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The influence of predation after release on the result of
salmon smolt planting

by

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Introduction

Great losses as a result of predation after release of reared salmonides is an international problem, as can be seen from various publications on the subject (for instance Elson 1962, Fraser 1974, Kanayama & Tuge 1968, Larsson & Larsson 1975, Piggins 1958, Thompson & Tufts 1967). For the salmon smolt planting in Sweden, the model of the Baltic Salmon population of the reared stock predicts a first-year mortality of about 85 % (Larsson 1975 and 1974). The major mortality factor is here indubitably the immediate post-release predation. This certainly holds true for the situation in the river Luleälven in the northern part of Sweden.

About 550 000 hatchery reared salmon smolt and 60 000 sea trout smolt are released every year at the hydro-electric power plant at Boden, some 40 km upstreams the river mouth. An attempt to estimate the extent of the immediate post-release predation was done in 1974. Burbot (*Lota lota*) has been found to be the most important predator in this river, and a gathering of burbot to the place of release occurs. The investigation was therefor focused upon this species.

Methods

Burbots were caught in two different areas of the outlet basin of the power plant. Area 1 situated close to the releasing place of the smolt, and area 2 about 50 m downstream in the "mouth" of the outlet basin (see fig. 1). The traps in area 2 were in use from May 22 to October 8, and the wire cages used in area 1 from May 27 to June 7. The traps in area 2 are normally used for the catching of spawning migrating salmon, and this fishing started on the 10th of June this year. In this case only the number of burbot was counted without estimation of weight.

Larger specimen of burbot could enter the outlet basin til the 4th of June. After that date the space between the traps was closed with net, allowing only smaller burbot to pass.

In the period of May 28 - June 7 an intensive investigation of the stomach content of burbot was undertaken. The burbot were cut open immediately after the examining of the traps and cages, and the number of salmon smolt and other identifiable species was counted. The weight of the burbots was estimated with the significans of the approximation within the range of 1 hektogram. Several controlweighing were made to check the significans of the estimations.

A number of burbot and also pike (*Esox lucius*) were caught with pole net and common fishing methods during this period.

Results

Totally 4 935 burbot were caught from May 22 to October 8, weighing about 7 000 kg. The result of the burbot catching is given in table 1.

Most of the burbot were caught in trap no 1 (area 2), indicating that the burbot were entering the outlet basin from the relatively calm part of the river. Trap no 2 in the middle of the swift current also had the lowest catching rate (fig. 1).

Table 1 has been divided into periods in order to show the correlation between the gathering of burbot and the release of smolt. In 1974, the release of smolt occurred during the period of May 20 - June 12. During this period the catch in trap no 1 was about 43 burbot/examining, compared to only about 5 burbot/exam. before the first occasion of release and about 20 burbot/exam. later in the summer.

Table 1: The catches of burbot at the hydro-electric power plant at Boden, river Luleälven, 1974.

Method of catch and time	no. exam.	no. burbot	weight		no. burbot/exam.
			Tot. kg	Mean weight	
Trap no 1, 16/5-20/5	4	20	17.5	0.9	5
"- 22/5-15/6	42	1731	2770.0	1.6 ^x	41
"- 17/6-30/6	17	399	598.5 ^{xx}	1.5 ^x	23
"- 1/7-22/7	21	393			19
Trap no 2, 17/6-30/6	15	127			8
"- 1/7-22/7	24	74			3
Trap no 3, 17/6-30/6	19	260			14
"- 1/7-22/7	21	156			7
Trap no 1, 2 and 3 23/7-8/10		1121			
Wire cage (area 1) 27/5-7/6	16	361	332.3	0.9	23
Fishing 29/5	-	8	18.0	2.3	
Pole net 27/5-4/6	-	14	14.0	1.0	
Total		4935		1.56	

x Only for the exam. 18/6 and 19/6, 70 burbot.

xx Calculated from the mean weight of 1.5 kg.

A further convincing support for the hypothesis of the gathering of burbot as a result of burbot being attracted by the released smolt, is given in a comparison between the daily catch of burbot in trap no 1 and the days of release for the smolt (see fig. 2). There is a strong correlation between the day of release and an increase in the number of burbot per examining. After the first release of smolt, the peak of burbot/exam. occurs two days later. After that, however, the "burbot peak" is closer to the releasing day, indicating that the burbot are gathering outside the outlet basin (probably in the calmer parts of the river) to enter the basin when smolt are released.

The result of the stomach analysis is given in table. 2. The mean number of smolt/burbot is 2.1 in area 1 and 0.7 in area 2. Burbot caught in area 2 are entering the basin, while burbot caught in area 1 already in the basin have had the opportunity to prey upon newly released smolt.

Table 2: Stomach analysis of burbot caught during the period of May 28 - June 6 1974 in river Luleälven.

	no. burbot	no. smolt	no. other spp.	% stomachs with smolt	no. smolt per burbot	no. smolt per kg burbot	no. other spp/burbot
Area 1	275	566	90	69 %	2.06	2.5	0.33
Area 2	949	674	544	42 %	0.71	0.5	0.57
Total	1224	1240	634	48 %	1.01	0.8	0.52

The size of the burbot is not positively correlated to the number of smolt eaten. The number of smolt/burbot was compared between burbot weighing 0.5 kg or less and 1.5 kg and more for burbot caught in area 1 on the 28th, 29th and 30th of May. The mean number of smolt/burbot was 3.2 for the 0.5-and-less category, and 2.9 for the 1.5-and-more category.

The length of the consumed smolt was not measured. In order to detect any selectivity of the burbot for smaller or larger prey, a comparison between the length distribution of all tagged smolt found in burbot stomachs (57), and the length distribution of all tagged smolt released in the river Luleälven this year was done. The meanlength of tagged smolt found in stomachs is 17.0 cm, and for all tagged smolt 18.0 cm. The difference is significant (0.01 p 0.001), indicating a preference for smaller prey, maybe on a relative basis.

At the 7th of June, 455 340 salmon smolt had been released. 28 285 of these were tagged, or about 6.2 %. Of the 1 240 salmon smolt found in burbot stomachs during the same period, 49 were tagged, or about 4 %. This indicates that burbot do not prefer tagged fish.

Discussion

The high predatory dependent mortality is of course influenced by many factors, both on the "predator side" and on the "prey side".

In river Luleälven there is a gathering of burbot to the place or area of release. This could either be caused by a natural migration being cut off by the dam building, or be caused by the burbot being attracted to the supply of prey easy to catch. The latter explanation is supported by the fact that there is a correlation between the increase of number of burbot/exam. and the day of release (fig. 2). Furthermore it has been found for many predatory species to switch from wild prey to reared prey of the same species as soon as the reared prey has been introduced (i.e. Thompson & Tufts 1967).

The concentration of burbot seems to be restricted to the area close to the outlet basin. A group of tagged salmon smolt was released about 5 km downstreams the power plant in 1973, and this group show a clearly significant increase in survival as compared with controlgroups released in the basin.

Observations of the predatory behaviour of burbot in a stream tank indicates that they are slow predators, hunting from what one might call "ambush behind its own cryptic colouration", usually lying on the bottom waiting for the prey to come close enough (Jacobsson & Järvi 1976). The burbot observed in the outlet basin showed a different behaviour. These burbot were actively hunting, swimming around in the current, chasing the prey. This indicates adaptations to the rather specific situation in the releasing area of this river.

Salmon smolt have furthermore to cope with other predators on their downstream migration. Pike is known to be an important predator in this river and in many other rivers. Salmon smolt seem, however, to have an innate avoidance reaction to pike or pike-like predators, but no reaction to predators like burbot (Jacobsson & Järvi 1976). This has of course consequences in the vulnerability of salmon smolt in encounters with burbot.

Reared salmon smolt are totally inexperienced with fish predators when released. In interactions with a pike, the genetically based avoidance reaction may help a reared smolt to escape predation even in the first encounter. Lacking such a reaction towards a burbot, released salmon smolt are a fairly easy prey for a burbot.

The lack of predator experience is an important factor in the predator-prey relation between salmon smolt and burbot, as can be seen from experiments with predator avoidance conditioning (Larsson 1977). Reared salmon smolt conditioned to avoid a burbot show a significantly increased survival compared to control smolt.

Similar results have been obtained by giving coho salmon fry (Patten 1977) or sockeyes salmon fry (Ginetz & Larkin 1976) experience with a natural predator, or by conditioning young of chum salmon to models of predators (Kanayama & Tuge 1968). These findings further emphasize the importance of predator experience.

Avoidance conditioning is useful in a case when the predator is of a "burbot type". A salmon smolt for instance, will survive a confrontation with a burbot by avoiding the very nearness of the predator. This can also be obtained with a conditioning procedure. The avoidance reaction established with conditioning does not necessarily mean that the salmon smolt have obtained an adequate reaction towards a burbot, but will help the smolt to survive the first encounter with such a predator. With other predators like pike or the common loon (*Gavia immer*) a conditioning procedure is quite ineffective and may even be harmful (Fraser 1974).

In order to get an idea of the total extent of predation within the outlet basin, the number of burbot has to be estimated.

More than 2 000 burbot were caught during the smolt release period when burbot had free access to the basin. Nearly 400 burbot were caught in a limited area in the basin with very simple means. A total catch of about 4 000 burbot per year seem to have very little influence on the population (burbot were caught 1975 and 1976 as well). On the basis of this, one can estimate the number of burbot within the area to be at least 10 000. With the minimum frequency of smolt per burbot - 0.7 - and assuming that the predation rate is constant throughout the period of smolt release, the total amount of smolt being taken by predators will be $10\ 000 \times 0.7 \times 25 = 175\ 000$ smolt. This is really minimum figures and the actual number is very probably much higher.

Considering the fact that the salmon smolt have several kilometers of migration in the river with many other predators it is obvious that the predation is of such importance that it probably is determining the result of salmon smolt planting in many Swedish rivers.

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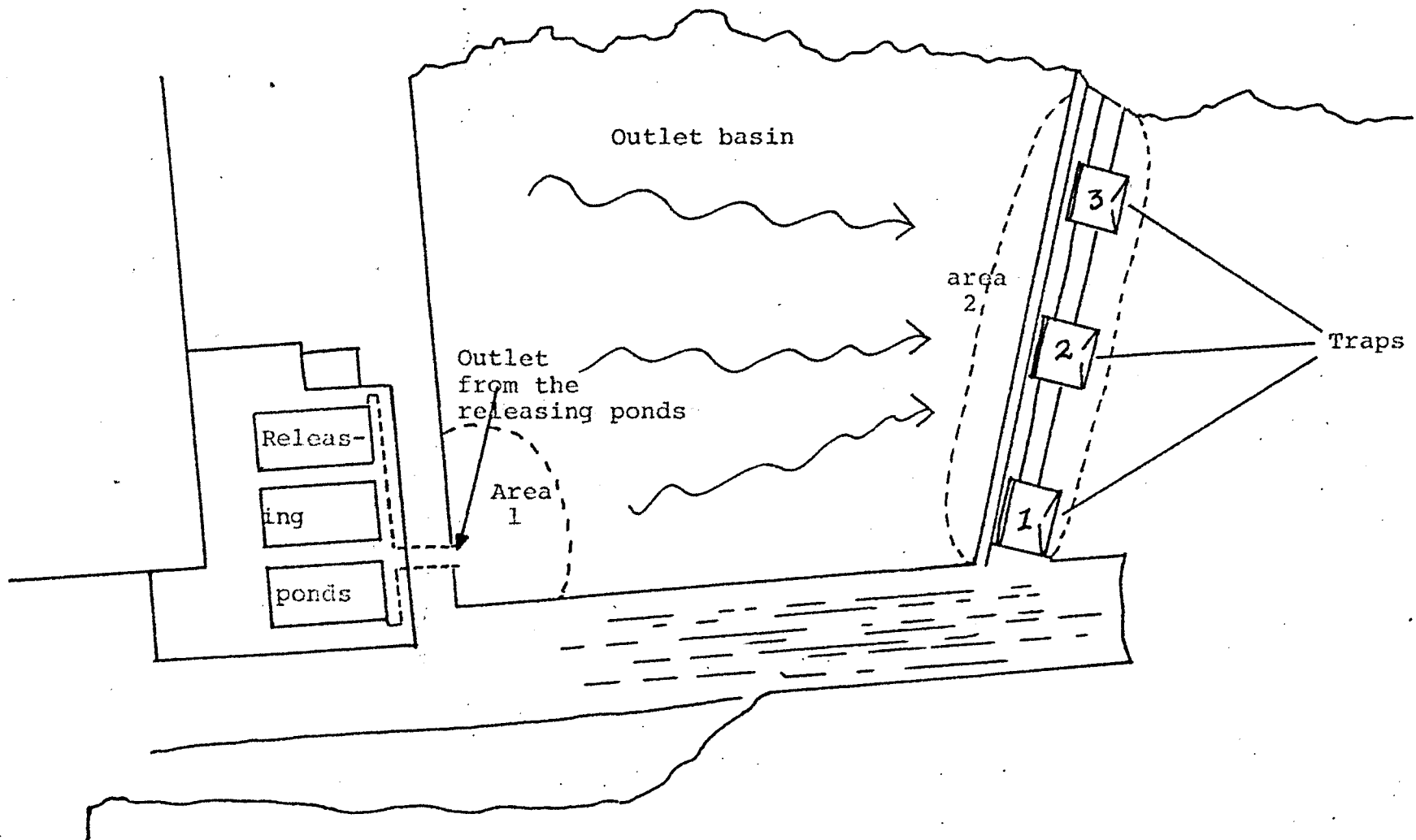


Fig. 1. Map over the area at the hydro-electric power plant at Boden, river Luleälven.

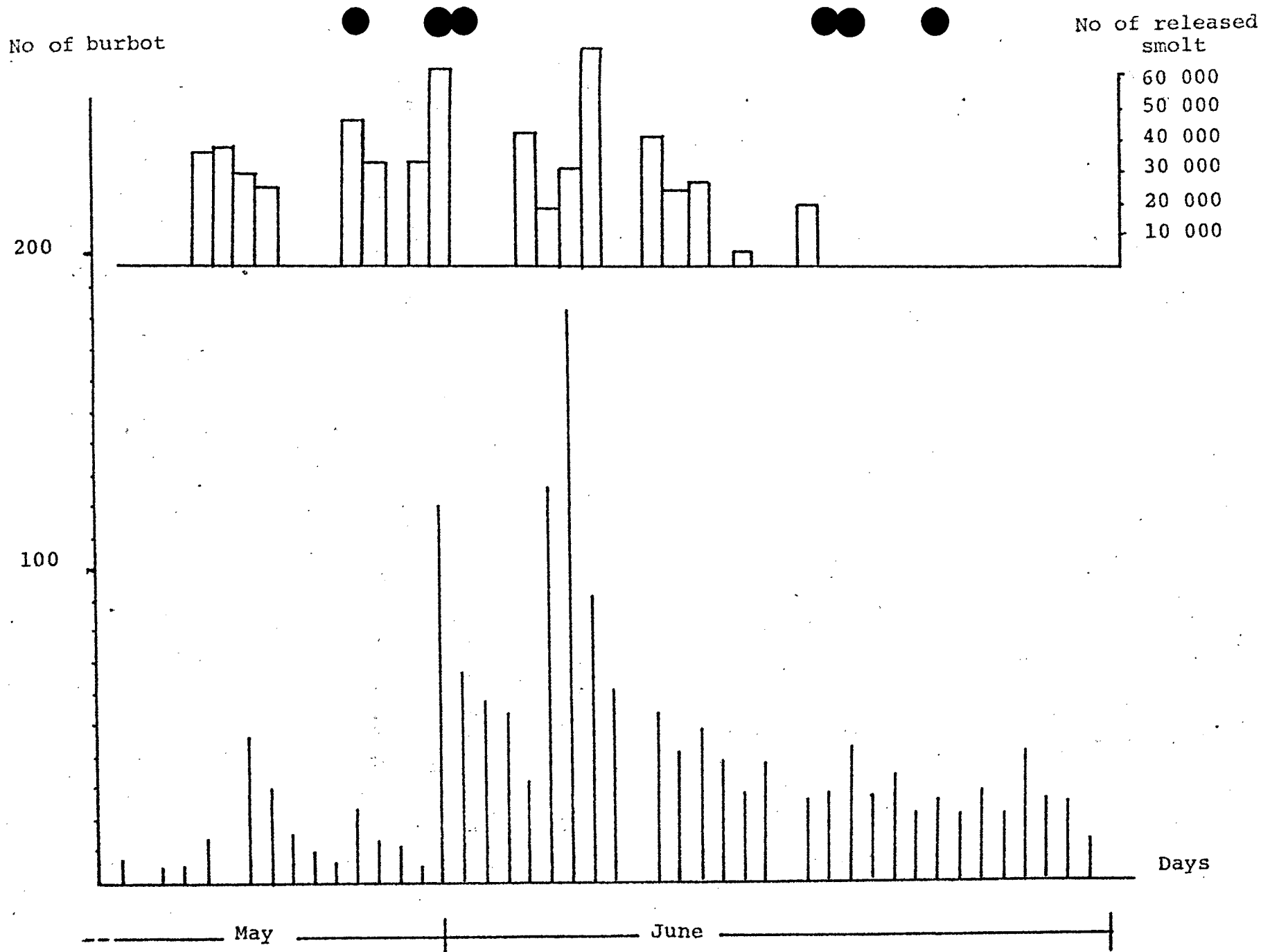


Fig. 2. Catch of burbot and release of salmon smolt at Boden, river Luleälven, 1974.