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LIVE AND FROZEN FRESHWATER ZOOPLANKTON AS ALTERNATIVE STARTFEEDING DIETS FOR ATLANTIC SALMON IN TRAYS

by

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ABSTRACT

Six groups of Atlantic salmon (Salmo salar) fry were starfed with frozen Daphnia longispina, standard start food type EWOS or water with natural content of live zooplankton drained from the littoral zone in a coastal lake. In last five days, those fed live zooplankton were given additional food in the form of frozen Daphnia.

Dry-fed groups were the only ones to have an overall weight gain but had the lowest activity. Fry fed live zooplankton had the highest activity but the natural species composition of the offer was not optimal for startfeeding. Survival was highest in the group fed frozen Daphnia whose tank had bottom drainage.

High yolk absorption rates (implicate early termination of yolk sac) found in live zooplankton groups may be favourable if a net energy gain is achieved due to early feeding on a live prey.

INTRODUCTION

The use of natural prey organisms in aquaculture poses some interesting questions. The use of live prey in salmonid freshwater culture have been part of a project at University of Bergen dealing with ecological aspects of salmonid culture in lakes.

Holm and Møller (1984) fed two groups of Atlantic salmon yearlings with lake zooplankton in an artificial current. Compared to a diet of dry food pellets, live zooplankton was satisfying when presented in sufficient amounts.

Promising startfeeding results in Atlantic salmon were achieved by Holm, Hansen and Møller (1982). Fry can use a varying part of their yolk sac energy content for activity. The yolk sac itself will cause friction and relatively high energy costs while swimming. Differences in food preferences related to prey movement, are expected to be obtained when feeding in yolk sac fry are compared to feeding in larger fry without yolk sac. Frozen Daphnia and live zooplankton was offered to equal groups of salmon fry. Finally, dry food was offered to verify possible nutritional advantages. Fish activity, mortality, yolk absorption and growth rates were suitable parameters.

MATERIAL AND METHODS

Experimental conditions

Eyed eggs (10 litre) of Atlantic salmon (*Salmo salar*) from Matre Aquaculture Station (Dept. of Aquaculture, Institute of Marine Research, Directorate of Fisheries) were transported in April 1983 to the coastal lake Kvernavatnet in the community of Austevoll southwest of Bergen, Norway. The eggs were incubated in hatching trays modified according to Hansen and Møller (1985). Hatching started 4 May, 254 day degrees (27 May) after 50% hatching, fry were transferred to six startfeeding trays (five with surface outlets, one with outlet through sieve in bottom). A total of 30.500 fry were transferred, providing nearly 5.100 in each group. At 27 May (Day 0), 41% of total fish dry weight consisted of yolk. At 8 June (Day 12), 12-24% of dry weight was yolk.

An account of the groups is given in Table 1.

Table 1: Different feeding regimes and tray outlets.

TRAY/GROUP NO	DRAINAGE AREA	PERIOD 27 MAY - 20 JUNE	PERIOD 21 JUNE - 28 JUNE
1	Surface	Dry food	Dry food
2	"	Live zooplankton	Live and frozen zoopl.
3	"	Frozen zoopl.	Frozen zoopl.
4	"	Dry food	Dry food
5	"	Live zoopl.	Live and frozen zoopl.
6	Bottom	Frozen zoopl.	Frozen zoopl.

Dry food (Ewos type 1 Startfood) was given from automatic feeders, four to six times per hour. Frozen zooplankton (mainly daphnids) captured according to a method reported by Jakobsen and Johnsen (1985) were offered twice a day in 100 g portions, thawing directly in the trays. Food were at least present in the tray for at least half an hour after introduction. Live zooplankton fed groups got unfiltered water taken from the littoral zone 1 m below surface.

Water temperature in trays rose from 12 to 19 degrees C in the experimental period.

Sampling and measurements

During the experiment, water containing live zooplankton of the same type of that entering trays 2 and 5 were sampled almost weekly with 0.045 mm plankton net (10 min filtering); not affecting the delivery to the actual trays. Half an hour later, 12 samples of 0,5 l each were taken from the two trays to monitor standing stock of live zooplankton. A minimum of 100 fishes were sampled parallel to zooplankton sampling from all six trays. Both zooplankton and fish were preserved in standard 4% neutral formaldehyde solution. Fish were then length measured (fork lengths), and 48 individuals from each sample were dissected and weighed after freeze drying to nearest milligram on an electronic microbalance.

Mean total weight, yolk weight and body weight (weight of fish without yolk sac) were calculated. Yolk conversion efficiency, YCE, (body weight increase in period/yolk weight decrease in period), 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 samples except for 28 June. Calculations of yolk values were carried out for the period 18 - 27 May (period before transfer), 27 May -8 June (Period 1) and 8 June - 21 June (Period 2). Yolk conversion efficiency was not calculated for period 2 due to high exogenous feeding. From each fish sample (except for 28 June) the stomach contents from 10 fish were examined.

Behaviour during feeding was recorded. The dead fish in each tray were removed and recorded daily. At the termination of the experiment, all groups were counted, and unregistered loss were added to observed mortality based on the probability P(M) = (observed mortality in group in the actual period)/(total observed mortality in group during experiment). No more than 15% unregistered loss was obtained in any group. Necrotic gill filaments were observed in some of the dead individuals.

RESULTS

Feeding on live zooplankton

The species composition of the zooplankton offer in trays 2 and 5 are given in Table 1. Numbers per litre of standing stock are given in Table 2. The species composition of zooplankton showed a large variation. Relatively high densities of copepods occurred in the beginning of June.

Feeding (presented in Table 3) increased until 14 June. Salmon showed a preference for Daphnia.

Feeding behaviour and mortality in all groups

Differences in feeding behaviour of the salmon are presented in Table 4.

When frozen Dapnia were introduced from June 21 to the groups given live zooplankton, extremely high feeding activity and fighting were observed around the clumps.

Mortality in the different groups is presented as survival curves in Fig. 1. The highest survival occurred in the groups fed frozen Daphnia in the tray with bottom drainage. Second came the two groups given live zooplankton with additional frozen Daphnia last week of experiment.

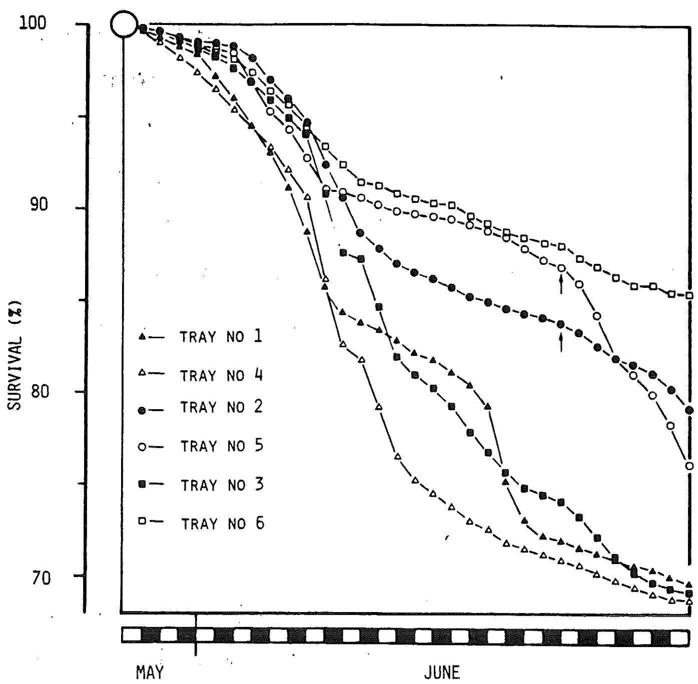

Fig. 1: Survival expressed as percentages from 28 May to actual date in all groups. Tray no 1 and 4 were offered dry pellets, no 2 and 5 live zooplankton, no 3 and 6 frozen Daphnia. Arrows indicate the addition of frozen Daphnia to the zooplankton-fed groups.

Growth and yolk absortion rates in all groups

Mean fork lengths and total weights are given in Figs 2 and 3, respectively.

At the end of the experiment, pellet-fed groups were significantly larger compared to all the other groups (Student's t-test, $P<0.05$). The group fed frozen Daphnia in a tank with bottom drainage was larger than other frozen Daphia or live zooplankton fed groups (criteria as above).

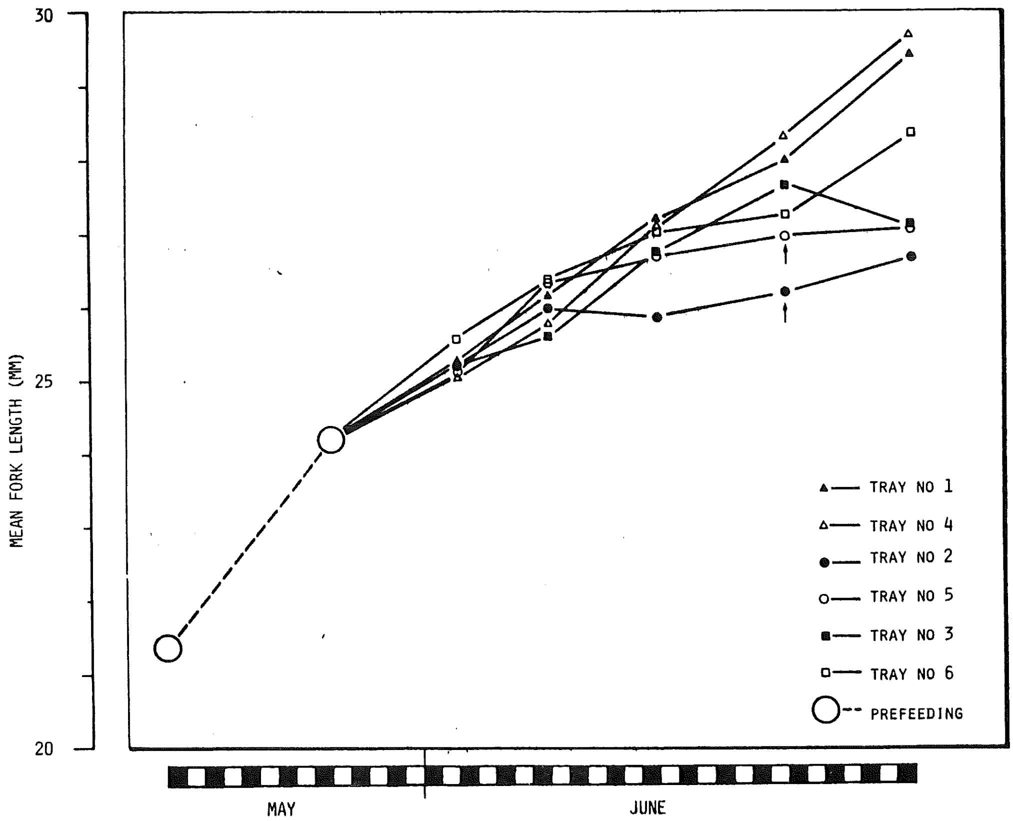

Fig. 2: Mean fork lengths in all groups. Tray no 1 and 4 were offered dry pellets, no 2 and 5 live zooplankton, no 3 and 6 frozen Daphnia. Arrows indicate start of additional feeding of frozen Daphnia. Large circles indicate mean lengths before start of experiment.

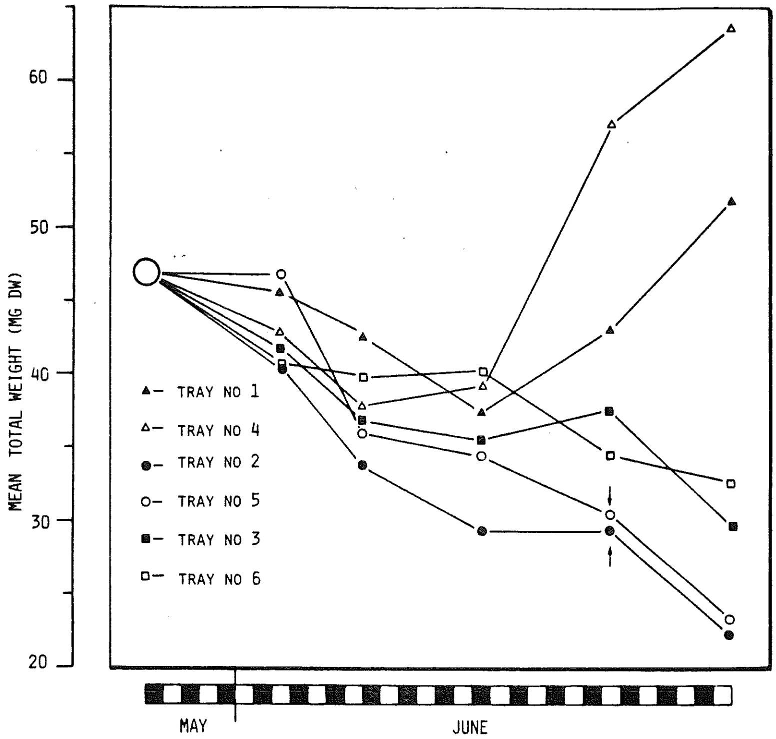

Fig. 3: Mean total dry weight. See previous figures for food types. Arrows indicate additional feeding.

At the end of the investigation, live zooplankton-fed groups were smallest whereas the pellet-fed groups were significantly larger than all other groups (Student's t-test, $P<0.05$). Results are outlined in Fig. 3. No significant between-group differences in mean total weights was found for either the zooplankton-fed or <u>Daphnia</u>-fed groups.

Mean body growth rates and yolk absorption rates are given in Fig. 4.

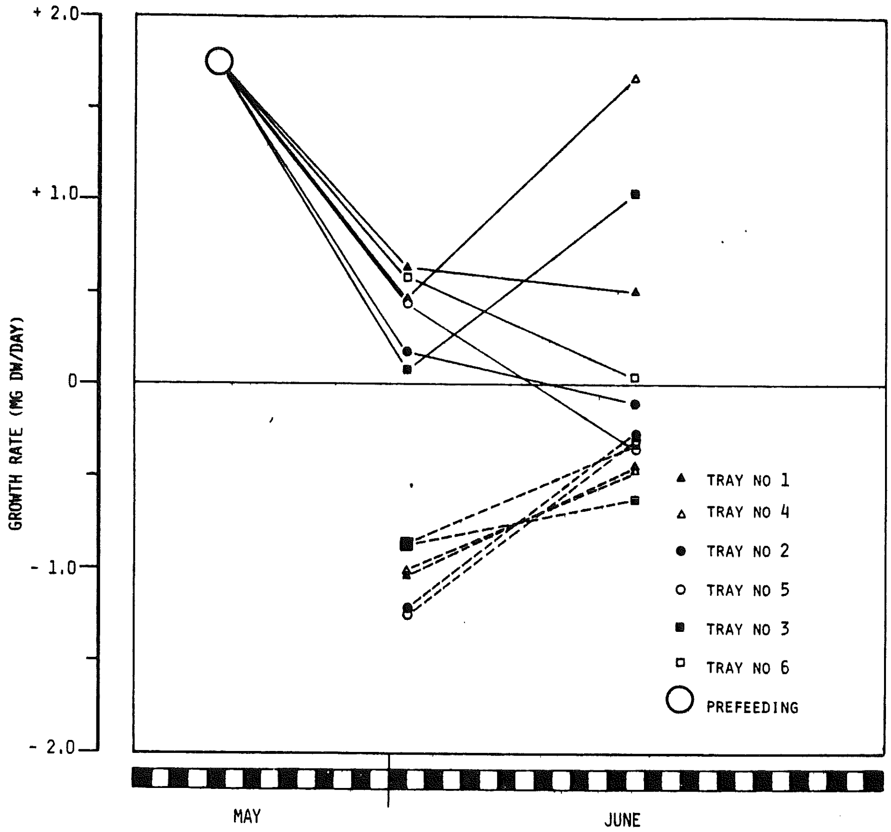

Fig. 4: Body growth rates and yolk absorption rates (YAR) expressed as mg DW/day. Solid lines indicate torso values, dashed lines indicate yolk values. Food types as in previous figures.

Negative body growth rates in both live zooplankton-fed groups occurred in the second period. Prior to this, YAR for different feeding regimes were quite consistent. Highest yolk absorption rate was found in live zooplankton fed fry, lowest in those fed frozen Daphnia.

In Table 5 the highest YCE occurs in the group fed frozen *Daphnia* and given bottom drainage. Relatively high values occur in both pellet-fed groups.

DISCUSSION

High densities of mostly calanoid copepods were offered to live zooplankton-fed groups, but consumption of calanoid copepods was not confirmed in the stomach samples. Calanoid copepods (in food offer mainly *Eudiaptomus* sp.) are more evasive prey than cyclopoid (mainly *Cyclops* sp.) due to longer antennas (Drenner, Strickler and O'Brien, 1978). Copepods seemed to aggregate in the trays. Sieves in the outlet may act as a predator to the zooplankton, and calanoid copepods are most effective at evading the sieve. High densities of zooplankton may have lead to confusion (Ohquchi, 1981) when maximum densities were ca 300 ind/l. The zooplankton offered in this investigation may thus have been iradequately available for consumption.

Zooplankton seemed to induce high feeding activity earlier than conventional dry food. Rimmer and Power (1978) concluded that for Atlantic salmon alevins to feed successfully, food need not be carried in a water current, but motion of the prey was necessary, which could be induced by the current. This can very well explain differences for the live zooplankton-fed groups and the rest, but not differences between pellet-fed and frozen *Daphnia*-fed groups.

It is believed that a certain proportion of free amino acids in live zooplankton may be important to fish larvae without fully developed gastrointestinal tract (Dabrowski and Rusiecki, 1983). Feeding Atlantic salmon fry with zooplankton could therefore be favourable, and the relatively high survival in live zooplankton-fed groups can be related to such nutritional aspects. Most free amino acids are lost from frozen zooplankton (Grabner *et al.*, 1981), which may partly explain the low growth rate of the groups fed frozen Daphnia. The effectiveness of first feeding in Atlantic salmon on live or frozen zooplankton should be expected to be increased due to exogenous protelytic enzymes, but probably decreased by low protein content. (According to Watanabe et al., 1983 Daphnia sp. content 7.5% crude protein on wet weight basis). Zooplankton may also be a suitable first feeding diet to salmon due to its carotenoid content, which has positive effects on embryonic development and fish growth (Deufel, 1975, Torrissen, 1984).

In live fed zooplankton group, high survival occured as expected, but growth rate must be characterized as low compared to dry fed groups. In dry fed and frozen zooplankton fed groups, mortality may also be affected by food spillage remaining on bottom. The high survival in the tray with bottom outlet supports this.

Observed high YCE values in pellet-fed groups should indicate low activity expences and/or additional feeding. The low YCE values in zooplankton-fed groups can be related to high activity expences.

Low YAR values (in numbers) as found in pellet-fed groups could be taken as an indicator of stress; fish inhibates their yolk sac assimilation when stressed (Hansen and Møller, 1985). Final YAR values are probably not a consistent parameter due to minimal yolk sac content.

Fry forced to hunt for a live prey will have advantages in high YAR, which will promote higher feeding efficiency. However, zooplankton offer has to be optimal. If zooplankton enhance additional growth early in startfeeding (indicated by Holm et al. 1982; Holm 1985), it may become favourable to obtain high activity, thereby promote high YAR and early yolk sac termination. This will enable the fry having a more active search image due to lower swimming costs, than fry of same age with larger yolk sac left.

Even activity-induced yolk sac constrictions, as reported by Hansen and Møller (op.cit.), could possibly be energetically favorable in an opportunistic strategy if feeding efficiency (on a live prey presented early in yolk assimilation period) could be adequately increased due to a better swimming ability.

In culture of Atlantic salmon, earlier start of exogenous digestion may be of economically importance. If feeding conditions are kept strictly optimal, a live prey as zooplankton may act as a trigger. Use of live zooplankton seems to pose some problems (species, composition, density) in addition to the fact that zooplankton is naturally scarce when startfeeding of Atlantic salmon normally occurs in pisciculture (early spring).

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TABLES

Table 1: Zooplankton composition (percentage values based on numbers) in water entering the trays (INLET) and standing stock in the trays (STOCK). Mean values for trays no 2 and 5.

	27 May	3 June	8 June		14 June		21 June	
	STOCK	STOCK	INLET	STOCK	INLET	STOCK	INLET	STOCK
Alona	0	0	0	0	0	0	0	0,4
Bosmina	31.3	2.7	0.7	0.6	37.6	45.5	9.1	6.1
Daphnia	55.3	8.5	5.2	4.6	54.1	4.6	10.6	1.9
Holopedium	4.9	2.3	1.0	0.4	0	1.5	0.6	0
Polyphemus	0	0	0	0	0	0	0	0.4
Copepoda:								
Cyclopoida	1.1	21.8	11.7	3.5	3.8	1.5	7.3	8.8
Calanoida	0.4	61.6	81.1	90.4	1.0	34.5	39.9	42.9
Harpacticoida	0	0.2	0	0	0	0	0	0
Nauplii	0	2.3	0.3	0.4	3.3	14.0	32.5	39.5
Insecta	7.0	0.6	0	0.1	0.2	0.4	0	0
N	1284	2485	1308	2997	423	264	483	263

Table 2: Density of different zooplankton groups in the standing stock of trays no 2 and 5. Numbers pr. litre (mean values of 12 samples).

	3 June		8 June		14 June		21 June	
	2	5	2	5	2	5	2	5
Bosmina	8	5	2	1	19	-	2	1
Daphnia	30	11	18	10	2	-	1	0
Holopedium	6	5	3	1	1	-	0	0
Copepoda:								
Cyclopoida	91	15	13	7	1	-	0	0
Calanoida	130	169	269	212	15	-	13	6
Harpacticoida	1	0	0	0	0	-	0	0
Nauplii	9	2	2	1	6	-	8	9
Insecta	1	2	1	0	0	-	0	0

Table 3: Food consumption in live zooplankton fed groups, trays no 2 and 5. Mean number of prey items pr stomach, empty stomachs included.

	3 June		8 June		14 June		21 June	
	2	5	2	5	2	5	2	5
Bosmina	0	0.4	0	0.1	2.6	3.1	1.9	2.2
Daphnia	0.1	0.1	2.1	2.0	19.0	13.1	0	0
Cycl.copepods	0.1	0	0	0	0	0	1.3	1.0
Insecta	0	0	0	0	0,1	0,1	0	0
Eye (salmon)							+	
Sand particles					+			+

Table 4: Behaviour during feeding.

DATE	FEEDING: DRY FOOD	FEEDING: FROZEN DAPHNIA	FEEDING: LIVE ZOOPL.
Period 1 (27 May - 8 June)	Fish mainly resting on bottom. Some swimming activity at end of period. Feeding activity low.	Some active individuals. Increase of activity at end period. Patchy distribution (follow thawing plankton clumps when feeding).	High feeding activity. Evenly distributed in water volume at end of period.
Period 2 (8 June - 21 June)	High feeding activity.	High feeding activity.	High feeding activity. Fish aggressive Attempts to feed on copepods with low success.

Table 5: Yolk Conversion Efficiency for all groups in period 1 (27 May - 8 June).

	FOOD	YCE (%)	OUTLET
1	Dry pellet food	61.0	Surface
2	Live zoopl.	14.3	"
3	Frozen zoopl.	9.1	"
4	Dry pellet food	45.0	"
5	Live zoopl.	35.1	"
6	Frozen zoopl.	66.9	Bottom