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Short communication

Weaning captive bred forktail blenny, *Meiacanthus atrodorsalis*, to a commercial formulated diet: Optimizing timing, feeding frequency and ration

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ABSTRACT

This study aimed to establish a benchmark regime for weaning the forktail blenny, *Meiacanthus atrodorsalis*, a popular marine ornamental fish, to a commercial marine fish hatchery diet. Three experiments were conducted to investigate the best age for weaning, and the optimal feeding frequency and ration for this species. Weaning *M. atrodorsalis* from live prey to the formulated diet was successful at all ages tested between 16 and 30 days post-hatch (DPH), with survival ranging from 71 to 95% on 40 DPH. However, fish weaned starting 19 DPH and beyond showed 35–54% greater standard length, 28–56% greater body depth and 121–291% greater dry weight, as well as a 30–49% reduction in deformity relative to those weaned starting 16 DPH. The greatest standard length, body depth and dry weight of 17.9 ± 0.2 mm, 5.0 ± 0.1 mm and 30.9 ± 1.2 mg respectively, and the lowest rate of deformity of 6 ± 3% was recorded in fish weaned latest, starting 30 DPH. Of the feeding frequencies tested (from 1 feed every 3 days to 4 feeds per day) high survival on 49 DPH of between 94 and 97% was achieved when *M. atrodorsalis* were fed once every 2 days or more frequently from 32 DPH. However, fish fed once per day or more achieved 10–26% greater standard length, 8–29% greater body depth and 54–300% greater dry weight relative to those fed once every 2 days and once every 3 days. Within the feeding rations tested (2–15% body weight per day), survival was the highest when fish were fed a ration of 5–15% body weight per day, ranging between 86 and 93% on 49 DPH. However, there was a clear growth advantage of 18–29% greater standard length, 9–20% greater body depth and 41–160% greater dry weight when *M. atrodorsalis* were fed a ration of 8% body weight per day or more, relative to a ration of 2 and 5%. Above an 8% daily ration, growth gains were negligible. Based on our findings, we recommend that weaning *M. atrodorsalis* onto a commercial hatchery diet commence between 22 and 25 DPH, followed by feeding at least once daily at a ration of 8% body weight per day.

1. Introduction

The trade of aquarium fish represents the highest value fisheries commodity by weight (Hardy, 2003). Relative to freshwater aquarium fish, the trade of coral reef fishes in particular has shown the strongest growth in the aquarium industry in the last 30 years and continues to increase in its market share (Moorhead and Zeng, 2010). However, in contrast to freshwater aquarium fish that are mostly captive bred, the bulk of coral reef fishes for aquariums are sourced from unmanaged stocks surrounding undeveloped tropical nations, raising grave concerns over the sustainability of the fishery (Mak et al., 2005; Moorhead and Zeng, 2010; Vaz et al., 2012). Accordingly there have been calls for increased research efforts to develop and establish aquaculture protocols for popular marine aquarium fishes (Moorhead and Zeng, 2010; Olivotto et al., 2011). However, the greatest hurdles to achieve this are believed to be at the hatchery stage, and lie chiefly in larval feeding (Planas and Cunha, 1999; Zohar and Mylonas, 2001; Muguet et al., 2011; Olivotto et al., 2016).

While live feeds are often instrumental in rearing early fish larvae, their use stands as a major cost to hatcheries in the form of infrastructure, floor space and skilled labor (Ruscoe et al., 2004; Curnow et al., 2006a). Live feeds are also prone to culture crashes, adding risk to hatchery operations, and they are a culprit in inconsistent survival and growth of fish, due to high variability in nutritional quality associated with culture and enrichment conditions (Curnow et al., 2006b; Engrola et al., 2009; Moorhead and Zeng, 2010). The use of formulated diets opens up avenues for precise control over the delivery of nutrients to fish (Cahu and Zambonino Infante, 2001; Bonaldo et al., 2011; Hamre et al., 2013), a field of research largely untouched in marine ornamental aquaculture (Sales and Janssens, 2003; Moorhead and Zeng, 2010; Olivotto et al., 2011). In fact, successful weaning to formulated feeds

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normally represents a key final step in food-fish hatchery operations and hence major research efforts have been devoted to this with the objective to reduce the use of live prey organisms in favor of formulated diets to the largest extent (Sorgeloos et al., 2001; Zohar and Mylonas, 2001; Nguyen et al., 2011; Ouraji et al., 2011; Takeuchi and Haga, 2015).

While research to optimize weaning techniques has been documented in various food fishes (Rosenlund et al., 1997; Kanazawa, 2003; Engrola et al., 2005; Nguyen et al., 2011; Hoestenberghe et al., 2015), there is a paucity of such information for marine ornamental fish (Gordon et al., 1998; Moorhead and Zeng, 2010). In general, three key considerations in establishing the best weaning protocol to formulated diets are: 1) identification of appropriate timing for weaning; 2) optimizing feeding frequency, and 3) optimizing feeding ration in order to achieve the best fish survival and growth while minimizing labor and feed wastage. Obviously, identifying the earliest possible time to wean cultured fish to a formulated diet will not only substantially simplify larval rearing procedures and significantly decrease labor and live-feed production costs (Muguet et al., 2011), but also opens the door for improved control over nutrient delivery to fish *via* diet formulation. Once fish are weaned onto a formulated diet, feeding frequency and ration are two important considerations as they dictate feed intake and utilization by fish, and therefore growth (Grayton and Beamish, 1977; Johnston et al., 2003). Optimized weaning procedures can positively impact hatchery economics, bringing about savings in labor and feed usage, maintaining water quality, and improving key industry metrics such as growth, size uniformity, and reduced rates of deformity (Olivier and Kaiser, 1997; Johnston et al., 2003). However, except for the clownfish, *Amphiprion* spp., and a seahorse, *Hippocampus abdominalis* (Gordon et al., 1998; Gordon and Hecht, 2002; Johnston et al., 2003; Woods, 2003), no other studies exist documenting effective protocols for weaning to non-live or formulated diets in ornamental fish species. Clearly such protocols are important to commercial hatchery production of popular marine ornamental fish for the aquarium trade (Gordon et al., 1998; Johnston et al., 2003; Sales and Janssens, 2003; Woods, 2003).

The forktail blenny, *Meiacanthus atrodorsalis*, has been identified as a valuable species in the marine ornamental market and shows promise for aquaculture production (Tellock and Alig, 1998; Moorhead and Zeng, 2011). To date early larval feeding protocols have been investigated and established (Moorhead and Zeng, 2011), however the best weaning techniques to formulated diets are yet to be identified. The objective of this study was hence to investigate and establish benchmark-feeding protocols to successfully wean *M. atrodorsalis* onto a commercial formulated diet. This study includes a series of 3 experiments that examine the effect of timing for weaning, feeding frequency and ration on survival, growth, and rate of deformities in *M. atrodorsalis*. In combination with other studies by the authors (Moorhead and Zeng, 2011; unpublished data), a reliable and complete hatchery feeding protocol for the culture of *M. atrodorsalis* larvae from first feeding to 49 DPH is successfully established.

2. Materials and methods

2.1. Larval culture

Newly hatched larvae were sourced from breeding groups of *M. atrodorsalis* maintained at James Cook University (JCU). Eggs were taken from the guarding males and hatched artificially. The newly hatched larvae were stocked and reared communally in a 100-L tank until they reached the designated ages for the experiments. The tank used for communal rearing was a 100-L fiberglass cylindrico-conical tank described by Moorhead (2015), lit overhead by fluorescent ceiling lights (twin Sylvania 36 W cool-white lighting fixture). The tank was connected to a recirculating system with 10-μm filtration, a biological filter with foam fractionation and UV sterilization.

Newly hatched larvae were initially fed the ss-type rotifer *Brachionus rotundiformis* at 10 individuals mL^{-1} from 0 to 2 DPH (days-post-hatching), and then transitioned to newly hatched nauplii of AF strain *Artemia* (INVE technologies, Belgium) from 3 DPH and fed at 3 individuals mL^{-1} until 7 DPH. Instar II metanauplii of the GSL strain of *Artemia* (INVE technologies, Belgium), enriched with algamac 3050 (Aquafauna Bio-Marine, Inc.), were then introduced from 8 DPH, with a co-feeding period with AF nauplii for 3 days, and fed at 3 individuals mL^{-1} until the larvae reached the designated ages for the trials.

From 0 to 10 DPH the in-flow of filtered water from the recirculating system to the communal tank was maintained at approximately 4.2 L h^{-1}, giving the tank a 100% water exchange every 24 h. From 11 DPH onward, water inflow rate increased to 12.6 L h^{-1} and the tank was topped up 4 times daily (at 8:30 am, 12:00 pm, 3:30 pm and 6:00 pm, respectively) with newly enriched GSL *Artemia* metanauplii to maintain a density of 3 individuals mL^{-1} throughout the light

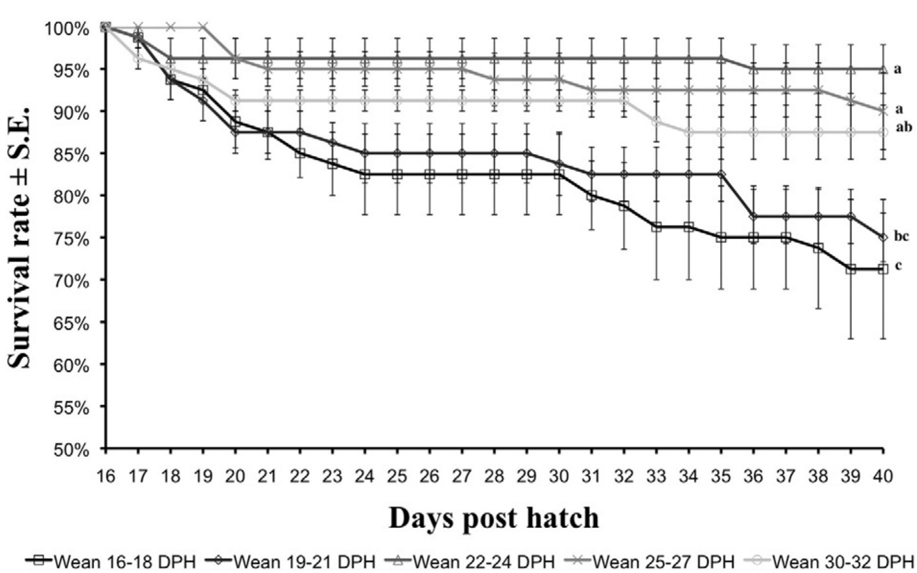

Fig. 1. Daily survival of *M. atrodorsalis* under five different weaning regimes, from live prey to a formulated feed. Different superscripts denote significant differences in survival at the end of the experiment ($p < 0.05$).