Journal of Experimental Marine Biology and Ecology 459 (2014) 160–168

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

# Species-specific and combined feeding rates and selectivity of dominant mysids from a subtropical estuary, Brazil

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ARTICLE INFO

*Article history:*
Received 8 January 2014
Received in revised form 21 May 2014
Accepted 22 May 2014
Available online xxxx

*Keywords:*
Biodiversity
Feeding behavior
Mysidacea
South Atlantic
Trophodynamics
Zooplankton

ABSTRACT

We studied the influence of mysid species number on their feeding rates to test how the structure of the mysid assemblage may affect carbon fluxes in the Cananeia estuary. Three types of experiments were conducted at the laboratory in order to: (i) evaluate mysid feeding rates and selectivity on the natural zooplankton assemblage; (ii) determinate mysid functional responses to varying food density using *Artemia* sp. nauplii as food; and (iii) check inter- and intraspecific predation between mysids. For the former two experiments, three mysid species were incubated isolated or combined (2 species: *Metamysidopsis elongata atlantica* + *Mysidopsis coelhoi*; 3 species: *M. e. atlantica* + *M. coelhoi* + *Chlamydopleon dissimile*), comprising 5 treatments. The three mysid species had opportunistic feeding behavior on the natural zooplankton assemblage, but there was evidence of avoidance of medium-size prey (300–400 μm) mostly comprised of *Oithona* spp., probably due to a combination of small size and prey swimming patterns. Ingestion rates showed a non-linear increase with increasing food concentrations, suggesting a type II functional response for all mysid species and combination of species. There were both positive (complementarity effect) and negative effects of species combinations on the investigated response. Negative interactions were probably linked to intraguild predation as confirmed by experiment (iii), which resulted in a reduction of mysid predation over the zooplankton.



## 1. Introduction

Mysids are predominantly marine organisms (>90% species; Porter et al., 2008), and may occur from subpolar to tropical estuarine, neritic and oceanic waters (Mauchline, 1980). They are omnivorous and prey mainly upon detritus, algae and small invertebrates (Fockedey and Mees, 1999; Lehtiniemi et al., 2009; Wooldridge and Webb, 1988). Because of their diverse diet and numerical dominance in coastal areas, mysids play a major role as intermediate consumers in coastal marine food webs (Rodríguez-Graña et al., 2008), serving as food for several fish, large invertebrates, birds and mammals (Mauchline, 1980). Moreover, because most of the species are benthopelagic (>75%; Heard et al., 2006) and have strong diel migratory behavior (Almeida Prado, 1973; Kouassi et al., 2006), mysids have an important role in the benthic-pelagic coupling (Jumars, 2007).

Biodiversity alteration can affect the stability of ecosystem functions and the capacity of communities to use resources, produce biomass, decompose and recycle nutrients (Cardinale et al., 2012). A more diverse ecosystem is generally more stable and productive because it has higher probability of including key species of outstanding performance (sampling effect); and because diverse assemblages ensure colonization by species with different niches, whose interaction can lead to greater efficiency in the use of available resources (complementarity) (Loreau and Hector, 2001). Despite the higher taxonomic and functional diversity in marine compared to terrestrial systems, relatively few works concerning the biodiversity-ecosystem functioning problem has emphasized the oceans, especially the pelagic ecosystem (Duffy and Stachowicz, 2006).

Three types of experiments were conducted here: (i) to determinate mysid feeding rates and selectivity on the natural zooplankton assemblage; (ii) to evaluate their functional responses to varying food density using *Artemia* sp. nauplii as food; and (iii) to test inter- and intraspecific predation between mysids. For these experiments, we used the three dominant mysid species from the Cananeia estuary: *Metamysidopsis elongata atlantica*, *Mysidopsis coelhoi* and *Chlamydopleon dissimile*. These species co-occur and are the main intermediate consumers in the Cananeia estuary (Tararam et al., 1996). Among the three species, *M. e. atlantica* is the most abundant and that with widest distribution along the estuary (Tararam et al., 1996), whereas *M. coelhoi* and *C. dissimile* are limited to regions of stronger marine influence (Almeida Prado, 1973). For experiments (i) and (ii), each of these species was incubated isolated or combined according to their in situ distribution pattern (2 species: *M. e. atlantica* + *M. coelhoi*; 3 species: *M. e. atlantica* + *M. coelhoi* + *C. dissimile*), totalizing 5 treatments.

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http://dx.doi.org/10.1016/j.jembe.2014.05.022
0022-0981/

Here, we studied the influence of mysid species number on predation rates and prey selectivity to explore how the structure of the mysid assemblage may affect carbon fluxes in the Cananeia environment. We hypothesized that species richness positively modulates feeding rates (resource use effectiveness), thus influencing carbon fluxes through the mysid compartment.

## 2. Materials and methods

### 2.1. Study site

The Cananeia–Iguape Coastal System (Cananeia estuary, 24°35′–25°10′S, 47°30′–48°05′W) is located in the south coast of the state of São Paulo, southeast Brazil. Annual mean air temperature and precipitation are 23.8 °C and 2269 mm, respectively (Miyao et al., 1986; Silva, 1989). This system is surrounded by a coastal plain area, salt marshes, mangroves and the Atlantic rainforest. It comprises a complex system of meandering channels delimited by four main islands (Cardoso, Cananeia, Comprida and Iguape), with two main connections to the Atlantic Ocean. The estuary is classified as partially mixed and weakly stratified (Type 2a; Miranda et al., 1995). Freshwater discharge is provided by several small rivers, whereas circulation along the estuary is forced mainly by semidiurnal tidal currents, with amplitudes of 0.83 m and 0.13 m during spring and neap tides, respectively (Miyao and Harari, 1989).

### 2.2. Mysid sampling

For all experiments, mysids were collected using an epibenthic sledge fitted with a 500-μm pore size mesh towed during daytime at depths of 0.3 to 1.5 m. After the tows, samples were immediately poured into 12 L buckets and brought to the laboratory, usually within 40 min after collection. In situ temperature and salinity were measured with a multiparameter sensor (Oakton, 600 series). At the laboratory, adult/subadult mysids were individually picked from the buckets using small beakers, sorted by species and left for acclimatization to laboratory conditions for at least 3 h.

### 2.3. Feeding selectivity

Experiments were carried out between November 16 and 21, 2011 to estimate mysid clearance and consumption rates according to the classical setup used in plankton ecology studies (Båmstedt et al., 2000). Zooplankton was collected by horizontal subsurface tows with a conical plankton net fitted with a 90-μm mesh size. The sample was diluted in 12 L buckets and brought to the laboratory. At the laboratory, the sample was gently sieved through a 1 mm mesh to eliminate larger predators (e.g., jellyfish, fish larvae) and obtain a "prey sample pool" to be used during experiments. The density of plankton in the prey sample pool was estimated by taking and rapidly counting several 10 mL subsamples after gentle and thorough mixing. The resulting density was used to estimate the volume of the prey sample pool needed to attain a nominal prey density of 40 individuals $L^{-1}$ in the experimental bottles, a typical density of mesozooplankton in the Cananeia estuary (Ara, 2004). For the experiment, six mysids (single species or combination of species) were incubated in 9 L of filtered in situ seawater (5 μm). The experiment thus considered a constant predator density of 0.67 mysids $L^{-1}$ for all treatments (Table 1), and four replicates in all cases. Four replicate samples of the prey sample pool of exactly the same volume as that added to the experimental bottles were established to estimate initial prey numbers. Bottles were incubated in darkness and at constant temperature (mean of 20.8 ± 0.2 °C), similar to those of the sampling site on the day of mysid collection. After 24 h of incubation, contents of the bottles were sieved (90 μm), and the status of the mysids checked and recorded (live/dead, anomalous swimming behavior was also noted) and each individual was measured (body length, from the tip of the rostrum to the end of the telson). Remaining preys were fixed in 4% formaldehyde–seawater buffered solution, identified to the lowest taxon possible (usually species or genus for copepods), counted and measured (total length for nauplii or prosome length for copepods, 20 individuals per taxon) by digital image analysis using public domain Image-J software (Schneider et al., 2012). Dry weight (DW), ash-free dry weight (AFDW) or carbon weight (C) was estimated based on length–weight regressions (Almeda et al., 2010; Ara, 2001; Berggreen et al., 1988; Fotel et al., 1999; Hansen, 1999; Hansen and Ockelmann, 1991; Turner et al., 2001; Uye, 1982; Uye et al., 2002; Webber and Roff, 1995). For copepods, we applied a conversion factor from AFDW to DW of 1.12 (Båmstedt, 1986), and from DW to C of 0.46 (Ara, 2001).

Clearance (mL $mysid^{-1}$ $d^{-1}$) and ingestion (ind. $mysid^{-1}$ $d^{-1}$ and μg C $mysid^{-1}$ $d^{-1}$) rates were calculated according to Frost (1972). Mysid feeding preferences were evaluated through the electivity index (E*) of Vanderploeg and Scavia (1979):

$$W = (Ri/Pi)/\sum(Ri/Pi);$$
$$E^* = [Wi-(1/N)]/[Wi + (1/N)],$$

where Ri is the proportion of each food item in the diet; Pi is the relative abundance of the food item; and N is the number of prey available. E* values range from +1 to −1: values >+0.3 indicate positive selectivity, <−0.3 negative selectivity, and values in-between indicate neutral selection.

### 2.4. Functional response

Experiments were carried out on March and May 2012. Six mysids (same species combination design as described above) were incubated in 6 L filtered seawater (5 μm) during 1–2 h with newly-hatched *Artemia* nauplii as food. Six different nauplii concentrations were supplied: 2, 5, 10, 50, 200 and 500 nauplii $L^{-1}$. Concentrations of 2 to 50 nauplii $L^{-1}$ were prepared by individually picking batches of nauplii in numbers required to attain the desired concentration in each bottle. The number of nauplii was double-checked before the addition to the experimental bottle. The concentrations of 200 and 500 nauplii $L^{-1}$ were prepared by an analogous procedure than that used for the "Feeding selectivity" experiment: the density of nauplii in the nauplii pool was first estimated and subsamples of the proper volume added to the experimental bottles to obtain a final concentration of 200 or 500 nauplii $L^{-1}$. At least three replicates and three control replicates (containing only *Artemia* nauplii and no mysid) were established for treatment. Control replicates were done only for concentrations of 200 and 500 nauplii $L^{-1}$. Bottles were incubated during daytime, in darkness and at controlled temperature (mean of 27.5 ± 0.3 °C), similar to that of the sampling site during mysid collection. At the end of the incubation, contents of the bottles were sieved (90 μm), and the status of the mysids checked and recorded (live/dead) and each individual was measured. Remaining prey were fixed in 4% formaldehyde-seawater buffered solution or in acid Lugol's solution, and counted. The total length (μm) of 20 *Artemia* nauplii per bottle was measured by digital image analysis (Image-J). Clearance and ingestion rates were calculated according to Frost (1972). The functional response type was determined by the fitting of the ingestion rate data to three different models: rectilinear, curvilinear, and sigmoidal (Holling, 1959).

### 2.5. Intraguild predation

Experiments to verify inter- and intraspecific predation between the three mysid species were done in January 24–25, 2013. One adult mysid of each species was incubated in 300 mL of filtered seawater (5 μm) with five juveniles of the same or other species. Three replicates were carried out for each treatment. Bottles were incubated in darkness, at controlled temperature (mean of 26.1 ± 0.3 °C) and constant salinity (30). After 2 h of incubation, the number of juveniles was counted, and the status of all mysids was checked and recorded (live/dead).