Reprinted from *J. Fish Biol.* (1981) **19**, 637–651

Experimental sea ranching of brook trout, *Salvelinus fontinalis* Mitchill

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(*Received 9 March 1981, Accepted 15 April 1981*)

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An experiment to induce anadromy in a population of wild brook trout, *Salvelinus fontinalis*, was conducted near Sept-Iles, Quebec, in 1978–1979. Brook trout were captured from the Matamek River, tagged and transported to the Matamek River estuary during late spring and early summer, and allowed free movement between an impassable waterfall 0·7 km upstream and the sea. Fish were recaptured in autumn as they returned to fresh water. Over two years, 34·0% of the released fish were recaptured. Best returns were in the 2+ and 3+ age classes with 38·0 and 62·1% recaptured, respectively. Straying of transplanted fish appeared to be < 1%. All age classes included sea run brook trout (sea trout) but the largest percentages of sea trout occurred in older fish. Growth was better in sea trout than in fish which did not develop anadromy, presumably a function of an increased food supply at sea. Severe tagging effects stunted growth and probably suppressed anadromy, especially among younger fish. Sexual characteristics of recaptured fish indicated suppressed maturation of gonads in sea trout compared to fish remaining in fresh water and there was a shift to a larger percentage of females in the sea trout. Comparisons between our results and data on other anadromous *Salvelinus* species underscore the potential for sea-ranching of trout and char as a moderate effort, high yield aquaculture technique.

I. INTRODUCTION

Brook trout, *Salvelinus fontinalis*, range throughout eastern North America, have been introduced throughout the world (MacCrimmon & Campbell, 1969), and can use a variety of resources and habitats (Power, 1980; McGlade & MacCrimmon, 1979). Throughout maritime Canada and the northeastern United States, rivers with free access to the sea often have natural runs of anadromous brook trout (White, 1940; Wilder, 1952; Scott & Crossman, 1964). Additionally, brook trout reared in hatcheries from non-anadromous parents can generate sea trout runs when stocked in rivers with free access to the ocean (P. Brezoski, pers. comm.). It is clear that most brook trout have the potential for anadromy, although evidence for the genetic basis of sea running is equivocal (Wilder, 1952; Smith & Saunders, 1958).

Previous studies indicated a small population of sea trout occurred naturally in the Matamek River estuary, but an impassable waterfall 0·7 km upstream and a lack of suitable spawning sites below the falls precluded successful reproduction by these fish (Haedrich, 1975). Recruitment to the sea trout population probably occurred as spillage from above the waterfall. Limited data suggested that sea trout in the estuary had better growth rates and condition factors than river fish of comparable ages, indicating that the Matamek River estuary was a favourable habitat for these fish. Marine food resources appeared readily available;

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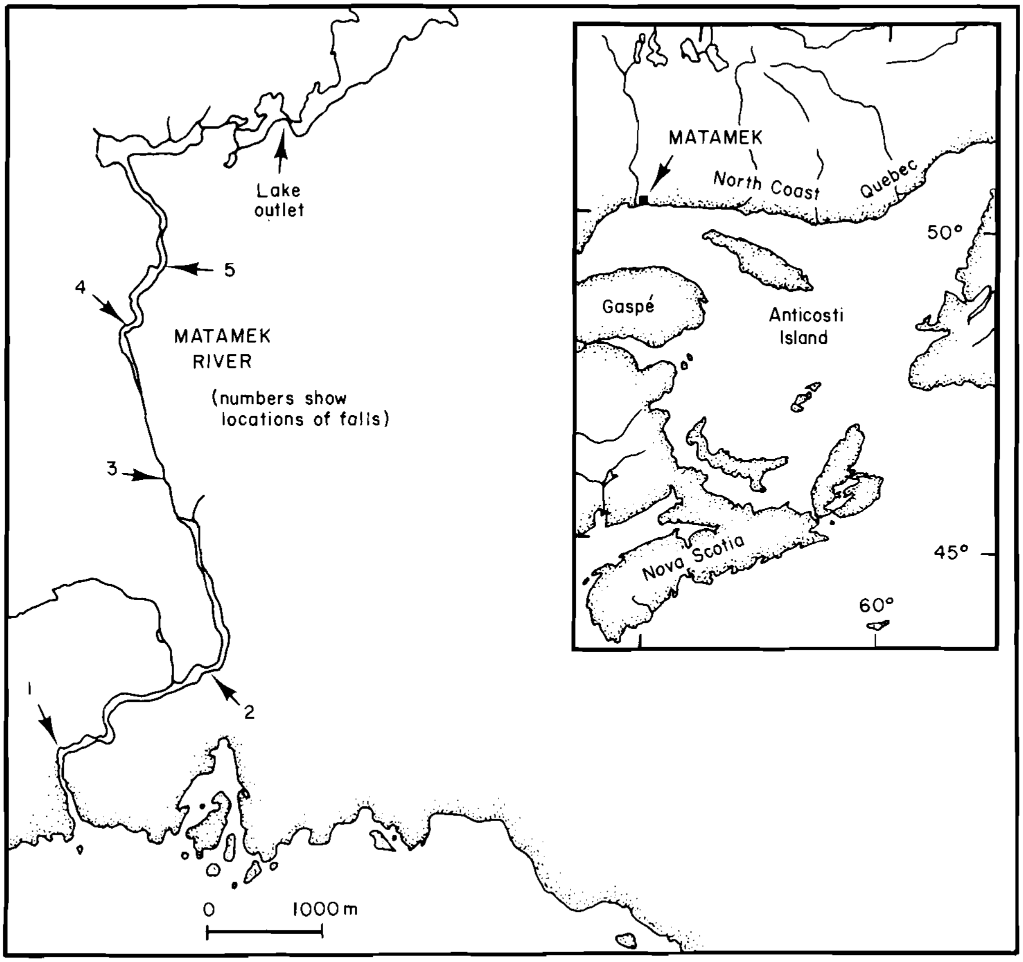

FIG. 1. The Matamek River is located about 25 km east of Sept Iles, Quebec, on the North Shore of the St Lawrence River. Fish were released in the estuary at an embayment at the mouth of the Matamek river, approximately 75 m from the Gulf of St Lawrence.

amphipods, mysids and sand launce (*Ammodytes* spp.) were abundant from June to October (Gibson & Whoriskey, 1980).

Based on these observations, the objective was to explore the possibility of significantly enhancing salmonid production in the Matamek River system through the artificial induction of a sea run population in the estuary, an area underutilized by salmonids. During the course of the study we examined survival, growth, feeding habits, movements, sexual characters, recoveries and potential predators of transplanted fish. Preliminary results from the first year are presented elsewhere (Gibson & Whoriskey, 1980). Here we present results from the second year and give an overview of the experiment. Results were promising as there were high returns and good growth rates for sea-run fish, but it is clear that techniques used in this study need refinement before expansion to a larger scale can be achieved.

II. MATERIALS AND METHODS

The Matamek River, a sixth order stream draining 684 km^2, is located near Sept Iles, Quebec, on the North shore of the Gulf of St Lawrence (Fig. 1). Mean annual discharge is 21·8 $m^3 s^{-1}$, with a range from 113 $m^3 s^{-1}$ during spring freshets to a winter low of about 2 $m^3 s^{-1}$. The water contains considerable dissolved humic material (10–15 mg $C \cdot l^{-1}$), with a pH ranging from 4·9–5·5. Benthic metabolism is low but is higher than several other rivers in the region (Naiman, unpubl.).

The lower section of the Matamek River exits from Matamek Lake (16·2 km^2 surface area) and flows 9·6 km to the sea, passing over five waterfalls. Our study areas were located in the section of river from the estuary to the first waterfall (1st Falls) and at the base of the second waterfall (2nd Falls).

The section from the 1st Falls to the estuary broadens into a small bay before running into the Gulf of St Lawrence. Salinities in the lower reaches of the estuary typically approach 33‰. Tidal influence and a salt water wedge can occur to a distance of 0·6 km upstream depending on tidal fluctuations and river discharge.

Wild trout were captured at the base of the 2nd Falls from 22 May to 23 July 1979 with fyke nets, beach seines, or by angling with artificial flies. Gibson *et al.* (1978) described the population structure of the brook trout in this area for the period 1974–1977. Captured trout were placed in a transport tank and driven to the estuary for tagging, usually within an hour of capture. Some trout were caught during Atlantic salmon, *Salmo salar*, smolt tagging studies and during the operation of a fishladder at the 1st Falls. Most fish had brook trout morphology (e.g. characteristic riverine coloration) but several were obvious sea trout when captured (e.g. silver sheen, robust, pink flesh).

Fish were anesthetized with MS 222, weighed, measured for fork length (F.L.), checked for identifying marks and tagged or fin-clipped. Tags used were based on the size of the individual since small fish (< 10 cm) could not withstand the rigours of tagging. Fish with F.L. > 12·5 cm were given serially numbered, 2·5 cm Floy anchor tags; fish 10·0–12·4 cm received serially numbered Carlin tags; fish < 10·0 cm received left ventral and adipose (LVAD) fin clips. After tagging, fish were allowed to recover in a holding pen before being released in an area with fresh water, low current and a temperature within 1° C of the site where captured.

Every attempt was made to minimize stress on fish during transplantation; consequently, no scales were removed at the time of planting. An approximation of age was made using length-frequency relationships determined for the 2nd Falls population in previous years (Gibson *et al.*, 1978; Gibson & Whoriskey, 1980). Size groups for age determinations in June releases were: 10·0–12·4 cm (1+ age class), 12·5–17·4 cm (2+), 17·5–22·5 cm (3+) and > 22·5 cm (4+ and older). Size groups for July releases were altered slightly to consider growth during June. Groups were: 10·0–13·4 cm (1+), 13·5–17·4 cm (2+), 17·5–22·5 cm (3+) and > 22·5 (4+ and older). Transplanting of fish ended in late July. Fish were recaptured, beginning in late August, by angling, seining, gill netting and trapping at the 1st Falls. Sea trout caught in fresh water were assumed to have recently returned there because of the high incidence of marine organisms in their stomachs. Date of recapture, F.L., weight, sex and state of maturity were noted; a scale sample was taken for age analysis. Stomach contents were preserved in 70% ethanol, sorted, identified to taxonomic order and the volume of each category determined by displacement in water. At the time of sampling, fish were classed as sea trout or river fish depending on the development of morphological changes associated with migrations to salt water (Wilder, 1952). The most evident changes were the loss of riverine coloration and development of a silver sheen, but other characteristics included large body to head proportions and the larger size associated with sea trout.

Growth was calculated as total percentage increase in body weight from release to recapture, and as percentage increase in body weight per day. Exact values for growth and number of days at liberty for fish marked with fin clips are not known. Growth for these fish was calculated as the difference between mean size of fin clipped fish recovered in autumn and mean size of fish released in spring. Time at liberty was calculated as the difference between date of recapture and date of release.

III. RESULTS

RECAPTURE

Of 821 fish released in 1979, 324 were recaptured for a total return of 39·5% (Table I). An additional 30 fish of the 931 released in 1978 overwintered below the 1st Falls and were recaptured in 1979, boosting the 1978 return from 29·2 to 32·4%. The strongest returns occurred in the 2+ and 3+ age classes with averages for the two years of 38·0 and 62·1%, respectively. The 1+ and ⩾4+ aged fish for the two years combined had returns averaging only 14·1 and 15·8%, respectively.

In 1978, only 7·7% of the total number of fish released returned as sea trout and, in 1979, only 4·5% of the original fish returned as sea trout. During the study sea trout were taken in all age classes but older age classes contained a larger percentage (Table I). Sea trout recaptured over the two years averaged 4·2, 14·9, 23·9 and 66·6% of the total number of fish recaptured in the 1+, 2+, 3+ and ⩾4+ age classes, respectively.

TABLE I. Summary of trout released and returned in 1978 and 1979 by age class. Data for 1978 from Gibson and Whoriskey (1980). The term 'all trout' refers to the total number of fish, regardless of their ultimate development into river fish or sea trout

Age	All trout						Sea trout			
	Released		Recovered		% Recovered		Recovered		% of total Recovered	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
1+	190	320	10	62	5·3	19·3	0	3	0	3
2+	451	309	139	150	30·8	48·5	22	21	15·8	14·0
3+	193	150	107	106	55·4	70·7	38	13	35·5	12·3
⩾4+	97	42	16	6	16·5	14·3	12	0	75·0	0
Total	931	821	272	324	29·2	39·5	72	37	26·5	11·4

GROWTH

Although the mean number of days at liberty was similar for sea trout and river fish (Table II), growth rates for all age classes of sea trout were >4 times that of brook trout remaining in the river (Table III, Fig. 2), and sea run fish had higher condition factors than river fish of comparable age (Table IV). In every case sea trout added significant amounts of weight during their two to three months at sea with daily growth rates of 0·8–3·5%, depending on the age and year. Fish choosing to remain in the river either had slight weight increases or lost weight over the summer. Maximum daily growth rates for river fish were only about 0·4% and some age classes had negative growth rates. Additionally, growth of tagged river fish was poor in comparison with undisturbed populations of brook trout in the Matamek River, possibly as a result of the tagging (Fig. 2).

SEXUAL CHARACTERISTICS

In contrast with river fish, returns of sea trout were dominated by females. The 2+ age class in 1978 and 1979 had F : M ratios of 1·00 and 2·17, respectively

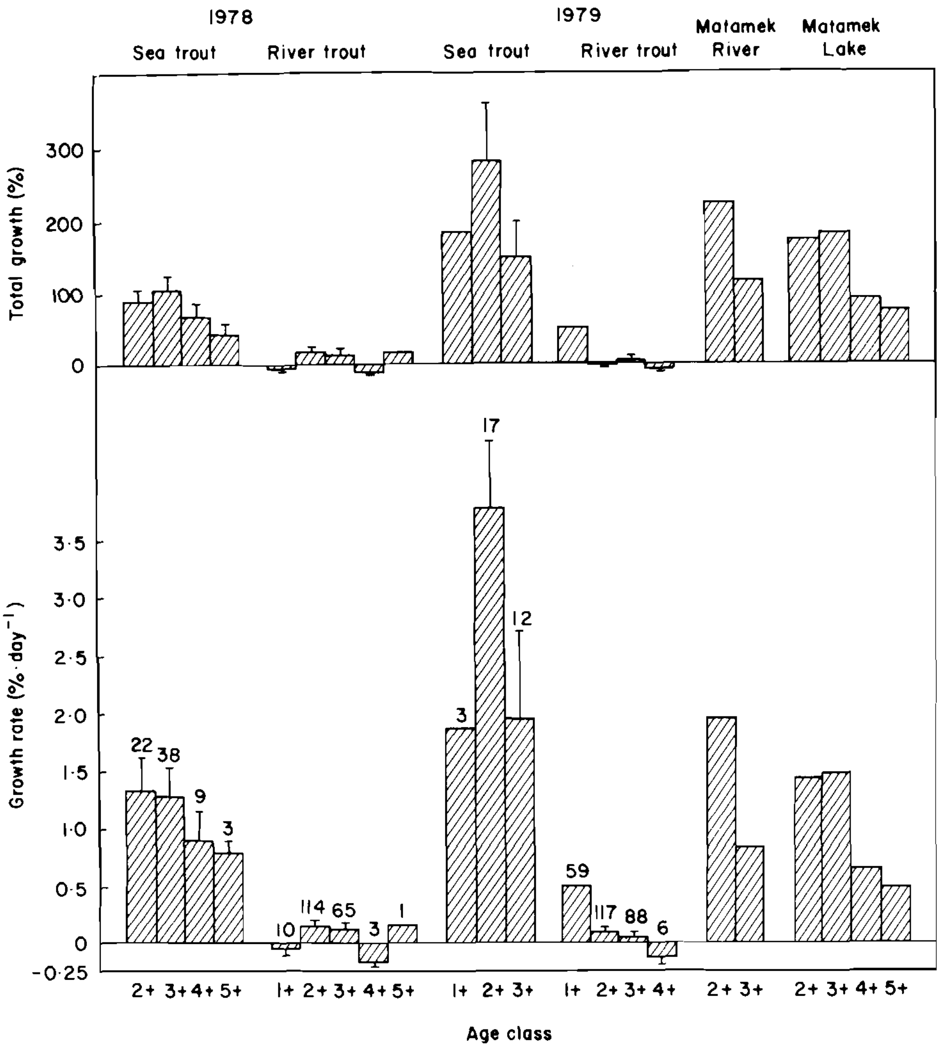

FIG. 2. Total growth, percentage increase of body weight and mean daily growth rate, are shown by age group for tagged sea trout and river trout for 1978 and 1979. Growth of untagged brook trout from Matamek Lake and the 3rd Falls area of the Matamek River are given for comparison. The 1978 sea trout data are calculated from Gibson & Whoriskey (1980); Matamek Lake and Matamek River data are from Gibson (1973) and Saunders & Power (1970). Vertical lines above bars represent S.E. and numbers the sample size.

TABLE II. Mean days at liberty for river and sea trout. Data for 1978 from Gibson & Whoriskey (1980)

Age	River fish 1978 $\bar{x}$	S.E.	n	River fish 1979 $\bar{x}$	S.E.	n	Sea trout 1978 $\bar{x}$	S.E.	n	Sea trout 1979 $\bar{x}$	S.E.	n
1+	67	3	10	98	–	59				94		3
2+	76	2	118	86	2	117	73	4	22	79	4	17
3+	73	2	65	76	2	88	79	3	33	81	5	12
4+	63	3	3	71	10	6	76	6	9			
5+	83	–	1				88	9	3			

TABLE III. Initial and final wet weight ($\bar{x} \pm$ S.E.) and net change in weight (g) of sea trout and river fish are given by age group. Data for 1978 from Gibson & Whoriskey (1980)

	Sea trout								
	1978				1979				
Age	Sample size (n)	Release wt. (g)	Recapture wt. (g)	%	Sample size (n)	Release wt. (g)	Recapture wt. (g)	%
1+	0				*	9·3 ± 0·3	26·0 ± 1·6	16·7
2+	23	39·0 ± 3·0	65·5 ± 3·7	26·5	20	25·4 ± 2·0	86·3 ± 15·1	60·9
3+	38	75·5 ± 9·9	126·3 ± 12·0	50·8	13	72·0 ± 14·5	106·6 ± 8·6	34·6
≥4+	12	157·0 ± 32·0	227·4 ± 38·0	70·4	0			
	River fish								
	1978				1979				
Age	Sample size (n)	Release wt. (g)	Recapture wt. (g)	%	Sample size (n)	Release wt. (g)	Recapture wt. (g)	%
1+	10	17·6 ± 2·2	17·2 ± 2·3	−0·4	59	10·8 ± 0·5	14·7 ± 0·5	3·9
2+	116	38·5 ± 1·7	41·7 ± 1·8	3·2	127	34·7 ± 1·4	36·6 ± 1·2	1·9
3+	66	83·4 ± 5·5	84·8 ± 4·7	1·4	88	88·4 ± 3·6	88·5 ± 3·3	0·1
≥4+	4	233·7 ± 22·8	220·5 ± 16·4	−13·2	6	262·7 ± 15·2	228·0 ± 16·3	−34·7

*A total of 264 fish were released but only three were recaptured as sea trout.

TABLE IV. Mean condition factors for river fish and sea trout returning in 1978 and 1979. Condition factor calculated as $(W \times 100)/L^3$. Data for 1978 from Gibson & Whoriskey (1980)

Age	1978						1979					
	River fish			Sea trout			River fish			Sea trout		
	$\bar{x}$	S.E.	*n*	$\bar{x}$	S.E.	*n*	$\bar{x}$	S.E.	*n*	$\bar{x}$	S.E.	*n*
1+	0·92	0·02	10				1·04	0·01	59	1·06	0·05	3
2+	0·95	0·01	11	0·99	0·01	20	0·99	0·01	128	1·15	0·06	20
3+	1·00	0·08	82	1·04	0·02	25	1·02	0·01	88	1·08	0·02	13
4+	1·05	0·03	3	1·12	0·03	9	1·09	0·04	6			
5+	1·16	–	1	1·04	0·02	3	1·09	–	1			

TABLE V. Sexual characteristics of recaptured sea trout, and brook trout remaining in the river for 1978 and 1979; F : M = ratio of females to males. Data for 1978 from Gibson & Whoriskey (1980). Numbers of fish in sample are in parentheses

Age	F : M		River fish % Fish mature		% Males mature		% Females mature	
	1978	1979	1978	1979	1978	1979	1978	1979
1+	1·50 : 1 (10)	0·59 : 1 (59)	0	0	0 (4)	0 (37)	0 (6)	0 (22)
2+	0·95 : 1 (231)	0·83 : 1 (128)	14	10	6 (67)	9 (70)	23 (164)	12 (58)
3+	1·23 : 1 (67)	0·77 : 1 (87)	54	49	47 (30)	39 (49)	59 (37)	63 (38)
4+	2·00 : 1 (3)	0·50 : 1 (6)	100	100	100 (1)	100 (4)	100 (2)	
5+	– (1)	– (1)	100	100	–	–	100 (1)	100 (1)

Age	F : M		Sea trout % Fish mature		%Males mature		%Females mature	
	1978	1979	1978	1979	1978	1979	1978	1979
1+	–	2·00 : 1 (3)	–	0	–	0 (1)	–	0 (2)
2+	1·00 : 1 (22)	2·17 : 1 (19)	18	0	18 (11)	0 (6)	18 (11)	0 (13)
3+	1·37 : 1 (38)	3·33 : 1(13)	39	31	17 (16)	0 (3)	64 (22)	40 (10)
4+	0·50 : 1 (9)	–	78	–	67 (6)	–	100 (3)	–
5+	0·50 : 1 (3)	–	67	–	50 (2)	–	100 (1)	–

(Table V). This contrasted with the values for river fish, which were 0·95 and 0·83 for the comparable age classes. This pattern was repeated in the 3+ age class where 1978 and 1979 sea trout F : M ratios were 1·37 and 3·33 *v.* 1·23 and 0·77 for river fish in the same years (Table V).

Fewer sea trout than river fish were mature in our samples although it may be argued that tagging may have differentially affected maturation of sea trout and river fish. In 1979, 2+ and 3+ aged sea trout averaged 0 and 31% mature fish, respectively, compared to 10 and 49% for the same age classes of river fish (Table V). A similar pattern emerged in 1978 but trends were less obvious.

TABLE VI. Food habits of sea trout sampled in autumn 1979 by age class. Frequency of occurrence calculated as % of stomachs in a sample containing the indicated food taxon. Volumes measured to 0·01 ml; S.E. in parentheses

Taxon	1+		2+		3+	
	Frequency of occurrence (%)	Mean food volume (ml)	Frequency of occurrence (%)	Mean food volume (ml)	Frequency of occurrence (%)	Mean food volume (ml)
Amphipoda	100	0·1	55	0·38 (0·15)	44	0·43 (0·21)
Ammodytes (sp.)			9	0·39 (0·24)	11	0·20 (0·20)
Mysidacea					11	0·01
Diptera						
Adults			5	0·01		
Larvae			11	0·01		
Trichoptera						
Adults			11	0·01		
Larvae			17	0·01		
Odonata			5	0·01		
Ephemeroptera			11	0·01		
Orthoptera					11	0·01 (0·01)
Unidentified and Debris			22	0·02 (0·01)		
$\bar{x}$ Stomach fullness (%)	25·0		48·5 (10·1)		42·5 (14·5)	
No. of Empty stomachs	0		5		4	
Sample size	1		18		9	

TABLE VII. Food habits of river fish sampled in autumn 1979 by age class. Frequency of occurrence calculated as % of stomachs in a sample containing the indicated food taxon. Volumes measured to 0·01 ml; S.E. in parentheses

Taxon	1+		2+		3+	
	Frequency of occurrence (%)	Mean food volume (ml)	Frequency of occurrence (%)	Mean food volume (ml)	Frequency of occurrence (%)	Mean food volume (ml)
Diptera						
Simulidae						
Adults	53	0·10 (0·68)			21	0·06 (0·03)
Larvae	7	0·01			7	0·01
Chironomidae						
Larvae	7	0·01	7	0·01		
Adults			7	0·01	7	0·01
Other Diptera						
Trichoptera						
Adults						
Larvae	60	0·01	33	0·02 (0·01)	21	0·01
Hymenoptera			7	0·1	14	0·01
Hemiptera	13	0·01	40	0·02 (0·01)	14	0·01
Homoptera						
Coleoptera	7	0·01	7	0·01	14	0·01
Orthoptera	13	0·01			7	0·05 (0·05)
Arachnida	7	0·01				
Plecoptera	33	0·01	13	0·01		
Ephemeroptera						
Insect Pieces	13	0·01	20	0·01		
Amphipoda	7	0·01	7	0·03 (0·03)	7	0·05 (0·05)
Unidentified debris	53	0·01	40	0·01	36	0·01
$\bar{x}$ Stomach fullness (%)	15·6 (4·6)		22·0 (6·5)		22·5 (8·5)	
No. Empty stomachs	1		0		5	
Sample size	15		15		14	

Sexual maturity in both sea trout and river fish was suppressed below levels found for undisturbed populations of brook trout in the Matamek River. There, Gibson *et al.* (1976) report samples of 2+ and 3+ trout contain 29 and 73% mature males, respectively, and 29 and 91% mature females, respectively, suggesting that the tagging procedure did affect maturation.

FOOD HABITS

Sea trout returning to fresh water in late August, September and early October had been feeding mostly on amphipods and sand launce (*Ammodytes* sp., Table VI). River fish during the same period fed most heavily on adult Simulidae and Trichoptera larvae (Table VII). Mean stomach fullness and the volume of food in sea trout were considerably greater than in river fish of all ages during this period.

OVERWINTERED FISH

Thirty fish tagged in June 1978 and recovered in June 1979 were measured and re-released. Eleven were recovered at the end of their second summer of liberty. Six fish of 2+ years when planted had growth rates of 34% (S.E. = 13%) and 36% (S.E. = 10%) of body weight for 1978 and 1979, respectively. Four fish of 3+ years when released grew 52% (S.E. = 8%, $n = 3$) and 71% ($n = 1$) for 1978 and 1979, respectively. One 4+ fish had a total growth of 74% in 1978, but only 10% in 1979. There were no sea trout in the final sample, and only two of the 30 over-wintering fish had sea trout morphology.

STRAYING

Only one tagged fish was reported from outside the Matamek River estuary in 1979. The fish, 23·8 cm F.L. and 162 g when tagged, was captured in the Moisie River estuary approximately 10 km from the Matamek River. The fish was not available to use for inspection. From other studies (White, 1942; Smith & Saunders, 1958; Wilder, 1952) and our own unpublished data, we know that sea trout do venture some distance along the coast from their natal river but they also appear to have a strong homing instinct (O'Conner & Power, 1973). The fact that only one tag was returned from outside the immediate area of the Matamek River suggests that the rate of permanent straying may be low.

PREDATORS AND COMPETITORS

We suspect losses to predators were minimal, as we were unable to detect any evidence for significant predation on sea trout. Potential avian predators visiting the Matamek estuary during this study included ospreys (*Pandion halioetus*), loons (*Gavia immer*), mergansers (*Mergus merganser*), kingfishers (*Megaceryle alcyon*), herring gulls (*Larus argentatus*) and terns (*Sterna* spp.). All species readily captured or were seen eating fish but in no case were those fish identified as brook trout or salmonids.

The most abundant fish in the estuary were tomcod, *Microgadus tomcod.* Forty-four specimens of tomcod taken in late August 1979 had fed primarily on amphipods (93% of stomach contents), sand launce (4%) and mysids (0·5%). Atlantic cod, *Gadus morhua,* up to 2·3 kg, occasionally venture into the estuary and adult Atlantic salmon migrate through the area.

IV. DISCUSSION

Some fish within each age class of trout developed a sea run response, but older age classes had higher percentages of sea trout among their returns. Over the two years of the experiment, 35·4% of released fish were recaptured, with best returns occurring in the 2+ and 3+ age classes (41·7 and 61·2%, respectively). In contrast, tagged Atlantic salmon smolt from the Matamek River typically yield returns of only 1% or less (R. J. Gibson, pers. comm.; F. G. Whoriskey, unpubl.). Relatively poor returns of 1+ fish (two year average = 14·1%) may be related to an inability of small fish to acclimate to sea water (Sutterlin *et al.*, 1976), or to shock of transport and tagging. Sutterlin *et al.* (1976) found greater salinity tolerance in larger brook trout than in small fish. In our experiment, perhaps an increased incidence of straying in 4+ and older fish may have contributed to poor recapture success of this age group ($\bar{x} = 15{\cdot}8\%$). The one fish recaptured away from the Matamek River in 1979 and the two that occurred in 1978 (Gibson & Whoriskey, 1980) were large fish when planted (23·8, 26·5 and 34·7 cm F.L., respectively) and presumably at least four years old. Fish of this age or size acclimate readily to sea water (Sutterlin *et al.*, 1976) and probably experience less stress from tagging than smaller individuals. In contrast with Matamek trout, 48·1% of Dolly Varden, *Salvelinus malma*, >30 cm F.L. returned to Alaskan natal streams after transplanting to sea water sites, but only 8·2% of fish <30 cm F.L. were recaptured; fish were transplanted 0·5–9·5 km from their home streams (Armstrong, 1974).

Long distance straying of *Salvelinus* spp. is generally low due to tendencies for at least young fish to remain near home streams (Montgomery, unpubl. data) and for fish to move along shorelines rather than out to sea. Sea run brook trout from the Moser River, Nova Scotia, are reported to frequent rocky, wave washed shore regions (White, 1942). Non-spawning Dolly Varden frequently wander to local streams other than their home stream (Armstrong, 1974); largest captures of sea run Arctic char, *Salvelinus alpinus*, occur along shore (Andrews & Lear, 1956; Moore, 1975); juvenile *S. leucomaenis* overwinter in estuaries and adults generally restrict their movements to inshore waters (Gritsenko & Churikov, 1977). Older *S. alpinus* wander farther from their home streams than younger fish (Moore, 1975).

Chars also seem to share a well-developed homing ability. Most anadromous brook trout entering Richmond Bay, Quebec, remained within 8 km of their home stream and within 5 km of shore (Dutil & Power, 1980). Displaced brook trout in Matamek Lake returned to home streams over distances of up to 4 km (O'Connor & Power, 1973). *Salvelinus malma* may move 40–50 km from their home stream (Moore, 1975) and *S. alpinus* may return from distances of 160–425 km (Gritsenko & Churikov, 1977; Mishima, 1975). In any event, sea run *Salvelinus* spp. which do not return to their home stream are likely to move into streams within a few kilometres; they are, therefore, not truly lost from the local population.

Low predator pressure may enhance survival of anadromous trout at Matamek. Although potential avian and piscine predators visited the estuary, we never documented a case of predation on transplanted trout. Of the potential avian predators, loons and mergansers were uncommon at the study site, successful osprey attacks were on marine flatfish, and gulls and terns concentrated on sand launce and capelin (*Mallotus villosus*). We found no tags at gull roosting sites near Matamek. Tomcod occur in the same habitats as sea trout but their generally small size in the estuary and adjacent waters and their dietary reliance on invertebrate foods suggest they are probably competitors of sea trout rather than predators. Atlantic cod, *G. morhua*, frequently capture capelin, which are as large as small sea trout; cod may, therefore, prey on sea trout. The decline of salmon spawning runs in recent years and their tendency to cease active feeding upon entry into brackish waters probably affords some protection to sea trout from salmonid predation. Predator pressure at Matamek seems to contrast with that in the Moser River, where stomach contents of mergansers and frequent scars on trout, attributed to eels and herons, indicate a more severe impact of predators (White, 1940).

Sea run fish generally exhibit higher growth rates, better condition factors and larger body size than fish remaining within rivers. Growth rates of tagged sea-run fish from Matamek greatly exceeded those for tagged river fish during 1978 and 1979, and for both years the average condition factor of sea trout was larger than that for river fish of corresponding age. In addition, natural sea trout sampled in the Matamek estuary prior to the present study were appreciably larger than river fish of comparable age (Haedrich, 1975; Whoriskey, unpubl.). Anadromous brook trout in Richmond Gulf, Quebec, exhibited a 2·3-fold increase in growth rates over freshwater specimens (Dutil & Power, 1980), and Moser River trout gained 2·2–32·4% of body length during their stay at sea (White, 1941). Condition factors of downstream migrating *S. malma* in Russia (0·65–0·76) are much lower than those of upstream migrants (1·03–1·07) and, although increases in length during five months at sea are slight, weights of five to six year old fish increased by 40–42% (Gritsenko & Churikov, 1977). Arctic char similarly exhibit increases in condition factors during summers at sea and weight increments are greater than increases in gonad weight (Grainger, 1953).

Negligible or negative growth of tagged river fish, when compared to positive growth of undisturbed river and lake populations, clearly demonstrates suppression of growth by tagging. Growth rates of tagged sea trout approximately equalled those of undisturbed river and lake fish, so that growth of undisturbed sea trout would probably greatly exceed that of the undisturbed river fish. Comparison of condition factors for river and sea trout also support this contention. Sea trout consistently exhibit condition factors superior to those of river trout; this difference is further emphasized by the general failure of the sea trout to channel growth into gonads, in contrast to river trout.

Abundant marine food reserves probably support the improved growth at sea. Sea trout stomachs were fuller than those of river trout (Table VI); primary foods were amphipods and sand launce, *Ammodytes americanus*. River fish fed on a variety of riverine and terrestrial organisms dominated by adult simulids and larval trichopterans (Table VII). Most growth of natural populations of brook trout in the Matamek River occurs during a six week period of peak food availability from early June to mid July (Gibson, 1973; Gibson & Gailbraith, 1975; Whoriskey *et al.*, 1980). After this period growth slows and mean stomach fullness drops. In contrast, sea trout stomachs generally contained large quantities of food when sampled. Seine hauls in the estuary often captured considerable quantities of sand launce and amphipods through September, making possible an extended feeding and growing season for sea-run fish.

Although the general pattern for *Salvelinus* is a strong shift to marine foods in estuaries, some dietary overlap occurs between sea and river fish at Matamek due to consumption of insects by sea trout. Abundant marine foods complement the often sparse and seasonal river foods available to freshwater populations. Elsewhere, insects are important in diets of anadromous brook and brown trout (Wilder, 1952; Pemberton, 1976). Russian *S. malma* migrating downstream depend almost as heavily on insects (41·7% of all foods, by weight) as on amphipods (48·7%) while in the Bogataya River estuary, but feed only on marine amphipods and fishes in Nyyskiy Bay; the East Siberian char (*S. leucomaenis*) exhibits a similar pattern (Gritsenko & Churikov, 1978).

Sea trout at Matamek feed heavily on marine organisms that frequent the shallow, rocky estuary (e.g. amphipods, sand launce, mysids). A similar pattern was noted for anadromous brook trout by White (1942) and Dutil & Power (1980).

Two patterns emerge from data on sexual characteristics of sea run and river trout (Table V). First, females tend to outnumber males. This pattern recurs in other species and populations of *Salvelinus* spp. Sea run brook trout from the Moser River were predominately female (72%), while males dominated among fish remaining in the river (71% male; Wilder, 1952). However, there is no overall or age-related pattern in sex ratios of anadromous brook trout from Richmond Gulf (Dutil & Power, 1980). Alaskan Dolly Varden migrating downstream were 52–53% female, but 200 of 309 (65%) returning spawners were female (Armstrong, 1970, 1974).

The second pattern discerned is a suppression of maturity in sea run fish compared to river fish. Haedrich (1975) captured 20 sea trout (18–29 cm) in the Matamek estuary in late August 1975, but none were mature. Dutil & Power (1980) failed to find maturing anadromous trout younger than four years of age; and only 20–23% of older fish taken prior to August in brackish water were mature. Brook trout reared in salt water spawned two months later than hatchery-reared or wild fish in fresh water (Sutterlin *et al.*, 1977). The causes, and generality, of such suppression are unknown but may be related to tagging effects and food availability. Although onset of maturity results in arrest of growth, softening of flesh and a loss of salinity tolerance (Sutterlin *et al.*, 1977), delayed or inhibited maturity may also interfere with establishment of natural sea-run stocks.

We thank Peter Heinermann, James Critchley and Fay Cotton for their excellent assistance with the sampling program, Dr Richard Backus for his constructive suggestions, and Elaine M. Ellis and Dianne M. Steele for typing the manuscript. Geoff Power allowed us access to an unpublished manuscript and shared his insights into salmonid fishes and the potential for sea ranching. This is contribution No. 46 from the Matamek Research Station and contribution No. 4729 from Woods Hole Oceanographic Institution.

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