Density of brown trout, Salmo trutta L., and Atlantic salmon, Salmo salar L., parr after point and scatter stocking of fry

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Density of brown trout, *Salmo trutta* L., and Atlantic salmon, *Salmo salar* L., parr after point and scatter stocking of fry

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Abstract Atlantic salmon, *Salmo salar* L., and brown trout, *Salmo trutta* L., fry were point and scatter stocked in the early part of June at densities of 63–263 fry 100 m^{-2} per species in the River Viantienjoki, a small river in northern Finland, and their population densities were assessed in late summer. Both species were always stocked together in similar quantities. Point stocking was used in the first 2 years and scatter stocking in the following 2 years. In point stocking, there was no correlation between the distance from the stocking sites (maximum = 250 m) and parr density in census sites ($r = -0.013$ and 0.019 for brown trout and Atlantic salmon, respectively). The stocking density of fry did not influence parr density in August by either method or by species. Stocking density explained only from 11% to 23% of the parr survival depending on the species or stocking method. The mean densities of Atlantic salmon and brown trout parr did not differ significantly from each other at any fishing site ($P > 0.05$). Both point and scatter stocking appear to be suitable methods for use in small rivers. The parr densities depend more on the other factors (e.g. habitat quality) than the stocking method, and the choice between methods could be based on the time and labour available.

KEYWORDS: brown trout fry, density, Atlantic salmon fry, stocking, survival.

Introduction

In Finland, over one million brown trout, *Salmo trutta* L., and Atlantic salmon, *Salmo salar* L., fry are now stocked annually; in 1994, the total was 1.3 million (Anonymous 1995). Stocking is labour intensive and expensive because most fry are stocked in small rivers, usually far away from roads. Fry are transported to the stocking places in plastic bags filled with water and oxygen, where they are released along rapids. Distribution has been considered important, although stocking is usually made after the highest spring flood, when the current is still strong. It has been assumed that fry are unable to disperse evenly into all suitable habitats, although the downstream movement of fry has been related to water velocity (Ottaway & Clarke 1981; Ottaway & Forrest 1983). According to several studies (e.g. Mortensen 1977; Randall 1982; Elliott 1986; Heggenes & Traaen 1988), the downstream dispersal of fry takes place

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immediately after emergence, and further downstream, dispersal occurs later as the fish grow in size and need larger territories.

Despite extensive stocking, dispersal of planted fry has not been studied in Finland. It is not known whether downstream movements are enough to spread fry throughout the rapids or whether the fry need to be spread widely when planted. The aim of the present study was to compare point and scatter stocking methods to determine which would give the best results. Because Ottaway & Clarke (1981), Crisp & Hurley (1991a,b) and Crisp (1991) observed differences between the behaviour patterns of young Atlantic salmon and brown trout, the dispersion and survival of these species stocked in the same place was also studied.

Materials and methods

The River Viantienjoki is a small forested river in northern Finland, flowing into the northern part of the Gulf of Bothnia (Fig. 1). The length of the river is about 25 km and the mean discharge (MQ) about 1.5 $m^3\ s^{-1}$. The width of the river is 2–3 m in the upper half and 8–10 m in the lower half. Because of its low gradient, the rapids are mostly short (50–100 m) and pool

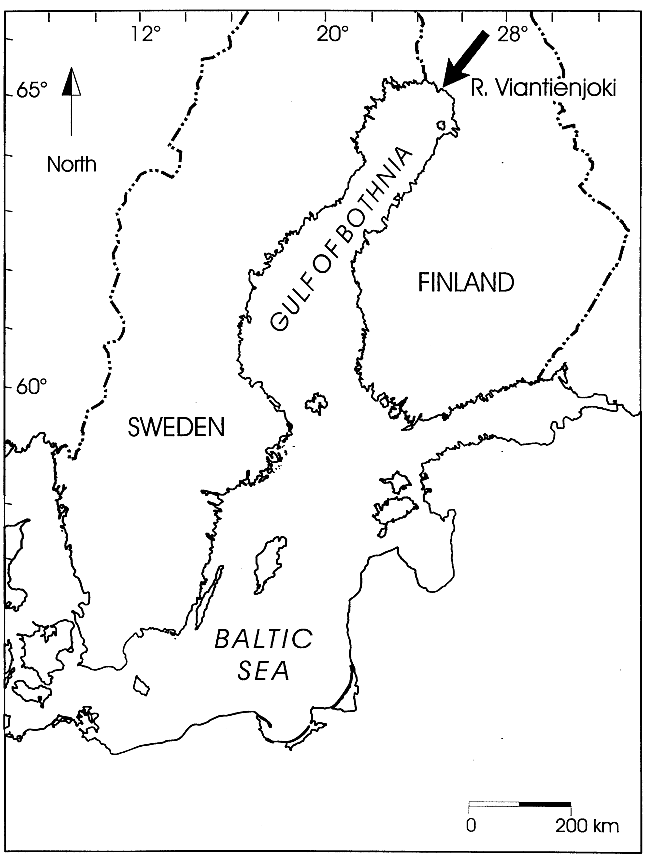

Figure 1. River Viantienjoki flowing into the northern part of Gulf of Bothnia.

areas dominate. The water is humic and brown in colour because of a swampy drainage area. The most common species of fish are grayling, *Thymallus thymallus* (L.), pike, *Esox lucius* L., burbot, *Lota lota* (L.), and Siberian bullhead, *Cottus poecilopus* L. The river is covered in ice from October until early May. Dredging of the river in the 1950s lowered the water level in the pools.

Rainfall data are available from the Simoniemi meteorological station (number 6302), which is situated ≈ 2 km from the river mouth. The rainfall during the period from stocking to electric fishing was relatively low in 1994, especially in July. During the next 3 years, summer rainfall was about twice as high as in 1994. During June, the daily mean precipitation did not vary very much from year to year (Table 1). This is important when results between years are compared

Table 1. Mean daily precipitation from the date of stocking in June to 10 August in 1994 and 1997. The daily mean is given for the whole period and for each month

	Mean daily precipitation (mm)			
Year	June–August	June	July	August
1994	0.84	1.48	0.35	0.88
1995	1.50	1.34	1.76	0.95
1996	1.52	0.92	1.74	1.87
1997	1.74	1.55	2.38	>0.14

because most of the dispersal of fry occurs within a few weeks of stocking when initial densities are high (Crisp 1993), and the number of fry moving downstream in experimental channels has been related to water velocity (Ottaway & Clarke 1981; Ottaway & Forrest 1983; Crisp & Hurley 1991a,b; Crisp 1991). Because no discharge information is available for the River Viantienjoki, the evaluation of current and water velocity was based on precipitation data.

Newly hatched, unfed brown trout and Atlantic salmon fry were released in several rapids in the River Viantienjoki over four successive years. The fry were stocked when about one-third of their yolk-sac remained, usually at the beginning of June. The mean stocking weight of fry varied from 0.1 to 0.2 g. Two species were used in the stocking to study differences in post-stocking dispersion and survival between species. Point stocking was done in spring 1994 and 1995, and scatter stocking in 1996 and 1997. The numbers of fry stocked were estimated from their wet weight.

In the point stocking, equal numbers of brown trout and Atlantic salmon fry were released simultaneously at a single site near the head of the rapid. The numbers of stocked fry, and thus, the corresponding density varied between rapids and also between years. In 1994, the densities were slightly lower than in 1995 (Table 2). In the scatter stocking, fish were kept in a tub and dispersed with a scoop along the length of the rapid. The stocking density in the scatter stocking in 1996 was about the same as in the point stocking in 1995. In 1997, the number of stocked fry was less than half of that in 1996. This was to test whether a considerable change in stocking density had any effect on the parr density in autumn. Also, brown trout and Atlantic salmon fry were released in equal numbers in the same rapid in scatter stocking, but the

Table 2. Numbers and the corresponding mean stocking densities of Atlantic salmon and brown trout fry released annually in the River Viantienjoki. Water temperatures when stocking occurred are also given

		Total number of stocked fry		Mean stocking density ± SD (n 100 m^{-2})*		
Date of stocking	Stocking type	Atlantic salmon	Brown trout	Atlantic salmon	Brown trout	Temperature range (°C)
7/6/94	Point	13 530	13 755	151.9 ± 55.2 (102–211)	154.7 ± 59.0 (103–214)	9.5–10.5
9/6/95	Point	20 420	20 460	193.7 ± 20.9 (140–203)	193.9 ± 20.3 (142–204)	13.4–14.5
13/6/96	Scatter	20 300	20 350	192.2 ± 21.4 (141–208)	192.3 ± 21.0 (141–204)	10.5–12.0
10/6/97	Scatter	7900	7900	75.0 ± 6.6 (63–83)	75.0 ± 6.6 (63–83)	13.4–15.9

densities varied between the rapids. Because of the stocking protocols used, upstream dispersal of fry could not be studied although it may happen (Elliott 1986; Hume & Parkinson 1987; Crisp 1995).

Stocking was carried out in six rapids in 1994, and in seven rapids in 1995, 1996 and 1997. The numbers and stocking densities of fry in different years are given in Table 2. The results from point stocking in 1994 and 1995 were pooled, and there was no statistical difference in parr densities between these years. The rapids were sampled by electric fishing with backpack electric fishing apparatus between late July and early August. Usually, two areas in each rapid were fished, one in the upper part directly below the stocking site and one in the lower part. The distance between the upper and lower site varied from 50 to 240 m depending on the rapid length. For the study of parr densities, the successive removal method was used (Zippin 1958). If the catches did not decrease in the three successive fishings required by this method, the densities were calculated by using the mean fishing efficiencies, as suggested by Bohlin, Hamrin, Heggberget, Rasmussen & Saltveit (1989). The annual mean fishing efficiency varied from 0.319 to 0.606 with Atlantic salmon, and from 0.402 to 0.515 with brown trout parr.

The following assumptions were made when the results were analysed. Firstly, no natural reproduction of these species occurred in the study rapids. This was supported by the results of electric fishing surveys made in previous years. Brown trout fry were stocked for several years in the River Viantienjoki; however, no evidence of natural reproduction was observed. Secondly, older parr did not have any influence on the results because of their low numbers (see also LeCren 1973), probably because suitable habitats for older parr were scarce. Parr densities were compared by year, stocking method and species, using a Mann–Whitney U-test. The correlation between the density of parr in sample areas and the distance from the stocking site was studied. The difference in density and survival between Atlantic salmon and brown trout parr was tested with a Mann–Whitney U-test and a Kruskal–Wallis test, using the Systat 6.0 program.

Results

There were no correlations between the densities of Atlantic salmon or brown trout parr in

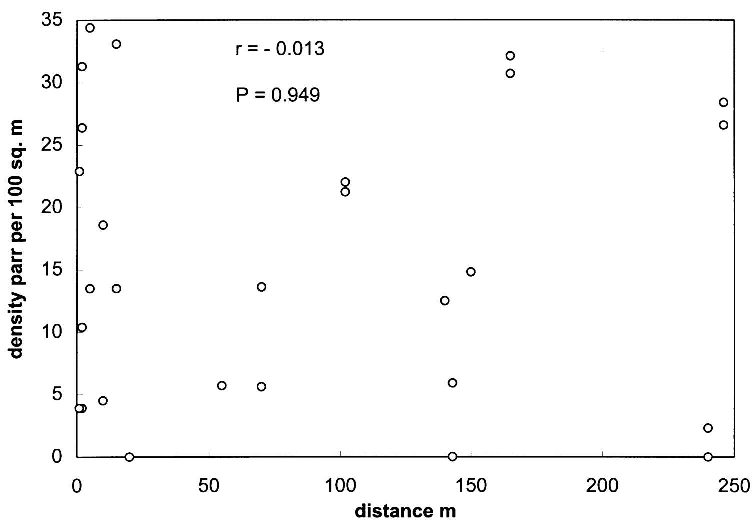

Figure 2. Plot of the density of brown trout parr against the distance from the stocking site after point stocking in 1994 and 1995.

autumn and the distance from the point of release of fry in point stockings (Figs 2 & 3). The mean densities of Atlantic salmon and brown trout parr produced from point and scatter stockings are given in Table 3. Statistically, there were no differences between the stocking methods either in brown trout densities (Mann–Whitney *U*-test: 405.0; $P = 0.815$) or in Atlantic salmon densities (*U*-test: 377.0; $P = 0.503$). Also, the densities of brown trout and Atlantic salmon were similar. In scatter stocking, the *U*-test value was 402.0 ($P = 0.478$), and in point stocking, it was 347.5 ($P = 0.465$).

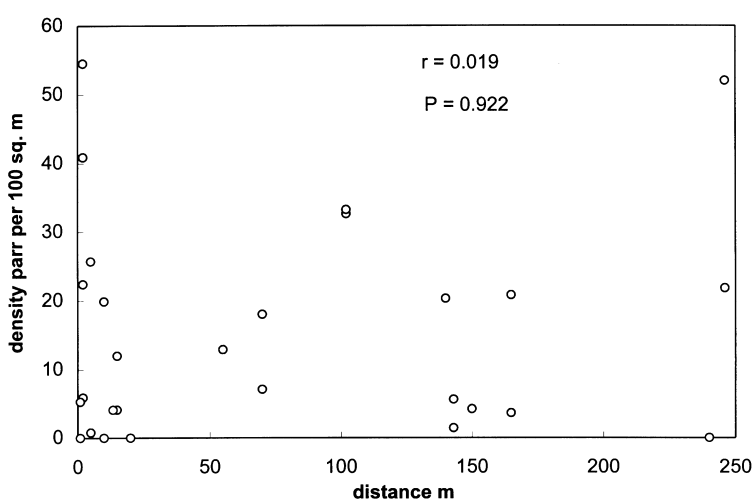

Figure 3. Plot of the density of Atlantic salmon parr against the distance from the stocking site after point stocking in 1994 and 1995.

Table 3. Mean density and survival of one-summer-old Atlantic salmon and brown trout parr after point and scatter stocking of fry in the River Viantienjoki between 1994 and 1997

Stocking type (year)	Species	Density (n 100 m^{-2}) Mean	Density (n 100 m^{-2}) SD	Number of census sites	Survival (%) Mean	Survival (%) SD
Point (1994)	Atlantic salmon	10.1	14.3	12	8.3	12.9
	Brown trout	15.6	12.5	12	11.9	11.2
Point (1995)	Atlantic salmon	19.0	16.3	16	10.5	10.0
	Brown trout	15.7	11.2	16	8.3	6.1
Scatter (1996)	Atlantic salmon	16.6	13.7	15	8.9	7.2
	Brown trout	19.8	14.7	15	10.5	8.0
Scatter (1997)	Atlantic salmon	13.8	12.2	15	18.6	16.4
	Brown trout	14.0	8.5	15	19.0	12.0

In point stocking, there was no difference in the densities of brown trout parr near the stocking place in the upper part of the rapid compared to the lower part (*U*-test: 104.0; $P = 0.494$), although the mean densities varied much between the rapids and also between the census sites inside the rapids (Fig. 4a). The same was noticed with Atlantic salmon parr (*U*-test: 88.0; $P = 0.922$, Fig. 4b). Also, in scatter stocking, there was no difference in parr densities in the census areas near the stocking place compared to the lower part of the rapid (brown trout parr *U*-test: 110.0; $P = 0.934$; Atlantic salmon parr *U*-test: 83.0; $P = 0.228$) despite the variation between the rapids and census sites (Figs 4c,d).

Despite the species or stocking method, the parr densities were very similar in some sites, indicating the significance of the habitat (Fig. 4). For example, in rapid number 1, the parr densities were always the highest in the uppermost census site. Rapid number 2 was obviously not suitable for Atlantic salmon or brown trout because parr densities were mostly low compared to other rapids. In rapid number 3, the parr densities were clearly higher in the upper census site compared to the lower site after point stocking and *vice versa* after scatter stocking. In rapid number 4, the lower census site seemed to be better than upper site because parr densities were always higher.

The parr densities in August varied randomly without any dependence with the number of released fry in both stocking methods (Table 4). The low coefficient of determination (r^2) showed that there was practically no relationship between the survival and the stocking density in both species and stocking methods (Table 5). The survival of parr varied from year to year (Table 3), but not significantly either with Atlantic salmon (Kruskal–Wallis: 6.285; $P = 0.099$) or brown trout (Kruskal–Wallis: 7.032; $P = 0.071$). When the stocking method was taken in to account, the only significant difference in survival between the years could be found in scatter stocking of Atlantic salmon (*U*-test: 63.0; $P = 0.04$). When scatter and point stocking was compared, no statistical difference could be found (Atlantic salmon *U*-test: 313.5; $P = 0.097$; and brown trout *U*-test: 309.5; $P = 0.085$). Although the survival of brown trout was slightly higher than that of Atlantic salmon, there was no statistical difference between the species

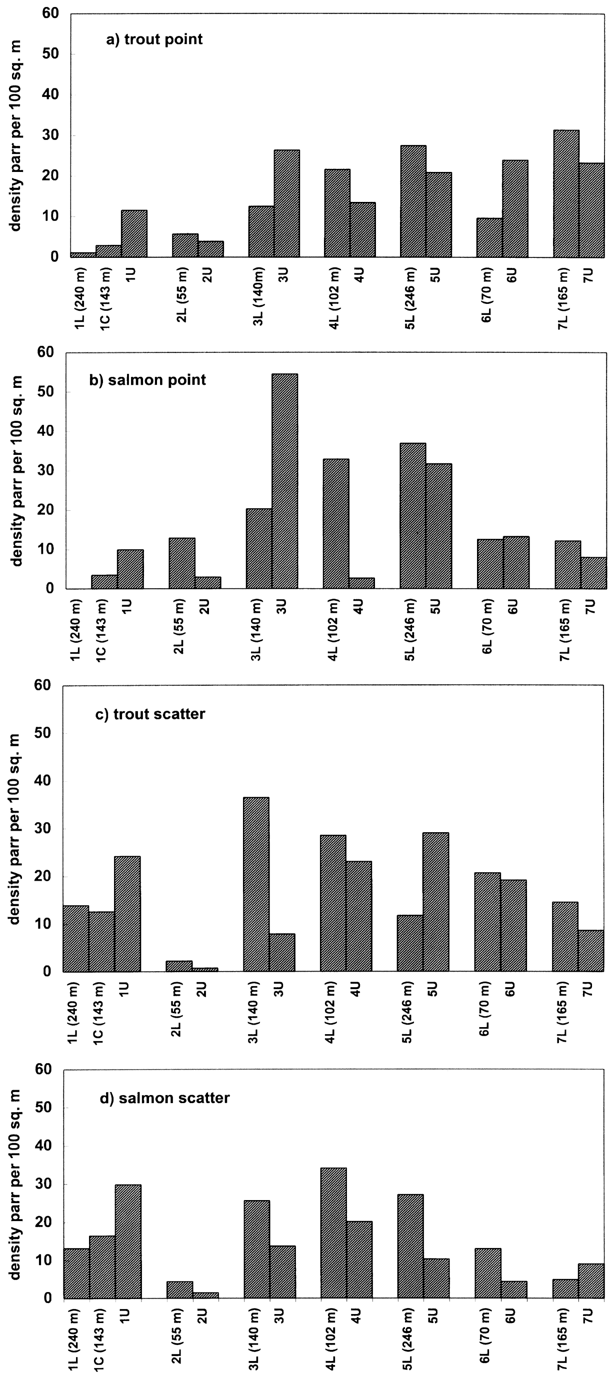

Figure 4. Mean population densities of brown trout and Atlantic salmon parr after (a, c) point and (b, d) scatter stocking in different rapids (1–7). The different census areas inside the same rapid have been separated with a letter: (L) lower; (C) centre; and (U) upper. The distance between the stocking site in point stocking and the upper limit of the lower census area is given in parentheses. The upper census area in each rapid was immediately below the stocking site.

Table 4. Summary of linear regressions relating the parr density in August to the number of fry stocked by point and scatter methods with the coefficient of determination (r^2) and the probability value (P)

Stocking type and species	Number of census sites	r^2	P-value
Point			
Atlantic salmon	28	0.016	0.516
Brown trout	28	0.032	0.361
Scatter			
Atlantic salmon	30	0.006	0.675
Brown trout	30	0.047	0.252

either in point stocking (U-test: 345.0; $P = 0.445$) or in scatter stocking (U-test: 396.5; $P = 0.429$).

Discussion

The present results show that there were no significant differences between the autumn brown trout and Atlantic salmon parr densities obtained with point or scatter stocking methods. In rivers of similar size to the River Viantienjoki, satisfactory results can be achieved with point stocking in rapids shorter than 250 m, which was the maximum length in the present study. The stocking densities used in the River Viantienjoki could be rated quite typical if these are compared to the densities mostly used in Finland. In the tributaries of the River Kiiminkijoki and River Iijoki, 350–900 brown trout fry were stocked 100 m^{-2} (Huovila 1982; Jutila, Karttunen & Niemitalo 1994). Also, the stocking densities in these rivers did not explain parr densities in autumn. The total densities of one-summer-old Atlantic salmon and brown trout parr (26–36 parr 100 m^{-2}) observed in the present study were slightly lower than Huovila (1982) found in stocking experiments with brown trout fry (32–101 parr 100 m^{-2}). Similar densities were found in a natural river (23 parr 100 m^{-2}) by Tuunainen & Kitti (1972) and by the stocking of brown trout fry in some restored rivers in northern Finland (Jokikokko 1987).

Table 5. Summary of linear regressions relating the survival rate (%) from stocking to August to the number of fry stocked by point and scatter methods with the coefficient of determination (r^2) and the probability value (P)

Stocking type and species	Number of census sites	r^2	P-value
Point			
Atlantic salmon	28	0.111	0.083
Brown trout	28	0.226	0.011
Scatter			
Atlantic salmon	30	0.159	0.029
Brown trout	30	0.189	0.017

The number of released fry was very low when compared to Crisp & Hurley (1991a,b) and Crisp (1991), who used 2000 and even 9400 fry 100 m^{-2} as an initial density in their dispersal studies in experimental channels. In these studies, the parr densities of trout and Atlantic salmon were significantly higher (120–1490 trout and 180–1380 Atlantic salmon - parr 100 m^{-2}) than in the River Viantienjoki, but despite the big difference, the ranges of population densities were similar for the two species. According to McMenemy (1995), the density of underyearling Atlantic salmon parr produced from fry scatter stocked at low density (mean = 32 fry 100 m^{-2}) was not significantly different from fry stocked at high density (mean = 117 fry 100 m^{-2}). Despite the higher stocking densities used in the River Viantienjoki, the final parr densities were very similar with McMenemy. Hume & Parkinson (1987) noted that an even bigger difference in fry densities did not affect the parr densities of rainbow trout, and according to them, 30–70 fry 100 m^{-2} maximized the production of parr and smolts. Gee, Milner & Hemsworth (1978) recommended 100 fry 100 m^{-2} as an optimum stocking density for unfed Atlantic salmon fry, a considerably lower number than is common practice.

McMenemy (1995) preferred stocking fry at low densities especially when fry were not abundantly available, but voluntary members of fisheries organizations can take care of the stocking because per-unit parr production is apparently not affected by low-density stocking. If large numbers of fry must be stocked in a short time, point stocking is a reasonable way to enhance the fish stocks in a small river, if the rapids are not long. According to Hume & Parkinson (1987) and Crisp (1995), to make the maximum use of available space, point-stocking should be made at points no more than 500 m apart, and preferably, at less than half this distance. In big rivers, newly hatched fry usually give poor results whatever the stocking method used and older parr should be used (Jutila, Huhmarniemi & Poikola 1987).

The results from the River Viantienjoki concern only yolk sack, unfed fry. Hume & Parkinson (1987) noted that fry did not respond to even very high densities in point stocking when they used fry which were fed for 1–2 months before stocking. After starting to feed externally, fry do not disperse as well as younger unfed yolk sac fry. The dispersal of point stocked unfed fry was three times greater than those of fry which were held for 1–2 months in the hatchery before being released. According to Heggenes & Traaen (1988), newly hatched fry cannot resist the speed of the current as well as fry which have started to eat. In the River Viantienjoki, the fry will enter the free-feeding swim-up stage soon after stocking, which is considered critical (Ottaway & Clarke 1981; Ottaway & Forrest 1983).

The physical condition of fry, the water velocity (Ottaway & Clarke 1981; Ottaway & Forrest 1983), and especially, the rate of flow change (Crisp & Hurley 1991a,b; Crisp 1991) and the quality of the stream bed (e.g. Karlström 1977; Jutila *et al*. 1994) are important factors. Heggenes & Traaen (1988) emphasized the importance of the complex current regime created by the rough substrata preventing the downstream wash-out of fry. The structure of the stream bed might also compensate the effects of the current changes possibly caused by the different precipitation in different years because the final parr densities did not differ from year to year. This may be one reason for similar densities of brown trout and Atlantic salmon parr in the River Viantienjoki.

Atlantic salmon and brown trout fry were noted to respond in different ways to different water velocities and flow changes (Crisp 1991), but in those experiments, the particle size was small (< 32 mm) compared with the natural river bottom with big stones and boulders giving shelter to fry against the current. Because of the stream bed roughness, the water velocity varies, giving a suitable habitat for both brown trout and Atlantic salmon, and this may be one reason that no species-specific differences in parr-stage densities could be seen in the River Viantienjoki. According to the mean parr densities, some census sites seemed to be better than others. It is obvious that the habitat properties are more a dec-sive factor for the parr density than stocking method, and for example, utila *et al*. (1994) have stressed the importance of stream bed structure for brown trout parr.

Heggenes & Traaen (1988) demonstrated that the critical current increases with increasing water temperature since the temperature influences swimming performance considerably. In the River Viantienjoki, the temperature was measured only at stocking and was quite similar in different years. It should not have affected the swimming ability and the dispersal of fry at stocking phase in the present study. However, water temperatures during the summer may increase or decrease the availability of suitable prey animals, and this can effect growth and survival of fish. Because water temperature during summer was not measured a possible effect upon dispersal rate cannot be excluded. Based on the quite similar results from year to year, it seems that the state of fry and the conditions in the river were comparable in different years.

When stocking densities of 300–400 fry 100 m^{-2} were used in the River Viantienjoki, the survival remained about the same (8.3–11.9%) despite the stocking method. When stocking density was halved (150 fry 100 m^{-2}), the survival was roughly doubled in scatter stocking. Such a large difference in stocking density was not tested in point stocking. It was noted earlier that survival of Atlantic salmon is density dependent, with high-density stocking yielding lower survival rates (LeCren 1973; Mortensen 1977; Gee *et al*. 1978; Hume & Parkinson 1987). With high stocking densities, the survival of Atlantic salmon and brown trout parr in point and scatter stocking in the River Viantienjoki was almost identical to the survival (11.6%) found by McMenemy (1995) in scatter stocking with a mean density of 117 fry 100 m^{-2}. Crisp (1995) observed 19% and 14% survival of 0 + Atlantic salmon in point stocking. Survival was even higher (27%) in scatter stocking, when stocking densities were 180 and 190 fry 100 m^{-2}. In earlier studies, Crisp (1993) mentioned that the survival of brown trout from swim-up to early August was a little less than 10% of the number stocked, regardless of stocking density (at least up to about 1000 fish 100 m^{-2}).

According to the present study, both species seemed to have equal survival rates and similar dispersal in the River Viantienjoki. As sampling was within the rapids where fry were stocked, emigration out of the study area was possible. Elliot (1986) found population losses were chiefly a result of mortality rather than migration during the first spring and summer of the lifecycle. If emigration happens in the River Viantienjoki, it means virtual mortality because the stocking rapids were segregated by very long (more than several hundred metres) pools both up- and downstream.

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