International Council for
the Exploration of the Sea

C.M.1985/F: 17
Mariculture Committee
Ref. Anadromous and
Catadromous Fish
Committee

INCREASED GROWTH RATE IN ATLANTIC SALMON PARR BY USING A TWO-COLOUR DIET

by

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ABSTRACT

Fishes hunting by sight are known to pay a cost of confusion when faced with high densities of uniform food particles. In such instances, awareness of other stimuli reduces feeding efficiency such that the fishes prefer low densities of food particles. Farmed Atlantic salmon parr (Salmo salar) with agonistic behaviour, have the additional pressure of conspecific aggression while feeding.

As factors such as swarm number, density and uniformity increase confusion, it is therefore profitable in pisciculture to introduce food particles in low densities or, alternatively reducing uniformity and density of each type of feed pellets. This latter was tested at the Matre Aquaculture Station (Directorate of Fisheries), by feeding salmon parr with brown pellets, yellow pellets or a mixed diet.

Mean growth rates were significantly higher for those fed with a mixed diet. When comparing the smallest fish in all groups, those in the mixed diet group showed the highest growth rate and condition factor. Larger salmon parr of that group also grew better, but difference between groups was not so large as for the smaller fish.

We suggest that small individuals have to pay more attention to conspecifics than large ones, and thus tolerate less confusion when feeding. Larger individuals, tolerating higher confusion costs, achieve higher feeding rate in high densities of uniform feed pellets.

Fish given a mixed diet (1) generally showed a higher growth rate and (2) the growth rate was less varied when fed a mixed diet in addition to that (3) the proportion of wasted pellets can be decreased.

INTRODUCTION

In Norwegian salmonid farming, large differences in individual growth rates are a problem of economic importance. Food is normally available in excess for the fish, therefore variable amounts are wasted and optimal utilization of the food is only obtained for those fish fit enough to maintain dominance in the hierarchy.

Animals concentrate on profitable prey if the abundance reaches a certain threshold (Emlen, 1966; MacArthur and Pianka, 1966). However, as there are remarkable individual differences when feeding, animals with less competitive abilities are not always able to select the optimal diet predicted for conditions without competition (Rubenstein, 1981; Milinski, 1982),

Feeding in high densities of prey also reduces feeding efficiencies and is termed the confusion effect (Miller, 1922; Milinski, 1977). The fish hesitates before attacking and has difficulties in aiming at one target which is quickly masked by other similar targets (Milinski, 1977). This is supported by field experiments with many taxa, showing that the subjects had difficulties in taking swarming prey (Allen, 1920; Mosebach and Pukowski, 1937; Eibl and Eibelsfeldt, 1962; Hobson, 1968; Potts, 1970; Radakow, 1973).

Current research indicates the following characteristics of a swarm which enhance the confusion effect: (1) **swarm number** (Welty, 1934; Neill and Cullen, 1974); (2) **density** (Milinski and Curio, 1975; Milinski, 1977) and (3) **uniformity** of swarm numbers (Muller, 1978; Ohguchi, 1978). However, Milinski (1979) has suggested that feeding in dense areas of prey may become possible if other costs (such as predation, Milinski and Heller (1978)) conflicting with feeding activity are low. Less documented is the influence of intraspecific aggression on the cost of confusion and how this can influence competitive success, expressed as the individual's growth rate. Salmon parr living in densities typical for commercial fish farming, are known to behave agonistically (Symon, 1971).

In the present experiment, Atlantic salmon parr of various sizes were held in tanks and fed artificial food in fairly high densities as in traditional aquaculture. The confusion was presumed reduced in one group of tanks by presenting 70% brown pellets and 30% yellow pellets. Small fish are expected to grow more slowly than larger due to their higher costs to aggression which permit less tolerance of the cost of confusion. Small subdominant fish were expected to have a relatively higher growth rate with this mixed diet.

METHODS

The genetic composition of the juvenile Salmo salar used in the expermiments stemmed from six mothers and two fathers. Each genetic group was assessed with respect to both length and weight distribution, and divided equally into the nine experimental tanks before starting the experiment.

Fish number varied between 1436 and 1339 fish in each tank, and was never more than 7.02 kg fish per cubic metre. The experimental arenas were nine dark green, circular, covered tanks measuring 1.5 m in diameter. Water depth was 80 cm. River water neutralized with a NaOH solution to a pH of 6.3 flowed continously into the tanks and the water was shifted on average every three hours.

The temperature varied between 4 and 5 degrees (C) in the first 30 days. Thereafter there was a gradual increase in temperature to 7 degrees at the end of the experiment.

The fish were exposed to 24 hour light from a 60 W light bulb, placed 30 cm above the surface. They were fed with an Ewos automatic feeder. Since the stream was directed from the feeder towards the light bulb, the food particles had the highest light exposure just after they were introduced into the tanks.

The experiment consisted of three groups of three parallels. In one group, the fish were fed a mixed diet consisting of 30% yellow food pellets and 70% brown. In the two other groups the fish were fed either homogenous brown or yellow pellets.

Small amounts of dietylether were added to all food pellets, while 2% (weight) curcumin E100 was used to give some pellets a light yellow colour with a greenish tint. The dietylether was dried off by storing the salmon food in 25 degrees (C) for at least 24 hours before it was introduced to the tanks. Since both brown and yellow pellets were treated with dietylether, and curcumin has no additional growth effect (Bhuvaneswaran et al., 1963), food value was equal for all diets.

The size of the granulated food particles (Ewos no 3 salmon feed) averaged 2.4 mm, and particle size distribution was equal throughout the experiment. At least 96% of the particles were within acceptable size of 0.018 - 0.051 times the fork length of the salmons, and all particles were of the size to elicit a response (Wankowski, 1979).

At least 400 particles were offered to the salmon every 10 minutes for 3 seconds. Throughout the experiment the fish were fed in excess.

Water level in the tanks was lowered to diminish size-dependent differences in avoidance when removing fish to measure length and weight. Sampled fish were anaesthized with benzocaine. Fork length and weight were measured for at least 100 individuals from each tank each time, except for the final measurement involving about 250 from each tank. Measurements were taken four times with approximately one month intervals.

RESULTS

In those tanks where salmon were offered a mixed diet, the increases in both length and weight were significantly higher than for those fed a homogenously coloured diet (Table 1).

At the end of the experiment, the smallest fish exposed to the mixed diet had a significantly better condition factor (mean 1.27) than those fed either yellow (1.18) or brown (1.21) pellets. The largest fish fed a mixed diet also showed a better condition factor (mean 1.23) which was, however, not significantly different from the average values of 1.19 and 1.21 for the other groups (Table 2).

All groups were fed to excess and there were no significant differences in the amount of food used in the three groups (Table 3). Mortality was low in all groups, ranging from a total of 0 to 14 individuals in each tank.

DISCUSSION

Atlantic salmon parr showed a generally higher growth rate when fed a mixed colour diet, then when fed uniformly coloured foo pellets. Small fish tended to grow better than those fed single colour pellets, thus indicating a reduction in intraspecific competition. As expected, the difference in food pellets had less of an effect for larger salmon then for small salmon.

Differences in growth can not be due to differences in food quality, as neither caloric value nor essential trace elements were added by the colouring agent, although the taste may have been affected. Growth rates were not significantly different in the two groups fed with yellow or brown food pellets. For this reason, neither of the groups seems to be more profitable when homogenously introduced to the fish.

Although the formation of search image (Tinbergen 1960; Allen and Clarke, 1968), on either of the two different coloured food-pellets, could give better conditions for fish fighting for the same particle, the presence of food in excess indicates that problems with food intake must be due to other factors such as feeding place. Differences between groups with two colours of food are therefore not due to search image formation.

The slightly better growth of large salmon fed a mixed diet also indicates other possible reduced costs. Since mixing of food types lowers the density of each food type, the most obvious explanation is that of Milinski and Heller (1978), found that feeding rate varied with hunger level and predation risk. When presented with a choice between high and low densities of prey, sticklebacks choose high densities only when hungry and when predation risk was low.

Milinski and Heller (op.cit.) found that animals have to pay a confusion cost when feeding in high densities of prey and have difficulties paying attention to other stimuli (Milinski, 1979). Although in our experiment there were no predation risk, high aggression between salmons under such conditions gives a similar effect (Owen et al., 1968; Fernö and Holm, 1985). Small fish, in particular, have to pay attention to others when feeding, thereby increasing the confusion and reducing the opportunity of feeding in areas of high food densities. Under such conditions, a mixed diet favours a higher feeding rate, since the density of uniform food particles is lowered, thus reducing the confusion cost.

Dominance in Atlantic salmon parr is size related (Kalleberg, 1958), implying that larger fish are more capable of feeding in high food densities. When uniform particle density is decreased, this could as well explain the better growth rate of the smallest individuals in the mixed diet group relative to small fish fed homogenously.

This obvious has implications in pisciculture. Feeding regimes favouring an improved and more even growth rate, promote a better and more stabile quality of the fishes. The decreased need for size grading the fish also reduces treatment and manhours. Additionally, mixing of foodparticles gives the fish an opportunity to consume a higher proportion of the offered food and may help the fishfarmer to optimize the production while reducing pollution from waste food.

AKNOWLEDGEMENTS

We would like to thank Dr. Kjell Lie Jakobsen at the TORO-laboratory (Bergen) for advice on colouring the food, and Carl Rasmussen (Bergen) for guidance in using curcumin.

The experiments were carried out at the Matre Aquaculture Station (Directorate of Fisheries), where Håkon Trodal conscientiously fed and watched over the fish daily.

Rita Johanne Lerøy was great help when carrying out the experiments and when weighing and measuring the fish. Prof. Dr. Petter Larsson and Ms. Karin Pittman gave valuable criticism to the manuscript.

The work is part of a research program investigating the ecological consequences of fish farming in lakes, funded by BP Petroleum Development (Norway) Ltd., Directorate of Fisheries and the University of Bergen.

Table 1: Weight and length increase in percent per day during the experimental period. Mann-Whitney U-TEST, two-tailed.

FOOD PELLETS	TANK	WEIGHT		LENGTH	
	1	0.70		0.15	
YELLOW	4	0.57		0.15	
	7	0.63		0.14	
			$P>0.5$		$P > 0.05$
	2	0.66		0.15	
BROWN	5	0.69		0.14	
	8	0.71		0.16	
			$P<0.024$		$P<0.024$
	3	1.00		0.20	
MIXED	6	0.86		0.19	
	9	0.74		0.16	

Table 2: The increase in condition factor from Februar 14 to April 10 (Mann-Whitney U-TEST, two tailed).

FOOD PELLETS	TANK	SMALL FISH		LARGE FISH	
YELLOW	1	0.05		0.07	
	4	0.04		- 0.01	
	7	0.11		0.15	
			P>0.5		P > 0.05
BROWN	2	0.02		0.01	
	5	0.08		0.08	
	8	0.13		0.11	
			P<0.024		P<0.013
MIXED	3	0.14		0.09	
	6	0.14		0.12	
	9	0.14		0.13	

Table 3: Amount of fish feed used, growth of fish and the ratio obtained in the experimental period. No significant differences between food inputs.

FOOD PELLETS	TANK	FEED (KG)	GROWTH (KG)	RATIO
	1	18.5	4.308	4.3
YELLOW	4	18.3	3.218	5.7
	7	18.9	3.484	5.4
	2	16.0	3.621	4.4
BROWN	5	19.6	3.783	5.2
	8	15.0	4.020	3.7
	3	17.6	5.498	3.2
MIXED	6	19.4	4.687	4.1
	9	21.4	4.422	4.8

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