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Research Document 2006/022 / **Document de recherche 2006/022**

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Using Harvest, Growth and Age to Assess the Efficacy of Bag Limits as a Management Option for Lake Trout, *Salvelinus namaycush,* for Labrador, Canada

Utilisation des données sur les prises, la croissance et l'âge pour évaluer l'efficacité de la limite de prises comme méthode de gestion du touladi, *Salvelinus namaycush*, pour le Labrador, Canada

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ISSN 1499-3848 (Printed / Imprimé)
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FOREWORD

This document is a product from a meeting that was not conducted under the Department of Fisheries Oceans (DFO) Science Advisory Process coordinated by the Canadian Science Advisory Secretariat (CSAS). However, it is being documented in the CSAS Research Document series as it presents some key scientific information related to the advisory process.

AVANT-PROPOS

Le présent document est issu d'un atelier qui ne faisait pas partie du processus consultatif scientifique du ministère des Pêches et des Océans, coordonné par le Secrétariat canadien de consultation scientifique (SCCS). Cependant, il est intégré à la collection de documents de recherche du SCCS car il présente certains renseignements scientifiques clés, liés au processus consultatif.

ABSTRACT

This paper describes a bi-annual point access creel and gill net sampling program established between 1997 and 2002 to monitor a lake trout, *Salvelinus namaycush,* fishery at Lobstick Lake, Labrador Canada. During this period the length and age of anglers catch declined. Mean length dropped from 69.4 cm in 1997 to 63.1cm in 2002. Age fell from 18.6 to 12 .7 years. This same trend was observed from lake trout taken with gill nets. The length of the netted catch dropped from 76.1 cm in 1997 to 60.1 cm in 2001. We established that lake trout in the watershed mature between 48 and 60 cm (between 8 and 13 years of age). We suggest that current regulations based on bag limits may be inadequate for preserving a viable fishery and therefore make recommendations for regulative amendments that account for lake trout sexual maturity.

RÉSUMÉ

Le document décrit un programme semestriel d'échantillonnage au filet maillant et de sondage au point d'accès établi entre 1997 et 2002, afin de contrôler une pêche du touladi, *Salvelinus namaycush,* au lac Lobstick, au Labrador (Canada). Pendant cette période, la longueur et l'âge des prises des pêcheurs ont diminué. La longueur moyenne est passée de 69,4 cm en 1997 à 63,1 cm en 2002. L'âge a chuté de 18,6 à 12,7 ans. La même tendance a pu être observée chez les touladis capturés au filet maillant. La longueur des captures a baissé, passant de 76,1 cm en 1997 à 60,1 cm en 2001. Nous avons établi que le touladi du bassin atteignait la maturité entre 48 et 60 cm (entre 8 et 13 ans). Selon nos constatations, il semblerait que la réglementation actuelle, fondée sur la limite de prises, est inappropriée pour la préservation d'une pêche durable et, par conséquent, nous recommandons d'apporter des modifications au règlement qui tiennent compte de la maturité sexuelle du touladi.

INTRODUCTION

In the province of Newfoundland and Labrador, the Department of Fisheries and Oceans relies on the arbitrary manipulation of season dates and bag limits as tools for the maintenance of sustainable inland sport fisheries. Lake trout, *Salvelinus namaycush,* have been managed for the last ten years by the establishment of a retention bag limit of two fish per day and a possession limit that is twice that of the daily bag limit. In this paper, I evaluate the response of a lake trout population to determine the efficacy of this bag and possession limit as a management option.

When heavy fishing mortality changes a population structure, population numbers decline and the age distribution shifts towards smaller, younger fish. It has been shown that heavily-exploited populations may respond by demonstrating improved growth and earlier maturation (Heino 1998; Power and Power 1996). Accordingly, changes in growth and age distribution patterns were used to trace the impacts of exploitation and to access the sustainability of the current management regime for lake trout in Lobstick Lake.

STUDY AREA

Lobstick Lake, a part of the Churchill River drainage basin, in western Labrador (Fig. 1) was selected for this case study for two reasons: first, it is regarded by residents as having an exceptional lake trout fishery and therefore in the spring receives a great deal of angling pressure (May through June); second, the fishery is regarded as being relatively new, and prior to completion of the trans-Labrador highway in 1992, there was limited accessibility by the communities of Labrador City, Wabush and Happy Valley-Goose Bay, which are the major population centres in the region. This changed in 1992 when the road was upgraded, improving accessibility. Provincial conservation officers from the Wabush detachment indicate that subsequent to the road upgrading, fishing pressure on the area has steadily increased.

Lobstick Lake is a shallow water lake with a mean depth of only 3 m and an annual mean water temperature of 5.12^{o}C. Its surface area is approximately 4825 ha. The lake is part of a larger complex of waterbodies know as the West Forbay (Fig. 2). The West Forbay consists of three additional areas which are Flour Lake (4615 ha), Upper Churchill River (1900 ha) and Jacobie Lake (3881 ha). Together the four areas encompass 15 221 hectares (Chaput and deGraff 1983) (Fig. 2).

Six additional lakes from the drainage basin were also sampled and two collections from Lakes Atikonak and Panchia were made available from Newfoundland and Labrador Hydro (Table 6; Fig. 1). Age and growth data collected from these eight lakes were compared with samples from Lobstick Lake to establish possible management alternatives appropriate for the entire watershed.

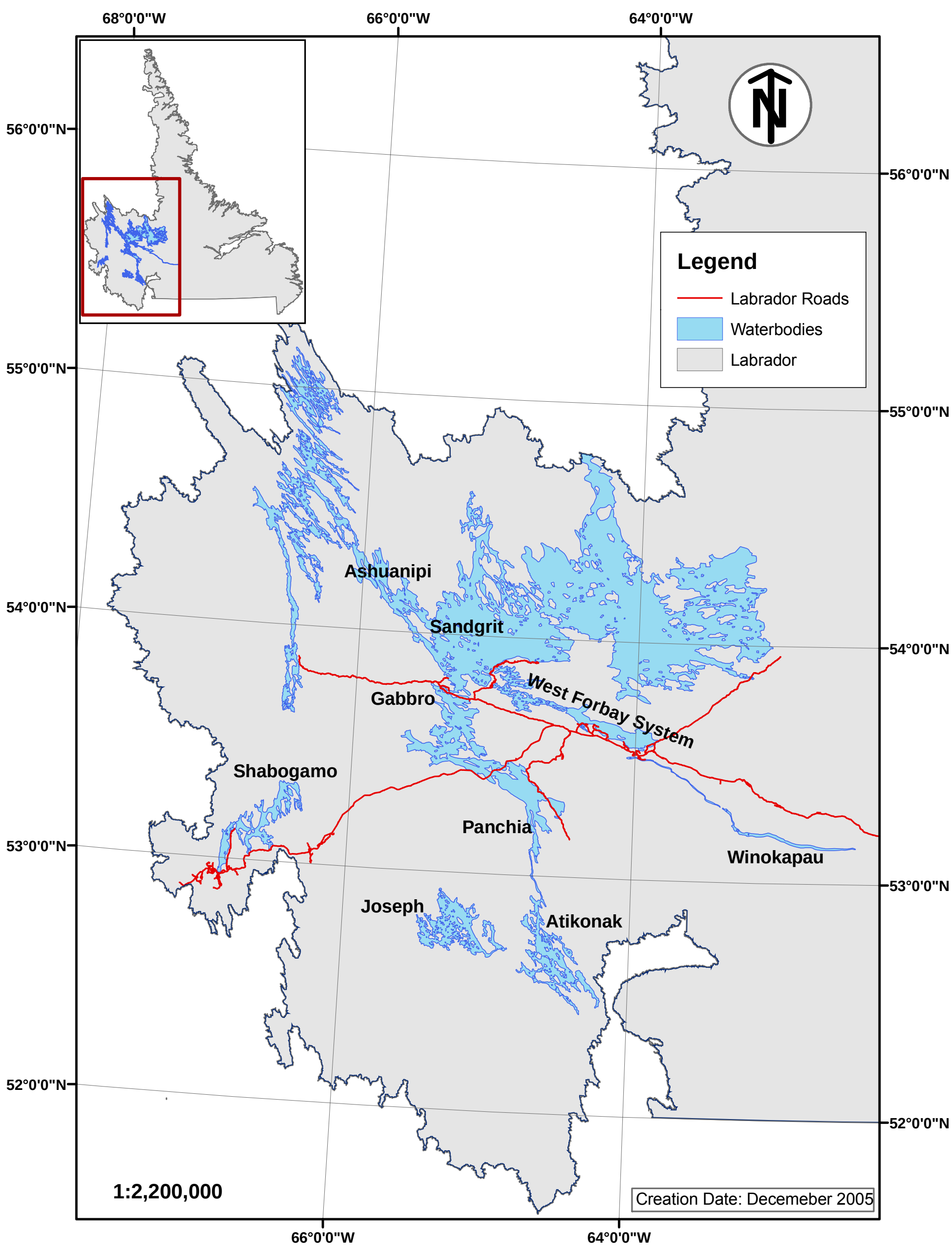

Figure 1. Locations of all surveyed lakes in the Churchill drainage basin.

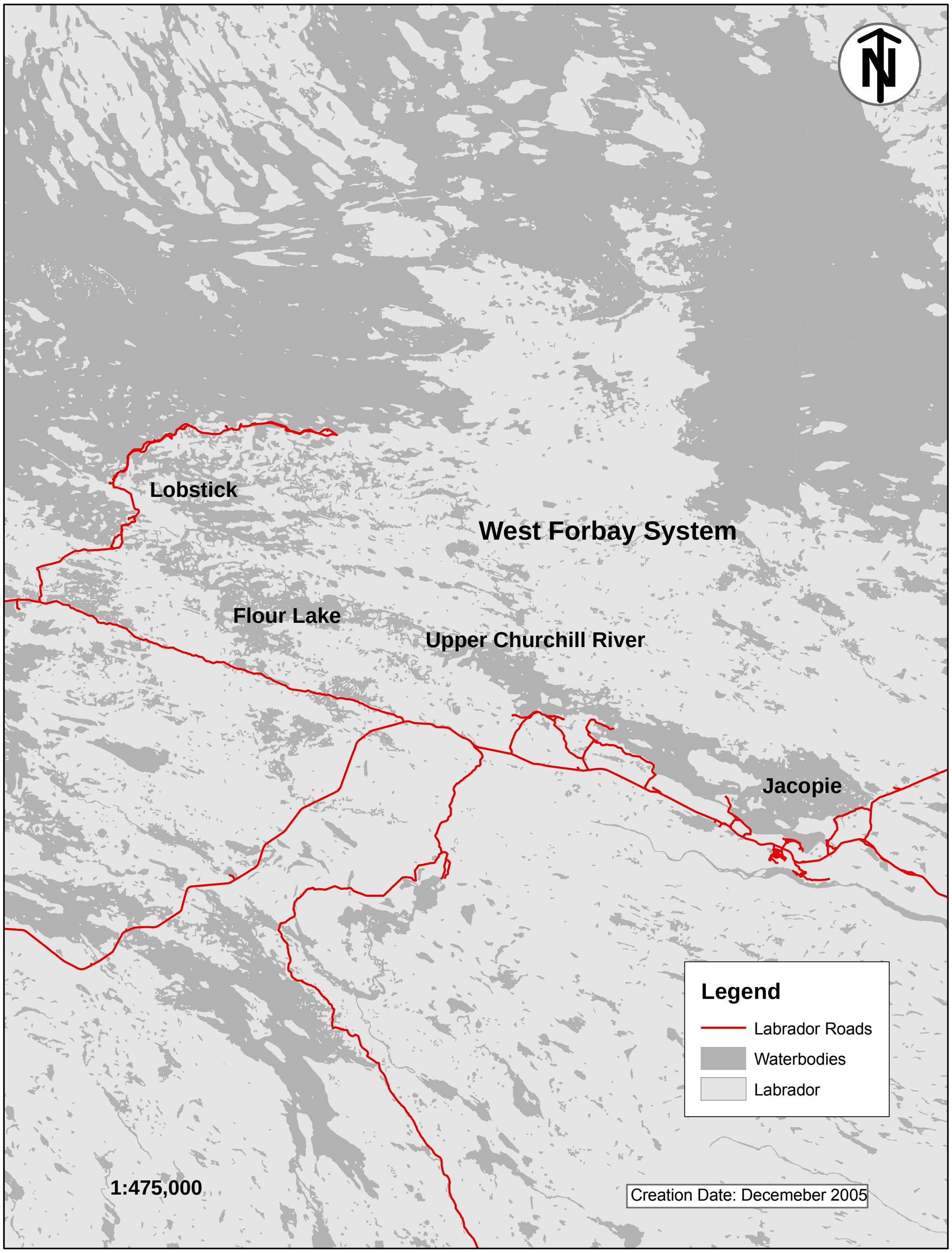

Figure 2. The four areas that comprise the West Forbay; Lobstick (4825 ha), Flour Lake (4615 ha), Churchill River (1900 ha) and Jacobie Lake (3881 ha).

METHODS

Harvest and fish attribute data were obtained from the establishment of a point access creel on Lobstick Lake and intermittent gill net sampling on each of the eight lakes surveyed during the spring months between 1997 and 2002.

Creel surveys were conducted daily between 06:00 and 23:00 in May and June. Effort (per hour) and harvest information were recorded from angler interviews. Anglers' catch was sampled for age and growth information.

Gill nets were standardized, such that a gang of eleven panels, increasing in size from 0.5 to 5.0 inches by 0.5 inch increments were attached in series from smallest to largest mesh sizes. Gangs were set perpendicular from the shore in all lakes. Equipment and sampling period were standardized so that samples were comparable. To calculate catch per unit effort (CPUE), total catch was divided by the total soak time per set. Calculated CPUE (fish per hour) values were then averaged by sample year.

In addition to our own collections two additional collections were made available by Newfoundland and Labrador Hydro for Lakes Atikonak and Panchia.

ANALYSIS

Seasonal angling effort, catch and catch rate

The following formulas were used to calculate seasonal angling effort, catch rate, Yield and catch using the creel data (seasonal effort and catch estimates were calculated assuming a constant rate of effort):

<u>Seasonal effort for Lobstick area (*SEj*)</u>

Mean daily effort = $\bar{f}_j = \frac{\sum_{k=1}^{n} f_{jk}}{n}$

$SE_j = \bar{f}_j \times N$

<u>Catch rate for Lobstick area (*CR j*)</u>

$$CR_j = \frac{\sum_l C_{jl}}{\sum_l e_{jl}}$$

Total seasonal catch for Lobstick (C_J)

$$C_j = \bar{f}_j \times N \times CR_j$$

Yield per unit area

$$Y_A = \frac{\bar{X}_w \times C_j}{ha}$$

Angling effort per unit area

$$A_e = \frac{SE_j}{ha}$$

Where;

$\bar{f}_j$ = average daily effort
N = number of days in the season
n = number of days sampled
f_{jk} = the fishing effort for Lobstick area (j) , for day (k).
C_{jl} = is the number of trout caught by party l
e_{jl} = is the number of anglers in an interview * hours reported for the group.
$\bar{X}_w$ = average weight of harvested fish per season
ha = hectares (lake surface area)

Length and age distributions

To determine if changes occurred in length of anglers catch, mean length for samples collected in each year (1997, 1999, 2000 and 2002) were compared. Additionally, lake trout otoliths sampled from these years were interpreted for age and a comparison of yearly mean age was undertaken. In both instances ANOVA's were used to test for differences.

This analysis was repeated for the gill net sampling done at Lobstick Lake. Both mean length and age for lake trout sampled in the years 1997, 1998, 1999, 2000 and 2001 were compared.

To determine if anglers catch had shifted between 1997 and 2002 to a composition that contained a larger percentage of immature fish I compared frequency distributions, fitting density function plots (normal distributions) to the two distributions (SYSTAT 9). This allowed for an examination for the general trend in data spread. Catch length and age distributions were also subdivided using percentiles to determine if an overall shift had occurred between 1997 and 2002. Additionally, using the upper mean limit of thirteen years to define an immature fish (Bruce 1984), the sampled catch from 1997 and 2002 were separated into mature and immature sub-groups. Using a chisquare test to compare the immature sub-group I tested for percentage differences between years.

I tested for differences at mean length and then mean condition factor (K = somatic weight (g) 10^5 * fork length $(mm)^{-3}$ Weatherly 1972)) between the 1997 and 2002 sampled catch using a paired t-test. I paired mean values using age classes that were common to both sample years. I also plotted the length weight-relationships for 1997 and 2002.

Mortality

Using the least-squares and Chapman-Robson maximum likelihood estimators, anglers' catch from 1997 and 2002 were used to calculate instantaneous and annual mortality (Ricker 1975; Everhart et al. 1975). Using two isolated lakes with the largest sample sizes I calculated natural mortality using the least-squares estimator (Lakes Atikonak and Lake Panchia). Due to their remote location I assumed fishing pressure was negligible and therefore assumed calculated annual mortality approximated natural mortality when using the least squares estimator.

Abrosov's index (Abrosov 1969) was used to determine the age of turnover (the average number of years a fish remains in the water between hatching and removal) for lake trout in the above mentioned populations.

Growth and sexual maturity

Sexual maturity of lake trout was established based on the assessment of gonad and ovary development using criteria described by Ricker (1970) and Vladykov (1956).

To describe the general period when lake trout matured samples were subdivided into length subgroups separated by 100 mm intervals and percent maturity for each subgroup was calculated and graphed.

To validate the maturity classifications additional collections were conducted in the fall when gonads and ovaries are considered to be ripe. Samples were collected from lakes Lobstick and Shabogamo in September of 2000 and 2001. Fall samples were also separated into sub groups and percent maturity was plotted. The zones of maturation between the fall and spring collections were compared.

Growth and reproductive potential

To describe the overall length-weight relationship for the watershed lake trout sampled in the spring were plotted (samples taken from lakes Atikonak and Panchia were also included) and a power function was used to describe the growth.

For discussion purposes, the potential fecundity for mean size was calculated for two lakes of the watershed. Total ova numbers for each fish were estimated by extracting and weighing a sub- sample of eggs. Number of eggs were counted in the sub-sample and divided by the sub-sample weight to give the number of eggs per gram. The number of eggs per gram was then multiplied by the total ovary weight to give total fecundity. To estimate fecundity I described the relationship between fecundity and fish length (eggs per mm) using the fall samples:

$$F = ax^{b}$$

Where;

F = fecundity (number of eggs),
x = length, weight or age,
a and b are derived parameters.

RESULTS: CREEL SURVEYS

With the exception of 2002 which consisted of 108 days, the angling season for each survey year was 123 days. During 2002 the angling season was reduced to minimize fishing pressure during a statutory holiday (Department of Fisheries and Oceans pers. comm.). Actual days surveyed ranged between one and three weeks.

In total 1079 anglers were surveyed. Anglers reported catching 657 lake trout from which a sub-sample of 371 was randomly sampled for biological information (Table 1). There was a decline among years for both catch size ($F = 8.268$, $P < 0.001$) and age ($F = 21.819$, $P < 0.001$) (Fig. 3). A Bonferroni multiple comparison test revealed that length and age differences existed between the years 1997 and 2002.

Table 1. Summary statistics for the point access creel surveys conducted between 1997 and 2002. Reported total catch for lake trout includes both kept and released fish. (In 1999 survey agents elected to interview anglers individually rather than on a fishing party basis)

Year	Days surveyed	Parties interviewed	Anglers surveyed	Total catch	Sampled Fish	Mean Weight (kg)
1997	23	311	555	237	155	4.76
1999	13	81	81	69	51	3.23
2000	5	27	65	59	19	3.68
2002	16	139	378	292	146	2.95

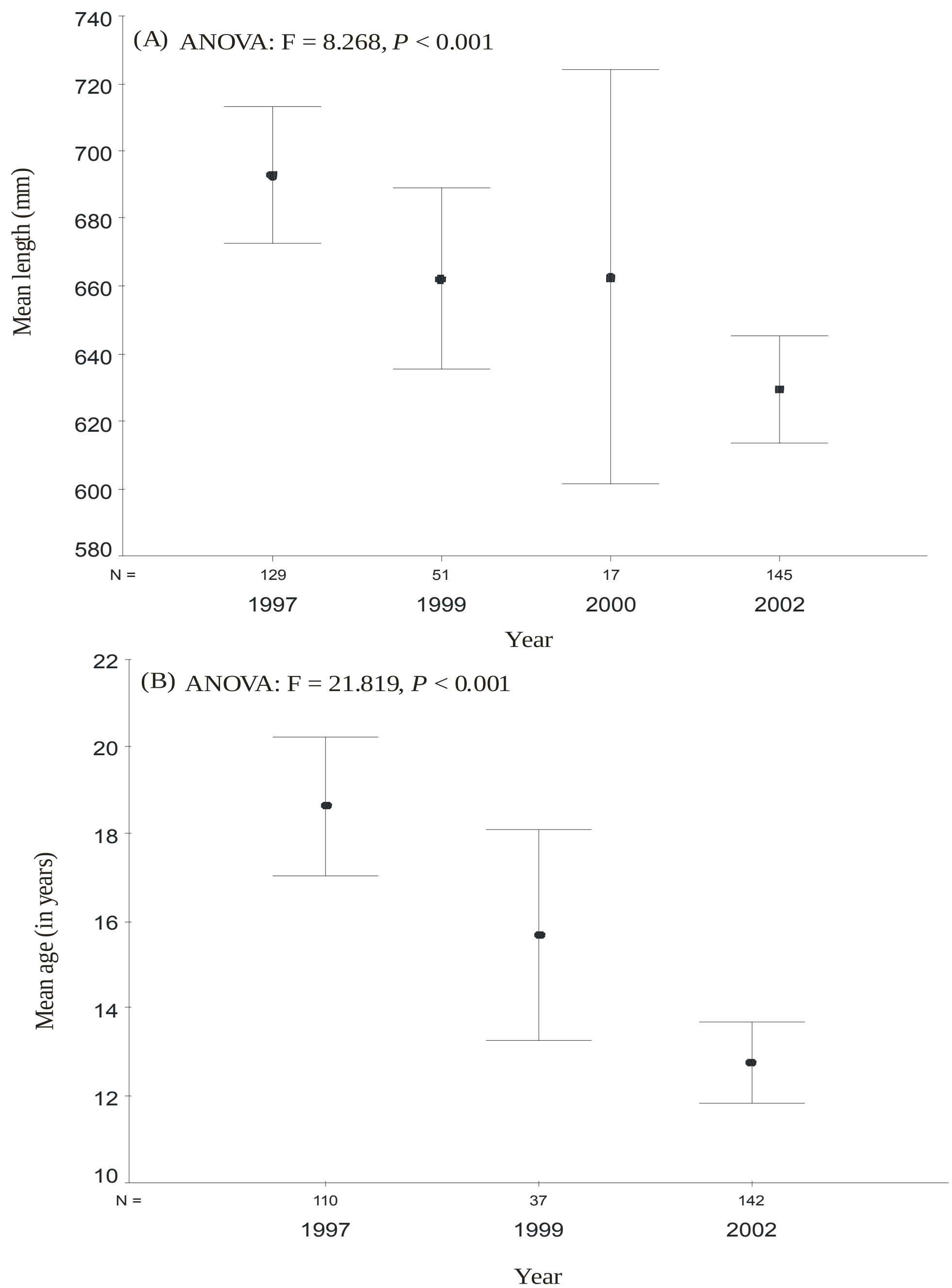

Figure 3. The relationships among sampling years for lake trout mean (A) length and (B) age. Samples were collected bi-yearly from creel surveys conducted at Lobstick Lake between the years of 1997 to 2002. Bars represent the 95% confidence intervals around the yearly means.

A comparison of lake trout age distribution plots, sampled from angler's catch in 1997 and 2002, indicated a greater percentage of younger aged fish being harvested in 2002 (Fig. 4). The comparison of percentiles showed a general shift in all groups from larger, older fish to smaller and younger (Table 2). Immature fish (13 years or younger) became a larger portion of the angled catch (34.5% for 1997; 64.8% for 2002; $\chi^2 = 14.802$, $P = 0.039$)

Table 2. The comparison of length and age percentile groups for lake trout sampled from anglers catch. The comparison is done using the largest sample groups (1997 and 2002). N represents the total number of samples in the comparison.

		Percentile						
	Year	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**
Length (cm)	1997 N = 129	50.8	57.8	61.2	68.3	76.0	83.8	90.5
	2002 N= 145	50.3	53.9	57.6	61.9	67.0	76.3	81.4
Age	1997 N = 110	8.6	10.1	12.7	16.0	24.3	33.0	34.5
	2002 N = 142	7.0	7.3	9.0	12.0	15.0	18.7	22.9

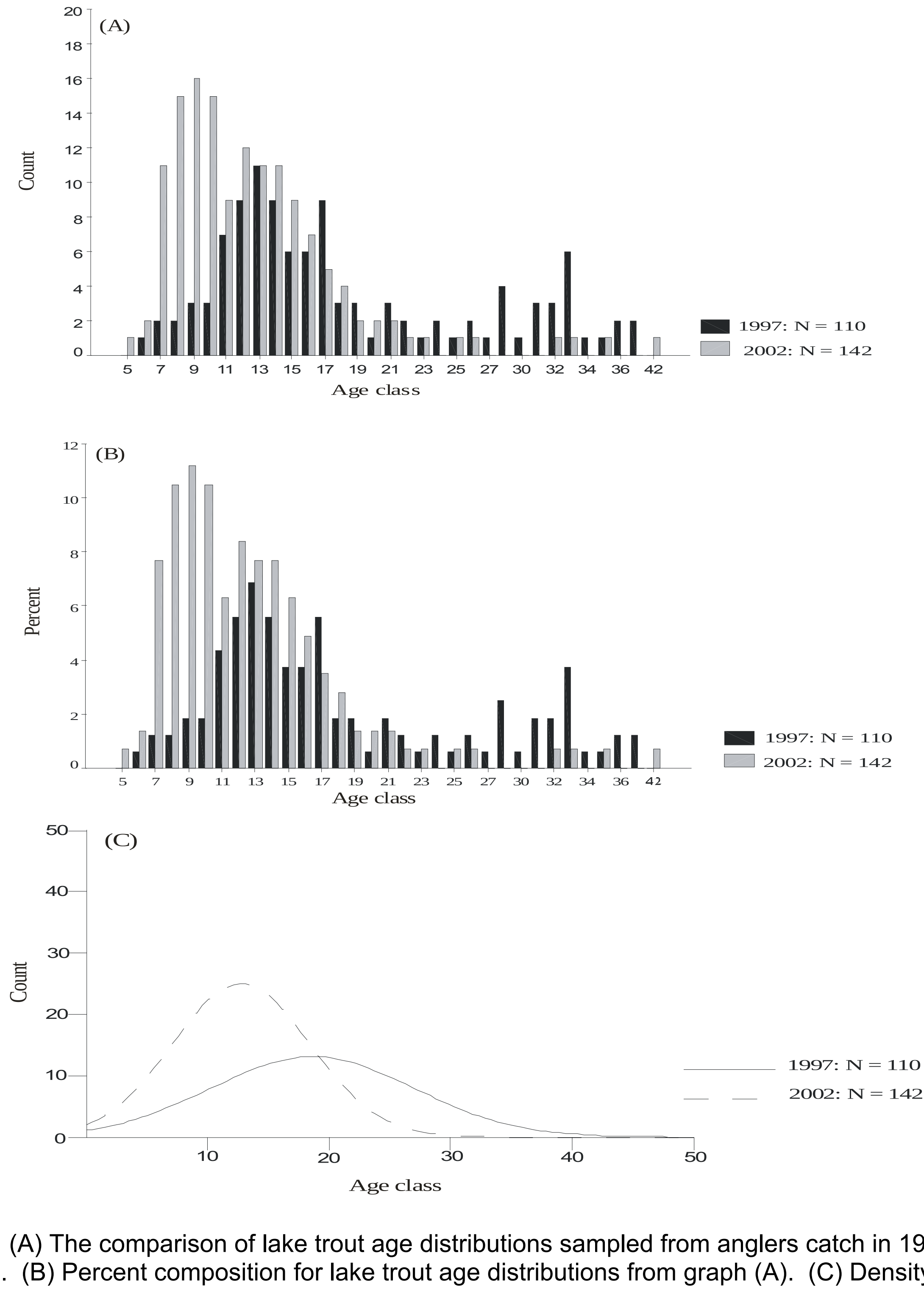

Figure 4. (A) The comparison of lake trout age distributions sampled from anglers catch in 1997 and 2002. (B) Percent composition for lake trout age distributions from graph (A). (C) Density function plots (normal distributions) fit to lake trout age distributions from graph (A). N represents the number of lake trout from each sample year.

We found no difference in paired t test for mean size at age between 1997 and 2002 anglers catch (Table 3, Fig. 5) (t = -1.199, df = 22, *P* =0.243). However mean condition factor did significantly differ with 2002 fish displaying poorer condition (Table 3, Fig. 5) (t = 2.090, df = 21, *P* = 0.049. Length-weight plots indicate that the exponent *b* has dropped below 3 in 2002, indicating that lake trout are putting less weight per unit of length when compared to 1997 (Fig. 6) (Ricker 1975).

Table 3. Comparing mean length (mm) and mean condition factor (CF) between 1997 and the 2002. Mean values for 23 age classes (sampled from anglers' catch) were paired. Frequency (N) for each age class is reported.

Age class	1997 (N)	2002 (N)	1997 Mean length	2002 Mean Length	1997 Mean CF	2002 Mean CF
6	1	2	484.00	560.50	0.95	1.04
7	2	11	460.00	540.91	0.96	1.05
8	2	15	598.00	577.87	1.69	1.15
9	3	16	569.33	597.44	0.88	1.00
10	3	15	741.00	602.53	1.14	0.97
11	7	9	631.43	599.67	1.14	0.95
12	9	12	671.11	619.00	0.96	0.96
13	10	11	633.20	662.09	1.31	0.98
14	9	11	663.56	659.73	1.02	0.89
15	6	9	658.33	685.44	1.01	0.96
16	6	7	701.00	662.43	1.11	1.00
17	9	5	675.78	662.60	1.00	0.92
18	3	4	688.67	697.00	1.01	1.03
19	3	2	676.00	742.50	1.31	1.09
20	1	2	706.00	675.50	0.91	0.96
21	3	2	665.33	693.50	0.94	0.85
22	2	1	725.50	785.00	1.06	1.15
23	1	1	840.00	762.00	1.03	0.80
25	1	1	628.00	840.00	1.04	0.84
26	2	1	653.50	661.00	0.92	0.87
32	3	1	700.67	890.00	1.00	1.12
33	6	1	750.00	685.00	---	---
35	1	1	752.00	882.00	1.00	1.13

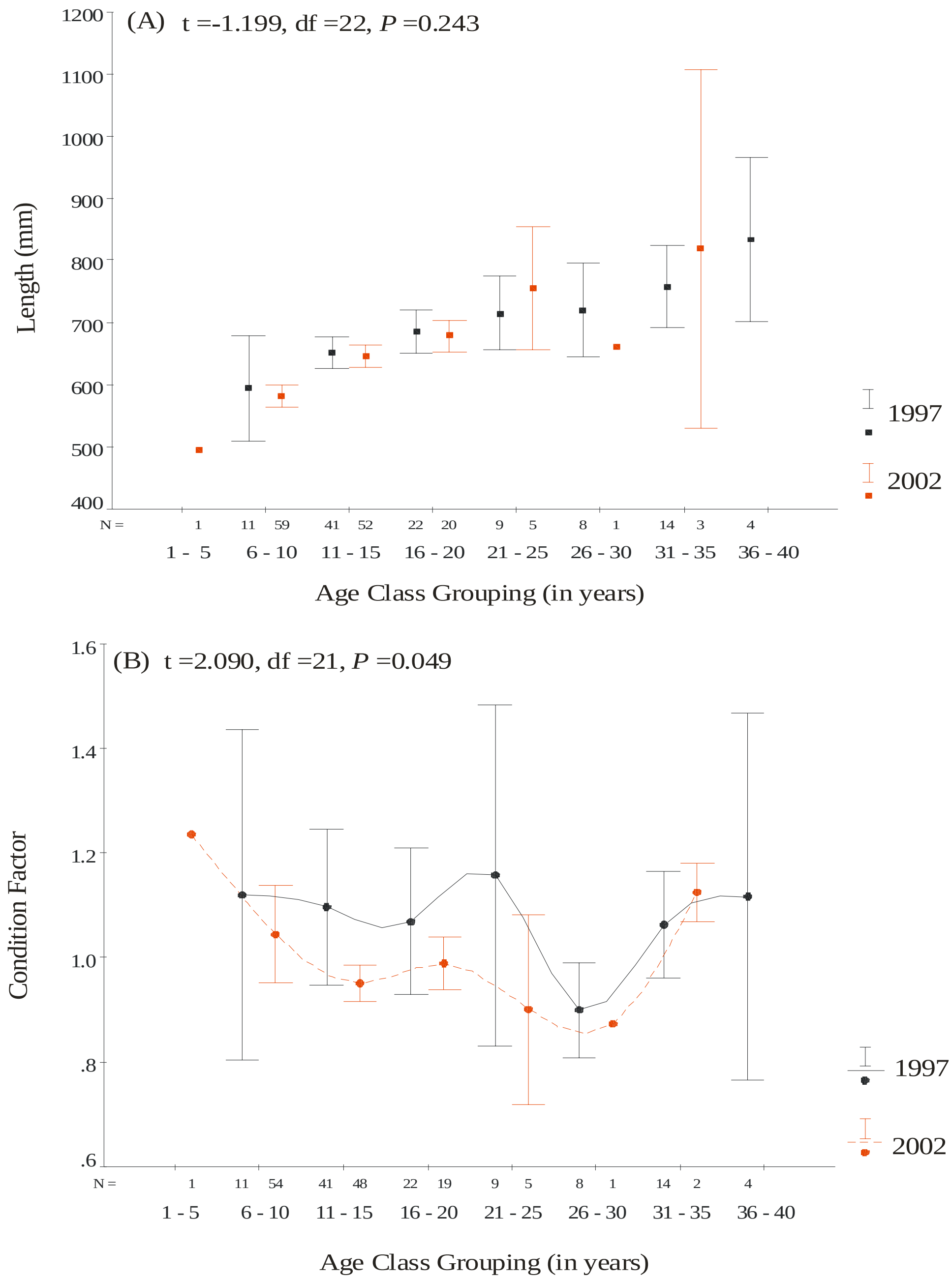

Figure 5. (A) Compares between length (A) and Condition Factor (B) at each age for lake trout sampled during the 1997 and 2002 fishery. Results of Paired t-test are reported. (To easily examine trend samples have been grouped by five year intervals.) Lines represent 95% confidence intervals. Sample size (N) is also reported.

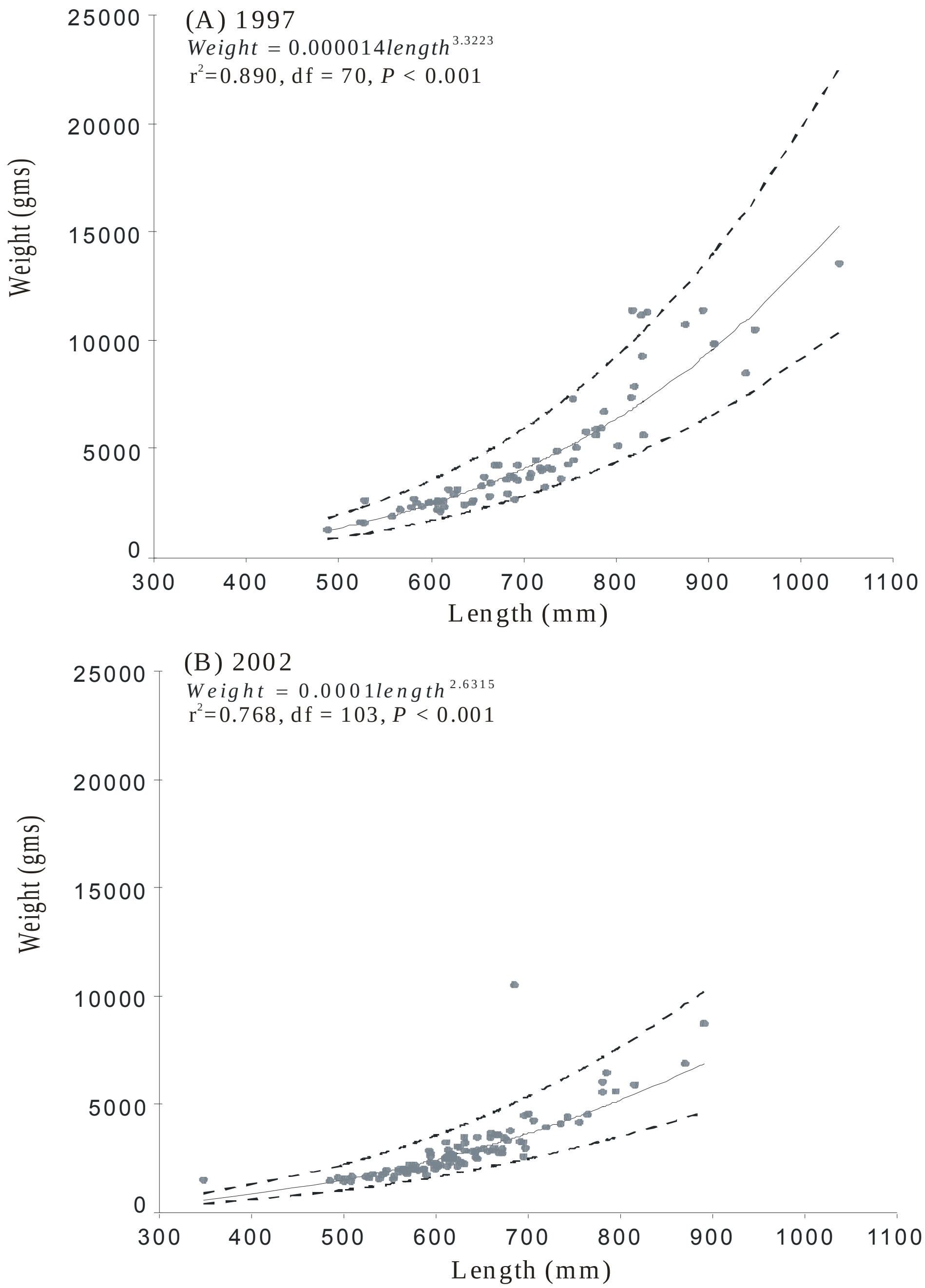

Figure 6. Length–weight relationships for lake trout sampled during the 1997 (A) and 2002 (B) spring creels.

In general, a comparison of the creel statistics between 1997 and 2002 indicates that CPUE has doubled. The mean CPUE for the four years surveyed was consistent at 0.2630 fish per hour (± 0.0402). The average yearly effort was 6397 hrs and the average yearly harvest was 1336 lake trout (Table 4).

Table 4. Daily catch rate, average daily effort, seasonal effort and seasonal catch results for years 1997, 1999, 2000 and 2002. Data were collected through spring exit access point creel surveys conducted in the Lobstick Lake area of the Smallwood Reservoir. (Total seasonal catch is calculated from the average daily effort * catch rate* number of fishable days). Effort per Hectare and Yield were calculated using surface areas (in hectares) for Lobstick (1) and entire West Forbay (2).

Year	CPUE (fish/hour)	Average Daily Effort (mean hours)	Season Length (days)	Seasonal Effort (total hours)	Effort per Hectare ($hrs \bullet ha^{-1}$)		Seasonal Catch	Yield ($Kg \bullet ha^{-1}$)	
					(1)	(2)		(1)	(2)
1997	0.1304	79.00	123	9717.00	2.01	0.63	1267	1.25	0.39
1999	0.2592	20.47	123	2517.81	0.52	0.16	653	0.44	0.14
2000	0.2606	45.28	123	5569.44	1.15	0.36	1451	1.10	0.35
2002	0.2532	72.07	108	7783.56	1.61	0.51	1971	1.20	0.38

Mortality

For the 2002 estimates both the least – squares and Chapman and Robson estimators approximated a 5% increase in annual mortality above 1997. Both control ponds had estimates of natural mortality lower than estimated annual mortality for Lobstick in 2002 (Table 5). Abrosov's index values indicated a downward shift in turnover where the age declined from 18.57 in 1997 to 12.7 in 2002. Lakes Atikonak and Panchia have natural mortality and turnover rates that more closely resemble the 1997 values for Lobstick (Table 5).

Table 5. Mortality estimates for Lobstick Lake (estimates derived from the 1997 and 2002 creel samples) and for two control ponds (Panchia and Atikonak). Abrosov's turnover estimate indicates the average time (in years) a fish remains in the population. (Least-square estimations were not truncated)

Lake	Instantaneous (Z) and Annual (A) Mortality				Abrosov's turnover age
	Least-Square		Chapman and Robson		
	(Z)	(A)	(Z)	(A)	
Lobstick (1997)	0.0598	0.0581	0.1145	0.1082	18.57
Lobstick (2002)	0.1079	0.1023	0.1765	0.1618	12.70
Panchia	0.0653	0.0632	0.1197	0.1128	16.57
Atikonak	0.0499	0.0486	0.1000	0.0952	16.64

STANDARDIZED GILL NETTING

Lake trout were sampled for five years at Lobstick Lake while the other lakes of the watershed were sampled with less frequency (Table 6). In total 44 net sets were placed throughout the watershed. Collectively the netting accounted for 444 lake trout being sampled. No discernable pattern was evident for catch rate at Lobstick Lake during the sampling period ($F = 0.791$, $P = 0.390$).

The comparison of sampled catch for Lobstick lake indicated lake trout differed among sampling years for both length (F = 9.436, $P < 0.001$) and age (F = 9.813, $P < 0.001$) (Fig. 7). A Bonferroni post Hoc test revealed differences existed for mean length between 1997 and all other years. Mean age also differed between 1997 and 2001. It should be noted that a difference existed for mean age at a reduced alpha (α = 0.1) between 1997 and 1999.

Table 6. Frequency of net sets and number of lake trout collected for the standardized sampling. Spring includes the months of May and June; fall includes only the month of September. (CPUE = lake trout /hour). Samples from Lakes Atikonak and Panchia were collected by Newfoundland and Labrador Hydro.

Location	Year	Season	Net Sets (N)	Mean CPUE	Lake Trout (N)	Mean Age (years)	Mean Length (mm)
Ashuanipi	2000	Spring	3	.6798	36	--	593.58
	2001	Fall	3	.2623	18	10.71	541.56
Gabbro	1997	Spring	2	.6340	23	21.73	567.48
Joseph	1998	Spring	4	.3645	36	16.79	573.03
	1999	Spring	4	.4027	33	16.24	546.88
Lobstick	1997	Spring	2	.3571	22	22.05	761.55
	1998	Spring	3	.4483	24	17.72	652.83
	1999	Spring	2	.6606	28	16.27	669.32
	2000	Spring	3	.9321	56	--	633.16
	2000	Fall	2	.8103	27	--	605.70
	2001	Fall	3	.3835	24	10.33	601.54
Sandgirt	1997	Spring	2	.0972	14	11.57	542.79
	1998	Spring	2	.1458	7	14.83	564.71
	1999	Spring	2	.5605	26	13.44	536.77
Shabogamo	2000	Spring	3	.8553	33		617.24
	2000	Fall	2	.3987	16	--	624.75
Winokapou	1997	Spring	2	.4193	21	16.00	530.67
Atikonak	1999	Fall	--	--	72	16.76	538.50
Panchia	1999	Fall	--	--	67	17.56	581.00

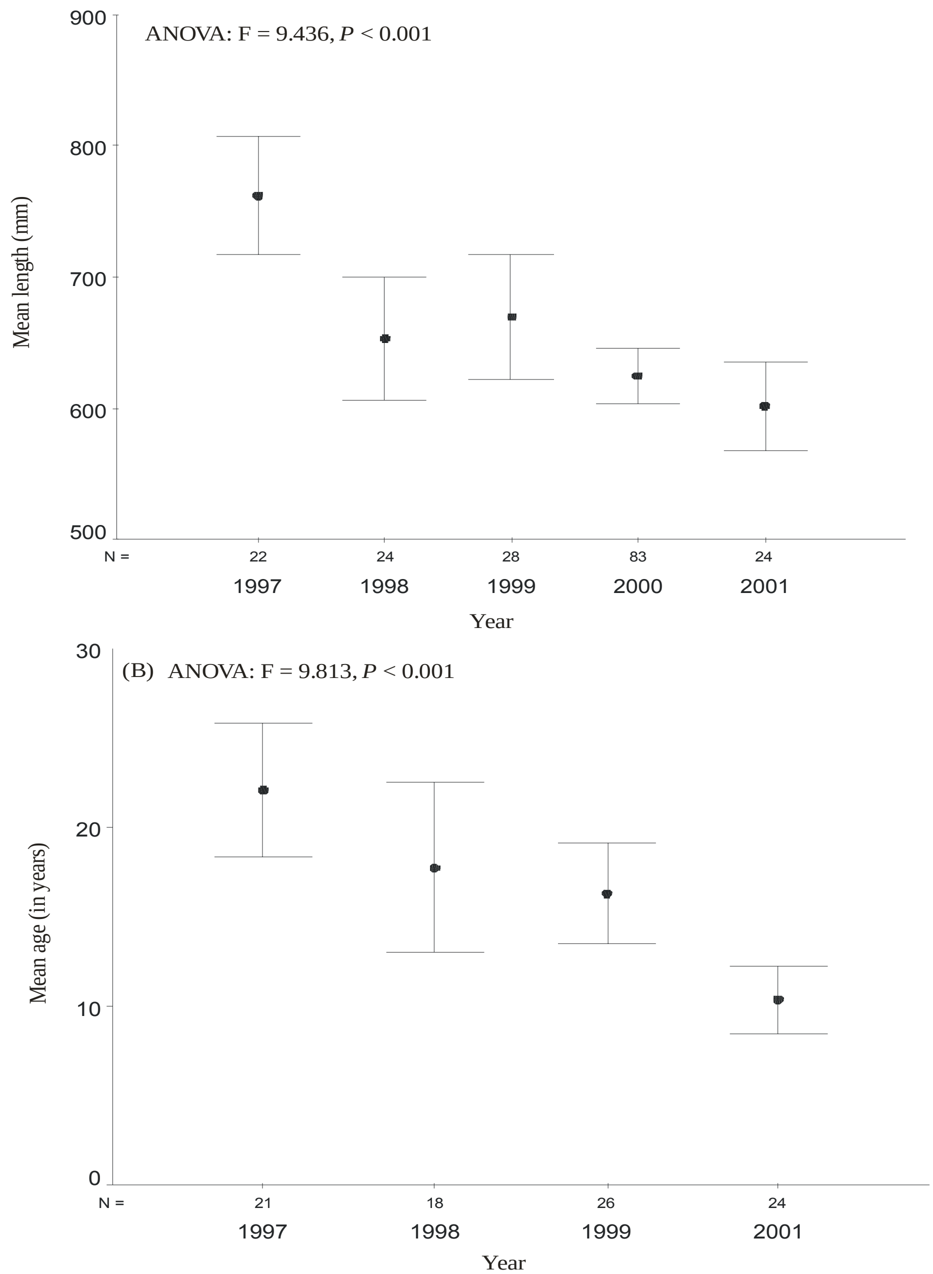

Figure 7. The relationships among years for lake trout mean (A) length and (B) age sampled from randomized gill nets. Bars represent the 95% confidence intervals around the yearly means. N represents sample size.

Growth, sexual maturity and fecundity

In accordance with the maturity graphs the zone of maturation begins at 48 cm and ends at 60 cm (Fig. 8). After 60 cm, the majority of the fish were identified as being mature. This same zone was observed in the fall collections (Fig. 8). The approximate age distribution for fish in this zone falls between 8 and 13 years of age. The pooled growth relationship for lake trout sampled from all lakes demonstrated a significant relationship with minimal data spread ($F = 6628.36$, $DF = 495$, $P < .0001$, $r^2 = 0.931$) (Fig. 9).

Using a power function, 14 ripe females were plotted for the estimate of fecundity at body length (Fig. 9). Using the resulting equation fecundity was calculated for size at 100 mm intervals for mature lake trout (Fig. 9).

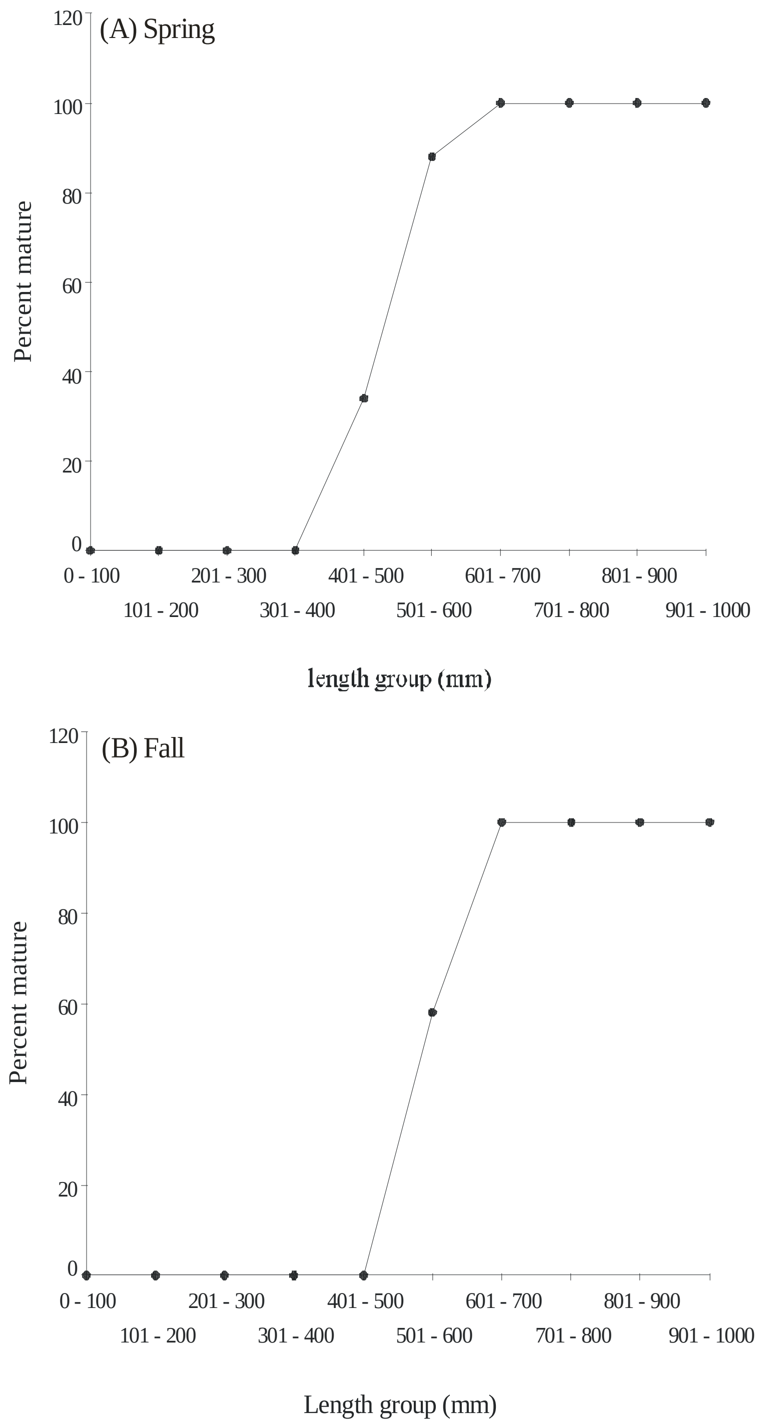

Figure 8. The percent of mature lake trout within each length group for the spring and fall collections. (A) Spring (B) Fall.

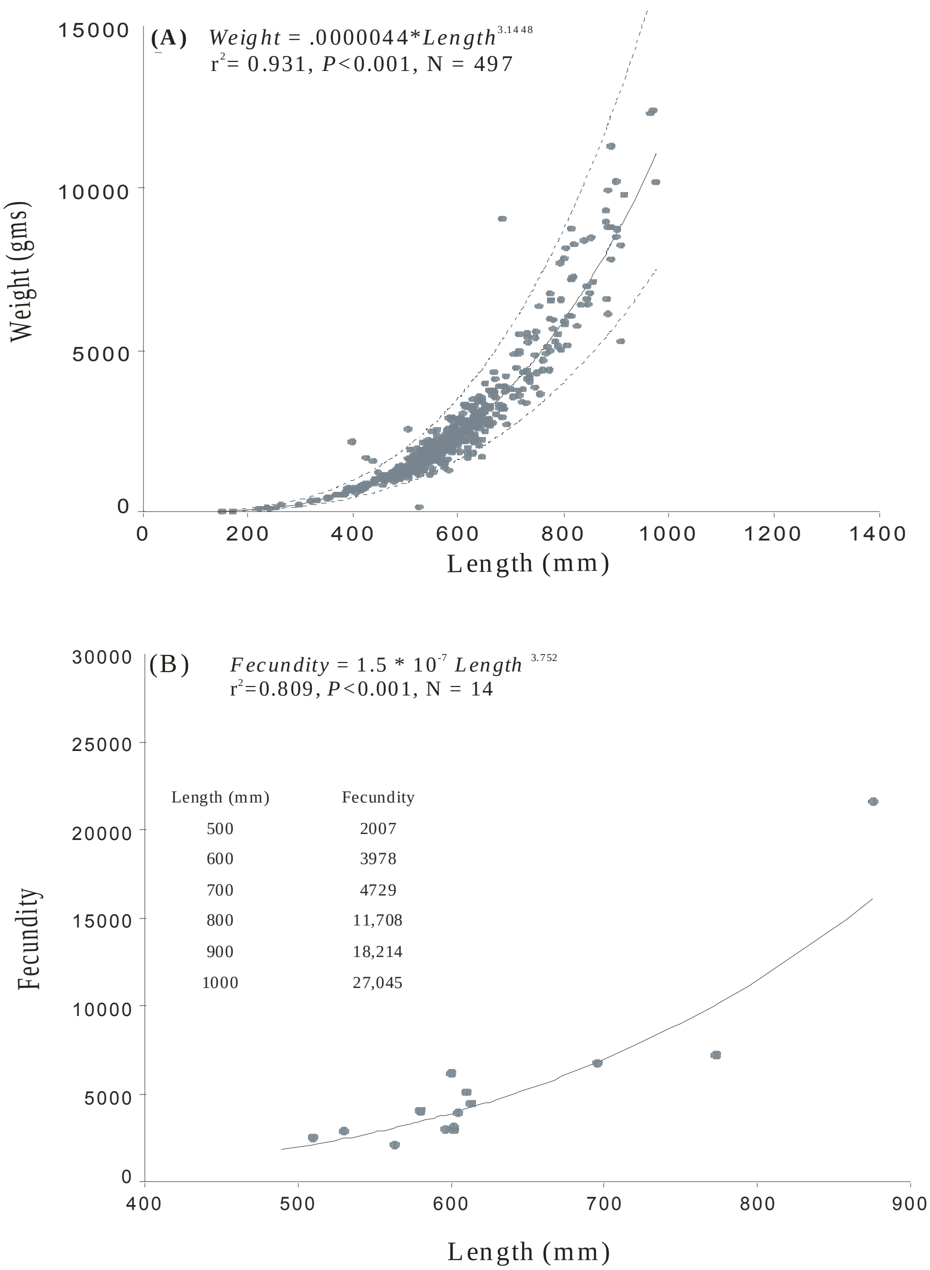

Figure 9. (A) The generalized weight vs length relationship (power function) for lake trout of the Churchill Drainage Basin. Hatched lines indicate the 95% confidence intervals. (B) The generalized relationship between length and fecundity for fecund lake trout sampled at Lobstick and Shabogamo Lake. Inserted table indicates the potential number of eggs produced by a female for a specified body length.

DISCUSSION

The bag and possession limits do not appear to be protecting lake trout populations exposed to current angling pressures. During the ten years this fishery has been monitored both the mean size and age of lake trout has declined. This decline indicates a shift where greater pressure is being exerted by anglers on immature fish.

The fitting of normal distributions to the anglers catch in 1997 and 2002 indicates a shift in the shape of the distribution from broad and flat in 1997 to one that is sharp and steep in 2002. Everhart et al. (1976) suggest that such a change indicates a population that has shifted from one with recruitment over several age groups to one that has recruitment over just a few. This combined with the greater emphasis being placed on immature fish suggests the fishery may be under stress. Gulland (1978) indicates that over harvest of immature fish can cause future year-class abundances to be low, which can decrease future recruitment. The decline in lake trout size is consistent with the suggestion that the average length of fish will decrease in an exploited population (Rawson 1961).

The turnover age for lake trout at Lobstick has fallen from 18.57 years in 1997 to 12.7 years in 2002. The 2002 turnover age falls in the established zone of maturation, if the depletion of the mature stock continues sufficient reproductive capacity to maintain the population could be lost. The loss of reproductive capacity may be of critical importance because lake trout in northern latitudes tend to be intermittent spawners (Johnson 1972; 1973). The reduction of mature lake trout has caused recruitment decline in other studies (McDonald and Hershey 1989; Paterson 1968). The suggestion by Healy (1978) of a compensatory mechanism, where increases in fecundity occur subsequent to exploitation, does not appear to be likely in the Lobstick fishery. An increase in body size at age did not occur between 1997 and 2002 but a decrease in body condition did. Additionally, Healy's supposition assumes there are sufficient numbers of mature individuals remaining in the population or that a sufficient number of individuals can reach sexual maturity rapidly. In arctic lakes it is not possible for large numbers of lake trout to reach maturity rapidly (Johnson 1972, 1976).

Johnson's suggestion that large lake trout may play a role in the regulation of their own recruitment may be accurate (Johnson 1976). I suggest the increased presence of younger fish is due to the removal of the larger, older fish from the composition. Normally the density of younger fish would have been regulated by the presence of older fish. The older fish either eat the younger or marginalize them into sub-optimal habitat positions (Burr 1997; Johnson 1975; 1976; Martin 1955). In this instance, the removal of the older fish may have allowed for the younger fish to occupy the primary habitat. The weakened body condition may be due to a redistribution of food resources amongst the population where a larger number of smaller fish are utilizing the macro-invertebrates and bait fish upon which they depend (McDonald and Hershey 1989).

The Lake trout in Lobstick Lake tend to grow slowly, mature late and achieve large size. These life history traits are indicative of a northern piscivorous classification (Post 2004). Such a population is characterized as existing in cold, low nutrient lakes and demonstrates slow juvenile growth, large adult body size, low mortality rate and late age-at-maturity. In northern distributions this type of fishery can be considered sensitive to minimal amounts of fishing pressure (Power 1978). Paul et al. (2005) report to achieve maximum-sustainable-yield the harvest rate for lakes of this type should average 0.3 $kg \bullet ha^{-1} \bullet yr^{-1}$ (95% confidence interval between 0.2 and 0.60 $kg \bullet ha^{-1} \bullet yr^{-1}$). If we assume that this yield is applicable to Lobstick fishery then the average harvest for West Forbay of 0.376 $kg \bullet ha^{-1} \bullet yr^{-1}$, is approaching the upper range of allowable yield. This yield in combination with average effort levels seems to exceed the modeled standards that were recommended by Shuter et al. (1998). To reduce the current yield to a more appropriate level we will have to ensure that a certain percentage of the current harvest is returned to the water.

Angling effort for Lobstick averaged 1.59 angler-hours$\bullet ha^{-1} \bullet yr^{-1}$during the four years surveyed (1999 removed). Post (2004) suggests that a wide range of size based management options are available to ensure sustainable fisheries if the angling effort is below 2 angler-hours$\bullet ha^{-1} \bullet yr^{-1}$; however, results from a modeling exercise indicate that virtually no harvest will be sustainable if length limits are too low or non-existent (Post 2004). Therefore, to correct for the declining turnover rate we recommend the incorporation of a minimum size limit regulation that takes into account the size at sexual maturity for lake trout.

Minimum limits have been used to control exploitation in several instances and are typically recommended as the favored option where fish populations have low to moderate recruitment rates (Novinger 1984; Brousseau and Armstrong 1987). Typically, minimum size limits require the release of all fish below a specified limit. Theoretically, this will protect enough spawning-size fish to sustain the population and increase the mean size of harvested fish.

For the Churchill drainage basin modeled growth indicates that the majority of lake trout, regardless of lake, are maturing at the same length interval (between 48 and 60 cm)(Wildlife Division unpublished data; Appendix 1; Table A1; Fig. A1). For mature female lake trout in this size range the median length was 55cm (mean = 54.8 cm). To reduce the yield we could establish a minimum size limit that will target sexually mature fish. The size limit should fall between 57 and 60 cm (between 25 and 37 percent of the anglers' current catch, respectively). This will reduce the yield to a more appropriate level while ensuring that some lake trout can reach spawning age.

It is preferable that a larger minimum size limit is put in place. In accordance with our findings 100% of the lake trout in the Lobstick fishery reach sexual maturity by 60 cm. The incorporation of this larger size limit will ensure that at least one spawning opportunity is had by each individual in the population. The larger body size may also ensure greater fecundity which may lead to better recruitment. By adopting a larger minimum size limit you may also sustain yields over an evolutionary time scale (Conover and Munch 2002). One of the principle concerns inherent with an inadequate minimum size limit is inadvertently selecting for delayed maturation (Heino 1998). Those individuals who remain small or develop slowly will not be harvested by anglers and therefore have a greater probability of reproducing. By choosing a larger size limit that encompasses the entire zone of maturation, you ensure that all fish get an opportunity to reproduce and thereby reduce the amount of selective pressure exerted by the anglers.

Alternatively, a second option would be to choose a minimum size limit that is less restrictive on anglers. As previously stated, by choosing the 60 cm size limit you will be removing 37% of the anglers catch from retention opportunities. This could generate a level of dissatisfaction amongst anglers which may lead to a loss in compliance (Renyard and Hilborn 1986). To increase the probability for compliance, a minimum size limit of 58 cm could be put in place. This would equate to a 25% loss in retention opportunities while ensuring at least 75% of the population reaches sexual maturity before harvest.

It is evident that our findings support the need for an alteration to the current management plan for lake trout. The downward shift in lake trout size and age indicates that the current fishing effort is altering year-class structure. The turnover age has dropped from at least five years of potential reproduction down to a point within the zone of maturation. This reduction combined with reduced mean size has lead to a loss in potential recruits. If the current trend continues it is likely that the lake trout fishery for Lobstick Lake will collapse. If the reduction of this important corner stone species continues it may seriously alter both the fish assemblage and the trophic dynamics for the area.

RECOMMENDATIONS

1) Implement a 60 cm minimum size limit for the entire watershed. Growth of lake trout is very similar for all water bodies in the watershed. The limit will ensure that 100% of the lake trout reach sexual maturity before being harvested. The larger size will ensure greater fecundity and allow greater spawning opportunities for lake trout. Approximately 37% of the anglers catch will be removed from harvesting opportunities.

2) Before any management change is put in place DFO should host a series of public consultations in those communities that will be affected by the change.

3) If one of the recommended changes is adopted then a public awareness

campaign explaining how minimum size limits work should be launched. This could be a cooperative effort between Department of Fisheries and Oceans and the Provincial Government. The campaign could take the form of radio spots, brochures, school visits, and tape measures for tackle boxes and signage.

Alternate recommendation

1) Implement a 58 cm size limit for the entire watershed and reduce the possession limit to two fish (same as the daily bag limit fish.). It will ensure at least 75% of the fish will reach maturity while removing only 25% of the fish from harvesting opportunities. This may ensure greater cooperation amongst the anglers and reduce public resistance to the management change.

Note: See also Appendix 2 which provides corroborative analyses, conclusions and recommendations by Dr. Nigel Lester, Ontario Ministry of Natural Resources.

ACKNOWLEDGEMENTS

I would like to thank Conservation Officers Gary O'Brien, Chuck Porter, Mark Pritchett and Biologist Don Keefe for their logistical support in the field. I thank Nigel Lester, Robert Korver, Robert Otto and Ken Curnew for their editorial comments. Funding for this work was provided by the Wildlife Division, within the Department of Environment and Conservation, Government of Newfoundland and Labrador.

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APPENDIX 1

Table A1. The total numbers of immature and mature lake trout used in Fig. A1. Samples are sub-grouped based on the lake of origin. Samples were collected from a variety of monitoring studies by the Provincial Wildlife Division, Quebec and Labrador Hydro and the Department of Fisheries and Oceans.

Lake Name	Immature	Mature
Ashuanipi	18	56
Atikonak	57	76
Gabbro	3	19
Joseph	16	79
Lobstick	38	183
Orma	5	15
Panchia	19	41
Sandgirt	14	25
Shabogamo	32	53
Wabush	5	15
Winakapou	9	6
Total	216	568

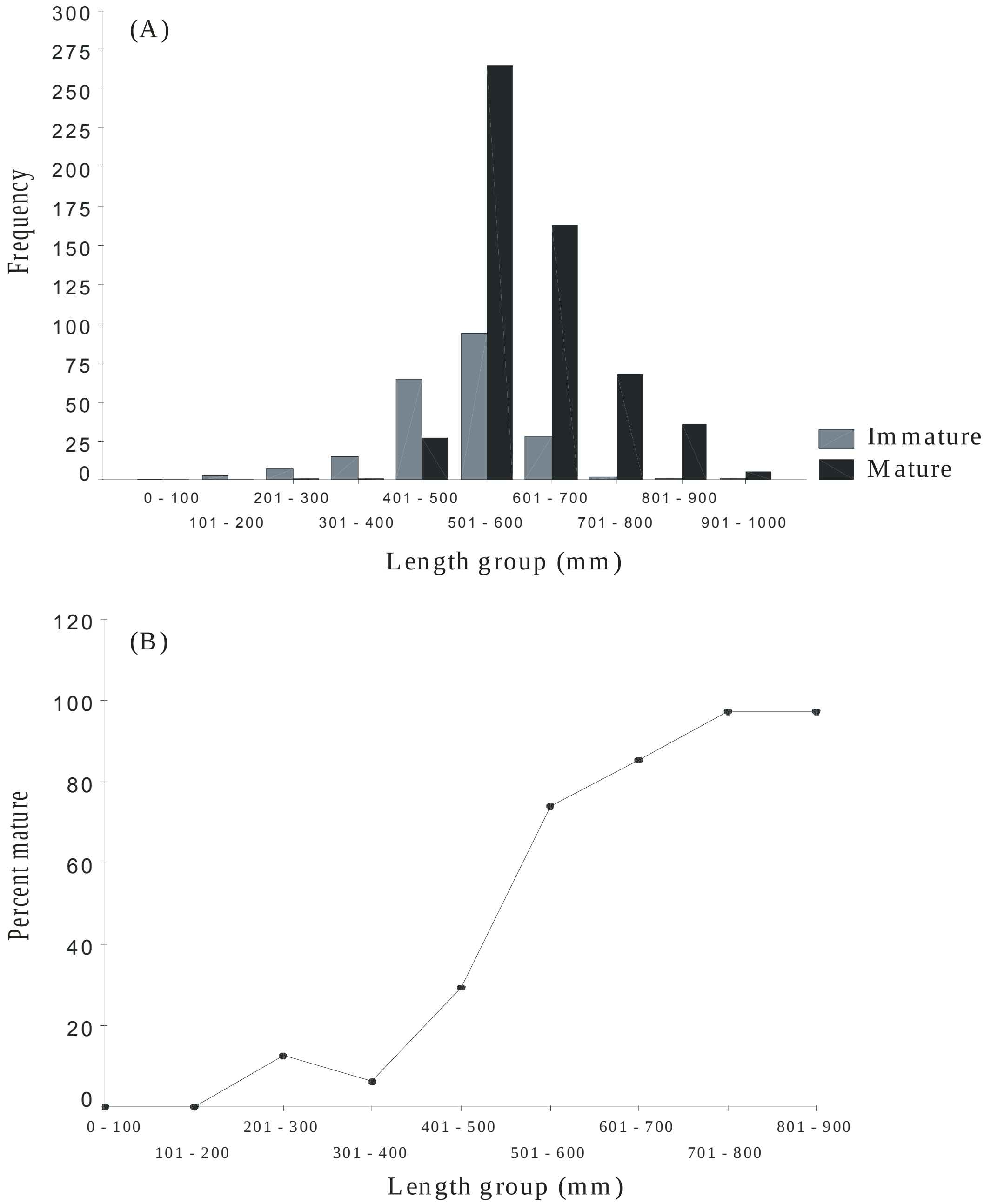

Figure A1. (A) the frequency of immature and mature lake trout in each length group. (B) Percent of mature fish in each length group.

APPENDIX 2

Comments on Perry 2006: Using harvest, growth and age to assess the efficacy of bag limits as a management option for lake trout for Labrador

From: Nigel Lester, 2006-02-10

Although I found some parts of this report confusing, I agree with the conclusions that recent harvest levels on Lobstick Lake are excessive, unlikely to be sustainable and more restrictive regulations are needed.

Lines of Evidence

1. Is current harvest level sustainable?
2. Has the population structure changed as a result of fishing?
3. Is fishing mortality too high?

1. Is Current Harvest Level Sustainable?

Table 3 indicates that lake trout yields have typically been in excess of 1kg/ha. As you point out, this yield is quite high compared to sustainable yield reported in the literature. So it seems unlikely that this high yield can be sustained.

Given that the fishery is relatively new, it is not surprising that the yield is high. The initial yield of a previously unexploited fish population will depend on the pristine biomass (i.e. biomass of lake trout when population is unexploited) and the level of fishing (i.e. fishing mortality rate). Given a constant level of fishing, biomass of the stock will decline until it reaches an equilibrium level when the density-dependent increase in recruitment compensates for increased mortality due to fishing. This density-dependent effect may be due to increased growth, earlier maturation, increased fecundity, or increased early-life survival. If none of these compensatory responses exist, an equilibrium biomass does not result and sustained fishing will drive the population to extinction. As the population biomass declines, catch rate and yield will decline. For a long-lived, late maturing species like lake trout, there may be a long time lag before the population reaches equilibrium.

The maximum sustainable yield (MSY) depends on two factors: pristine biomass (B_∞) and F_{msy} <=M. So the assumption of F_{msy} =M/2. Appealing to the Graham-Schaefer model (B_{may} = 0.5 B_∞), it follows that an upper estimate of MSY is

$$MSY = 0.5\ M\ B_\infty$$

and a more conservative estimate is:

$MSY = 0.25\ M\ B_\infty$

A rough estimate of B_∞ can be obtained from the initial yield and F:

B_∞ = Initial Yield/ F

The Chapman-Robson estimate of mortality in Panchia and Atikonak indicate natural mortality is about 0.11. This value matches the 1997 mortality rate for Lobstick – so it seems likely that exploitation was very low prior to 1997. The 2002 estimate of mortality rate in Lobstick (Z=0.18) suggests F=0.07 (i.e., 0.18 – 0.11). Given that average yield from 1997 to 2002 was 1.0 kg/ha, pristine biomass is estimated as:

$B_\infty = 1.0/0.07$

B_∞ = 14.3 kg/ha

An upper estimate of MSY is therefore

$MSY = 0.4\ M\ B_\infty$

$MSY = 0.5 \times 0.11 \times 14.3$

MSY = 0.79 kg/ha year

and a more conservative estimate is ½ this value:

MSY = 0.39 kg/ha year

So this rule of thumb approach implies MSY is in the range of 0.4 – 0.8 kg/ha year. Given that observed yield exceeds values in this range, this analysis indicates that current harvest levels are not sustainable.

This analysis is very rough because estimates of M and F are not very precise, but analysis of the effect of errors in estimating these components of mortality implies a higher estimate of M would be needed to support recent yields.

2. Has the population structure changed as a result of harvesting?

YES. You show a dramatic decline in means size and age. Such changes are expected as a result of harvesting. The alarming issue is that changes have not slowed down. Mean age has dropped almost 2-fold in the index catches and there is no indication that the rate of decline has reduced in recent years. It is probably lower now!

One important recommendation is to re-assess the age structure in 2006. Such data would provide an important benchmark for evaluating the effect of a change in regulations.

The dramatic change in mean age is worrisome! The question is whether it will stabilize given the current (and predicted) level of fishing.

3. Is Fishing mortality rate too high?

From above, one can argue an approximate estimate of fishing mortality is F = 0.07, which is close to the level of natural mortality. Given the rules of thumb (see above) one could argue that F is fairly high. One must also recognize that the recent age structure may underestimate F because older cohorts have not been exposed to the same fishing pressure throughout their lives as have younger cohorts. So their age structure is molded by many years of natural mortality and a few recent years of fishing mortality. It will be very interesting to see how age structure and estimated mortality rate have changed since the last sampling episode in 2001.

Bottom Line

I think you have lots of evidence to indicate greater protection is needed. The suggested regulation change makes sense. It's worth checking with Rick Salmon at the Lake Nipigon Fisheries Assessment Unit to see how lake trout are managed in another large, cold inland lake that supports large fish. (email: rick.salmon@mnr.gov.on.ca). A modeling exercise (i.e. FMSS) would be useful to compare the expected benefits of this regulation with other regulation changes.