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Western rock lobsters (*Panulirus cygnus*) in Western Australian deep coastal ecosystems (35–60 m) are more carnivorous than those in shallow coastal ecosystems

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ABSTRACT

The western rock lobster (*Panurilus cygnus* George.) is a conspicuous consumer in the coastal ecosystems of temperate Western Australia. We used stable isotope analysis and gut content analysis to determine the diet and trophic position of western rock lobsters from mid-shelf coastal ecosystems (35–60 m depth) at three locations. Lobsters were primarily carnivorous, and no consistent differences in diet were detected with varying lobster size, sex or among locations. The main components of the diet were bait (from the fishery) and small crustaceans – crabs and amphipods/isopods. Foliose red algae, bivalves/gastropods and sponges were minor contributors to diet. The diet of lobsters in deep coastal ecosystems differed from the results of previous studies of diets of lobsters from shallow coastal ecosystems. In particular, coralline algae and molluscs – important prey in studies of lobsters from shallow coastal ecosystems – were minor components of the diet. These differences are likely to reflect differences in food availability between these systems and potentially, differences in choice of prey by lobsters that inhabit deeper water. Given the high contribution of bait to lobster diet, bait is likely to be subsidizing lobster production in deep coastal ecosystems during the fishing season.

1. Introduction

Knowledge of species' diets and trophic position is fundamental to understanding food webs, which is key to understanding the dynamics of ecosystems. The composition of a consumer's diet can provide numerous insights including how energy is transferred through food webs, and the ultimate sources of production supporting food webs (Polis and Strong, 1996). Trophic position provides a general framework for understanding the direct and indirect interactions between predators and prey (Polis and Strong, 1996).

Understanding the diet and trophic position of spiny lobsters is important as their feeding ecology can strongly influence ecosystem structure (Tarr et al., 1996; Tegner and Dayton, 2000; Shears and Babcock, 2002; Langlois et al., 2005). Predation by spiny lobsters has caused differences in the abundances and sizes of their prey in New Zealand (Shears and Babcock, 2002; Langlois et al., 2005, 2006b), Tasmania (Pederson and Johnson, 2006), South Africa (Tarr et al., 1996; Mayfield and Branch, 2000) and California (Tegner and Levin, 1983). These changes in prey abundance can lead to indirect effects on other elements of the ecosystem (e.g. Babcock et al., 1999).

The diet of spiny lobsters can change with lobster size (Goni et al., 2001; Mayfield et al., 2001; Langlois et al., 2006b). Differences in choice of prey have been demonstrated for *Jasus edwardsii*, with larger lobsters tending to choose large prey and smaller lobsters tending to choose small prey (Langlois et al., 2006b). Such patterns may relate to an increased ability of larger lobsters to consume larger, hard-shelled prey (Robles et al., 1990), although prey choice may also be influenced by a relationship between energetic value of prey and energetic costs of prey capture and consumption (Hughes, 1980). Changes in choice of prey with increases in lobster size have been shown to affect prey community composition inside marine reserves where large lobsters are more abundant (Langlois et al., 2006a).

The western rock lobster (*Panulirus cygnus*) is conspicuous along the west coast of Australia (Phillips, 1990). Previous studies have found that juvenile *P. cygnus* consume a wide range of benthic biota including molluscs, polychaetes, small crustaceans and coralline algae (Joll and Phillips, 1984; Edgar, 1990; Jernakoff et al., 1993). However, these investigations have focused on shallow coastal

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ecosystems (<5 m depth). The diet of lobsters in deeper coastal ecosystems (>35 m depth) has been poorly studied. The size structure of lobsters in these deep coastal ecosystems differs significantly from those in shallow water. Deeper coastal ecosystems are occupied by a greater proportion of adult lobsters; approximately 25% of *P. cygnus* in deeper water (>35 m) are >80 mm carapace length (unpublished catch and effort statistics, Department of Fisheries Western Australia 2007), while the proportion of >80 mm *P. cygnus* in shallow coastal ecosystems (<5 m) is approximately 4% (L.D. MacArthur, unpublished data). In addition, approximately 40% of the commercial catch of *P. cygnus* is taken from depths >35 m (unpublished catch and effort statistics, Department of Fisheries Western Australia 2007). The differences in lobster size structure between deep and shallow coastal ecosystems may therefore result in differences in diet, and so differences in trophic interactions by lobsters. Because of this, the potential indirect effects of fishing between shallow and deep coastal ecosystems may differ in important ways.

In this study, we used stable isotope and gut content analyses to determine the diet and trophic position of *Panulirus cygnus* in deep coastal (35–60 m depth) ecosystems. Stable isotopes of carbon and nitrogen provide a low resolution estimate of diet integrated over long periods of time (months) that can help unravel complex food webs and identify important trophic relationships within ecosystems (Fry, 1988; Jennings et al., 1997; Davenport and Bax, 2002; Post, 2002). Analyses of gut contents provides higher resolution dietary information for a shorter time period – between ingestion and assimilation of food (Overman and Parrish, 2001) – and are also useful in verifying results from stable isotope analyses (Whitledge and Rabeni, 1997). The aim of this study was to determine diet and trophic position of *P. cygnus*, focusing on whether these varied spatially, or according to lobster size or sex.

2. Methods

2.1. Study area

This study was conducted at three locations on the west coast of Australia: Lancelin (30° 58.2 S, 114° 57.1 E), Jurien Bay (30° 12.5 S, 114° 39.1 E) and Dongara (29° 18.9 S, 114° 38.5 E). These locations span 200 km of coast near the centre of the distribution of *Panurilus cygnus*. Four sites were selected at Lancelin and Jurien Bay and five sites were selected at Dongara, with sites separated by at least 2 km. Sites contained higher relief than the surrounding reef habitat, and were selected to maximize probability of encountering lobsters. The sites were located 20–40 km from the shore in 35–60 m depth. The sea floor is comprised of limestone reefs, which are remnants of Pleistocene/Holocene coastal sand dunes (Seddon, 1972; Searle and Semeniuk, 1985). Offshore reefs are typically low relief (<1 m relief) and are dominated by kelp, *Ecklonia radiata*, and sponges (Kris Waddington, unpublished data).

2.2. Collection

Divers breathing mixed gas (Enriched Air Nitrox, Trimix) from SCUBA collected biota at each site between 28th March and 10th April 2006. For reef biota, the entire contents of a 0.25 m^2 quadrat were removed using a paint scraper and placed in a calico bag, ensuring no material was lost ($n = 2$ per site for Dongara and Jurien Bay and $n = 3$ per site for Lancelin). For sediment biota, cores (100 mm diameter × 200 mm deep) were collected from sediment adjacent to the reef ($n = 2$ for each site). Small sample sizes reflect the difficulty of sampling at these depths. At the completion of each dive, samples were frozen for later sorting in the laboratory.

Lobsters were collected by the divers from three of the sites at each location. Lobsters were collected within 2 h of sunrise using a noose and were between 53.7 and 144.6 mm carapace length (CL). Collection occurred soon after sunrise to minimise error associated with variable evacuation rates of gut contents (Waddington, in press). Following collection, lobsters were immersed in an ice-slurry to induce a chill coma. Lobster size, sex and moult stage were recorded. Lobster foreguts were then removed and frozen for later gut content analysis. A sample of muscle tissue for stable isotope analysis was dissected from the tail and frozen. Additional lobsters were collected from Jurien Bay using unbaited pots. Pots were set overnight and retrieved within 1 h of sunrise and foreguts and tail muscle removed as described above. Baited pots were unsuitable for collecting lobsters for gut content analysis as the lobsters fed on bait in the pots, and so gut contents would be biased. Exclusion of the bait using 'bait savers' attracted isopods (*Natatolana* sp.), which the lobsters fed on, also causing bias (Kris Waddington personal observation, 2005). However, baited pots were suitable for collecting lobsters for stable isotope analysis, and were used to collect additional lobsters from Lancelin and Dongara between 20th and 30th April 2006.

2.3. Stable isotope analyses

In the laboratory, biota collected from quadrats and cores were defrosted, sorted, and identified to at least family level. Sediment cores were sieved and potential lobster prey removed. Bulk tissue of macroalgae, muscle tissue from tails of lobsters, and whole (or multiple whole) polychaetes, crabs, amphipods and isopods were used for stable isotope analysis. The flesh of imported mackerel (*Scomber* spp.) and Australian pilchards (*Sardinops sagax* Jenyns) – two baits commonly used in the fishery – were also analysed as they were possible lobster dietary items. All samples were rinsed in de-ionised water, dried in an oven at 60 °C until completely dry, then ground to a fine powder using a ball mill grinder. Samples containing non-dietary carbonates (crabs, amphipods, isopods, coralline algae) were treated with 1 M HCl to dissolve these non-dietary carbonates (Bunn et al., 1995).

Continuous-flow isotope ratio mass spectrometry using Europa Scientific (Roboprep-CN/Tracermass and ANCA-NT/20-20 units) and Isogas Sira 9 instruments were used to measure $\delta^{15}N$ and $\delta^{13}C$. Most samples were analysed in dual isotope mode, allowing $\delta^{15}N$ and $\delta^{13}C$ to be measured simultaneously. Samples containing non-dietary carbonates were analysed for $\delta^{15}N$ prior to acid treatment, and analysed for $\delta^{13}C$ after acid treatment. Analytical precision of the instruments was 0.081‰ and 0.046‰ (±SE) for $\delta^{15}N$ and $\delta^{13}C$ respectively. Cornflour, lobster muscle tissue and turnip calibrated against IAEE reference materials (IAEA-CH-6, IAEA-N-1, IAEA-N-2, USGS40, USGS41, USGS24) were used as internal standards for stable isotope analysis.

2.4. Defining lobster dietary sources

The mixing model software IsoSource (Phillips and Gregg, 2003) was used to determine the range (1–99%) and mean contribution of each potential prey to lobster diet for each location (Lancelin $n = 25$ lobsters, Jurien Bay $n = 19$ lobsters, Dongara $n = 35$ lobsters) (source increment 1%, tolerance 0.1). To reduce variability in mixing model outputs, we sought to combine similar diets prior to analysis. Only taxonomically related groups with similar life histories and feeding strategies were considered for combination (Phillips et al., 2005). The K nearest-neighbour randomization test was used to test for differences in $\delta^{15}N$ and $\delta^{13}C$ isotope signatures of those groups considered for combination (Rosing et al., 1998), and taxa were combined if $\delta^{15}N$ and $\delta^{13}C$ were not significantly different ($p < 0.05$).

The IsoSource method is appropriate when the number of dietary sources $= i + 2$, where i is the number of elements (Phillips and Gregg, 2003). While no unique solution for the contribution of