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Feed wastage, feeding activity and behaviour of rainbow trout in net cages with pendulum feeders

by
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Abstract

The feeding and locomotor activity of a rainbow trout school was observed at a commercial fish farm in the Archipelago Sea in Finland. Certain factors which can be used to decrease feed wastage were observed. The maximum wastage observed was estimated to be 3% of the daily feed ration. Wastage took place only during the night. When the pendulum feeder was closed for the night, the consequence was an immediate change in the behaviour of the fish. The number of feeding pauses decreased and active continuous feeding increased. In order to increase the conversion efficiency in net cage farming, there must be a special focus on feeding activity.

Introduction

Most of the nutrient load from fish farming in Finland goes into sea. All measures which can be taken to decrease the load are of great importance for the development of farming. The most effective way to reduce the nutrient load is to adjust the composition of the feed and feeding to suit the requirements of the fish (Mäkinen 1991). Increasing feed efficiency is not only the most effective but also the most economical way to reduce the load, and is therefore the most beneficial measure for the farmer.

Some highly sophisticated systems have been studied in order to develop a technical system to control the feeding in net cage farming (Anon. 1988, Juell et al. 1990, Juell & Westerberg 1993). To protect the more sensitive coastal areas, farming sites are commonly being moved to the open sea in all Scandinavian countries. This change of location makes the general conditions on an average fish farm more demanding. As a result the use of highly sophisticated feeding control systems at these exposed sites will become more difficult. Reducing the nutrient load calls for simple feeding control methods based on fish behaviour.

This report contains the results of a preliminary study of the feeding behaviour of rainbow trout in a net cage using a pendulum feeding device. The aim of the study was to establish the measures that must be taken to reduce feed wastage. The goal of the project is to develop a simple feeding control method to adjust the daily feed ration so as to give higher feed efficiency.

2. Material and methods

2.1 Conditions at the study location

The experiment was made in September-October in a single net cage at a commercial net cage farm in the Archipelago Sea (Fig. 1). The farm consists of four octagonal net cages (19 m diameter; 6 m deep at the sides, 8.5 m in the centre; 25 mm square net). 20 000 rainbow trout were stocked in each cage in

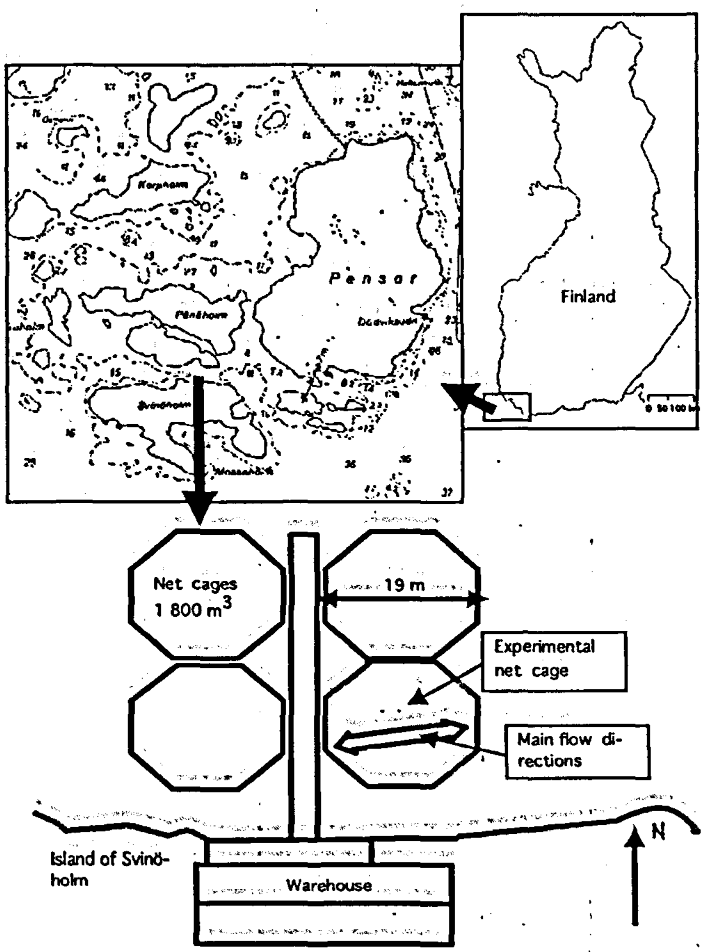


Figure 1. Location of the farm and the experimental cage

May. According to the estimated mortality and average weight of the fish (1.3 kg) the fish density during the experiment was 14 kg/m³. A commercial dry feed (9 mm pellet size) and pendulum feeding devices were used (Fig. 2). The feeding rate was estimated based on how often the feeding device containers had to be filled. Consumption averaged 250 kg/d/cage during the experiment. Because of the observed nightly wastage, the pendulum feeding devices were closed and no feed was given during the night (about 19-07 h) from September 25 onwards, with the exception of the nights of September 27 and 28.

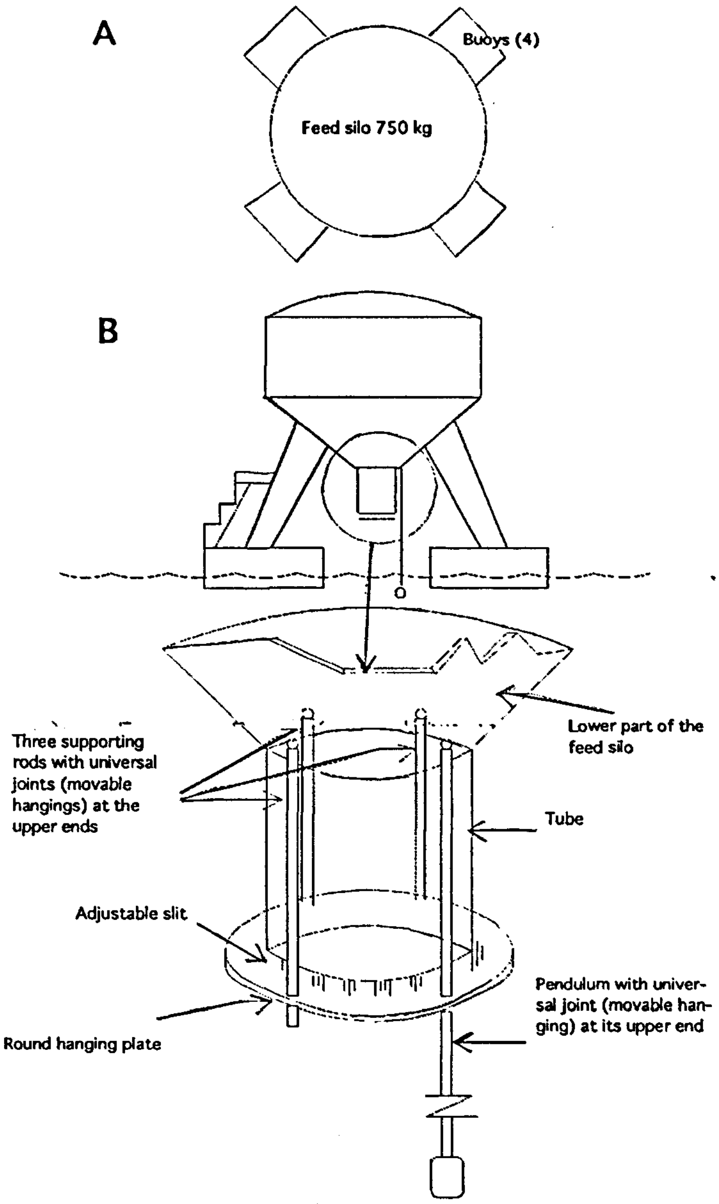


Figure 2. Structure of the pendulum feeding device. (A) View from above (B) Side view.

The water temperature during the experiment ranged from 12° to 15°C (Table 1). The direction and speed of water flow was measured with a flow meter made from a rudder blade and a flow screw meter. The main flow at the site varied indefinitely,

Table 1. Water temperature during the experimental time (°C)

Depth (m)	Date 06.09.	16.09	23.09	02.10	09.10
Surface	14.8	14.6	14.2	13	12
1	14.8	14.5	14.2	13	12
2	14.8	14.5	14.2	13	12
3	14.8	14.5	14.2	13	12
4	14.8	14.5	14.2	13	12
5	14.8	14.5	14.3	13	12
6	14.8	14.5	14.3	13	12
7	14.8	14.5	14.3	12.9	12

with both east and west flows. Compared with the inner archipelago, the water is clear at the study site; the secchi depth varied between 5.7 and 7 m during the experiment.

2.2 Recording the feeding activity

Feeding activity was measured using a plotter and a switch connected to the pendulum of the feeding device (Fig. 3). The paper speed of the plotter used was 2 mm/min. The highest values were checked separately by changing the speed of the paper to 600 mm/min, which gave an average of 57/min. (range from 44 to 69) as the recorded maximum value. The recorded values cannot be directly converted into quantities of feed. Their correlation to the feeding activity of the fish is not straightforward either: during active feeding the pendulum was sometimes stuck at one side, meaning that the switch had short circuited and no recorded marks were plotted during this time. It was established that all marks recorded by the plotter were caused by the fish; neither waves nor wind was strong enough to close the pendulum switch.

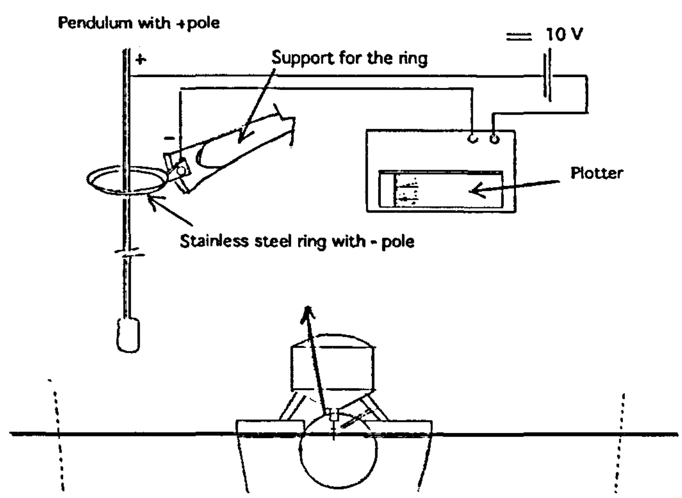


Figure 3. Pendulum switch and its connection to the plotter

As well as actually counting the marks recorded on the plotter paper, we observed three different types of feeding activity: pause, periodic and continuous feeding. When a classification of the quantity consumed during these different types is added, five different types of feeding activity are found (Fig. 4).

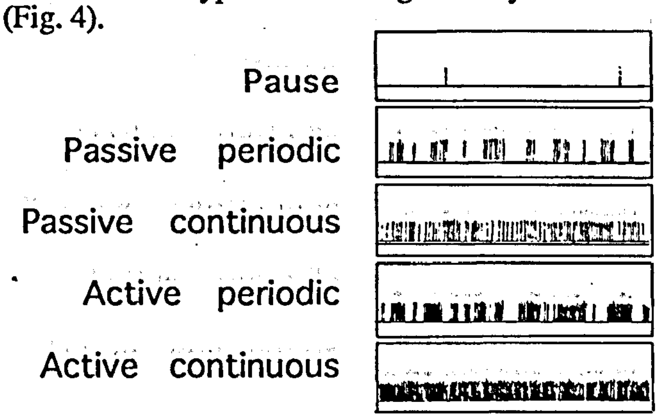


Figure 4. Typical plotter registrations for different feeding activity types. See text for details.

2.3 Recording the locomotor activity

The behaviour of the fish was observed using an echo sounder (Lowrance X-16) between September 14 and October 4, 1992. The sound transmitter was hung under the pendulum feeding device at a depth of about 6 m (Fig. 5). The echograph was adjusted

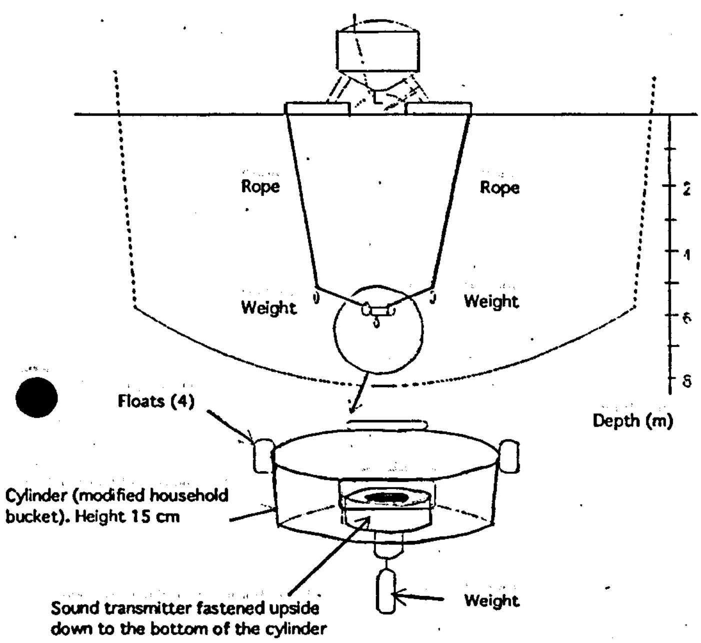


Figure 5. Echo sounder in the experimental cage

so as to avoid recording small particles in the water. The recording was done for periods of two minutes at 10 minute intervals (12 min recording/h). The data were divided into 30 min periods and three different behaviour types were classified:

-single fish swimming near the surface
-schools
-slow moving and unmoving fish

The recorded echo does not describe the number of fish but, with the help of the classification mentioned, can be used to describe circadian changes in behaviour and the relationship between different behaviour types at the feeding device.

2.4 Recording feed wastage

Feed wastage was recorded using a sampler developed for the purpose. This was made from plastic household buckets (Fig. 6) and hung along the observed main flows near the bottom of the net cage. The inside of the cage was used because no cases of feeding fish were ever observed in the deeper part of the cage. Wastage of the feed ration was checked using this sampler. The total amount of wasted feed was estimated on the basis of the pellets remaining in the sampler's buckets (Fig. 7).

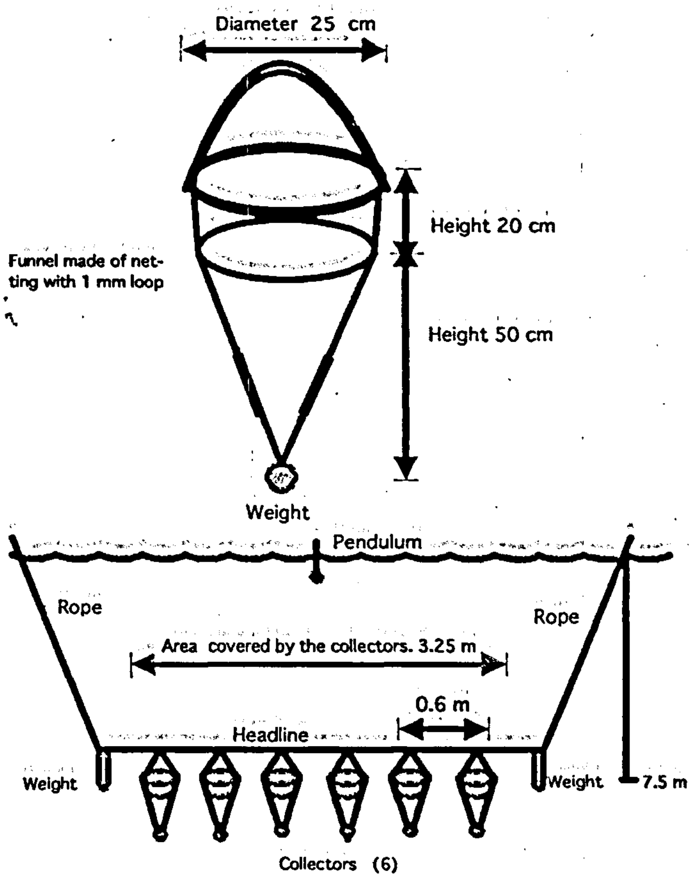
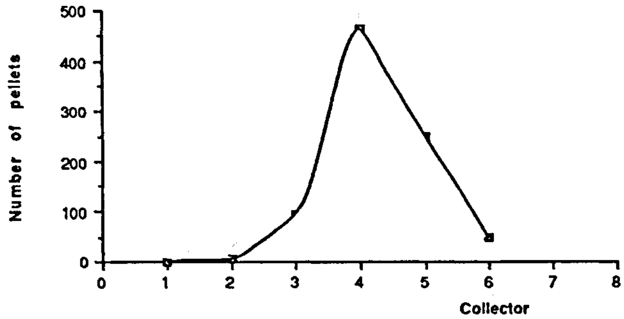
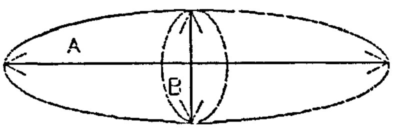


Figure 6. Sampler for wasted feed. Six collectors were made of 10 l plastic household buckets





$$A = (n-1)*p+k$$
$$Wf_{tot}=A_n*(A_A/A_c)$$

Figure 7. Calculations to estimate the total amount of wasted feed. Because of the observed water flows, it was assumed that the sedimentation area of wasted feed had the form of an ellipse, its length and breadth being calculated according to the results obtained with the sampler. For example, the following numbers of feed pellets were found in the collector buckets on September 23, 1992: collector 1=1, 2=5, 3=95, 4=464, 5=250, 6=48 (see the graph). The results obtained for collectors 1 and 2 were 7 and 8 respectively (Assuming the distribution was normal, this was presumed to result from 'mirroring').

The total sedimentation area was then calculated using the following formula:

$A = (n-1)*p+k$. where A=Length of the sedimentation area, n=estimated number of collectors in that area, p=distance of collectors from each other = 0.60 m, k=0.25 m.

An average of 300 pellets was used as the limit between (A) outer and (B) central areas. The calculations were made separately for central and outer areas using the average number of pellets in collectors in that area. The total number of pellets for both areas was calculated using the formula:

$Wf_{tot}=A_n*(A_A/A_c)$. where Wf_{tot} = Total amount of wasted feed, A_n = Average number of pellets in collectors in that area. A_A = Area of sedimentation. A_c = Area of the collectors.

2.5 Video recording

Underwater video recording was used to compare the other methods (pendulum switch, echo sounder) and to help interpret the results. The video camera was used for observation on October 10 and 21 - 23 for a total of 68 h, of which 21 h was recorded on tape. Recordings were made of the behaviour of the fish near the pendulum, and of feeding and resting fish at different depths. The movements of sinking feed pellets and fish following them were also recorded. The fish were also observed visually from the quay during the experiment.

3. Results

3.1 Feeding activity

The time of a feeding period varied from a few minutes to several hours. Periodicity with four to five day intervals was observed (Fig. 8). When the feeders were closed for the night the maximum amount of feeding activity remained the same, but the periodicity was no longer so clear. Before the closing, the daily feeding activity was distributed more or less evenly during the day. After the closing, the day-time feeding activity increased (Fig. 9), the length and number of pauses decreased and continuous active feeding increased. The most observable phenomenom was the increase in periodic passive feeding (Fig. 10).

After the pendulum feeding device was closed, some major changes in the circadian distribution of different feeding activity types were recorded (Fig. 11a-e). The pauses were shifted to the early hours (06 - 09 h) and active continuous feeding concentrated around noon. The largest relative increase was in periodic passive feeding which took place in the early morning and late at night, when the pendulum device was closed.

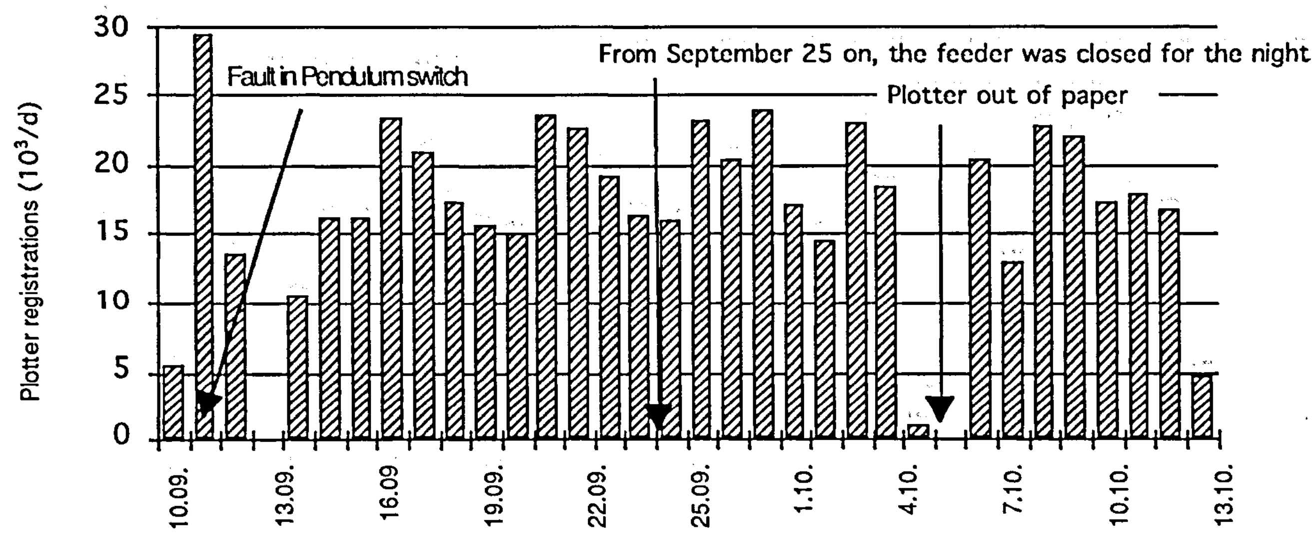


Figure 8. Recorded feeding activity of rainbow trout, September 9 - October 10, 1992. Initially the pendulum switch malfunctioned and on October 4-5 the plotter ran out of paper

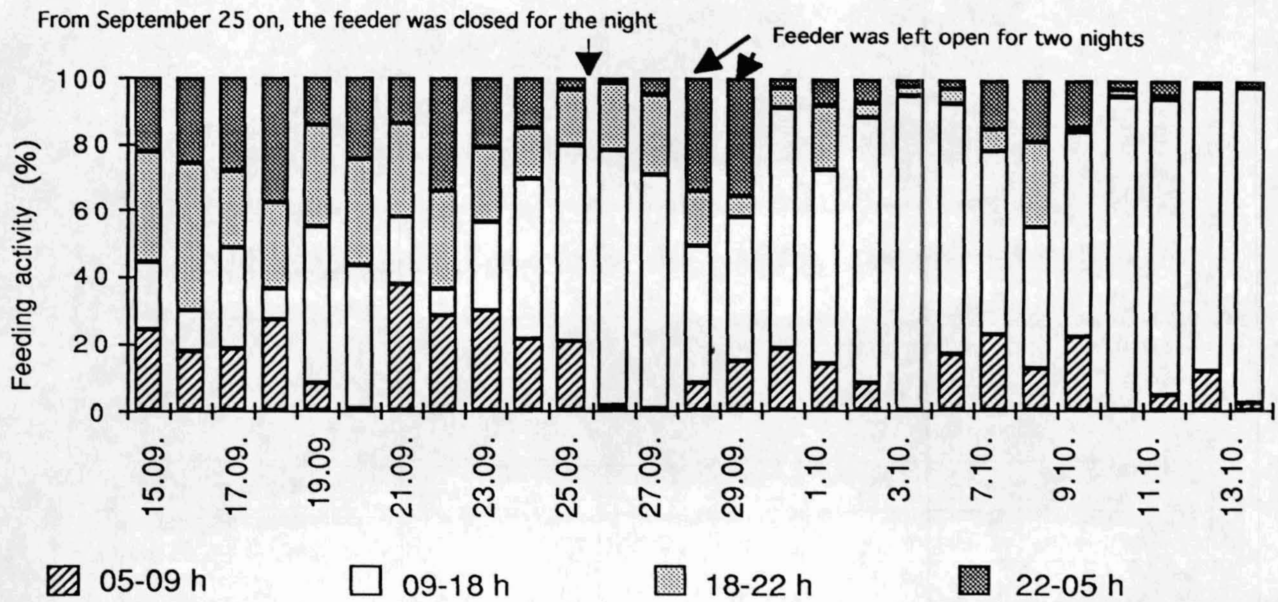


Figure 9. Distribution of feeding activity (%) during the day. Note the effect of opening the feeder on the two nights of September 28-29.

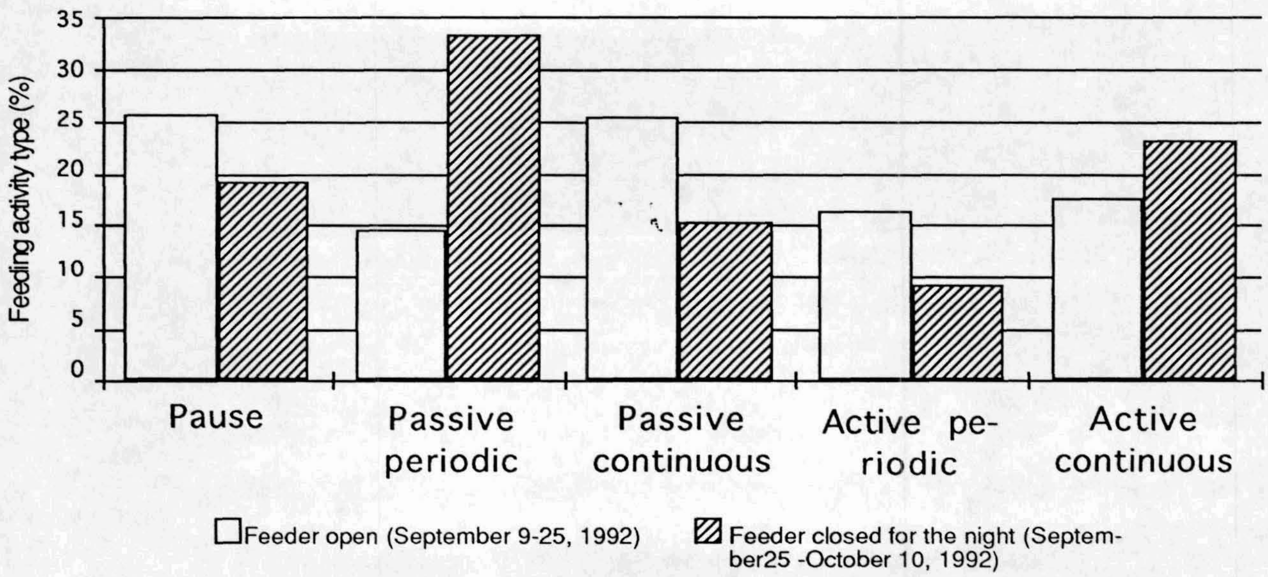


Figure 10. Average change in the share of different feeding activity types after the pendulum feeding device was closed for the night on September 25.

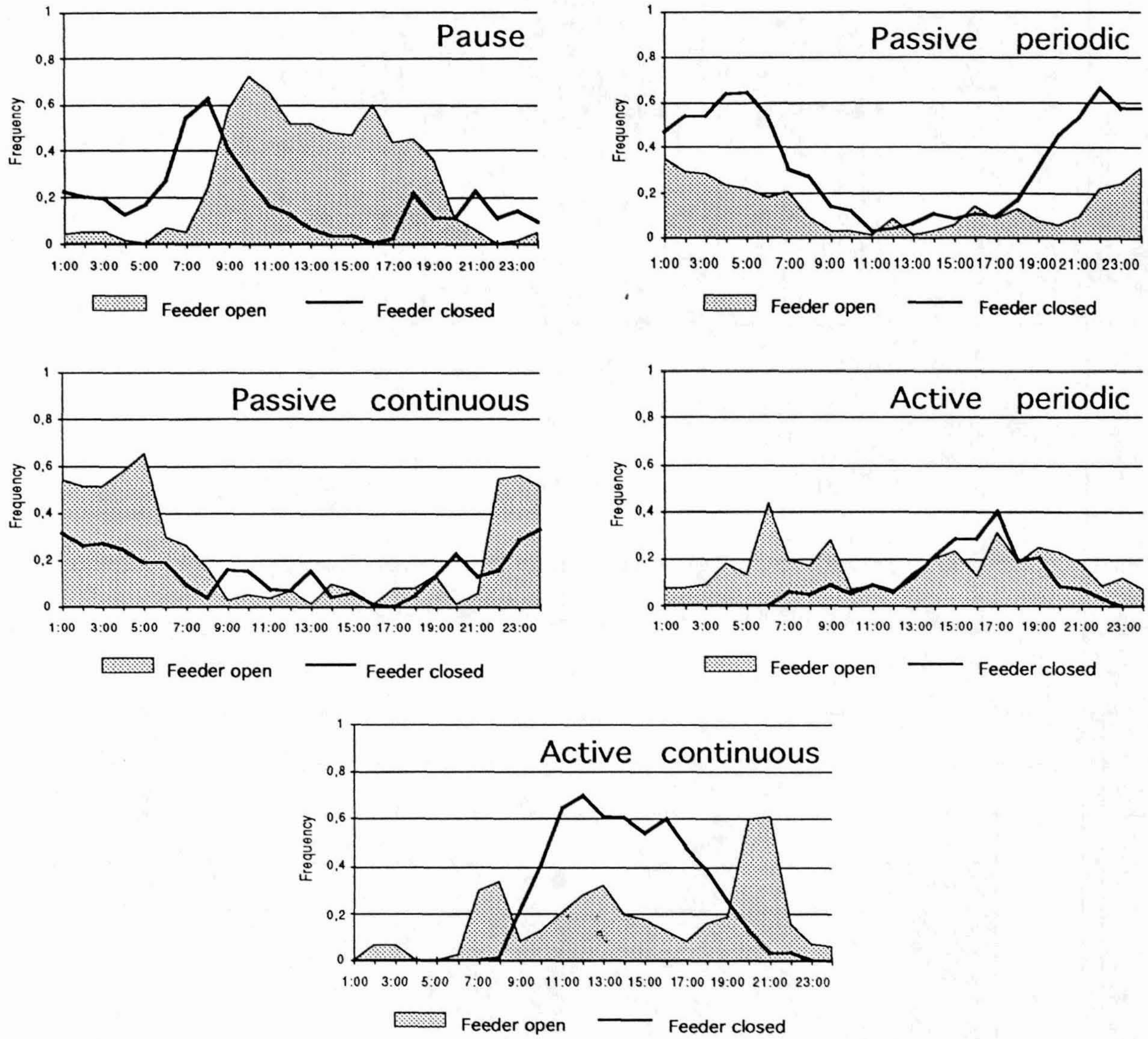


Figure 11. Circadian distribution of the feeding activity types before and after the nightly closing of the feeder.

3.2 Swimming behaviour near the pendulum

The number of schools in the vicinity of the pendulum was highest at 07 and 19 h (Fig. 12a, b). The frequency of schools was highest during the day time, and this was even more distinct after the feeders were closed for the night. The observations made with the echo sounder and the video recordings corresponded.

The frequency of fish near the surface was initially highest during the night. During the day time this frequency decreased with increasing feeding pauses. Closing the feeding devices for the night markedly increased the frequency of the fish near the surface under the feeder. The increase in the number of fish near the surface is noticeable during the time of highest feeding pause frequency (06-09 h, see Figs 11a and 12b).

The number of unmoving fish decreased after 06 h and increased again after 18 h. Once the pendulum was closed, these 'sleeping' fish became active earlier (see Figs 12a, b).

3.3 Feed wastage

Twelve sampling periods of 02 to 24 hours were used (Table 2). The number of pellets in a single bucket was highest (456) during darkness. As the light increased, the number of pellets decreased markedly. During the day time, no wastage of pellets was observed. The highest wastage was estimated to have been about 8 kg/night/cage (Table 3).

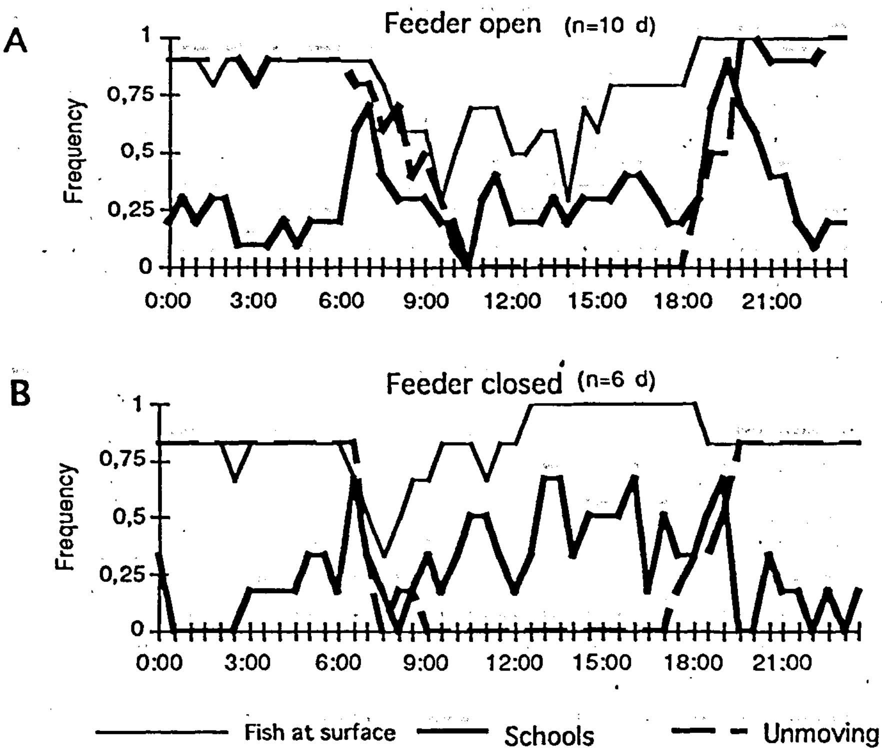


Figure 12. Behaviour of the fish in the vicinity of the pendulum feeding device. (A) Before Sebtember 25, feeder open, (B) After September 25, feeder closed for night. The vertical axis shows the relative frequency of the observations.

Table 2. Sampling of wasted feed pellets

Exp.	Date	Start time	Duration (h:min)	Collector number (number of feed pellets) 1	2	3	4	5	6	Total
1	21.09.	15:45	2:05	0	0	0	0	0	0	0
2	21.09.	18:00	12:25	0	1	31	223	456	162	873
3	22.09.	6:50	2:50	0	0	1	1	2	2	6
4	22.09.	9:55	3:15	0	0	0	0	0	0	0
5	22.09.	13:20	3:50	0	0	0	0	0	0	0
6	22.09.	17:15	13:30	1	5	95	464	250	48	863
7	23.09.	7:15	2:25	0	0	0	0	0	0	0
8	23.09.	9:45	4:15	0	0	0	0	0	0	0
9	23.09.	14:30	24:20	0	1	1	88	473	411	974
10	24.09.	18:00	20:00	0	0	0	1	2	1	4
11	27.09.	18:00	21:00	0	0	0	0	75	57	132
12	28.09.	15:20	18:50	0	3	19	111	123	31	287

Table 3. Estimated feed wastage (number and total weight of pellets) and calculated sedimentation areas

Exp.	Centre Pellets	Area(m2)	Side-area Pellets	Area(m2)	Total Pellets	kg	Wasted feed of daily ration (%
1	0	0	0	0	0	0	0
2	2074	1.4	6065	26.8	8139	5.7	2.3
3	0	0	96	21.7	96	0.1	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	2110	1.4	5739	31.8	7849	5.5	2.2
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	9046	6.5	1746	16.6	10791	7.6	3
10	0	0	49	11.6	49	0	0
11	0	0	1947	11.6	1947	1.4	0.5
12	0	0	4238	31.8	4238	3	1.2

Average weight of a pellet (n=150) 0.703 g (range 0.696- 0.712)
Average daily ration 250 kg/d/cage

3.4 Underwater video observations

The rainbow trout school observed took feeding pauses of up to one day. During these pauses the school swam in a small circle (diameter about half that of the cage) or in a figure-of-eight. This 'milling' was observed down to a depth of 6 m. Fish were rarely observed at depths below 6 m. During the pauses, there were no fish under the pendulum feeding device.

Before the feeding period, swimming activity increased noticeably. Small schools began to separate from the big 'milling' school, drawing closer to the pendulum, though individual fish still avoided touching it. When feeding began a fish either actively nibbled or bumped the pendulum, or the pendulum was moved passively for example with a fish's tail. In periodic feeding, the school involved was clearly distinguishable from the main 'milling' school (Fig. 13a). In continuous feeding, the school was not distinguishable, but a 'loop' moved via the feeder area (Fig. 13b). The bulk of the fish constantly maintained the 'milling' movement. The maximum volume of the feeding school observed under the feeding device was 3 m in depth.

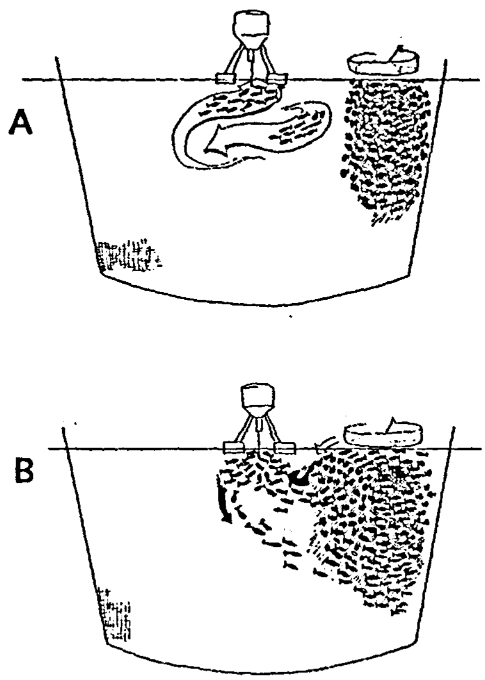


Figure 13. Fish behaviour during periodic and continuous feeding. (A) Periodic feeding. A school is separated from the 'milling' main school. (B) Continuous feeding. The fish continuously swim through the area in the vicinity of the pendulum feeding device and afterwards return to the main school. The feeding fish are not the same individuals and a separate school can not be distinguished from the other fish.

4. Discussion

The present study is the first to clearly record and measure the feed wastage for which fish farming is criticised. The wastage took place during the obscurity of night. It is thus presumed to be dependent on the amount of light. Alanärä (1992a) showed a dependence on temperature, i.e., that wastage increased with increasing temperature. A study must be made of whether wastage takes place on light summer nights when the water temperature is over 10°C.

After the observed wastage, the feeding devices were at once closed by the farmer for the night. This caused some dramatic changes in the behaviour of the fish. It may be that the fish trying to get feed from the pendulum device during the night are always the same subordinate individuals.

Because data of this preliminary study comes only from one net cage, we can make no recommendation for the daily closing time for pendulums. It seems reasonable to close the feeder from 19 to 07 h, as this corresponds to the high frequency of unmoving fish. This, however, must be confirmed with further observations.

The circadian activity patterns and the annual change in them have been studied in many fish species (Thorpe 1978). The usual model is a shift from winter-time day activity, through crepuscular activity in the spring to activity round the clock in mid-summer, and vice verse in the autumn (Müller 1978). There is great variation in the behaviour of individuals in these studies and the effect of different experimental arrangements is obvious (Eriksson 1973, Landless 1976, Jørgensen & Jobling 1989). The small change in pendulum feeding made in this study had a major effect on the behaviour of the fish. This shows that circadian demand-feeding behaviour can be modified very easily. This should be borne in mind both by researchers seeking to establish the natural circadian behaviour of cultured fish and by fish farmers seeking to ensure the optimum feeding of a fish school.

Alanärä (1992b) concluded that restricting demand feeding by closing the pendulum feeding devices for part of the time results in better feed conversion without any loss in growth rate. We need better understanding of the interaction between circadian feeding rhythms and the feeding schedule used if we are to find a valid basis for recommendations for practical fish farming. Nevertheless, this preliminary study indicates an interesting way of affecting the behaviour of the fish, thus avoiding feed wastage and achieving better feed conversion. The projected automatic technical ways of controlling feeding at fish farms based on echo sounders or video equipment are probably not feasible. For actual fish farms, the reliability of such automatic methods would be too low, their costs too high and their use too complicated. A simple method based on controlling the daily feeding times of pendulum feeders and on the farmer's understanding of the fish's feeding behaviour seems the most feasible solution for the near future.

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