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Photoperiod can be used to enhance growth and improve feeding efficiency in farmed rainbow trout, *Oncorhynchus mykiss*

J.F. Taylor [a,*], B.P. North [a], M.J.R. Porter [b], N.R. Bromage [a], H. Migaud [a]

[a] *Institute of Aquaculture, University of Stirling, Stirling, Scotland, FK9 4LA, UK*
[b] *Tasmanian Aquaculture and Fisheries Institute, School of Aquaculture, Tasmania, Australia*

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Abstract

The current studies examined whether photoperiod techniques could be successfully transferred to commercial freshwater rainbow trout farming practices, with the key aim being to enhance winter grow-out and production in "open/uncovered systems". Four experiments were undertaken to assess the effects of photoperiod in relation to: growth and feeding regime in tank reared fry; light intensity and growth in tank reared fry; growth and feeding efficiency in cages; and the use of different lighting technologies (bulb colour temperature) in cages. Commercial field trials conducted over a 3-year period showed that exposure of different developmental stages of rainbow trout to periods of constant light from autumn to spring appeared to enhance growth rates and could improve feed conversion. Furthermore, exposure to higher light intensities appeared to promote greater growth and feeding efficiency in all stages of production. The importance of even light distribution in the culture system rather than a critical light intensity was also evident. The outcome of artificial light regimes has been the ability to increase growth rates by up to 25%, alter stock out times, and reduce production time by as much as 2 months.

Keywords: Photoperiod; Light intensity; Melatonin; Growth; Feed conversion; Culture system; *Oncorhynchus mykiss*

1. Introduction

Animal growth is influenced by genetic, environmental and nutritional factors. Extrinsic factors are particularly important in the growth of ectothermic vertebrates such as teleost fish, which rely on temperature, photoperiod and food availability to initiate developmental processes (Thorpe et al., 1989; Boujard et al., 1995; Imsland et al., 1995; Jobling and Koskela, 1996). In the comprehensive review by Boeuf and Le Bail (1999) light-induced effects on growth in a variety of species have been observed. In the case of salmonids, photoperiod is classified as a directive factor, either controlling growth as a "zeitgeber" through its influence on endogenous rhythms (Porter et al., 1998; Endal et al., 2000), or direct photostimulation of the somatotropic axis (Komourdjian et al., 1976; Bjornsson, 1997). These effects are certainly evident in Atlantic salmon (*Salmo salar*), where abrupt exposure to long photoperiods during naturally short-days (winter) has been shown to advance the natural growth rhythm (Krakenes et al., 1991; Hansen et al., 1992) in a manner similar to that observed in advances in circannual spawning rhythms

* Corresponding author. Tel.: +44 01786 467929; fax: +44 01768 472133.
E-mail address: jft2@stir.ac.uk (J.F. Taylor).

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following photoperiod manipulation (Randall and Bromage, 1998; Randall et al., 1999). Several studies have shown that increasing photoperiods result in increased appetite, growth, GH production and IGF-I levels in higher vertebrates (Webster et al., 1996; Rhind et al., 1998; Ditchkoff et al., 2001). Consequently, it has been proposed that the rise in IGF-I is a component of the photoperiodically entrained seasonal drive of growth, and the increase in food intake is a response to satisfy the increased energy demand for maintaining growth (Webster et al., 2001). Similar changes in the principal hormones of the somatotropic axis (GH-IGF) have been reported in salmonids following exposure to long-day photoperiods (Bjornsson, 1997; McCormick et al., 2000; Beckman et al., 2004; Taylor et al., 2005) in addition to advancing seasonal patterns of appetite, feed conversion ratio and growth (Nordgarden et al., 2003).

Although numerous studies report growth enhancing effects of extended and constant light (LL) photoperiod regimes in a variety of species including Atlantic salmon (Saunders and Henderson, 1988; Villarreal et al., 1988; Saunders and Harmon, 1988; Saunders et al., 1989; Stefansson et al., 1989; Krakenes et al., 1991; Hansen et al., 1992; Oppedal et al., 1999), largemouth bass, *Micropterus salmoides* (Petit et al., 2003), Japanese medaka, *Oryzias latipes* (Davis et al., 2002), Atlantic halibut, *Hippoglossus hippoglossus*, (Jonassen et al., 2000; Norberg et al., 2001), turbot, *Scophthalmus maximus*, (Imsland et al., 1995, 1997), haddock, *Melanogrammus aeglefinus* (Trippel and Neil, 2003), European sea bass, *Dicentrarchus labrax*, (Rodriguez et al., 2001) and gilthead sea bream, *Sparus aurata*, (Kissil et al., 2001), very little literature exists regarding the effect of extended photoperiods on growth of rainbow trout (*Oncorhynchus mykiss*), especially considering the species is the second most commonly cultured salmonid in Europe. Solbakken et al. (1999) observed no effect of LL application on winter growth rate of seawater cage reared rainbow trout. Contrary evidence suggests that exposure to long or continuous light photoperiods can improve growth rate in covered freshwater tanks (Taylor et al., 2005). Similarly, in freshwater reared rainbow trout it has been demonstrated that under natural photoperiod cycles a reduction in the rate of decreasing daylength improves growth and feed conversion efficiency (Makinen and Ruhonen, 1992). Mason et al. (1991) related this observation to increased food intake during the extended photophase. Cho (1992) also reported improved growth of rainbow trout in covered tanks under conditions of high (1600 lx) rather than of low (100 lx) light intensity, where fish under high intensity appeared to be more active, with a subsequently greater energy requirement, although no effect on feed conversion was observed.

However, the mechanisms that convey photoperiodic information to the reproductive and somatotropic axis are not clearly understood. Certainly, the clear effects of photoperiod on the timing of reproduction and growth and the corresponding diel and seasonal patterns of melatonin provide strong circumstantial evidence that melatonin may be an intermediary in the process (Randall et al., 1991; Porter et al., 1996; Bromage et al., 2001). In this respect, melatonin levels may act to provide a signal to entrain endogenous rhythms. It has been proposed that the effectiveness of artificial illumination on altering the timing of such biological processes is dependent upon achieving sufficiently high light intensities during the dark phase to reduce plasma melatonin below a "critical" threshold level (Porter et al., 1999a,b). Furthermore, the response of plasma melatonin to changes in light is affected by both light intensity and water temperature (Porter et al., 2001). Thus, melatonin analysis provides a valuable tool for assessing the perception of light by fish and the effectiveness of artificial lighting systems.

In order to address some of the questions raised by farmers and provide evidence for future studies, four on-farm experiments were undertaken to assess the effects of photoperiod in relation to: growth and feeding regime in tank reared fry (trial 1); light intensity and growth in tank reared fry (trial 2); strain, growth and feeding efficiency in cages (trial 3); light intensity and different lighting technologies (bulb colour temperature) in cages (trial 4). Overall, the main aim of these trials was to examine the potential for growth enhancement during the autumn to spring grow-out period in "open-uncovered" systems.

2. Materials and methods

For confidentiality purposes commercial sites cannot be named and will be referred to as site A and site B. Site A at which trials 1 and 2 were performed was a tank and raceway site supplied by local river water located at 55.6°N, 2.8°W, while site B was a freshwater cage site located at 55°N, 1.8°W at which trials 3 and 4 were undertaken.

2.1. Experimental protocols

2.1.1. Trial 1: the effect of constant light and feeding regime on fry growth in freshwater tanks

The aim of this first trial was to differentiate the effects of photoperiod enhanced growth and feeding opportunity