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- 1 -

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THE EFFECT OF DIFFERENT PHOTOPERIODS ON GROWTH AND SMOLTIFICATION
IN ATLANTIC SALMON (SALMO SALAR)

BY

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ABSTRACT

Photoperiod has been implicated as an effective mediator of growth and smolting in Atlantic salmon (Salmo salar). To investigate this 0+ parr of Atlantic salmon were treated with three different photoperiods: 24Light:0Dark, 16L:8D, 8L:16D, held static during the experimental period.

This preliminary report shows that growth was greatest under the continuous light regime, followed by the 16L:8D photoperiod and the 8L:16D regime.

Several bloodparameters were measured as indicators of stress. These indicators showed no large differences between photoperiods. Thus, extended periods of light does not seem to stress the fish, on the contrary, manipulating photoperiods is an effective means of increasing growth and controlling smolting in Atlantic salmon.

INTRODUCTION

The effect of light on growth and smolting in Atlantic salmon (Salmo salar) has recently become a field of great interest. Studies have been carried out concerning growth in Atlantic salmon, rainbow trout (S. gairdneri), brown trout (S. trutta), pacific salmon species and others. However, different workers have reported contrasting results. Several workers have concluded that extended periods of light stimulate growth in salmonids (Pyle, 1969; Saunders & Henderson, 1970; Clarke et al., 1980; Brauer, 1982).

On the other hand, studies made by Brown (1946) and Phillips et al. (1958) showed that extended periods of light reduced growth in brown trout and brook trout (Salvelinus fontinalis). Both workers attributed this effect to increased activity. Thus it may seem like the fish need some intermittent darkness and that continuous light may stress the fish.

Several indicators of stress have been measured in salmonids. The Leucocrit as described by McLeay & Gordon, 1977 is currently recommended as a screening test to provide information on the physiological effects of environmental stress on fish health (Wedemeyer & McLeay, 1981). The Hematocrit test, however, is easy to carry out, but its sensitivity and reliability as an indicator of stress is more uncertain (McLeay & Gordon, 1977).

Cortisol, the major glucocorticoid in salmonid fish, has become widely accepted as a means of assessing the activity of the HPI-axis in response to both acute and chronic stress (Pickering: Stress and fish, Wedemeyer & Yasutake, 1977).

During smolting the cortisol level changes dramatically, being involved in the reorganisation of body tissue and activation of certain osmoregulatory enzymes, e.g. Na-K-ATPase (Pickford et al., 1970; Doneen, 1976; Folmar & Dickhoff, 1980). This dual function of cortisol (a stress-hormone and a "smolting-hormone") has been a problem (e.g. handling-stress during sampling).

MATERIAL AND METHODS

Fish stocks

At the beginning of the experiment, January 1985, eight groups of 0+ parr were selected which were large enough at that time to produce a reasonable amount of 1-year smolts. The fish were all hatched in January 1984. The time of first feeding differed among the groups, being either t1 or t2. The fish were fin-cut with a different pattern for each group and then distributed into the rearing-tanks. In this paper the fish will be treated

as a pooled material.

Rearing conditions

The fish were held in 9 (3x3) circular tanks of approximately 1500 litres rearing volume. Diameter was 1.5 meters and water-depth was about 0.75 meters. All tanks were covered and light-sealed with black plastic.

Water was supplied through an adjustable inlet to produce a similar watercurrent pattern in all tanks. The waterflow was about 15 l/min. The watercurrent in the surface water was about 12 cm/s, 50 cm from the inlet.

The salinity was about 7 - 8 ppt throughout the experimental period. Water-temperature varied from 7 to 9 0C.

Experimental design

All fish were held for 14 days under a constant 16L:8D photoperiod before any bloodsamples were taken, to make sure they had all recovered from the handling stress associated with the distribution into the tanks. The photoperiods were held constant from Jan.18th until May 31st at 24L:0D, 16L:8D and 8L:16D respectively. Light was supplied from two ordinary 40W bulbs placed opposit to eachother and attached to the ceiling of the tanks. This was done to provide uniform illumination and prevent occurrence of any shaded areas in the tanks. The lights were switched on and off by automatic timers without any twilight periods.

Feed was given by automatic feeders in excess for 8 hours a day. This was done during the hours when all tanks had the lights switched on. This feeding-regime was deigned to provide the maximum growth given the restriction that all fish should have the same feeding opportunity irrespective of photoperiod, thus isolating light as the only varying parameter. The feed used was a comercial dry feed (EWOS) size 3, changing to size 4 for the last three weeks.

Sampling procedure

The fish used for bloodsamples were captured with a handnet and immediately given a shock-dose of Benzocain. The fish were then transferred to a light maintainance anaesthetizer, and blood was sampled using a heparinized single-use syringe. The sampling/anaesthetizing all took place within 30 secs, in order to avoid the stress-related increase in cortisol level following handling (see Pickering: Stress and fish, 1981 pp 29/30). The blood was sentrifugated and plasma stored at -200C for subsequent analyses. Sampling mortality was low, usually less than 5%. Sampling was always done in the same procedure and at the same time of day.

Analysis-Radioimmunoassay

Plasma cortisol was determined by Gammacoat I-125 Cortisol Radioimmunoassay Kit from Travenol-Genentech Diagnostics.

This kit was chosen because of its ease in use and its very low cross reactivity with other major glucocorticoids. Cross-reactivities are as follows:

Compound	%Cross-reactivity
Cortisol	100
Prednisolone (a drug)	73
6-Methylprednisolone	18
11-Deoxycortisol	4.4
Corticosterone	3.8
Prednisone	2.0
Others	<0.5

Samples as well as standards were run in duplicates.

Bloodcellcounts (Hematocrit% and Leucocrit%) were measured as other indicators of possible continuous stress caused by light. The measurements were done within two hours after bloodsampling because of the time dependent change of both values (McLeay & Gordon, 1977). The same procedure was followed for each sampling; 12 minutes sentrifugation at 4800 rpm, and 100C.

RESULTS

Growth

The curves shown in fig.1 represent growth as an increase in weight (fig.1a) and length (fig.1b). It must be noted, however, that these growth curves only shows the growth of the larger individuals (upper modal group), namely those used for blood-sampling, and not necessarily gives the correct picture of the total growth of the fish stocks. However, the differences between the photoperiods are clearly visible from these curves. Towards the end of the experiment the larger fish from the continuous light regime was about 28.8% heavier than the fish from the 16L:8D regime, and 61.8% heavier than the fish from the 8L:16D regime. Thus, maximum weight is strongly affected by the photoperiods. The same trend can be seen from the differences in increase in length between the three photoperiods (fig.1b)

Cortisol

Plasma levels of cortisol are shown in fig.2. Fish from all three photoperiods show the same development, starting with a decline during late winter and then rising to about twice the initial value towards the end of the experiment. However, the cortisol levels of the fish from continuous light seem to be somewhat higher than from the other two photoperiods, which are nearly identical. The differences tend to decrease during early spring (Apr.10th, May 7th), but increases again at May 21th.

Leucocrit

The leucocrit% of the fish from the three photoperiods are shown in fig.3. Again one will notice the close similarity between photoperiods in change during the experiment. The only noticeable difference between photoperiods is at Feb.26th, With a slightly lower level at photoperiod 16L:8D. However, since the two "extremes" show nearly identical levels, this difference is probably due to a random error and therefore not important.

Hematocrit

The results from the hematocrit-test are shown in fig.4. All three photoperiods show the same steady increase in in hematocrit% from January through May. Again no noticeable differences are seen between photoperiods.

The increase from about 40-45% in January to approximately 60% by the end of May is quite remarkable, but since this increase is consistent in all photoperiods, it is probably not caused by different light-regimes.

DISCUSSION

Extended periods of light has proved to be a good mediator of growth in Atlantic salmon parr during their second spring. With the limited material available at the moment, the results shown in the growth curves gives an indication of the effect of three photoperiods on growth of the upper modal. The effect seems to be evident quite early in the spring. In late February there are indications which become even clearer by mid April. Thus, there are no indications of any harmful effects of light in the growth results. On the contrary, the longer the light periods the faster the growth of the fish of the upper modal.

The reason for investigating the blood-parameters only of the upper modal fish of the stocks are mainly two. First, this experiment has also concerned growth of the whole stock, both lower- and upper modal (the results will be given in a later paper). Therefore, no sacrificial blood-samplings could be accepted. Since fish smaller than 10 cm died from the blood loss and/or damage caused by the syringe, these lower-modal fish had to be excluded from the blood-samplings. Secondly, the other main part of this experiment was to describe the changes in cortisol level during smolting. Since very few of the lower-modal fish become smolts in their first spring (Thorpe et al., 1982), these fish are irrelevant as far as cortisol during smolting is concerned. Both cortisol, hematocrit and leucocrit show the same development in all three photoperiods during the experiment, cortisol being somewhat elevated under the 24L:0D regime. Whether this is significant or due to other random disturbances is uncertain at the moment.

Hematocrit shows a steady rise during the experiment, under all three photoperiods. This may be due to several causes, but these appear to be common for all the three photoperiods. The hematocrit-test therefore gives little reason to argue that light is stressing the fish.

Leucocrit shows a major rise from January 17th to February 26th. This co-occurs with a fall in cortisol level, both indicating a less stressing environment than at the beginning of the experiment. The decrease from February 26th to April 10th may be due to an acclimation to this new environment. The leucocrit% changes little during the rest of the experiment, and is not very different between photoperiods. The conclusion from the leucocrit-test must be that light does not stress the fish.

It must be noted that under all three photoperiods, one can observe the same trend in cortisol-level during the experiment. These changes in cortisol-level are very similar to those reported by Specker & Schreck(1982) for coho salmon (*Onchorhynchus kisutch*) during smolting. The changes however are not as dramatic as for coho, merely leading to a twofold cortisol concentration, whereas for coho the increase may be fivefold. Of great interest is the fact that these changes take place without any environmental cues, except a slight increase in water-temperature. This suggests the existence of a circannual rhythm in changes of cortisol level, occurring even under constant environmental conditions. Under natural conditions one may imagine these rhythms brought in synchrony by seasonal cues such as naturally increasing daylength and rise in water-temperature (see Eriksson & Lundqvist,1982).

In a constant environment however, this synchronisation will not take place, suggesting one of the reasons for the incomplete smolting often observed in hatchery-reared fish. Even though the fish may be able to osmoregulate because of increased Na-K-ATPase activity following a rise in cortisol, other physiological changes and adaptations may be incomplete or absent.

Extended periods of light doubtlessly increases growth in Atlantic salmon parr, without any major stressing effects to the fish. Used in combination with natural photoperiod to time the smolting, light is an effective means of achieving bigger smolts.

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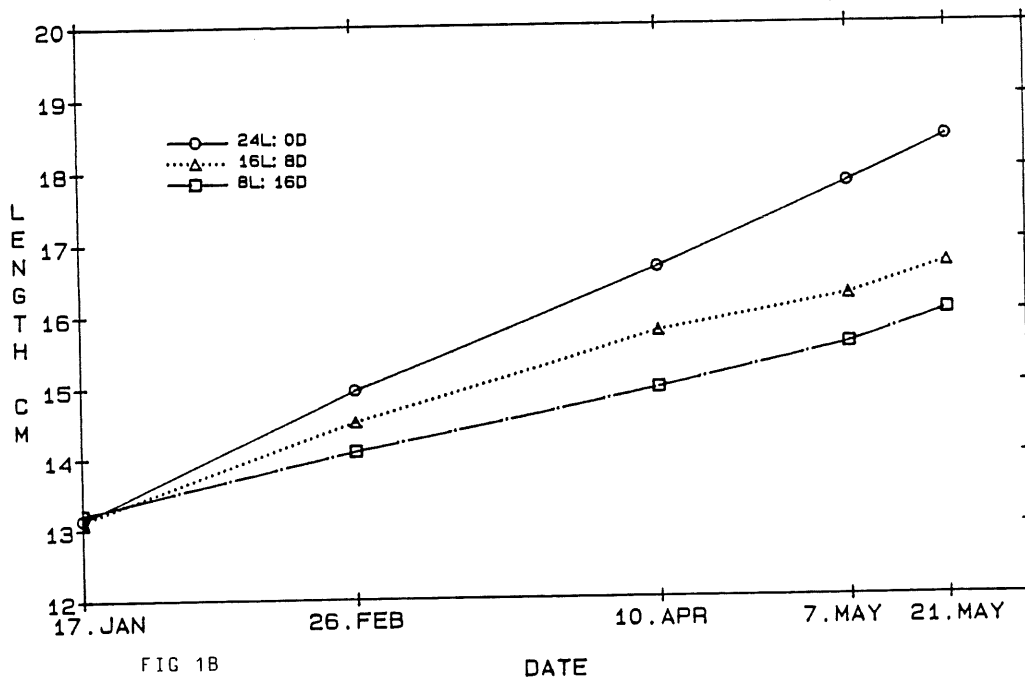
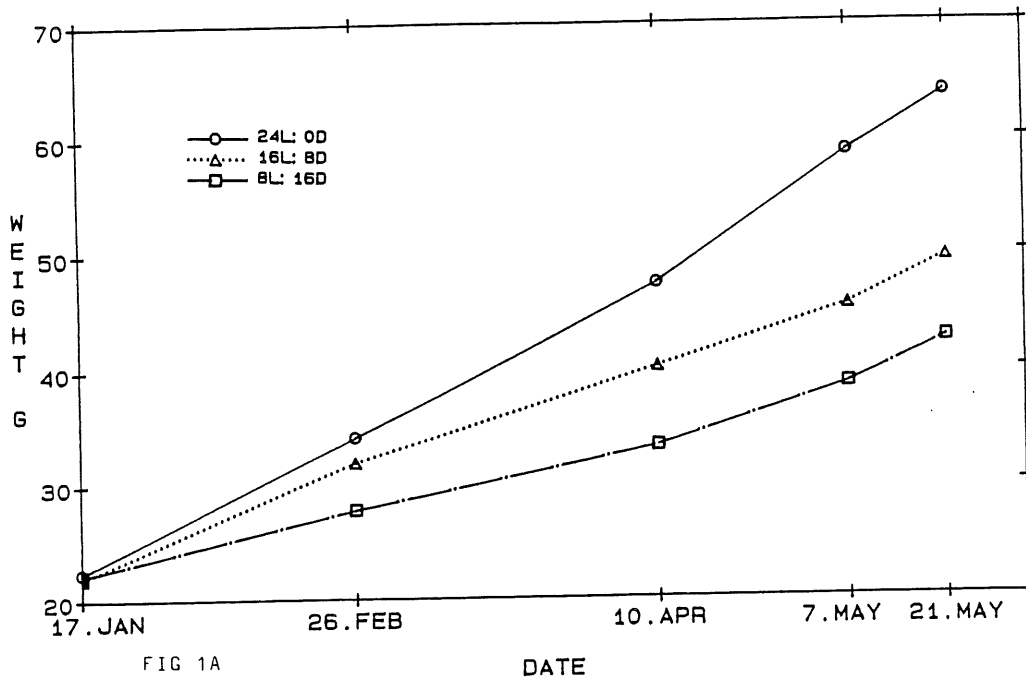


FIGURE 1. The growth rate during the experimental period.

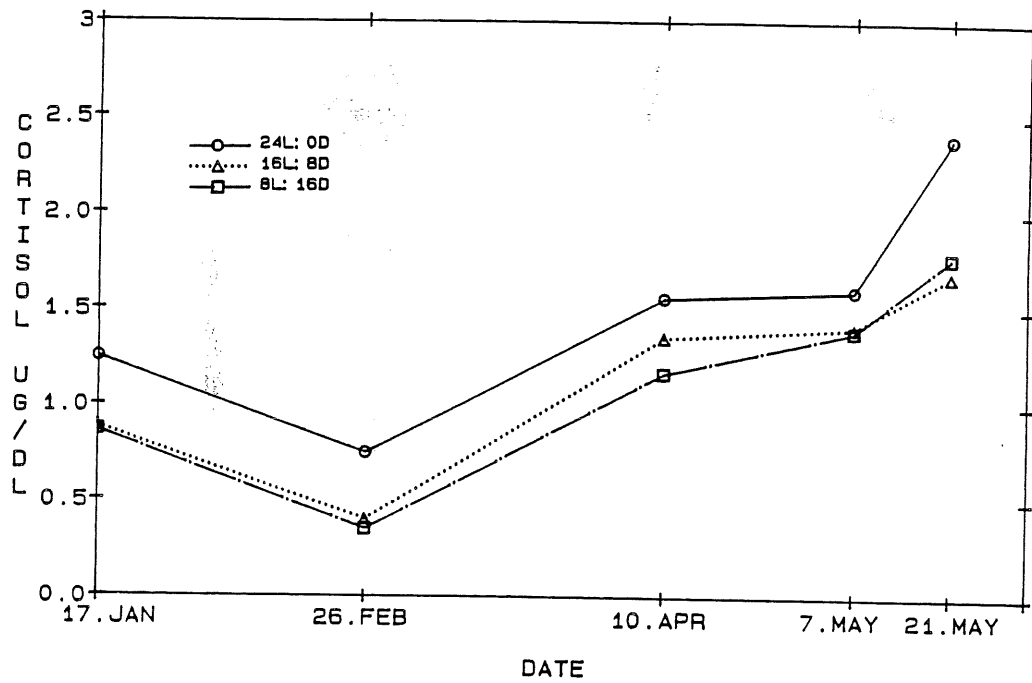


FIGURE 2. The development of cortisol level in plasma during the experimental period

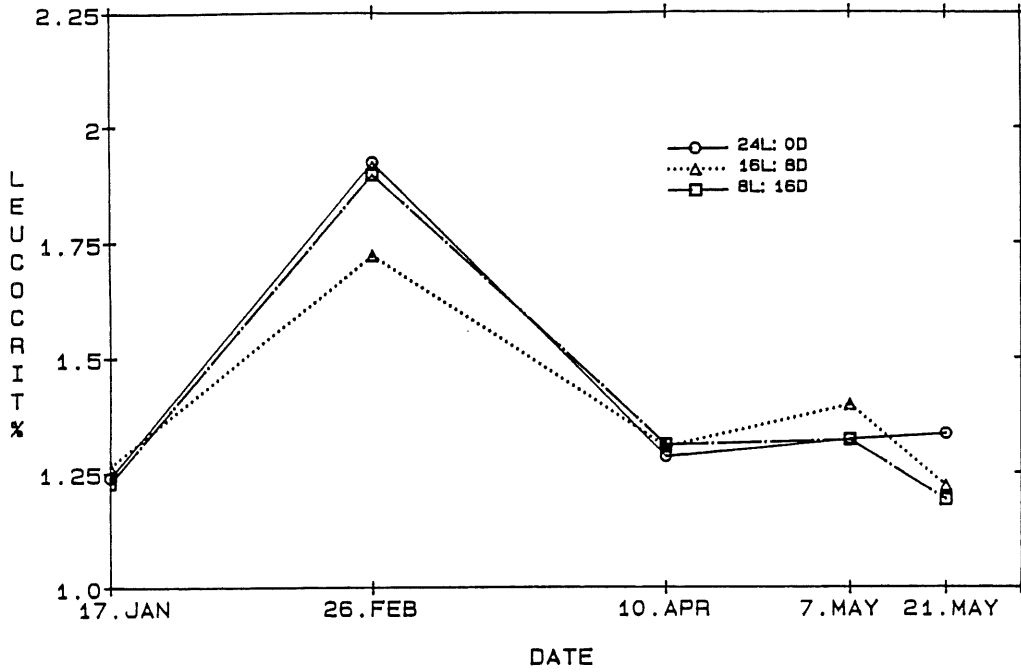


FIGURE 3. Development of leucocrit during the experimental period.

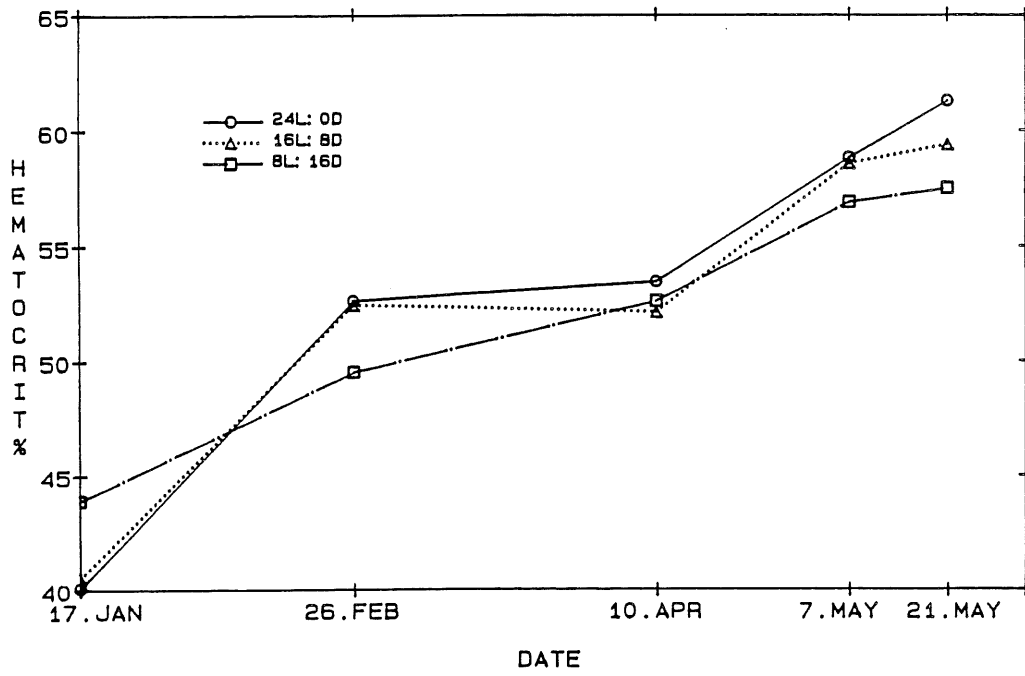


FIGURE 4. Development of hematocrit during the experimental period.