Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Research Document 86/111

Comité scientifique consultatif des
pêches canadiennes dans l'Atlantique

CSCPCA Document de recherche 86/111

Overview of Lacustrine Stocking Experiments with Swim-Up and Fall-Fingerling Atlantic Salmon (*Salmo salar*) in Newfoundland

by

V. A. Pepper
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland A1C 5X1

[1] This series documents the scientific basis for fisheries management advice in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the Research Documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research Documents are produced in the official language in which they are provided to the Secretariat by the author.

[1] Cette série documente les bases scientifiques des conseils de gestion des pêches sur la côte atlantique du Canada. Comme telle, elle couvre les problèmes actuels selon les échéanciers voulus et les Documents de recherche qu'elle contient ne doivent pas être considérés comme des énoncés finals sur les sujets traités mais plutôt comme des rapports d'étape sur les études en cours.

Les Documents de recherche sont publiés dans la langue officielle utilisée par les auteurs dans le manuscrit envoyé au secrétariat.

Abstract

Published data from lacustrine stocking experiments in Newfoundland, using swim-up Atlantic salmon fry, are reviewed in the context of smolt production per unit of standing water habitat. As well, more recent data from similar experiments with fall-fingerling salmon (i.e. 90 to 100 day fed parr) are presented and results are compared with with those from the swim-up fry stocking experiments. Survival, from stocking to smoltification, suggests average survival from swim-up fry stocking in standing waters (3.5%) may be inferior to average survival from fall-fingerling stocking (10.9%). Annual smolt production from swim-up fry stocking ranged from 5 to 53•ha^{-1} (mean = 25.5 smolts•ha^{-1}). Preliminary results suggest that smolt production from fall-fingerling stocking of lacustrine habitat will exceed maximum production realized from swim-up fry stocking. Grilse returns from lacustrine smolt indicated marine survival from swim-up fry stocking of standing waters ranged from 6 to 15%. Marine survival of smolt from fall-fingerling stocking may exceed 40%. Apparent inferior marine survival of smolts, from fry as opposed to fall-fingerling stocking of lacustrine habitats, is attributed to excessive handling (i.e. marking) of smolt produced from swim-up fry stocking.

Résumé

On a passé en revue les données publiées sur des expériences d'empoissonnement de lacs à Terre-Neuve avec du saumon de l'Atlantique. La production de saumoneaux par unite d'habitat à partir d'un alevinage avec de jeunes alevins émergeants a été comparée à celle résultant d'un alevinage avec des tacons à leur premier automne (tacons d'élevage âgés de 90 à 100 jours). Les données indiquent que le taux moyen de survie depuis l'alevinage jusqu'à la transformation en saumoneaux a été supérieur suite à des alevinages avec les tacons (10,9 %) comparativement aux alevinages avec des alevins émergeants (3,5 %). La production annuelle lacustre de saumoneaux à partir d'alevins émergeants a varié de 5 à 53 • ha^{-1} (moyenne = 25,5 saumoneaux • ha^{-1}) et les résultats préliminaires suggèrent que la production à partir de tacons a surpassé le niveau maximal obtenu avec les alevins.

Les données indiquent que le taux de survie en mer c'est-à-dire les retours en eaux douces de madeleineaux par rapport aux nombres de saumoneaux ayant migré auparavant vers la mer, fut de 6 % à 15 % pour des saumoneaux originaires d'alevinages effectués avec des alevins émergeant, et pouvait dépasser 40 % pour des alevinages avec des jeunes tacons.

Cette différence entre les taux de survie en mer est attribuée à une manutention excessive (par exemple le marquage) des saumoneaux provenant d'alevinages avec des alvins émergeants.

Introduction

Atlantic salmon enhancement projects and related activities such as biobaseline studies have been ongoing in Newfoundland for the past 30 years. During the late 1960s and early 1970s, researchers involved in salmon enhancement activities, that up to that time had utilized only river habitats, began to encounter significant numbers of juvenile salmon in standing waters. Since Newfoundland has about 33% of its area taken up by fresh water (Cox 1977), much of which is confined to lakes and ponds, enhancement planners became interested in evaluating enhancement potential of these standing water areas. Studies in the mid-1970s (Pepper 1976; Pepper et al. 1985a) confirmed that significant numbers of juvenile Atlantic salmon utilized ponds with large littoral areas in which gravel, rubble, and boulder substrates predominate. On the basis of data from these studies and on surveys of shallow, rocky ponds of an obstructed tributary of Indian Brook (49°28'N, 56°27'W), a program was implemented to evaluate swim-up fry stocking to three ponds of the Indian Brook tributary (Black Brook). This study area was chosen because it was relatively accessible for study purposes and had no resident (ouananiche) or anadromous salmon population to confuse interpretation of results from stocking experiments. Using resident brook trout (Salvelinus fontinalis) population size and growth characteristics for these ponds, Pepper et al. (1984) deduced that fry stocking should be regulated to approximate $1000 \cdot ha^{-1}$. Results of the initial stocking program are reported by Pepper et al. (1985b) and are reexamined for the present manuscript, together with some preliminary results from more recent lacustrine stocking experiments with fall-fingerling (90-100 day fed juvenile) Atlantic salmon.

Methods

The first experiments with stocking swim-up Atlantic salmon fry in lacustrine habitat in Newfoundland were conducted in 1977 through 1979. Fry from a grilse stock were obtained from an artificial spawning channel at Indian Brook and were distributed by helicopter, either to stream areas immediately above lake habitat or directly to the lakes. Mark and recapture studies were conducted thereafter to determine the extent to which juvenile salmon were utilizing lacustrine habitats. Smolt were enumerated at weirs at the outlets of each of the three study areas. Most of these smolt were marked (fin clip or nose tag), as they were counted through the enumeration weirs, to allow identification of returning adult salmon.

Experiments with fall-fingerling Atlantic salmon began in Newfoundland in 1982. These experiments are part of a long-term experimental design to evaluate smolt production from swim-up fry vs. fall-fingerling stocking and of consecutive vs. non-consecutive (i.e. once every four years) stocking of standing waters. Swim-up fry from an artificial spawning channel, and more recently from deep-substrate incubators, have been reared in semi-natural enclosures (Pepper et al. in press) for 90 to 100 days, and distributed directly to two of the study ponds used in the 1977 to 1979 swim-up fry experiments. The first of the fall-fingerling distributions took place in the same year as the last of the smolt emigrations (Age 4) from the last year-class (1979) of swim-up fry stocked in these ponds.

All fall-fingerlings were marked by lateral fin removal (either right or left pelvic depending on release pond) one week prior to release around the perimeters of the two ponds. Fall-fingerling mortality was monitored for five days subsequent to marking, during which time they were held in a lake cage and were fed sporadically. Feeding was discontinued two days prior to distribution. Smolts were enumerated as described above. Only small subsamples, collected periodically throughout these smolt runs, were examined for evidence of fin clips. Parr from fall-fingerling releases were sampled only in October (i.e. at Age 1+) for evidence of precocious maturation.

Results

Results of the 1977 to 1979 experiments with swim-up fry are presented by Pepper et al. (1985b). Summary results are presented in Tables 1 and 2 (Tables 3 and 10 from Pepper et al. 1985b). Smolt runs from each of the three fry year-classes stocked had an average composition of: 48% Age 2, 47% Age 3 and 5% Age 4. On a year-class basis (i.e. $\sum_{n=2}^{4}$ # smolts of Age n), smolt production from these standing waters ranged from 5 to 53 $smolts.ha^{-1}$. Average annual smolt production from all three ponds (125 ha) over the three year-classes stocked, was 25.5 $smolts{\cdot}ha^{-1}$ (Table 3). More informative is the fact that smolt production from the first year-class stocked (1977) averaged $36{\cdot}ha^{-1}$ (all sites) whereas smolt production from the third consecutive stocking (1979) averaged only $12{\cdot}ha^{-1}$. Mark and recapture studies conducted in the lacustrine habitats of the study area between fry distribution and smolt migration indicated that juvenile salmon were in fact utilizing the lacustrine habitats to which they were distributed. Growth characteristics of parr produced from fry stocking of these standing waters are given in Table 4 (Table 7 from Pepper et al. (1985b)).

Results from fall-fingerling experiments are preliminary at the present time. To date, only three smolt runs have been enumerated. Smolts enumerated, from these fall-fingerling distributions, have had a very high rate of fin regeneration. Regeneration to the Age 2 smolt stage (1982 year-class) was 74% (117 marked smolts of 447 smolts examined). Smolt counts, though incomplete due to a fence wash out, indicate that fall-fingerling to smolt survival in the two ponds to date (unadjusted) is 7 and 13% (Table 5). The three smolt runs, that have resulted from the 1982 fall-fingerling stocking, have had 36% Age 2, 54% Age 3, and 10% Age 4 smolts. Age 2 smolts enumerated in 1984 in Traverse Pond had a mean fork length (mfl) of 160.4 mm and mean weight (mw) of 39.4 g (N=164). Upper Micmac smolts (all Age 2) in 1984 had a mfl of 145.2 mm and mw of 28.1 g (N=283). Based solely on the 1982 year-class of fall-fingerlings, smolt production from these two ponds is 53 and 81 $smolts{\cdot}ha^{-1}$ (mean production = 62 $smolts{\cdot}ha^{-1}$).

Pepper et al. (1985b), based on assumptions of commercial salmon fishery exploitation rates ranging from 55 to 62%, calculated that smolts resulting from lacustrine stocking of swim-up fry had a marine survival of 6 to 15%. At the present time, calculation of marine survival of smolts resulting from lacustrine stocking of fall-fingerlings is hampered by only two years of grilse returns that were produced from the Age 2 smolt run of 1984. While this calculation entails several assumptions (see discussion), it appears that marine survival of smolts from lacustrine stocking with fall-fingerlings could be 41 to 49%. These calculations are based on the observation that 35 of 1150 grilse brood, collected randomly from the Indian Brook spawning escapement in 1985 in support of Indian Brook/Black Brook enhancement activities, had missing pelvic fins and that fin regeneration rate to the smolt stage was 74%. I have assumed there was no further fin regeneration during marine migration.

Discussion

Results of experiments thus far serve as examples of what has been produced from stocking experiments but do not meet the requirement of a model to establish a functional relationship between juvenile salmon stocked and number of smolts produced in the variety of lacustrine habitats found in Newfoundland. A factor that mitigates against such a model at the present time is that standing waters seem to vary considerably in their production potential. This is reflected in the present study by smolt production from Upper Micmac Pond that exceeded that of Traverse Pond and supports interpretations of relative production potential of these ponds (Pepper et al. 1984) based on calculated standing stock of resident brook trout. One of the factors that appears to be a major contributor to standing water carrying capacity for juvenile salmon is water mass turnover rate as discussed in terms of zooplankton abundance by Pepper et al. (1984). On the assumption that the water mass is not stagnant, there appears to be the basis for an inverse correlation between standing water turnover rate and juvenile salmon carrying capacity, at least relative to the present study area.

Although swim-up fry stocking in this Newfoundland study area has resulted in an average smolt production of about $26 \cdot ha^{-1}$, and has ranged as high as $53 \cdot ha^{-1}$ (Table 3), there is as yet no optimal stocking level defined that will achieve lacustrine carrying capacity through a cost-effective stocking strategy. It appears also that competing juvenile salmon year-classes may impact negatively on economical attainment of lacustrine carrying capacity since fry to smolt survival decreased over successive year-classes (Table 1). Another factor that may determine potential smolt production from lacustrine enhancement projects is the size of the juvenile salmon stocked. Preliminary data from fall-fingerling stocking have indicated that an average smolt production of $62 \cdot ha^{-1}$ from standing waters is a reasonable aspiration from an average stocking level of 667 fall-fingerlings$\cdot ha^{-1}$. The present limited data suggest that there are freshwater production advantages to lacustrine stocking with fall-fingerlings as opposed to swim-up fry (mean production = 26 smolts$\cdot ha^{-1}$). Age composition of smolt runs from standing waters suggests little difference between stocking with swim-up fry as opposed to fall-fingerlings. However, comparison of smolt age distribution from these ponds, with those of Indian Brook, suggests that standing waters may yield an earlier return on investment (i.e. in terms of smolt production per unit of brood stock). Historical data on the Indian Brook, Atlantic salmon stock (Pond 1971) indicate a smolt age composition of 20-30% Age 2 and 68-79% Age 3. The Age 4 component often has exceeded 15% from Indian Brook habitats. It appears that lacustrine nursery areas have an enhanced Age 2 component relative to those from the riverine habitats of Indian Brook, especially when one considers that the grilse stock of Indian Brook was the source of young salmon for the lacustrine stocking experiments described in this manuscript.

At face value, the 35 marked grilse of the 1985 complement of brood salmon used for enhancement purposes at Indian Brook (N=1150 of the 2420 spawning escapement to Indian Brook) represent 3.04% of that brood population. However, considering the fact that only 26.17% of the 1984 smolt population had retained the marks applied shortly before release, the 1985 brood stock may have contained up to 134 grilse (i.e. 35/0.2617) or 11.65% (i.e. 134/1150) from lacustrine origin smolt stocked as fingerlings. With a total spawning escapement to Indian Brook in 1985 of 2420 (i.e. fishway count of 2020 + 400 spawners that circumnavigated the fishway in late summer), grilse from lacustrine origin smolt may account for 282 spawners (i.e. 2420 X 0.1165). Assuming a standard recreational harvest pressure of 25%, as per Pepper et al. 1985b, and a commercial exploitation rate of 55% (Pippy 1982), a spawning escapement of 33.75% (i.e. 0.45 X 0.75) of the adult production would suggest an adult grilse population before exploitation of 836 (i.e. 282/0.3375). As an example of the "sensitivity" of these calculations to commercial exploitation rate, a commercial harvest of 62% (Reddin 1981), indicates grilse production from lacustrine origin smolts may have been 989 (i.e. 282/(0.38 X 0.75)). Though nebulous, these calculations suggest that marine survival of smolt from fall-fingerling stocking of standing waters may have approached 41% (i.e. 836 grilse/2031 Age 2 smolts) to 49% (i.e. 989 grilse/2031 Age 2 smolts). Considering that these calculations are the same as those of Pepper et al. (1985b), it is likely that a marine survival for smolts from lacustrine stocking of fall-fingerlings (41 to 49%) has been greater than for smolts from lacustrine stocking with swim-up fry (6 to 15%; Pepper et al. 1985b). However, since smolts from the 1977 to 1979 fry stocking experiments were handled much more than those in 1984, it is expected that marine survival from the first experiments was eroded greatly by application of marks and tags during smolt enumeration rather than at the time of lacustrine stocking as was done with the fall-fingerlings.

Data of Tables 1 (fry stocking) and 5 (fall-fingerling stocking) suggest advantages to lacustrine stocking with the larger juveniles. This is supported further by the fact that smolt counts of Table 5 are incomplete, and by the timing of fall-fingerling stocking relative to the earlier fry stocking experiments. The last smolt emigration from fry stocking in these ponds took place approximately three months prior to the stocking schedule of Table 5 and suggests the possibility that potential food supply for fingerlings in these ponds may not have recovered to the pre-stocking level of 1977. However, assuming that diet preference of fall-fingerlings would be directed to smaller prey items than for Age 4 smolt that emigrated earlier that year, carrying capacity of these lacustrine habitats should not be adversely affected by fry stocking prior to the fall-fingerling experiments. This being the case, it is curious that Age 2 smolt from Traverse Pond in 1984 were larger on average (mfl=160.4 mm, mw=39.4 g) than those produced from fry stocking (mfl=153.7 mm, mw=37.9 g) while those from Upper Micmac in 1984 (mfl=145.2 mm, mw=28.1 g) were smaller than those produced from fry stocking (mfl=158.7 mm, mw=42.0 g). It appears that the higher stocking level in the Upper Micmac fall-fingerling experiments (i.e. average of 413 fry•ha^{-1} in 1977 to 1979 vs. 552 fall-fingerlings•ha^{-1} in 1982) may have resulted in a density dependent depression in growth rate. Further discussion of the significance of these concerns will have to await completion of the present cycle of fall-fingerling experiments.

Results of lacustrine stocking experiments conducted in Newfoundland indicate that standing water areas can serve as good nursery areas for juvenile Atlantic salmon. It is likely, considering the abundance of shallow and rocky ponds in Newfoundland, that these habitats can yield significant additional salmon production if subjected to stocking strategies that will develop production potential on a cost effective basis. However, it is not likely that all standing waters will yield smolt production levels comparable with those of the present study ponds. Lacustrine community structure and population dynamics are likely to play a significant role in determining juvenile Atlantic salmon carrying capacity. In the presence of a wider range of predator and competitor species than is found in Newfoundland's relatively simplistic lacustrine community structures, lacustrine waters may not offer as attractive a nursery environment for juvenile salmon as has been the case in the present Newfoundland experiments. A greater diversity of lacustrine habitats and species communities will have to be examined before holistic evaluations of juvenile salmon carrying capacity will be possible for this kind of fresh water environment. Newfoundland salmon enhancement experiments with lacustrine habitats have provided encouragement that these habitats can have significant Atlantic salmon production potential and can serve as a foundation from which to continue research on enhancement strategies for standing waters.

References

Cox, K. 1977. Sportfishing in Newfoundland. A Survey of anglers. Fisheries and Marine Service. FS-99-11/1977. 61 p.

Pepper, V.A. 1976. Lacustrine nursery areas for Atlantic salmon in insular Newfoundland. Environment Canada, Fisheries and Marine Service, Technical Report No. 671, 61 p.

Pepper, V.A., T. Nicholls and N.P. Oliver. In press. Seminatural rearing of Atlantic salmon (*Salmo salar*) in Newfoundland. Can. J. Fish. Aquat. Sci. 44.

Pepper, V.A., N.P. Oliver and R. Blundon. 1984. Lake surveys and biological potential for natural lacustrine rearing of juvenile Atlantic salmon (*Salmo salar*) in Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1295: iv +72 p.

Pepper, V.A., N.P. Oliver and R. Blundon. 1985a. Juvenile anadromous Atlantic salmon of three lakes of Newfoundland. Int. Rev ges. Hydrobiol. 70: 733-753.

Pepper, V.A., N.P. Oliver and R. Blundon. 1985b. Evaluation of an experiment in lacustrine rearing of juvenile anadromous Atlantic salmon. N. A. J. Fish. Mgmt. 5: 507-525.

Pippy, J. (Chairman). 1982. Report of the working group on the interception of mainland salmon in Newfoundland. Can. MS Rep. Fish. Aquat. Sci. 1654: x + 196 p.

Pond, S.G. 1971. A review of the Indian River project 1963-68. Resource Development Branch, Prog. Rept. No. 70, St. John's, Nfld. 56 p.

Reddin, D.G. 1981. Estimation of fishing mortality for Atlantic salmon (Salmo salar) in Newfoundland and Labrador commercial fisheries. ICES, C.M. 1981/M:24.

Table 1. Fry and smolt counts for three year-classes (1977, 1978, and 1979) of Atlantic salmon planted at three sites (from Pepper et al. 1985b, Table 3).

Location	Year	Fry stocked	Smolt counts Age 2	Age 3	Age 4		Fry:smolt survival (%)[a]
Traverse	1977	58,618					
	1978	65,248					
	1979	59,000	733				4.1
	1980		148	1333			1.5
	1981		379	772	306		0.9
	1982			167	34		
Aggregate		182,866				3872	2.1
Upper Micmac	1977	6,234					
	1978	17,451					
	1979	16,000	749				19.0
	1980		857	403			9.7
	1981		290	716	31		4.8
	1982			477	112		
Aggregate		39,685				3635	9.2
Lower Micmac	1977	10,878					
	1978	20,264					
	1979	21,000	766				8.4
	1980		616	126			5.0
	1981		60	382	18		1.2
	1982			192	6		
Aggregate		52,142				2168	4.2

[a]Approximate year-class survival based on calculated age distribution of smolt runs. Calculated as: $[(\sum_{n=2}^{4} \#\text{ smolts age } n)/\sum_{i=1}^{3} \#\text{ fry stocked year } i) \times 100]$.

Table 2. Smolt fork length and weight by age group (from Pepper et al. 1985b, Table 10).

		Age					
		2+		3+		4+	
Pond	Year	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
Traverse	1979	146.3	34.5				
	1980	157.4	42.8	164.7	46.9		
	1981	159.5	39.9	158.4	43.9	165.7	56.3
	1982			169.4	54.4	170.1	55.0
	All years	153.7	37.9	162.2	48.5	167.4	55.8
Upper Micmac	1979	156.1	41.1				
	1980	164.7	44.5	179.0	54.3		
	1981	159.2	44.5	185.1	65.6	201.2	93.6
	1982			179.5	54.7	181.0	58.0
	All years	158.7	42.0	182.7	61.0	193.6	80.3
Lower Micmac	1979	154.6	36.1				
	1980	147.0	29.0				
	1981	150.9	32.3	158.8	41.7	157.5	40.8
	1982			168.0	46.8	169.0	47.4
	All years	153.2	34.6	165.4	45.4	164.1	44.6
	Averages	154.9	38.1	169.7	51.2	169.3	56.3

Table 3. Lacustrine smolt productions from Atlantic salmon stocking experiments in Newfoundland

Fry year-class stocked	Smolt counts (by year-class) for Traverse Pond (66 HA)	Upper Micmac (32 HA)	Lower Micmac (27 HA)	Total smolt	Average smolt ($\cdot pond^{-1}$)
1977	2379 (36.1)[a]	1183 (37.0)	910 (33.7)	4472	1490 (35.8)
1978	954 (14.5)	1685 (52.7)	1004 (37.2)	3643	1214 (29.1)
1979	546 (8.3)	767 (24.0)	144 (5.3)	1457	486 (11.7)
Totals	3879	3635	2058	9572	
Averages	1293 (19.6)	1212 (37.9)	686 (25.4)	3191	1064 (25.5)[b]

[a]Numbers in brackets represent smolt$\cdot ha^{-1}$

[b]9572 smolts/3 years/125 ha.

Table 4. Growth of juvenile Atlantic salmon stocked as fry in three lakes (from Pepper et al. 1985b, Table 7).

		0+			1+			2+		
Location	Year	Mean fork length	Days at large	Mean daily G(%)	Mean fork length	Days at large	Mean daily G(%)	Mean fork length	Days at large	Mean daily G(%)
Traverse	1978	5.3	61	1.25	11.2	435	0.35	Not applicable		
	1979	5.4	66	1.19	11.3	422	0.36	13.8	787	0.22
	1980	Not applicable			11.6	413	0.37	14.7	778	0.23
Upper Micmac	1978	5.7	61	1.37	12.0	535	0.36	Not applicable		
	1979	7.6	71	1.58	11.9	439	0.36	14.6	780	0.23
	1980	Not applicable			10.2	424	0.33	13.9	782	0.22
Lower Micmac	1978	-	-	-	11.8	435	0.36	Not applicable		
	1979	-	-	-						
	1980	Not applicable			11.5	428	0.36	15.1	781	0.23

Table 5. Fall-fingerling and smolt counts from lacustrine stocking experiments in Newfoundland

Location	Year	Fall-fingerlings stocked	Smolt counts	Fingerling to oldest smolt survival
Traverse	1982	47723		
	1983			
	1984		893 (all 2+)	
	1985		2527 (all 3+)	7.2
	1986		75 (all 4+)	
Upper Micmac	1982	17651		
	1983	30269		
	1984	30013[a]	1168 (all 2+)	
	1985		1466[b] (519-2+) (947-3+)	12.9[c]
	1986		3832 (279-2+) (3065-3+) (488-4+)	

[a]Corresponding smolt emigrations expected in 1986 through 1988. Not included in survival calculation.

[b]Partial count due to flooding.

[c]Based on all but Age 4 smolt (due in 1987) from 1982 and 1983 stocking.