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COMPARATIVE PRODUCTION OF *Salmo salar* (ATLANTIC SALMON) AND *Salmo trutta* (BROWN TROUT) IN A SMALL NOVA SCOTIA STREAM

R.G. RANDALL[1], R.R. CLAYTOR, and E.M.P. CHADWICK
Department Fisheries and Oceans
Gulf Fisheries Center, P.O. Box 5030
Moncton, New Brunswick, E1C 9B6

E. MORTENSEN
National Environmental Research Institute
Division of Freshwater Ecology, Lysbrogade 52,
DK - 8600, Silkeborg, Denmark

The production rate of juvenile Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) was estimated at a site in Mountain Brook, a small tributary of River Philip, Nova Scotia. *S. salar* were usually more abundant than *S. trutta*, but growth rate of *S. trutta* was significantly greater. For both species, seasonal growth was restricted to a six month period (May to October). For nine sampling dates between June 1986 and June 1988 total salmonid biomass averaged 3.6 g m^{-2} (range 1.2-5.6 g m^{-2}). Production rate was similar for both species; total production was 3.5 g m^{-2} y^{-1} from June 1986 to June 1987 and 5.9 g m^{-2} y^{-1} from June 1987 to June 1988. Although *S. trutta* are not native to eastern Canada, a naturalized population has become established in River Philip, and they are cohabiting successfully with native *S. salar*. Future studies on population interactions and possible range extensions of introduced *S. trutta* would be beneficial for the management of salmonids in eastern Canada.

Le taux de production du jeune saumon atlantique (*Salmo salar*) et de la truite brune (*Salmo trutta*) a été estimé relatif à un lieu sur Mountain brook, un petit affluent de River Philip, Nouvelle-Ecosse. *S. salar* s'est ordinairment démontré plus nombreux que *S. trutta*, mais le taux de croissance de *S. trutta* est significativement plus élevé. Les deux espèces laissent voir une croissance saisonnière restreinte à une période de six mois (de mai à octobre). Neuf dates d'échantillonage entre juin 1986 et juin 1988 ont décelé une biomasse totale, en moyenne, de 3.6 g m^{-2} (avec une distribution de 1.2 à 5.6 g m^{-2}). Les taux de production étaient semblables quant aux deux espèces; la production totale s'élevait à 3.5 g m^{-2} pendant l'année juin 1986 à juin 1987, et à 5.9 g m^{-2} de juin 1987 à juin 1988. Quoique *S. trutta* ne soit pas natif du Canada de l'est, cette population naturalisée s'est évidement bien établie dans la River Philip, et elle cohabite avec succès à côté du *S. salar* natif. Des études ultérieures des interactions entre les populations, et des prolongements possibles de superficie occupée par la truite brune introduite bénificiraient la gestion des salmonides au Canada de l'est.

Introduction

Brown trout (*Salmo trutta*) are not native to eastern Canada but hatchery stocking of this species has occurred throughout the maritime provinces (MacCrimmon & Marshall 1968) and naturalized populations have become established in Newfoundland and Nova Scotia. Except for a study on the Avalon Peninsula of Newfoundland (Gibson & Cunjak 1986), there have been few studies describing the population traits of introduced *S. trutta* where they live sympatrically with native brook trout (*Salvelinus*

[1] Present address: Department of Fisheries and Oceans, Great Lakes Laboratory for Fisheries and Aquatic Sciences, P.O. Box 5050, Burlington, Ontario, L7R 4A6.

fontinalis) and Atlantic salmon (*Salmo salar*) in eastern Canada. In this note, we compare the seasonal growth, biomass, and annual production rate of naturalized *S. trutta* with native *S. salar* and *Salvelinus fontinalis* in a localized riffle habitat in River Philip, Nova Scotia. Estimates of production from this site were of interest because they have not been estimated in streams cohabited by *S. salar* and *S. trutta* in eastern Canada. Freshwater production rates by salmonid populations are greater where species live sympatrically rather than allopatrically (Chapman 1978; Kennedy & Strange 1986). Because of the presence of three salmonid species living sympatrically in River Philip, and because of its southern location, studies at this site might be expected to indicate relatively high or possibly maximum production rates of fish for rivers flowing into the Gulf of St. Lawrence.

Methods

Study site. Juvenile *S. salar* and *S. trutta* were monitored at a small site (about 200m^2) in Mountain Brook, a small second order tributary of River Philip, Nova Scotia. River Philip is a small watershed (about 98 ha of rearing area) which flows northeast and empties into Northumberland Strait (45°50'N, 63°40'W). Initially, the Mountain Brook site was established as part of an extensive study on geographic variation in the morphology of juvenile *S. salar* (R. Claytor, in progress); observed densities of *S. salar* and *S. trutta* at the site, however, indicated the potential for comparing life history traits of both species. The site was predominantly shallow riffle habitat; mean and maximum depths within the site at low summer flow (August) were 20 and 50 cm, respectively and the substrate was about 60% cobble, 30% gravel, and 10% bedrock. At the times of sampling, water temperatures lay in the range 5° and 16°C, water conductivities 20-40 micro Siemens cm^{-1} (Table I).

Density estimates. The density of fish at the study site was estimated on nine dates: June, August and October, 1986; May, June, August and October, 1987; and May and June, 1988. On each date, barrier nets (0.3 cm mesh) were erected at the upstream and downstream boundaries of the site, and fish densities were estimated using electrofishing gear and the removal method (Zippin 1956; Seber 1982). For each estimate, 2 to 4 successive electrofishing runs were made. Capture probabilities were usually high (0.4 to 0.5), and the proportion of the total population (N) actually captured (T) during the survey usually exceeded 90%. Between each run, captured fish were counted, sampled (see below) and retained in stream-side cages; most fish were returned alive into the site following the final electrofishing run. Mortality resulting from electrofishing or sampling stress was usually less than 1% during the few hours that the fish were observed in cages.

Growth and production. Three age groups of *S. salar* and *S. trutta* were found: age 0 fry and ages 1 and 2 parr. Age 0 *S. salar* and *S. trutta* could be identified from length frequency data; ages of older fish were determined from subsamples. Subsampling included collecting scales from at least 3 fish of each modal length group and from all fish in intermediate size ranges. Most fish captured were measured for fork length (mm). For age 0 *S. salar* and *S. trutta* which were abundant, subsamples only were measured. Random subsamples of fish of all ages were also weighed in the field; weights of remaining fish were estimated from length-weight relationships established from the subsamples. Growth rates were estimated by comparing the mean weight of each year class on successive dates. Biomass (g m^{-2}) was calculated as the product of mean weight and population density (D m^{-2}).

Production rates (P) of *S. salar* and *S. trutta* were calculated as the product of instantaneous growth rate (G, % day^{-1}), mean biomass (B), and time (t, days), where P = ΔtGB (Ricker 1975). Average biomass (B) was calculated using formulae given by Ricker (1975).

Table I Estimated densities of fish (numbers m^{-2}) at the Mountain Brook site on nine sampling dates, 1986 to 1988. + indicates the species was captured but in low densities (<0.01 m^{-2}).

	1986			1987				1988	
	June 6	Aug 11	Oct 8	May 6	June 5	Aug 24	Oct 28	May 9	June 15
Temperature (°C)	12	16	6	8	11	12	9	5	12
Conductivity (μS cm^{-1})	30	-	20	20	25	40	25	-	30
Salmo salar	0.30	0.88	0.82	0.37	0.77	0.95	0.36	0.26	3.00
Salmo trutta	0.18	0.63	0.52	0.14	0.63	0.96	0.40	0.05	0.35
Salvelinus fontinalis	0.02	0.07	0.06	0.01	0.05	0.07	0.02	0.01	0.06
Petromyzon marinus	-	+	+	+	+	+	+	-	+
Gasterostidae	-	+	-	-	-	-	-	-	+
Anguilla rostrata	+	-	-	-	-	-	-	-	-
Total	0.50	1.58	1.40	0.52	1.45	1.98	0.78	0.32	3.41

Results

Density. The densities of *S. salar* ranged from 0.26 to 3.00 fish m^{-2}, and the densities of *S. trutta* from 0.05 and 0.956 fish m^{-2} (Table I). *Salvelinus fontinalis* were captured on each sampling date, but their density was low, < 0.10 fish m^{-2}. Ammocoete larvae (*Petromyzon marinus*), sticklebacks (Gasterostidae) and American eels (*Anguilla rostrata*) were also captured but their densities were low. Thus, salmonids dominated the fish community; total densities of the three species ranged bertween 0.32 and 3.41 fish m^{-2} (Table I).

S. salar and *S. trutta* were abundant enough to follow seasonal trends in density of individual year classes. Following a recruitment period between the June and August sampling period, most year classes decreased in abundance with respect to time (Fig 1). Judging from the size of fry (about 0.2g or less; Randall 1982), *Salmo* fry emerged from the gravel in early June each year. Because of their small size, newly emerged *Salmo* fry could not be identified for certainty as being either Atlantic salmon or brown trout. Relative abundance of the two species in June was calculated by applying the *S. salar/S. trutta* ratio observed in August to the total fry density estimated in June. In 1986 and 1987, both species showed a significant increase in densities of age 0 fish between June and August (Fig 1). This suggested that either emergence had not been completed by the June sampling dates, or that net immigration affected fry densities between these months. Following August, both year classess fluctuated somewhat between sampling dates, but generally decreased.

Growth. Length-weight regressions calculated the *S. salar, S. trutta* and *Salvelinus fontinalis* are compared in Table II. Regression coefficients (b=3) were not significantly different for any of the species. For estimating the mean weight of each year class on each sampling date, length frequencies were first converted to weight frequencies using these length-weight regressions.

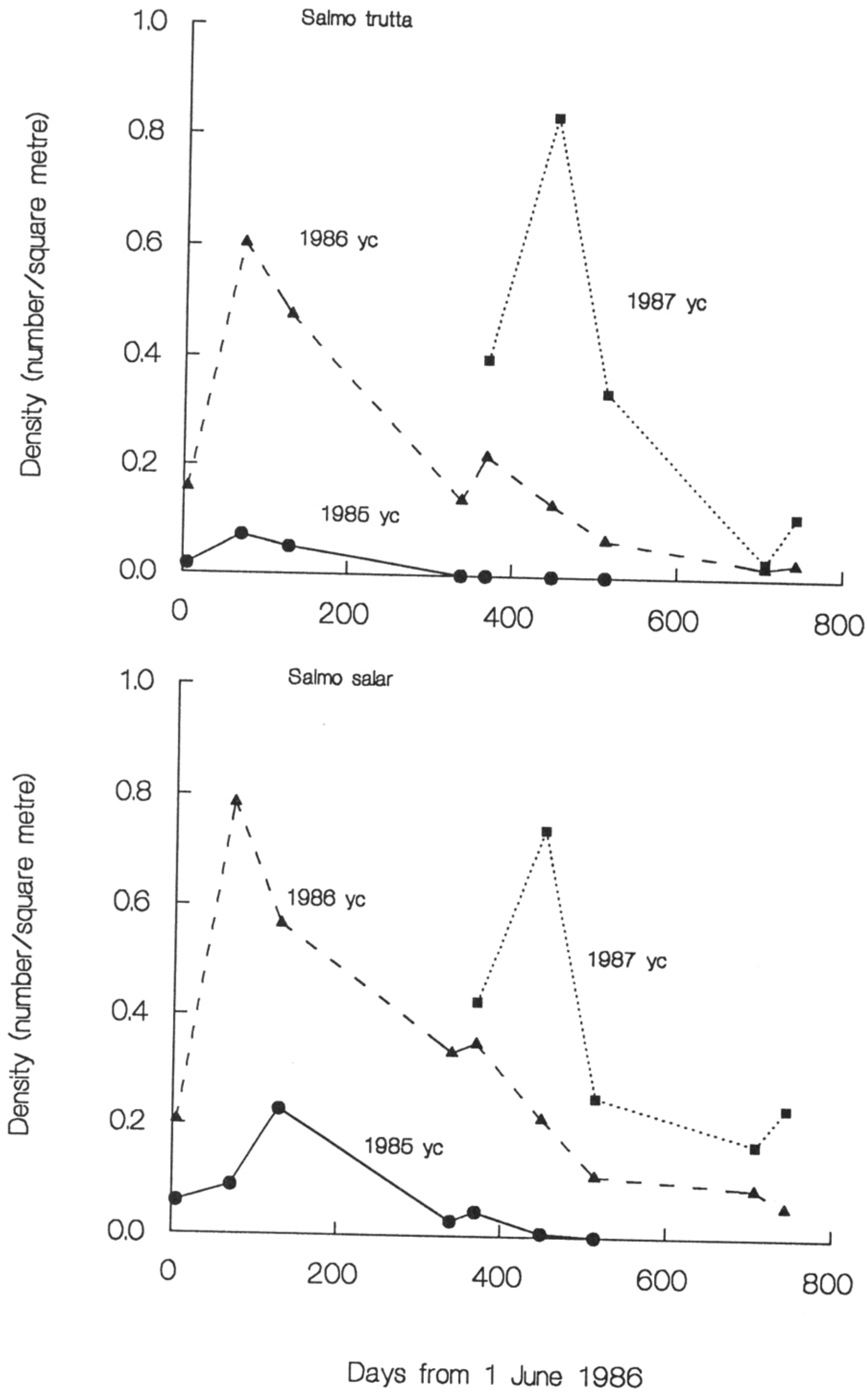

Fig 1 Density (numbers m^{-2}) of *S. salar* and *S. trutta* on nine sampling dates between June 1986 and June 1988 at Mountain Brook, Nova Scotia. Specific dates are given in Table I. Individual year classes (YC) are identified for each species.

Table II Regression equations for the relationship between wet weight (W, g) and fork length (FL, mm) of *Salmo salar, S. trutta,* and *Salvelinus fontinalis* at Mountain Brook. Regression equation: $\log_e(W) = \log_e a + b\log_e(FL)$.

Species	a (SE)	b (SE)	n	R^2
Salmo salar	-11.45 (0.12)	3.03 (0.03)	407	0.97
Salmo trutta	-11.14 (0.11)	2.95 (0.03)	304	0.98
Salvelinus fontinalis	-11.40 (0.33)	3.01 (0.07)	26	0.99

Growth in length was restricted to a five to six month period each year. For *S. salar* and *S. trutta* of the 1986 year class, for example, mean size was similar on the October and following May sampling dates, indicating very little growth occurred during the winter months (Fig 2). Thus, although quantitative sampling was not feasible during winter because of snow and ice cover, apparently little growth was occurring during this time.

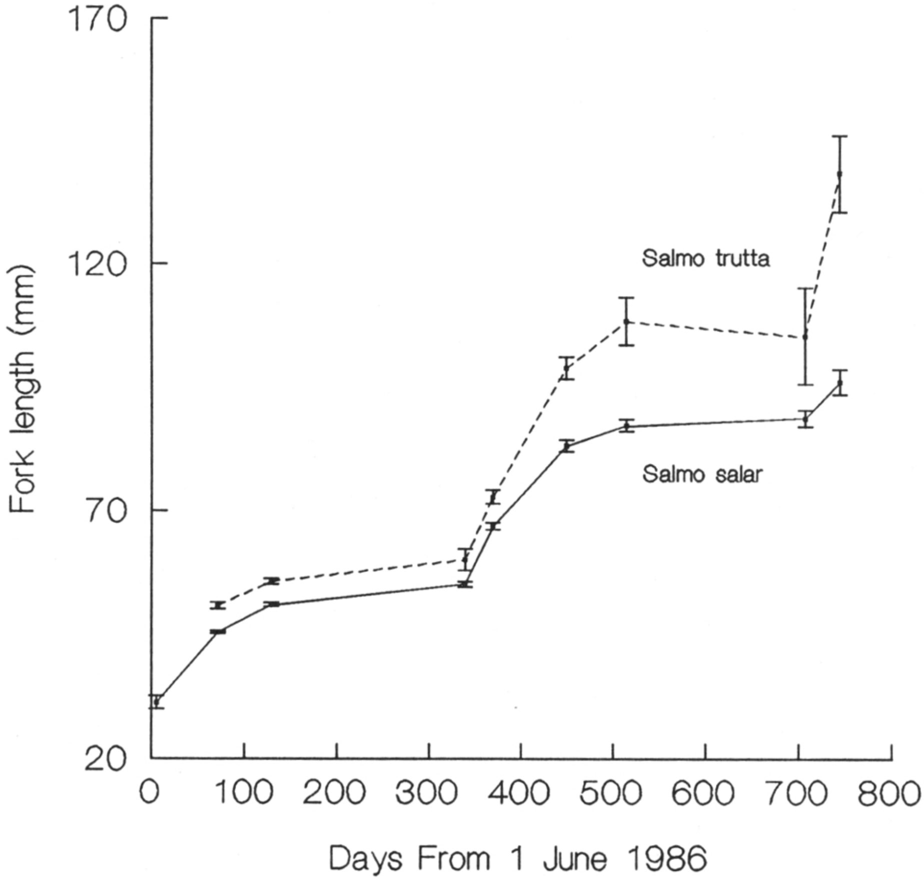

Fig 2 Seasonal growth of *S. trutta* and *S. trutta* at Mountain Brook, as indicated by increases in mean fork length with time of the 1986 year classes. Vertical lines indicate actual sampling dates and represent one standard error (SE).

Table III Comparison of mean length (FL, mm) of *Salmo salar* and *Salmo trutta* in August, 1986 and 1987. CV is coefficient of variation. Statistical differences in fork lengths between species were identified using *t*-tests.

Date	Age	*Salmo salar* n	*Salmo salar* FL	*Salmo salar* CV	*Salmo trutta* n	*Salmo trutta* FL	*Salmo trutta* CV	
August 1986	0+	141	45.4	8.2	108	50.7	13.4	($P<0.01$)
August 1987	0+	128	45.7	6.4	148	49.1	11.6	($P<0.01$)
August 1986	1+	14	84.6	7.6	13	109.0	12.5	($P<0.01$)
August 1987	1+	40	83.2	8.7	26	99.1	11.8	($P<0.01$)

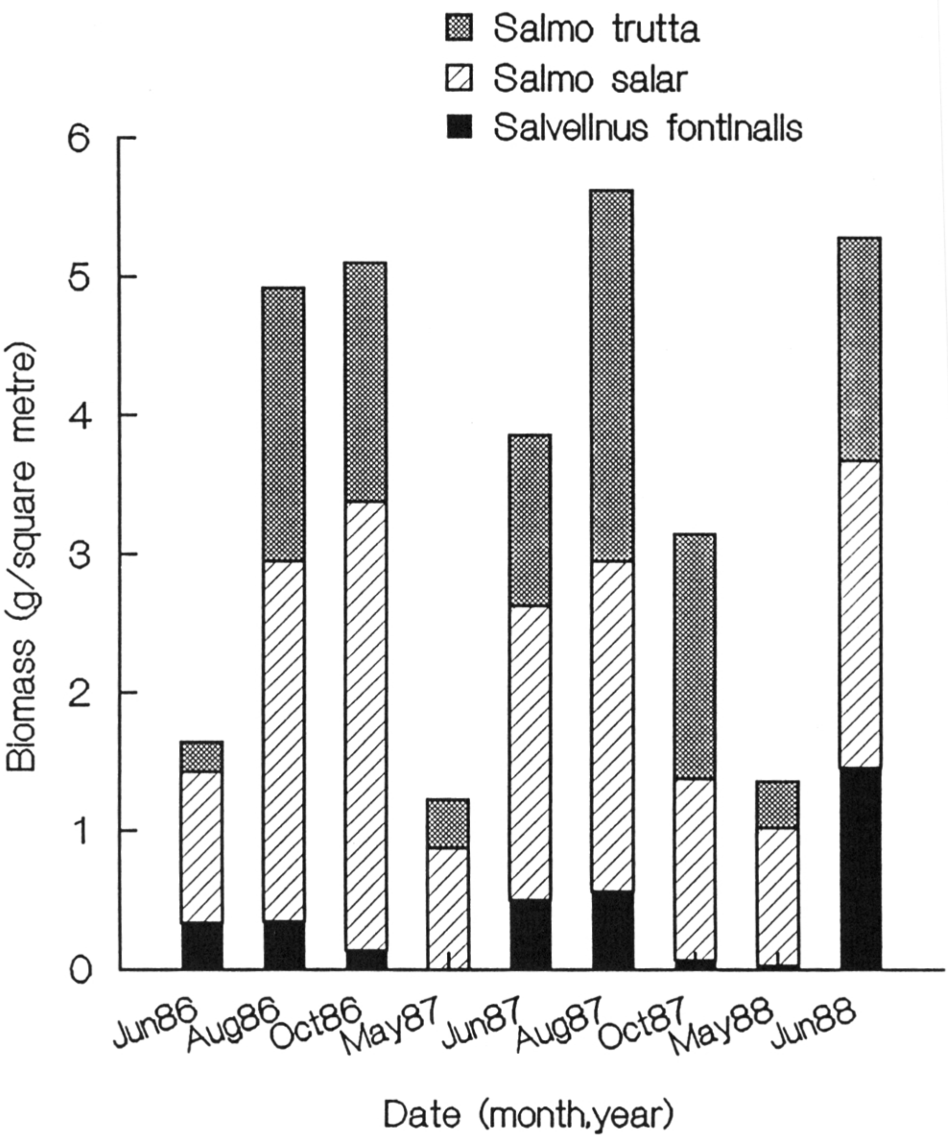

Fig 3 Biomass (m^{-2}) of salmonid fish at Mountain Brook on nine sampling dates.

Growth rate of *S. trutta* was greater than for *S. salar.* Mean size at age of *S. trutta* was consistently greater than for *S. salar,* and the relative difference increased during the growing season (compare the slopes of the growth curves for *S. salar* and *S. trutta* in Fig 2). *S. trutta* collected during August and October of 1986 and 1987 were significantly larger than *S. salar* (Fig 2 and Table III). Also, coefficients of variation (CV) were greater for each age group of *S. trutta* than *S. salar* (Table III). By the end of their second growing season (age 1 fish in October), the fork length of *S. trutta* lay in the range 85-142 mm and their weight 7.6-32.2 g. By contrast the analogous statistics for *S. salar* were 73-99 mm and 4.6-11.2 g.

Biomass and production. Biomass (g m^{-2}) of salmonids at the Mountain Brook site on each sampling date was estimated as the product of mean live weight and density. Total biomass ranged between 1.23 and 5.63 g m^{-2}, and was generally least in May and greatest in August and October (Fig 3) after the age 0 fish had fully recruited to the site and seasonal growth had occurred. The biomass of *S. salar* exceeded the biomass of *S. trutta;* average biomass for the nine sampling dates was 1.9 g m^{-2} for *S. salar* and 1.3 g m^{-2} for *S. trutta*. Biomass of *Salvelinus fontinalis* was low (average of 0.4 g m^{-2}; Fig 3).

The production of *S. salar* and *S. trutta* over the two years were similar; *S. trutta* contributed 42% of the total *Salmo* production the first year and 56% the second year (Table IV). Total annual production increased from 3.5 g m^{-2} y^{-1} for the period June 1986 to June 1987 to 5.9 g m^{-2} y^{-1} for the period June 1987 to June 1988 (Table IV). Increases in production between the two periods resulted from the greater density and biomass of the age 1 fish in the latter period (Table IV). Growth rates during the two periods were similar (Table III). Densities of *Salvelinus fontinalis* were too low to estimate the production of this species.

Discussion

The average total production rate of *Salmo* spp. at Mountain Brook in Nova Scotia over the two years was 4.7 g m^{-2} $y^{-1.}$ As *S. salar* and *S. truttas* contributed 90% of the fish biomass (Fig 3), this rate was a rough estimate of the total community production rate at this site. Fish production at Mountain Brook was within the range observed for other rivers flowing into the Gulf of St. Lawrence (Table V), where the range of annual production was 0.3 to 6.3 g m^{-2} y^{-1}. Although production by the two sympatric salmonids at Mountain Brook was relatively high, it was not as high as allopatric brook

Table IV Comparison of the annual production (g $m^{-2}y^{-1}$) of *Salmo salar* and *S. trutta* at Mountain Brook, 1986 and 1987.

Period	Year class (age)	*Salmo salar*	*Salmo trutta*	Total	% *S. trutta*
June 86	1984 (2)	0.12	0.00	0.12	
to June 87	1985 (1)	0.42	0.18	0.60	
	1986 (0)	1.49	1.29	2.78	
	Total	2.03	1.47	3.50	42%
June 87	1985 (2)	0.04	0.00	0.04	
to June 88	1986 (1)	1.26	1.82	3.08	
	1987 (0)	1.31	1.47	2.78	
	Total	2.61	3.29	5.90	56%

Table V Comparative production rate of salmonids in rivers flowing into the Gulf of St. Lawrence.

River	Location	Predominant species	Production ($g\ m^{-2}\ y^{-1}$)	Reference
Philip	Nova Scotia	*Salmo salar* *Salmo trutta*	4.7 (3.5-5.9)	This study
Miramichi	New Brunswick	*Salmo salar*	2.5 (0.3-5.1)	Randall & Paim 1982
Matamek	Québec	*Salvelinus fontinalis*	3.5 (1.5-6.3)	O'Connor & Power 1976
Western Arm	Newfoundland	*Salmo salar*	2.2 (1.6-2.9)	Chadwick and Green 1985)
Highlands	Newfoundland	*Salmo salar* *Salvelinus fontinalis*	2.1 (0.8-5.0)	Gibson and Myers 1986

trout production at Kaikhosru Creek in Québec, where production over two years was estimated to be 6.1 and 6.6 $g\ m^{-2}\ y^{-1}$. Production at Kaikhosru Creek was high because of the good nursery habitat and the high biomass of age 0 trout in this stream (O'Connor & Power 1976). It may also be significant that fish populations in Québec were unexploited, while salmon and trout at all other locations cited in Table V were harvested. Production and yield of salmonids in eastern Canada is directly related to spawning stock, which in turn is influenced by fishing mortality (Chadwick 1985). Production rates of about 6 to 7 $g\ m^{-2}\ y^{-1}$ may represent the maximum for Gulf of St. Lawrence rivers. In European rivers the yield of salmonids is higher, sometimes exceeding 20 $g\ m^{-2}\ y^{-1}$, due to the greater productivity of rivers in Europe than rivers in eastern Canada (Gibson & Myers 1986).

The production of naturalized *S. trutta* at the Mountain Brook site was about equal to the production of native *S. salar* during the study period. Individual population traits that contributed to production however differed between the two species. *S. salar* were usually more abundant than *S. trutta* at the time of sampling, but their seasonal growth rates were significantly less. These differences between *S. salar* and *S. trutta* in population densities and growth rates counter-balanced one another to some extent and resulted in similar production rates.

Greater growth rates of *S. trutta* than *S. salar* have been observed often where the two species live sympatrically (Egglishaw & Shackley 1973; 1977; Gibson & Cunjak 1986Z). In a Scottish stream, where the population dynamics of the two species were compared for ten years, Egglishaw & Shackley (1977) found that the larger size of *S. trutta* resulted from a longer growing season than *S. salar*; *S. trutta* emerged earlier and continued to grow later in the fall than *S. salar*. Growth rate of *S. salar* during the spring/summer growth period actually equalled or exceeded the growth rate of *S. trutta* in this Scottish stream. In contrast, growth of *S. trutta* at Mountain Brook exceed that of *S. salar* during the summer months, indicating that mechanisms other than length of growing season caused the different growth of the two species. At Mountain Brook, sampling was not frequent enough to compare emergence dates of the *S. salar* and *S. trutta* fry, and therefore it was not possible to identify exactly when the *S. trutta* fry initially achieved their growth advantage over *S. salar*.

Given the characteristics of the stream habitat at the Mountain Brook site, densities of *S. trutta* relative to *S. salar* were surprisingly high. As noted earlier, the Mountain Brook site was predominantly riffle habitat, with water currents, depth and substrate characteristics ideally suited for juvenile *S. salar* (Symons & Heland 1978; Morantz et al. 1987). *S. trutta*, in contrast, prefer deeper and slower water (Egglishaw & Schakley 1982; Kennedy & Strange 1982; Gibson & Cunjak 1986). In their Newfoundland study, Gibson & Cunjak (1986) found that the two species were usually spatially segregated, with *S. trutta* older than age 0 preferring deeper, slower water than *S. salar*, although the differences were not statistically significant at all the sites studied. They also noted that overhanging cover can substitute for depth for *S. trutta*. Alders and other streamside vegetation provided abundant shade at Mountain Brook, and this may account for the relatively high *S. trutta* densities at this riffle site. Despite differences in preferred habitat, there is obviously considerable overlap in the type of habitat utilized by each species.

At River Philip, the above observations on the growth, relative density, and production rate indicated *S. trutta* have become established, and they are cohabiting successfully with native *S. salar* at this localized site. Obviously, interpretations of the relative status of the naturalized *S. trutta* popultion from this study are limited because of the small area surveyed. Information on harvests of *S. salar* and *S. trutta*, however, confirm that *S. trutta* populations have become well-established over extensive areas; estimates of angling catches from Cumberland county, where River Philip is a major stream, indicated that landings of *S. trutta* usually equalled or exceeded landings of *S. salar* in this region (Table VI).

Kennedy & Strange (1986) have found that juvenile *Salmo salar* living allopatrically survived twice as well and grew larger than when living sympatrically with *S. trutta*. Similarly, the latter species has replaced the native *Salvelinus fontinalis* population in some rivers in the United States (Fausch & White 1981; Waters 1983). Concern about the expansion of *S. trutta* into the native *Salmo salar* habitat in the Avalon peninsular, Newfoundland prompted a study of the interactions of the two species (Gibson & Cunjak 1986). These authors concluded that extension of the range of *S. trutta* in Newfoundland will probably be limited, but they warned that deliberate stockings to extend the range of the species should be discouraged until further research was done. The work reported in this paper shows that production of *S. trutta* and *S. salar* in a riffle habitat in a small Nova Scotia stream was similar; hence the concerns and conclusions of the Newfoundland workers apply equally to Nova Scotia.

Table VI Numbers of *Salmo salar* and *S. trutta* landed by anglers in Cumberland County, Nova Scotia, 1980-1987.

Year	Angling catch (numbers) *Salmo salar*	*Salmo trutta*
1980	110	289
1981	99	292
1982	349	300
1983	964	442
1984	370	383
1985	204	536
1986	206	934
1987	N/A	252

Data sources - *S. salar:* Swetnam and O'Neil 1984; O'Neil et al 1985; 1986; and 1987. *S. trutta*: N. Adams, Nova Scotia Department of Lands and Forests, personal communication.

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