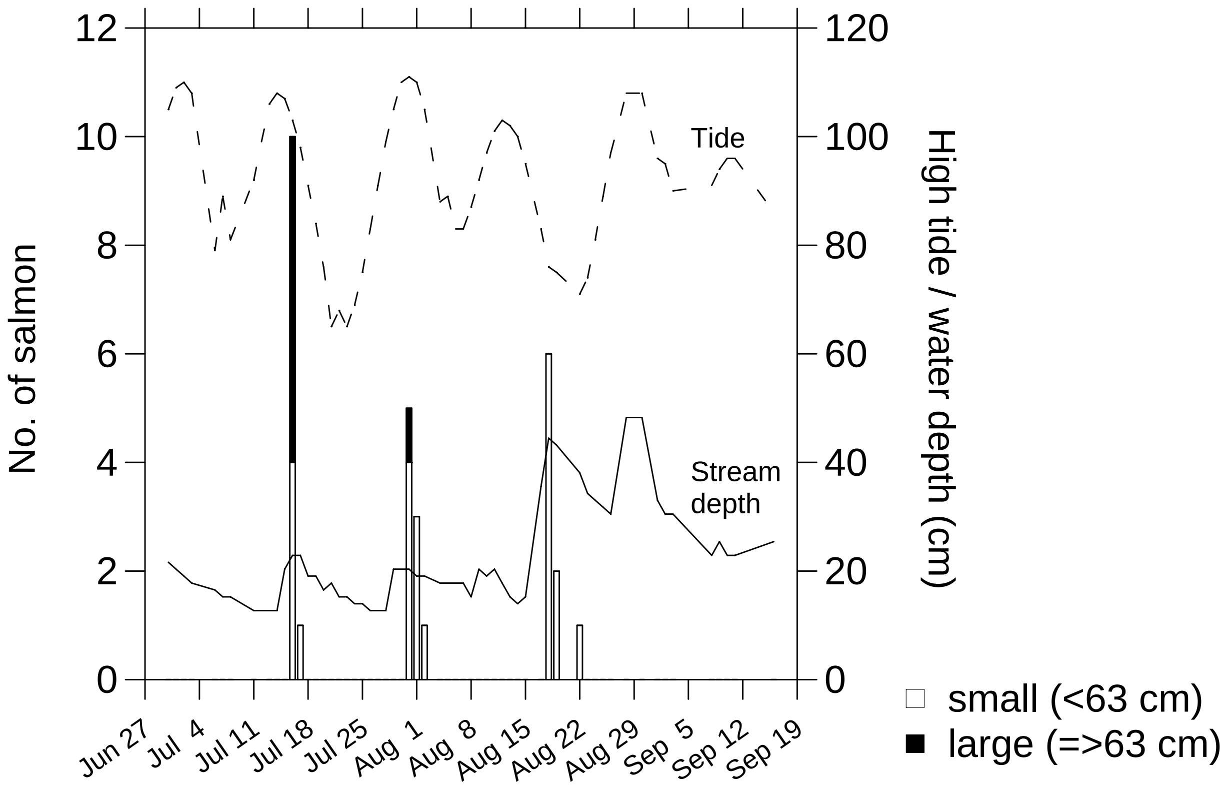

Figure 4: Atlantic salmon returns to Minchin Brook, 1999 (bars), in relation to water depth (solid line) and daily maximum tidal height (dashed line).

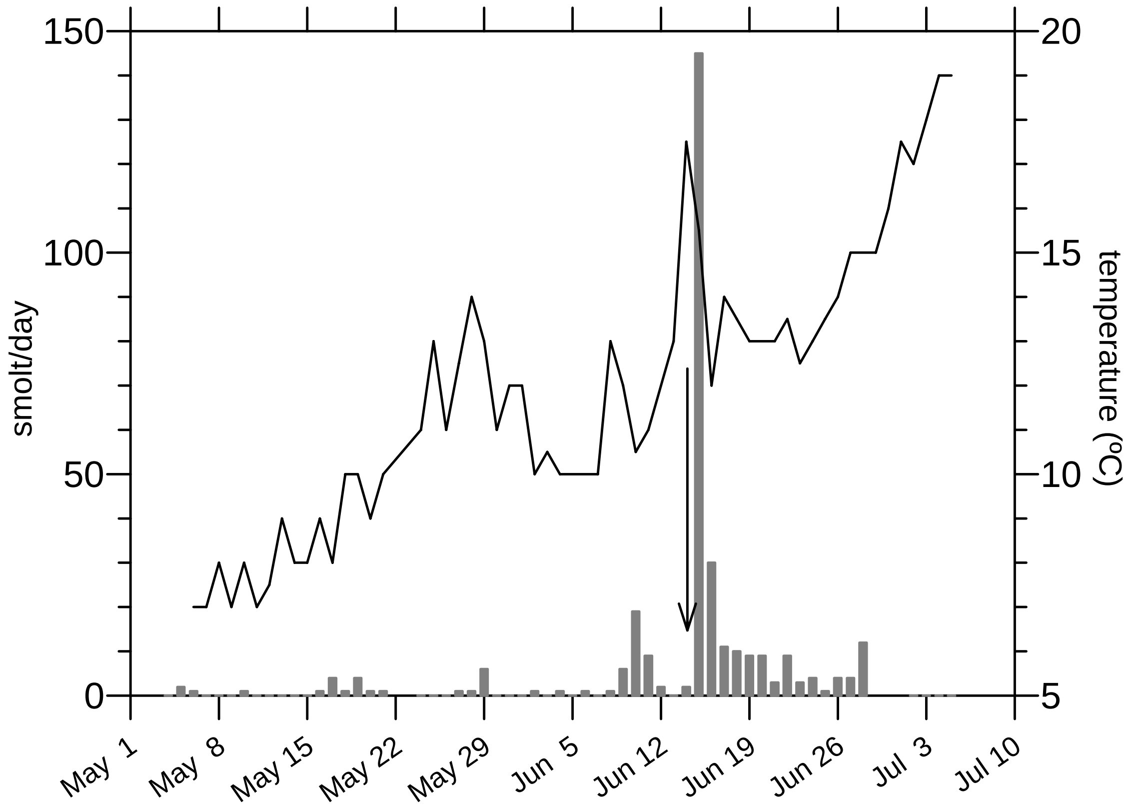

Figure 5: Timing of the 2004 smolt run (bars) and water temperature (line) in Minchin's Brook. The arrow indicates when the trap was situated farther downstream.

DISCUSSION

The salmonid community structure in Big Pond, dominated by Atlantic salmon, was considerably different than that documented for Bluehill Pond, despite their similar spatial extent and fish diversity. In Bluehill Pond, char were the most numerically abundant followed by brook trout and Atlantic salmon, though no one species dominated. In terms of age structure, Arctic char appear to live much longer in Bluehill Pond (maximum age of 13 years) than in Big and Minchin ponds (maximum age of 5 years). The truncated age structure of Big Pond Arctic char could be partially attributed to the reduced numbers of fish sampled in Big Pond since older age-classes in Bluehill Pond occurred at relatively low densities. Age structure of Atlantic salmon was similar in both systems.

Movement of anadromous salmon through the adult counting fence coincided with pulses of increased run-off through Minchin Brook. Due to the shallow nature of the brook, salmon in that system may be required to wait for higher levels to move upstream. Sightings of large salmon trapped in pools in the brook between Minchin Pond and Minchin Cove during low water support this.

Only one anadromous trout was counted returning to the Big Pond system, though anadromous trout have been captured by rod and reel in Minchin Cove (pers. obs.). Potter (1989) observed annual returns of 40 and 403 trout during the 1982 and 1983 seasons in Wing’s Brook – a system of similar size. Returns in that system came in from May to September but peaked in July of both years. Since monthly mean sizes of fish moving into Wing’s Brook from the estuary ranged from 5.0 – 13.5 cm, it is possible that fish were able to slip between the bars of the adult counting fence. Still, low numbers of trout would be expected given the salmon-biased ratios of fish in Big Pond.

Both anadromous and nonanadromous salmon were present in Big Pond. Although of the same species, recent genetic work conducted in three Newfoundland Rivers (Northwest River, Indian Bay and Rocky River) suggest that sympatric anadromous and nonanadromous Atlantic salmon can occur as separate populations; anadromous populations being more similar to other anadromous populations around insular Newfoundland than to the nonanadromous populations in their natal river (Adams unpubl. data). If this holds true for salmon in Big Pond it is possible that the two life history forms in Big Pond populations are reproductively isolated. Nonetheless, other interactions, mediated through predation and competition, likely occur and presence of nonanadromous salmon may influence the carrying capacity of the anadromous population.

Anadromous salmon in Big Pond contribute more eggs than do nonanadromous salmon; most likely an order of magnitude greater. Nonanadromous salmon in Big Pond greatly outnumber anadromous salmon, however their reduced size, lower fecundity and lower proportions of females result in substantially less egg deposition. Based on estimates of egg deposition required for the available habitat and deposition achieved, it appears anadromous population are adequately seeding the Big Pond watershed. Nonanadromous contributions augment the anadromous seeding of habitat to an estimated level of 110%. Despite conclusions of sufficient seeding, the magnitude of the 2004 smolt run was far below (22%) the numbers expected based on the assumed availability of suitable habitat and the levels of egg deposition. The conservation requirement approach, applied to many rivers in Newfoundland by DFO, is useful in managing Newfoundland rivers given that management resources are finite. However, application of this technique to the Big Pond system has some notable limitations. First, the use of fixed parameters for egg-deposition rates, egg-to-smolt survival, and smolt production must be qualified in that there will be inter annual and inter river variation in these estimates (O'Connell et al. 1991). Hutchings (1994) expressed reluctance to use these fixed parameters because they were not accompanied with associated error values. Second, because smolt production rates from lacustrine habitat in Newfoundland were calculated for systems without nonanadromous populations, the applicability of these targets has been questioned for systems with both anadromous and nonanadromous populations occurring sympatrically (Cote et al. 2001). In Wing's Pond, a smolt production estimate of 3.25 smolt/ha was derived for its sympatric lacustrine population (Hutchings 1985). Application of this value to the Big Pond system would almost halve the estimated smolt production (1520 to 847) – though not enough to explain the shortfall in smolt production. Furthermore, assuming similar egg hatching success, anadromous parr likely outnumber nonanadromous parr by a factor of 10, making competition-related reductions in anadromous smolt populations less significant than in Wing's Pond. Our results suggest, that in 1999 at least, egg deposition was sufficient to achieve predicted numbers of smolt based on the habitat-based model. Since the smolts produced in 2004 were most likely spawned by fish returning in 1999 and 2000, a severe shortfall in adult returns in 2000 could partially explain the low smolt numbers in 2004 (if 3+ smolts are typically the dominant age-class). However, of the smolts captured in 2004, the majority were 3+, suggesting poor spawning success in 1999 or poor survival of juveniles spawned in that year. This indicates that some of the assumptions associated with the model are not appropriate for the Big Pond watershed.

Egg deposition by anadromous salmon may be less consistent than those of nonanadromous fish. Although the commercial fishery for salmon is closed and recreational fishing for salmon is restricted in all Park systems except for Northwest River, salmon homing to Big Pond may still be impacted by illegal netting in the marine environment. Further, passage into Minchin Pond and beyond may also be restricted by the presence of beaver dams – which are frequently placed at the outlet of Minchin Pond. Therefore in certain years, nonanadromous populations may play a more significant role in maintaining salmon production in the Big Pond system.

Catch rates of smelt, brook trout and Arctic char decreased sharply after June 10, which may be related to an increase in water temperature. Brook trout grow best at temperatures between 13 and 18ºC. Arctic char, sympatric with other species of salmonids, are known to utilize littoral areas in spring when food resources in these habitats are abundant but move to deeper water in other times of the year (Johnson, 1991). Brook trout, however, are known as a shallow water species and rarely go below 4.5 – 6 m unless water temperatures become too warm and shallow cool water refuges (e.g. seeps) are lacking (Flick, 1991). Other work (cited in Evans 1991) reports that as summer progresses, the midpoint in depth distribution of brook trout increases from a few meters to 8-9 m. Even though 4-6 m is considered shallow, it is still beyond the reach of most shore-set fyke nets. Another factor impacting catchability is seasonal changes in foraging activity. Brook trout and Arctic char feeding in Bluehill Pond peaked in June and levelled out in summer (Fraser 1996). In contrast, parr foraging peaked in July and

August in the same system. If associated with increased activity, increased foraging by parr in summer may make them more susceptible to capture by fixed gear and may explain why catch rates do not drop off as quickly during summer as found for the other life stages and species. Though abundance and biomass estimates for Atlantic salmon and brook trout may be impacted by movements in and out of the system, the Arctic char population is landlocked (the southern limit of anadromy for this species is the Northern Peninsula of Newfoundland, Johnson 1991) and therefore the mark-recapture assumptions regarding immigration / emigration out of the system are not a concern. However, seasonal movements in and out of accessible fishing zones are likely influencing the population estimates of this species.

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Component 3: Reference condition for High Pond & Hancock's Pond fish communities prior to increased visitor access

ABSTRACT

Baseline data was collected on fish from two small ponds on the Park Harbour Peninsula prior to the development of a hiking trail that would increase access to the area. High Pond (13.0 ha) was sampled during spring and summer and Hancock's Pond (15.6 ha) was sampled in autumn. In both ponds brook trout and American eel were the only species present. Though the abundance estimates for the two ponds were similar, biomass/ha of Hancock's Pond was only 60% of that of High Pond. This difference in biomass was driven by the smaller average size of fish in Hancock's Pond. Age structure of High Pond suggests that the age of senescence is 5 years old. Size structure of the two trout populations was similar, with modal pulses occurring at similar lengths in each population. However, the Hancock's Pond trout population appeared to be missing the size classes that corresponded to age 4 and age 5 trout in High Pond (age structure was not measured in Hancock's Pond). The absence of these older age-classes may be related to the temporal difference in sampling period; as mature fish may have moved to spawning grounds and out of reach of the sample gear during autumn. If components of the population were missing due to temporal differences in sampling, then Hancock's Pond biomass estimates have been underestimated. For the purposes of monitoring, future fish sampling should be conducted prior to the spawning season.

INTRODUCTION

STUDY PONDS

Understanding and predicting fish abundance, and biomass in Terra Nova National Park (TNNP) ponds requires baseline data from a representative body of ponds. TNNP straddles two ecozones; the central Newfoundland and the North Shore ecozones. To date, most fisheries data have been acquired from inland portions of the Park and there is no representation from the North Shore Ecozone. Further, fish population estimates in TNNP have been largely limited to the small trout ponds adjacent to the Trans Canada highway (but see Fraser 1996). Little information pertaining to larger and more remote ponds are available. The ongoing development of the Outport Trail for hiking will provide visitors with increased access to Park Harbour Peninsula ponds – most of which have, up until this point, been remote and pristine. This work documents the characteristics of two ponds located on the Park Harbour Peninsula prior to the development of the Outport Trail with the aim of providing baseline data to which the impact of increased access can be assessed.

METHODS

Both ponds under investigation lie on the Park Harbour Peninsula in the North Shore Forest Ecozone (Figure 1). Hancock's Pond (15.6 ha [734800W, 5380600N]; max depth =12 m; mean depth = 3.8 m) flows, via a 1st order brook, into High Pond (13.0 ha; max depth = 18 m; mean depth = 2.8 m [734100W, 5380300N]), which in turn, is drained by a 2nd order brook (average gradient = 2.4%) into the ocean at the Lion's Den.

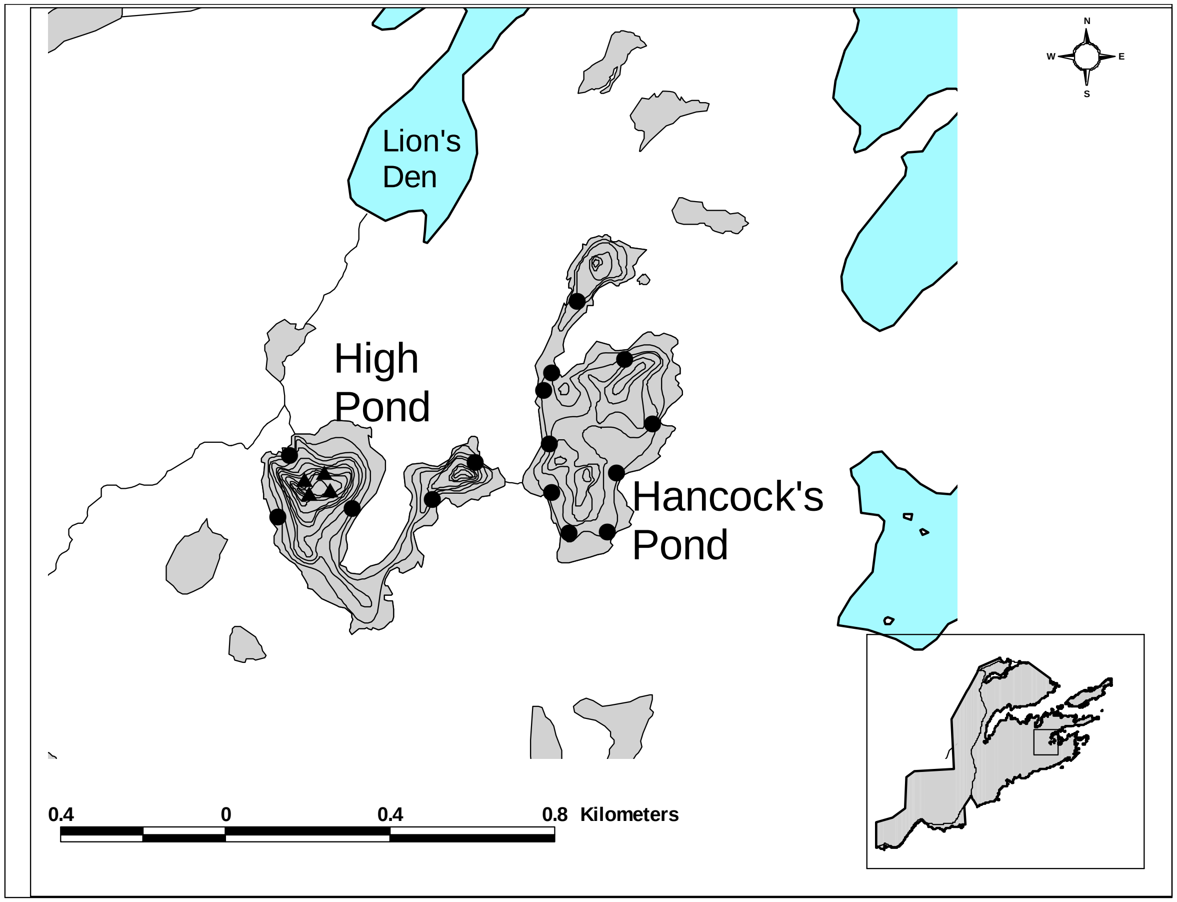

Figure 1: Bathymetry and gear locations (circles: fyke nets; triangles: Takvatn traps) in High Pond and Hancock's Pond. Inset: Terra Nova National Park.

FISH CAPTURE

In High Pond, 5 fyke nets were deployed each sampling day and were augmented by 2 to 9 Takvatn traps / sampling day (May 26 – June 11: 2 traps; June 16 – June 25: 5 traps; July 14 – July 16: 9 traps; July 21 – August 28: 8 traps) to sample deeper water (Figure 1). Increased effort was put forth with the Takvatn traps as water temperatures increased and catch rates declined. In Hancock's Pond sampling was conducted with 11 fyke nets. Sampling was conducted in High Pond from May 26 to June 25 and from July 14 to August 28 in 1998 whereas Hancock's Pond was sampled from September 9 to October 10.

Captured fish were identified, weighed, measured (FL) and marked (only fish > 6 cm) by clipping the adipose fin. Age structure of the High Pond population was assessed using scales taken from the area just posterior to the dorsal fin and 2-3 scale rows above the lateral line. Samples (N=92) were taken daily from 6 to 9 High Pond trout over 13 sampling days from May 26, to June 25. Scale analysis was not conducted for Hancock's Pond. Population estimates were calculated using the Schabel method (Ricker 1975).

ENVIRONMENTAL SAMPLING

Environmental sampling was conducted in High Pond and Hancock's Pond where surface and air temperatures were measured on each day fish sampling took place. Water chemistry was also measured at High Pond four times during the study period (Table 1).

Table 1: Water chemistry in High Pond, 1998.

	July 16	July 24	July 31	Aug 7
Sulfate (mg/l)	6.72	7.84	5.09	5.36
Silica (mg/l)	0.68	0.47	0.53	0.53
Phosphate (mg/l orthophosphates)	0.07	0.07	0.03	0.05
Turbidity *(FTU)	15.7	11.1	12.9	10.2
Chloride (mg/l)	15	18	12	10
Total Alkalinity (mg/l CaCO3)	28	24	24	20
Total Hardness (mg/l CaCO3)	4	10	8	11
pH	6	6	5.9	5.9
Conductivity @ 25 oC (micromhos/cm)	22	22	21	18.5

RESULTS

Brook trout and American eels were the only fish species taken in High and Hancock's Pond. In High Pond 598 brook trout were captured (523 marked, 63 recaptured, 0 mortalities) whereas in Hancock's Pond 283 were captured (265 marked, 16 recaptures, 3 mortalities). Population estimates (95% confidence limits) for brook trout, derived with the Schnabel method, were 2059 (1287 – 3535) for Hancock's Pond and 2156 (1689 – 2754) for High Pond (Table 2). Despite similar abundance, the size structure was significantly different between ponds (Kolmogorov-Smirnov Two Sample Test: $p<0.001$) and the median length of fish in High Pond was 2.3 cm larger (mean = 1.0 cm) than that of Hancock's Pond. Though weights were not measured in Hancock's Pond, estimates calculated from High Pond length-to-weight relationships, indicate that biomass/ha in Hancock's Pond is only 60% of that in High Pond. Ages of trout in High Pond ranged from age 1 to age 5 but age 3 and 4 trout most prevalent in the catch (Figure 2; Table 3).

Eels were less prevalent than brook trout with 11 and 5 eels captured in Hancock's and High ponds respectively.

In High Pond, where multiple gear types were used, fyke nets appeared to be most successful for fish capture. Of the 598 brook trout caught in High Pond, 568 were caught in fyke nets, 28 in Takvatn traps, and 2 by angling. When standardized by gear sets, the median number of fish / fyke net haul in High Pond was 2.0 (range: 0.6 – 15.0) and 1.6 (range: 0.33 – 4.1) fish / net haul in Hancock's Pond. Median fish / trap haul was only 5% of the High Pond fyke net catch rates (median = 0.1; range 0 - 1.0). Kolmogorov-Smirnov Two Sample Test showed that the mean size (SE) of trout caught in the Takvatn traps (18.8 cm ± 0.3 cm) was significantly larger than that for trout caught in the fyke nets (13.1 cm ± 0.1 cm) ($P<0.001$).

Seasonally, fyke net catch rates were highest early in the year in High Pond and declined to less than 4 fish / net after June 21 (Figure 3). The highest catch rates coincided with the lowest water temperatures (10ºC) in the first week of sampling and catch rates generally seemed to be negatively correlated with surface water temperatures. Water temperatures seemed to stabilize at 18 – 23 ºC, as did catch rates. Low catch rates continued on through autumn during netting in Hancock's Pond even though water temperatures were below 18ºC and periodically dipped to lower levels than found during the high spring catch rates observed in High Pond.

Table 3: Size and age structure of brook trout captured in High Pond, 1998.

	n	Median length (SL) at age (range)	Median weight (g) at age (range)	% of population
Age 1	14	7.9 (6.6-10.4)	8 (8-8)	15.5
Age 2	18	11.4 (9.3-14.6)	11 (8-31)	20.0
Age 3	26	15.0 (13.0-17.5)	42 (33-69)	28.9
Age 4	27	17.5 (15.0-22.2)	50 (50-50)	30.0
Age 5	5	19.5 (17.6-20.4)	66 (64-68)	5.6

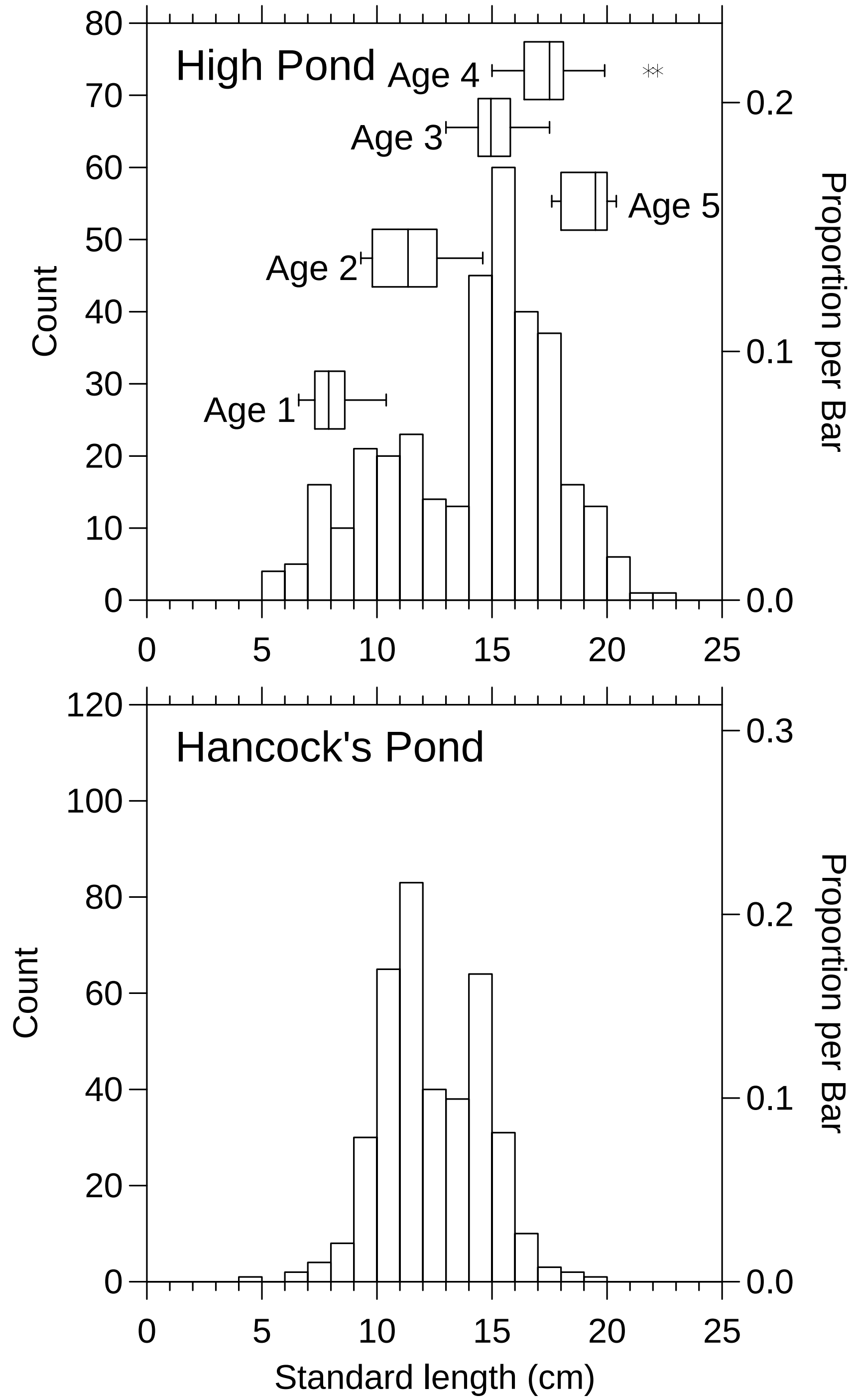

Figure 2: Size distributions (bars) and age structure (box and whiskers) for brook trout in High Pond and Hancock's Pond, 1998.

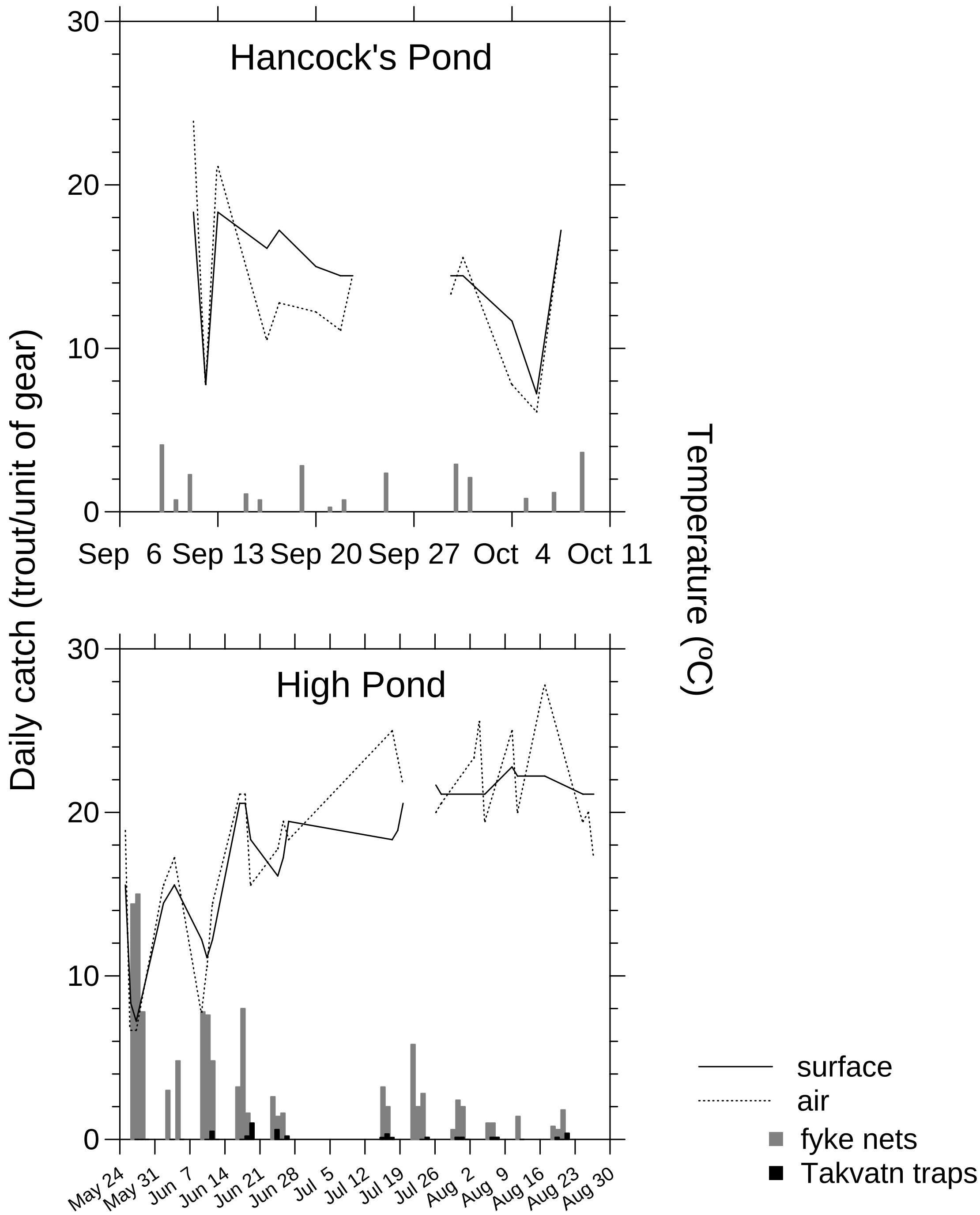

Figure 3: Gear catch rates (bars) of brook trout in relation to air and water (surface) temperature (lines) from High and Hancock's Pond, 1998.

Table 2: Captures by species, salmonid population estimates and biomass estimates for High and Hancock's Ponds.
*Weight for Hancock's Pond calculated from length-weight relationship for High Pond (weight (g)= $e^{2.993 * \ln SL (cm) - 4.407}$ (R^2 = 0.974; P<0.001). Mean length for Hancock's = 12.4 cm therefore mean weight is estimated to be 22.8 g.

Pond	Eels captured	Brook trout marked (recaptured)	Salmonid population estimate (95% confidence intervals)	Mean weight of salmonids (g)	Total biomass (salmonids)	Salmonid biomass/ha (95% confidence intervals)
Hancock's	11	265 (16)	2059 (1287-3535)	22.8*	46.95 kg (29.34-80.60 kg)	3.0 kg/ha (1.88 – 5.20 kg/ha)
High	5	519 (63)	2156 (1689-2754)	36.1	77.83 kg (60.97 – 99.42 kg)	5.97 kg/ha (4.69 – 7.65 kg/ha)

DISCUSSION

Environmental conditions in High Pond are characteristic of oligotrophic lakes and pH's were suitable for brook trout (pH > 5.2; Mount et al. 1988; Ingersoll et al. 1990; Wood et al. 1990). Oligotrophic conditions are typical of nutrient poor TNNP ponds (Kerekes 1977) and acid deposition from long range transports are not at levels which compromise water quality (Clair et al. 1997).

Fish diversity in the study ponds was low, and was dominated by brook trout, though eels were also present. Atlantic salmon and Arctic char were not present, though common in other park systems. The relatively small profundal zones of High and Hancock's ponds, compared to those in which they occur elsewhere in the park (Dunphy's, Bluehill and Big ponds), may explain the absence of char. When living sympatrically with other trout, arctic char are often restricted from the littoral zone, except in spring when food is abundant (Johnson 1991). In High Pond the area of the 4 m and 10 m depth range is 2.8 and 0.69 ha respectively and in Hancock's Pond it is 6.3 and 0.22 ha. In comparison, the surface area of these depth strata in char-bearing ponds in TNNP ranges from approximately 82 – 413 ha for depths beyond 4 m and 25 to 300 ha for depths beyond 10 m. The absence of anadromous salmon is not clear, as average stream gradients in this system are not excessive – though they may be at smaller spatial scales. Landlocked salmon are also absent, however, which may be related to the small area of lacustrine habitat; as they tend occur only in systems with a relatively large lacustrine area in TNNP.

Both ponds had similar brook trout populations but total biomass in Hancock's Pond was estimated to be only 60% of High Pond. When pond area is taken into account, Hancock's has only 50% of the standing biomass. These differences are attributable to the fact that Hancock's Pond trout were estimated to be on average only 63% of the weight of High Pond trout. The cause of the biomass disparity between the two ponds is not obvious as the morphometry of the two ponds is very similar in terms of size, mean depth and maximum depth. Stunting occurs in populations of trout occur elsewhere in TNNP (Garside et al. 1971) but are typically associated with high densities of trout; a characteristic not observed in Hancock's Pond. Possibly, unmeasured factors such as the availability of suitable spawning grounds and/or thermal refuges are less available in Hancock's Pond. A more likely explanation is that the temporal difference in sampling periods is responsible. Though age structure was not examined in Hancock's Pond, year-class pulses are evident in the size-structure plots. The modal pulses in Hancock's Pond, in terms of size, correspond to the lengths of age 1, 2, and 3 age-classes in High Pond. Brook trout generally reach sexual maturity at age 3 and spawn during late summer or autumn in headwaters of streams or in upwelling zones of lakes (Scott and Crossman 1990). Since sampling in Hancock's Pond was conducted during the spawning season, the sexually mature trout may have moved out of range of the sampling gear (i.e. into the brooks). In Wing's and Bluehill ponds (which contains anadromous and non-anadromous brook trout), trout movements out of the pond were high in May, dropped to low levels during summer and increased again in October and November (Potter 1989). Fish moving in the fall were generally larger than those moving at other times of year. If this pattern holds true for the landlocked population in Hancock's Pond, then the fish biomass was likely underestimated.

The maximum size of trout captured in this study was 22 cm in High Pond and 19 cm in Hancock's Pond. These sizes are relatively small compared to maximums found for this species in Bluehill (SL = 37 cm; Fraser 1996), Wing's (SL = 34 cm; this report), Davey Ann's (FL = 41.1 cm) and Trout (FL = 31 cm; Hicks 1992) ponds but comparable to those found in Ochre Hill #3 (Hicks 1992) and Juicey's Pond South (Hicks 1993) and Little Broad Cove (this report). Trout growth can be limited by an absence of large prey (Fausch 1991) and laboratory experiments on brown trout by Bannon and Ringler (1986) showed that the lack of large prey limits growth of brown trout to 23-25 cm. High and Hancock's ponds lack small fish species (e.g. 3-spine sticklebacks and smelt) that are found in Wing's and Bluehill ponds, which suggests that maximum growth may be limited by the lack of large prey species. However, Davey Ann's and Trout ponds do not have large prey species yet still have relatively high maximum sizes. Obviously other factors besides prey size play a role in determining the maximum size of fish in a pond. Trout grow and survive best at temperatures between 13 and 18ºC (Flick 1991). Low catch rates, when water temperatures increase above this range, restrict effective sampling to spring / early summer. Trapping in the fall is attractive as it allows a "second sampling season" with cool waters. Unfortunately, the results of this study suggest that cool waters in the fall do not necessarily equate to high catch rates. Possibly other factors such as reduced feeding activity in the fall (Fraser 1996) plays a role. More importantly, because it is during the trout (Flick 1991) and salmon (Scott and Crossman 1990) spawning season, fall lake sampling may miss a segment of the population that is present in the spring. As a result, sampling that is conducted for the purpose of estimating biomass or examining the age-structure of fish (often used to assess the impacts of harvesting) is likely best done in the spring.

Fyke netting was far more effective than trapping with Takvatn traps, though a direct comparison cannot be made as the Takvatn traps were deployed in a different habitat (deep basins) than were the fyke nets (coastal littoral zone). High littoral catch rates are consistent with the fact that brook trout are known to be a predominantly littoral species and seldom use depths greater than 4.5 – 6 m unless water temperatures in shallow water become too high and no cold water refuges are available (Flick 1991). Fish captured in Takvatn traps were significantly longer than those caught in fyke nets, but again, this is more likely a reflection of habitat. Despite the low catch rates, Takvatn traps allow for more representative sampling and are a non-lethal alternative to gill nets.

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Component 4: A comparison of brook trout (*Salvelinus fontinalis*) populations in Ochre Hill Pond #2 and Arnold's Pond

ABSTRACT

Two small ponds (Arnold's Pond and Ochre Hill Pond #2) in Terra Nova National Park (TNNP) were sampled with fyke nets to establish brook trout abundance. The results were compared to estimates obtained from an "off-the-shelf" fish finder being tested for its utility for monitoring. The mark recapture component in Arnold's Pond and Ochre Hill Pond #2 indicated that 1791 (95% CI at 1548 and 2071) and 583 (95% CI at 500 and 680) brook trout inhabited the respective ponds. In general, trout in Arnold's Pond did not grow as large (in length or weight) as those in Ochre Hill Pond #2. Furthermore, trout in Ochre Hill Pond #2 were in better condition. However, the biomass per unit surface area in Arnold's Pond was 144% (12.72 kg/ha) of that in Ochre Hill Pond (8.85 kg/ha). Population estimates from acoustic surveys were highly variable and did not correspond well with those obtained with conventional methods. It is likely that the shallow nature of the ponds contributed to the ineffectiveness of the vertical beam hydroacoustic system. Other technologies (i.e. horizontal beam hydroacoustic systems) may be required to streamline fish population monitoring in TNNP.

INTRODUCTION

National Parks of Canada are mandated to maintain ecological integrity (EI) while providing, where possible, positive visitor experiences. Recreational fishing has long been sanctioned in National Parks despite its potential for negative impacts on fish populations (Post et al. 2002; Jones 2001). Therefore in keeping with Parks Canada's mandate, fishing should only be permitted where it can be ensured that it is having little to no impact on EI. Unfortunately population assessments with current mark/recapture techniques are time consuming and can only be realistically undertaken on a few small ponds per year (e.g. Hicks 1992, Fraser 1996). Creel censuses are another tool that have been utilized in TNNP (Rogers 1981; Thompson 1981; Orr and Arnold 1984a; 1984b; Tordon 1986; Hicks 1992) but, like mark-recapture, it is labour intensive, cannot realistically provide comprehensive coverage and has not proven to be sustainable in TNNP. Further, unless augmented by population sampling, indicators provided by creel censuses (e.g. CPUE) may not be sensitive to serious changes in the population structure (Post et al. 2002). Other remote sampling methods, such as hydroacoustics, could provide more efficient techniques to estimate fish biomass and abundance (Hyatt and Stockner 1985; Ransom et al. 1998; Hughes 1998). The advantages of using hydroacoustics are independence from fishery catch statistics, a favourable sampling time scale, low operational costs, low variance and the potential for absolute population estimation (Thorne 1983). Although some important population level information (e.g. age structure, growth, condition etc.) would require capture and handling of fish, sampling for these purposes alone could be conducted with considerable less effort relative to that put forth toward mark/recapture estimates. Unfortunately, most hydroacoustic systems used for fisheries research, are expensive and are not sufficiently portable for use in small craft (e.g. canoe) in backcountry areas. However, Gjernes et al. (1986) compared an inexpensive, portable echosounder (modified to include time varied gain) with a scientific-grade sounder developed specifically for fish census. They determined that the inexpensive model was reliable enough to sample limnetic fish populations. Even if inappropriate for determining absolute fish abundance, off-the-shelf models may be useful for determining relative abundance if a standardized methodology is used. Such information would be useful for monitoring purposes as it would allow managers to fill in data gaps between mark-recapture studies and focus increased monitoring efforts or interim management strategies in ponds with declining trends. We compared fish abundance estimates from a standard "off-the-shelf" fish finder to those concurrently acquired from mark-recapture studies in two small ponds.

STUDY SITE

Two small oligotrophic ponds in the Central Newfoundland forest ecozone were investigated in this study. Arnold's Pond (4.0 ha, average depth = 2.1 m, max depth = 5 m [722 813W, 5390807N]) is a small headwater pond in the Southwest Brook watershed. It is drained by a first order stream, Arnold's Pond Brook (gradient average = 4.9%; max gradient = 9.4%), that flows approximately 1 km before is enters Southwest Brook just upstream of the Southwest Arm estuary. Creel census has indicated that brook trout are the present in this pond (Thompson 1981; Hicks 1992) and electrofishing surveys have detected both brook trout and Atlantic salmon in Arnold's Pond Brook below the Trans Canada highway (Cote unpubl. data). However, only brook trout were found above the Trans Canada highway. It is likely that, prior to culvert restoration, Atlantic salmon could not access the upper tributary due to a barrier to fish passage caused by the culvert. Ochre Hill Pond #2 (3.6 ha, average depth = 2.6 m, max depth = 6 m [724 264W, 5376 742N]) is intermediate in size to two other ponds in the same complex (Ochre Hill #1: 1.2 ha and Ochre Hill #3: 4.1 ha). A small, shallow brook separates each pond in this complex. The 2nd order brook (average gradient = 1.9%, max gradient = 5.7%), which drains this system, runs 7.1 km before it flows into Newman Sound. Trout are known to be present in the system (Thompson 1981; Hicks 1992); a fact that is corroborated by fyke netting efforts conducted in Ochre Hill #3 (Hicks 1992). Atlantic salmon were not detected in Ochre Hill Pond #3 and are probably restricted from the ponds in this system by the steep stream gradients of Rocky Pond Brook and Ochre Hill Brook (> 5% in some areas).

METHODS

Fyke net sampling was done from May 15 to May 24, 2002 in Ochre Hill Pond (10 fyke nets) and Arnold's Pond (4 nets). All fish were identified, counted and salmonids were fin clipped, weighed, and measured. Population estimates were calculated with the Schnabel multiple mark recapture method (Ricker 1975).

ACOUSTIC ASSESSMENTS:

Acoustic sampling was conducted using a Hummingbird 200DX "off-the-shelf" vertical dual beam fish finder. This system was not outfitted with user controls for time varied gain (required to account for signal attenuation at depth; Gjernes et al. 1986), however since it was being used in shallow water we deemed this modification unnecessary. This model was selected as it had a narrow (20º) and wide beam width (53º). The wide beam width was particularly desirable as most ponds in TNNP are small and relatively shallow and therefore would be less suitable to a narrow beam width (only small areas could be sampled in shallow water with a narrow beam width). Effective beam width was ground-truthed by setting ping-pong balls at known locations and depths (Gjernes et al. 1986). Transects (cumulative distance $_{\text{Arnold's}}$ = 705 m; cumulative distance $_{\text{Ochre Hill \#2}}$ = 809 m), placed 30 m apart and parallel to one another, were surveyed from a canoe, with one individual propelling the canoe and the other recording the numbers of acoustic detections (echo counting) in addition to the size of the fish (3 sizes classes were discriminated by the system). Transects were surveyed twice in each pond at night when fish behaviour (dispersed and away from cover) was thought to be most conducive to hydroacoustic assessment. Estimates of fish abundance in the pond were extrapolated from the numbers detected based on the ratio of insonified volume to total pond volume (Gjernes et al. 1986). The insonified volume of a transect was assumed to be wedge shaped because high overlap of acoustic pulses would be expected (Kieser and Mulligan 1984) given the slow velocity of the canoe. The insonified volume, therefore, was calculated as product of the transect distance and the cross sectional area of the acoustic sounder (cross sectional area = 2 x water depth x tan (beamwidth). At a given location, the cross sectional area sampled was greater at depth than in shallow water. Since it was not likely that fish were distributed evenly across depths we stratified abundance estimates by 1 m depth intervals (depths of fish positions were recorded on the display). Abundance estimates reported are from fish detected within the 53º beam. Pond bathymetry was acquired from Hammond (1987) and stratified in Arc-View GIS to determine volume within depth strata.

RESULTS

Brook trout was the only fish species captured in Arnold's Pond while brook trout, American eels and threespine sticklebacks were identified in Ochre Hill Pond #2. Fyke netting efforts resulted in 944 (763 marked, 180 recaptured) trout captured in Arnold's Pond and 515 (363 marked, 163 recaptured) in Ochre Hill #2 Pond. The trout population size for Arnold's Pond was estimated to be 1791 (1548 – 2071) trout while for Ochre Hill Pond #2 it was estimated to be 583 (500-680). The higher abundance of fish in Arnold's Pond was offset by the smaller mean size of these fish (Arnold's: 14.9 cm, 28.2 g; Ochre Hill #2: 18.0 cm, 55.0 g). These size differences resulted in more similar standardized biomass estimates; though the biomass for Arnold's Pond (12.72 kg/ha) still exceeded that for Ochre Hill #2 (8.85 kg/ha).

The size structure of the population differed considerably (Figure 1). Very few fish (0.5%) in Arnold's Pond grew above 20 cm and only 19% of the individuals were above 17 cm (the length of maturity for trout in Juicey's Pond – Garside et al. 1971). In contrast, Ochre Hill Pond had 15% of individuals above 20 cm and 69% above 17 cm. Condition of Ochre Hill Pond (mean = 0.921) trout was significantly greater ($t_{d.f.=775.4} = 12.0$; $p<0.001$) than that for Arnold's Pond (mean = 0.821).

ACOUSTIC ASSESSMENTS

Population estimates for Arnold's Pond ranged from 755 to 1256, which was 42 – 71% of the mark recapture estimate and outside of the 95% confidence intervals (Table 1). In contrast, the Ochre Hill Pond hydroacoustic estimate ranged from 0 to 202% of the mark recapture value and was also outside of the 95% confidence intervals. Such variable population estimates resulted in the early termination of this study component.

Table 1: Fish abundance estimated with hydroacoustics relative to that from conventional mark recapture techniques.

Pond	Trial	Fish detected (hydroacoustics)	Predicted fish abundance (hydroacoustics)	Abundance estimate from fyke netting (95% C.I.)
Arnold's	July 15, 2002	32	755	1791 (1548 – 2071)
	July 17, 2002	36	1266	
Ochre Hill #2	July 15, 2002	41	1175	583 (500-680)
	July 17, 2002	0	0	

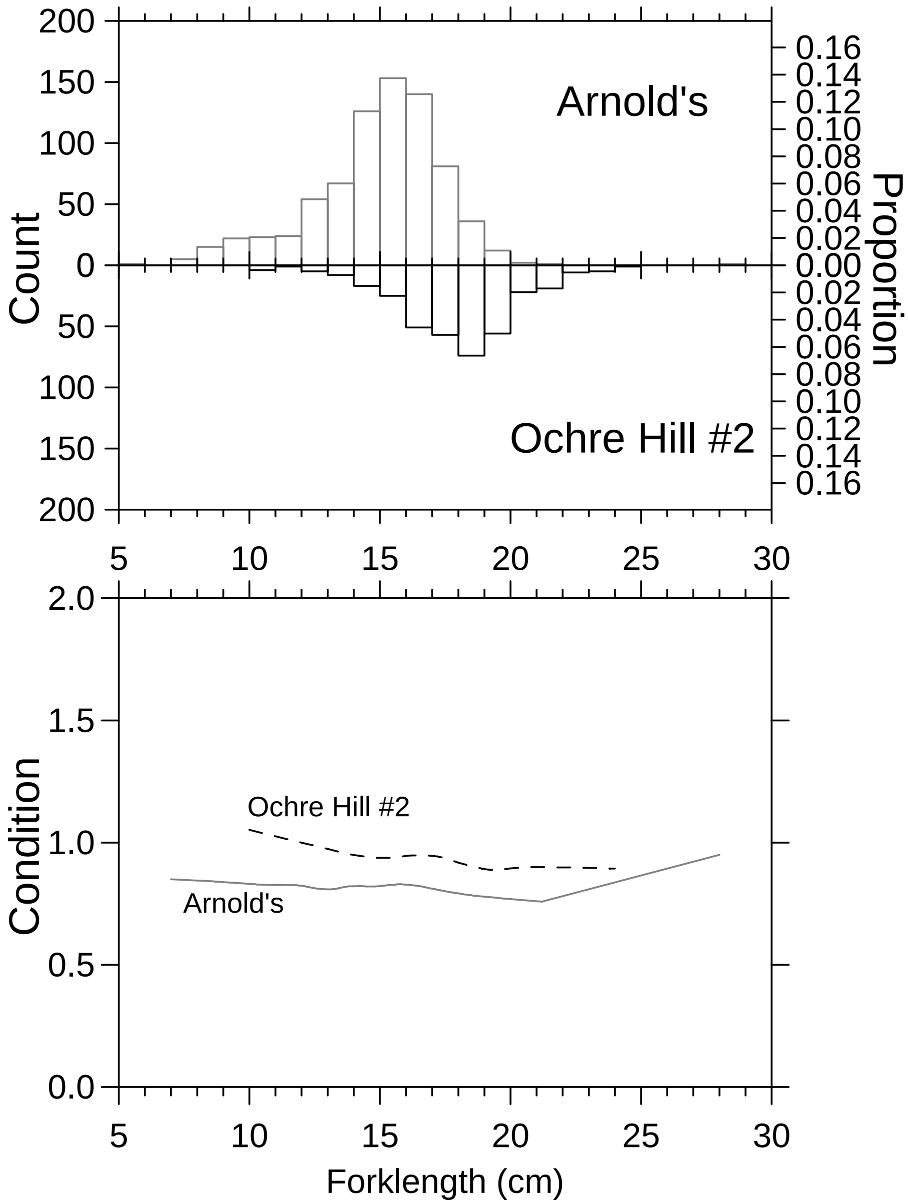

Figure 1: Length distribution (top panel) and Fulton's condition (locally weighted smoother; bottom panel) of brook trout (*Salvelinus fontinalis*) in Arnold's Pond and Ochre Hill Pond #2 during May 2002.

DISCUSSION

Abundance of trout in Ochre Hill was only one third of Arnold's Pond even though the ponds were of similar size. The population in Arnold's Pond, however, had smaller average size, poorer condition and widespread infections of black spot – all characteristic of stunted populations. The largest fish captured in this study (28 cm) was taken in Arnold's Pond however, and demonstrates that some individuals may grow well beyond what is typical for a stunted population (Kerekes 1968). Interestingly condition was considerably lower for stunted trout in Arnold's Pond (K < 1.0) compared to stunted trout sampled in Juicey's Pond in 1970 (K = 1.1 - 1.2, Garside et al. 1971). Biomass was more similar between ponds in this study but Ochre Hill #2 still only had 69% of the biomass / ha. The cause of the lower biomass in Ochre Hill Pond is uncertain. Potentially, lower biomass may be a result of recreational fishing pressure (e.g. Post et al. 2002). A creel survey (Hicks 1992) indicated that 13.5% of all fish creeled in TNNP were from Ochre Hill Ponds. Thompson (1981) indicated that angling effort (anglers per hour of observation) was three times greater in Ochre Hill Pond relative to Arnold's Pond. Despite this pressure, catch per unit effort was higher in Ochre Hill Pond (Ochre Hill: 2.4 fish/hour; Arnold's: 2.0 fish/hour). Unfortunately both of these creel studies suffered from low sample sizes and are of limited utility. With regards to size structure, Ochre Hill Pond #2 has more spawning size fish (>17cm, Garside et al. 1971) and more large trout (>20 cm) than Arnold's. If overfished, these larger individuals would be expected to be less prevalent in the population. The absence of larger trout in Arnold's Pond may also superficially lead one to conclude that overfishing may be a problem. However, of the 36 fish creeled in 1981 (Thompson 1981) none were greater than 20 cm and only 17% were greater than 17 cm, showing that the population size structure has not changed in over 20 years. Furthermore, Arnold's Pond has a comparable fish size structure to Juicey's Pond (Garside et al. 1971); a relatively unfished population (Tordon 1986). Alternatively, the disparity in biomass between Arnold's and Ochre Hill Pond may be explained by the presence of higher trophic levels. Slobodkin (1966) estimated an ecological efficiency of 10% between successive trophic levels. Field estimates, conducted by Kerekes (1977) for the non piscivorous fish population (3^{rd} order trophic level) in Juicey's Pond, TNNP indicated an ecological efficiency of 0.8% (1% was predicted). If the larger fish in Ochre Hill Pond constitute yet a higher (piscivorous) trophic level, then a comparatively lower standing biomass may be expected. The occurrence of threespine sticklebacks provides an opportunity for Ochre Hill Pond trout to become piscivorous. Such predation has been previously been documented for trout in the Wing's Pond system in TNNP.

Efforts to streamline fish population monitoring with off-the-shelf fish finders were unsuccessful. Other "inexpensive" systems (< $5000, Gjernes et al. 1986) have been found to be reliable in the deep lakes but were considerably more expensive than the Hummingbird 200DX (~ $400) used in this study. Population estimates in Ochre Hill and Arnold's Pond varied widely within ponds and did not reflect the known or relative population size estimated from fyke netting. Failing to account for fish behaviour (avoidance reaction, schooling behaviour, habitat use) is known to cause bias in abundance estimates (Freon and Gerlotto 1988). Nonetheless, avoidance reactions should have been limited as the sound generated from the canoe would have been minimal.

Further, sampling was conducted at night when trout would have been least likely to school and seek protective cover from predators. Nonetheless, the wide variance observed in Ochre Hill Pond #2 is consistent with what would be observed if trout were schooling. Conversations with the manufacturer's development engineer indicated that these systems were designed for anglers who may be using these systems in areas with substantial boat traffic. Therefore factory adjustments were necessary to eliminate sensitivity to acoustic noise in shallow environments for these users. Since the majority of the survey transects occurred in shallow water it is quite probable that many fish were not detected. Other studies using scientific grade hydroacoustic systems also indicate difficulties in shallow water (e.g. Kubecka and Wittingerova 1998). Kubecka and Wittingerova (1998) indicated that vertical beam sonars needed to be supplemented by horizontal beam systems because most fish in their study were confined to shallow water (0-4 m) where favourable environmental conditions could be found. Other work confined to shallow water also utilized horizontal beams (Hughes 1998; Ransom et al. 1998). Future efforts in TNNP will likely require horizontal beam sounders since most ponds are relatively shallow or have significant shallow components. To date most scientific grade systems are expensive (> $50 000, Thorne 1983) and too large to operate from small craft. However, given the current cost of monitoring with conventional techniques, it may be economical to purchase a more expensive system (particularly if shared over several parks) if portability issues can be addressed.

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Component 5: Changes to brook trout population structure in Trout Pond and Yudle Pond, Terra Nova National Park, after two decades of recreational fishing

ABSTRACT

Two small accessible ponds in Terra Nova National Park (TNNP) were sampled to assess if changes in brook trout abundance, condition, biomass, and age structure have taken place over a 19-year period. Abundance of brook trout remained stable in Trout Pond compared to 1984 and 1992 estimates, although mean lengths and weights of brook trout were significantly smaller. The result of the mean size reductions was a decline in biomass by approximately 55%. Older age classes were less prevalent in 2003 though condition of these fish improved. Fish larger than 20 cm, which is the typical minimum retention size, dropped from 24.6% in 1992 to 15.6%. More alarming was the decline in spawning sized fish, whose abundance declined from 62% of the population to 18%. No brook trout were recaptured in Yudle Pond and as a result, little inference can be made regarding its population abundance or biomass. Considering changes to Trout Pond's population's structure, changes to management in the recreational fishery are warranted.

INTRODUCTION

Recreational fishing has been a past time in National Parks since their inception. In the TNNP area, brook trout and Atlantic salmon resources have been utilized as a source of food and recreation long before the establishment of the Park. Early research in TNNP was focused on the productive capacity of ponds for the purpose of recreational fishing (e.g. Thompson 1981). More recent work by Hicks (1992) expressed concern about overharvesting in Trout Pond. Parks Canada is mandated with managing its natural resources so as not to impair the ecological integrity of its systems. Despite the potential of recreational harvesting to negatively influence fish populations (Post et al. 2002; Sullivan 2003a; Cooke and Cowx 2004), there have been few investigations that have examined impacts in TNNP or elsewhere in Newfoundland.

Trout Pond and Yudle Pond represent two of the most well studied ponds in TNNP. Fish sampling in Trout Pond has occurred in 1968 (Kerr 1969), 1984 (Beauchamp and Kerr 1984) and 1992 (Hicks 1992); providing the best long-term fish population data set that is available for the park. Yudle Pond fish populations were sampled in 1968 (Kerr 1969) and other work has examined the limnology of this system (Kerekes 1974; Kerekes 1975; Kerekes 1977). Both of these ponds have also been regularly included in creel censuses (Rogers 1981; Thompson 1981; Orr and Arnold 1984a, 1984b; Tordon 1986; Hicks 1992). The ease of access for Trout and Yudle ponds contributes to their status as favourite trouting areas and similarly for their frequent inclusion in park research initiatives. Such characteristics make these ponds ideal for investigating the impacts of recreational fishing. It has been over a decade since Trout and Yudle Pond have been sampled and no information is available regarding the status of the population since Hicks (1992) indicated concerns of overharvesting. We resampled these fish populations to determine trout abundance, biomass and age structure and compared it to data collected over the past four decades.

METHODS

SITE DESCRIPTION

Trout and Yudle ponds (Figure 1) lie adjacent to the Trans-Canada highway near the enclave community of Charlottetown. They are the two most accessible ponds of the six that lie at the headwaters of Charlottetown Brook. Water from these ponds drain through separate tributaries, meet at Charlottetown Brook and run 2.5 km to the marine environment. A waterfall below Charlottetown obstructs salmonid access to these ponds from the marine environment (though the presence of eels (Hicks 1992) indicates some fish species may be able to bypass the barrier). Trout Pond is relatively small (8.2 ha), shallow (max depth = 3 m, mean depth = 0.6 m) and has no thermal stratification while Yudle Pond, though similar in areal extent (10.1 ha), is deeper (mean depth = 2.0 m max depth = 12 m) and exhibits thermal stratification. Due to the accessibility of these ponds, fishing pressure is relatively high compared to other park waterbodies; particularly early in the year when water temperatures are more suitable for fishing (Orr and Arnold 1984a).

FISH SAMPLING

Fish sampling was conducted from May 6 to May 16, 2003 with fyke nets ($N_{Trout} = 6$; $N_{Yudle} = 7$) and baited Takvatn traps ($N_{Trout} = 2$; $N_{Yudle} = 2$). Traps were used to sample deeper areas of the ponds where fyke nets were unsuitable. Captured trout were measured for length and weight and marked by clipping the left pelvic fin. Length and weight information was not normally distributed. Therefore, comparisons of these measures (for fish captured for the first time) were conducted with the non-parametric analog of the t-test, the Mann-Whitney U-test. Scales, taken above the lateral line posterior to the dorsal fin, were taken from all unmarked fish for aging. Scales were aged by the Canadian Department of Fisheries and Oceans. A subset (n=50), re-aged by a different observer to assess precision, indicated that 88% of the samples had matching ages.

Population estimates were calculated using the Schnabel multiple mark recapture method (Ricker 1975) while biomass was estimated by multiplying the trout abundance estimate by the mean weight. Fulton's Condition factor was calculated with the following equation:

$$K=100ML^{-3}$$

Where K is Fulton's Condition factor, M is mass (g) and L is forklength (cm).

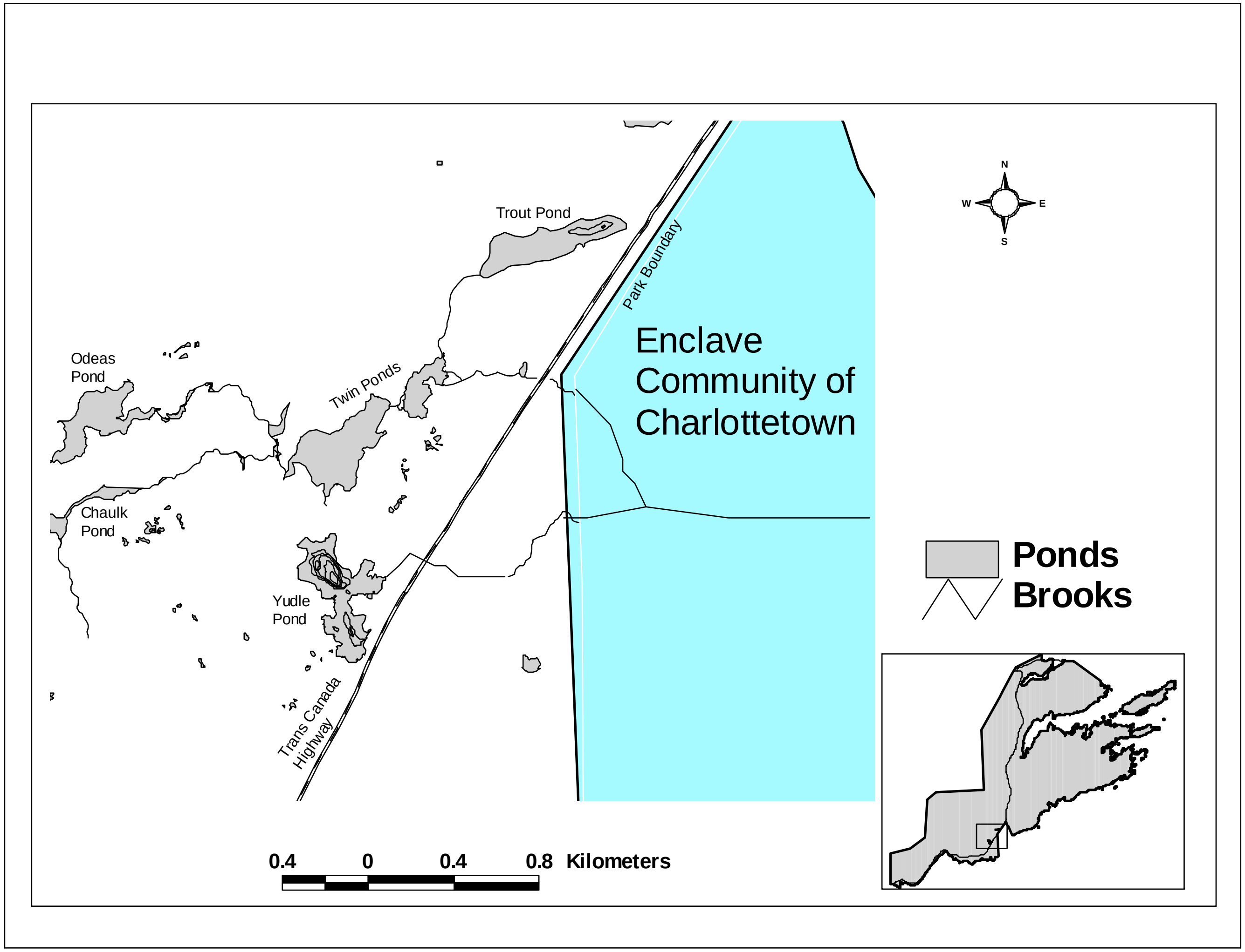

Figure 1: Trout and Yudle Pond.

RESULTS

TROUT POND

Two hundred and thirty-seven brook trout were captured (26 recaptures) in Trout Pond producing a population estimate of 846 (95% CI: 561 – 1235). With an average weight of 63 g per fish the trout biomass was estimated to be 53.3 kg or 6.5 kg/ha (Table 1). Age classes represented in the catch ranged from 1+ to 5+ (Table 2) with the modal peak occurring at the 2+ age-class (Figure 2). The much greater size-at-age of fish captured in 1984 and 1992 likely indicated a discrepancy in aging techniques. Interestingly, Hicks (1992) increased the ages of all fish sampled in 1969 by one year as suggested by Garside et al. (1971). However, based on the size-at-age of trout in the nearby Indian Bay watershed (aged with the more reliable otolith technique) we feel that the 1969 and 2003 ages are correct and therefore we have adjusted their ages back one year.

Assuming that fishermen only retain fish 20 cm or greater (which make up 15.6% of the population), an estimated 132 (87 – 191) fish were available to the fishery. Eighteen percent of Trout Pond trout were greater than 17 cm - the size at which approximately 50% of the population has reached maturity in Yudle and Juicey's Pond (Garside et al. 1971). Fulton's Condition factor for these fish ranged from 0.71 to 1.84 with the best condition occurring for the older age-classes (Figure 3). Trout from 2003 were significantly smaller in length ($U = 29{,}634$; $p<0.001$) and weight ($U = 30603$; $p<0.001$) than those captured in 1992 (Table 1; Figure 4).

YUDLE POND

In Yudle Pond, 68 fish were captured and marked however no recaptures were taken thus eliminating the possibility of calculating the population size. In Yudle Pond the 1+ to 3+ ages were represented (Table 3) with the mode occurring at the 2+ age-class (Figure 2). Fulton's Condition ranged from 0.91 (for age 1) to 1.12 (for age 2 and age 3). Only 4.4% of the sampled population was above 20 cm in length but 51% were above the 17 cm threshold where approximately 50% of fish are sexually mature (Garside et al. 1971).

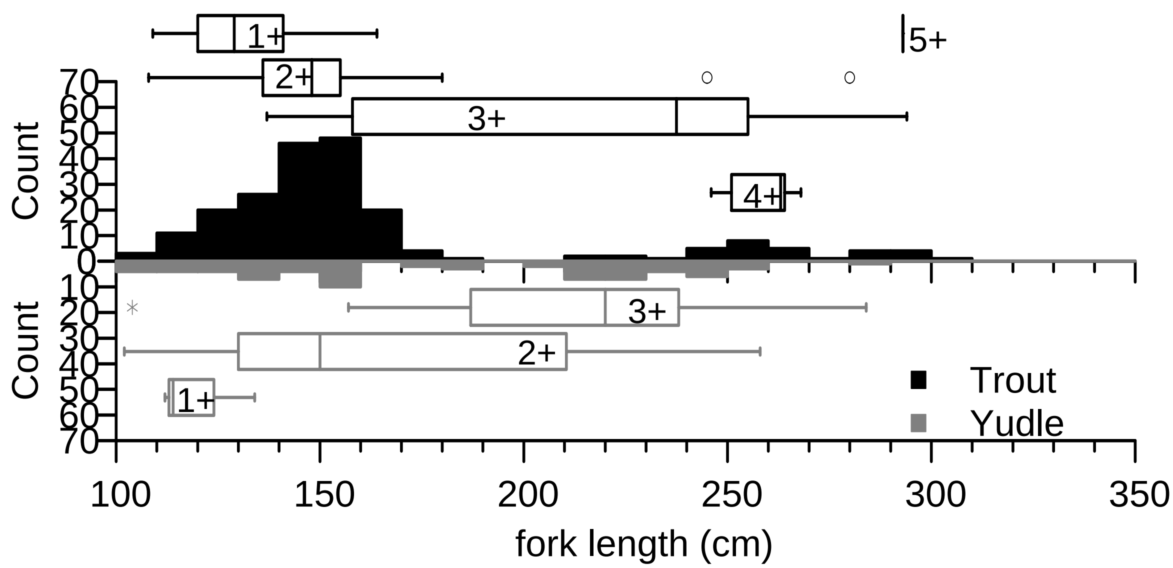

Figure 2: Size and age distribution of brook trout from Trout and Yudle Pond, 1999.

Table 1: Comparison of length, weight, abundance and biomass of Trout Pond brook trout in 1984, 1992, and 2003.

Year	Length (cm)	Weight (g)	No. of trout (upper – lower CI (95%))	Trout biomass (kg) (upper – lower CI (95%))
1984		108.9	889 (531 – 1805)	96.8 (57.81 – 196.52)
1992	18.4	93.2	707 (498-1003)	65.88 (46.40 – 93.46)
2003	16.2	63.0	846 (561 – 1235)	53.33 (35.37 – 77.85)

Estimated biomass based on a pond area of 8.1 ha: Fish biomass = 8 + 67 * log10 (pond area) = 63.56 kg.

Table 2: Age distribution (in % of total catch) of trout in Trout Pond based on scale samples. Data from 1969, 1984*, and 1992* are taken from Hicks (1992). *One year subtracted from reported ages.

Age	2003	1992	1984	1969*
1	13.2%	8.7%	19.4%	
2	64.1%	14.8%	16.4%	48.7%
3	17.9%	50.0%	34.3%	24.3%
4	2.8%	17.8%	21.6%	16.2%
5		5.7%	4.4%	10.8%
6			3.7%	

*data acquired from gill nets with a sample size of n = 37

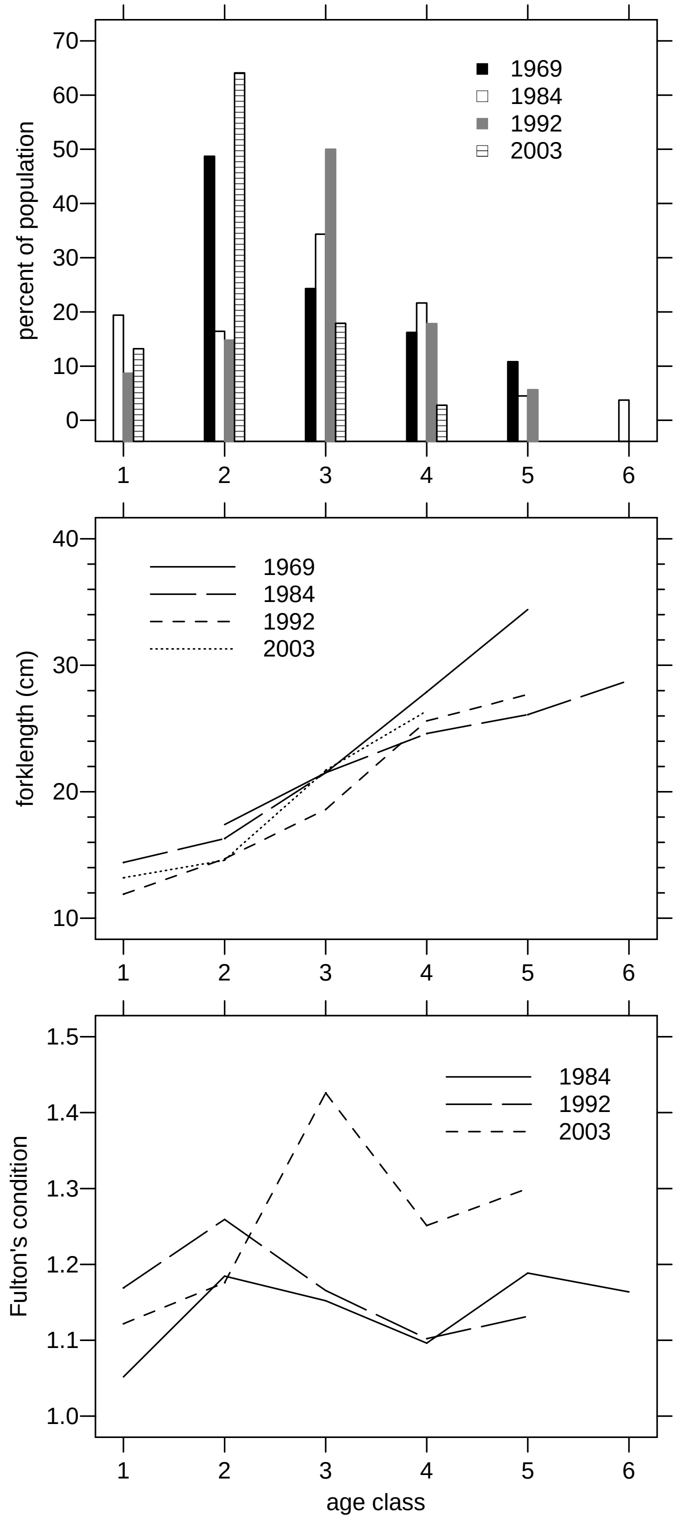

Figure 3: Size and age class distribution and Fulton's condition of brook trout in Trout Pond in 1969, 1984*, 1992*, and 2003. *One year subtracted from reported ages.

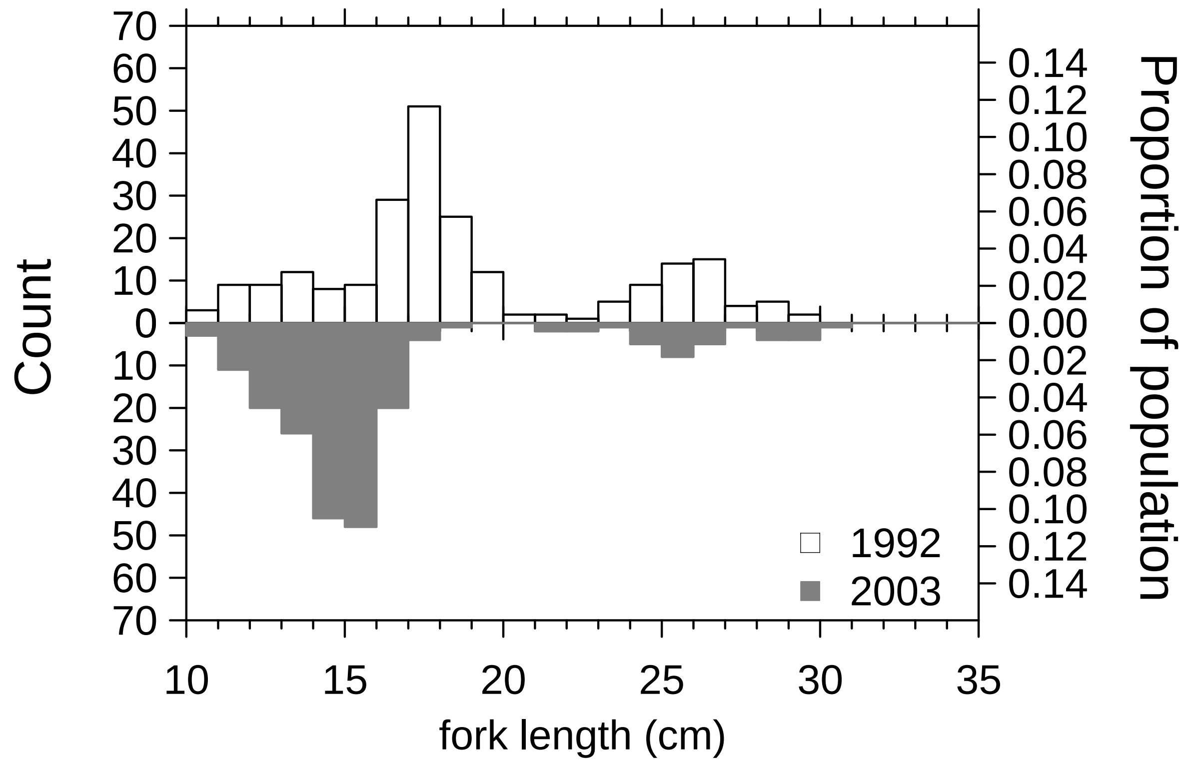

Figure 4: Size distribution of Trout Pond brook trout in 1992 and 2003.

Table 3: Yudle Pond morphometric data in 1971 and 2003.

Age	n		Length (mm) [range]		Weight (g) [range]		K [range]	
	1971	2003	1971	2003	1971	2003	1971	2003
1	3	3	11.3 [106-120]	12.0 [11.2-13.4]	19.9 [14.4 – 24.2]	16.7 [8-26]	1.368	0.91 [0.57-1.08]
2	16	39	15.6 [146 – 165]	16.5 [10.2-25.8]	46.0 [38.8 – 59.8]	61.4 [12-209]	1.212	1.12 [0.84-1.48]
3	36	25	17.8 [166 – 190]	21.3 [10.4-28.4]	64.4 [51.0 – 83.1]	117.6 [12-227]	1.150	1.12 [0.94-1.29]
4	21		19.7 [191 – 204]		88.9 [77.6 – 96.2]		1.159	
5	6		21.3 [206 – 225]		107.7 [95.7 – 115.2]		1.111	

Table 4: Harvest estimates for selected sites in Terra Nova National Park based on creel censuses (based on Tordon 1986).

Site	Area (ha)	Mean effort / trip (h)	Total effort (h)	Total effort / ha	CPUE	Estimated Harvest	95% conf. Int.
Yudle Pond	10.1	0.99	351.5	34.8	1.6	562	104-1022
Trout Pond	8.2	1.16	598.6	73.0	0.5	299	167-430
Chatman's Pond	3.7	0.50	71	19.2	1.0	71	8-134
Arnold's Pond	4.0	0.75	205.5	51.4	1.0	274	82-329
Juicey's Pond	8.5	0	0	0	-	0	-
Big Brook	-	1.40	995.4	-	3.5	3483	1906-5061

DISCUSSION

The abundance of brook trout in Trout Pond appears to have remained stable over the past two decades, however other metrics suggest that the population is in decline. Mean length and weight of trout in 2003 were significantly less than in past years, a fact that is reflected by the decrease in biomass by up to 55% since 1984. Age structure of the population has also shifted to younger age classes. These attributes are characteristic of populations that are being overfished (Post et al. 2002; Rochet and Trenkel 2003). Previous creel work conducted in TNNP indicates that 73% of trout angled and retained from Trout Pond are above 20 cm (Hicks 1992). In 2003, trout larger than 20 cm made up only 15.6% of the population compared to 24.6% in 1992. Given the estimated population size, only 132 fish were available to the fishery in 2003 – down from 208 fish in 1992. The current abundance of this size class is approximately equivalent to 13 fishermen catching their daily limit of 10 fish. Creel censuses have indicated that even when large fish were more prevalent, Trout Pond had the lowest catch rates (14 – 50%) of the six ponds examined (Tordon 1986); indicating angling may have impacted this population prior to the current study. Removals from Trout Pond in 1984 were estimated to be 299 fish (95% confidence intervals: 167 – 430) (Tordon 1986). This magnitude of removals would not be sustainable given the current population abundance and size structure. Assumptions that low catch rates will regulate angling pressure may not be well founded because Trout Pond had the highest fishing pressure and the lowest catch rates in 1984 (Table 4). Therefore, anglers may be selecting fishing spots for other reasons other than catch rates alone (i.e. accessibility, tradition etc.); a trend that has been observed on Newfoundland’s Northern peninsula (van Zyll de Jong unpubl. data).

Secondly, since fish often continue to aggregate at low densities (e.g. in prime habitat) they remain vulnerable to harvesters. Therefore, catch rates may not decline substantially until considerable damage is done because catch per unit effort does not exhibit a linear relationship with population size (Post et al. 2002; van Zyll de Jong et al. 2002). Maturity of brook trout in TNNP appears to occur at a size threshold as opposed to an age threshold. Research conducted in Juicey's Pond and Yudle Pond (Garside et al. 1971) showed that >50% of trout mature by age 3 whereas in Juicey's Pond, a stunted population, this threshold is surpassed at age 4. Though the age at maturity differed, both ponds were similar in that the threshold was achieved at mean lengths of 16-17 cm. A comparison of the number of fish in Trout Pond over 17 cm in length indicates that spawning-size fish have dropped off from 62% of the population in 1992 to 18% of the population in 2003. The absence of key life history data for these ponds makes it difficult to assess to what degree the population's ability to sustain itself has been compromised but such a decline is nonetheless alarming. Even though the number of spawners has been depleted, reductions in intra specific competition could reduce natural mortality and compensate for angling losses. The improved condition of older age classes in 2003 support that the remaining individuals may be benefiting from less competition, although reductions in biomass indicate that the population is still under carrying capacity. Aside from reducing reproductive potential, heavy angling pressure may affect the population in other ways by changing its evolutionary trajectory. Higher mortality of older age classes may favour those fish that mature earlier. Such changes have been found in other exploited populations (Sullivan 2003a).

Creel census information for Trout Pond (Table 4; Tordon 1986) indicate that in 1984 Trout Pond sustained approximately 73 angler*h/ha/year [to put this in perspective, the maximum yields for the relatively large (but likely less productive) ponds in the nearby Indian Bay watershed are achieved at 3 angler hours per hectare per year (van Zyll de Jong et al. 2002)]. Despite this relatively heavy angling pressure, the fish biomass in Trout Pond remains higher per unit area than other unfished ponds in the park (Wing's and Big Pond). Direct comparisons of ponds differing in size, however, are tenuous as pond area and morphometry are thought to impact brook trout productivity (Flick 1991). All other monitored ponds in TNNP, that are the same size or smaller that Trout Pond, have higher fish biomass estimates.

A reassessment of recreational fisheries management in TNNP is prudent, particularly for small, accessible ponds that are vulnerable to overfishing. Reducing bag limits or protecting the larger fish (e.g. Beard et al. 2003) may not be suitable options as studies have shown that such measures do little to increase the sustainability of populations (van Zyll de Jong et al. 2002). Other tactics such as increasing the minimum retention size have shown more promise (van Zyll de Jong et al. 2002; Sullivan 2003a) because retention sizes can be set to ensure that maturing fish will have a few years of spawning before they are vulnerable to the fishery. However, poor compliance in areas with low catch rates and increased hooking mortality has been shown to offset some of the benefits of this management approach (Sullivan 2003a, 2003b). Whatever measures are taken, consultation will be required to inform stakeholders and find solutions that are acceptable to all parties involved.

We were unable to examine the Yudle Pond population in detail because insufficient fish were sampled. Although a similar sampling effort to Trout Pond was put forth, catch rates were extremely low; particularly early in the sampling period. Extension of the sampling season into the angling season was considered but was decided against due to political pressure by local residents and businesses who were upset about missing fishing opportunities early in the season. Future work may benefit from public consultation prior to any work to notify communities about potential temporary closures required for the proper management of the fishery.

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