
Effects of temperature on the growth of Pollack (*Pollachius pollachius*) juveniles

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Abstract: Growth of juvenile pollack was assessed at five constant temperatures (9, 12, 15, 18 and 21 °C) in an 84-day trial. Duplicate groups of 75 fish (initial weight 143 ± 2 g) were held in O₂ saturated water (102–103% saturation) and fed to apparent satiation. Growth increased as temperature increased from 9 °C up to a plateau at 12–15 °C (NS differences between 12 and 15 °C) followed by a decrease from 18 °C. No growth occurred at 21 °C. For the overall period, specific growth rates were 0.52% and 0.53% day⁻¹ at 12 and 15 °C compared to 0.40% day⁻¹ at 18 °C. Feed intake was maximum at 15–18 °C (0.68–0.69% day⁻¹) and it was significantly lower at 21 °C (0.45% day⁻¹). Apparent feed conversion ratio was significantly higher at 18 °C than at 12–15 °C (1.8 compared to 1.2–1.4). There was no significant change in fish whole body composition related to temperature.

At the end of the experiment, fish growth recovery following a transfer from 18 and 21 °C to 15 °C was assessed using a 50-day challenge test. Growth rate of the previous 21 °C group was the same as in the 15 °C group (NS differences) and in the previous 18 °C group it was significantly lower. The study showed that pollack have a high capacity to recover from a prolonged period of low or no growth induced by high temperatures.

Keywords: Pollack; Temperature; Growth; Feed efficiency

1- Introduction

Pollack, *Pollachius pollachius* (Gadidae) has been selected as a potential new candidate for aquaculture in the Atlantic and North Sea coastal waters of France using a panel of criteria covering farmers to consumers demand (Suquet et al., 2000, Quéméner et al., 2002). Pollack distribution is from Portugal to North of Norway. First rearing attempts showed that reproduction in captivity and larval rearing seem easy, although there is no well-established culture method for larvae even at a laboratory scale (Suquet et al., 1996, 2005; Gatesoupe, 2002.). Pollack has a fast growth potential, wild juveniles trapped in sea cages and fed dry pellets can weigh 400 g at 2 years in 9-18°C waters (first market size, 300 g). Similar growth has been obtained in a small group of hatchery-reared fish held in out-door tanks (Suquet et al., 1996).

Despite the trials mentioned above, there is no data available on the rearing conditions for optimum growth of pollack especially with regards to water quality or nutrients requirements. As fish growth is under control of temperature, it is of high interest to study the effects of this major ecological factor on growth performances of any new candidate for aquaculture (Brett and Groves, 1979). As thermal effects interact with most ecological factors (oxygen, salinity) and with feeding conditions (food supply) it is also beneficial to hold the fish under controlled environmental and unrestricted feeding conditions when determining thermal effects. For example, when feeding or oxygen availability is restricted, the temperature at which fish grow best is lower than when feeding and oxygen supply are not limiting (Jobling, 1996).

The main focus of this study was the examination of the effects of stabilised temperatures covering North Atlantic coastal water temperatures on pollack growth. To this end, the temperature-related growth rate, feed consumption and feed conversion, were determined in juvenile fish. At the end of the experiment, growth recovery of fish following a transfer from 18 and 21°C to a more suitable temperature (15°C) was assessed.

2- Materials and methods

2.1. Fish and rearing conditions

The experiment was carried out using 10 month-old hatchery reared juveniles obtained from a captive broodstock. It started with 900 fish (103 g) held for one month in two 4-m² tanks supplied with running seawater (15-16°C, oxygen 90-95% air saturation prior to feeding, 34-34.5‰ salinity). The photoperiod was maintained constant on a 18 L:6 D cycle and light intensity was 100 lux (0.4 W m⁻²) maximum at the water surface. Fish were fed by hand twice a day at 0930 and 1500 hours to apparent satiation on a commercial extruded dry pellet (Le Gouessant[®], protein 56% and crude fat 12%, pellet diameter 4 mm). At the end of the pre-acclimation period, fish were individually weighed and 750 fish were randomly distributed among the 10 experimental tanks (1-m² tanks with an effective volume of 450 l) and then allowed to adapt at 15-16°C for 14 days to the new conditions (acclimation period).

2.2. Experimental design

The 84-day test was carried out using duplicate groups of 75 fish held at 5 constant temperature: 9, 12, 15, 18, 21°C. On day 0, the initial mean mass per tank was estimated by weighing individually all fish per tank; mean weight range was 143-144 g and there was no significant differences between fish mass in each tank (Table 1). From day 0 onwards, two

tanks were maintained at 15°C and in the other 4 groups, temperature was gradually increased or decreased by 3°C day⁻¹ until the chosen temperature was attained. O₂ concentration in each tank was checked once a day and adjusted when necessary by changing the O₂ injection rate to maintain pre-feeding levels at 102-103% air saturation. Salinity and ambient pH were checked weekly. Fish were hand-fed to apparent satiation. Feed intake of each tank was measured and corrected, when necessary, from uneaten pellets counted after each meal (water outflow was fitted with a waste trap). At regular intervals, an equal number of fish was randomly removed from each tank to maintain stocking density below ca. 25 kg m⁻³. Removed fish were individually weighed for mass estimation and for comparison with fish remaining in each tank.

Table 1. Growth results of the 84-day test and final fish whole body composition related to temperature.

Temperature (°C)	12.2 ± 0.1	15.4 ± 0.1	18.0 ± 0.1	21.2 ± 0.1	
Day 0 fish weight (g)	144.2 ± 1.6	143.4 ± 1.5	143.6 ± 1.4	142.9 ± 1.5	NS
Day 0 weight CV (%)	9.6	9.3	8.4	9.2	NS
Day 84 fish weight (g)	224.9 ± 4.1	225.4 ± 4.7	201.3 ± 3.3	147.2 ± 2.8	***
Day 84 weight CV (%)	12.5	14.3	11.3	13.1	NS
Day 0-84 SGR (% day ⁻¹)	0.52±0.05 a	0.53±0.02 a	0.40±0.03 b	0.04±0.03 c	***
Day 0-84 Feed intake (% day ⁻¹)	0.60±0.02 a	0.68±0.02 a	0.69±0.02 a	0.45±0.05 b	**
Day 0-84 Feed conversion ratio (g g ⁻¹)	1.18±0.10 a	1.42±0.13 a	1.76±0.18 b	2.98	*
Day 84 fish water (% wet weight)	73.9±0.3	73.1±0.7	72.2±0.5	74.6±0.6	NS
Day 84 fish protein (% wet weight)	15.3±0.2	16.3±0.4	16.7±0.4	14.9±0.3	NS
Day 84 fish fat (% wet weight)	7.0±0.1	6.5±0.4	6.8±0.5	7.0±0.4	NS

Means are given with S.E.; day 0 fish weight, n=150; day 84 fish weight, n=98; weight CV, SGR, FI, FCR and fish whole body composition, n=2 replicates. NS, P>0.05 indicate no statistical differences between temperature groups and statistical differences are reported as * P<0.05, ** P<0.01, ***P<0.001.

At the end of the growth experiment a challenge test was carried out for 51 days (day 85-136) using 67 fish from each previous 21, 18 and 15°C temperature. Selected fish of each temperature group were placed in a 4-m² tank supplied with running water. Mean weight ranged from 149 to 227 g depending on the temperature groups, and the stocking density range was 5-7 kg m⁻³. In the previous 15°C group, temperature was unchanged (15-15) and in the other two groups it was decreased from 18°C or 21°C to 15°C (18-15 and 21-15 groups, respectively). O₂ concentration was stabilised at 91% saturation using a flow rate of 100 % h⁻¹. Food and feeding procedures were unchanged.

2.3. Studied parameters

The average weight of fish in a tank was calculated using individual fish weights of all fish measured on day 0, 14, 28, 42, 56, 70 and 84 for the growth test and on day 115 and 136 for the challenge test. Specific growth rate (SGR, % day⁻¹) was calculated as: $100 \times (\ln w_f - \ln w_i) \text{ day}^{-1}$, where w_i and w_f are the initial and final mean wet body weight for each tank

respectively. The coefficient of variation for weight (CV, %) was: $100 \times \text{standard deviation} \times \text{mean body weight}^{-1}$. As some fish were regularly removed from the tanks, daily feed intake (FI) and apparent feed conversion ratio (FC) were calculated for each tank taking into account the average mass per t_1 - t_2 period (t_1 and t_2 are the first and the last day of the period respectively) using the following expressions:

- FI: $100 \times (\text{mean daily mass of dry feed ingested, g} \times \text{mean wet fish mass}^{-1}, \text{ g})$ where $\text{mean fish mass} = (\text{fish mass at } t_2 + \text{fish mass at } t_1) \cdot 2^{-1}$ and $\text{fish mass} = \text{mean body weight} \times \text{fish number}$;

- FC: $\text{dry feed ingested, g} \times \text{fish mass gain}^{-1}, \text{ g}$, where $\text{fish mass gain} = \text{fish mass at } t_2 - \text{fish mass at } t_1$.

On day 84, body composition of whole fish was determined on 3 samples of 4 fish taken in each replicated tank. Fish were ground and moisture content was determined on homogenates samples (24 h at 105°C) and subsequently freeze-dried and ground before further analyses. Chemical analyses of fish was performed in triplicate for each sample according to AOAC methods (Association of Official Analytical Chemists, 1984): crude fat (dichloromethane extraction with a Sostec System Ht[®]), and crude protein (Dumas method with an Elementary NA 2000[®], $N \times 6.25$).

2.4. Data analysis

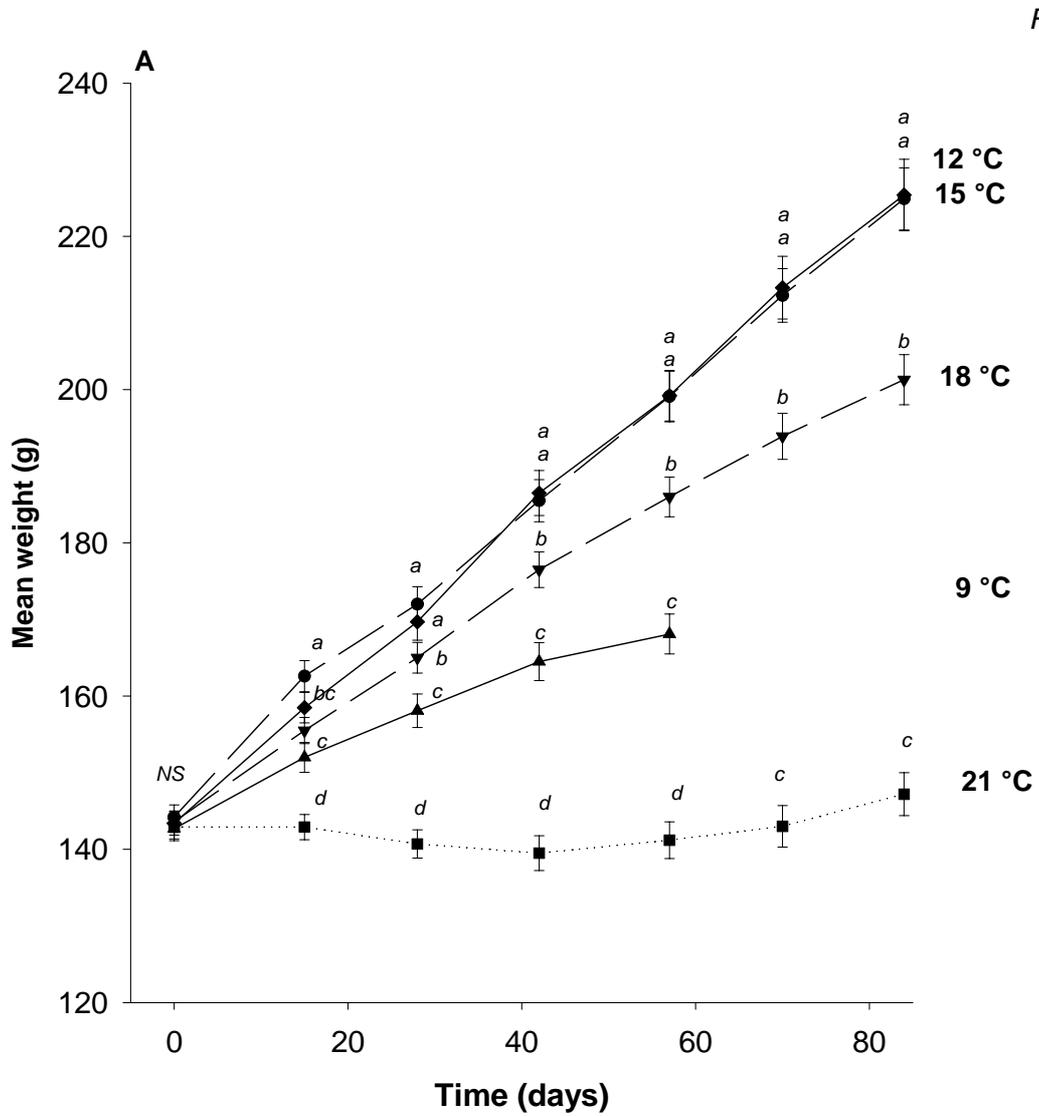
All results are expressed as mean \pm S.E. For growth test, differences in fish mass versus temperature and time were tested by a two-way nested ANOVA using Statistica[®] for Windows, and tanks were considered as nested factor. One-way ANOVA was used for SGR, FI and FC. Significant ANOVA were followed by a *post hoc* multiple comparison test (Newman-Keuls test). Differences were considered significant at $P < 0.05$. Prior to ANOVA analysis, data expressed in %, were arcsine square-root transformed. For the challenge test, regression lines of weight to time were tested for goodness of fit prior to comparison of regression line slopes (Zar, 1984).

3- Results

Temperature remained stable over the 84-day experiment (CV was 10% at 9°C and 2% at 21°C). In all groups, fish appeared healthy and no mortality was observed (9°C group was accidentally lost at day 65). Mass gain increased as temperature increased from 9°C up to a plateau at 12-15°C (NS differences between 12 and 15°C) followed by a decrease from 18°C (Fig. 1). No growth occurred at 21°C. Fish weight dispersion was low and in the same range in all groups, with CVs for final weight of 11-14 % (Table 1).

Fig. 1. Changes of mean weight over time in relation to the five constant temperatures tested. Means are given with S. E. Letters indicate statistical differences between temperature groups, means not sharing a common letter are significantly different ($P < 0.05$) and NS = no significant differences ($P > 0.05$).

For the overall growth test period, specific growth rate was 0.52 and 0.53% day^{-1} at 12

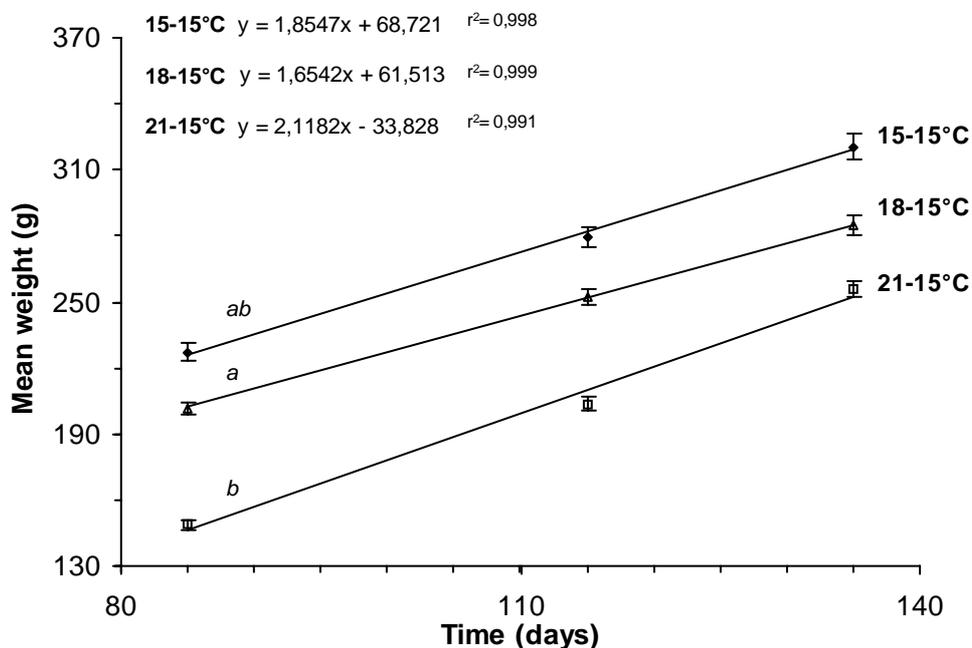


and 15°C respectively and it was significantly lower (-25%) at 18°C (Table 1). The relationship between day 0-84 SGR and temperature (T) could be described by following equation: $SGR = -1.47 + 0.291 T - 0.014 T^2$ (n=8, $r^2=0.997$). Feed intake was maximum at 15-18°C (0.68-69 % day⁻¹); it was slightly lower at 12°C (NS from 15-18°C) and at 21°C it was significantly different from all other groups (0.45% day⁻¹). Apparent feed conversion ratio was significantly higher at 18°C than at 12-15°C, 1.8 compared to 1.2-1.4. On day 84, there was no significant change in fish body composition related to temperature (Table 1).

During the challenge test, transferring fish from 18 or 21°C to 15°C led to a major enhancement in growth rate compared to their rate before the transfer, with differences in fish response related to their initial conditioning (Fig. 2). Growth of 21-15°C group was significantly higher than in 18-15°C group, with day 85-135 SGRs of 0.45% and 0.23% day⁻¹ respectively. Both groups had growth rates similar to the 15°C group (NS differences in regression lines slopes). The change in growth following the transfer at 15°C resulted primarily from an increase in fish appetite. FI was dependent on previous conditioning, 1% day⁻¹ in 21-15°C group compared to 0.73% in the 18-15°C and 15-15 groups. Feed conversion ratio was 1.0 in the 21-15°C group and 1.2 in the others two groups.

Fig. 2. Changes of mean weight during the challenge test at 15°C in relation to previous temperature conditioning.

Means are given with S.E. Letters indicate statistical differences between temperature groups, regression lines not sharing a common letter have significantly different slopes (P<0.05).



4- Discussion

This study demonstrated for the first time the temperature dependence of growth of a population of pollack juveniles reared when food and oxygen supply were not restricted. Growth of 145 g fish was the highest at 12-15°C and the upper limit for long-term survival was around 21°C. A severe growth decrease may be expected in waters below 9°C and over 18°C. Fish weight dispersion was not affected by temperature, no skin or fin injury was observed in any temperature groups suggesting that possible social interactions induced by the experimental conditions used had not acted on growth response. Temperature effects on growth were primarily explained by feed intake and at 21°C, it was near minimum required for weight maintenance. The pronounced decrease in growth at 18°C compared to 12-15°C resulted from an increase in feed intake concomitant to an increase in feed conversion ratio suggesting some difficulties to adapt, 18°C seems near the upper limit for long-term growth.

The thermal responses of pollack juveniles in terms of feeding and growth performances and the stability in whole fish body composition are in line with other studies on teleosts (Jobling, 1996; Burel et al., 1996; Imsland et al., 2001; Van Ham et al. 2003; Person-Le Ruyet et al., 2004a,b). In comparison with cod of the same size, temperature for maximum growth of pollack seems 3-4°C higher, that is in agreement with differences observed in the geographic distribution of cod and pollack stocks (Bjornsson et al., 2001). This study indicates that the best temperature range for rearing pollack juveniles is 3-5°C higher than for reproduction in captivity (8-10°C, Suquet et al., 2005).

This study has clearly shown the high capacity of pollack juveniles to recover from unsuitable growth conditions induced by high temperatures. For the 21-15°C group, specific growth rate was 0.45% day⁻¹ during the recovery period (day 85-135) compared 0.04% day⁻¹ when reared at 21°C (day 0-84 period). The strong growth recovery following a change from 21 to 15°C was mainly achieved by hyperphagia. Compensatory growth has been reported in fish previously exposed to different stressful environmental conditions such as long-term food privation, re-feeding after a period of starvation, or feed restriction (Person Le Ruyet et al., 2003; Nikki et al., 2004; Tian and Qin, 2004).

The choice of the best temperature range is required to improve pollack growth especially as its wholesale selling price is low. It will have been of high interest studying the physiological mechanisms involved by fish to adapt to high temperatures and to recover from a prolonged break of growth following a transfer to suitable thermal conditions.

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