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A decrease in photoperiod shortly after first feeding influences the development of Atlantic salmon (*Salmo salar*)

I.K. Berrill [a,*], A. Smart [b], M.J.R. Porter [c], N.R. Bromage [a]

[a] *Institute of Aquaculture, University of Stirling, FK9 4LA, Scotland*
[b] *PO Box 106, Melrose, South Australia, 5483, Australia*
[c] *School of Aquaculture, University of Tasmania, Launceston, 7250, Tasmania, Australia*

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Abstract

Four groups of Atlantic salmon fry ($n = 2000$) were exposed to continuous light (LD24 : 0) from first feeding on 18th April 2001, after which they were exposed to either an 8 or 12 week period of short days (LD10 : 14) starting on either the 21st May or the 18th June. Each group was then returned to LD24 : 0 until the conclusion of the experiment the following March. In August 200 fish per treatment were individually PIT tagged. All groups were maintained under an ambient temperature regime.

The highest levels of sexual maturation in 0+ male parr were recorded in the 12 week/May group (>11% of the entire male and female population), with the lowest levels (<1%) in the 12 week/June treatment and intermediate levels (>6%) in the 8 week/May and 8 week/June groups ($P < 0.05$). Between mid August and late October mature parr were heavier than their immature counterparts, but subsequently both cohorts maintained similar sizes. Fish showing signs of silvering were found from mid October onwards. However, it was only in the 12 week/June group that silvered fish had a significantly reduced condition factor and an increased gill Na^+, K^+-ATPase activity, indicative of smoltification. At the conclusion of the experiment, fish showing signs of silvering were most prevalent (30%) in the 12 week/June group.

It is concluded that the initiation of maturation can be influenced by an 8 or 12 week period of short days (LD10 : 14) applied from mid May or mid June in the first growing season. The duration and timing of a stimulatory short day photoperiod during early development may also influence whether a fish undergoes smoltification in the coming year or whether it delays the parr–smolt transformation for at least a further year.

Keywords: Atlantic salmon; Parr; Growth; Maturation; Smoltification; Photoperiod

1. Introduction

In recent years, efforts have been made to understand variations in the life history strategies of juvenile Atlantic salmon. A prominent aspect of juvenile salmonid development when reared under a natural photoperiod regime is the emergence of a bimodal population structure during late summer in the first growing season (Thorpe, 1977; Kristinsson et al., 1985; Skilbrei, 1988), with this division determining which fish will smolt in the following spring and which will remain in fresh water for a least a further year (Thorpe, 1977; Kristinsson et al., 1985). Increasingly, accelerated

* Corresponding author. Current address: School of Ocean Sciences, University of Wales, Bangor, Menai Bridge, Anglesey, LL59 5AB. UK. Tel.: +44 1248 351151; fax: +44 1248 716367.
E-mail address: i.k.berrill@bangor.ac.uk (I.K. Berrill).

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production regimes are used stabilize seasonal fluctuations in the production of smolts and market sized fish. Photoperiod manipulation in particular can be used to influence the numbers of smolts and the yearly timing of seawater transfer. Similar to the influences received in the wild, a short day, winter photoperiod can be used to initiate smoltification, with the parr–smolt transformation then completed during a long day spring regime (Duston and Saunders, 1992; Sigholt et al., 1995; Duncan and Bromage, 1998). However, in using accelerated rearing regimes the incidence of sexual maturation can also be affected. Parr maturation is usually only found in male salmon, due to the lower nutritional requirements for male gonadal development (Adams and Thorpe, 1989), and although mature parr have been found to undergo smoltification (Saunders et al., 1994; Duston and Saunders, 1997), maturation can inhibit the parr–smolt transformation to some degree (Thorpe and Morgan, 1980), with increased androgen levels during maturation thought to play a role in this inhibitory process (Aida et al., 1984; Miwa and Inui, 1986). Mature parr are therefore poorly adapted to seawater (Saunders et al., 1994) and they are typically removed from commercial populations as soon as they are identified.

Maturation is influenced by a photoperiodically entrained endogenous rhythm(s) (Bromage et al., 1984; Duston and Bromage, 1986) which can be advanced by a long- and then short day photoperiod regime (Bromage et al., 1984). As a result of these photoperiodic cues complex interactions can occur between the initiation and completion of both maturation and smoltification. However, further to these influences it is believed that a size and/or nutritional threshold has to be surpassed before smoltification (Elson, 1957; Kristinsson et al., 1985) and maturation (Thorpe and Morgan, 1980; Saunders et al., 1982) can occur. It is also likely that maturation in particular can be influenced by such thresholds during specific times in development. Metcalfe (1998) and Thorpe et al. (1998) suggested that maturation could be initiated in November, although it could be “switched off” during a second sensitive period in spring. Furthermore, Thorpe (1994) has suggested that the initiation of maturation could be influenced prior to first feeding. Similarly, Berrill et al. (2003) found that an 8 week period of short days (LD10:14) applied in May, shortly after first feeding in March, increased maturation rates compared to similar regimes applied later in the summer, highlighting a specific period of sensitivity in early development.

Clearly, the interactions between winter photoperiod and life history strategy are poorly understood, especially with regards to early development. Consequently, the current study leads on from that of Berrill et al. (2003) and aims to investigate the importance of the timing and duration of short day photoperiod regimes during a proposed sensitive period in early development. In order to achieve this 8 and 12 week periods of short days were applied at two times from shortly after first feeding.

2. Materials and methods

2.1. Fish stock and rearing conditions

Experimental fish were of Loch Lochy stock, maintained at the Buckieburn Freshwater Research Facility, Scotland (Lat. 56°N) under ambient water temperatures (monthly averages ranged from 14.9 °C in August 2001 to 3.1 °C in December 2001). Flow rates were 1 l s^{-1} and oxygen levels were >8 mg l^{-1}. Feed was supplied at the manufacturer’s recommended rate (Trouw Aquaculture; UK), throughout the light phase of the photoperiod.

2.2. Experimental regimes

From first feeding on 18th April 2001, 1000 fish were placed into each of eight 2 m square tanks and exposed to LD24:0. On both 21st May and 18th June, two duplicate groups were exposed to either an 8 or 12 week winter photoperiod (LD10:14) after which they were returned to LD24:0 until the conclusion of the experiment in March 2002 (Table 1). This created four treatments termed: the 8 week/May, 12 week/May, 8 week/June and 12 week/June treatments, respectively. The timing of the photoperiods was determined in order to compliment the study of Berrill et al. (2003); in the current experiment the May treatments replicated the yearly timing of the May photoperiod group of Berrill et al. (2003) regardless of age from first feeding. Then, due to a difference in the time of first feeding between the two experiments, the fish from the June photoperiods of the current experiment were of a similar

Table 1
The start and end dates of the four experimental short day photoperiod regimes (LD10:14) used in the current study

Experiment regime	L10:14 photoperiod	
	Start date	End date
8 week/May photoperiod	18th May	16th July
12 week/May photoperiod	18th May	14th August
8 week/May photoperiod	21st June	14th August
12 week/May photoperiod	21st June	12th September

At all other times fish were exposed to continuous light (LD24:0).