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The Effect of Shading in Pen Rearing of Atlantic Salmon (*Salmo salar*)

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ABSTRACT

A full scale Atlantic salmon pen rearing experiment with light-reducing black polyethylene netting covers was carried out over one year in order to elucidate effects of reduced illumination on growth, mortality, ecto-parasite infestation and net pen fouling. Illumination was reduced by 76% and 44%, respectively, for the two cover types used. Growth was marginally reduced by covers in winter and spring, but was slightly enhanced by the covers in summer and early autumn. Infestation of salmon lice was slightly reduced by the covers. Algal fouling was reduced by the covers, but hydroid settling was higher in covered than in uncovered pens.

INTRODUCTION

Pen rearing of salmonids has developed into an important industry in many countries around the world (Rosenthal, 1985; Ackefors, 1986). The method is cost effective and farms can easily be expanded in protected coastal areas. While a substantial effort has been put into enhancing the method in terms of operational functionality, little is done to improve the conditions for the fish. One aspect of the environment, which can often be controlled in aquaculture, is the level of light the fish are exposed to.

It is well known among river anglers that salmon tend to occupy shady areas in the river (Jones, 1972). Fish farmers also observe that salmon are less willing to surface feed in bright sunlight than in overcast weather.

Pickering *et al.* (1987) showed that overhead cover significantly increased the growth rate of juvenile Atlantic salmon in fresh water. Sun burns in shallow water fish and in fish kept near the surface in net pens are reported by Bullock *et al.* (1979) and covered in depth by Bullock (1988). The parasitic copepod *Lepeophtheirus salmonis*, one of two parasites also known as salmon lice, represents a major problem in pen rearing of Atlantic salmon. The pelagic larvae of this parasite are positively phototrophic (Johannessen, 1975). A preliminary study indicated reduced *Lepeophtheirus* infestation in a group of salmon kept in a pen covered by a light-proof roof compared to a control group in an uncovered pen.

Fouling of net pens by algae and invertebrates also represents an important problem in net pen operations due both to decreased water exchange and to the necessity of antifouling procedures, or the use of environmentally harmful antifoulants. Shading of net panels could be expected to reduce algal growth through reduced light available for photosynthesis, as was demonstrated in the above-mentioned pilot study.

In the present study, possible effects of shading pen reared Atlantic salmon from direct sunlight are investigated with special reference to growth, mortality, ectoparasites and net pen fouling.

MATERIALS AND METHODS

The experiments were carried out at the pen rearing facilities of the Institute of Marine Research, Austevoll Marine Aquaculture Station near Bergen, Norway. Five net pens of 12 m × 12 m with a depth of 6 m were used. Three of the pens were covered with a fine mesh black polyethylene netting. The experiment was divided into two subexperiments, U1 and U2. In addition to an uncovered control pen, U2 had two covered pens. The two covers were specified by the manufacturer to absorb 70% and 40% of the direct sunlight, respectively. Measurements carried out with a luxmeter at noon on 26 November gave absorption values of 76% and 44%. U1 had one pen covered with the 70% netting in addition to an uncovered control pen.

The net pens were all exchanged on the same day when this was considered necessary with regard to the most fouled pen. The fish in all pens were treated for ectoparasites on the same day when this was considered necessary with regard to the most infested group. The general arrangement is shown in Fig. 1, while the arrangement of a single pen is shown in Fig. 2. The experimental blocks were not randomized as one wanted to keep the shaded pens together for practical reasons.

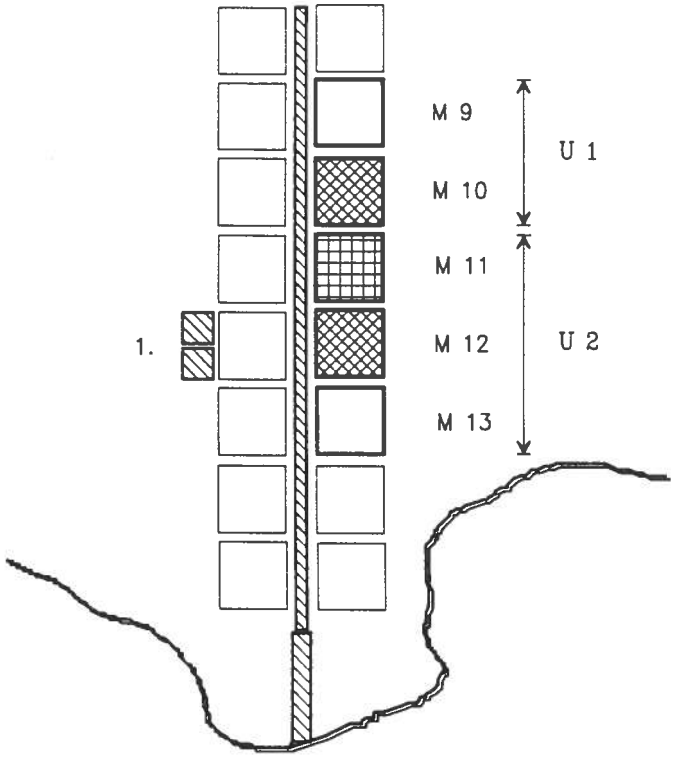

Fig. 1. General arrangement of net pen site with experimental units. 1, Observation rooms.

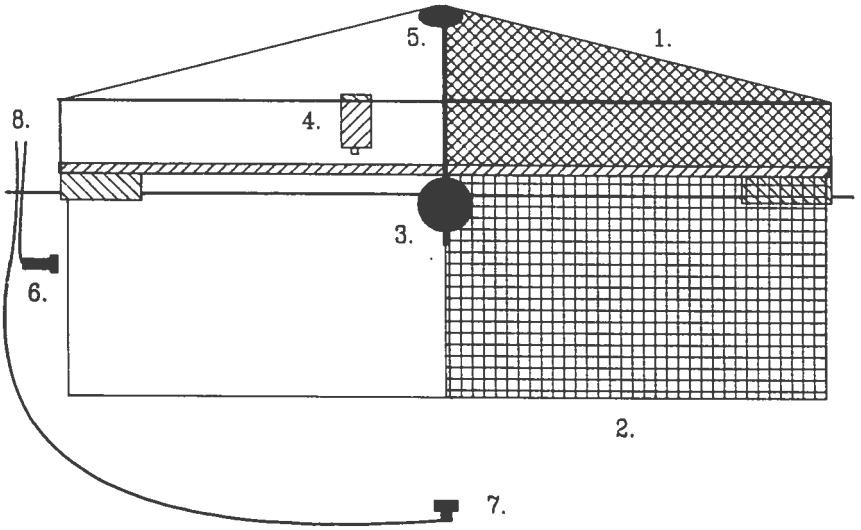

Fig. 2. Arrangement of one experimental unit; one half shown with net panels. 1, Cover netting panel; 2, pen net panel; 3, feed automat and cover netting support float; 4, feed automat; 5, cover netting support cushion; 6, underwater television camera; 7, echo sounder transducer; 8, cables to observation rooms.

The pens in U2 were stocked with 3222, 3225 and 3230 smolts, respectively. The fish were produced by a commercial hatchery and were put to sea one-year-old medio May 1986 at a mean weight of 100 g. The pens in U1 were stocked with 5540 and 5528 smolts. The fish were produced at Matre Aquaculture Station and were put to sea primo June at a mean weight of 35 g. The experimental groups were set up on 8 October, and the fish were measured for the first time one week later.

All groups were measured for length and weight every third month. Parasite infection was also recorded. A subsample was obtained by dividing each pen into four compartments in one operation. All fish in one compartment were measured. Before each parasite treatment, 150 fish from each group were sampled and the degree of parasite infection was registered and categorized as follows:

Category	*Parasites*
1	0
2	1–5
3	6–10
4	11–20
5	>20

No sampling was carried out in advance of a parasite treatment that took place on 9 July, as a main measurement had been undertaken only one week before.

During measurements and parasite controls, the fish were anaesthetized with saturated ethanol solution of benzocaine. The time of the different fish measurements and parasite controls are given in Table 1.

TABLE 1
Fish Measurements

Measurement no.	*Type*	*Date*	
1	M	Oct	13–17
2	P	Dec	1–5
3	M	Jan	5–10
4	M	Apr	1–4
5	M	Jul	1–3
6	P	Aug	3–7
7	P	Sep	8–9
8	M	Oct	1–3

M, Main measurement; P, parasite control.

Weekly mortality per pen was noted. In early July, maturing fish were sorted out from U2, reducing the number per pen by 16%.

The fish were fed a commercial high-energy dry pellet (Ewos Vextra), distributed with automatic feeders set at equal feeding intensity in each pen of U1 and U2. In addition, the fish were hand fed to satiation twice daily. The fish were starved one day before measurement, net change and parasite treatment.

The covers over the pens were removed when this was required due to handling procedures. Also, from December to March the covers were removed in snowfall periods. Altogether, the covers were off 70 days of the 355-day experimental period. Before every net pen change, the fouling of each net panel was observed and compared with the other pens. Samples of fouling organisms were also collected.

Underwater television and echo sounders were used to observe the behaviour and vertical distribution of the fish (Fig. 2). Two sets of each equipment type were shifted between the five pens. Behaviour and vertical distribution as well as environmental parameters were observed from two observation rooms (Fig. 1). For details, see Fernö *et al.* (1988) and Floen *et al.* (1988).

RESULTS

The growth data from the experiment are given in Table 2.

The fish in U1 were substantially smaller than the fish in U2 from the start, but the overall growth rates in both subexperiments were similar. Condition factor developments indicate that the fish were fed suboptimally during the last six months of the experiment.

Data for infection of the ectoparasite *Lepeoptheirus salmonis* are given in Table 3.

Table 4 presents mortality during the experimental period. The 78 fish in the fifth interval were killed by an overdose of anaesthetics.

Fouling was estimated by comparing panels of the different pens at each net pen change. No enumeration of these observations were, however, conducted.

The behaviour studies (Fernö *et al.*, 1988) are published elsewhere, and only a few of the results are referred to in the discussion.

DISCUSSION

There were no significant growth differences in either of the two subexperiments in the third (January) measurement. In the fourth (April)

TABLE 2
Fish Measurement Data (weights in g)

Sampling no.		*U1*		*U2*		
		Pen 9 no cover	*Pen 10 70%*	*Pen 11 40%*	*Pen 12 70%*	*Pen 13 no cover*
1	N	936	829	628	646	584
	W (mean)	260	262	476	467	462
	SD	75	71	116	115	112
	C. fact.	1·12	1·12	1·10	1·08	1·08
3	N	800	800	711	703	702
	W (mean)	526	517	996	970	980
	SD	153	145	258	251	256
	C. fact.	1·36	1·21	1·26	1·28	1·28
4	N	750	782	762	756	767
	W (mean)	725	771	1 459	1 453	1 548
	SD	243	246	378	403	423
	C. fact.	1·16	1·18	1·27	1·29	1·31
5	N	874	1 131	870	632	725
	W (mean)	1 056	911	2 135	2 168	2 267
	SD	364	407	674	647	652
	C. fact	0·91	0·82	1·07	1·10	1·15
8	N	1 297	973	610	530	742
	W (mean)	1 565	1 671	2 868	2 959	2 955
	SD	495	513	720	730	810
	C. fact.	1·00	1·00	1·07	1·09	1·08

measurement, however, the covered pen showed a slight but significant ($p < 0{\cdot}001$) lead over the uncovered pen in U1. In U2, the uncovered pen countered this result by having significantly larger fish than both the covered pens ($p < 0{\cdot}001$). In the fifth (July) measurement, the uncovered pen in U1 had gained a strong lead on the covered pen ($p < 0{\cdot}001$), as was also the case in U2, where the fish in the uncovered pen were significantly ($p < 0{\cdot}01$) larger than in the two covered pens. In the final measurement (8), however, the group with 70% cover was again in the lead in U1 ($p < 0{\cdot}001$), and in U2 the fish in the 70% pen had reached the same size as the fish in the uncovered pen, while the 40% group was still significantly smaller ($p < 0{\cdot}05$) than the two other groups.

These small but significant differences can of course be caused by sampling artefacts, but looking at the development in the two sub-

TABLE 3
Infestation Rates of *Lepeoptheirus*, given as Mean of Infestation Categories[a]

Sampling no.		*U1*		*U2*		
		Pen 9 no cover	*Pen 10 70%*	*Pen 11 40%*	*Pen 12 70%*	*Pen 13 no cover*
1	N	936	829	628	646	584
	Mean inf.	3·2	3·5	2·9	3·0	3·1
	SD	0·53	0·62	0·68	0·57	0·64
2	N	150	150	150	150	150
	Mean inf.	3·5	3·2	4·1	4·1	4·0
	SD	0·67	0·67	0·55	0·64	0·67
3	N	799	799	710	702	702
	Mean inf.	2·1	1·8	2·1	1·7	1·8
	SD	0·50	0·45	0·62	0·55	0·44
4	N	750	781	760	756	767
	Mean inf.	1·7	1·8	2·5	2·8	2·9
	SD	0·53	0·50	0·60	0·66	0·67
5	N	874	1 131	870	632	466
	Mean inf.	3·7	3·6	3·7	3·9	4·3
	SD	0·73	0·70	0·70	0·72	0·76
6	N	150	150	139	150	150
	Mean inf.	4·1	4·1	4·0	4·5	4·4
	SD	0·77	0·68	0·59	0·58	0·63
7	N	151	175	151	150	155
	Mean inf.	4·4	4·3	4·7	4·6	4·7
	SD	0·57	0·59	0·45	0·59	0·53
8	N	1 297	973	610	857	742
	Mean inf.	2·6	2·4	2·8	2·7	3·0
	SD	0·69	0·77	0·75	0·82	0·81

[a]See Materials and Methods.

experiments there are similarities to indicate a biological explanation. Apart from the slight difference in measurement 4 (April) in U1, it seems that the fish grew slightly better in uncovered pens in the winter, spring and early summer, while in late summer and early fall covered pens seemed to give best growth. This could be expected, as the low illumination levels of winter and early spring were even more reduced by the shading, thus inhibiting feeding, and also prolonging the typically low appetite pattern of winter feeding in salmon. On the other hand, the high

TABLE 4
Mortality Numbers in the Intervals between Measurements (see Table 1)

Interval no.	*U1*		*U2*		
	Pen 9 no cover	*Pen 10 70%*	*Pen 11 40%*	*Pen 12 70%*	*Pen 13 no cover*
1	32	21	23	15	16
2	17	16	1	6	3
3	53	27	14	7	11
4	34	16	15	27	10
5	67	94	60	36	111
6	19	4	9	78	11
7	27	8	3	2	3
Total	259	186	125	171	165
%	4·7	3·4	3·9	5·3	5·1

illumination levels in summer may have inhibited ingestion and growth in the unshaded pens, while the fish in the shaded pens were experiencing favourable conditions in this period. New experiments with more frequent measurements and with good account of ingestion would have to be carried out in order to further evaluate the seasonal relationship between illumination and growth in the sea for Atlantic salmon.

Mortalities varied between 5·1% and 3·4% which is low considering the degree of handling the fish were exposed to. There were no significant differences between groups.

In U1, the uncovered pen had significantly higher infestation rates of *Lepeoptheirus* in measurements 2, 3, 5 and 8. In measurements 4, 6 and 7 there were no significant differences. Although the differences were small, this indicates that shading had an effect on louse infestation. In U2, the uncovered pen had a significantly higher infestation rate than either of the covered pens in measurements 4, 5 and 8. In measurement 6, the rate was equal to the 70% pen but both these had significantly higher infestation rates than the 40% pen. In measurements 2 and 7, there were no significant differences. If both subexperiments are pooled and a sign test is applied the result is a significantly ($p < 0{\cdot}04$) higher infestation rate in the uncovered pens using a one-tailed test. A one-tailed test can be justified since the experiment was based on positive findings in a pilot experiment, giving a hypothesis that cover would reduce infection. Overall, this indicates that shading reduces the infestation rate of *Lepeoptheirus* in marine net pen rearing of Atlantic salmon, although to a marginal degree in this experiment.

In the pilot experiment the differences were much more pronounced. In that experiment, however, no light could penetrate to the pen surface as the roof and walls were made of tin plates. This difference could account for the less clear-cut results in this experiment.

In the pilot study with covered nets, fouling was also drastically reduced. The picture was more complicated in this experiment. Algal growth was reduced in the covered pens compared to the uncovered ones. However, the decreased algal fouling seemed to give better settling conditions for hydroids, which are much more difficult to clean off than algae. Also, the large population of hydroids in the covered pens seemed to cause a spreading to other parts of the sea cage unit, resulting in a very high settling rate of hydroids in all cages. Accordingly, the covers did not have an overall positive effect on fouling.

Apart from a significantly higher tail beat rate and leaping activity in pen M 13 (no cover) compared to pen M 12 (70% cover), there were no significant differences in observed behaviour or vertical distribution within subexperiments (Fernö *et al.*, 1988; Furevik *et al.*, 1988). See also Bjordal *et al.* (1988).

The way this experiment was designed, small but significant effects on growth and salmon louse infestation from light-reducing covers were identified. No definite negative effects were found. To investigate further these results and the results of the pilot study, full scale experiments with light-proof covers should be carried out, with regard to growth, parasite infection and fouling.

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