J. Fish Biol. (1983) **22**, 567–575

Abundance and distribution of *Salmincola edwardsii* (Copepoda) on anadromous brook trout, *Salvelinus fontinalis*, (Mitchill) in the Moisie River system, Quebec

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(*Received 4 May 1982, Accepted 28 May 1982*)

Rivière à la Truite, a tributary of the Moisie River, is probably a focus of *Salmincola edwardsii* transmission within the system. Differences in prevalence of the copepod on fish between Rivière à la Truite and the main river suggested that up to 41% of anadromous brook trout, *Salvelinus fontinalis*, in the Moisie River system overwinter in the tributary. Infected fish were generally less than 200 mm long and copepods were attached almost exclusively to the fins and their bases. The primary site of copepod attachment at low intensities of infection was the adipose fin but at high intensities the dorsal fin was most frequently infected. This displacement in attachment location with increased intensity may result in density-dependent mortality of copepods. Copepods were overdispersed on the host population at each major sampling time and data fit a negative binomial distribution (k ranged from 0·2 to 0·8).

I. INTRODUCTION

Salmincola edwardsii (Olsson) has a holarctic distribution and infects only char, *Salvelinus* spp. (Kabata, 1969). In North America, brook trout, *S. fontinalis*, are most frequently infected (Hoffman, 1967; Margolis & Arthur, 1979). This parasite is found on the body surface, fins and gils (Kabata, 1969) although prevalence and intensity on gills increases with host size (Black, 1982). Development of *S. edwardsii* has been described (Savage, 1935; Debie, 1940) but little is known about its ecology.

Anadromous populations of brook trout are common in rivers with free access to the sea (Power, 1980). In the Moisie River, Quebec, anadromous *S. fontinalis* leave a major tributary, Rivière à la Truite, in late spring in a highly synchronized emigration (unpubl. data). Many brook trout develop a silver coloration (morphological smoltification) by the time they begin their downstream movements. Fish first appear in the Moisie River estuary within a week after brook trout start emigrating. During summer, many fish remain in the Moisie estuary and forage in the marine environment. Other brook trout apparently remain in

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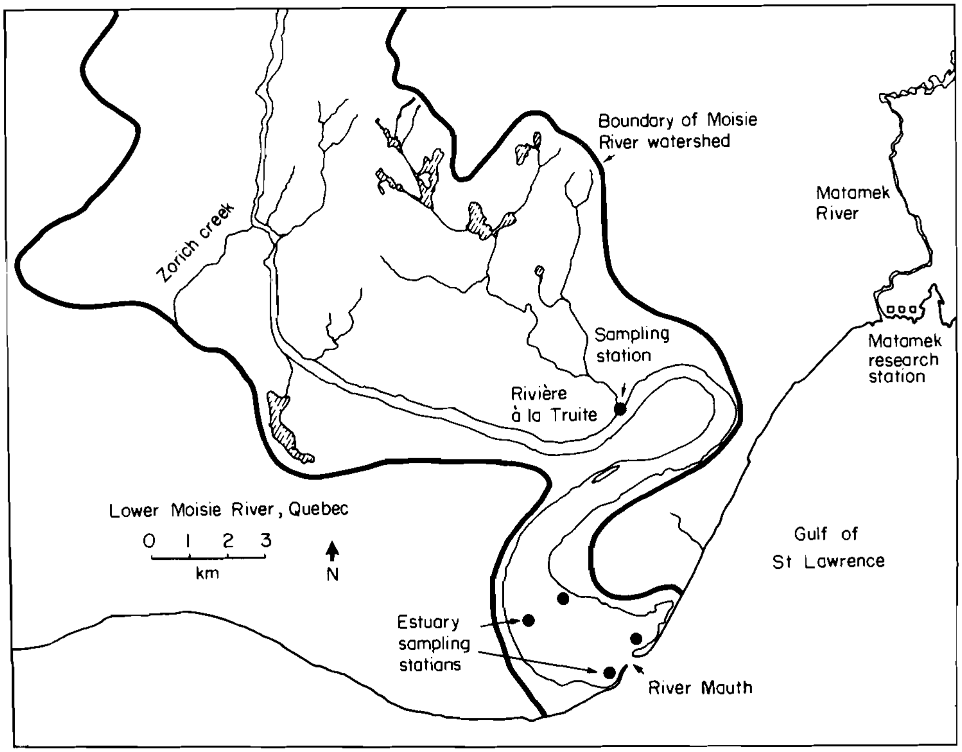

FIG. 1. Map of the lower Moisie River watershed showing location of Rivière à la Truite and Zorich Creek and estuary sampling stations.

fresh water upstream of the maximum extent of salt water influx (Black, 1981). Sea-run fish first return to Rivière à la Truite in early August although some are present in the estuary in late September (unpubl. data).

The purpose of this study was to determine changes in the number of copepods on anadromous brook trout of the Moisie River system during their migrations, investigate the distribution on parasites on the body surface of the host and determine the effect of different intensities on parasite distribution.

II. MATERIALS AND METHODS

The mouth of the Moisie River is located 25 km east of Sept-Iles, Quebec on the north shore of the Gulf of St Lawrence. It is a ninth order stream draining 19 871 km. Salinities at the river mouth approach 30‰. Maximum extent of saltwater influx is 2 km upstream of the river mouth. The Moisie River has only two notable tributaries entering into the lower 50 km. Rivière à la Truite is a fourth order stream located 14 km upstream of the mouth of the Moisie River and Zorich Creek, probably a second order stream, is located 24 km upstream of the mouth (Fig. 1).

Fishes were captured with fyke nets in Rivière à la Truite from 18 May–21 June and 3 Aug.–20 Oct., 1980 and with fyke and seine nets from 8–18 July. Four sampling stations were established at the Moisie River estuary, two at the river mouth and two upstream of saltwater influence (Fig. 1). We tried to capture fishes each week at each station from 3 June–30 Sept. Three species of salmonid fishes (4055 brook trout; 394 juvenile atlantic salmon, *Salmo salar* L.; and 16 round whitefish, *Prosopium cylindraceum* (Pallas)) and 24 species of non-salmonids were examined for *S. edwardsii*.

Fishes were anaesthetized with MS-222 (tricaine methane sulphonate), fork length (F.L.) was recorded, and brook trout distinguished as smolts or non-smolts. Fishes were examined macroscopically for attached *S. edwardsii*. Presence or absence of egg sacs on copepods was noted. Copepods were collected during specific sampling periods to estimate fecundity at different ambient temperatures (Rivière à la Truite, 3–7 June, $n = 49$ and 9 July–4 Aug., $n = 7$; and Moisie estuary, 25 July–10 Aug., $n = 20$). Copepods were preserved in 70% alcohol and egg sacs teased apart with dissection needles. Only copepods with well differentiated and easily separated eggs were used in this study. Midday surface temperatures were recorded at regular intervals throughout the study.

Prevalence is the percentage of fish infected, and intensity is the mean number of parasites on infected fish. Statistical procedures follow Zar (1974). Negative binomial distributions were fitted using the maximum likelihood estimate of Bliss & Fisher (1953) and an APL program in Liu (1978). Significance of all analyses was at the 0·05 probability level.

III. RESULTS

Salvelinus fontinalis was the only fish infected with *S. edwardsii* in the Moisie River. Prevalence and intensity of copepods were similar on brook trout smolts and non-smolts. Therefore these data were combined.

Prevalence of *S. edwardsii* on brook trout leaving Rivière à la Truite during spring decreased with increasing host length [Fig. 2(a)]. Data were combined for June and July at all estuary stations since prevalence and intensity within length classes were similar. Prevalence between length classes was not significantly different in fish 80–200 mm long [Fig. 2(b)]. Few fish were examined in the estuary in August. In September, prevalence was 4% ($n = 458$). Intensity on trout leaving Rivière à la Truite in spring was greater than on those captured in the estuary in June and July (mean ± S.D.: $1{\cdot}5 \pm 0{\cdot}8$ and $1{\cdot}3 \pm 0{\cdot}6$, respectively; Mann-Whitney $Z = -3{\cdot}2$, $n = 593$). Prevalence on fish returning to Rivière à la Truite in late summer was 11·8% [Fig. 2(c)]. Prevalence was 53% on 32 trout (80–140 mm long and presumably residents) in Rivière à la Truite during July. There was no significant relationship between intensity and fish length.

Salmincola edwardsii was overdispersed (Table I). A negative binomial distribution fit the data from Rivière à la Truite both in spring and in late summer and from the estuary in June and July (Fig. 3). The dispersion parameter, k, increased as intensity increased (Table I). A poisson distribution did not fit these data. The frequency distribution of *S. edwardsii* from the estuary in September fit a Poisson distribution (mean ± S.D.: $0{\cdot}044 \pm 0{\cdot}046$). The fit of a negative binomial to the latter data could not be tested since there were only three levels of infection and zero degrees of freedom.

Salmincola edwardsii usually attached directly to the fins or on the body within 5 mm of the fin base (Table II). Thirty-one per cent of copepods at the adipose fin attached directly to the fin and 52% at the dorsal fin attached directly. Percentages of copepods attached on the fin and at the fin base were similar on hosts with one or two parasites. Copepods attached to the fin and the base of the fin were not distinguished at Rivière à la Truite in May and early June. Consequently, there was insufficient data to determine if these proportions were maintained at higher intensities.

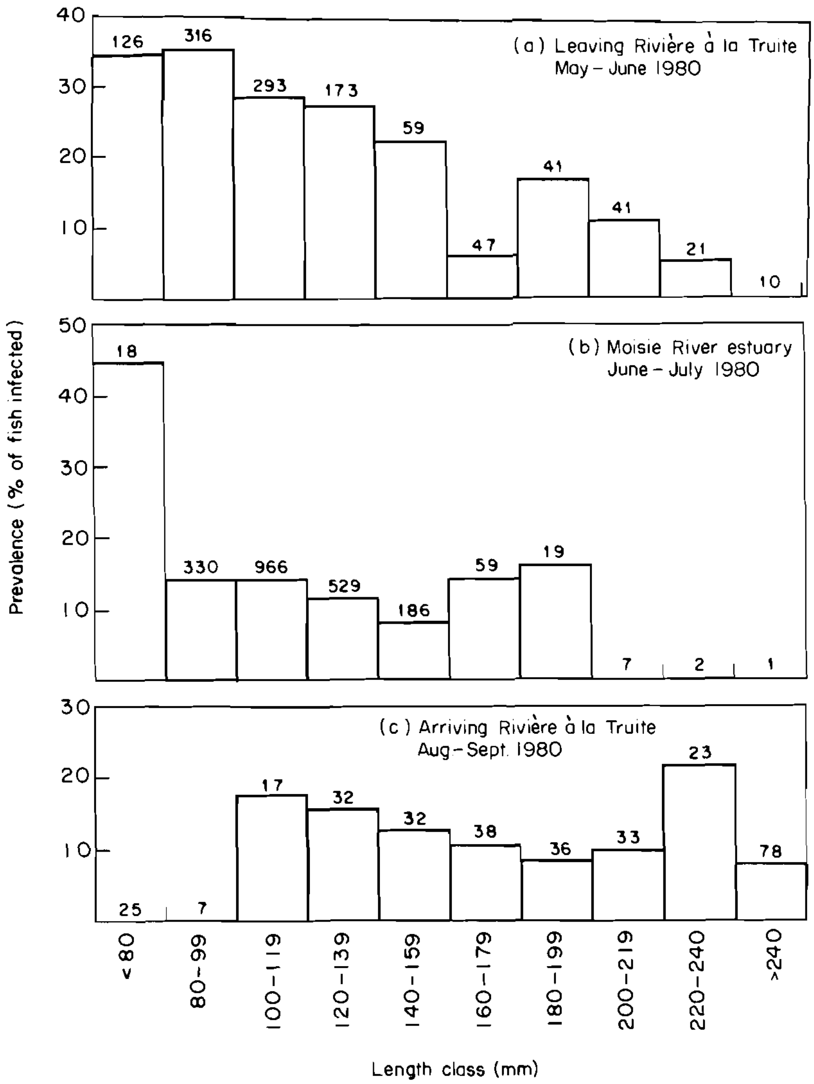

FIG. 2. Histograms showing the prevalence of *Salmincola edwardsii* on *Salvelinus fontinalis* of each length class. (a) Prevalence on brook trout leaving Rivière à la Truite in spring. (b) Prevalence on brook trout captured in the Moisie River estuary in June and July. (c) Prevalence on brook trout returning to Rivière à la Truite in late summer.

At low intensities the region on and around the adipose fin was the primary site of attachment (Table II). At higher intensities, the proportion of parasites on the adipose fin decreased ($\chi^2 = 19{\cdot}0$, d.f. = 1) and at the dorsal fin increased ($\chi^2 = 11{\cdot}4$, d.f. = 1). There was no significant change in the proportion of copepods on other body locations.

Fifty per cent of all copepods had egg sacs with eggs in various stages of development. This proportion did not differ significantly between body locations or with season. The mean number of eggs in individual copepods was 103 (S.D. = 21, range = 61–168). Water temperature in Rivière à la Truite at the time of cope-

TABLE I. Calculated values for negative binomial distributions fitted to frequency distributions of *Salmincola edwardsii* on brook trout in the Moisie River, Quebec, 1980

Location*	Time	Mean ($\bar{x}$) ± S.D.	k	χ^2	d.f.
Truite	May–June	0·42 ± 0·63	0·80	1·01*	3
Estuary	June–July	0·18 ± 0·24	0·45	0·07*	1
Truite	Aug.–Sept.	0·15 ± 0·24	0·20	0·81*	1

*Not significantly different from the theoretical distribution ($P>0·05$).

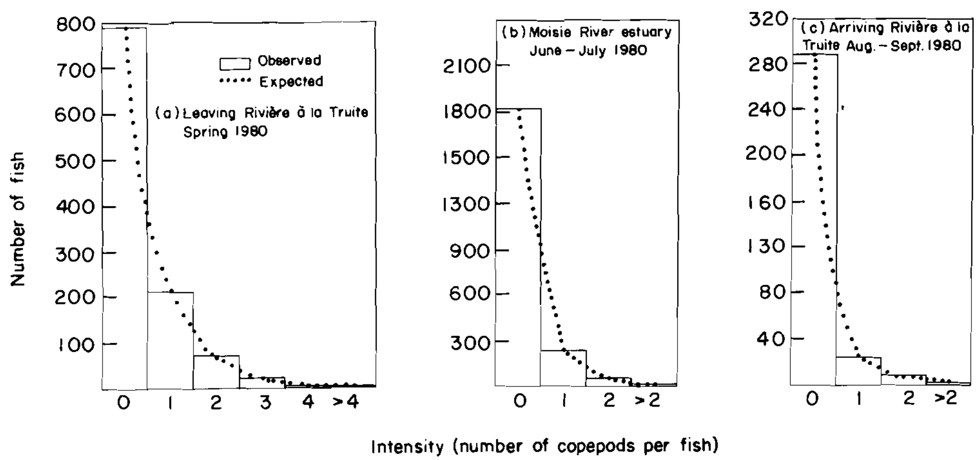

FIG. 3. Frequency distributions of *Salmincola edwardsii* on *Salvelinus fontinalis* fitted to a negative binomial distribution. (a) Copepods on brook trout leaving Rivière à la Truite in spring. (b) Copepods on brook trout captured in the Moisie estuary in June and July. (c) Copepods on brook trout returning to Rivière à la Truite in late summer.

pod collections ranged from 4 to 6° C in early June and from 11 to 13° C from mid-June to early August (Fig. 4). Temperatures at the estuary varied from 18 to 21° C during July and early August (Fig. 4). There were no differences in the number of eggs in copepods attached at different body locations and at different intensities but sample sizes were small.

IV. DISCUSSION

Brook trout leaving Rivière à la Truite in spring were the most frequently and heavily infected group. Prevalence in the estuary dropped during the latter part of the summer and prevalence on fish which returned to Rivière à la Truite in autumn was lower than those which left in spring. The high prevalence of *S. edwardsii* on trout leaving Rivière à la Truite in spring and on those resident during summer suggests that this stream is important in transmission in the Moisie system.

Emigration of brook trout from Rivière à la Truite in spring was highly

TABLE II. Distribution of *Salmincola edwardsii* on brook trout *Salvelinus fontinalis* in the Moisie River, Quebec during the summer, 1981

Location	1–2 Copepods per fish		Two copepods per fish	
	Percentage	x̄	Percentage	x̄
Dorsal fin	30·6	0·36	44·7	1·51
Adipose fin	50·3	0·60	31·3	1·06
Others:	19·1	0·24	24·0	0·82
Pelvic fins	11·6	0·15	10·2	0·36
Pectoral fins	4·2	0·05	6·6	0·22
Opercula	2·4	0·03	6·6	0·22
Miscellaneous*	0·9	0·01	0·6	0·02
Total	100·0	1·20	100·0	3·39

*Includes caudal and anal fins, anus and gill filaments.

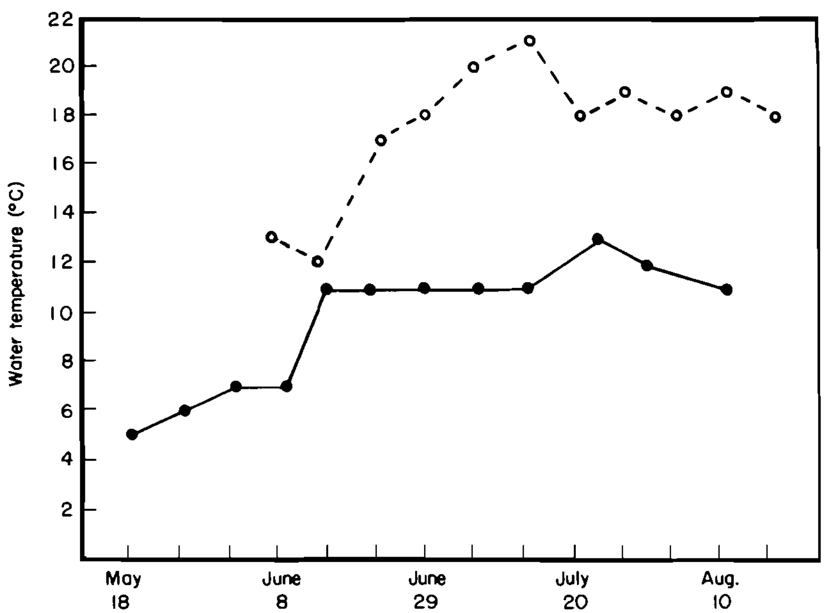

FIG. 4. Water temperatures during the study period collected from Rivière à la Truite (●—●—●) and from the Moisie River (○--○--○).

synchronized with 90% of migrants having left the tributary by 9 June (unpubl. data). Prevalence of *S. edwardsii* was higher on brook trout leaving Rivière à la Truite than on fish arriving in the estuary in June. In contrast, prevalence and intensity did not change on fish in the estuary throughout June and July. Loss of parasites from fish probably cannot account for differences in prevalence between these sampling sites in spring. The length of time under consideration was short and parasites are securely embedded in host tissue. Salt water is unlikely to affect the copepod adversely. Cousens (1977) reports that the cuticle of *S. californiensis* (Dana) is impermeable. Consequently, the parasite is probably more resistant to high salinities than its host. Also, apparently healthy *S. edwardsii* were found on brook trout in saline conditions during this study and two related species, *S. salmonae* (L.) and *S. californiensis*, are known to survive on salmonids at sea (Friend, 1941; Dr. L. Margolis, Pacific Biological Station, Nanaimo, B. C., pers. comm.).

The high prevalence of *S. edwardsii* on brook trout leaving Rivière à la Truite in spring and the low prevalence on fish arriving at the estuary suggests heavily infected fish from the tributary mix with trout from some other area. Rivière à la Truite and Zorich Creek have been considered the only major sources of sea-run brook trout in the Moisie River (M. Campbell, Manager, Moisie Salmon Club, pers. comm.). Zorich Creek no longer contributes significantly to the anadromous fish stock (unpubl. data). Differences in prevalence between Rivière à la Truite and the estuary can be used to estimate the maximum possible contribution of this tributary to the sea-run stock. Only fish less than 200 mm long are considered. Prevalence on fish leaving Rivière à la Truite was 29% and on those in the estuary in June was 12% ($n = 1141$). Even if brook trout acquire the copepod exclusively in Rivière à la Truite then this tributary accounts for only 41% of the fish in the estuary in the spring. If brook trout acquire the copepod elsewhere, this contribution would be even lower. This suggests that over half of the anadromous brook trout in the Moisie River system overwinter somewhere other than in Rivière à la Truite, probably in the main river.

Copepods were rarely attached to the gill filaments of brook trout in the Moisie River. Most fish were less than 200 mm long. Similarly, fins are the most frequent attachment site on small arctic char, *S. alpinus* (L.) (Debie, 1940; Fryer, 1981). Prevalence and intensity of *S. edwardsii* on the gill filaments of brook trout in Dickson Lake, Ontario increases with host size with the gills of few fish less than 350 mm long being infected (Black, 1982). *Salmincola californiensis* exhibits a similar shift on sockeye salmon, *Oncorhynchus nerka* (Walbaum), from the pectoral and pelvic regions on fry to the gill filaments on adults (Kabata & Cousens, 1977).

At low intensities the region around the adipose fin was the most frequent site of attachment of *S. edwardsii*. When preferred sites become crowded less preferable sites are more frequently chosen by *S. californiensis* (Kabata & Cousens, 1977). Also, differential larval mortality of *S. californiensis* apparently exists at different body locations (Kabata & Cousens, 1977). The major attachment site of *S. edwardsii* changes from the adipose fin at low intensities to the dorsal fin at high intensities. This suggests that the area around the adipose fin is selected initially but as intensity increases the dorsal fin becomes more frequently infected. This shift in attachment sites may reflect a higher mortality of copepods in multiple infections of the adipose fin or a selection by larval stages for a less crowded permanent attachment site. If there is differential larval mortality of *S. edwardsii* between attachment sites, as there is in *S. californiensis*, then both of these alternatives results in a density-dependent mortality of parasites.

The number of eggs carried by copepods did not vary with ambient temperature. At each location water temperatures had remained fairly constant for several weeks prior to sampling. Thus egg sacs present on animals had developed at the approximate temperatures from which they were collected (Debie, 1935; Friend, 1941; Kabata & Cousens, 1973). The number of eggs did not vary with site of attachment or intensity. However, in view of the shift in attachment site with altered intensity more study is required of the relationship between fecundity and attachment site.

The value of the dispersion parameter, k, increased with intensity. Boxshall (1974) reported a positive linear relationship between k and mean intensity of the copepod *Lepeophtheirus pectoralis* (Müller) on plaice, *Pleuronectes platessa* L. However, Amin (1981) reported no relationship between k and intensity of *Echinorhynchus salmonis* (Müller) in rainbow smelt, *Osmerus mordax* Mitchill.

We thank Dr R. J. Naiman of Woods Hole Oceanographic Institution for his support during this project. Mr Jim Guston kindly collected data from brook trout in Rivière à la Truite during July. Prof. R. C. Anderson, Drs R. G. Appy and J. D. Smith, Department of Zoology, University of Guelph provided valuable criticism of an earlier draft of the manuscript. This work was supported in part by an NSERC operating grant to Prof. R. C. Anderson, Department of Zoology, University of Guelph. This is Contribution No. 5161 from Woods Hole Oceanographic Institution and Contribution No. 57 from Woods Hole Oceanographic Institution's Matamek Research Station.

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