Aquaculture 315 (2011) 61–68

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Ploidy effects on hatchery survival, deformities, and performance in Atlantic salmon (*Salmo salar*)

J.F. Taylor [a,*], A.C. Preston [a], D. Guy [b], H. Migaud [a]

[a] Institute of Aquaculture, University of Stirling, Stirling, Scotland, UK
[b] Landcatch Natural Selection, Alloa, Scotland, UK

ARTICLE INFO

Article history:
Received 2 August 2010
Received in revised form 27 October 2010
Accepted 19 November 2010
Available online 26 November 2010

Keywords:
Triploid
Hatchery
Growth
Survival
Deformity
Atlantic salmon

ABSTRACT

The production of sterile triploid Atlantic salmon (*Salmo salar*) may help address the increasing pressure on the industry to reduce potential breeding between farmed escapees and wild fish populations. However, many previous studies have observed poor performance at sea in triploid stocks (growth, survival, and deformity). This may result from poor early hatchery performance and a strong parental effect. Therefore, in the present study, two year classes (2007 and 2008) of mixed sex fish were created (10 males:10 females) to examine ploidy interactions on hatchery performance. Egg batches were divided in two at fertilisation with one group subjected to a hydrostatic pressure shock to induce triploidy. Triploid rate was confirmed at 100% in all groups, verified by red blood cell nucleus length measurements. Survival to hatch did not differ between ploidy. However, reduced survival was found to strongly correlate with gamete quality. During the hatchery phase ploidy significantly affected size at hatch, with diploids generally larger than triploids. Growth advantage of diploids over triploids was only maintained for 6 weeks post-first feeding, with triploids generally out-growing their diploid siblings by the end of the hatchery phase. Deformity prevalence in first feeding stages was generally low (mean <2%), with no overall effect of ploidy. Our findings show that triploid salmon can perform as well if not better than their diploid siblings. The low incidence of deformity during the hatchery and freshwater phases is also a significant improvement over previous reports in triploid salmon stocks.

1. Introduction

The use of sterile Atlantic salmon (*Salmo salar*) triploids has been considered a possible strategy to reduce potential problems of interbreeding between escaped farmed and wild salmon (Heggberget et al., 1993; McGinnity et al., 1997; Cotter et al., 2000; Lacroix and Stokesbury, 2004). However, for triploids to be accepted in aquaculture they must perform as well as diploids. Studies have indicated that triploid Atlantic salmon often show lower survival in freshwater (McGeachy et al., 1995), poorer growth in freshwater (McGeachy et al., 1995; O'Flynn et al., 1997) and saltwater (Friars et al., 2001), although improved growth performance in saltwater has been reported (Oppedal et al., 2003) and increased deformity prevalence (O'Flynn et al., 1997; Sadler et al., 2001) when compared with diploids. Although the concept of triploidisation is not new, with significant advances in salmonid husbandry techniques, a generally improved knowledge of salmon physiology and the development of selective breeding program within the last decade, many of the problems associated with triploidy may be less common. However, there is a clear need to examine all stages of the production cycle, beginning with hatchery performance of triploid stocks to assess their suitability for commercial scale production.

During hatchery rearing of salmonids it has been suggested that a multitude of factors influencing growth at the early stages of development can significantly affect later growth and performance during ongrowing (Herbinger et al., 1999; Johnston et al., 2000). In particular, muscle fibre recruitment and subsequent growth in seawater varies according to the thermal regime during egg incubation (Macqueen et al., 2008) and early freshwater grow-out (Johnston et al., 2003). Furthermore, occurrence of deformities can result from genetic (Gjerde et al., 2005), nutritional (Baeverfjord et al., 1998) or environmental factors (Takle et al., 2005; Wargelius et al., 2005) in addition to poor gamete quality (Aegerter and Jalabert, 2004). Deformity can lower the level of production due to decreased survival and deformed individuals can result in increased downgrading at processing. As with variation in growth, occurrence of deformities may arise during embryonic development or in later life-history stages (Andrades et al., 1996). Some studies also suggested that the interaction between parental genomes plays a key role in the development of spinal deformity in embryonic Chinook salmon (*Oncorhynchus tshawytscha*) (Evans and Neff, 2009). Similarly, Gjerde et al. (2005) found evidence for additive genetic effects on spinal

* Corresponding author. Tel.: +44 1786 467 929; fax: +44 1786 472 133.
E-mail address: jft2@stir.ac.uk (J.F. Taylor).

0044-8486/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.aquaculture.2010.11.029

deformity expressed in adult Atlantic salmon. Furthermore, there is also a high degree of individual variance in quantitative traits such as growth rate (Hanke et al., 1989; Quinton et al., 2005; Powell et al., 2008). In this respect, numerous studies now recommend the need for selection programs for successful triploid production in salmonids, particularly since triploids often show greater variability both within and between family performances (Bonnet et al., 1999; Friars, et al., 2001; Cotter et al., 2002; Oppedal et al., 2003; Johnson et al., 2004).

To this end, the aim of this study was to assess the effect of ploidy on Atlantic salmon survival, performance and deformity prevalence throughout the freshwater hatchery phase.

2. Materials and methods

2.1. Fish

The trials were performed in the Institute of Aquaculture (University of Stirling) freshwater facilities (Cottrell Aquarium and Howietoun hatchery). Ten full-sib mixed sex families were produced in two consequent year classes (2007 and 2008) on the 5th and 10th December in 2007 and 2008 respectively. Randomly selected green eggs and milt from 2 sea-winter broodstocks (unrelated individuals) were supplied by Landcatch Ltd. (Ormsary, UK). Gametes were transferred to the University experimental facilities in insulated polystyrene boxes. For each family cross, eggs were subdivided into 2 batches corresponding to diploids and triploids (~3000 eggs/ploidy) prior to fertilisation. Ova were dry fertilised using 0.5 ml of milt (1 male:1 female) and immediately incubated in 10 °C water. Triploidy was induced in one egg batch/family using a hydrostatic pressure shock of 9500 psi applied for 5 min, 300° min post-fertilisation at 10 °C according to Johnstone and Stet (1995). Each family egg batch was pressure treated separately in order to prevent possible disease transmission. Control diploid eggs were handled similarly although not shocked. The fertilised diploid and triploid ova were then water hardened for 1 h prior to laying down for incubation. Sub samples (50 ml ~270 eggs) of ova were removed and counted to allow measurement of water hardened egg diameters and establish approximate egg numbers prior to laying down.

2.2. Incubation

Eggs were laid down and incubated in 20 separate aluminium egg trays (1/family) placed in individual 20 L fibreglass tanks (water depth of 150 mm and a flow rate of 0.3 L/min) within a flow through system at Cottrell Aquarium facilities (University of Stirling, UK). The eggs were maintained in complete darkness until hatch. Water temperature was regulated within the incubation room by a combination of chilled air conditioning and a water cooler (Teco systems, UK) which was used to gradually reduce inflowing water from 10 °C to an optimum temperature of 8 °C (±0.5 °C) over the course of a week. The rate of embryogenesis was monitored using degree days (°DD, number of days × water temperature). The eggs were mechanically agitated by siphoning to remove weak embryos on 28th January 2008 (360 °DD) and 14th January 2009 (333 °DD) prior to transfer to Howietoun Hatchery Unit on 1st February 2008 (395 °DD) and 27th January 2009 (425 °DD) for each respective year class. Prior to hatchery transfer, water temperature was gradually reduced over a period of 7 days to 6.5 °C to match ambient temperatures at the hatchery and minimise ova transfer stress.

2.3. Hatchery rearing

On the day of transfer to fry rearing tanks all ova were manually counted to obtain accurate numbers and placed into aluminium trays within 0.9 m^3 tanks (1/family/ploidy), with mean water flows of 6 L/min. Rearing occurred under identical environmental conditions for all groups. Water temperature was of ambient river water

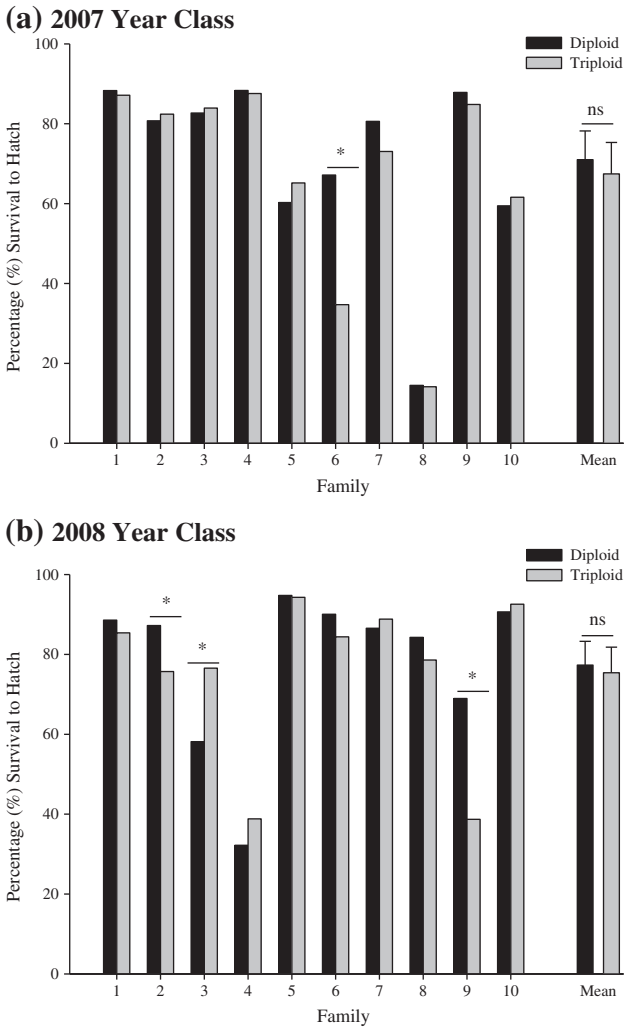

Fig. 1. Cumulative incubation survival at hatch (%) as influenced by ploidy and family in 2007 and 2008 year classes (a–b). Family means (±SEM, n = 10) are also shown for each ploidy. Statistical differences between ploidy within a given family are denoted by asterisk (*) ($p<0.05$). *NS* denotes no significant difference.

Table 1
Differences in survival, growth (Wt–L–K) and deformity at key stages of freshwater production cycle (hatch, hatchery transfer, and smolt unit transfer) in diploid and triploid Atlantic salmon in two subsequent year classes. Asterisk (*) denotes significant differences between ploidy (mean ± SEM, n = 8–9).

	2007 year class		2008 year class	
	Diploid	Triploid	Diploid	Triploid
Hatch				
Survival (%)	71.0 ± 7.2	67.5 ± 7.9^{ns}	77.3 ± 6.0	75.4 ± 6.4^{ns}
Weight (g)	0.14 ± 0.01	0.11 ± 0.01*	0.13 ± 0.01	0.12 ± 0.01*
Hatchery stock-out				
Survival (%)	99.0 ± 0.2	99.5 ± 0.2	99.0 ± 0.1	99.0 ± 0.1
Weight (g)	8.0 ± 0.4	8.9 ± 0.4*	8.2 ± 0.5	8.3 ± 0.5^{ns}
Length (mm)	89.3 ± 1.9	94.0 ± 1.8*	89.8 ± 0.9	91.1 ± 0.8*
Condition (K)	1.09 ± 0.01	1.05 ± 0.01*	1.11 ± 0.01	1.08 ± 0.01*
Deformity (%)	1.3 ± 0.2	1.2 ± 0.2^{ns}	1.5 ± 0.3	1.6 ± 0.6^{ns}
Smolt-unit				
Survival (%)	99.4 ± 0.1	99.5 ± 0.2^{ns}	98.9 ± 0.2	99.0 ± 0.1^{ns}
Weight (g)	12.5 ± 0.5	15.9 ± 0.6*	15.0 ± 0.4	14.6 ± 0.3^{ns}
Length (mm)	110.3 ± 1.2	100.3 ± 1.3*	109.8 ± 1.1	108.7 ± 0.7^{ns}
Condition (K)	1.21 ± 0.01	1.17 ± 0.01*	1.13 ± 0.01	1.13 ± 0.01^{ns}
Deformity (%)	1.7 ± 0.1	2.5 ± 0.2^{ns}	1.3 ± 0.2	1.7 ± 0.1^{ns}