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USE OF LIVE FRESHWATER ZOOPLANKTON FOR STARTFEEDING ATLANTIC SALMON IN NET PENS

by

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ABSTRACT

The experiment was carried out 1984 in a coastal lake near Bergen, Norway. A total of four (later doubled) groups of Atlantic salmon (Salmo salar) fry were startfed with live zooplankton delivered by a pump. Small fine-meshed net pens were used. Supplemental feed were offered and promoted additional growth, but after the startfeeding phase.

The zooplankton fed groups increased its average length 0.15 mm/day first 30 days. Initial food lack (low density of cladocerans) is the main explanations to the low growth rates. Food selection and pump-increased zooplankton capture probabilities are also discussed. An unexpected negative selection for cala-

noid copepods, even when debilitated, was observed in end of experiment when other potential prey species were scarce. Even *Dapnia* was not preferred as expected. Live zooplankton is recommended for initial startfeeding, but dry food should be available to salmon when yolksac is absorbed.

INTRODUCTION

Most fishes feed on plankton prey during some period of their lives. The crustacean zooplankton plays an important role, specially for the youngest stages. Young stages of the genera *Salmo* and *Oncorhynchus* have been successfully reared on live zooplankton for shorter periods (Paul *et al.*, 1976; Fast, 1978; Urquhart and Barnard, 1979; Holm and Møller, 1984).

Preliminary experiments on first feeding in net pens of Atlantic salmon and rainbow trout with live zooplankton gave surprisingly high growth rates up to a certain period, after which it decreased (Holm, Hansen and Møller, 1982). Atlantic salmon fry rearing with live zooplankton in culture is also reported by Pepper *et al.* (1983) and Reinertsen *et al.* (1984). Seminatural first feeding in ponds is reported by Arnemo *et al.* (1980) and natural feeding on zooplankton in a river is described by Lillehammer (1973).

Food selection on species and size level occurs in general. Different mechanisms are involved, one is prey flight success. Milinski and Löwenstein (1980) tested the hypothesis that threespined sticklebacks should prefer debilitated waterfleas. They did not show such preference, probably due to the fact that three-spined sticklebacks almost never miss a pursued (healthy) waterflea. Holm (1985), reports negative electivity for some of the offered zooplankton species when startfeeding Atlantic salmon. This is probably partly due to high evasive success specially of the copepods. Holm (op.cit.) found that normally frozen zooplankton gave unsatisfactory growth rates. This can be related to low nutritional value and/or suboptimal feeding intensity. If decreased flight success in copepods can be achieved, a better feeding condition to the salmon should be suggested as a result, when using a natural zooplankton offer.

The experiment reported here evaluates the use of a pump system to shock the plankton, reducing the evasion efficiency of the zooplankton. The aim of the design was to offer the fish a slowly evasing or freshly killed zooplankton.

MATERIAL AND METHODS

Experimental conditions

A total of 24 000 Atlantic salmon (Salmo salar) fry from Matre Aquaculture Station (Dept. of Aquaculture, Institute of Marine Research, Directorate of Fisheries) were transported 3 May 1984 (Day 0) to the coastal lake Kvernavatnet (Community of Austevoll, southwest of Bergen, Norway). The fry were held 200 day degrees post hatching before the transport. The fry were divided into four net pens, providing 6000 fry/group. At Day 0, 37% of total dry weight consisted of yolk, at day 11, 20-23%.

A special pen unit was constructed for the experiment. It consisted of maximum 8 pens (only four of them used from the start of this experiment), each with a volume of 2 m . A 5 mm (stretched mesh) net was used in the pens - and inner pens of 1x1 mm meshes plankton net were used in the first three weeks ensuring no escape. A sketch of the experimental pens are given in Fig. 1.

Water was delievered by a jet pump with a capacity of 1500 l/min. High pressure for shocking zooplankton was obtained in the pipeline system simply by adjusting essential valves to almost closed positions. Water supply to each pen unit could be adjusted seperately. Inlet current velocities were adjusted to equal values. Water was taken 2 m below surface.

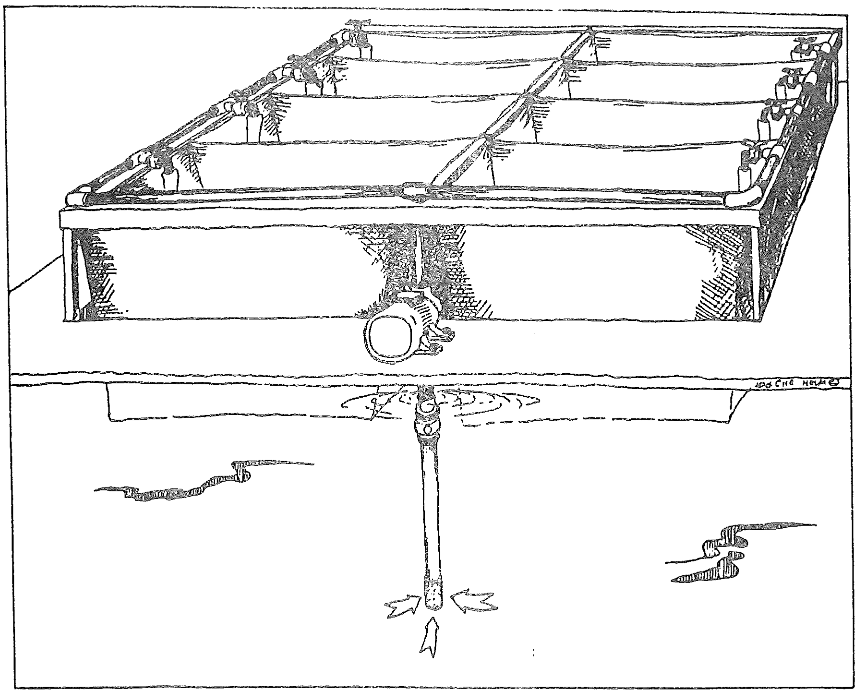

Fig 1: Experimental pens. Arrows indicate water inlet.

In the first period (5 May - 4 June), 4 groups were offered naturally occuring zooplankton through the pump-delievered water. The last group was offered dry food (Ewos type 1) in addition. On 4 June (Day 32), all groups were split, making a total of 8 groups. In the last period (4 June - 18 July), four groups were offered live zooplankton only, and four groups were offered both live zooplankton and dry food. Two of these were fed both food types through the whole experimental period, two were switched from live zooplankton to both food types at day 32.

Water temperature varied between 15 and 20 degrees C in the experimental period.

Sampling and measurements

Zooplankton entering the cages through the pump and pipelines were sampled almost every week (except for 12 June - 17 July) with a 0.045 mm plankton net for at least 5 minutes. Length measurements of the cladoceran *Bosmina longispina* was taken from the top of the crest to the base of the shell-spine.

Samples for estimating zooplankton survival after passing pump and pipelines were obtained with the same net. The zooplankton were transferred to a cylinder and kept in the dark for 10 minutes. A small fraction (4% of total volume) from bottom was supposed to contain dead animals, the rest contained live (healthy or debilitated) animals.

A minimum of 90 fishes were sampled parallel to zooplankton sampling from each net pen. Both zooplankton and fishes were preserved in standard neutral 4% formaldehyde solution. Fork lengths were measured on preserved material. From each sample, 48 individuals were dissected and weighed after freeze drying to nearest milligram on an electronic microblance. Mean total weight, yolk weight and torso weight (body weight) were calculated. Mean yolk absorption rate (YAR), ((Yolk weight at time 2 - yolk weight at time 1)/days between time 1 and 2) were also calculated. Yolk was present in all fishes in samples taken in May (beyond Day 26). From each fish sample, the stomach contents from at least 10 fish were examined.

RESULTS

Offered and consumed zooplankton

Table 1 presents the zooplankton composition entering the net pens through pump. Bosmina longispina increases it's relative abundance from Day 11 to Day 40. Daphnia longispina are scarce, highest values were obtained in end of experiment.

The pump produced high pressure in the pipeline system from pump to valves supplying each net pen. An indication of species-specific survival of the pressure-shock are outlined in table 1. Bosmina survived the treatment relatively well, mortality varied from 20 til 30%. Survival of Daphnia and calanoid copepods was judged as fairly similar, while cyclopoid copepods showed highest mortality when passing the pump/pipeline system.

In order to evaluate bias between natural occuring zooplankton in free water masses and zooplankton entering the pump inlet, the ratio between Bosmina and Daphnia occurence was calculated. The results are given in table 2, showing relatively higher occurence of Bosmina in the pump system compared to free water masses.

From the two original zooplankton fed groups, zooplankton consumption in salmon are obtained from two samples for each sampling date. Copepods were main prey items until end of May, when Bosmina became most important. As long as copepods were most abundant food source, half of the salmon had empty stomachs. In the sample of Day 26, all fish had stomach contents (mainly Bosmina), and at this date the highest mean number of prey in stomach occured. Later, the prey number decreased and relative number of empty stomachs increased. The values of zooplankton consumption are given in table 3.

In table 4 zooplankton feeding (composition) in group fed both dry food and live zooplankton in the whole experimental period are presented. Fish with both food types in stomach content are seperated from individuals with only zooplankton present in stomach. Species selection seems not to be affected by dry food occurrence in stomach. Same table presents percentages of empty stomachs in groups fed both food types. From no food present 14 May, relative number of empty stomachs decreases. Number of zooplankton in stomachs increases through the experimental period. Relative number of fish with both food categories present (type B) varied from 46 to 72 %.

In table 5, Bosmina lengths in both offer and stomach contents from zooplankton fed groups are presented. Significant size selection was obtained Day 26 and Day 75, not Day 40.

Table 6 presents mean number of zooplankton found in stomachs from fish fed both food categories Day 40. Numbers of zooplankton were significantly higher in the zooplankton fed group in fish larger than 30 mm, compared with combined fed group. Dry food were present in combined fed group for fishes larger than 26 mm.

Growth rate and survival in salmon

In the first 30 days of experiment, zooplankton fed groups increased its length on an average of 0.15 mm/day. Fish which received both zooplankton and dry food obtained a growth rate of 0.08 mm/day. Mean dry weights are given in Fig. 2. Zooplankton fed groups showed highest growth rate until Day 32, and were significantly larger on Day 32 than dry fed group ($p<0.05$, Student's t-test). At termination of experiment groups fed with a combined diet were significantly heavier than zooplankton fed groups ($p<0.05$, Student's t-test).

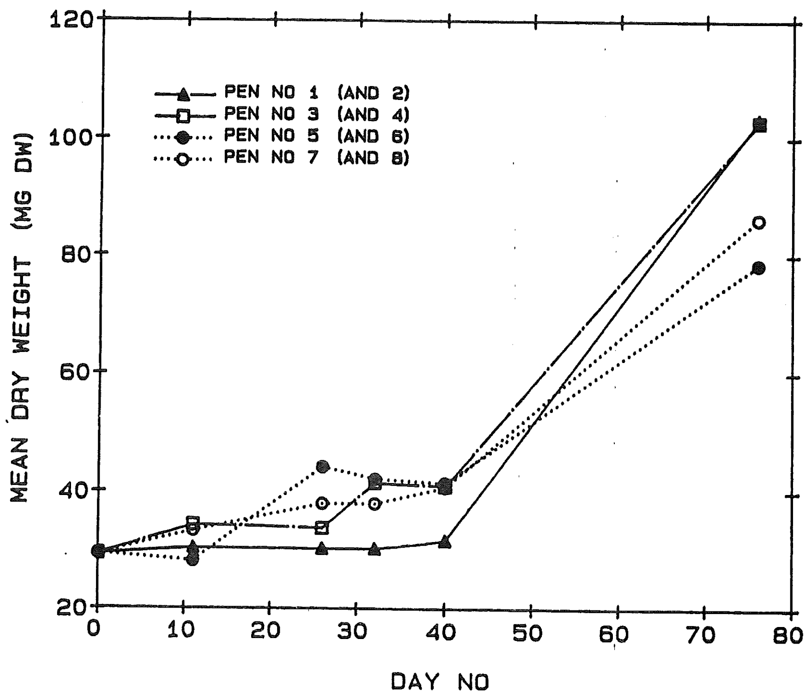

Fig 2: Mean dry weights of Atlantic salmon. Pen no 5-8 got live zooplankton, pen no 1-2 got both food types whole period, no 3-4 got live zooplankton until Day 32 and later on both food categories.

At termination of the experiment, fish were counted, survival values are given in table 7. Survival rates were highest in groups fed dry food during the whole experimental period. Second came groups given dry food in addition from day 32.

In Fig 3, torso growth rates are presented.

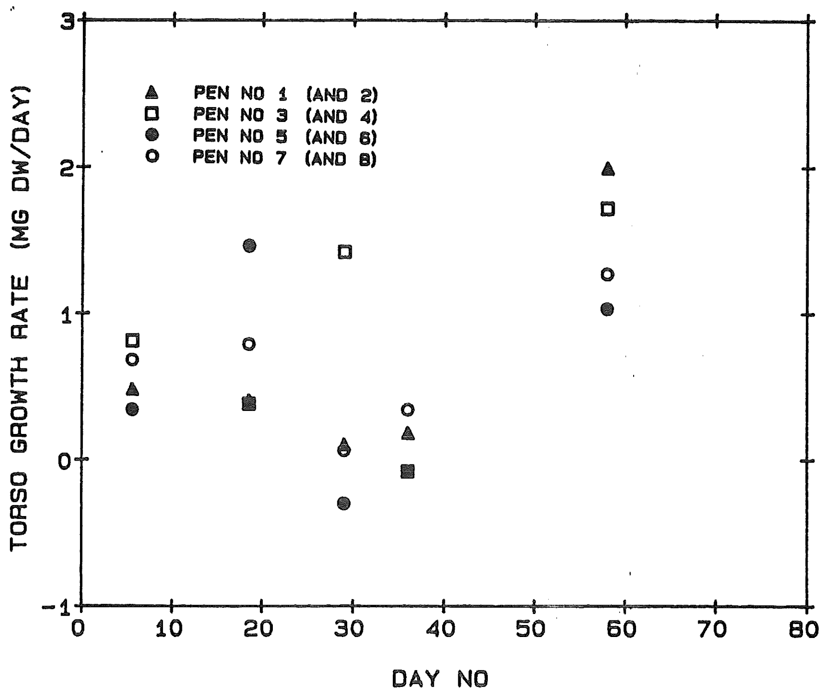

Fig. 3: Torso growth rates in different groups. See Fig. 2

DISCUSSION

Electivity as a function of total food density and fish size

When offered both food types on Day 40, the salmon seemed to prefer different food types depending on its own size. This occured when Bosmina was the main prey item and no significant size-selection occured in zooplankton fed groups. According to Holm and Møller (1984), this can be taken as an indicator for lack of food, and observed size selection on Day 75 could be gill raker dependent. Smallest Bosmina individuals (below 0.4 mm length) have the ability to evade between the salmon gill rakers. According to Visser (1982), (i) preference for the preferred prey increases when the total prey density increases, and (ii) preference for the relatively scarce prey increases when the total prey density increases.

When offering the salmon both live zooplankton and dry food, the total prey density is higher than in the zooplankton fed groups. Dry food must be expected to be most popular due to (1) larger fish in competition with smaller fish show positive electivity for dry food, and (2) zooplankton fed fish select Bosmina and Daphnia in **higher** rates than fish fed both food types. If one of the cladoceran species was most popular, strongest selection should occur in groups fed both food types (higher total prey densities).

Pump-increased capture propabilities

Copepods were taken on Day 40 in so high numbers by the salmon that negative electivity not can be assumed. High feeding rate on copepods occured simultanously with cladoceran depletion. Copepods were negatively selected again on Day 75. This is hard to explain due to the observed empty stomachs (20%) in zooplankton fed groups. Cyclopoid copepods seemed to be slightly more popular than calanoid, they have shorter antennas and showed the highest mortality rate when passing the pump system.

Scheibling (1984) showed that rock crabs (Cancer irroratus) preferred diseased or narcotized sea urchins (Strongylocentrotus droebachiensis) over healthy ones and fed upon them at much higher rate than crabs given only healthy sea urchins as prey. Scheibling suggested that healthy sea urchins may aggregate and avoid predation. Therefore, other factors influating predator success than prey movement itself can be of importance when prey is debilitated or morbid. Copepods will normally evade capture when attacked by Atlantic salmon under normal conditions (Arnemo et al., 1980; Holm and Møller, 1985; Holm, 1985). Zooplankton flight success and ability of patching can be influenced by high current velocity (Holm, Hansen and Møller, 1982) or by pressure shock.

In end of experiment, almost no cyclopoid copepods were offered to the salmon, so if food specialization are established, lack of calanoid copepods in stomach can partly be explained. The observed negative electivity for calanoid copepods should not be expected due to their pump-induced debilitation. Dapnia did not show up to be the major food item, but was more popular in zooplankton fed group. Holm and Møller (1985) reported Dapnia specialization in salmon yearlings, which did not occur in present experiment. Dill (1983) showed that learning can result in training biases and food specialization. The low survival rate, combined with occurence of empty stomachs indicate suboptimal conditions to the zooplankton fed salmon.

Electivity and growth rate

Dependent of fish size, salmon selected the different food types at Day 40. Milinski (1982), feeding threespined sticklebacks with Daphnia, showed that more successful competitors concentrated on large prey, whereas the poorer competitors fed as generalist but not unselectively. Holm, Jakobsen and Johnsen (1985) reported better growth rate in Atlantic salmon fed on a two-colour diet compared to normal one-colour diet. They suggested that the smaller fish have to pay more attention to conspecifics than large ones, and thus tolerate less confusion when feeding. Thus, lowering cost of confusion will promote a better total growth rate. Therefore, other explanations have to be found for the relatively poor growth rate (day no 0 - 30) found in groups offered both food types. A possible explanation is that live zooplankton may consist of important nutritional components (free amino acids, enzymes), which is difficult to keep in commercial dry food (Holm and Møller, 1984; Holm, 1985), in addition to the fact that zooplankton itself has to be characterized as heterogenous.

Later on groups fed both food types showed high growth rates. This could be explained by lowered intraspecific competiton in combined fed groups in addition to food lack in zooplankton fed groups where the relative numbers of empty stomachs increased late in experiment.

Concluding remarks

Table 8 compares some results from start feeding experiments. Hansen and Torrissen (1984) observed negative or no weight increments first 32 days of feeding in large scale dry food rearing of Atlantic salmon. Physiological age of these fry were quite comparable to the groups outlined in table 8, but mean water temperature was lower.

As long as fry absorb yolk, zooplankton seems to have the potential to enhance additional growth. Live zooplankton are therefore recommended for first feeding phase when available. However, when yolk absorption is finished, optimal feeding with live zooplankton is difficult to obtain. The author have not been able to verify better growth in older stages of salmon when zooplankton fed compared to dry fed, except for a period reported in Holm and Møller (1984). Growth feeding of salmon with live zooplankton must be considered as problematic primarily due to the problems to achieve sufficient food amounts and optimal species composition. The zooplankton feeding may be started earlier than conventional dry feeding (no bottom deposits) and finished at termination of yolk absorption period.

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TABLES

Table 1: Composition (percentages) of pumped zooplankton entering the net pens. Percent survival 10-15 minutes after pump passage in parantheses. N = Number in sample.

GROUP	DAY 11	DAY 19	DAY 26	DAY 33	DAY 40	DAY 75
Bosmina	2.5 (80.1)	2.9	8.6 (70.5)	12.1	49.3 (72.0)	0.6 (78.0)
Daphnia	0.1 (43.8)	0.2	0.2 (45.5)	5.0	6.7 (30.4)	20.0 (10.5)
Other clad.	0	0.1	0	0	0.7 (-)	29.0 (-)
Cal.cop.	77.8 (27.6)	70.4	59.8 (35.4)	48.6	24.0 (38.1)	49.8 (25.6)
Cycl.cop.	19.6 (16.1)	26.4	31.4 (5.9)	34.3	19.3 (4.0)	0.6 (7.1)
N	2831		4586		12994	1550

Table 2: Bosmina/Daphnia ratios in free water masses and in pumped water. Data from free water masses are mean values of 1 and 3 m depth of three stations from Johnsen (unpubl.).

	DAY 19	DAY 26	DAY 23	DAY 33	DAY 75
Free water masses	0.7	1.2	0.3	0.2	0.1
Pumped water	14.5	43.0	2.4	7.4	<0.1

Table 3: Prey group composition (mean percentages) in zooplankton fed Atlantic salmon group. Mean prey number pr fish with stomach content is also presented. N = number of fishes examined.

GROUP	DAY 11	DAY 19	DAY 26	DAY 40	DAY 75
Bosmina	3.8	7.4	59.2	51.5	93.0
Daphnia	3.8	7.4	1.2	4.6	7.0
Cal.cop.	11.5	33.3	19.8	18.1	0
Cycl.cop.	80.9	51.9	19.8	25.8	0
% empty stomachs	48	48	0	19	20
Mean prey number/fish	5.2	8.0	9.3	8.3	6.1
N	21	23	30	27	49

Table 4: Prey group composition (percentages) in groups fed both zooplankton and dry food during whole experimental period.

B = Based on fishes with both food categories in stomach

Z = Based on fishes with only zooplankton present in stomach.

N = Number of fishes examined.

Except for empty stomach occurence, all values are based on fishes with food present in stomach.

GROUP		DAY 11	DAY 19	DAY 26	DAY 40	DAY 75
<u>Bosmina</u>	B	-	15.1	52.1	21.9	86.7
"	Z	-	28.6	21.6	21.6	92.2
<u>Daphnia</u>	B	-	0	0	0	0
"	Z	-	0	0	0	0
Other clad.	B	-	0	0	0	0
" "	Z	-	0	0	0	0
Cal.cop.	B	-	36.2	20.8	37.2	6.6
" "	Z	-	23.8	25.5	47.3	3.5
Cycl.cop.	B	-	48.7	27.1	40.9	6.7
" "	Z	-	47.6	52.9	30.1	4.3
Empty stomachs (%)		100	29.8	27.8	12.5	5.5
Mean number of zooplankton /fish type B		0	8.0	5.6	12.4	37.4
Mean number of zooplankton /fish type Z		0	3.8	5.1	14.8	66.3
N		18	57	36	56	18

Table 5: Mean *Bosmina* lengths (mm) from offer (inlet) and stomach contents (pen nos 5-8, groups fed zooplankton), 95% confidence limits are indicated.

DATE	INLET	STOMACH
Day 26	0.43 ± 0.03	0.55 ± 0.03
Day 40	0.51 ± 0.03	0.50 ± 0.03
Day 75	0.49 ± 0.04	0.61 ± 0.04

Table 6: Predator-size selective feeding Day 40. Based on large samples of fish not included in table 4. 95% confidence intervals are indicated. Sample size in parantheses.

Fish size group (mm)	Mean number of zooplankton present in stomachs: Zooplankton fed group	Combined fed group
< 24.0	10 ± 7 (6)	10 ± 8 (7)
24.0 - 25.9	8 ± 6 (11)	15 ± 9 (9)
26.0 - 27.9	12 ± 11 (21)	13 ± 5 (23)
20.0 - 29.9	20 ± 11 (20)	10 ± 6 (30)
30.0 - 31.9	28 ± 15 (12)	7 ± 4 (22)
> 32.0	35 ± 10 (12)	0 (15)

Table 7: Survival in net pens, 3 May - 18 July (Day 76). Sampled fish are subtracted from initial number before calculation.

PEN NO	DIET	SURVIVAL
1	COMBINED	71.58
2	COMBINED	74.07
3	ZOO-COMB.	55.63
4	ZOO-COMB.	56.31
5	ZOOPL.	35.03
6	ZOOPL.	39.63
7	ZOOPL.	49.94
8	ZOOPL.	47.04

Table 8: Comparisons of growth rates of Atlantic salmon, first 30 days.
Z = fish fed live zooplankton
B = fish fed both dry food and live zooplankton

Food type	Length increment (mm/day)	Weight increment (mg DW/day)	Reference
Z	0.51[1)]	-	Arnemo *et al.*,1982
Z	0.25	1.31	Holm *et al.*,1982
Z	0.07	-0.68	Holm, 1985
Z	0.15	0.57	Present paper
B	0.15	0.67	Holm *et al.*,1982
B	0.08	ca 0	Present paper

1) First 20 days only.

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