Shore Based Angling for Brown Trout (*Salmo trutta*) in the Renews River Estuary, Newfoundland: A Case Study

Geoff Veinott

Science Branch
Fisheries and Oceans Canada
P.O. Box 5667
St. John's NL Canada A1C 5X1

2011

Canadian Technical Report of Fisheries and Aquatic Sciences No. 2923

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 2923

2011

SHORE BASED ANGLING FOR BROWN TROUT (*SALMO TRUTTA*) IN THE RENEWS RIVER ESTUARY, NEWFOUNDLAND: A CASE STUDY

by

G. Veinott

Fisheries and Oceans Canada
Science Branch
P.O. Box 5667
St. John's NL A1C 5X1

Cat. No. Fs 97-6/2923E ISSN 0706-6457
Cat. No. Fs 97-6/2923E ISSN 1488-5379

Correct citation for this publication:

Veinott, G. 2011. Shore based angling for brown trout (*Salmo trutta*) in the Renews River Estuary, Newfoundland: A case study. Can. Tech. Rep. Fish. Aquat. Sci. 2923: iv+ 23 p.

ABSTRACT

Veinott, G. 2011. Shore based angling for brown trout (*Salmo trutta*) in the Renews River Estuary, Newfoundland: A case study. Can. Tech. Rep. Fish. Aquat. Sci. 2923: iv+ 23 p.

Basic biological data were collected from brown trout angled from 2007 to 2009 in the Renews River estuary on the south-east coast of the island of Newfoundland. In 2008 the average length of angled fish (22.2 cm) decreased by 7 cm compared to 2007 and 2009 despite the modal age remaining at 3+ years. The average length of the 3+ age group in 2008 also decreased compared to 2007 and 2009. However, the Fulton condition factor for the 3+ fish did not change between 2008 and 2009. The cause of the reduction in average length is unknown. Formal creel surveys carried out in 2008 and 2009 showed that angling effort was greatest at the start of the angling season (mid May) and steadily declined as the season progressed. Effort was also concentrated on the weekends but catch per unit effort (CPUE) varied between years and among sampling periods (time of day and time of week). On average about 2 anglers fished per day with the average fishing trip lasting between 1 and 3 hours. Fewer than 2 fish per trip were angled. Total number of fish angled was estimated at approximately 250 in each of 2008 and 2009 with approximately 50 % retained. This translated into an exploitation rate of 5 %. Juveniles and smolt emigrate annually (~ 1400/year) from the river to the estuary with juveniles likely the main source of recruits to the fishery. Full recruitment to the fishery occurs at age 3+ whereas spawning does not begin until age 4. Despite the harvest of immature fish, the current level of fishing pressure should be sustainable. Fisheries managers, however, may want to consider the impact, viable and expanding invasive brown trout populations could have on native salmonids.

RÉSUMÉ

Veinott, G. 2011. Shore based angling for brown trout (*Salmo trutta*) in the Renews River Estuary, Newfoundland: A case study. Can. Tech. Rep. Fish. Aquat. Sci. 2923: iv+ 23 p.

Des données biologiques de base ont été recueillies sur des truites brunes prises à la ligne de 2007 à 2009 dans l'estuaire de la rivière Renews, sur la côte sud-est de Terre-Neuve. La longueur moyenne des prises (22,2 cm) en 2008 a diminué de 7 cm par rapport à ce qu'elle était en 2007 et 2009, mais l'âge modal est demeuré de 3+ ans. La longueur moyenne chez ce groupe d'âge a également diminué en 2008, mais le coefficient de condition de Fulton des individus de 3+ ans n'a pas changé entre 2008 et 2009. La cause de cette diminution est inconnue. Des enquêtes officielles par interrogation des pêcheurs sportifs menées en 2008 et 2009 ont révélé que l'effort était plus élevé au début de la saison de pêche (mi-mai), pour ensuite diminuer progressivement à mesure que la saison avançait. L'effort était plus grand durant les fins de semaine, mais les prises par unité d'effort (PUE) variaient d'une année à l'autre et entre les périodes d'échantillonnage (heure du jour et jour de la semaine). Le nombre moyen de pêcheurs actifs par jour se situait à deux et la durée moyenne d'une sortie de pêche, entre une et trois heures. Moins de deux poissons ont été pris par sortie. Le nombre total de poissons capturés a été estimé comme se chiffrant à environ 250 en 2008 et 2009, dont environ la moitié ont été gardés, ce qui s'est traduit par un taux d'exploitation de 5 %. Les juvéniles et les smolts migrent chaque année (~ 1 400/an) de la rivière vers l'estuaire, les juvéniles constituant probablement la principale source de recrues à la pêche. Le plein recrutement à la pêche se produit à l'âge 3+, alors que la fraie ne débute qu'à l'âge 4. Malgré la prise d'individus immatures, le niveau actuel de pression par pêche devrait être soutenable. Les gestionnaires des pêches voudront toutefois considérer les impacts que des populations viables et croissantes de truite brune envahissante pourraient avoir sur les salmonidés indigènes.

INTRODUCTION

In the Newfoundland and Labrador Region of Fisheries and Oceans Canada, brown trout (*Salmo trutta*) are managed and regulated under the general category of "trout" along with rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), and non-anadromous Atlantic salmon (*Salmo salar*) known as ouananiche (DFO 2010a). However, brown trout angling is different from the other trout fisheries. For example, on the island of Newfoundland brook trout are fished almost exclusively in ponds, whereas the directed brown trout fishery occurs in ponds, small urban streams and in estuarine waters. The estuarine brown trout recreational fishery is almost exclusively a shore based rod and reel fishery carried out primarily with baited hooks. Anglers are targeting what are referred to as "sea trout" or the anadromous form of the brown trout.

Special brown trout management measures are in place for specific scheduled Atlantic salmon rivers and non-scheduled rivers (DFO 2010a). Renews River is one such case. As a scheduled Atlantic salmon river angling for brown trout can take place in the river during the salmon season provided the regulations for salmon angling are followed. During the trout season angling can occur in the estuary as it is treated as unscheduled inland waters. Baited hooks can be used and no salmon licence is required. After the trout season closes (usually September 7) angling for brown trout can continue in the mouth of Renews River until October 7. This is on condition that the angler holds a valid salmon licence and uses artificial flys only. Despite the differences in the location and form of the trout sought, bag and possession limits are the same regardless of the species or form of trout being fished. A lack of data on the brown trout fishery makes it impossible to determine if these are reasonable management measures.

Conservation concerns have been expressed for brook trout in several watersheds and special management measures are in place for "trout" in areas where brook trout are the primary target species. Popularity of brown trout angling appears to be increasing, especially in the small streams in the capital city of St. John's. Others (Lewin et al. 2006; Cooke and Cowx 2004) have suggested that recreational angling can have a significant impact on fish stocks. Again, no data exist to verify trends in angler participation or to evaluate the impact angling may be having on brown trout populations in Newfoundland. A further confounding factor is that brown trout are not native to Newfoundland. Despite over 100 years of residency (Scott and Crossman 1964) brown trout are still spreading (Wesley and Fleming 2011). The species, which as recent as 20 years ago, was thought to be confined primarily to the Avalon Peninsula, has now been reported in Notre Dame Bay and Fortune Bay (Westley et al. 2011: their Fig 1.). This spread may be impacting native salmonid species (Westley et al. in press). If there is no desire to have the spread of brown trout continue then the management of the species would take on a completely different form compared to the management of a native species like brook trout. If the popularity of brown trout angling increases there could be pressure to maintain or expand populations. The needs of the

brown trout sport fishery have to be weighed against the potential impact brown trout may have on native brook trout and Atlantic salmon populations.

Regardless of the direction managers take there is a paucity of angling data from the brown trout fishery in Newfoundland. The purpose of this study, therefore, was to provide basic biological data on the fish caught in the Renews River brown trout fishery; determine the catch and effort exerted in the fishery and to estimate the exploitation rate of the fishery. These data can be used as a baseline from which additional studies can be compared and management decisions and policy made.

METHODOLOGY

STUDY SITE

The Renews River is located on the south east portion of the Avalon Peninsula on the island of Newfoundland (Fig 1). The mouth of the river (46^0 56' 02" N, 52^0 77' 09" W) opens into a shallow estuary. The estuary is separated from Renews Harbour by a narrow opening which is about 3 km from the open ocean. Angling for brown trout takes place mainly in three locations (Fig 1). The first is off a beach on the north side of the opening to the harbour. This is where most of the baited hook angling takes place. The second location is near the main road inside the scheduled salmon waters. Anglers must have a salmon licence and it is fly fishing only at this location. Fishing also occurs less frequently on the south side of the harbour opening near a boat basin.

BIOLOGICAL DATA

In 2007 biological data on angled fish were collected opportunistically. In 2008 and 2009 a formal creel survey (described below) was carried out. In all three years, fork lengths (FL) and scale samples were taken from retained and released fish. As well, in 2008 and 2009 whole weights (WW) were taken. For all three years von Bertalanffy growth curves (von Bertalanffy 1938) were fitted to the data visually. For fish with length weight data Fullton condition factors (K) were also calculated using the formula $K=WW/FL^3*100$ (Fulton 1904; Heincke 1908). If fish were retained anglers were asked if the head and guts could be sampled so that otoliths could also be collected and a sex determination made. Scale samples were used to age fish based on the Elliot and Chambers (1996) guide and to determine age at first spawning.

CREEL SURVEY

Formal creel surveys, based on the method described by Malvestuto et al. (1978), were carried out in 2008 and 2009. The entire fishing area can be observed

from a central vantage point so it was not necessary to divide the estuary into survey areas. All anglers present during any survey were sampled.

The entire fishing season was divided into time blocks of one month, or a part of a month where the season started or ended within a month. Each month was divided into sampling units of 4 h. The sampling units were designated AM (0700-1100 h), Noon (1100-1500 h) and PM (1500-1900 h). First, a day of the month was randomly selected, and then a sampling unit for that day was randomly selected. There was no a priori information on effort so every day of the month and every time unit had an equal probability of being selected.

Anglers were questioned regarding: the length of time they had fished; the number of fish caught, retained, and released; expected duration of their trip; target species, and by-catch. In 2009 anglers were also asked if they fished for brown trout at locations other than Renews. Data from the surveys were categorized into months, weekday, weekend, and sampling unit (AM, Noon, PM). Holidays were considered weekends. Catch, effort, and CPUE were calculated for each strata based on the equations found in Beckley et al. (2008).

Total angling effort, in angler trips, for each category or sampling unit was calculated as:

$E_{ti} = E_i * D_i$ Where:
E_{ti} is the total effort for strata i;
E_i is the mean number of anglers per day or sampling unit in i;
D_i is the number of days or sampling units in i;
i is the category or sampling unit (month, weekend, AM, etc.)

Total effort, in angling hours, was calculated by multiplying angler trips by the average length of a trip.

CPUE was calculated as:

$$CPUE = \frac{\sum_{j=1}^{n} \left(C_j / E_j \right)}{n}$$ Where:

C = the number or mass of fish caught by the jth angler
E = the effort expended by the jth angler
n = number of anglers sampled

Total catch was estimated by multiplying the total effort by the CPUE. Errors on catch and effort were calculated as the variance in the sampled angler's catch and effort.

MARK-RECAPTURE EXPERIMENTS

To be able to estimate the exploitation rate, some estimate of the population of brown trout in the estuary was necessary. Therefore, in 2010 mark-recapture experiments were carried out. In early July and again in late August the perimeter of the estuary was sampled for four days using a Fleming seine and a beach seine. Brown trout and Atlantic salmon were given a unique fin clip and the length of each marked fish was recorded. Fish were then allowed to redistribute for three days followed by four more days of sampling. The mark-recapture experiment was designed as a bi-census but because of the low number of captures and recaptures a Schumacher-Eschmeyer estimate for multiple census was applied to the data (Ricker 1975).

$$N = \frac{\sum_{d=1}^{n} C_d M_d^2}{\sum_{d=1}^{n} R_d M_d}$$

Where:

N = population estimate in numbers of fish;
$C_d = U_d + R_d$ = total number of fish caught during day *d*;
U_d = number of unmarked fish caught during day *d*;
R_d = number of recaptures during day *d* (of the type of mark under consideration);
M_d = number of marked fish available for re-capture at **start** of day *d*;
d = day number ranging from first (d_1) to last (d_n).

and:

$$s^2 = \frac{\sum_{d=1}^{n}\left(\frac{R_d^2}{C_d}\right) - \left[\frac{\left(\sum_{d=1}^{n} R_d M_d\right)^2}{\sum_{d=1}^{n} C_d M_d^2}\right]}{m-1}$$

Where:

s^2 = variance of samples;
m = number of days in which fish were actually caught.

$$\text{Variance of N} = N^2\left[\frac{Ns^2}{\sum_{d=1}^{n} R_d M_d}\right]$$

Standard Error of N = $\sqrt{Varance\ of\ N}$

95 % confidence limits of N = N $\pm$ t (standard Error); where t is Students t for C - 1 degrees of freedom.

The model assumes a closed system and acoustic tagging of brown trout in this estuary (Veinott 2010) showed that during the sampling period there appeared to be no directed migration either into or out of the estuary. Therefore, the system was treated as closed for modeling the population.

DOWNSTREAM MIGRATION

To obtain information about fish emigrating to the estuary from Renew River a fyke net was installed near the mouth of the river, above head of tide, in April and May from 2008 to 2010. Numbers of captured fish along with their lengths and weights were recorded. As well, scale samples were taken for aging. To obtain an estimate of the efficiency of the fyke net, fish were marked and released. In 2008 salmon smolt that were captured in the fyke net were marked, then released one km upstream from the fyke net location. In 2010 two fyke nets were used. One fyke net that was installed approximately 2 km upstream of the mouth of the river and a second was installed in the same location as in 2009. The upstream net was used to capture and mark fish for re-capture downstream. Both Atlantic salmon and brown trout were captured and marked in the upstream net. A simple proportion of the total number of recaptured marked fish was used to estimate fyke net efficiency.

RESULTS

BIOLOGICAL CHARACTERISTICS

In 2007 the recreational fishery was sampled opportunistically. Therefore, the 2007 sample is not a random sample. Nevertheless, 66 fish were sampled and the data were compared to later years. The average length of the fish sampled in 2007 was 29.7 cm and the modal age was 3+ (Fig. 2). The modal length category was 30-35 cm (Fig. 3) although the fishery appears to be targeting fish 20 cm and greater. This suggests that fish are not fully recruited into the fishery until 3 years of age. The age length curve (Fig. 4) suggests that around 60 cm is the maximum length obtained by Renews fish with growth rates of 9-11 cm per year early in life and 2-3 cm per year by ages 7-8.

The results from 2009 match very closely those from 2007. In 2009 a formal creel survey was carried out so the sampled fish were randomly selected from the fishery. The average length of fish sampled was 28.9 cm compared to 29.7 cm in 2007. As in

2007 the modal age was 3+ (Fig. 2) with most of the angled fish 20 cm in length or greater (Fig. 3). Again, the 2+ fish seem not to be available to anglers. Similar growth rates and a maximum length were obtained in 2009 compared to 2007 (Fig. 4).

In contrast to the 2007 and 2009 results, the average length of trout sampled in 2008 (22.2 cm) was significantly shorter (Table 1). Although the modal age was 3+ in 2008 (Fig. 2), the average length of 3+ fish was also significantly shorter (Table 1) compared to 2007 and 2009. This resulted in a shift in the modal length category for 2008 down to 15-20 cm (Fig. 5). Despite the drop in average length in 2008 the Fulton Condition factor of the 3+ age group was not significantly different in 2008 compared to 2009 (Table 1). This suggests that the fish caught in 2008 would not have appeared unusually thin for their length.

Less than 6 % of all the brown trout sampled from 2007 to 2009 showed evidence of spawning on their scales. With only a few exceptions first spawning occurred in the fourth year. The recreational fishery, therefore is harvesting sexually immature fish.

The sex ratio in all years was approximately 50:50 males to females. The fishery therefore does not appear to be targeting one sex over the other. The otoliths that were collected were archived for later use.

CREEL SURVEY

The 2007 recreational fishery was sampled opportunistically so catch and effort was only calculated for the season as a whole. When compared to the 2008 and 2009 seasons there was no significant difference (ANOVA; $P > 0.05$) in the average number of hours fished per trip (Fig. 6). However, the average number of fish caught per trip was significantly less in 2009 compared to 2008 (ANOVA; $P < 0.05$) (Fig. 6). In all years the majority of anglers reported catching no fish and no angler retained the legal bag limit of 12 fish or 2.27 kg plus 1 fish.

When broken down by month, the greatest effort in 2009 occurred in May (Table 2) with an average of 5.9 anglers fishing per day. The large number of anglers per day resulted in nearly 41 % of the total annual effort occurring in May despite the fact that there were only 17 angling days in May. The shorter fishing period in May is because the angling season doesn't start until mid May. Effort declined steadily through the fishing season to a reported low of 2 anglers fishing the last week of the season, in October. A similar trend was recorded in 2008 where June was the month with the highest reported effort and October the lowest (Table 3).

The increased effort, early in the season, did not translate into fishing success as evidenced by the lower CPUE's in May and June (Tables 2 and 3), and the tendency for CPUE to increase later in the season. The data for October 2009 is likely an overestimate of the effort and CPUE as only one day in October was surveyed.

However, successful early season anglers were rewarded with larger fish on average (Fig. 8).

Catch and effort were also influenced by the time of day and the time of the week. In 2008, effort was greatest on weekends (Fig. 9), but fairly evenly distributed through the day (Fig. 10). In 2009 effort was greatest on weekends as well, but more variable during the day with very little effort in the morning (Figs. 9 and 10). Catch varied between years with a greater catch recorded during the week in 2008 compared to the weekend in 2009 (Fig. 9) and a much greater catch in the evening in 2008 compared to 2009 despite the similar PM effort between years (Fig. 10).

MARK-RECAPTURE IN THE ESTUARY

Two attempts were made in 2010 to estimate the number of brown trout present in the estuary. The first was in early July (early summer) and the second in late August-early September (late summer). During the late summer sampling, most fish were captured and subsequently re-captured in the same location. This suggests a school of fish remaining somewhat stationary. Therefore a population estimate was made for the early summer sampling period only. Further, even though fish were captured throughout the estuary in early summer, capture rates were low (average ~ 57/day) as were the number of recaptures (average ~ 3/day). The low re-capture rate also meant that the population estimate could only be made on a wide size range (8-20 cm). Given the above constraints the estimated number of 8-20 cm brown trout in the estuary in early July was 3700 with a range of 1200-6200.

The 8-20 cm size group includes 90 % of all the fish captured in the mark-recapture experiment. For the purpose of calculating exploitation rates most of these fish would be too small to be captured in the recreational fishery. Even if smaller fish are caught they are usually released. Based on the 2009 data, retention appears to begin in earnest at 20+ cm (Fig. 3). Therefore, an adjustment must be made to the July population estimate to account for mortality that will occur between the time of sampling and when the fish will be large enough to be taken in the recreational fishery. With a growth rate of about 10 cm/year, most of the sampled fish will not be available to the recreational fishery until the spring of 2011.

Annual mortality rates for juvenile anadromous brown trout can be quite high, and have been reported to average 40 % (Jonsson and Jonnson 2006). Applying a 40 % mortality rate to the population range given above, results in an estimated population range for the 18-30 cm size class of 720-3720. Given that only 20-30 trout are retained each year in July (Tables 2 and 3) the exploitation rate would be at most 5 %. Even assuming a high mortality rate for released fish does not produce an exploitation rate of 10 %.

DOWNSTREAM MIGRATION

It was felt that the main source of brown trout for the estuarine fishery was the Renews River. Therefore, from 2008 to 2010 fyke nets were used to capture fish moving downstream in Renews River in spring. The greatest numbers of fish trapped were Atlantic salmon parr and smolt which during peak run times could be over 50 fish in a day. Brown trout were the second most abundant species and averaged just over 5 fish trapped per day over the run (Fig. 11). Atlantic salmon and brown trout smolt had similar fork lengths of about 17 cm.

The efficiency of the fyke net at the mouth of the river was estimated twice; once in 2008 by transporting marked fish up stream, and once in 2010 by operating 2 fyke nets at different locations in the river. In 2008 approximately 10 % of the transported fish were re-captured the next day. However, in 2010 no fish marked up stream were captured in the down stream net. Assuming no mass die-off of marked fish due to handling, this suggests either no down stream movement or a much lower than 10 % down stream net efficiency. Many of the captured brown trout had smoltified and marked fish from up stream were later captured in the estuary. Both observations support a downstream migration. Therefore a fyke net efficiency of 10 % is likely an overestimate of the true efficiency. Nevertheless, with a 10 % net efficiency, 5 fish per day over a four week run results in an estimated 1400 brown trout leaving the river annually.

DISCUSSION

BIOLOGICAL CHARACTERISTICS

The 7 cm decline in average length of the 2008 trout sample compared to the 2007 and 2009 samples suggest significantly retarded growth in the Renews brown trout population during the winter of 2007 and the spring of 2008. There is no obvious explanation for poor growth or survival during this time period. In fact, support to the contrary may be found in the Atlantic salmon returns. In 2008, returns of Atlantic salmon to Newfoundland rivers was one of the highest on record (DFO 2010*b*), suggesting good growth and survival conditions, at least in the marine environment, for that period. Further, there is no evidence in the oceanographic data to suggest that the near shore environment during the winter of 2007 and spring of 2008 was unusually harsh (Colbourne et al. 2009). Ricker (1954) suggested that smaller than average individuals may be an indication of large year class. Competition for food could result in an average smaller size.

However, there was no difference in the Fulton condition factor for the 2008 sample compared to the other two years. The Fulton condition factor basically describes the shape of the fish. Short fat fish have a high Fulton condition factor while long skinny fish have a low condition factor. Although according to the Barnham and Baxter (1998) grading system, Renews brown trout are considered fair to poor, approximately 40-70 %

of the fish caught in June, July and August, in 2008 were retained (Table 2). Similar retention rates were found in 2009 (Table 3) so it would seem that the anglers did not find the fish in the 2008 fishery substandard despite the 7 cm shorter average length. It would seem that something slowed the growth of these fish but they gained enough weight prior to being caught in the recreational fishery to appear healthy to the angler.

CREEL SURVEY

One hypothesis that was the impetus for the creel survey was that anglers were harvesting brown trout smolt as they entered the estuary from the river. It was felt that anglers were labeling the smolt “sea trout” because of their silver colour. However, the monthly creel data does not support this hypothesis. The average length of the trout caught in May and June in 2009 and in June 2008 are over 30 cm (Fig. 8), whereas the brown trout smolt leaving the river in April and May averaged about 17 cm. Growth in the 2-6 week time lag between the downstream migration and the capture in the estuary can not account for the size difference. Therefore, the fish taken early in the recreational fishing season either migrated from the river before the fyke net was installed, over-wintered in the estuary, or migrated from elsewhere into the estuary in the spring.

Fyke nets could not be set up earlier in the spring because of high water conditions so no direct evidence of an earlier migration of larger non-smolt could be provided. However, O’Connell (1982) reported outward movement of brown trout from rivers on the Avalon Peninsula coinciding with outward movements of brook trout. He did not specify if the trout were smolt so they may have been larger fish. Regardless, peak movement in the O’Connell (1982) study did not occur until early to mid May which is when peak migration occurred on Renews River (Fig. 11).

Water temperatures of 6-8 ^{o}C have been reported to coincide with peak brown trout smolt movement in Norway (Hembre et al. 2001). However, it does not appear that smolt are being taken in the early part of the angling season. Therefore, if the larger fish taken in the recreational fishery are coming from Renews River they would have to be moving in colder temperatures. In Newfoundland Atlantic salmon kelts (previous fall’s spawners) move coincidently with smolt, with runs peaking between 8-10 ^{o}C (Dempson and Stansbury 1991; Peter Downton, Fisheries and Oceans Canada, Pers Comm). If brown trout are behaving in the same way then the fyke nets were in the water early enough and it would be expected that larger numbers of large fish would have been caught migrating downstream.

Overwintering outside the river or migration to the estuary from other systems are both possible. Veinott (2010) reported finding large brown trout at the mouth of Renews River in November. These fish were tagged moving upstream on what was presumed to be a spawning migration. In three of the four cases the tagged fish were last located 4-5 weeks later in tidal waters. This suggests movement out of the river after spawning. Bendall et al. (2005) reported similar seaward movement of post spawn brown trout in the River Fowey in England. Kelts remained in fresh water between 4 and 70 days after

spawning then entered the estuary eventually moving to coastal waters. If Renews fish are overwintering in coastal waters they may be mixing with fish from other near by rivers. Brown trout in Newfoundland continue to spread (Westley and Fleming 2011) so straying must be occurring.

Regardless of the source of trout to the Renews' fishery, one important issue is whether the fishery is sustainable. A sustainable fishery is one where enough fish escape to spawn to replace the ones that die from natural causes or as a result of a fishery. In salmonid fisheries this is often accomplished by setting an escapement limit and managing the fishery to ensure that the escapement limit is achieved (Potter et al. 2003). However, no such reference points exist for brown trout in Newfoundland. For Atlantic salmon in Newfoundland, spawning escapement targets are based on available habitat. To meet conservation the spawning escapement must be large enough to produce 2.40 eggs/m^2 of river habitat and 368 eggs/ha of lake habitat (O'Connell and Dempson 1995; Chaput et al. 1998). For the Renews River watershed those numbers translate into approximately 300 adult salmon required to meet conservation limits (Veinott 2009).

Assuming a similar requirement for brown trout, ignoring for the moment any differences in watershed area occupied and fecundity between the two species, the population estimate in the estuary could produce enough spawners to reach a target of 300 adult spawners. Even at the low end of the population estimate (1200) and assuming 4 % annual natural mortality the population should produce about 300 fish aged 5+ or greater. The angling catch in those age groups is less than 20 % of the total harvest (Fig. 2) so angling is not likely to have much of an impact on whether spawning escapement is sufficient.

When compared to other brown trout exploitation rates the estimated rate in this study (~5 %) falls within the range reported by Shields et al. (2006) of 1.3 % to 10.1 % for five rivers in England and Wales, and is close to the 8.8 % reported by Faragher and Gordon (1992) in Lake Eucumbene, Australia. As in the Renews study, Shields et al. (2006) reported having no biological reference points against which escapement or spawning biomass could be compared.

In terms of total effort it is unlikely, in the near future, that Newfoundland will have the population density to compete with other large scale shore based fisheries. For example, in the Hudson River estuary there was an estimated 19,000 shore based angler trips between March and November (New York State Department of Environmental Conservation 2003), and in Richards Bay Harbour, SA there was an estimated 69,000 shore based angler outings per year in just 15 km of shoreline (Beckley et al. 2008).

Anecdotal evidence suggests that Renews is typical of the effort that takes place in other brown trout estuaries. Given that there are only approximately 50 brown trout rivers in Newfoundland (DFO 2010a) total effort for the entire island may only be from 18,000 to 19,000 angler trips per year. In comparison the Atlantic salmon fishery in

Newfoundland records about 100,000 angler trips (rod days) per year (Robertson et al. 2011).

In Renews, there was an average of about 2 angler outings per day. The average trip lasted between 1 and 3 hours, and fewer that 2 fish were angled per trip. With that type of effort is seems unlikely that the fish would be overly stressed. Again, in comparison to the Atlantic salmon fishery, anglers are known to line up to wait for a chance to fish particular spots or pools in a river. This type of effort does not occur in the brown trout fishery.

In Renews anglers were more likely to fish early in the season, on the weekends and in the evening (Figs. 7, 9, and 10). Similar weekend trends were reported elsewhere (Beckley et al. 2008, Smallwood et al. 2006), and although Renews anglers were not asked about the purpose of their trip, the short duration and preference for weekend trips suggests that the purpose is for leisure and not necessarily for food.

Despite the increased effort on the weekends it did not translate into consistently higher catches (Fig. 9). Time of day (Fig. 10) was a much more important factor in determining success in the fishery. This lends support to the belief that brown trout are nocturnal feeders.

There seems to be little need, given the catch and effort in Renews, for fishery managers to take measures to further regulate or restrict the brown trout recreational fishery. This assumes, of course, that managers want to maintain the brown trout populations that currently occur in Newfoundland rivers and that there is no interest in stopping further expansion. Westley and Fleming (2011) have reported that abiotic factors alone are unlikely to prevent further expansion of brown trout populations in Newfoundland. In other words, all of Newfoundland's rivers are suitable to brown trout. They believe the larger more productive systems are most susceptible to future invasions. The risk of further expansion is the impact brown trout invasions may have on native Atlantic salmon and brook trout.

Interactions between native salmonids and brown trout are beyond the scope of this discussion. However there have been several publications on the subject (e.g., Westley et al. 2011; Chaisson et al. 1990; Gibson and Cunjak 1986), and although the effects of brown trout invasions are complex, negative impacts on native fishes is commonly reported. Recently, the Atlantic salmon population along the south coast of the island of Newfoundland was listed as "threatened" by the Committee on the Status of Endangered Wildlife in Canada. Brown trout populations have already been found on the Burin Peninsula on the south coast and brown trout expansion is expected to continue westward (Westley and Fleming 2011).

Having brown trout invade rivers where salmon stocks are already threatened is unlikely to improve the recovery of salmon stocks. To slow the expansion of brown trout, fisheries managers could implement a number of policies. Anglers could be educated to distinguish brown trout from Atlantic salmon and brook trout, at all life stages, so that

they could be used as an early warning of new invasions. A “no release” policy could be implemented for brown trout. In Renews over 50 % of the fish caught were released. Bag limits could be increased or lifted. There is currently no bag limit for rainbow trout in Conne River on the south coast because the rainbow trout are assumed to be aquaculture escapees and undesirable (DFO 2010*a*). However, in Renews, no angler reported catching their bag limit so lifting the bag limit in Renews would have little impact on total catch. Finally, the season could be extended especially in estuarine waters. It seems from the Renews data that a later finish to the season would not have much impact but an earlier start may since anglers seem to be anxious to start the season and most of the catch was early in the season.

SUMMARY

The shore based recreational brown trout fishery in Renews estuary was sampled from 2007 to 2009. The modal age of fish sampled in all three years was 3+, but the average length of the 2008 sample was smaller by about 7 cm. However, the Fulton condition factor for the 3+ fish did not change between 2008 and 2009. Formal creel surveys carried out in 2008 and 2009 showed that angling effort was greatest at the start of the angling season (mid May) and steadily declined as the season progressed. Effort was also concentrated on the weekends but CPUE varied between years and among sampling periods (time of day and time of week). On average about 2 anglers fished per day with the average fishing trip lasting between 1 and 3 hours. Fewer than 2 fish per trip were angled. Total number of fish angled was estimated at approximately 250 in each of 2008 and 2009 with approximately 50 % retained. This translates into an exploitation rate of about 5 %. Juveniles and smolt emigrate annually (~1400/year) from the river to the estuary with juveniles likely the main source of recruits to the fishery. Full recruitment to the fishery occurs at age 3+ whereas spawning does not begin until age 4. Despite the harvest of immature fish, the current level of fishing pressure should be sustainable.

ACKNOWLEDGMENTS

This work was funded by Fisheries and Oceans Canada. Special thanks to Linda Reddy, Jaime Thomson, and Brandon Crane who conducted the creel surveys and mark recapture experiments under contract with the Renews River Conservation Association. Thanks to Don Caines (DFO) who provided scale ages.

REFERENCES

Barnham, C., and Baxter, A. 1998. Condition factor, K, for salmonid fish. Fisheries Notes, State of Victoria, Department of Primary Industries 2003. ISSN 1440-2254.

Beckley, L.E., Fennessy, S.T., and Everett, B.I. 2008. Few fish but many fishers: a case study of shore-based recreational angling in a major South African estuarine port. Afr. J. Mar. Sci. **30**: 11-24.

Bendall, B., Moore, A., and Quayle, V. 2005. The post-spawning movements of migratory brown trout *Salmo trutta* L. J. Fish. Biol. **67**: 809-822.

Chaput, G., Allard, J., Caron, F., Dempson, J.B., Mullins, C.C., and O'Connell, M.F. 1998. River specific target spawning requirements for Atlantic salmon (*Salmo salar*) based on a generalized smolt production model. Can. J. Fish. Aquat. Sci. **55**: 46-261.

Chiasson, A.G., Gibson, R.J., and Bastien-Daigle, S. 1990. A review and annotated bibliography of competitive interactions between salmonids with particular reference to Atlantic salmon (*Salmo salar*) in New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. 1610: v + 51p.

Colbourne, E., Craig, J., Fitzpatrick, C., Senciall, D., Stead, P., and Bailey, W. 2009. An assessment of the physical oceanographic environment on the Newfoundland and Labrador Shelf during 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/032: iv + 20 p.

Cooke, S.J., and Cowx, I.G. 2004. The role of recreational fishing in global fish crises. Bioscience, **54**: 857-859.

Diana, James S., John P. Hudson, and Richard D. Clark. 2004. Movement patterns of large brown trout in the mainstream au sable river, michigan. Transactions of the American Fisheries Society **133**:34-44.

Dempson, J.B., and Stansbury, D.E. 1991. Using partial counting fences and a two-sample stratified design for mark-recapture estimation of an Atlantic salmon smolt population. N. Amer. J. Fish. Manag. **11**: 27-37.

DFO. 2010*a*. Newfoundland and Labrador Angler's Guide 2010/2011. www.nfl.dfo-mpo.gc.ca/.../anglersguide_guidedepecheur_2010_11-eng.pdf [accessed March 21, 2011].

2010*b*. Stock Assessment of Newfoundland and Labrador Atlantic Salmon - 2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/068.

Elliott, J.M., and Chambers, S. 1996. A guide to the interpretation of sea trout scales. Natioonal Rivers Authority, R&D Report 22, Bristol, UK.

Faragher, R.A., and Gordon, G.N.G. 1992. Comparative exploitation be recreational anglers of brown trout, *Salmo trutta* L., and rainbow trout, *Oncorhynchus mykiss*

(Walbaum), in Lake Eucumbene, New South Wales. Aust. J. Mar. Freshwater Res. **43**: 835-845.

Fulton., T.W. 1904. The rate of growth of fishes. 22nd Annual Report of the Fisheries Board of Scotland 1902 3:326-446.

Gibson, R.J., and Cunjak, R.A. 1986. An investigation of competitive interactions between brown trout (*Salmo trutta* L.) and juvenile Atlantic salmon (*Salmo salar* L.) in rivers of the Avalon Peninsula, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1472: v + 82 p.

Heincke, F. 1908. Bericht über die Untersuchungen der Biologischen Anstalt auf Helgoland zur Naturgeschichte der Nutzfische. Die Beteiligung Deutschlands an der Internationalen Meeresforschung. **4/5**:67-155.

Hembre, B., Arnekliev, J.V., and L'Abee-Lund, J.H. 2001. Effects of water discharge and temperature on the seaward migration of anadromous brown trout, *Salmo trutta*, smolts. Ecol. Freshwat. Fish. **10**: 61-64.

Jonsson, B., and Jonnson, N. 2006. Life history of the anadromous trout *Salmo trutta*. *In* Sea Trout: Biology, Conservation and Management. *Edited by* G. Harris and N. Milner. Proceedings of the First International Sea trout Symposium, Cardiff, July 2004. Blackwell Publishing, Oxford, pp. 196-223.

Lewin, W.-C., Arlinghaus, R., and Mehner, T. 2006. Documented and potential biological impacts of recreational fishing: insights for management and conservation. Rev. Fish. Sci. **14**: 305-363.

Malvestuto, S.P., Davies, W.D., and Shelton, W.L. 1978. An evaluation of the roving creel survey with nonuniform probability sampling. Trans. Amer. Fish. Soc. **107**: 255-262.

New York State Department of Environmental Conservation. 2003. Assessment of Hudson River recreational fisheries. New York State Department of Environmental Conservation, 625 Broadway, Albany, NY. Contract Number C004005. Prepared by Normandeau Assoc. Inc. Drumore PE.

O'Connell, M.F. 1982. The biology of anadromous *Salvelinus fontinalis* (Mitchell, 1815) and *Salmo trutta* (Linnaeus, 1758) in river systems flowing into Placentia Bay and St. Mary's Bay, Newfoundland, Ph.D. Thesis, Memorial University of Newfoundland.

O'Connell, M.F., and Dempson, J.B. 1995. Target spawning requirements for Atlantic salmon, *Salmo salar* L., in Newfoundland rivers. Fish. Manage. Ecol. **2**:161-170.

Potter, E.C.E., MacLean, J.C., Wyatt, R.J., and Campbell, R.N.B. 2003. Managing the exploitation of migratory salmonids. Fish. Res. **62**: 127-142.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191.

1954. Stock and recruitment. J. Fish. Res. Board Can. **11**: 559-623.

Robertson, M.J., Dempson, J.B., Reddin, D.G., Veinott, G.I., Cochrane, N.M., Bourgeois, C.E., and Caines, D. 2011. Status of Atlantic Salmon (*Salmo salar* L.) Stocks of Insular Newfoundland (SFAs 3-14A), 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/ 139. iv + 50 p.

Schneider, James C. 1998. Lake fish population estimates by mark-and-recapture methods. Chapter 8. *In* Manual of fisheries survey methods II: with periodic updates. *Edited by* J.C. Schneider. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Scott, W.B., and Crossman, E.J. 1964. Fishes occurring in the fresh waters of insular Newfoundland. Department of Fisheries, Ottawa, Canada. 124 pp.

Shields, B.A., Aprahamian, M.W., Bayliss, B.D., Davidson, I.C., Elsmere, P. 2006. Sea trout (*Salmo trutta* L.) exploitation in five rivers in England and Wales. *In* Sea Trout: Biology, Conservation and Management. *Edited by* G. Harris and N, Milner. Proceedings of the First International Sea trout Symposium, Cardiff, July 2004. Blackwell Publishing, Oxford, pp. 196-223.

Smallwood, C.B., Beckley, L.E., and Sumner, N.R. 2006. Shore-based recreational angling in the Rottnest Island Reserve, Western Australia:spatial and temporal distribution of catch and fishing effort. Pacific Conserv. Biol. **12**: 238-251.

Veinott, G. 2009. Renews River salmonid research project: year 1 (2007) data and results. Can. Manuscr. Rep. Fish. Aquat. Sci. **2894**: v + 30 p.

2010. Renews River salmonid research project: Year 2 (2008) data and results. Can. Manuscr. Rep. Fish. Aquat. Sci. **2927**: v + 49 p.

Westley, P.A.H., and Fleming, I.A. 2011. Landscape factors that shape a slow and persistent aquatic invasion: brown trout in Newfoundland 1883-2010. Diversity and Distributions, **17**: 566-579.

Westley, P.A.H, Ings, D.W., and Fleming, I.A. 2011. A review and annotated bibliography of the impacts of invasive brown trout (*Salmo trutta*) on native salmonids, with an emphasis on Newfoundland waters. Can. Tech. Rep. Fish. Aquat. Sci. **2924**: v + 81 p.

Table 1. Results of single factor ANOVAs comparing mean lengths of brown trout sampled in the Renews River recreational fishery.

	All data		Common sampling months		3+ fish only	
Groups	Mean length (cm)	n	Mean length (cm)	n	Mean length (cm)	n
2007	29.7	64	30.4	53	26.6	27
2008	22.2	118	20.4	103	19.0	56
2009	29.1	139	26.2	62	24.0	54
	$p < 0.01$		$p < 0.01$		$p < 0.01$	

Table 2. Monthly catch and effort data for 2008.

Month	Average hours fished/angler	Mean number of anglers/day	Fishing days/month	Effort (angler trips)	Effort (hours)	% of Effort	CPUE	Catch (#s of fish)	% Released
May									
June	3.0 (0.47)	1.9 (0.77)	30	57.3	170.4	47.3	0.23	39.9	22.2
July	1.5 (0.17)	1.5 (0.29)	31	46.5	71.6	19.9	0.91	65.3	62.9
Aug	1.7 (0.28)	1.8 (0.44)	31	56.4	96.7	26.9	1.46	141.7	58.3
Sept	1.7 (0.17)	0.3 (0.29)	30	8.6	14.3	4.0	0.33	4.8	100.0
Oct	3 (n=1)	0.3 (0.33)	7	2.3	7.0	1.9	0.33	2.3	0.0
Totals				171	360	100		254	

Numbers in brackets are standard errors

Table 3. Monthly catch and effort data for 2009.

Month	Average hours fished/angler	Mean number of anglers/day	Fishing days/month	Effort (angler trips)	Effort (hours)	% of Effort	CPUE	Catch (#s of fish)	% Released
May	2.4 (0.21)	5.9 (1.10)	17	100.7	275.3	41.1	0.22	61.11	47.5
June	1.6 (0.17)	3.6 (0.89)	30	107.6	169.9	25.4	0.51	86.91	52.5
July	1.4 (0.22)	2.5 (0.61)	31	77.5	105.3	15.7	0.31	33.14	58.8
Aug	1.6 (0.19)	1.0 (0.26)	31	29.7	37.6	5.6	0.56	20.92	52.0
Sept	1.6 (0.15)	1.4 (0.29)	30	42.7	67.6	10.1	0.87	58.67	31.3
Oct	1.0 (n=2)	2.0	7	14.0	14.0	2.1	2.50	35.00	80.0
Totals				372	670	100		296	

Numbers in brackets are standard errors

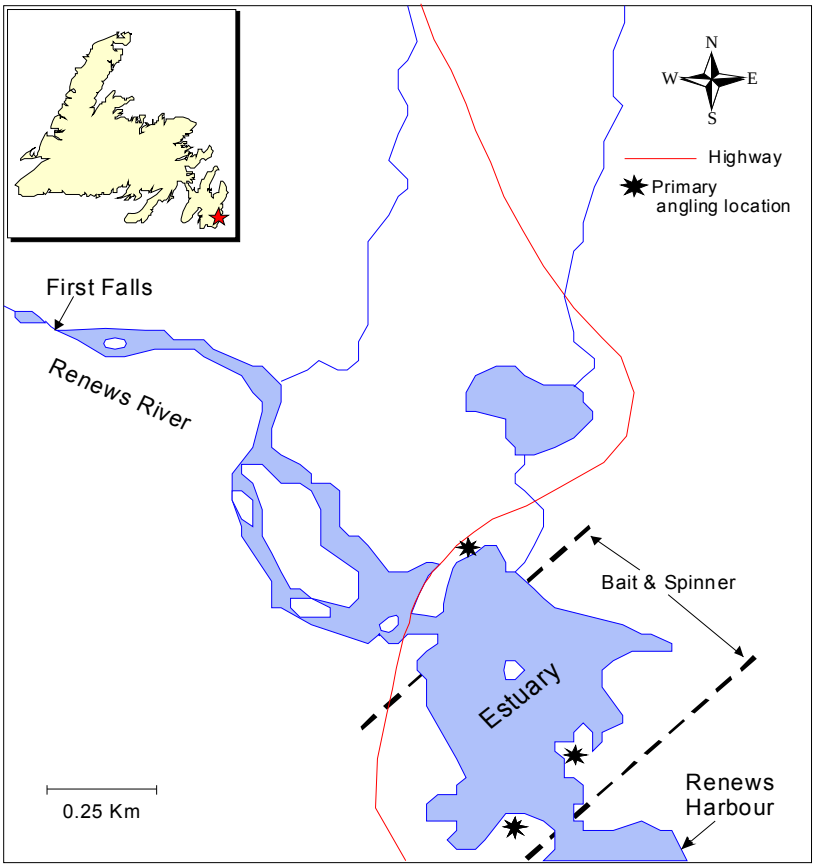

Fig. 1. Map of the lower section of Renews River including the estuary. Dashed lines indicate approximate area designated as inland waters where bait and spinner angling is permitted. Inset of Newfoundland shows approximate location of Renews River.

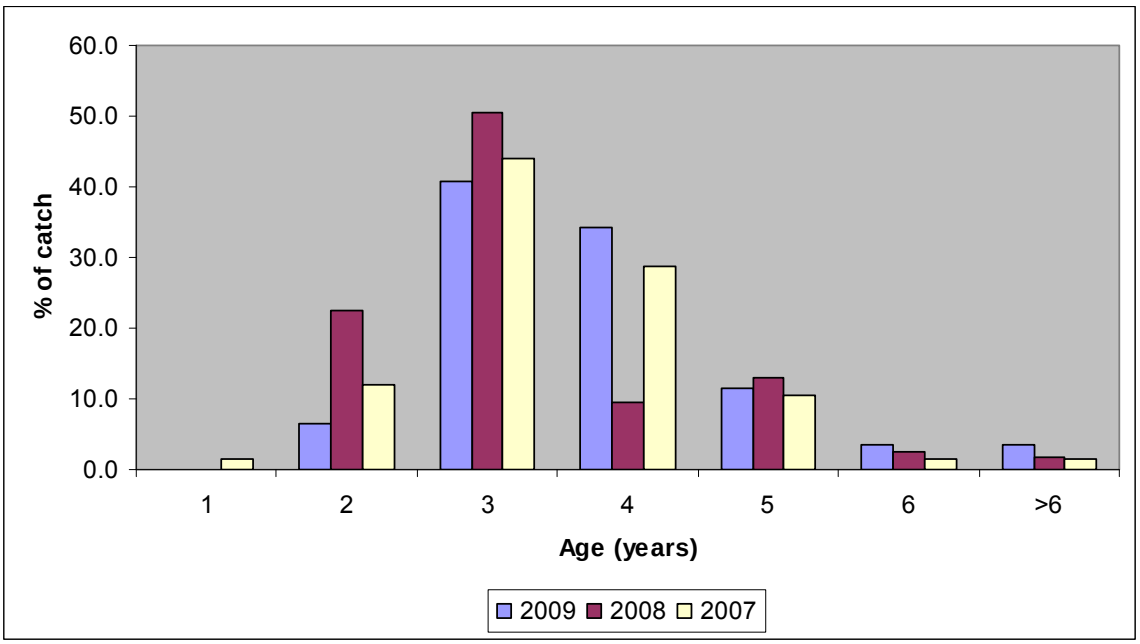

Fig. 2. Age distribution in the recreational fishery from 2007 to 2009.

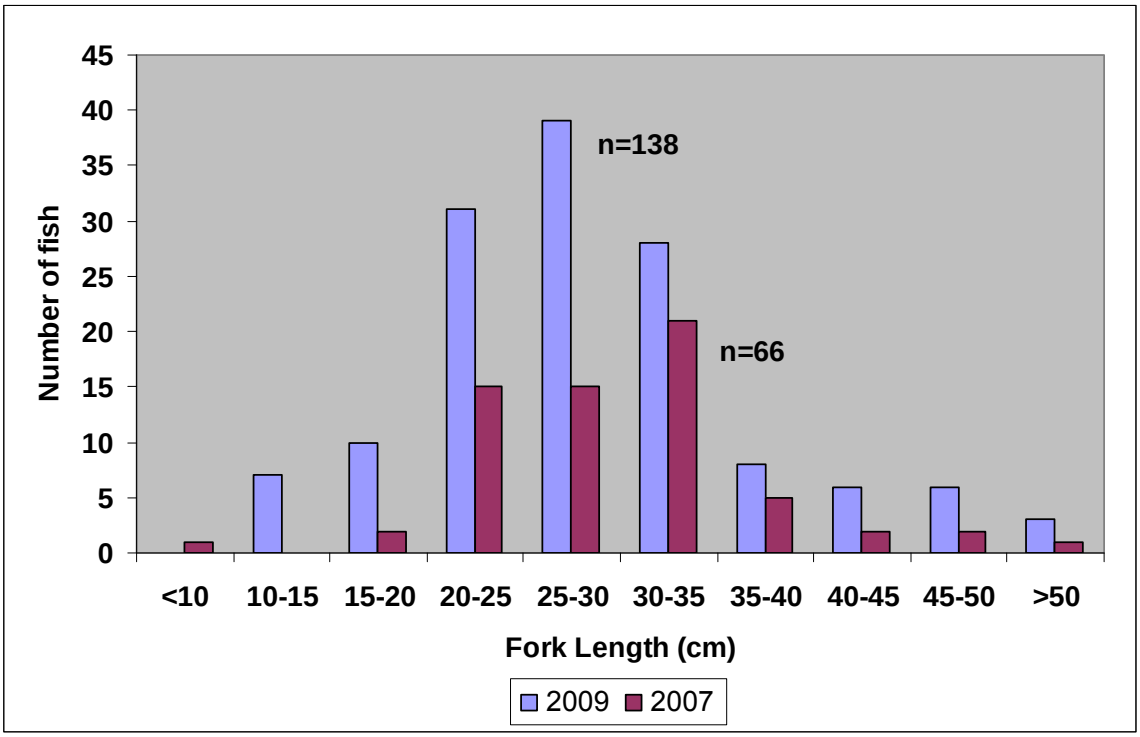

Fig. 3. Distribution of fork length in the recreational fishery in 2007 and 2009.

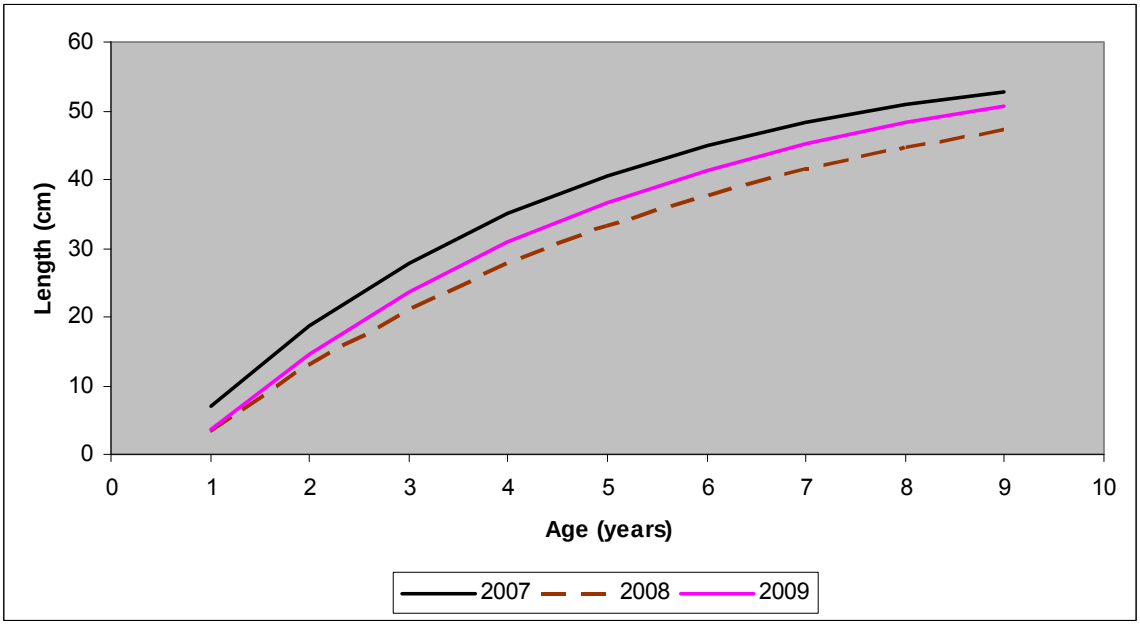

Fig. 4. von Bertalanffy curves for the age length data.

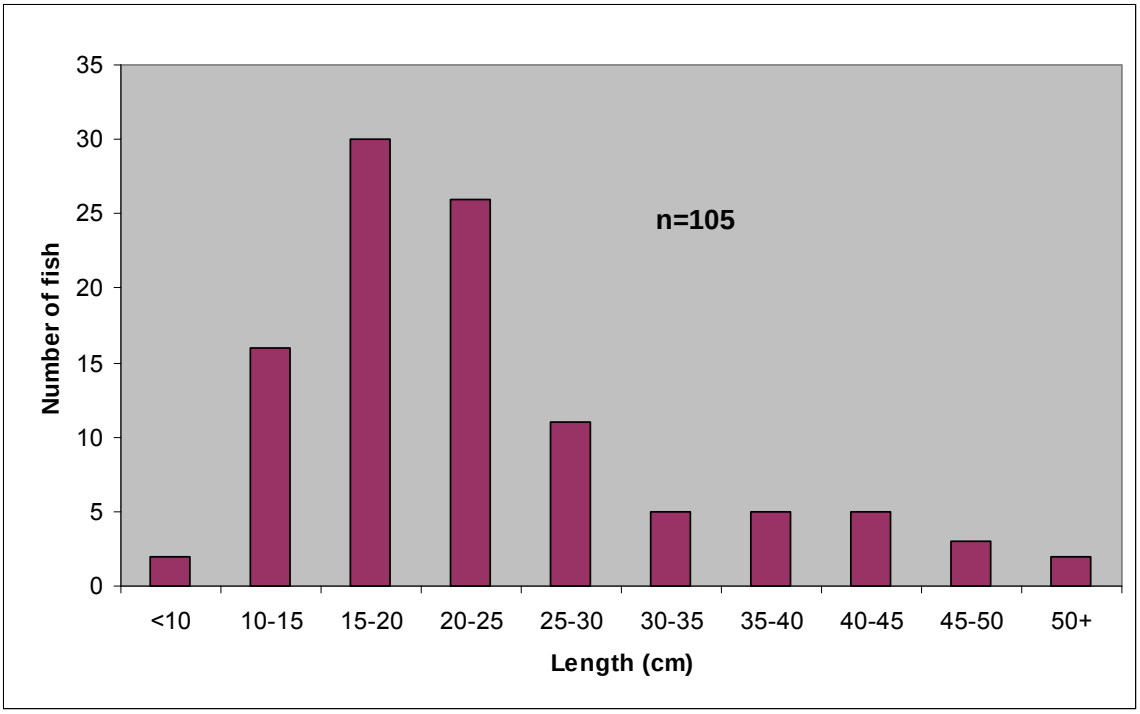

Fig. 5. Distribution of fork length in the recreational fishery in 2008. Compare with Fig. 3.

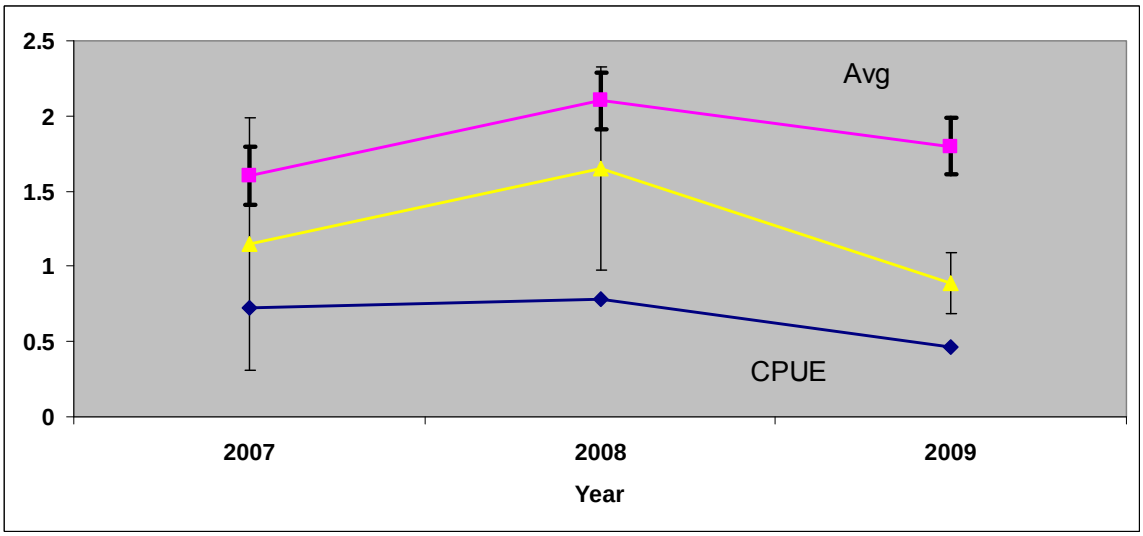

Fig. 6. Fishing season catch and effort data for 2007-09. Error bars represent 95 % confidence intervals. There are no error bars on CPUE.

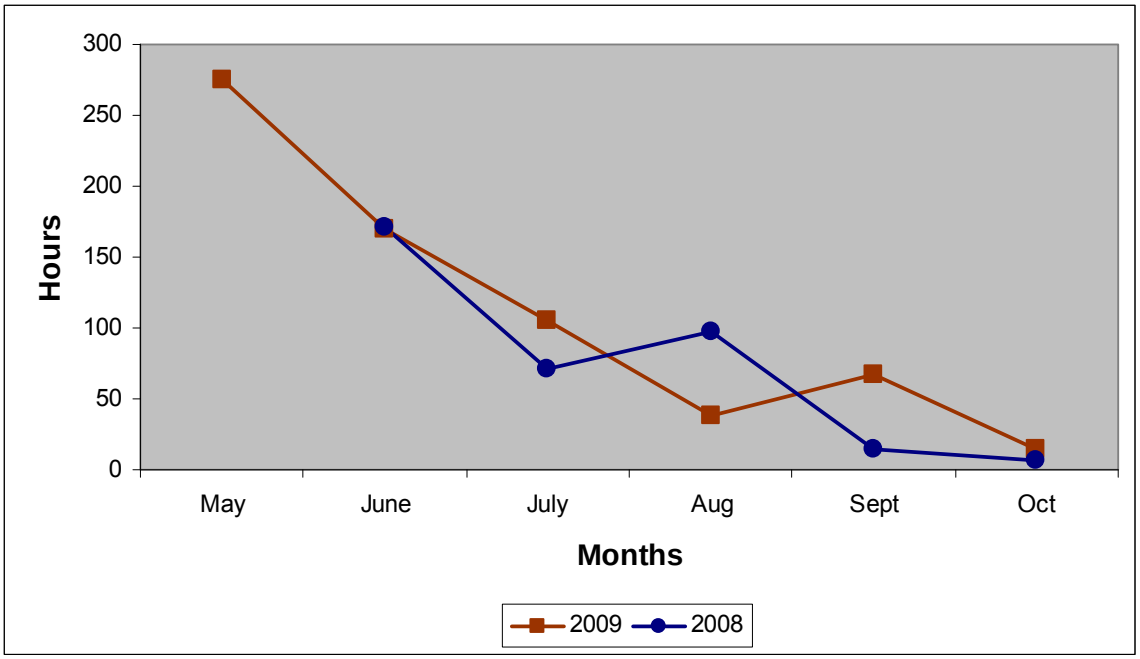

Fig. 7. Monthly effort (hours fished) in the recreational fishery in 2008 and 2009.

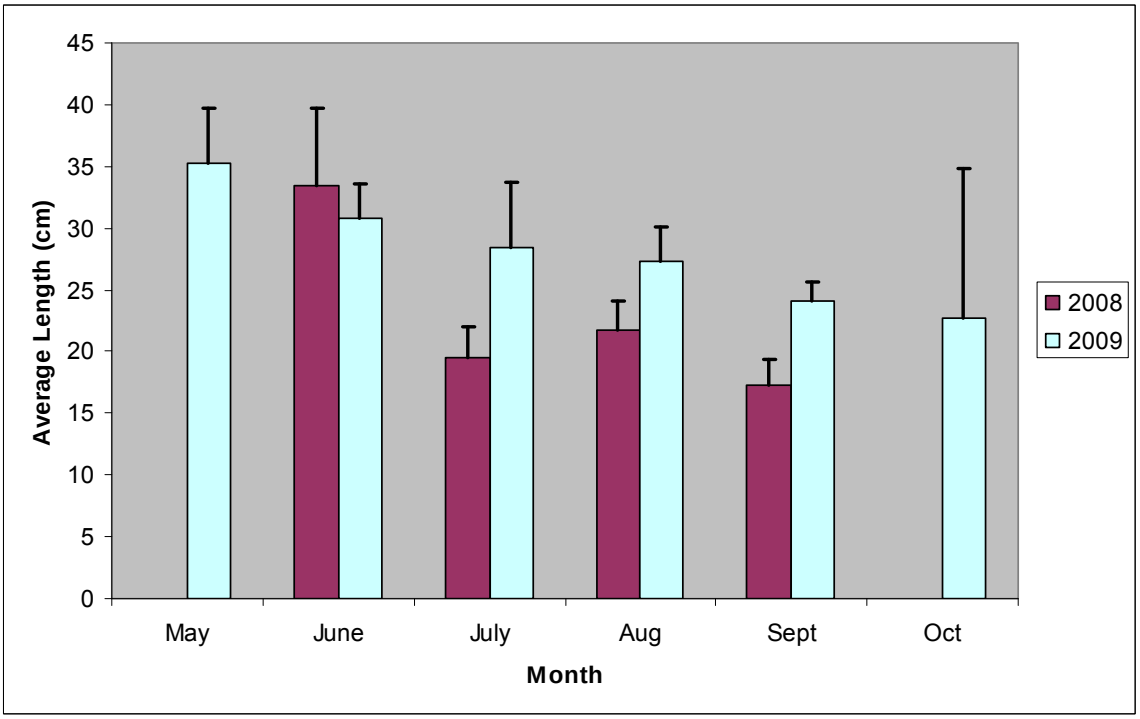

Fig. 8. Average length (cm) of brown trout sampled in the recreational fishery in 2008 and 2009. Error bars represent +95 % confidence interval.

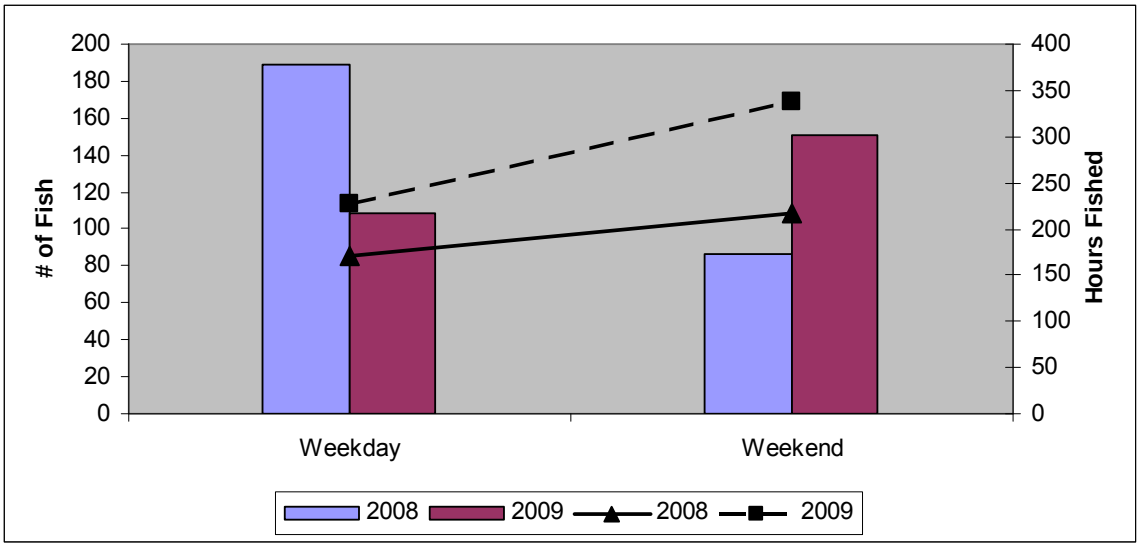

Fig. 9. Catch and effort for weekends and weekdays. Bars represent catch (# of fish) and lines represent effort (hours fished).

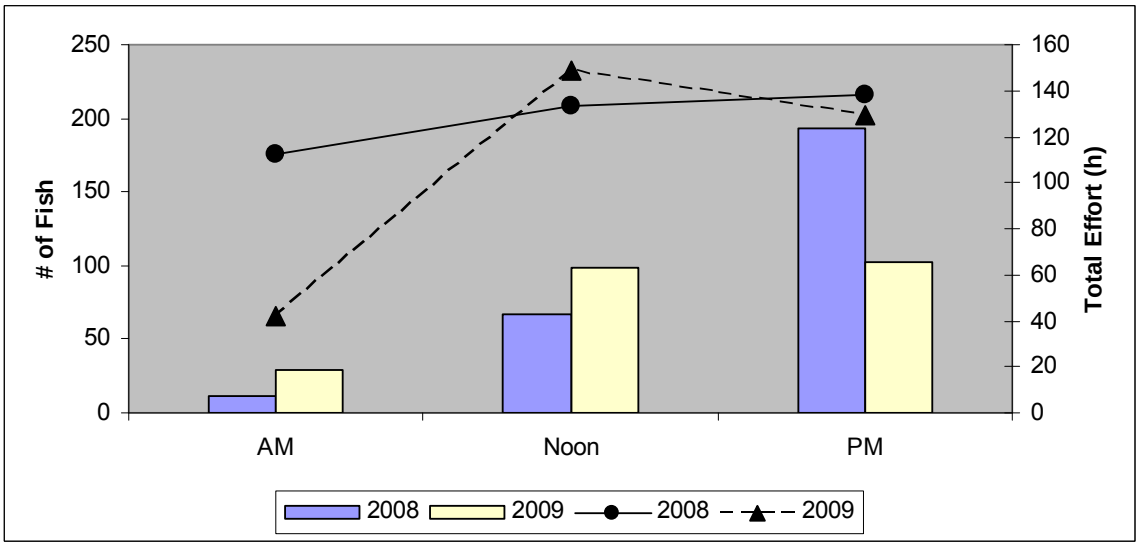

Fig. 10. Catch and effort for time of day. Bars represent catch (# of fish) and lines represent effort (hours fished).

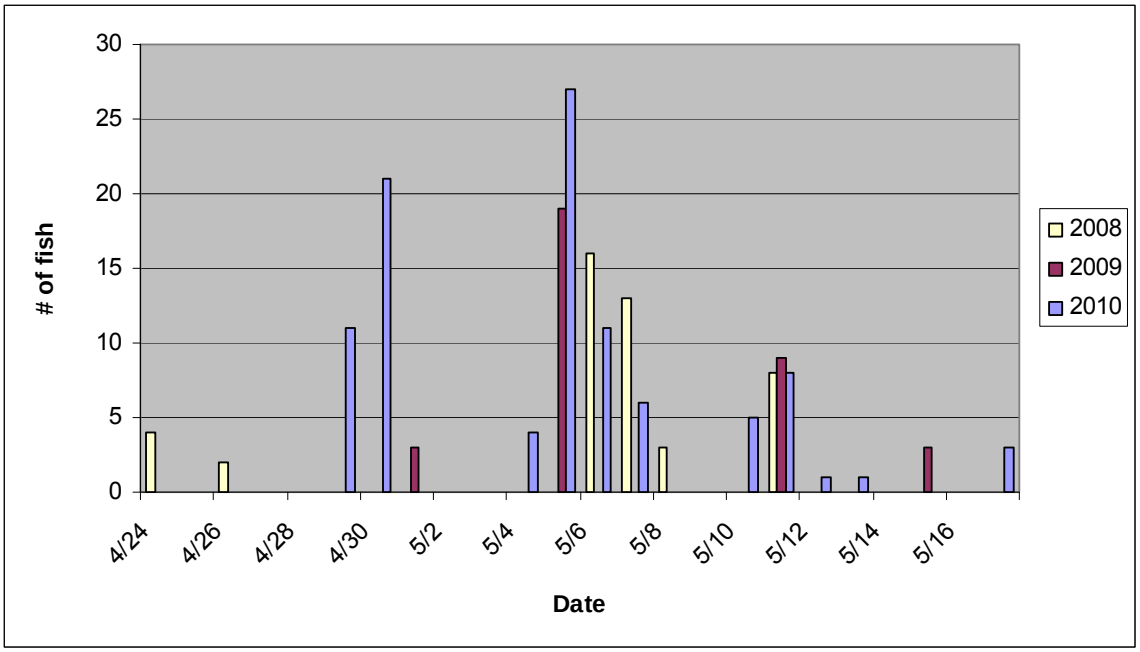

Fig. 11. Daily downstream fyke net captures of brown trout from 2008 to 2010.