Journal of Experimental Marine Biology and Ecology 336 (2006) 42 – 53

Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

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Fatty acids as trophic tracers in an experimental estuarine food chain: Tracer transfer

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Received 30 September 2005; received in revised form 16 March 2006; accepted 14 April 2006

Abstract

The transfer of fatty acid (FA) biomarkers was assessed by an experimental food chain comprising three trophic levels: leaves of the mangrove *Avicennia marina*, the grapsid crab *Parasesarma erythodactyla*, and the blue swimmer crab *Portunus pelagicus*. FA compositions for each trophic level were investigated through a feeding/starving regime designed to reveal the transfer of FAs along the food chain. Comparison of the FA profiles of the mangrove leaves, the tissues and faecal material of *P. erythodactyla* suggests that the crab, contrary to previous studies, lacks the necessary enzymes to incorporate some FAs in its diet. Long chain FAs were egested while polyunsaturated acids seemed to be efficiently assimilated. The polyunsaturated FAs 18:2ω6 and 18:3ω3 were identified as useful biomarkers of the mangrove leaves for tracing their transfer to the higher trophic levels. The contribution of these markers to the FA profiles of the crabs was investigated and it was found that both 18:2ω6 and 18:3ω3 could be successfully traced across the first trophic transfer. However, only 18:3ω3 demonstrated a clear second transfer into the tissues of *P. pelagicus*. Multivariate analysis of the FA profiles of the study organisms was found to be a potentially useful tool for demonstrating differences in diet within a species and also what FAs, and therefore dietary items, are responsible for those differences. MDS analysis of the FA profiles of faecal material from *P. erythodactyla* showed that this species provides an important ecological link in estuarine systems by providing a substrate for the colonisation of bacteria.

Keywords: *Avicennia marina*; Estuary; Fatty acid; Food web; Lipid biomarker; Mangrove; *Parasesarma erythodactyla*; *Portunus pelagicus*

1. Introduction

Estuarine habitats in tropical environments are generally dominated by mangrove forests. They are characterised by a large biomass, and production rates are high, attaining up to 4000 g dry wt $m^{-2}y^{-1}$ (Valiela, 1995). Very little mangrove productivity is, however, utilized directly by grazers, and most enters the trophic web following leaf fall, and often requires considerable modification by bacteria and fungi before being utilized by the macrofauna (Lee, 1995; Wilson, 2002). The incorporation of these various sources into the food web is also variable, as the palatability of the organic matter produced is strongly dependent on factors such as the carbon to nitrogen ratio, and the concentration of feeding deterrents, e.g. tannins.

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0022-0981/$ - see front matter
doi:10.1016/j.jembe.2006.04.004

The explanation and prediction of food web patterns is central to the understanding of the processes at work in estuarine ecosystems. Food webs in estuaries are often complex, largely due to the high diversity of both producers and consumers inhabiting estuarine ecosystems. The high productivity of estuarine wetlands has long been hypothesised to be the trophic base of nearshore secondary production, through the process of tidal export, commonly termed "outwelling" (Teal, 1962; Odum, 1980). The trophodynamics of estuaries and their relationship with nearshore secondary production have been subjects of intense research in the last 50 years. The advance of various chemical tracer techniques, such as stable isotopes and fatty acid (FA) biomarkers, has significantly contributed to the analyses of organic matter flow in estuaries and beyond (Canuel et al., 1995; Lee, 1995; Meziane and Tsuchiya, 2000; Shi et al., 2001).

Many studies have successfully used FAs to trace the transfer of organic matter in coastal and estuarine food webs (e.g. Canuel et al., 1995; Kharlamenko et al., 1995; Napolitano et al., 1997). There is an increasing focus on the application of the FA trophic tracer technique to the relatively higher trophic levels of these food webs such as macroinvertebrates (Meziane and Tsuchiya, 2000, 2002; Bachok et al., 2003; Copeman and Parrish, 2003), which have both important ecological and economical roles. Few studies have focused on the transfer of FAs beyond a single trophic transfer, and where they have, it has been in lower levels of pelagic food webs (e.g. Ederington et al., 1995; Falk-Peterson et al., 2002). This is an important area of research because trophic markers can be vastly more useful if they are transferred further along a food chain than a single trophic level. Information of this type could potentially enable the elucidation of the ultimate sources of organic matter input into the higher trophic levels of estuarine food webs. No known studies have applied the trophic tracer technique across multiple trophic transfers in estuarine environments.

The use of this technique for tracing organic matter transfer across multiple levels in estuarine food webs would be a useful tool given the importance of estuarine environments for supporting a diversity of habitats and the organisms within them (Day et al., 1989). There is therefore a clear need to investigate the use of FA markers beyond a single trophic transfer in estuarine food chains. This information could potentially provide the basis for expanding the use of the technique in these environments.

This study involves an experimental food chain comprising 3 trophic levels (mangrove leaves, sesarmine crabs, and blue swimmer crabs), which were used to investigate some important, yet neglected areas of research regarding the FA trophic tracer technique. The primary goal of this experiment was to determine how far certain FAs of a primary producer could be traced along an estuarine food chain. In doing so, it was also expected that an indication of the efficiency of this transfer between trophic levels could be obtained. This experiment also aimed to investigate the application of multivariate analyses to the FA profile data to determine to what extent these analyses are useful for this type of study.

2. Materials and methods

An experimental detritus-based food chain was established that comprised three trophic levels. The first trophic level used was freshly senescent leaves (yellow and brown) of the grey mangrove, *Avicennia marina*. The red-fingered crab, *Parasesarma erythodactyla*, was used as the detritivore in the food chain. The final trophic level organism was the blue swimmer crab, *Portunus pelagicus*, which acted as the carnivore. These organisms were selected for their practicality in terms of analyses and maintenance, they do however, represent a realistic natural food chain in subtropical estuarine habitats in northeastern Australia.

2.1. Collection and maintenance of organisms

All mangrove leaves and *P. erythodactyla* specimens were collected from the same intertidal mangrove forest on the Gold Coast, Australia during April 2004. The mangrove leaves were collected regularly throughout the duration of the experiment and soaked for approximately 24 h to allow some of the tannins and other feeding deterrents to leach out. A total of ~ 240 *P. erythodactyla* individuals were obtained, with carapace widths ranging in size from approximately 13–18 mm. Thirty-five of these crabs were used for initial FA analysis and the bulk of the remainder were used as a food source for *P. pelagicus*. All *P. erythodactyla* specimens were maintained separately in individual storage compartments. Approximately 100 mL of estuarine water was added to each compartment to provide moisture for the crabs. The water in these compartments was changed daily when feeding took place.

Sixteen *P. pelagicus* individuals from the same spawn were obtained from aquaculture ponds at the Queensland Department of Primary Industries (DPI) Bribie Island Aquaculture Research Centre, Queensland. The crabs ranged in size from 38–49 mm carapace width. They were kept individually in separate aquaria with approximately 16–18 L of water. The water in these aquaria was changed