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EFFECTS ON SALMON (SALMO SALAR) FROM DIFFERENT OPERATIONAL PROCEDURES IN FISH FARMING

By

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ABSTRACT

The effects on farmed salmon caused by operational procedures as handling, de-lousing, removal of dead fish, grading and transfer were studied by underwater TV-observations, ultrasonic telemetry of heart rate and analyses of blood cortisol level. Handling and de-lousing were identified as important stressors.

1. INTRODUCTION

Intensive pen culture of Atlantic salmon has during the last decade developed to a large scale industry, with a global production of 76.259 metric tons in 1987 (pers.comm. A. Sletvold, Norwegian fish farmers sales organization). In this development, the main emphasis has been put on the technical aspects - with less attention to the prosperity of the fish during different stages of the production cycle.

However, during the last years, several authors have focused on the negative effect on cultured fish from different stressors as crowding, handling and transportation (Barton et al., 1980; Specker & Shcreck, 1980; Wedemeyer, 1976).

Todays salmon farming is dominated by rearing the fish in floating net cages of approximately 700 m^3 volume, at densities up to 40 kgs of fish per cubic metre. A maximum production is dependent on rapid growth and low mortality. Both growth rate and survival is believed to be proportionally related to fish prosperity (Wedemeyer & Wood, 1974).

Stressors on farmed salmon may be classified in two categories:

1) Environmental stressors that can be controlled only to a small extent, e.g. temperature and oxygen.
2) Operational stressors as fish handling, medical treatments and feeding, and also noise and visual stimuli from different sources.

The aim of this work was to study the effects of possible stressors from normal operational procedures in salmon farming.

2. MATERIALS AND METHODS

The experiments were conducted at Austevoll Marine Aquaculture station during 1986-1987, mainly as case studies on different groups of fish. The salmon were kept under normal rearing conditions with respect to cage size (12x12x5 m), fish density (20 kgs/m^3) and operational procedures.

2.1 Operational procedures

Feeding

Feeding is the most common procedure in fish farming, but there are great variations with respect to type of feed, feeding method (manual, automatic) and feeding strategies. The reaction to feeding was studied by observations of general behaviour, heart rate and vertical fish distribution.

Handling procedures

The following handling procedures were studied: De-lousing, removal of dead fish, change of fish cages, grading and fish sampling/measurement. These handling operations all include different degrees of crowding by decreasing the cage volume by hauling up the cage webbing.

Mass infestation of salmon lice (Lepeophteirus salmonis) is a severe problem in intensive salmon farming. The common method to remove the parasites is a bath treatment with a chemical solution (Neguvon or Nuvan) in sea water (Brandal & Egidius, 1979). The fish is crowded and forced to swim from the rearing cage to the bath cage, and then retransferred to the rearing cage. The whole procedure takes about 1 hour. The fish is exposed to different potential stressors as crowding, forced transfer and the chemical solution. The reaction to de-lousing was observed by underwater-TV, heart rate and cortisol measurements.

Removal of dead fish is another routine procedure which might be a possible stressor. Dead fish normally sinks to the bottom of the cage and is removed by partly hauling in the net. The possible stress effects from this procedure has been studied by underwater-TV and heart rate.

Due to fouling, the net cages have to be exchanged with clean ones. This operation include possible stressors as crowding and forced swimming into the new net cage.

The fish are length- and weight measured every 3 months at the research station. This operation includes crowding, and lifting the fish from the cage to tanks where they are anaesthetized, measured and thrown into a new cage. This operation was studied by underwater-TV observations, cortisol- and heart rate measurements.

Grading is another common procedure in salmon farming. Except from anaestetizing, this operation is similar to the above mentioned measuring procedure.

Other possible stressors

Besides the routine procedures, the fish might respond to incidental stressors. The reaction to different auditory and visual stimuli as noise from propellers, pumps, power tools, detonations, people walking on the gangway, was thus included in the study. The reaction to bird predators was studied by moving an artificial bird silhouette over the cage.

2.2 Methods of observation

The methods of monitoring and observation are basicly as decribed by Bjordal et al. (1986).

Fish behaviour was observed either by eye or by underwater TV-cameras (Osprey-SIT OE 1321 and OE 1336). The cameras were positioned either viewing sideways into the cage at 2.5 m depth or upwards from underneath the cage.

Heart beat frequency was monitored by acoustic tags (Mohus & Holand, 1983) operated into the buccal cavity of the fish (Fernø et al., 1988). The signals were either recorded manually or by a newly developed automatic recording system (Floen et al., 1988). The life time of the tags were normally 1-2 months (limited by battery capacity). Up to four fish could be monitored at the same time, but normally one or two tagged fishes were used in the experiments.

For analysis of blood parameters, blood samples from 5 fish were taken in connection with special events like de-lousing (the blood sampling procedure is described by Fernø et al. 1988). In these experiments, the cortisol level was used as a stress indicator.

3. RESULTS

3.1 Feeding

The observations show a marked change in salmon behaviour when feeding starts. From a structured school-like swimming formation, feeding fish will normally do an upward directed burst swimming towards the food particle, and there is a general increase in swimming activity among the feeding part of the cage population. However, this is a typical behaviour for the fish in the upper part of the cage, while fish deeper in the cage tend to maintain the general swimming pattern (see also Fernø et al. 1988).

Registration of heart beat frequency show that feeding induce a rapid pulse increase of about 10 beats per minute, with a

slower pulse decrease in the period after feeding (Fig. 1). Figure 2 give an example of 2 fish in the same cage where one shows reaction to feeding by increased heart rate, while the other shows no reaction.

De-lousing

The de-lousing process starts by crowding the fish by hauling in the net of the rearing cage. During this stage the fish swim calmly and release air from the swimbladder which is interpreted as a stress reaction (Furevik et al., 1988). After a while in the treatment cage there is a high leaping activity which decreases at the end of the treatment period. The leaping activity of smolts starts earlier, and is more intense than for larger fish. UTV-observations show that fish deeper in the cage are negatively buoyant, and swim calmly with the heart tilted upwards. Some fish were observed to swim downwards, turn sideways and scratch the side against the bottom of the cage. After retransfer to the rearing pen, there is no leaping, but high rolling activity (the fish break the surface with head and upper dorsal side). (See Furevik et al. 1988 for further details on changes in surface activity.)

Figure 3 shows the heart rate for 6 salmon during different stages of the de-lousing process. From an undisturbed condition (rest), all the fishes responded to the de-lousing process with an increased heart rate, although there were marked individual differences.

The cortisol levels before and after de-lousing of different groups (cages) of salmon and rainbow trout are given in Table 1. Blood samples from 5 fish were taken before the crowding stage and another sample series was taken during retransfer to the rearing cage. All fish groups had a marked increase in cortisol level.

Table 1. Cortisol levels 1 hour before and after de-lousing for salmon (S) and rainbow trout (RB), August 19 and 20, 1986.
$\bar{x}$ = average cortisol value (µg/100 ml), from samples of 5 fish. -84/-85/-86 indicate the year the fish were transferred from fresh- to sea water.

Cage no.	Species/year	Before de-lousing $\bar{x}$	SD	After de-lousing $\bar{x}$	SD
1	S-84	1.1	1.4	14.4	4.4
2	S-84	1.9	3.6	4.8	1.8
3	S-84	1.5	0.4	8.3	2.3
4	S-84	4.0	2.3	15.2	4.1
5	S-86	0.6	0.5	7.8	3.9
6	S-86	2.0	1.5	4.8	2.6
7	RB-85	2.3	1.7	4.1	1.0
8	RB-85	0.5	0.7	4.1	1.0
9	RB-85	0.2	0.2	6.0	2.1
	$\Sigma\bar{x}$-S	1.9		9.2	
	$\Sigma\bar{x}$-RB	1.0		8.7	

Removal of dead fish

There are few data on the effects of this operational procedure. In five out of six cases the heart rate increased during removal from 1 to 18 beats/min.

Change of net bag

This process includes crowding and transfer by forcing the fish to swim over to the new net bag - and is such fairly similar to the first two stages of the de-lousing process. Table 2 gives the heart rate for different salmon at an undisturbed condition compared with the maximum observed value for the same fish during crowding or transfer.

Table 2. Heart rates of salmon before and during change of net bag. Values on the same date refer to different fish.

Date	Undisturbed condition	Max. heart rate
190286	38	54
161086	39	42
271086	30	57
260387	37	45
260387	31	36
310387	30	36
310387	30	33
310387	35	40
270887	53	80
Average	35.9	47

All fish reacted to the net change with increased heart rate. However, there was great individual variations, with the increase ranging from 3 to 27 beats per minute.

Fish measurements and grading

In addition to crowding, the measuring- and grading process includes anaesthetizing the fish and taking the fish out of the water. Average cortisol values of samples from 5 fish during five different operations are given in Table 3.

Table 3. Average cortisol values from 5 salmon during measuring/grading operations.

Group	Date	Cortisol level (µg/100 ml)	SD
1	250686	40.9	15.3
2	250686	38.2	8.6
3	070886	15.1	1.8
4	070886	15.6	3.5
5	141086	9.6	2.7

Cortisol levels prior to the sampling operation was only measured in groups 1 and 2 (1.6 and 1.3, respectively).

The fish reaction to the sampling procedure is also illustrated in Figure 4, which show heart rate values before and after sampling for 3 fish. Data are few and incomplete because heart tagged fish are not easily identified, and the transmitter signals are often disturbed after anaestetizing.

Auditory- and visual stimuli

Several different sources of auditory- and visual stimuli might be possible stressors for farmed salmon. The reaction to this type of stimuli has been studied, mainly by UTV-observations. The change in behaviour was classified as : a) No change in behaviour with the fish maintaining normal swimming speed and direction, b) Avoidance reaction with the

fish swimming slowly away from the stimuli source, and c) Fright reaction with an instantaneous change in swimming speed and direction with the fish usually diving away from the stimuli source at high speed.

a) **No reaction.** The following had no effect on the fish as observed by behaviour studies: Scuba diver, both outside and inside cage (when a scuba diver was inside the cage, the fish kept a certain distance, but showed otherwise no fright reactions), small crafts with outboard engines passing the cage, running of pumps, power tools used on the gangway (like drills and angle grinders), and high pressure water cleaners used on the net wall of the cage.

b) **Avoidance reaction.** This type of reaction was observed when people was approaching the cage and when running trolleys down the gangway.

c) **Fright reaction** was observed during the following cases: Detonations on land close to the fish farm, propeller noise from large vessels, and when experimental bird silhouettes were moved over the cage.

Methodological experiences on heart beat tags

In this study, the use of ultrasonic heart beat tags was chosen as one of the main methods. It was therefore of importance to clarify to which extent a tagged fish is representative. From April 1986 to August 1987, acoustic tags were implanted in 20 fish. The transmitters lasted from 4 to 73 days, with an average lifetime of 40 days.

Some fish would feed as soon as 2 hours after the implantation, but normal recovery time was 1-3 days.

During sampling, 5 tagged fish were identified at different time intervals from the implantation date. The lengths (measured to the closest 0.5 cm) at implantation and sampling

and the intervening times were: 53-64.5 (150 days), 56-64 (137 days), 62-63.5 (41 days), 60-61 (33 days) and 59-60 (27 days).

Fish with heart tag were also at two incidents identified during blood sampling. These fishes both had a lower cortisol level than the average value of the sample from five fish, 1.18 versus 1.33 and 23.61 versus 38.20 µg/100 ml (the last sample taken during fish measuring).

DISCUSSION

In this study on the reaction of salmon to possible stressors in intensive farming, fright reactions were rarely observed. The results indicate that strong, low frequency sound and objects passing over the cage are types of stimuli leading to fright reactions. Possible habituation effects to such stimuli were, however, not studied.

De-lousing and fish measurements were identified as important stressors on farmed salmon, by increased cortisol level. A corresponding increase in heart rate suggests that this parameter might also be a good indicator of stress. However, increased heart rate is also characteristic for feeding fish. This might be a stress reaction due to feeding competition, but may also be caused by increase in physical activity and metabolic rate.

A moderate increase in heart rate during removal of the dead fish from the cage classifies this as a mild stressor. This is supported by observations of reduction of appetite during feeding periods after removal of dead fish (Juell, 1988).

The implanting technique of heart beat transmitters seems to be an interesting method for long term monitoring of heart rate without imposing methodological stress on the fish. The rapid and significant change in heart rate due to different

stressors suggests a possible application of this method by using tagged fish to indicate the general state of the cage population. However, this calls for a development towards transmitters of smaller size and longer lifetime.

REFERENCES

Barton, B.A., R.E. Peter & C.R. Paulencu, 1980. Plasma cortisol levels of fingerling rainbow trout (Salmo gairdneri) at rest, and subjected to handling, confinement, transport and stocking. J.Fish.Res.Bd.Can. 37, 805-811.

Bjordal, Å., S. Floen, J.E. Fosseidengen, B. Totland, J.T. Øvredal, A. Fernø & I. Huse, 1986. Monitoring biological and environmental parameters in aquaculture. Modeling, Identification and Control, 1986, Vol. 7, No. 4, 209-218.

Brandal, P.O. & E. Egidius, 1979. Treatment of Salmon Lice (Lepeophteirus salmonis Krøyer, 1838) with Neguvon$_R$ - Description of Method and Equipment. Aquaculture, 18 (1979), 183-188.

Fernø, A., D. Furevik, I. Huse & Å. Bjordal, 1988. A multiple approach to behaviour studies of salmon reared in marine net pens. Coun.Meet.int.Coun.Explor.Sea, 1988, F:15.

Floen, S., B. Totland & J.T. Øvredal, 1988. Automatic recording of fish heart rate on a personal computer. Coun. Meet.int.Coun.Explor.Sea, 1988, B:34.

Juell, J.E. 1988. Feeding of salmon in net pens: Maximum food intake measured by acoustic detection of food waste. Master thesis. Dept.Fish.Biol. U. of Bergen, 106 pp (in Norwegian).

Mohus, I. and B. Holand, 1983. Fish telemetry manual. SINTEF rep. STF21, A87050. The Found. of Sci. and ind. Res./ Norw.inst.Techn., Trondheim.

Specker, J.L. & C.B. Schreck, 1980. Stress responses to transportation and fitness for marine survival in coho salmon (Oncorhynchus kisutch) smolts. J.Fish.Res.Bd. Can., 37, 765-769.

Wedemeyer, G., 1976. Physiological response of juvenile coho salmon (Oncorhynchus kisutch) and rainbow trout (Salmo gairdneri) to handling and crowding stress in intensive fish culture. J.Fish.Res.Bd.Can., 33, 2699-3702.

Wedemeyer, G. & J. Wood, 1974. Stress as a predisposing factor in fish diseases. U.S. Fish Wildlife Serv., Fish Dis.Leafl., 38, 8 pp.

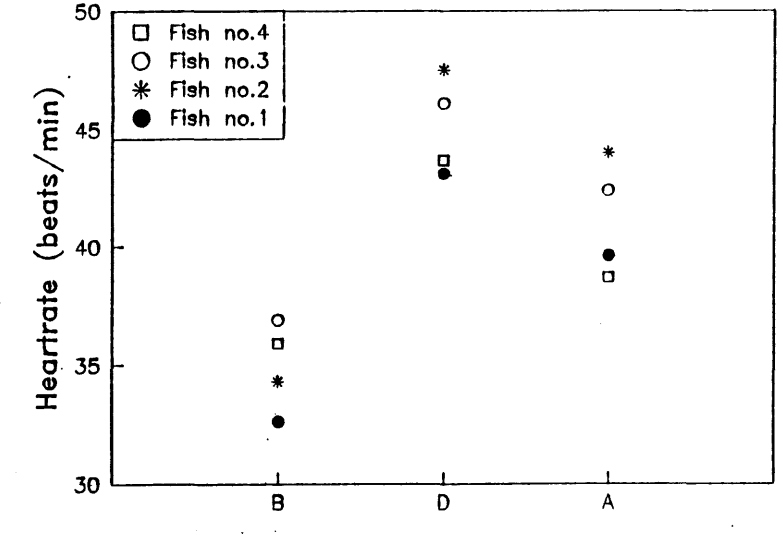

Figure 1. Heart beat frequencies for four salmon, 30 minutes before (B), during (D), and 30 minutes after (A) feeding, during the period 200586 to 190686. Average values from 19 - 23 observations per fish.

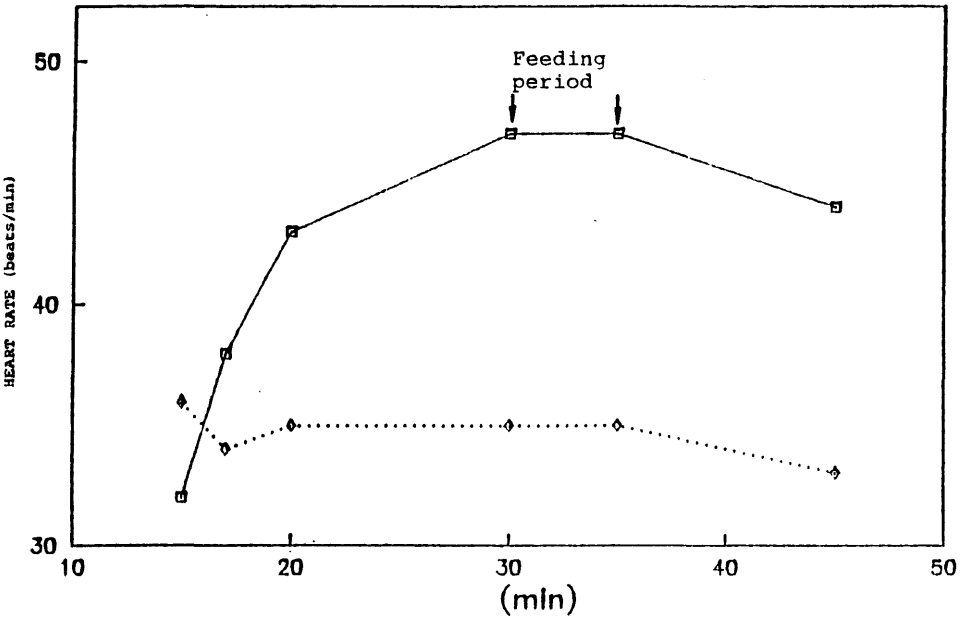

Figure 2. Heart rate of 2 salmon in the same cage during feeding.

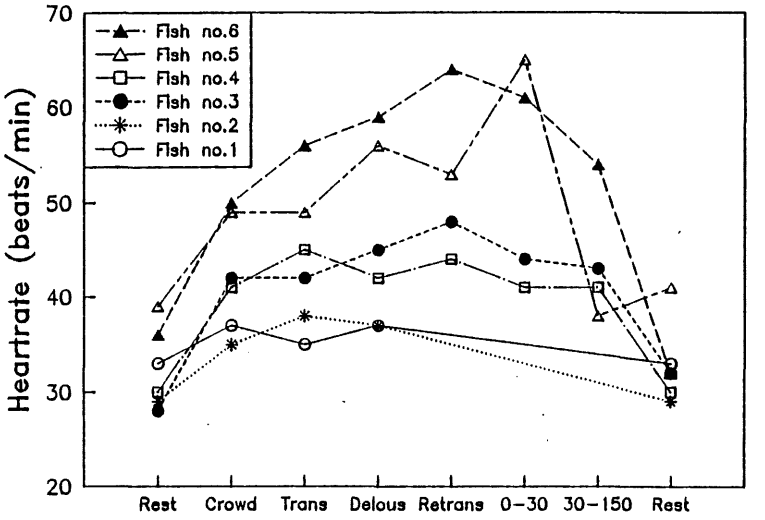

Figure 3. Heart rates of 6 salmon during different stages of the de-lousing process: Rest (morning at day of de-lousing), crowd(ing), Trans(fer) to treatment cage, in Delous(ing) cage, Retrans(fer) to rearing cage, 0-30 (min) -, 30-150 (min) after retransfer, and Rest (next morning).

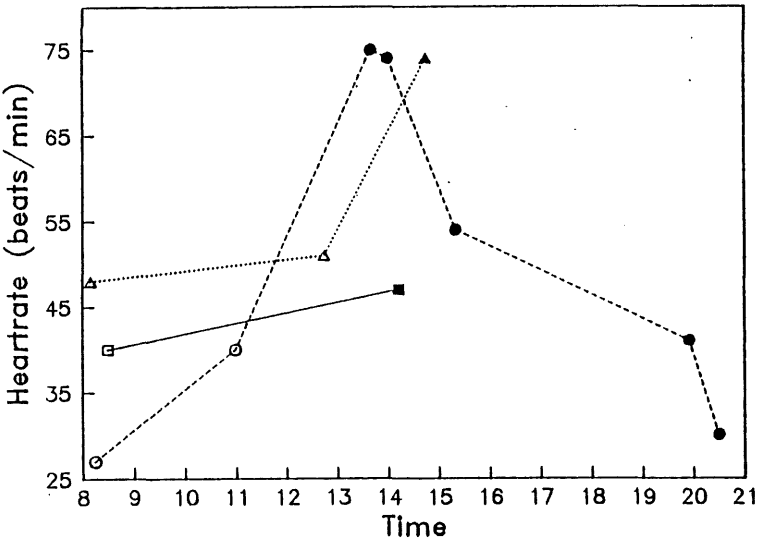

Figure 4. Heart rates of 3 salmon before (open symbols) and after (filled symbols) sampling/fish measuring.