Feeding of the scyphomedusa *Stomolophus meleagris* in the coastal lagoon Las Guásimas, northwest Mexico

Alimentación de la escifomedusa *Stomolophus meleagris* en la laguna costera Las Guásimas, noroeste de México

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ABSTRACT

The cannonball jellyfish (*S. meleagris*) has reached production levels that has led it to become an important fishery resource in Las Guásimas, Sonora, a coastal lagoon in northwestern Mexico; however, its ecological importance and role in the ecosystem remain unstudied. This contribution describes the diet composition of this species in order to reveal its trophic importance in this coastal lagoon. Up to 17 jellyfish were captured in each of three surveys (March 2008, February and April 2009), their stomachs were extracted and analyzed to determine their diet composition. The quantitative methods: frequency of occurrence (F), numeric (N), gravimetric (W) and the index of relative importance, were used to measure the diet components, and Levin´s index to measure the diet amplitude. Thirteen preys were identified; all belonging to the zooplankton community; the most important prey were the anchovy eggs. Our results show that *S. meleagris* is a specialist predator (with a marked preference for certain prey), classified in the third trophic level (3.2), as a secondary consumer.

Key words: Medusae, trophic levels, trophic preferences, zooplankton.

RESUMEN

La medusa "bola de cañón" (*S. meleagris*), ha alcanzado altos niveles de producción en la laguna costera de Las Guásimas, Sonora, en el noroeste de México, lo que la ha llevado a ser un recurso pesquero importante; no obstante, se desconoce su importancia y papel ecológico en el ecosistema. Este trabajo describe la alimentación de esta especie, con el fin de conocer su importancia trófica en esta laguna costera. Se capturaron 17 organismos en cada una de tres campañas realizadas (marzo, 2008, febrero y abril, 2009); se les extrajeron los estómagos y se analizaron para determinar la composición de su dieta. Se utilizaron los métodos cuantitativos de frecuencia de ocurrencia (F), numérico (N), gravimétrico (P) y el índice de importancia relativa (IIR) para determinar la composición de la dieta. Para estimar la amplitud de la dieta, se usó el índice de Levin. Se identificaron 13 tipos de presas, todas pertenecientes a la comunidad del zooplancton; los huevos de anchoa fueron el tipo de presa más importante. Los resultados mostraron que *S. mele-*

agris es un depredador especialista (con una preferencia marcada por un tipo de presa), con un nivel trófico terciario (3.2), lo que permite clasificarla como un consumidor secundario.

Palabras clave: Medusa, niveles tróficos, preferencias tróficas, zooplancton.

INTRODUCTION

Currently, the state of Sonora in northwestern Mexico is one of the countries' regions where the highest production of jellyfish -as a fishery resource-, is obtained. Particularly, in the coastal lagoon of Las Guásimas, the jellyfish *Stomolophus meleagris* (Agassiz, 1862) is captured since 2003, with volumes up 17,000 t per year (López-Martínez & Álvarez-Tello, 2008), mostly intended for the international market, mainly Asian (Hsieh *et al.*, 2001; Omori & Nakano, 2001).

There have been several efforts focused on the development of processing technologies, and also studies aimed to evaluate the potential use of this fisheries resource, including aspects such as growth, mortality, recruitment, abundance, and the use of predictive models (López-Martínez & Álvarez-Tello, 2008). Despite these research efforts, no previous data are related to feeding and quantitative analyses of *S. meleagris* diet in this region. Such basic studies are necessary to determine the trophic role of this species in the ecosystem.

Jellyfish are generally considered carnivorous organisms and have a great importance as planktonic predators. Some include in their diet first and second order carnivores (Ramírez & Zamponi, 1981), other species prefer small crustaceans, fish larvae and eggs (Alvariño, 1985); these preferences appear to be highly related to the prey size (Purcell & Arai, 2001). Jellyfish also play an important role in the ecosystem because they are part the diet of other pelagic organisms, including siphonophores, ctenophores, chaetognaths (Alvariño, 1985), other jellyfish (Larson, 1987), fish (Runge *et al.*, 1987), and turtles (Johnson-Diaz *et al.*, 1993; Márquez, 1996).

Some aspects related to the feeding of *S. meleagris* were described by Larson (1991) based on a survey of populations from the Florida region. Puente-Tapia (2009) studied this species in Mandinga lagoon and in the Carmen-Pajonal-Machona lagoon system, both in the southern Gulf of Mexico. Both studies emphasized that their results are representative of the conditions prevailing in their regions. This paper aimed to perform a quantitative

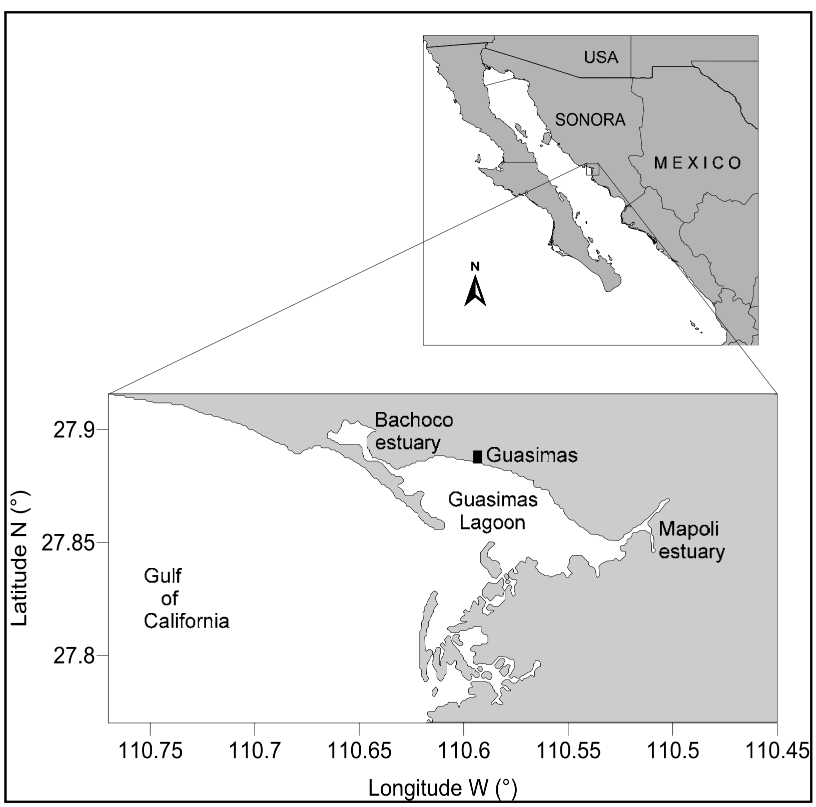

Figure 1. Study area. Las Guásimas costal lagoon, Sonora, NW Mexico.

analysis of *S. meleagris* diet and to determine the trophic role of this jellyfish in the coastal lagoon of Las Guásimas, Sonora, NW Mexico.

MATERIALS AND METHODS

The study area is located in NW Mexico, in the coastal plain of the state of Sonora (27 °49´- 27 °55´N and 110 °29´- 110 °40´W) (Fig. 1). The coastal lagoon of Las Guásimas has an area of 51 km^2, it has two estuaries (Bachoco and Mapoli) and two sandy barriers at both ends of the system's mouth, one in the north and one in the south. The lagoon has a channel of 3.25 km width, through which it maintains a continuous communication with the Gulf of California (Chávez-López & Álvarez-Arellano, 2006).

The highest abundance of *S. meleagris* has been observed to occur from February to April in this area (López-Martínez & Álvarez-Tello, 2008); this is why jellyfish were sampled within this time period during three sampling surveys: March 2008 and February and April 2009. Seventeen jellyfish were captured in each survey, using a ring or spoon net (1 cm mesh aperture). Specimens were fixed in 10% formalin -buffered with borax- for subsequent analysis. In the laboratory the total weight (g) and the total length (mm) of each jellyfish were recorded, and dissections were performed to extract their stomachs.

Stomach contents were removed and analyzed with the aid of a stereoscopic microscope. The organisms found in each stomach were identified to the lowest taxon possible, based on specialized keys for zooplankton (Snyder & Fleminger, 1965; Shanks, 2001). After the identification of prey items, the number and wet mass of each prey group was registered.

Cumulative prey curves derived from plotting the cumulative number of stomachs analyzed against the cumulative number of prey taxa (or prey categories), were performed. This allowed assessment of the sufficiency of sample sizes for an accurate characterization of the diet (Ferry & Cailliet, 1996; Wetherbee & Cortés, 2004). The cumulative curves were generated using the method proposed by Jiménez-Valverde and Hortal (2003) and following Clench's equation:

$$S_n = \frac{(a[1 - \exp(-b \cdot n)])}{b}$$

where:

S_n is the number of species observed in each sample,

a is the increase rate of new species and

b is the parameter related to the shape of the curve. These curves reach an asymptote as the sample size becomes sufficient to describe the entire range of the diet. The asymptote of curve -total number of species predicted- is calculated as a/b.

To assess the reliability of analysis, two criteria were taken into consideration: 1) when the proportion of preys is greater than 70% that allows estimation of species richness (asymptote) is stabilized; and 2) values <0.1 on the asymptote of the curve indicate that new preys are less frequent. Even when the species richness was considered incomplete, if it meets the second criterion, it was considered reliable.

The relationship between predator size (TL) and prey abundance was determined through the Pearson's correlation (Ríus-Díaz *et al.*, 1999); the correlation between the variables was estimated through direct permutations method (Zar, 1996).

The quantitative analysis of the food components found in the stomachs was performed through diverse methods proposed for Hyslop (1980):

$$\%F = N_o/N_s \quad \text{Frequency of occurrence}$$

where:

N_o is the number of occurrences of category *i* and

N_s is the total number of stomachs analyzed.

$$\%N = N_i/N_t \quad \text{Numerical}$$

where:

N_i is the number of organisms in category *i* and

N_t is the total number of organisms found in all categories.

$$\%W = W_i/W_t \quad \text{Gravimetric}$$

where:

W_i is the weight of category *i* and

W_t is the total weight of all the categories found.

$$IRI = (\%N + \%W) \times \%F \quad \text{the index of relative importance}$$

The IRI incorporates the three first methods (Pinkas *et al.*, 1971), and was used to calculate the relative contribution of each food category to the diet (Cortés, 1999). Dietary specialization was calculated via Levin's measure, using the technique proposed by Labropoulou and Eleftheriou (1997). Levin´s standardized equation is as follows:

$$Bi = 1/(n - 1\{1/(\sum pij^2)\} - 1)$$

where:

Bi is the measure of Levin´s niche breadth,

pij is the proportion of each prey category *i* in the diet and

n is the total number of prey categories in the diet.

The standardized Levin´s index was used on a scale of 0 to 1 where values <0.6 indicate a narrow niche breadth (specialist predator) and ≥0.6 indicate a broad niche breadth (generalist predator) (Labropoulou & Eleftheriou, 1997).

The trophic level was estimated to establish the position of *S. meleagris* within the food web following Cortés (1999) as:

$$TL_k = 1 + \left(\sum_{j=1}^{n} Pj * TL_j \right)$$

where:

TL_k is the trophic level for each species

TLj is the trophic level of each prey category j,

Pj is the proportion of each prey category j (using the% *IRI*) in the diet of *S. meleagris*, and n is the total number of prey categories.

RESULTS

Fifty one specimens of *S. meleagris* ranging from 40 to 140 mm of TL (Fig. 2) and representing a wet biomass between 23.3 to 815.6 g were analyzed during the three surveys in Las Guásimas coastal lagoon. These size ranges suggest that the specimens analyzed include young and adult stages. A total of 51 stomachs were examined, of which 44 contained at least one prey item; only 7 stomachs were empty.

The cumulative curves reached an asymptote (values of the asymptote 0.012) and the preys proportions (>70% and up 99%) indicated that the stomachs analyzed (51), were sufficiently reliable for describing *S. meleagris'* diet. The trophic spectrum of *S. meleagris* diet was composed of 13 prey types; the most important dietary component during the surveyed period was the anchovy

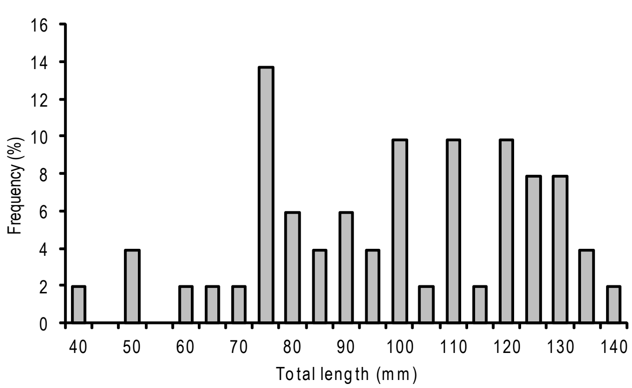

Figure 2. Size-structure of *S. meleagris* from samples collected in Las Guásimas coastal lagoon, NW Mexico, during 2008 and 2009.

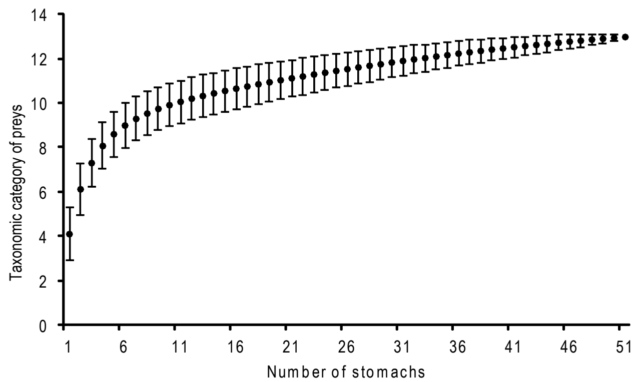

Figure 3. Evaluation of the sufficiency of sample sizes (number of stomachs examined) thought the cumulative curves, for an accurate characterization of the diet of *S. meleagris*.

eggs. Ten prey types were identified in the March 2008 survey, 6 in February 2009 (survey with the lower abundance of prey types) and 10 in April 2009 survey (Fig. 4).

Other prey groups like amphipods, cladocerans, foraminiferans, and eggs of *Opisthonema libertate* (Günther, 1867) were of low importance in terms of occurrence. They were occasional prey in *S. meleagris'* diet.

The relationship between predator size and prey abundance showed that the largest sizes of *S. meleagris* have a higher rate of prey ingestion (Fig. 5). A positive correlation between the predator size (jellyfish) and the abundance of eggs of anchovy ($r = 0.48$; $p < 0.05$; $n = 42$) was observed (Fig. 6).

Results of the quantitative stomach contents analysis of *S. meleagris* captured during the study period are presented in figure 7. According to the numeric methods used, the quantitative composition of *S. meleagris* diet was composed of 3,334 preys and the gravimetric method showed 1,465.75 mg of prey weight. Fish, mollusks, and crustaceans were identified as the most important groups by both methods. The frequency of occurrence method diverged as it marked the crustaceans as the most frequent group followed by fish and mollusks. At the species prey level, anchovy eggs were the most important prey according to the three methods (Fig. 7).

Overall, the IRI showed that fish are the principal diet component of *S. meleagris*, which revealed that they are prey at the early stages, followed by mollusks (larval and young stages), and crustaceans. The most representative preys were anchovy eggs and bivalves mollusks (Fig. 7). Levin´s index showed that *S. meleagris* is a specialist predator (Bi = 0.12), indicating a diet based in few preys. According to Cortés' (1999) criteria, *S. meleagris* was classified at the third trophic level (3.2), as a secondary consumer.

DISCUSSION

In general, jellyfish are considered carnivore and important plankton predators, so they are deemed as first and second order carnivores. The prey preference has relation with the size of the jellyfish (Purcell & Arai, 2001; Hansson & Kiørboe, 2006). The feeding spectrum of *S. meleagris* from Las Guásimas coastal lagoon includes a reduced species number (13), in comparison with previous studies about the feeding of the same species in other geographical areas. In the northwestern sector of the Gulf of Mexico (Florida, U.S.A.), Larson (1991) reported a total of 24 taxa and Puente-Tapia (2009) reported 20 taxa in coastal systems of the southern Gulf of Mexico. The difference between the numbers of prey components can be attributed to the higher salinity conditions inside Las Guásimas (36-41 ups; Arreola-Lizárraga, 2003) in comparison with those in the adjacent oceanic waters. Local

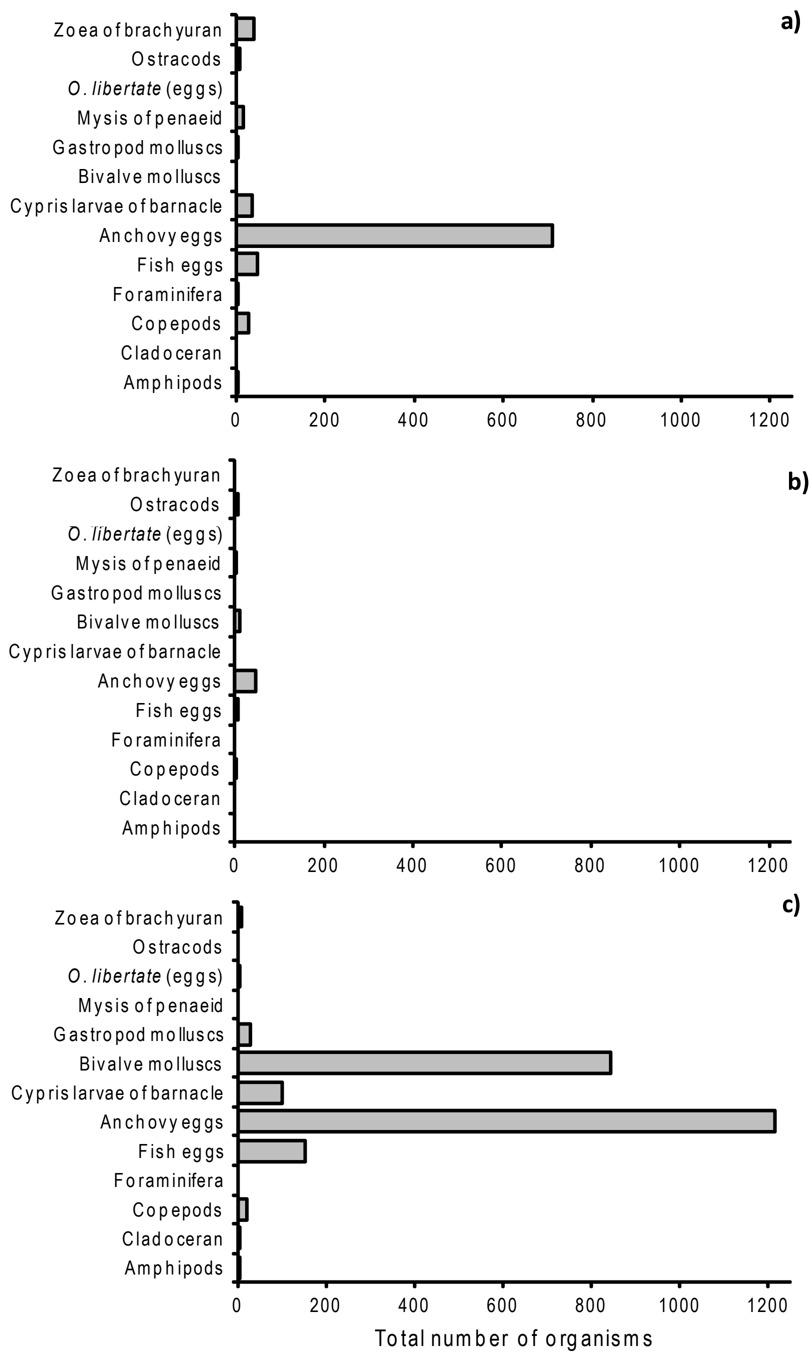

Figure 4a-c. Abundance of different prey species in the diet of *S. meleagris* in: a) March 2008, b) February 2009, c) April 2009.

evaporation rates are ten times higher than pluvial precipitation over the lagoon (antiestuarine lagoon) (García, 2004; Arreola-Lizárraga, 2003), which causes the variation on abundance and a lower diversity of prey.

Considering the relationship between predator size and prey abundance, it was observed that largest jellyfish individuals consumed larger preys. A similar behavior was observed in the freshwater medusa *Craspedacusta sowerbyi* (Lankester, 1880) (Spadinger & Maier, 1999). The planktonic medusoid stage of *S. meleagris* has a span of 3-6 months; during this period its growth rate is higher than that of its benthic stage (López-Martínez *et al*., 2007; López-Martínez & Álvarez-Tello, 2008). At this time the species starts its reproductive period; as a result, feeding activities increase to store energy in order to improve gonadic development and subsequent growth (Carvalho-Saucedo *et al*., 2010).

In relation to the preference of *S. meleagris* for a specific type of prey, Purcell (1992) and Purcell *et al*. (1994), mentioned that fish eggs are an important component of jellyfish diet. In the present study the anchovy eggs were the principal feeding component for *S. meleagris*; this behavior could result from the high availability of this prey in the system, something that should be confirmed by the prey availability analysis. A different behavior was observed by Larson (1991), who determined that mollusk larval stages (veligers) are the principal prey. Puente-Tapia (2009) determined copepods as the most important prey group for this species.

The results obtained about the prey size preferred by *S. meleagris* were similar to those reported by Larson (1991), differing only on their abundances, which suggest that jellyfish captures a similar size range of prey because the feeding structures are size-selective. The channels formed by the scapulets (folds at the bases of the lobes of the manubrium) of *S. meleagris* can be very narrow and it is where food is handled. Selectivity could also result from structural differences of nematocysts that favor the

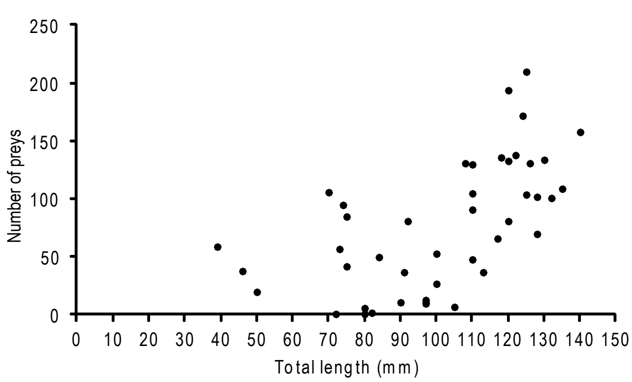

Figure 5. Relationship between *S. meleagris* size and the abundance prey (number of organisms) in Las Guásimas coastal lagoon, NW Mexico.

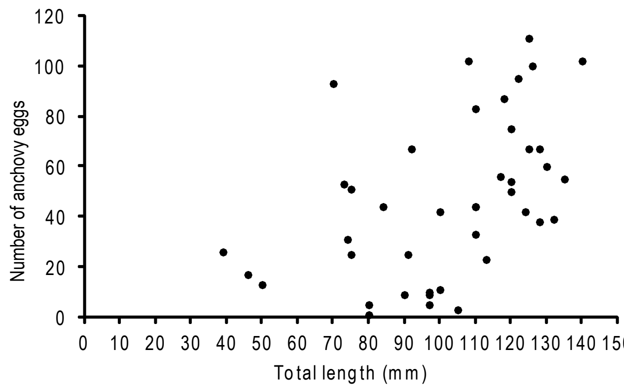

Figure 6. Dispersion diagram of the relationship between *S. meleagris* and the abundance of anchovy eggs (number). Both variables present a positive significant correlation (Pearson, r = 0.48; $p < 0.05$; n = 42).

capture of a particular kind of prey (Purcell & Mills, 1988; Carr & Pitt, 2008; Regula *et al*., 2009). In comparison with other jellyfish, this species lacks tentacles that would help capturing a wider range of prey (Costello & Colin, 1995). It has been suggested that the mucus production in this species can play an important role in prey capture; nevertheless, this behavior appears to result from stress caused by manipulation (Larson, 1991). Shanks and Graham (1988) found that mucus secretion is a response to predation.

Anchovy eggs have no mobility, thus explaining the major importance of this item on *S. meleagris* diet (Fancett, 1988; Costello & Colin, 1994). In jellyfish, the different mechanisms determining predation rates and prey selection are not well defined yet (Costello & Colin, 1994; Colin & Costello, 2007). However, some prey species have visual and sensory mechanisms to detect and escape before contact with the jellyfish. In addition, very small prey can escape through the scapulets' filters (Larson, 1991). In general Cnidarians are effective predators of fish eggs and other zooplankton that have a relatively low mobility (Bunn *et al*., 2000).

Larson (1991) suggested that *S. meleagris* is a planktivorous polytrophic (but feeds in major quantity from a few species), a behavior that was also found during the present study, where the anchovy eggs represented 83.3% of their diet. Furthermore, Levin´s index showed the same trend, the diet is largely based in a few species, thus indicating that *S. meleagris* is a specialist predator at Las Guásimas coastal lagoon.

The low relative abundances of other prey could be caused by the lack of knowledge of the circadian rhythm and digestion (Nogueira-Júnior & Haddad, 2008). However, Fancett and Jenkins (1988) mentioned that the efficiency of jellyfish feeding is similar during the day and night. For this reason we suggest that future studies should include specimens captured both at night and during daytime in order to determine if prey selection varies during

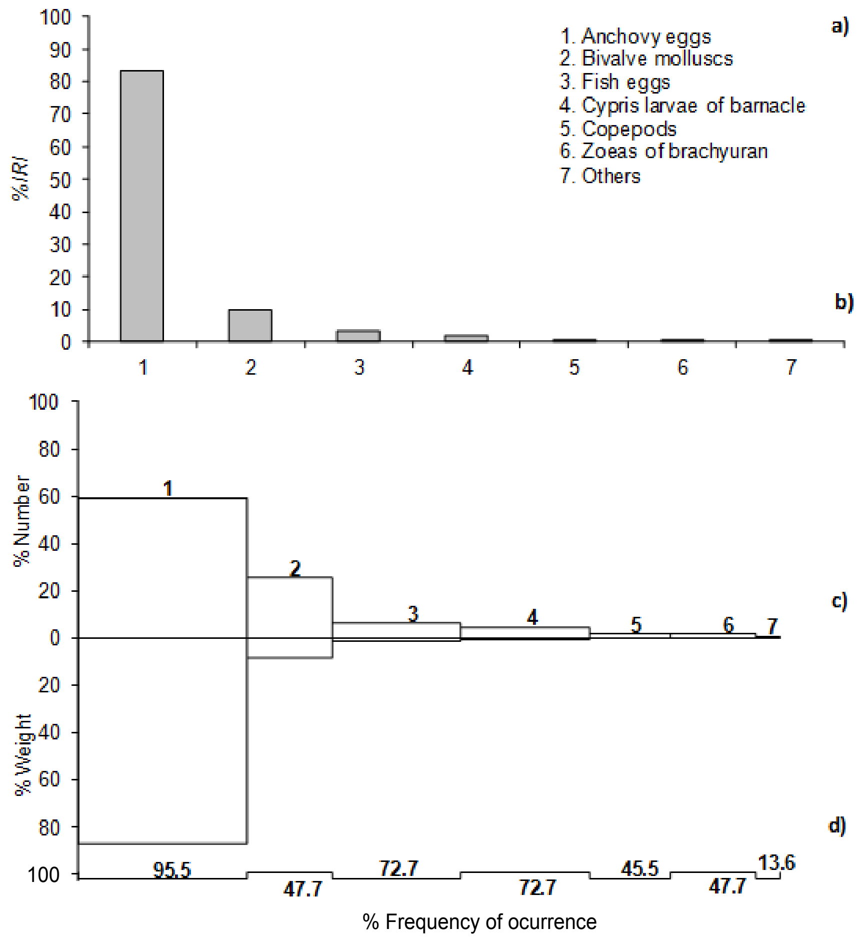

Figure 7a-d. Trophic spectrum of *S. meleagris* expressed in perceptual values of four numeric methods: a) numeric (N), b) importance relative index (IRI), c) gravimetric (W) and d) frequency of occurrence (F).

the cycle. The lower prey abundance observed in February 2009 is attributed to the fact that organisms were not fixed immediately after collection, which allowed a longer digestion time, thus causing a lower prey number; the same was observed by Larson (1976).

Sommer *et al.* (2002) considered jellyfish as the end of the trophic chain in the pelagic environment because of their low nutritional value; they represent a relatively low value as food for vertebrates. Heeger *et al.* (1992) did not consider them important in the food chain. According to our results the jellyfish *S. meleagris* can be situated in the trophic level three (3.2) as a zooplankton consumer and it can be deemed as a secondary consumer too.

Based on the results of this study, we can conclude that *S. meleagris* is an important zooplankton predator in the surveyed area, feeding preferably on anchovy eggs, thus agreeing with the observations by Purcell *et al.* (1994) and Kremer (2005). This fact has ecological implications, because the periods of massive jellyfish aggregations (characteristic of this species according to Alvariño, 1985 and Loman-Ramos *et al.*, 2007), can be affected negatively by the abundance of prey species, while increasing natural mortality due to predation of *S. meleagris.* It has been documented that in other important fisheries regions, high jellyfish populations have contributed to the collapse of fisheries because of the high rates of zooplankton consumption that disrupt the zooplankton community (Kingsford *et al.*, 2000; Hiromi *et al.*, 2005; Coll *et al.*, 2006; Tremblay, 2010).

The fact that *S. meleagris* is a specialist predator is most relevant because Las Guásimas (like other coastal systems) is an important area for breeding and reproduction of many organisms including commercially valuable species, such as *Sardinops sagax* (Jenyns, 1842), *O. libertate*, the blue shrimp *Litopenaeus stylirostris* (Stimpson, 1874) and the crab *Callinectes* spp, plus some mollusks. Hence, the high abundance of jellyfish in the area could become a factor affecting the volumes of these important resources both for fishing activities and management and for the regional economy. This is an issue that requires a deeper analysis.

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