Carrying Capacity of an Enhanced Side-Channel for Rearing Salmonids

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Two attempts were made to establish the yield of steelhead smolts (sea-run rainbow trout) (*Salmo gairdneri*) from a seminatural side-channel and compare it to that of the parent river. In the first, 10 000 fry were introduced to the channel which was maintained at a discharge of 0.42 m^3/s. The fry, however, were largely displaced by extraneous coho salmon (*Oncorhynchus kisutch*), appeared unable to withstand the water velocity in winter, and were greatly reduced by infection from *Cryptobia*. In the second trial discharge was 0.14 m^3/s. The fry tolerated this. The yield (i.e. numbers) per unit area of steelhead smolts, of mean weight 14.5 g, was 31 times that of the river; in terms of biomass it was 10 times. Channel discharge was 2.6% of the river discharge. Physical and biological factors determining smolt yield from streams are considered.

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Nous avons tenté par deux fois de déterminer le rendement de la truite arc-en-ciel anadrome (*Salmo gairdneri*) d'un chenal secondaire semi-naturel et de le comparer à celui de la rivière d'origine. Au cours du premier essai, 10 000 alevins ont été introduits dans le chenal, dont le débit a été maintenu à 0,42 m^3/s. Toutefois, des saumons cohos étrangers ont déplacé en grande partie les alevins, qui semblaient incapables de résister à la vitesse de l'eau en hiver et ont été décimés par une infection de *Cryptobia*. Au cours du second essai, le débit s'élevait à 0,14 m^3/s, vitesse bien tolérée par les alevins. Le rendement des saumoneaux de truite are-en-ciel anadrome, dont le poids moyen s'élevait à 14,5 g, a été de 31 fois plus élevé que celui de la rivière par superficie unitaire. En terme de biomasse, cela équivalait à 10 fois celui de la rivière. Le débit du chenal représentait 2,6 % de celui de la rivière. Les auteurs étudient aussi les facteurs physiques et biologiques qui déterminent le rendement des saumoneaux dans les ruisseaux.

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THERE is evidence that side-channels of streams, either single channels or the multiple channels of braided rivers, can be more productive of juvenile salmon and trout than the main stems. For example juveniles of coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) in Campbell River, east Vancouver Island, B.C., occur in conspicuously higher numbers in a channel that runs a short distance along the north side of the river than in the main stem (Hamilton and Buell 1976). Side-channels may also be favored by overwintering juveniles, if they have less extreme freshets than the main river, contain pools with clean rubble, and have overhead cover (cf. Bustard and Narver 1975).

The construction of a side-channel, initially used for high-density seminatural rearing of coho (Mundie 1980), alongside the Big Qualicum River on east Vancouver Island, presented an opportunity to assess the natural carrying capacity and to compare it with that of the river. The river is exceptional in having controlled flow (Lister and Walker 1966). The channel also has controlled flow, and in addition has features that are known to enhance natural production. Our objective was to measure the difference in annual yield, per unit area, of salmonids from the two systems. Steelhead trout (sea-run rainbow trout) (*Salmo gairdneri*) was the selected species. In the first year (1980–81) only one age-class was reared, but in the second (1981–82) two coexisted so the wild state was simulated. Results from the 1st year compelled changes in conditions to be made for the second; moreover, unforeseen factors arose that influenced the outcome of the trials.

Methods — The experimental channel was a diversion, 396 m long, off the Big Qualicum River about 5 km upstream of the river mouth. A screened intake and outlet prevented fish escaping from the channel. Channel width was 4.57 m and area 1810 m^2. Discharge was controlled by an intake valve and was set initially at 0.42 m^3/s. The bed was a series of 25 gravel riffles, each 6 m long and 15 cm deep, alternating with 25 pools 9 m long and 0.9 m deep. The surface velocity of the riffles was 60 cm/s and of the pools 10 cm/s. Floating plywood on the pools gave cover for the fish and a net canopy kept out herons and mergansers.

Fertilized eggs from Big Qualicum River 1980 steelhead adults were incubated, and fry were reared in tanks for 4 mo.

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In early October 1980 (first trial), 10365 fry of 5 g mean weight, tagged with coded wire nose tags and with adipose fin removed, were introduced to the channel along its length. No artificial food was offered (but see Results). In May 1981 the outlet screen of the channel was removed and outmigrants were collected in a trap, counted, and then released. In October 1981 (second trial) 1000 fry from 1981 adults, similarly treated, were introduced to the channel at 8 g mean weight. Outmigrants were again recorded in May and June, 1982. Remaining nonmigrants were then enumerated.

To maintain the gravel for benthic production, the channel was cleaned in stages in August 1980 and 1981. Each riffle was scoured with a jet from a fire hose to a depth of 20 cm. During this operation discharge was 0.42 m^3/s so that dislodged sand could be transported out of the channel.

Results — Monthly mean temperatures of the channel over the two trials ranged from 4.7°C to 13.0°C as follows:

	J	F	M	A	M	J	J	A	S	O	N	D
1980									12.7	11.8	10.6	7.5
1981	7.2	6.7	7.7	9.0	8.3	11.7	12.5	12.0	11.5	12.3	10.8	7.6
1982	5.2	4.7	5.2	7.6	10.7	13.0						

As the river was lake-fed the temperatures were high enough to permit feeding by the trout at least until January. The diet consisted of ephemeropteran nymphs and chironomid larvae, with smaller quantities of trichopteran larvae. Filamentous algae were also present. This suggested that the trout were grazing insects off the substrate.

The first trial lasted from October 1980 to June 1981. During November and December, dead or dying fish, amounting to about five per day collected on the downstream screen. Unrecorded mortality also occurred, as moribund fish were removed by birds and mink (*Mustela vison*). Throughout January and February deaths increased, until in late February they amounted to 50 per day. The fish were emaciated and had difficulty holding position. Some of the moribund specimens were infected with the flagellated protozoan *Cryptobia salmositica*, which occurs naturally in *S. gairdneri* in streams and hatcheries (Putz 1972). We decided to conclude the experiment and to feed the remaining fish so that they could provide a 1+ class for the second trial. Accordingly, fish were fed a commercial food lightly in March only. In addition, discharge was lowered to 0.14 m^3/s until the following summer. Mortality diminished to a few fish per day.

In mid-May the downstream screens were removed and outmigrants counted. Most of the trout migrated between May 20 and May 26. The total numbers at the end of the migration (June 25) were 99 steelhead smolts (mean weight 19.5 g with a range of 10.5−36.0 g) and 22 parr which were returned to the channel. In addition were 1553 coho smolts of mean weight 15.0 g. Therefore, the trout had coexisted with coho which must have entered the channel from the river through the screen immediately after emergence in May.

The second trial lasted from October 1981 to June 1982. Discharge was maintained at 0.14 m^3/s and the 1+ steelhead parr coexisted with the 0+ fry.

In the winter of 1981−82 recorded deaths of trout of both year-classes amounted to 2300. Death was attributed to infection by *Cryptobia* as evidenced by swollen eyes in the fish recovered. The disease also affected the Big Qualicum hatchery stock of coho. The trout were thin, but not emaciated; nor had they difficulty holding position at the lower discharge. In January the ratio of the 0+ and 1+ fish was 6:1 on the basis of tags extracted from dead fish. By April it was 9:1.

The outmigration of trout in spring 1982 amounted to 1200 smolts of mean weight 14.5 g, and range 7.5−46 g; 7% were over 20 g. Half the run left between May 19 and 22, and the run continued until June 15. (The natural run from the river usually peaks between late May and early June.) In addition 15 coho smolts migrated. The small numbers of coho are attributed to the fact that any newly emerged coho entering the channel in the spring of 1981 would be eaten by the trout; alevins were found in trout stomachs at that time.

Between June 15 and 17 the remaining nonmigrant population was assessed. Discharge was lowered to 0.014 m^3/s so the riffles were exposed and the fish were confined to the pools. Each pool was seined and a total of 2598 parr of mean size 19 g was obtained. Each pool was then electrofished and a further 350 parr were collected. In total, then, the yield of migrant and nonmigrant trout by mid-June was 4248.

The possible categories of trout that migrated or remained in the channel were smolts, parr that migrated (parr commonly disperse in the spring), parr that remained but would become smolts within the next few weeks (some parr were taken that were losing their parr marks and becoming silvered), parr that would smoltify next spring, and finally resident trout that would not leave. The bulk of the trout migrating had the appearance of smolts; they had lost their parr marks and were silvered, but in view of their small size there was some question as to their readiness to live in salt water. Several (identified by their marks) were taken in a trap for migrants near the mouth of the Big Qualicum River at the peak of the run, indicating migration from the river. In addition, a sample of 24 migrants of mean weight 18 g demonstrated excellent seawater adaptability in a 24-h seawater challenge test on May 31. In a second challenge test on June 15, nine nonmigrants (mean weight 13 g) suffered very high blood sodium levels in seawater while three out of four migrants (mean weight 22 g) again showed excellent seawater adaptability typical of smolts; there was no overlap of the two groups in the test (Dr C. Clarke, Fisheries and Oceans Canada, personal communication). Nearly all the nonmigrants had distinct parr marks. Their mean weight in June was 19.9 g; 4% were 1+ fish of mean weight 30 g.

Discussion — The first trial was an instructive failure. We deduced from it that the discharge of 0.42 m^3/s submitted the fish to excessive velocities in winter. Protection from high flows in winter appears necessary. For age 0 steelhead in natural streams this is usually found in shallow water among rocks; age 1+ steelhead seek cover under boulders in the main stem of rivers (Bustard and Narver 1975). Habitat diversity is therefore a requirement of survival. Crowding and disease also contributed to losses.

In the second trial the small size of the migrant smolts was attributable to their density in the channel; presumably surviving numbers were determined largely by the available food, hence much of what was consumed went into maintenance rather than growth. Small smolt size is likely to result in low marine survival and consequently very low returns of adults. We wonder if a similar biomass of trout could be produced with say, a third of the numbers. The thermal regime of the channel would have permitted the trout in the second trial (mid-October to mid-May) to reach a mean size of 45 g if fed to satiation (calculated from the model of Iwama and Tautz 1981). The mean weight of steelhead smolts leaving the river in years prior to flow control (1961/62, n = 50) was 35 g; after flow control (1973, n = 303) it was 55 g, but the age composition of these catches is not recorded (Fisheries and Oceans, unpublished data).

The numbers and biomass of trout smolts leaving in the spring of 1982 amounted to 0.663 smolts/m^2 and 9.94 g/m^2. The Big Qualicum River produces on average 0.021 smolts/m^2 and 0.94 g/m^2 (Federal/Provincial unpublished data; a commonly accepted figure for steelhead smolt yield in west-coast streams is 0.025/m^2). The channel, therefore, produced per unit area 31 times as many smolts as the river and 10 times the biomass. The residual parr amounted to 1.684/m^2 or 25.26 g/m^2.

Apart from flushing flows (which may reach 24 m^3/s) in September, the river is usually run at about 5.6 m^3/s in the fall, 8.5 m^3/s in January and February, 4 m^3/s in April and May, and between 1.3 and 2.8 m^3/s in the summer months (Minaker et al. 1979). This gives a mean discharge of about 5.4 m^3/s in the period October–May, which is 38 times the discharge of the channel, i.e. the channel discharge was 2.6% of the river discharge.

For coho, small streams in B.C. yield about 0.73 smolts/m^2 or 4.6 g; large ones yield about 0.24 smolts at 3.5 g/m^2. The Big Qualicum yields 0.17 smolts/m^2 at 2.0 g (D. E. Marshall, Fisheries and Oceans, unpublished data). The data on coho smolt yields for the channel in 1981 represented a yield of 0.85 coho/m^2, or 12.8 g/m^2.

In addition to having a discharge more beneficial, both for summer residence and for overwintering, than that of the river, the channel had features that presumably contributed to high survival, i.e. the canopy, floating cover, a 1/1.5 riffle/pool ratio, and a uniform gravel that promoted benthic food organisms. It is not possible to assess the relative importance of these features. It is apparent, however, that there are contrasting requirements of the fry feeding from spring to winter, and of the overwintering fingerlings. Whereas the latter require low-velocity water and submerged and overhead cover, the former need higher discharges to promote food production and to maintain gravel quality. In the channel, gravel quality was maintained by an "artificial" freshet when the channel was cleaned.

From the yield of steelhead smolts and residual parr it appears that a commonly employed biologists' guideline of a twofold difference between side-channel and mainstem juvenile carrying capacity is conservative. Finally, it is evident that advances in understanding the factors determining salmonid production in streams are most likely to be made in field situations where discharge can be controlled.

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