EFFECTS OF WAVELENGTH ON ATLANTIC COD (*GADUS MORHUA*) LARVAE PERFORMANCES

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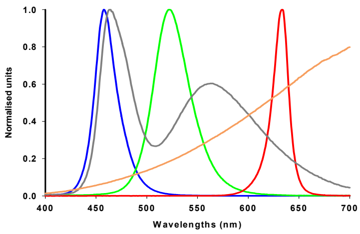
INTRODUCTION

Most farmed marine fish species are carnivorous visual feeders which mainly rely on visual photoreceptors to detect their prey. As such the light environment can directly affect feeding behaviour and consequently larval growth and survival. Light is a complex environmental factor that depends on the lighting systems used (intensity and spectrum), photoperiod, water absorbance properties as well as the specific light sensitivities of the species being reared. While it is well documented that light intensity (Downing and Litvak 1999; Puvanendran & Brown, 2002; Brown et al., 2003) and to a lesser degree photoperiod (Downing and Litvak, 2000) can play a significant role in improving gadoid larvae growth and survival, little is known on the importance of light spectral properties with very few studies on marine larvae reported to date (Villamizar et al., 2009). This communication will present the findings from a number of studies during which the impact of light intensity and spectrum on cod larvae growth and survival to weaning were investigated. The optimised rearing of Atlantic cod is of great commercial interest as juvenile supply is one of the key production bottlenecks that limits this industry.

MATERIALS AND METHODS

Three experiments were performed. Eggs were collected from freely spawning cod broodstock (Viking Fish farm, Ardtoe, 2002-2003 year classes). Lighting systems were developed by Intravision Aqua AS (Norway). In the first experiment, cod eggs (5000/tank) were stocked at stage IV to 16 experimental rearing tanks (80 L, clear water) assigned to one of two intensities (0.5 Watts/m^2 and 0.25 Watts/m^2) and four spectra (blue-460nm, green-540nm, red-640nm and white-580nm) in duplicate. The eggs were left in total darkness in static conditions until 100% hatching was observed, at which time continuous light was applied (24L:0D) using novel cold cathode lighting systems (CCL) equipped with dimming systems. Dry weight (5x10 larvae sampled every ten days, freeze dried), standard length (SL), myotome height (MH) and eye diameter (ED)(10 larvae/tank/time point) and survival (end of the trial) were analysed. In the second experiment, cod eggs (5000/tank) were exposed to 4 different light spectra (Blue-455nm, Green-535, Red-640 and White-460/560 light) using a custom designed Light Emitting Diodes (LED) system equipped with dimming systems in triplicate using 12 semi-conical rearing tanks (80 L, green water). Light intensity was set at 0.37 W m^{-2} at the bottom of the tank. Sampling and analyses performed as described for experiment 1. In the third experiment, rearing tanks were filled with different concentrations (from 50 to 1,200,000 cells/ml) of either *Nannochloropsis atomus* or *Pavlova lutheri* algae. The light intensity and spectral profile was measured at the tank bottom using a portable spectroradiometer with fiber optic umbilical.



RESULTS

1- Effects of light intensity and wavelength on cod larvae performances

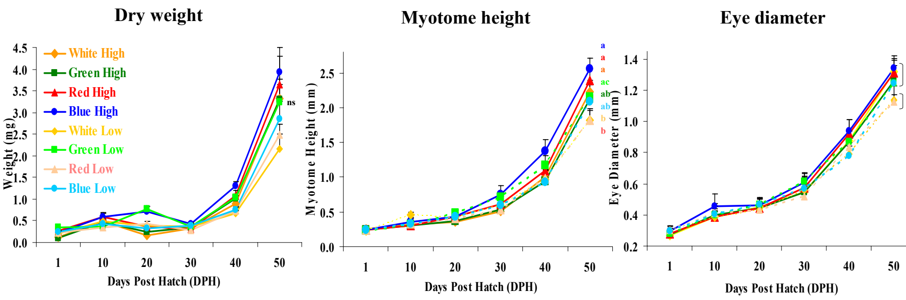
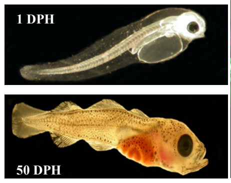


Figure 1: Effects of light intensity and wavelength on dry weight (mg), myotome height (mm) and eye diameter (mm). Data are expressed as Mean ± SD, n=2, 10 larvae per replicate. Superscripts on the graphs and in the table denote significant differences between treatments at a given time point.



Results confirmed previous findings (Puvanendran and Brown, 2002; Brown *et al*., 2003) on the effects of light intensity on cod larvae performances. Larvae exposed to higher intensities showed significantly better growth irrespective of the spectrum (Table I). Furthermore, growth performance (SL, MH, ED and CI) was best in larvae reared under a blue spectrum (as opposed to red) although weight data did not differ significantly due to high intra-batch variability. These results are in accordance with recently published data on sea bass (Villamizar et al., 2009). Survival at 50DPH from egg stocked ranged from 3 to 10% in all treatment.

Table 1: Cod larvae performances at 50 DPH when exposed to different light intensities and spectrum using CCL lighting (n=2, 30 larvae/sampling/tank). CI: condition index. Swim-bladder inflation (SB, %) was determined at 10DPH. Superscripts indicate significant differences between treatments (ANOVA, p<0.05).

	Weight	SL	MH	ED	CI	SB	Survival
White High	3.31±0.46	14.85±0.27^{bd}	2.23±0.07^{bc}	1.32±0.03^{c}	0.15±0.002^{a}	75	9.3
Blue High	3.93±0.58	15.32±0.26^{d}	2.56±0.05^{c}	1.34±0.02^{c}	0.17±0.001^{b}	90	3.8
Green High	3.29±0.36	14.01±0.37^{bcd}	2.13±0.07^{b}	1.26±0.03^{abc}	0.15±0.002^{a}	70	3.2
Red High	3.64±0.65	15.39±0.38^{bcd}	2.39±0.09^{bc}	1.32±0.03^{c}	0.16±0.003^{ab}	55	2.9
White Low	2.15±0.36	12.10±0.32^{ac}	1.81±0.07^{a}	1.13±0.02^{a}	0.15±0.003^{a}	75	5.2
Blue Low	2.84±0.41	13.77±0.29^{bc}	2.09±0.06^{b}	1.24±0.02^{abc}	0.15±0.002^{a}	80	3.6
Green Low	3.25±0.56	13.87±0.29^{c}	2.15±0.11^{b}	1.24±0.04^{b}	0.15±0.003^{a}	70	5.6
Red Low	2.48±0.26	12.05±0.22^{a}	1.82±0.06^{a}	1.12±0.01^{a}	0.15±0.002^{a}	85	6.6

2- Effects of LED narrow bandwidth light on cod larvae performances

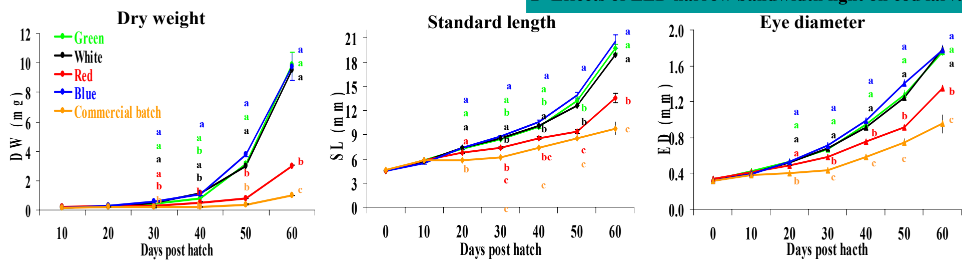
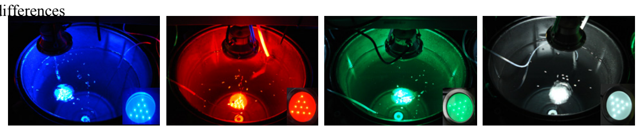


Figure 2: Effects of light spectrum on dry weight (mg), standard length (mm) and eye diameter of cod larvae. Data are Mean ± SEM, n=3, 10 larvae/replicate. The trial was performed in parallel of a commercial run using the same egg batch. Superscripts denote significant differences between treatments at a given time point (ANOVA, p<0.05).

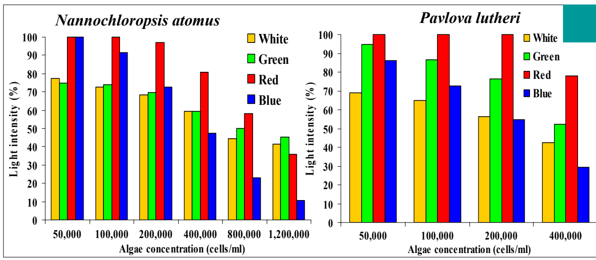
Table 2: Summary of cod larvae performances at 50 DPH when exposed to different spectrum using LED lighting (trial 2, n=3, 30 larvae/sampling point/tank). SL: standard length, MH: myotome height, ED: eye diameter, CI: condition index. Superscripts indicate significant differences between treatments (ANOVA, p<0.05).

	DW (mg)	SL (mm)	MH (mm)	ED (mm)	CI	Survival (%)
White	9.52±1.08^{a}	18.69±0.55 ^{a}	2.83±0.11^{a}	1.78±0.04 ^{a}	15.13±0.65 ^{a}	3.40±0.81
Blue	9.72±3.06^{a}	20.57±0.84 ^{a}	2.95±0.15 ^{a}	1.77±0.05 ^{a}	14.39±0.48 ^{a}	3.33±1.18
Green	9.88±1.79^{a}	19.69±0.55 ^{a}	2.75±0.11^{a}	1.75±0.04 ^{a}	14.04±0.43 ^{a}	2.58±0.64
Red	2.97±0.41^{b}	13.52±0.57^{b}	1.69±0.08 ^{b}	1.34±0.03 ^{b}	12.96±0.76 ^{b}	5.81±0.53

Significantly improved performances (SL, ED, CI) were observed in larvae exposed to short wavelengths (blue and green) in comparison to a red spectrum (Figure 2). Larvae reared under red spectrum were 4-5 times smaller than siblings exposed to white, blue or green spectra (dry weight, Table 2). However, survival determined at 50 DPH (from number of eggs stocked in the tanks) was low (2.5-5.8%) with no significant spectral effects.



3- Green water effects on light absorbance



Finally, results showed that *Nannochloropsis atomus* and *Pavlova lutheri,* the two main algal species used in cod larviculture, can influence the photic environment within the rearing systems depending on algal species spectral absorbance and densities. Both algae showed different light absorbance characteristics with *N. atomus* and *P. lutheri* absorbing preferentially green and blue wavelengths respectively but not red.

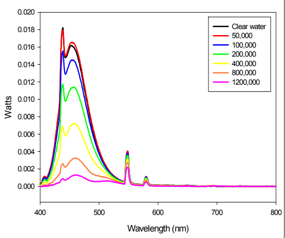


Figure 3: Effects of different algal species, *Nannochloropsis atomus* and *Pavlova lutheri at different* concentrations (from 50,000 to 1,200,000 cells/ml) on the relative light intensity measured at the bottom of the tanks for each of the four species (left graph) and example of normalised spectral content obtained under blue wavelength for different concentrations of *N. atomus (right)*.

CONCLUSIONS

Together, these results clearly demonstrate the importance of light characteristics and especially spectrum on marine larviculture. Depending on species specific light sensitivities, particular wavelengths may maximize visual sensitivity, as shown in deep-sea fishes or, visual contrast, as for fish living in complex photo-environments, like in shallow or coastal waters. There is therefore the possibility that larvae visual system could be predisposed to perform best under spectral conditions most frequently encountered in its particular ecological niche. However it must be considered that light sensitivities may change with development. These trials have implications for current commercial hatchery practices suggesting methods of improving husbandry methodologies. There remains a lack of standardisation of protocols (especially for light) in the industry but clearly the use of new lighting technologies could cut operating costs while also providing specific light environments tailored to the photic affinities of larval cod. More research and development is needed in this area to determine the photosensitivities of larval cod visual pigments throughout development so that the full benefit of enhanced growth and survival can be obtained through the implementation of new hatchery protocols.

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References: Brown, J.A, Minkoff, G. & Puvanendran, V., 2003. Larviculture of Atlantic cod (*Gadus morhua*): progress, protocols, and problems. Aquaculture 227:357-372; Downing, G and Litvak, M.K., 1999. The influence of light intensity on growth of larval haddock. North American Journal of Aquaculture 61: 135-140; Downing, G and Litvak, M.K., 2000. The effects of photoperiod, tank color and light intensity on growth of larval haddock. Aquaculture International 7: 369-382; Puvanendran, V. and Brown, J.A, 2002. Foraging, growth and survival of Atlantic cod larvae reared in different light intensities and photoperiods. Aquaculture 214: 131-151; Villamizar N., García-Alcazar A., Sánchez-Vázquez F. J., 2009. Effect of light spectrum and photoperiod on the growth, development and survival of European sea bass (*Dicentrarchus labrax*) larvae. Aquaculture 292: 80-86.