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The effect of temperature on the growth, survival and food consumption of the east coast rock lobster *Panulirus homarus rubellus*

J.O.G. Kemp *, P.J. Britz

Department of Ichthyology and Fisheries Science, Rhodes University, PO Box 94, Grahamstown, 6170, South Africa

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ABSTRACT

The successful culture of the east coast rock lobster *Panulirus homarus rubellus* is reliant, among other factors, on the provision of optimal water quality for growth and survival. This study investigated the effect of temperature over a range of 9.7 °C (18.9±0.7 °C to 28.6±1.5 °C) on the growth and survival of juvenile (40.4±9 mm CL; 63.64±12.05 g) *P. h. rubellus* fed a diet of fresh mussel flesh. Specific growth rate (SGR) was significantly different between temperatures ($p=0.01$), with the highest values recorded for the 24 and 28 °C treatments. There was no significant difference in moult increment (MI) between temperatures in terms of both an increase in weight ($p=0.83$) and carapace length ($p=0.54$). Intermoult period (IMP) differed significantly between temperatures ($p=0.0015$) with mean IMP lowest at 24 °C, although not significantly different from the means of the 26 and 28 °C treatments. IMP was highest at 19 and 21 °C. Apparent feed intake was significantly different between treatments ($p<0.0001$) and exhibited a strong positive correlation with increasing temperature ($y=-1.67+0.16x$; $r^2=0.81$). Food conversion ratio (FCR) differed significantly between temperatures ($p=0.02$) with 24 °C exhibiting the most efficient FCR. Results indicate that efficient growout of juvenile *P. h. rubellus*, in terms of both growth and food conversion efficiency, is obtainable at 24 °C.

1. Introduction

The east coast rock lobster *Panulirus homarus rubellus* is one of three subspecies of the scalloped spiny lobster *P. homarus* (Linnaeus) and occurs in the south-western Indian Ocean along the south-east coasts of Madagascar and Southern Africa (Berry, 1974; Smale, 1978). Within the south-east African region, *P. h. rubellus* is distributed from Port Elizabeth in the south to at least Barra Falsa, Mozambique, in the north, with the greatest abundance centred along the Natal coast (Heydorn, 1969). It inhabits shallow water reef environments (surfzone down to 20 m depth) and distribution and abundance appear to be correlated to the availability of its primary food organism, the brown mussel *Perna perna* (Berry, 1971b).

No commercial exploitation of *P. h. rubellus* currently exists in South African waters as it forms an important component of the intertidal subsistence fishery along the former Transkei coast and supports a large recreational lobster fishery in Natal (~150 tonnes annually) (Cockcroft and Payne, 1999; Fielding et al., 1994; Tomalin, 1993). Along the former Transkei coastline, enforcement of the minimum legal size (MLS) of 65 mm carapace length has proved problematic, and the removal of sublegal size animals for sale to tourists or personal consumption is therefore common among artisinal fishers (Fielding et al., 1994). Subsequently, interest has arisen in the possibility of the growout of these undersize lobsters, in conjunction with a commercial partner, as a means of adding value to the resource for subsistence fishers.

The harvest and subsequent growout of wild caught pueruli and juveniles is, given the difficulties associated with larval rearing (Cox and Johnston, 2003; Kittaka, 2000), considered to be the most feasible short term option for lobster aquaculture (Crear et al., 2000; Johnston et al., 2006). Growout of wild harvested juvenile lobsters is an area of much research interest (Phillips and Melville-Smith, 2006) and is currently employed in a number of countries including Taiwan, Singapore, India (Booth and Kittaka, 2000) and notably in Vietnam, where production in the cage-reared *P. ornatus* industry is estimated to exceed 3000 tonnes annually at an export value of US$90 M (Williams, 2007). The majority of research aimed at developing culture systems and protocols for on-growing has centred on land-based systems, although the prospects of sea-cage farming have been explored (Jeffs and James, 2001; Simon and James, 2007). The high energy nature of the South African coastline necessitates the use of land-based systems. Successful culture of *P. h. rubellus* will require the development of a cost-effective and nutritionally adequate formulated diet (Williams, 2007), optimisation of the design of growout tanks and rearing protocols, and provision of optimal water quality for growth and survival within these systems (Crear et al., 2000).

Water temperature is one of the most important environmental factors determining the growth rate of crustaceans (Hartnoll, 1982)

* Corresponding author. Tel.: +27 76 2014142; fax: +27 46 622 4827.
E-mail address: groovypalm@gmail.com (J.O.G. Kemp).

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and has been shown to affect the growth of a number of spiny lobster species including *Jasus lalandii* (Dubber et al., 2004), *J. edwardsii* (Crear et al., 2000; Thomas et al., 2000), *P. argus* (Lellis and Russell, 1990), *P. cygnus* (Phillips et al., 1977) and *P. interruptus* (Serfling and Ford, 1975). While some studies have reported on the growth of *P. homarus* sp. under captive conditions (Berry, 1971a; Kulmiye and Mavuti, 2005; Rahman et al., 1997), only one to date has investigated the effect of temperature on the growth of *P. h. rubellus* (Smale, 1978). Considerable variations in growth at the same temperature have been noted for other species, most notably *J. edwardsii* (Thomas et al., 2000). Furthermore, it has been shown that crustaceans of the same species that have been collected from geographically different locations vary in their response to similar environmental conditions (Sastry and Vargo, 1977). While Smale (1978) attempted to define the upper thermal limit of *P. h. rubellus*, the range of temperatures the lobsters were grown at was limited to the upper portion of the range of those experienced within its natural distribution. In addition, Smale's animals were sourced from the Kwa Zulu Natal coast which possesses higher ambient water temperatures than the Transkei coast to the south, which is the target area for on-growing lobsters collected by artisinal fishers.

The aim of this study was to determine the effect of water temperature (19–28 °C) on survival, growth, feed intake and feed utilization of juvenile *P. h. rubellus* collected from the former Transkei coastline to identify the most efficient temperature for culture.

2. Materials and methods

2.1. Collection, transport and acclimation of experimental animals

Approximately 200 juveniles were collected by hand using free-diving and SCUBA from near-shore reefs (2–15 m depth) in the Mdumbi region of the Eastern Cape, South Africa. Following capture, the lobsters were transferred to seawater filled 180 l PVC drums loosely lined with 8 mm oyster mesh to purge for 48 h. Water in the drums was oxygenated and exchanged twice daily. Lobsters were transported in these drums (7 h by road) to the Port Alfred Marine Research Laboratory where they were placed in mesh baskets (0.8×0.5×0.5 m; 6 mm mesh) and held in ambient re-circulating seawater at approximately 18 °C. The lobsters were acclimated to captivity for two months on a diet of crushed fresh mussel (*Mytilus galloprovincialis* and *P. perna*) fed in excess three times a week.

2.2. Experimental system

Following acclimation a total of 48 lobsters (40.4±9 mm carapace length (CL); 63.64±12.05 g) were selected from the holding cages and stocked into the experimental system. Pairs were randomly allocated to each of 24 fibreglass tanks (0.5×0.3×0.3 m; 45 l). The tanks were aerated with an air stone and each held two lidded oyster mesh baskets (0.2×0.15×0.3 m; 6 mm mesh) into which one lobster was placed. Shelter for lobsters was supplied in the form of a 10 cm length of PVC piping (63 mm diameter). Housing lobsters in individual cages not only prevented cannibalism and competition for food, but also allowed the exact time of moulting and growth of each individual to be accurately determined (Dubber et al., 2004). The tanks were housed in a constant environment laboratory held at 18 °C and formed part of a biologically filtered partial re-circulating system (5500 l total volume; 1000 l filter volume; 10% daily water exchange). Water temperature in each tank was controlled by chilling a shared supply sump tank to 18 °C, from which water was pumped directly to each individual tank where submersible heaters heated the water to the desired temperature. A temperature range of 9.7 °C (18.9±0.7 °C to 28.6±1.5 °C) was attained using this method with treatments being divided into 5 temperature groupings, i.e. 19.2±0.3, 21.1±0.5, 24±0.4, 26.3±0.2 and 28.3±0.2 °C, with significantly different means (mean±SE; ANOVA, $F_{4,19}=705.92$, $p=0.0000$) (Table 1). A uniform flow rate to achieve 1 exchange per hour was maintained across all treatments.

2.3. Feeding

The experimental animals were fed in excess of their feed uptake on a mixed diet of fresh, opened brown mussel *P. perna* and Mediterranean blue mussel *M. galloprovincialis* on days 1, 3 and 5 of each week. Before being placed in the tank, mussels were opened, air dried shell side up on a mesh tray for 30 min and weighed to 0.01 g (Denver Instruments MXX-612). Shell and remaining uneaten food (feed was always in excess on collection) were removed 24 h after feeding on days 2, 4 and 6 of each week and dried and weighed as previously described. Lobsters were fed at 16h00 as *P. h. rubellus* is nocturnal with the greatest peak in feeding activity occurring during the initial stages of the dark photophase (Smale, 1978). The feeding regime described ultimately resulted in lobsters remaining unfed on days 2, 4 and 6 and, for logistical reasons, on day 7. The 7 day feeding regime was maintained throughout the trial, except on days 161–164, 179–180 and 191–194 when high seas prevented the collection of mussels.

2.4. Experimental procedure

Experimental animals were acclimated to the experimental system for four weeks. During the first two weeks the water temperature in each tank was gradually raised to the experimental temperature followed by a further two weeks of acclimation at the designated temperature. The growth trial ran for a further 223 days. A 12L:12D cycle was maintained using overhead fluorescent lighting throughout the acclimation period and growth trial. Water temperatures and pH (7.9–8.1) were recorded on average two times per week (Hanna pH/Temp probe HI98128). Water quality was monitored by measuring the ammonium levels (Red Sea Ammonia Test Kit, NH_3 and NH_4^+ 0–1 mg/l) of a random sample of 5 tanks every second week, with values remaining below 0.25 mg/l for the duration of the trial. Dissolved oxygen levels (Hanna Waterproof DO Meter HI9143) remained at or near saturation across all treatments.

Wet weight and carapace length (CL) of all animals were measured at the start of the trial and then at 37 day intervals following. No lobsters moulted more than twice in the inter-weighing period. Wet weight was measured, after removing excess water, to the nearest 0.01 g using an electronic balance (Denver Instruments DXX-612) and CL was measured to the nearest 0.1 mm using vernier calipers. Moults and mortalities were recorded and removed each day. Dead lobsters were replaced with similar sized animals to maintain densities. Tanks

Table 1
Water temperatures (°C, mean±SE) of tanks used to house juvenile *P. h. rubellus* during a 223 day growth trial

Parameter	Temperature group (°C)				
	19	21	24	26	28
Mean water temperature (°C) of group	19.2±0.3[a]	21.1±0.5[b]	24±0.4[c]	26.3±0.2[d]	28.3±0.2[e]
Mean water temperature (°C) of replicate tanks	18.9±0.7 19.2±0.8 19.2±0.8 19.5±0.8	21±0.7 21±0.6 21.6±0.7 21±0.6 21.4±0.5	24±0.9 23.7±0.7 23.8±0.7 23.9±0.7 23.5±0.6 24.8±0.9	26.2±1.1 26.3±0.3 26.3±0.8 26.6±0.6	28.6±1.5 28.2±1 28.4+1 28.2±1.3 28.2±0.9
Number of tanks	4	5	6	4	5
Number of lobster	8	10	12	8	10

Values in the same row with different superscripts are significantly different ($p<0.05$).