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The impact of diet on the growth and proximate composition of juvenile whelks, *Dicathais orbita* (Gastropoda: Mollusca)

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Abstract

Dicathais orbita is a predatory marine whelk of interest as a new source of protein for potential production in aquaculture. Establishment of a successful aquaculture industry based on this species will require optimisation of their diet for fast growth and survival, whilst maintaining a good proximate composition in the flesh. Here we compare the effects of four diets fed to juvenile *D. orbita* over a 12 week period, to evaluate consumption, feed conversion, growth rates, mortalities and proximate composition. It was found that diet impacts significantly on the growth and survival rates of this whelk, with bivalve feeds resulting in significantly higher consumption ($P<0.0001$) and growth rates ($P<0.0001$) compared to artificial pellets, despite similar feed conversion ratios ($P=0.359$). The artificial pellets were found to have significantly less moisture, but higher protein, glycogen and lipid content than the bivalve feeds ($P<0.05$) and resulted in whelk flesh with significantly higher energy and ash content ($P<0.05$). *D. orbita* showed a preference for scavenging frozen bivalves over predation on live molluscs in captivity, which could reflect an optimal foraging strategy to minimise the energy required to subdue prey. Overall, juvenile *D. orbita* display similar growth (up to 0.8 g/month) and high survival (>90%) compared to other gastropods in culture. Their flesh has a high calorific value (~19 kJ/g), with significantly higher protein (>26 mg/g) and glycogen (>35 mg/g) content than their bivalve prey ($P<0.05$). Consequently, this species has a promising future as a new species for molluscan aquaculture in Australia.

Keywords: Feeding preference; Growth rate; Muricidae; Nutritional quality; *Dicathais orbita*

1. Introduction

The demand for protein rich food is increasing, especially in developing countries, stimulating exploration of underutilised or non-traditional resources. Whelks are predatory marine gastropods that are highly favoured for their high protein meat (Xavier Ramesh and Ayyakkannu, 1992). Whelks in the family Muricidae are currently fished throughout Asia (Nugranad et al., 1994; Xavier Ramesh et al., 1994), Europe (Marin et al., 1995; Ramon and Amor, 2002), Central and South America (DiSalvo, 1994; Leiva and Castilla, 2002; Naegel, 2004a). These whelks are primarily exported to Europe, Japan, China and Korea where their meat is considered a delicacy (Marin et al., 1995; Ramon and Amor, 2002). In Australia, the collection of whelks only occurs at a recreational level (Kingsford et al., 1991), with no consistent supply through established fisheries or aquaculture. Consequently, the commercial potential of locally common species, such as the Dogwhelk *Dicathais orbita* (Gmelin 1791) remains to be investigated.

Murcid whelk fisheries can provide a valuable commodity for local communities (e.g. FOA, 2002; Leiva and Castilla, 2002), with additional resources including the natural dye Tyrian purple (Naegel, 2004a), operculum and shell (Patterson and Ayyakkannu, 1993; Patterson Edward et al., 1994), greatly adding to their meat value. However, fishery pressure on some whelks has led to serious stock depletion and localised extinction (e.g. Cadee et al., 1995; Uyan and Aral, 2003), thus instigating controlled harvest as part of an active management regime in some places (e.g. Central and South America, DiSalvo, 1994; Naegel, 2004a). Excessive harvesting has also led to the development of several research programs aimed at reseeding natural populations and reducing fisheries pressure

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through the aquaculture of valuable Muricidae species (DiSalvo and Carriker, 1994; Nugranad et al., 1994; Xavier Ramesh et al., 1994; Naegel, 2004b).

On-growing efficiency (growth rate and feed conversion) is one of the three principle biological criteria that must be considered for the production of a new species by aquaculture (Webber and Riordan, 1976; Le Francois et al., 2002). Feed can represent 40–50% of overall production costs in aquaculture (Webber and Riordan, 1976; Craig and Helfrich, 2002). Therefore it is important to understand the nutritional requirements of a species, to devise optimal, physiologically-efficient and economic feeds (Webber and Riordan, 1976). Previous laboratory studies on predatory whelks (Neogastropods) indicate that providing food in excess can lead to increased growth rates and survival (Morton, 1986; Chaitanawisuti and Kritsanapuntu, 1999; Chaitanawisuti et al., 2001). Prey type has been shown to influence growth rates both in laboratory experiments (Gutiérrez and Gallardo, 1999; Nasution and Roberts, 2004) and in the field (Moran et al., 1984; Etter, 1996). Diet has also been shown to have an impact on the nutritional composition and taste of the Muricidae *Chorus giganteus* (Carrasco et al., 2006). Consequently, proximate (nutritional) analyses of whelks fed on different diets could be useful for optimising the diet to obtain a high quality muricid product.

The Muricidae are dominant gastropod predators, feeding opportunistically on a range of prey (Etter, 1996; Gutiérrez and Gallardo, 1999; Morton, 1999; Carrasco et al., 2006; Peharda and Morton, 2006). Prey selection can be influenced by the detectability, accessibility and nutritional content, as well as the ease of prey capture and time required for processing (Hughes and Dunkin, 1984; Gutiérrez and Gallardo, 1999). Feeding studies on *Chicoreus ramous* in culture have revealed that they will only eat live food, contributing greatly to the cost and logistical difficulties of culturing this species (Nugranad and Kerdpoom, 1995). However, some Muricidae including *D. orbita*, have been observed to scavenge fresh carrion (Phillips, 1969; Morton, 1999). This behaviour provides opportunity to explore the potential use of frozen or artificial feeds in Muricidae culture.

The aim of this research was to study the dietary preference, growth rates and nutritional quality of the Australian muricid *D. orbita*, to assess the grow-out prospects for using this whelk as a future aquaculture species. *D. orbita* is distributed along the temperate coast of Australia and New Zealand, within the intertidal and shallow subtidal zones of rocky shores (Phillips et al., 1973). Phillips and Campbell (1974) have established that the size at sexual maturity is approximately 38 mm for this species. The current investigation involved two separate experiments; the first compared growth and nutritional quality parameters of *D. orbita* fed four different diets; and the second looked at preference between two diets. The null hypotheses tested in these experiments were: (1) diet will have no impact on the growth rate of *D. orbita*; (2) food type will have no impact on the proximate composition of *D. orbita* and (3) *D. orbita* will display no preference for food type.

2. Materials and methods

2.1. Animal collection and maintenance

D. orbita juveniles were sourced from sub-populations along the Fleurieu and Eyre Peninsulas, South Australia. All whelks were combined in the laboratory and juveniles less than 30 mm (maximum shell length dimension mean 22.4±3.19 mm and fresh weight mean 1.78±0.728 g) were marked (using coloured nail polish) then randomly allocated to one of 12 feeding tanks. Each tank contained a total of 15 individually marked whelks that were left to acclimatise without feed for 2 weeks prior to the commencement of feeding trials. Dead whelks were removed as soon as noticed and replacement whelks were uniquely marked and added in exchange to ensure consistency in the number of whelks consuming prey between treatments. Replacement whelks were excluded from the growth and nutritional analyses.

Feeding and growth experiments took place in a saltwater recirculation system attached to a bio-filter and protein skimmer, with a constant mean temperature of 18 °C and salinity of 41‰ (natural salinity reaches as high as 46‰ towards the head of the Spencer Gulf, S.A. where *D. orbita* occurs). Twelve aquaria (395 mm×295 mm) were used with a constant flow rate (Pan World Magnet Pump HH-200ps STD point flow rate 50 L/min L), whereby the water outlet was situated halfway up the aquarium to allow whelks to migrate in and out of the water (tank height 300 mm and water depth 135 mm, 16 L).

2.2. Effect of diet on growth rates

Four feeding treatments were replicated in three separate tanks, randomly distributed in the aquarium system. Feed treatments included: (1) live mussels, (2) frozen mussels, (3) frozen cockles, and (4) pellets. Mussels (*Xenostrobus pulex*, Lamarck 1819) were collected from rocky reefs along the Fleurieu Peninsula. Frozen cockles (*Katelysia* spp.) were obtained from a commercial supplier (Born to Fish, O'Halloran Hill, South Australia). Hikari Tropical Sinking Wafers, designed for bottom feeding fish, were employed as artificial feed. Several other pellet types were tested in a pilot study, however the Tropical Sinking Wafers were the only artificial feed ever observed to be consumed by the whelks.

Whelks were fed to satiation by providing each feed treatment in excess throughout the 12 week growth experiment. All food was replaced three times a week, except for pellets, which were replaced more regularly (morning and night 5 days/week) due to the relatively rapid loss of structural integrity. Feed was weighed on a bench top scale (Mettler Toledo, Mono Bloc inside PB 602-S) before and after the feeding period to determine consumption. Uneaten pellets were removed from aquaria and dried in a drying oven at 60 °C for 24 h before weighing. Consumption was adjusted to account for autogenic changes in the weight of feed due to tank conditions (Table 1). This was achieved by recording the weight of replicate batches of each feed placed in aquaria without whelks for the same time period as the feeding trial for each diet.

Growth measurements of weight (g) and shell length (mm) were undertaken at the beginning of the feeding experiments (t_0) (Table 1), then again at weeks three (t_3), six (t_6), nine (t_9) and 12 (t_{12}). Shell length was measured using SON TAX 150 mm digital calipers to the nearest 0.01 mm, from the apex of the shell spire to the anterior (siphon) canal. Wet weight was measured to the nearest 0.01 g on bench top scales (Mettler Toledo, Mono Bloc inside PB 602-S) after drying with paper towel. Growth increments were calculated as the change in shell length and weight over time according to Nasution and Roberts (2004).

2.3. Nutritional proximate analysis

Proximate analysis was conducted on all distinct feed types used in the feeding trials, with data collected from frozen mussels used to represent both the live and frozen mussel diet. Analysis was also carried out on 30 randomly-selected whelks from each treatment, at the end of the 12-week growth trial, to determine if feed type influenced the proximate composition of *D. orbita* flesh. Analysis of proximate composition included amounts of moisture, lipid, protein, glycogen, ash and total energy of flesh. Five whelks were randomly selected from the frozen 30 for each diet treatment and allocated to one of the six proximate measurements. Samples were pre-frozen and shells and opercula were