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# FEEDING DYNAMICS OF *OLIGOSARCUS JENYNSII* (GÜNTHER, 1864) IN A SUBTROPICAL COASTAL LAKE ASSESSED BY GUT-CONTENT ANALYSIS AND STABLE ISOTOPES

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**ABSTRACT:** The present study aimed to identify the seasonal feeding dynamics of two size classes of *Oligosarcus jenynsii* (< 14 cm total length and > 14 cm total length) using stomach content analysis and stable isotope analysis of carbon and nitrogen. Sampling was carried out seasonally, from winter 2006 to autumn 2007 in the northern part of Mangueira Lake, southern Brazil. *Palaemonetes argentinus* (Crustacea, Decapoda, Palaemonidae) was the prey type most frequently observed in the stomachs of *O. jenynsii*. However, the dominant prey type changed with season and size class. Terrestrial insects (Coleoptera, Hemiptera and Hymenoptera) were important for both size classes in the winter and summer, and *Aegla prado* (Crustacea, Decapoda, Aeglidae) were important in the spring for fish > 14 cm. Individuals > 14 cm ingested more crabs (*A. prado*) and terrestrial insects and fewer prawns (*P. argentinus*). Stable isotope analysis indicated that *O. jenynsii* from both size classes was similar in $\delta^{15}N$, but the $\delta^{13}C$ signature varied with size class, with individuals > 14 cm more depleted in $^{13}C$, suggesting different carbon pathways. Larger individuals may have obtained their carbon from macrophytes or allochthonous sources, whereas smaller individuals were likely supported by periphyton and *P. argentinus*.
**Key words:** Diet, isotopic analysis, stomach contents, shallow lake.

## INTRODUCTION

Fishes of the genus *Oligosarcus* (Characidae) are recognized by their large buccal aperture, allowing the ingestion of whole prey in a single bite [6]. Most species of this genus feed mainly on insects, crustaceans, and small fish [20]. *Oligosarcus jenynsii* occurs in the Rio Grande do Sul State in Brazil, in Uruguay and in northern Argentina [28]. Some studies have recorded a preferentially piscivorous feeding habit for the species [15, 17 and 24]. Other studies have described the species as a generalist carnivore, with shrimp and terrestrial insects as the main feeding items [14].

Previous studies on the feeding biology of *O. jenynsii* have focused on stomach content analysis. Although this approach is well suited to show a snapshot of what was eaten within the last few hours, no direct information is obtained related to the ultimate organic matter source and the trophic level of the species. On the other hand, analysis of the stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$), although uninformative regarding the frequency of prey items, can reveal the primary carbon source and trophic position [27].

Stable isotope ratios, particularly $\delta^{13}C$ and $\delta^{15}N$, have been used since the 1970s to provide information on the energy flow through ecosystems [37]. Fish, because of their mobility and flexible feeding behavior, link littoral, benthic, and pelagic habitats in a much more significant manner than was historically considered [30 and 35], to the point of influencing nutrient cycling in many aquatic ecosystems [29 and 31].

Different photosynthetic pathways ($C_3$ or $C_4$), specific growth rates, $CO_2$ concentrations and pH levels can affect the $\delta^{13}C$ signature of primary producers [16]. Because $\delta^{13}C$ fractionate very little in the food web, with around 1‰ enrichment per trophic level [25 and 35], carbon stable isotope values indicate the origin of organic carbon in any level of the food web [16]. That is, the ratio of $^{13}C/^{12}C$ in any consumer will be related to the signature of the producer that constitutes the primary carbon source.
Nitrogen stable isotopes can be used to identify the relative trophic level of an organism. At each successive trophic transfer, tissue $\delta^{15}N$ values increase at a predictable rate [5]. Studies quantifying the average $\delta^{15}N$ difference between an animal and its food source have identified enhancements from 2.5 to 3.5‰ [8]. [34 and 35], although different fractionation values are related to the environment, taxonomic group and type of tissue sampled [36].
In this study, we used stomach content analysis and stable isotope analysis of carbon and nitrogen to describe how the feeding dynamics of *O. jenynsii* in a subtropical Brazilian lake changed with body size and season.

## MATERIAL AND METHODS

### Study site

Mangueira Lake is a large shallow lake (3m average depth, 90 km length, 3-10 km width, area ≈ 880 km$^2$) located along the Atlantic coast-line in southern Brazil (33º31'22"S 53º07'48"W) (Fig.I). The lake was formed after the last Post-Glacial Marine Regression (Holocene ~5,000 BP), when the ocean level fell five meters and attained the present level (Tomazelli et al., 2000). This lake is surrounded by a variety of habitats such as beaches, dunes, forests, grasslands and wetlands. This heterogeneous and productive landscape harbors an exceptional biological diversity, which motivated the Brazilian federal authorities to protect part of the entire hydrological system as the Taim Ecological Reserve in 1991 (Motta Marques et al., 2002). In the northern part, the lake interfaces the Taim wetland, presenting large areas covered with macrophytes including *Zizaniopsis bonariensis, Sagittaria montevidensis, Egeria densa* and *Cabomba caroliniana*.

### Fish sampling and data analysis

Sampling was carried out in August and November of 2006 and February and May of 2007 in macrophyte beds in the littoral zone of northern Mangueira Lake (depth ~2m). Fish were caught using multi-panel gill nets with three panels measuring 3 × 1.5 m, with 5, 6.25, 8, 10, 12.5, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, and 70 mm mesh size, modified after [1]. Nets, in triplicate, were set in the afternoon and retrieved the following morning after approximately 15 h.
All captured fish were preserved in 4% formalin, except samples for stable isotope analysis, which were frozen. Voucher specimens were deposited at the Departament of Zoology of the Universidade Federal do Rio Grande do Sul and numbered as UFRGS 11301.
At the laboratory, fish were weighed to the nearest 0.1 g, measured as total length to 1.0 mm, and dissected for digestive-tract analysis. Food items were examined using a stereomicroscope, and analyzed as frequency of occurrence (Hyslop, 1980) according to size and season. Two size classes were determined: fish less than 14 cm total length and fish more than 14 cm total length. This size threshold was chosen from direct inspection of size frequency data, and represents a natural limit between two dominant age-groups.
Dietary items were classified according to the Dajoz constancy index [7]. This index is the percentage ratio between the number of samples in which an item is present and the total number of samples. Constant items are defined as being present in more than 50% of the samples, accessory items are present between 25% and 50% of the samples, and accessory items are present in less than 25% of the samples.

### Sample processing and data analysis for isotope analysis

Primary producers (emergent macrophytes - *Zizaniopsis bonariensis* and *Sagittaria montevidensis*, submerged macrophytes - *Egeria densa* and *Cabomba caroliniana,* and periphyton removed from the macrophytes), decapod crustacean (*Palaemonetes argentinus*), and fish (*Oligosarcus jenynsii*) were collected and immediately placed on ice for transport to the laboratory, where they were frozen (-18ºC).

Muscle tissue collected from three specimens of *O. jenynsii* collected during each sampling period were analyzed. Samples were dried in an oven at 60ºC for at least 48 h until constant weight was achieved. Dry samples were then ground to a fine powder with a mortar and pestle and stored in glass vials. Subsamples were weighed to $10^{-6}$g, placed in Ultra-Pure tin capsules (Costech, Valencia, CA), and sent to the Department of Plant Sciences Stable Isotope Facility at the University of California, Davis, for determination of stable isotope ratios ($^{13}C/^{12}C$ and $^{15}N/^{14}N$).

Results are reported as parts per thousand (‰) differences from a corresponding standard: $\delta X = [(R\text{sample}/R\text{standard}) - 1] \times 10^3$, where $R = {}^{15}N/{}^{14}N$ or $^{13}C/^{12}C$. Standards were carbon in the PeeDee Belemnite and nitrogen in air. Standard deviations of $\delta^{13}C$ and $\delta^{15}N$ replicate analyses were 0.14‰ and 0.13‰, respectively.

Trophic level of fishes was estimated assuming an increase in $\delta^{15}N$ values of 2.98‰ between successive trophic levels, following Vanderklift and Ponsard (2003). We used baseline organism of snails and bivalves (trophic level 2) following Post (2002). Trophic level ($TL_f$) was estimated according to the following formula: $TL_f = [(\delta^{15}N_f - \delta^{15}N_{ref}) / 2.98] + 2$; where $\delta^{15}N_f$ and $\delta^{15}N_{ref}$ are respectively the nitrogen stable isotope signature of a fish and a baseline reference organism; 2.98 is the $\delta^{15}N$ fractionation per trophic level; 2 is the trophic level of the baseline organism (primary consumer). Values of $\delta^{13}C$ and $\delta^{15}N$ of *O. jenynsii* were used to evaluate patterns of isotopic variation according to size and seasons.

## RESULTS

A total of 365 specimens of *Oligosarcus jenynsii* were captured. The weights of the specimens ranged between 4.8 and 120 g, and the lengths between 7.8 and 22.5 cm. Size distributions of animals captured in each season are presented in Fig. II. Although the sampling pressure was constant, the number of captured animals varied with season. During winter of 2006 and autumn of 2007 sampling seasons, individuals seemed to be concentrated into bimodal distributions consisting of individuals < 14 cm and individuals > 14 cm (Fig. II).

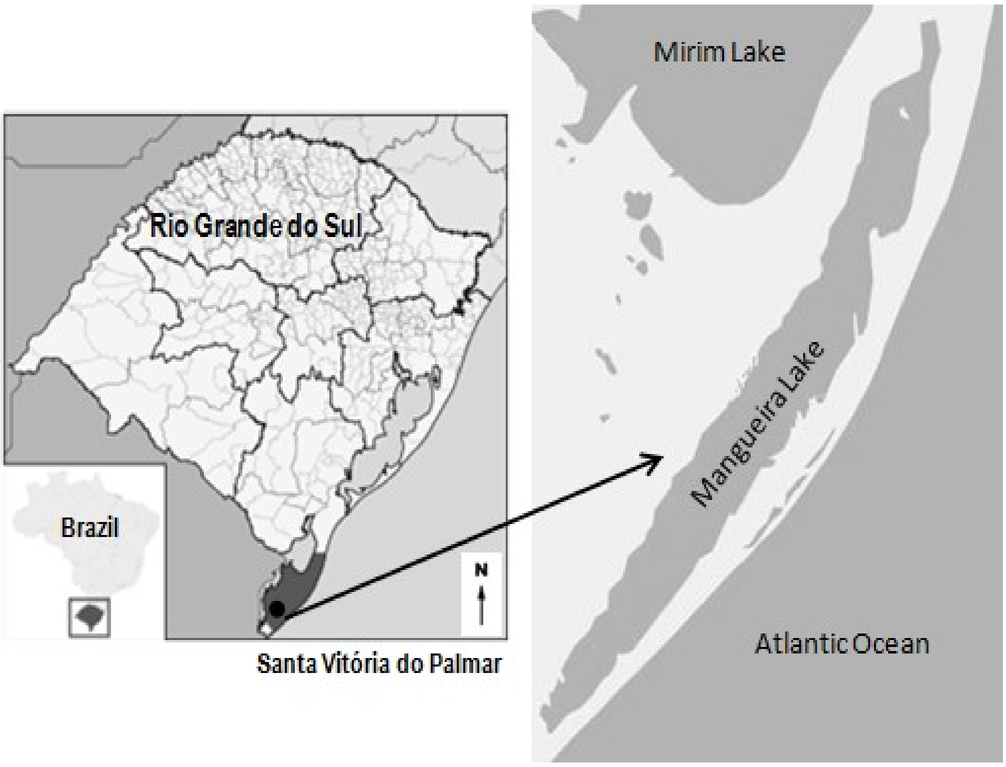


**Fig. I. Mangueira Lake, a large coastal lake in the state of Rio Grande do Sul, southern Brazil.**

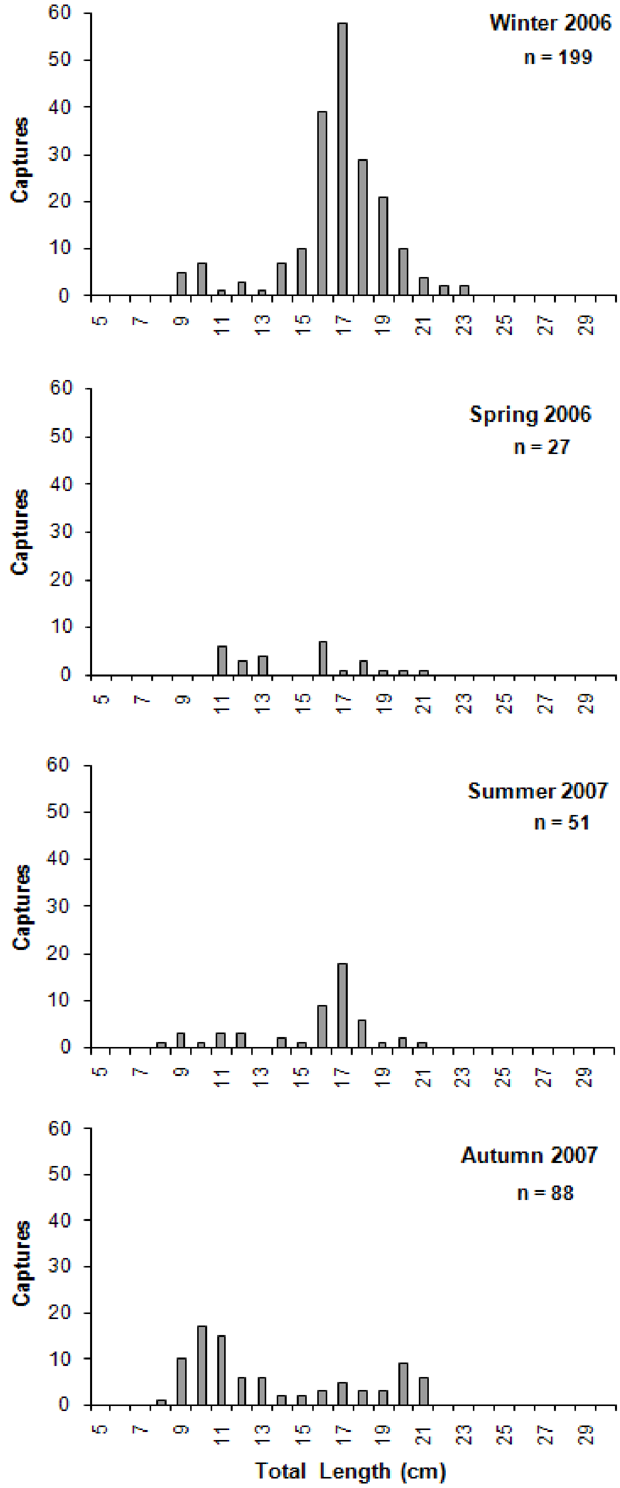


**Fig. II. Length classes (cm) of *Oligosarcus jenynsii* collected from Mangueira Lake.**

The stomach contents of 337 individuals were analyzed. Based on stomach contents, *O. jenynsii* was classified as a generalist carnivore, feeding mainly on decapod crustaceans such as the prawn *Palaemonetes argentinus* (Nobili, 1901) (Palaemonidae) and the crab *Aegla prado* Schimitt, 1942 (Aeglidae). Terrestrial adult insects (Coleoptera, Hemiptera and Hymenoptera) were also present (Fig. III) indicating the importance of allochthonous material. *P. argentinus* was classified as a constant item in the diet for *O. jenynsii* < 14 cm by the Dajoz constancy index. In contrast, no diet items were classified as constant but insects and *A. prado* were classified as accessory items for individuals > 14 cm (Table 1).

**Table 1. Classification of items in the diet of *Oligosarcus jenynsii* in Mangueira Lake, Rio Grande do Sul, Brazil, according to the Dajoz constancy index. Constant items are present in > 50% of the samples, accessory items between 25% and 50%, and accessory items in < 25%.**

| Food item | Length classes (cm) | |
|---|---|---|
| | <14 | >14 |
| Insects (mainly adult Coleoptera, Hemiptera and Hymen-optera) | accidental | accessory |
| *Palaemonetes argentinus* | constant | accidental |
| *Aegla prado* | accessory | accessory |
| Fish | accidental | accidental |
| Macrophyte fragments | accidental | accidental |

Seasonal changes in the diet of *O. jenynsii* were mainly related to body size (Fig. III). In the winter, diets of specimens < 14 cm mainly fed on the prawn *P. argentinus*, found in 50% of the stomachs (Fig. III). Diets of individuals > 14 cm were more diverse and based mainly on insects, although *P. argentinus*, *A. prado* and fish were also present. During the spring, individuals < 14 cm preferentially consumed *P. argentinus*, whereas specimens > 14 cm mainly consumed *A. prado*. Fish, insects, and macrophyte fragments were only consumed by animals > 14 cm. In the summer, *A. prado* was the dominant item for *O. jenynsii* < 14 cm, weareas insects were a main part of the diet of *O. Jenynsii* > 14 cm. Although not present during the summer, *P. argentinus* was the most consumed item in both size classes during the autumn. Fish and *A. prado* were also ingested by both size classes, whereas insects were injected only by individuals < 14 cm.

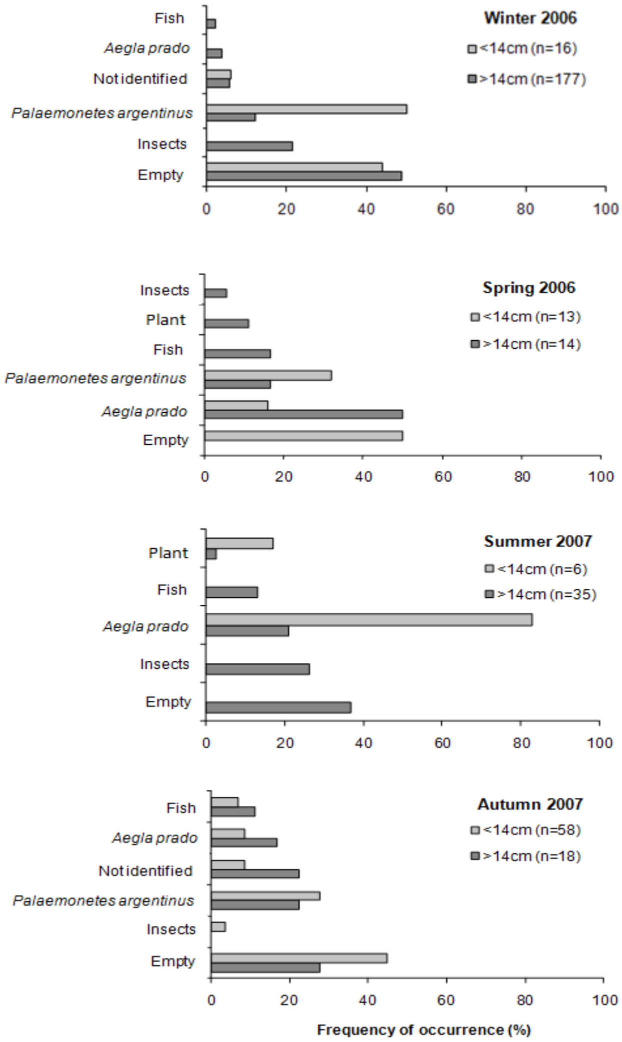


**Fig. III. Frequency of occurrence (%) of food items in stomachs of *Oligosarcus jenynsii* < 14 cm and > 14 cm.**

Values of $\delta^{15}N$ for *O. jenynsii* were similar irrespective of size (range 11.41 - 12.23), indicating that the trophic level is constant with growth, whereas $\delta^{13}C$ values varied according to size class (Fig. IV). Values of $\delta^{13}C$ for *O. jenynsii* < 14 cm (-23.91; -23.68) were closer to *P. argentinus* (-24.39) and periphyton (-24.70), confirming the importance of the *P. argentinus* carbon pathway for smaller fish. On the other hand, *O. jenynsii* > 14 cm was more depleted in $^{13}C$ (-24.85; -24.43), suggesting that macrophytes (range -27.10 to -28.06) are the most important production source. Also, the depleted $^{13}C$ values of *O. jenynsii* > 14 cm in relation to *P. argentinus* suggest that ingested fish, alloctonous insects and *A. prado* should all have lower carbon signatures, compatible with the macrophyte carbon values.

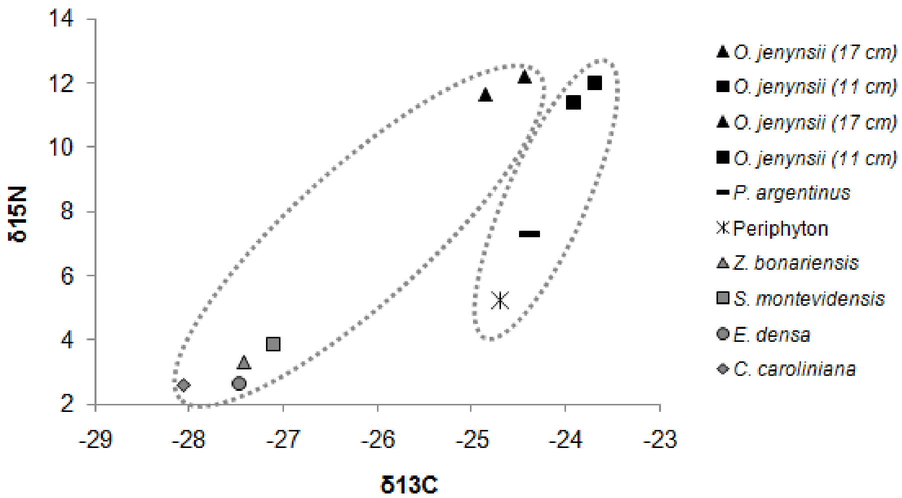


**Fig. IV. Values of $\delta^{15}N$ and $\delta^{13}C$ of *Oligosarcus jenynsii* in Mangueira Lake. Sources of carbon assimilated by consumers are indicated by the relative positions of taxa on the x-axis; trophic level is indicated by the relative position on the y-axis.**

## DISCUSSION

In Mangueira Lake, *O. jenynsii* had carnivorous feeding habits, mainly injesting decapod crustaceans, terrestrial adult insects and fish. These major diet items were also consumed by *O. jenynsii* in some ecosystem in some part of Argentina [3, 14] and in a coastal lagoon in southern Brazil [15].

*O. jenynsii* changed its main food items in relation to season and body size. Seasonal differences in the diet composition of fish are a pattern usually associated with changes in prey availability due to reproductive pulses and environmental changes. Additionally, a niche shift related to size frequently occurs in nature, especially for species with large size differences between adults and offspring..

Crabs *(A. prado*) and terrestrial insects were important components of the diet of *O. jenynsii* individuals > 14 cm, while prawns (*P. argentinus*) were consumed less frequently. Fish consumption was almost entirely exclusive of larger *O. jenynsii*. The observed data pattern suggests niche partitioning related to gape width, habitat occupation in the water column and macrophyte proximity.

Many of the items consumed by *O. jenynsii* are patchily distributed throughout Mangueira Lake. For example, terrestrial insects are only present on the surface of the water-column. Additionally, we have observed that *P. argentinus* is most frequently associated with macrophytes. The prevalence of *P. argentinus* in the diet of *O. jenynsii* < 14 cm is an indication of smaller *O. jenynsii's* association with macrophyte stands in the littoral zone. In contrast, terrestrial insects, fish and *A. prado* in the diet of *O. jenynsii* > 14 cm reveal that larger *O. jenynsii* is distributed throughout the pelagic zone.

In wetlands and lake littoral zones there are generally three major groups of production sources supporting higher consumers: epiphytic algae (periphyton), macrophytes and suspended particulate matter [11 and 19].

Mangueira Lake macrophytes had a $\delta^{13}C$ range in accordance with reported values for terrestrial plants using the $C_3$ photosynthetic pathway (-27 to -29‰, [9]; -25 to -27‰, [13]. Studies conducted in the Taim Hydrological System in [13] and the Paraná River floodplain [22] have found a high linkage between $\delta^{13}C$ values of macrophytes and consumers, suggesting they are an important carbon source supporting aquatic food webs.

Periphyton, which covers a wide range of submerged surfaces, can also be a key carbon source in shallow lakes. Periphyton plays a fundamental role in nutrient cycling and storage [2], and can be used by freshwater fish as a food source either in direct or indirect pathways [26]. The stable isotope signature of periphyton reported in this study was within the range reported for other freshwater environments ($\delta^{13}C$ range of -12 to -30 by [4]; -15 to -27 by [10]; -17 to -28 by [33]; and $\delta^{15}N$ range of 1.5 to 7 by [21]; 2.3 to 7.2 by [33].

Stable isotope analysis indicated that there was little variation in the $\delta^{15}N$ signature of *O. jenynsii* in relation to size, suggesting that trophic position remains similar throughout development. However, a diet shift was identified both by stomach content analysis and $\delta^{13}C$. Smaller *O. jenynsii* were more enriched in $^{13}C$ and had similar $\delta^{13}C$ values as *P. argentinus* and periphyton. Individuals in this size class probably obtain much of their carbon from *P. argentinus*, which feeds directly on periphyton.

Larger *O. jenynsii* was more depleted in $\delta^{13}C$ than *P. argentinus* or periphyton. Considering that fractionation results in approximately 1‰ enrichment in $^{13}C$ at each trophic level [12], the values of $\delta^{13}C$ identified for *O. jenynsii* are incompatible with *P. argentinus* and periphyton as a primary carbon sources. On the other hand, *O. jenynsii* was >1‰ enriched in $\delta^{13}C$ than macrophytes, suggesting that they may contribute as carbon source through a primary consumer pathway. Allochthonous carbon sources could also be important for *O. jenynsii* through consumption of terrestrial insects. Unfortunately, there are no data on the isotopic concentration for insects and *Aegla*, so this carbon pathway cannot be quantified.

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