Journal of the Marine Biological Association of the United Kingdom, 2014, 94(8), 1721–1729.
doi:10.1017/S0025315414000198

Feeding habits of *Eucinostomus entomelas* and *Micropogonias megalops* in Las Guasimas lagoon Gulf of California

DANA I. ARIZMENDI-RODRÍGUEZ[1,2], J. LÓPEZ-MARTÍNEZ[1] AND E. HERRERA-VALDIVIA[1]

[1]Centro de Investigaciones Biológicas del Noroeste, S.C. Km 2.35 Carretera a Las Tinajas, S/N Colonia Tinajas. Guaymas, Sonora, C.P. 85460, Mexico, [2]Instituto Nacional de la Pesca, CRIP Guaymas, Calle 20 Sur No. 605, Guaymas, Sonora, C.P. 85400, Mexico

The trophic spectrum of both Eucinostomus entomelas *and* Micropogonias megalops*, the two most abundant fish species in Laguna Las Guásimas, Sonora, México is described in our study. A total of 21 types of prey were identified belonging to seven taxonomic groups (Crustacea, Mollusca, Annelida, Rhodophyta, Copepoda, Echinodermata and Chordata) to analyse the feeding spectra and diet breadth. The preferred prey items of* Eucinostomus entomelas *(Dark-spot mojarra) were Polichaeta (index of relative importance = 46.7%), followed by bivalves* (36.6%)*, and* Luidia columbia (5.6%)*, while those of* Micropogonias megalops *(Bigeye croaker) were Portunidae (22.8%) followed by Gammaridae (20.55%) and Crustacea (18.37%). The trophic spectrum for male* E. entomela *was composed of Bivalvia and Polychaeta. Both predators showed low values in diet breadth (*E. entomelas *(Levin's index* Bi *= 0.14) and* M. megalops *(Levins's index* Bi *= 0.43)). The low trophic overlap ($C\lambda = 0.14$) between predators suggests that both fish are not competing with each other for food resources in Laguna Las Guásimas.*

Keywords: Gulf of California, *Eucinostomus entomelas*, *Micropogonias megalops*, Laguna Las Guásimas, specialist predator, carcinophagus, trophic overlap, diet breadth, Gerreidae

Submitted 2 July 2013; accepted 23 January 2014; first published online 3 September 2014

INTRODUCTION

Coastal lagoons are separated by a barrier from the adjacent ocean and connected to it at least intermittently (Kjerfve, 1994); they are characterized by elevated productivity, allowing the establishment of numerous marine populations (Contreras-Espinosa & Castañeda-López, 2004; Hauenstein *et al.*, 2008). In coastal areas, fish are among the faunal groups with the most biological success because these areas offer them food and protection, favouring their development during their lifetime (Yáñez-Arancibia & Nugent, 1977; Castro-Aguirre *et al.*, 1999; Arceo-Carranza *et al.*, 2010).

On the coasts of Sonora, Mexico, the largest lagoons are Bahía de Guaymas, Bahía Yavaros, Estero Agiabampo, Estero de Lobos, Estero El Tóbari and Las Guásimas (Burrola-Sánchez *et al.*, 2008); this last one is a very important ecological area (declared RAMSAR) for mollusc, crustacean and fish species (Varela, 1990; Campoy & Calderón, 1991; Audeves *et al.*, 1997; Ontiveros-Granillo, 2011). In Las Guásimas, 79 fish species have been recorded (Rodríguez-Félix, 2010; Ontiveros-Granillo, 2011), of which *Eucinostomus entomelas* Zahuranec, 1980 (Dark-spot mojarra) (Yáñez-Arancibia, 1977) and *Micropogonias megalops* Gilbert, 1890 (Bigeye croaker) are two of the ten most abundant species (Ontiveros-Granillo, 2011), both subjected to fisheries exploitation (Sólis-Celada *et al.*, 1996; Aragón-Noriega *et al.*, 2009). In spite of their economic importance, knowledge about their biology is scarce.

It is known that *E. entomelas* reaches 18 cm in standard length; it ranges from the southern part of the Baja California Peninsula and Central Gulf of California region down to Peru, and it inhabits coastal waters and shallow bays with soft substrates, generally forming schools. Juveniles are found in coastal lagoons and estuaries and are considered to be omnivorous (Fisher *et al.*, 1995; Allen & Robertson, 1998). As for *M. megalops,* it has been reported to reach ≥49 cm in total length; it lives in coastal lagoons, estuaries and river mouths, but it is also found in deep waters far from the coast. It ranges from the Rio Colorado delta down to the surroundings of Acapulco, Mexico (Fisher *et al.*, 1995; Allen & Robertson, 1998). Román-Rodriguez (2000) reports that in the northern region of the Gulf of California, *M. megalops* grows allometrically and lives up to 16 yr, reaching first maturity at 40 cm in total length and spawning in April.

Fish play an important role in the structure and functioning of many aquatic ecosystems through trophic interactions (Cruz-Escalona *et al.*, 2007). The study of their feeding habits allows knowledge about the biology and ecology of the organisms providing data on their interaction in the marine environment (Cailliet *et al.*, 1996). This is the first work analysing the feeding spectrum of *E. entomelas* and *M. megalops* of Laguna Las Guásimas in Sonora, Mexico. Our objective was to characterize the diet of both species and identify if they compete for food, considering they are the two most abundant species in this lagoon.

MATERIALS AND METHODS

Biological samples of *Eucinostomus entomelas* and *Micropogonias megalops* were collected in November 2010,

Corresponding author:
J. López-Martínez
Email: jlopez04@cibnor.mx

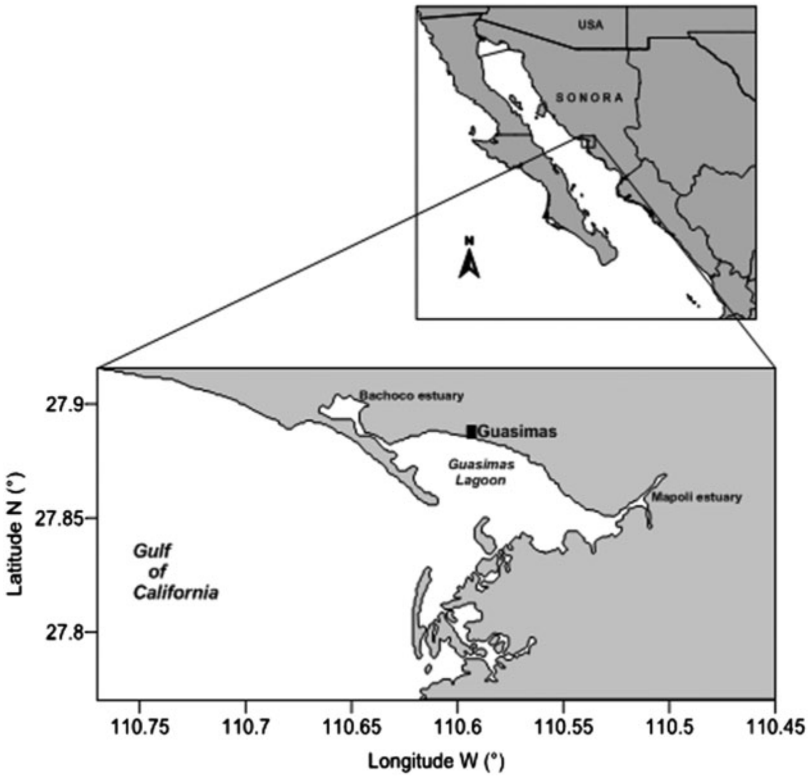

Fig. 1. Study area, Laguna Las Guásimas.

September 2011 and February 2012 in Laguna Las Guásimas, Sonora (27°50′–27°51′N 110°41′–110°26′W) (Figure 1). Boats known locally as 'pangas' were used for the collection. The capture of the individuals was performed with 5.7 cm mesh trawling nets of 15 m in length in the headrope, at a speed of 2 knots. Additionally, a 5.7 cm mesh gill net, 200 m in length and 1.70 m in height was used for collection near the bottom at a depth of 3 m. Individuals of *E. entomelas* and *M. megalops* were separated at capture, injected with formaldehyde at 10% directly into the stomach and placed in tagged plastic bags and preserved in 10% formaldehyde. In the laboratory, fish were identified to the species level using the keys by Fisher *et al.* (1995) and Robertson & Allen (2010) (Smithsonian Tropical Research Institute, 2008).

Fork length (FL ±0.1 cm) of each individual was measured with a Vernier and total weight (TW ±0.1 g) with an Ohaus balance. Each fish was eviscerated and the sex was identified macroscopically. Size structure was analysed for each species with size intervals of 10 mm FL.

Stomachs were removed and preserved in formaldehyde at 10%. The emptiness index, which relates to the number of empty stomachs with the total number of stomachs, was determined. Stage of stomach fullness was identified using Stillwell & Kohler's (1982) methodology, and they were grouped into four categories (1–25%, 26–50%, 51–75% and 76–100% fullness).

For taxonomic identification of prey items, specialized keys were used according to the type of prey. Algae were identified by Dawson's (1966) key, copepods by using Palomares-Garcia *et al.* (1998) and echinoderms and molluscs were identified using the key by Fischer *et al.* (1995). Fish identification was performed by analysing the skeleton parts. Vertebrae were counted following Miller & Jorgensen (1973). For fish showing a minimum digestive stage, Fischer *et al.* (1995) keys were used.

Prey that were too macerated or digested to be visually classified were identified starting from their hard structures, such as claws and other crustacean appendages, using Brusca's (1980) specialized guide. For each prey category, the number of individuals corresponding to each food component was quantified and their wet weight was recorded to 0.0001 g. The quantification of fragmented prey was based on the number of pairs of eyes, head, mouth parts (mandibulae), telson and other anatomical structures that serve as reference to determine complete specimens.

Several methods have been proposed to quantify the importance of the different types of prey in aquatic species' diets (Berg, 1979; Hyslop, 1980; Tirasin & Jorgensen, 1999). To analyse the diet of each predator, the following factors were used in the present study: frequency of occurrence percentage (%FO), referred to as occurrence of prey type and total number of stomachs with food; %FO = (number of stomachs including type of prey/number of stomachs with food)*100; percentage in number (%N) that relates to the number of individuals of prey *i* found in stomachs with the total number of prey in all the stomach contents; and weight percentage (%W) that relates to the weight of all the individuals of prey *i* with the total weight of all the prey in the stomachs with food.

The index of relative importance (IRI) combines the three previous methods; it was proposed by Pinkas *et al.* (1971) and modified by Hacunda (1981). The IRI was used to evaluate each species in general, by sex and by the importance of each food category in the trophic spectrum (Liao *et al.*, 2001).

https://doi.org/10.1017/S0025315414000198 Published online by Cambridge University Press

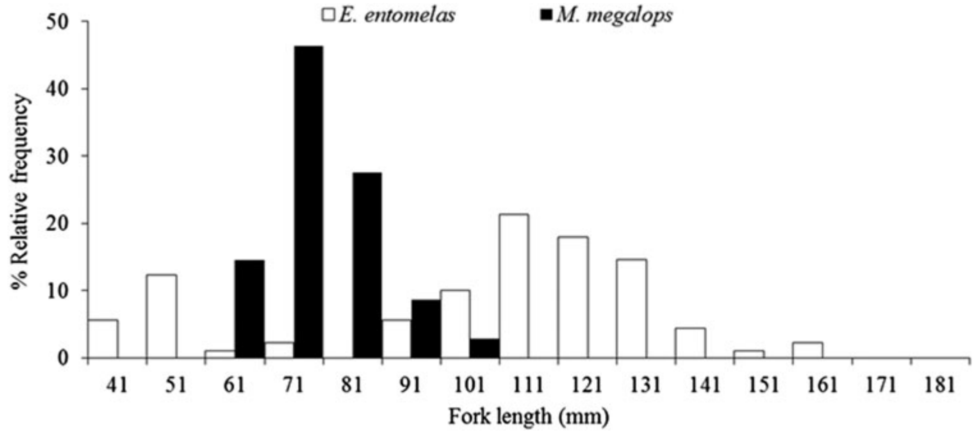

Fig. 2. Size–frequency distribution of *Eucinostomus entomelas* and *Micropogonias megalops*, captured in Laguna Las Guásimas, Sonora.

The index formula is as follows:

$$IRI = \%FO * (\%N + \%W)$$

where $\%FO$ is the percentage of frequency of occurrence; $\%N$ is the percentage of numerical abundance; and $\%W$ is the weight percentage.

This index was expressed as:

$$\%IRI = \frac{IRI}{\sum IRI} * 100$$

To estimate the diet breadth, IRI absolute values were used according to Levin's (Krebs, 1989) standardized index, which assumes *Bi* values close to zero when the predator is a specialist and close to one when it is a generalist (Krebs, 1989).

To evaluate *E. entomelas*' diet overlap among predators and by sex, the Morisita–Horn (Smith & Zaret, 1982) index was applied, using IRI absolute values ($C\lambda$), which can vary from zero, when diets are completely different, to one, when diets are identical.

To determine if the number of stomachs analysed was adequate to characterize the diet, the program EstimateS Win v.7.52 was used to obtain the cumulative curve of prey according to Jiménez-Valverde & Hortal (2003).

RESULTS

A total of 87 individuals of *Eucinostomus entomelas* were collected with a fork average length of 119 ± 32 mm (Figure 2) and average weight of 51 ± 31 g. From the whole sample, 52 stomachs contained food (60%) and 35 stomachs were empty (40%).

A total of 69 individuals of *Micropogonias megalops* were collected with average fork length of 79.5 ± 9.1 mm (Figure 2) and average weight of 10.2 ± 3.5 g. 42 stomachs (61%) had food and 27 stomachs were empty (39%).

The percentage of gastric repletion for both species (*E.entomelas* and *M. megalops*) was the 1–25% range for 50% and 31% of the organisms analysed, respectively (Table 1).

Table 1. Percentage of stomach fullness in a total sample of stomachs with food.

Category	*Eucinostomus entomelas*		*Micropogonias megalops*	
	No. of stomachs	% of stomachs	No. of stomachs	% of stomachs
1–25%	26	50	31	74
26–50%	10	19	1	2
51–75%	7	13	2	5
76–100%	9	17	8	19
Total	52	100	42	100

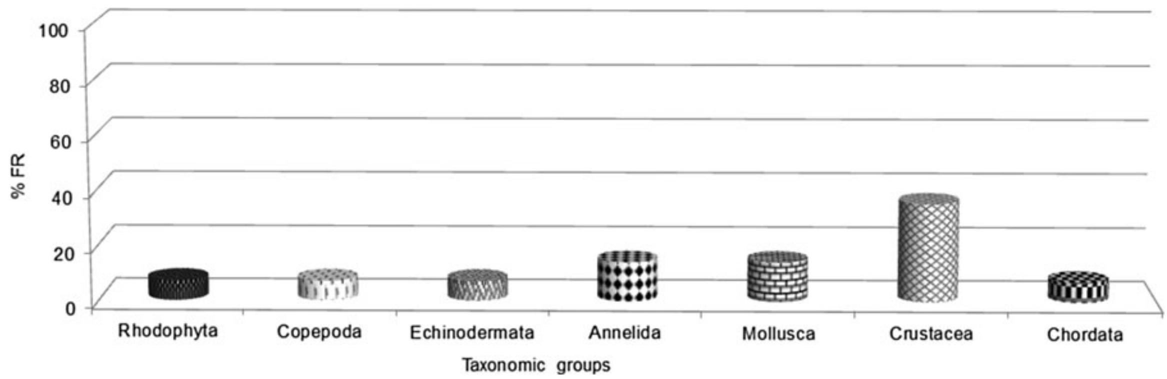

Fig. 3. Feeding preference of *Eucinostomus entomelas* by taxonomic group in Laguna Las Guásimas, Sonora.

https://doi.org/10.1017/S0025315414000198 Published online by Cambridge University Press

Table 2. General feeding spectrum of *Eucinostomus entomelas* and *Micropogonias megalops* in Laguna Las Guásimas, Sonora, expressed in absolute and percentage values of the frequency of occurrence (FO and %FO), numerical (N and %N), gravimetric (W and %W) methods and index of relative importance (IRI and %IRI).

Prey	*Eucinostomus entomelas*								*Micropogonias megalops*							
	FO	%FO	N	%N	W	%W	IRI	%IRI	FO	%FO	N	%N	W	%P	IRI	%IRI
Rhodophyta	1	1.9	1	1.09	0.3154	3.96	4.18	0.07	1	2.4	1	1.9	0.00864	0.3	5.1	0.16
Copepoda	1	1.9	1	1.1	0.0003	0.003	4.18	0.1								
Echinodermata																
Holothuroidea	2	3.8	2	2.2	0.2668	3.3	16.72	0.3								
Platyasterida																
Luidia columbia	9	17.3	9	9.8	0.6856	8.6	338.63	5.6								
Annelida																
Polychaeta	26	50.0	26	28.3	3.5897	45.1	2826.09	46.7								
Polichaeta remains	5	9.6	5	5.4	0.6310	7.9	104.52	1.7								
Mollusca																
Gasteropoda	5	9.6	5	5.4	0.0014	0.02	104.52	1.7								
Bivalve	23	44.2	23	25.0	1.2563	15.8	2211.54	36.6	2	4.8	2	3.7	0.0186	0.7	21.0	0.65
Phyllonotus erythrostoma									1	2.4	1	1.9	0.0096	0.3	5.2	0.16
Crustacea	1	1.9	1	1.1	0.1358	1.7	4.18	0.1	10	23.8	10	18.5	0.1803	6.4	592.4	18.37
Gammaridae									8	19.0	8	14.8	0.5661	20.0	662.8	20.55
Barnacle	1	1.9	1	1.1	0.0030	0.04	4.18	0.1								
Peneidae									3	7.1	3	5.6	0.2971	10.5	114.6	3.55
Litopenaeus vannamei									1	2.4	1	1.9	0.0386	1.4	7.6	0.24
Brachyura									3	7.1	3	5.6	0.2571	9.1	104.5	3.24
Portunidae									8	19.0	8	14.8	0.6720	23.7	733.9	22.8
Callinectes spp.	2	3.8	2	2.2	0.5585	7.0	16.72	0.3	9	21.4	9	16.7	0.2300	8.1	531.1	16.47
Paguridae	3	5.8	3	3.3	0.1043	1.3	37.63	0.6								
Crustacean remains	5	9.6	5	5.4	0.1518	1.9	104.52	1.7								
Chordata																
Sardinops spp.									2	4.8	2	3.7	0.0286	1.0	22.4	0.71
Fish remains	8	15.4	8	8.7	0.2635	3.3	267.56	4.4	6	14.3	6	11.1	0.5268	18.6	424.4	13.16
Total	52	176.9	92	100	7.9634	100	6045.2	100	42	128.6	54	100	2.8331	100	3225.1	100.0

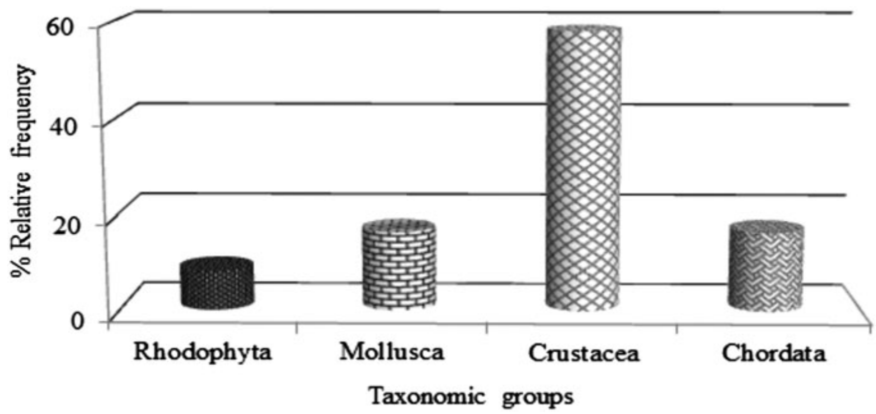

Fig. 4. Feeding preference of *Micropogonias megalops* by taxonomic group in Laguna Las Guásimas, Sonora.

The trophic spectrum of *E. entomelas* consisted of 14 types of prey, corresponding to eight food categories. Of the total prey consumed, five (Figure 3) prey items were crustaceans (36%), two of each belonging to annelids, echinoderms and molluscs (14% each), and only one to rhodophytes, copepods and chordates (7% each).

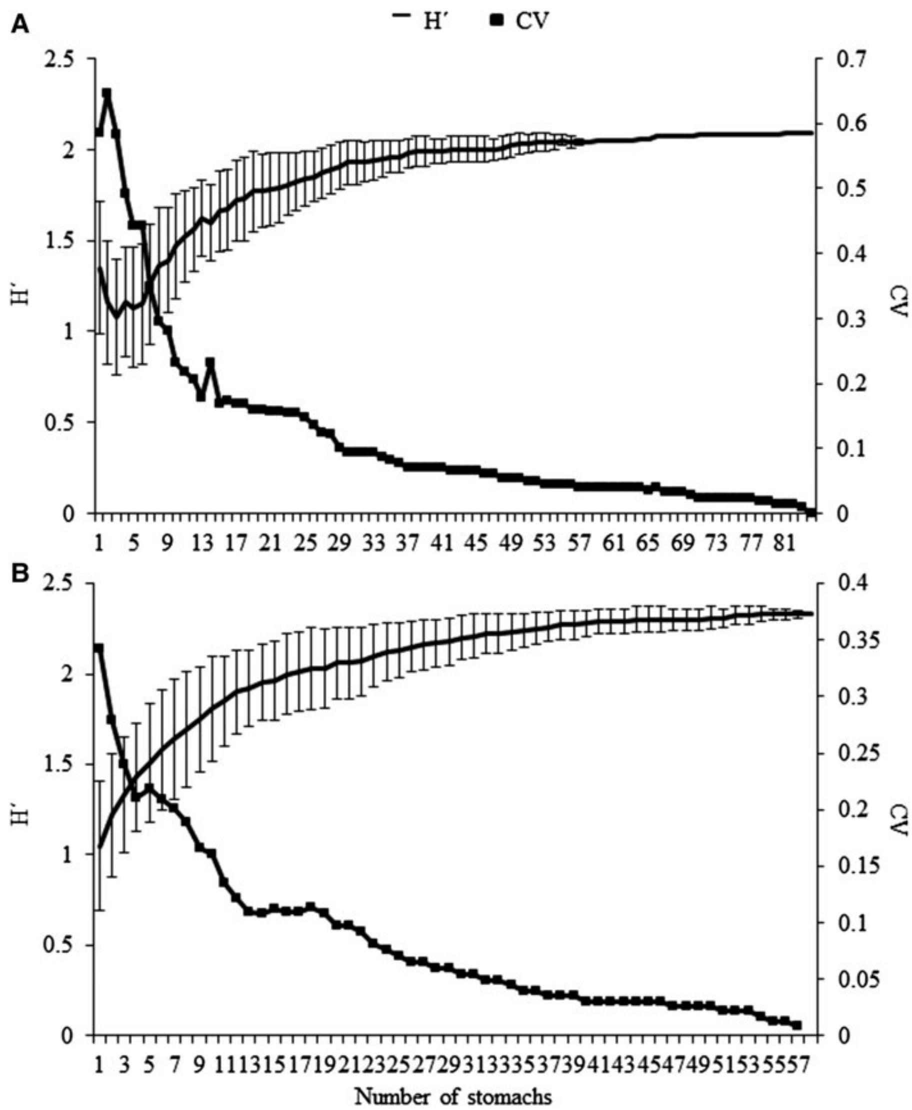

Fig. 5. Cumulative prey curve in the diet by predator in Laguna Las Guásimas, Sonora: (A) *Eucinostomus entomelas*; (B) *Micropogonias megalops*.

https://doi.org/10.1017/S0025315414000198 Published online by Cambridge University Press

The most frequent prey species in stomachs were polychaetes (50.0%), bivalves (44.2%), *Luidia columbia,* Gray 1840 (17.3%) and fish remains (15.4%) (Table 2).

A total of 92 prey specimens were recorded. The most important items were polychaetes (28.3%) followed by bivalves (25.0%), *Luidia columbia* (9.8%) and fish remains (8.7%).

Total weight of prey was 7.9634 g; those showing higher weight percentage were polychaetes (45.1%), bivalves (15.8%), *L. columbia* (8.6%), polychaete remains (7.9%) and *Callinectes* spp., Fausto 1980 (7.0%). According to the IRI, the most important species were: polychaetes (46.7%); bivalves (36.6%); and *L. columbia* (5.6%).

While analysing diet by sex, of the 32 females collected, 16 stomachs were with food (50%) and 16 stomachs were empty (50%). The most important items were bivalves (38.1%), polychaetes (22.7%) and *L. columbia* (17.5%).

Of 35 males sampled, 21 stomachs were found with food (60%) and 14 were emply (40%). Based on %IRI, the males' diet was composed mainly of bivalves (55.9%) and polychaetes (29.9%).

In stomachs of *M. megalops*, 12 items were found, of which seven belonged to crustaceans (58%), two to molluscs and chordates (17% each) and one to rhodophytes (8%) (Figure 4).

In terms of frequency of occurrence, crustaceans contributed with 23.8% (10 stomachs), followed by crab *Callinectes* spp. with 21.4% (9), portunids and gammarids with 19.0% (8 each) and fish remains 14.3% (6) (Table 2).

A total of 54 prey items were found: 18.5% (10) were crustaceans; 16.7% (9) *Callinectes* spp.; 14.8% (8) portunids and gammarid amphipods; and 11.1% (6) fish remains.

The items in stomachs had a total weight of 2.8331 g. In terms of %W, the most important components were the family Portunidae with 23.7% (0.6720 g), Gammaridae Amphipoda with 20% (0.5661 g), fish remains 18.6% (0.5268 g) and Peneidae 10.5% (0.2971 g).

With respect to the IRI, Portunidae represented 22.76%, followed by Gammaridae with 20.55%, Crustacea 18.37%, *Callinectes* spp. 16.47%, fish remains 13.16% and the rest of the items contributed 8.69%.

With reference to sex, six males were obtained (9%), 63 juvenile (91%), and no females were identified. The trophic spectrum of six *M. megalops* males was composed of two types of prey. Amphipods of the family Gammaridae were the most important prey, with 50% frequency of occurrence (%FO), contributing 85.7% in number, 99.8% in weight and 92.8% in IRI. Fish remains contributed to 50% in FO, 14.3% in %N, 0.2% in weight and 7.2% in IRI, occupying second place in IRI.

With respect to diet breadth for *E. entomelas*, a value of $Bi = 0.14$ was found, classifying it as a specialist predator. On the other hand, when comparing by sex, females had values of $Bi = 0.32$ and males of $Bi = 0.21$, classifying them as specialists.

Micropogonias megalops was characterized as a specialist predator according to the estimated value of diet breadth ($Bi = 0.43$). The same behaviour was recorded for males ($Bi = 0.16$).

According to feeding preferences between *E. entomelas* and *M. megalops*, we found a low overlap ($C\lambda = 0.14$). Nonetheless, when comparing *E. entomelas*' diet by sex, we found a high overlap ($C\lambda = 0.86$).

The cumulative prey species curve for each predator indicated the number of stomachs analysed was sufficient, obtaining coefficient of variation values under 0.05 (Figure 5).

DISCUSSION

In our work we considered that variation between prey digestion degree and stomach fullness (1–25%) did not relate to the time of the day in *Micropogonias megalops* and *Eucinostomus entomelas* feeding, because this percentage was found in organisms collected during day and night, suggesting both predators consume food throughout the day. It could be attributed to the fact that once captured, the individuals were fixed one hour after having been collected, a period during which the digestion process continues degrading food (Abitia-Cárdenas *et al.,* 1998).

In spite of the prey digestion stage, the preferential prey item found in *E. entomelas* stomachs was polychaetes (%IRI = 46.7), which agrees with that reported by Varela (1990), Arenas-Granados & Acero (1992) and Aguirre-León & Díaz-Ruiz (2004) with respect to the predator pressure that other components of the family Gerreidae place upon polychaetes. *Eucinostomus entomelas* also consumed six other taxonomic groups (Rhodophyta, Copepoda, Echinodermata, Mollusca, Crustacea and Chordata), of which only four (algae, copepods, polychaetes and crustaceans) have been found in stomach contents of other Gerreidae such as *Eugerres plumier* Cuvier 1830 (Aguirre-León & Díaz-Ruiz, 2000) and *Diapterus rhombeus* Cuvier 1829 (Aguirre-León & Díaz-Ruiz, 2004).

The trophic spectrum of *E. entomelas* indicates that it is a carnivorous predator which consumes mainly benthic organisms (e.g. Polychaeta, Bivalvia and *Luidia columbia*) and pelagic species (Copepoda) in smaller numbers. The presence of benthic prey in *E. entomelas*' diet is characteristic of the family Gerreidae, because they have a protractile mouth that allows them to feed on small invertebrates at the bottom and small quantities of plant material (Fisher *et al.*, 1995).

In the stomachs of *E. entomelas* Rhodophyta algae contributed 1.6% FO, which was considered as occasional feeding. When compared to Arenas-Granados & Acero (1992), who reported that in 27 digestive tracts of *Diapterus auratus* Ranzani 1842, 60% FO of algae was found, this fish is classified as a euriphagus predator, differing from the feeding habits of *E. entomelas*.

Males consumed more bivalves (%IRI = 55.9) than females (%IRI = 38.1). The similarity in both main prey indicates that there is a good abundance of feeding resources in Las Guasimas, allowing them to consume the same types of prey but in different proportions. Feeding preference of *E. entomelas* males agrees with that reported on other Gerreidae: *E. plumier*; *Gerres cinereus*; *D. rhombeus*; *Diapterus auratus*; *Eucinostomus melanopterus*; *E. harengulus*; *E. argenteus*; and *E. gula* (Arenas-Granados & Acero, 1992).

In the trophic spectrum of *M. megalops*, four feeding categories were identified (Crustacea, Chordata, Mollusca and Rhodophyta) with Crustacea being the most important group (85.17% IRI). The food components of *M. megalops* were similar to those reported for the same sciaenid by Román-Rodríguez (2000), who found crustaceans, molluscs, ophiuroids, polychaetes, fish and unidentified organic material were the most important in this predator's diet. Feeding preference also agrees with that reported for other genera of the family Scianidae such as: *Menticirrhus undulatus* (Bocanegra-Castillo *et al.*, 2000) and *Cynoscion parvipinnis* (Cruz-Escalona *et al.*, 2010), but it differs from that found for *Cynoscion othonopterus* (Román-Rodríguez, 2000) and

Micropogonias furnieri (Bertrán *et al.*, 2013); in both predators, clupeiform fish are the preferred prey (*Cetengraulis mistecetus* and *Engraulis ringens*, respectively).

Micropogonias megalops preference for crustaceans classifies it as a carcinophagous predator. The high consumption of crustaceans and molluscs confirms it is a predator living close to the bottom and feeding preferably on the two most abundant of benthic fauna in Laguna Las Guásimas (Campoy & Calderón, 1991).

In the diet of *M. megalops* males, gammarid amphipods that inhabit soft bottoms (Winfield *et al.*, 2011) were their main prey. Consumption of this type of prey suggests *M. megalops* males search for sandy areas for feeding. In our work we did not characterize the diet of females; however, for the scianid *Cynoscion guatucupa* Cuvier, 1830 (Garcia 2007) both males and females were found feeding on the same types of prey on the south-western Atlantic coasts.

Although *E. entomelas* feeds on 14 prey types in Laguna Las Guásimas, Levin's index value ($Bi = 0.14$) classified it as specialist predator because of the high incidence of bivalves and polychaetes found in its diet. The same result was obtained in females and males ($Bi = 0.32$ and $Bi = 0.21$, respectively).

Micropogonias megalops consumed 12 types of prey in Laguna Las Guásimas, but Levin's index value ($Bi = 0.43$) classified it as specialist predator because of the occurrence of crustaceans (shrimp, crabs and amphipods) found in the stomachs. The specialist behaviour of *M. megalops* has also been reported in other scianids by Bocanegra-Castillo *et al.* (2000), Giberto *et al.* (2007) and Cruz-Escalona *et al.* (2010), who classify *Menticirrhus undulatus, Micropogonias furnieri* and *Cynoscion parvipinnis* as specialist predators because of the high consumption of crustaceans or molluscs.

Both predator fish (*E. entomelas* and *M. Megalops*) had a low overlap ($C\lambda = 0.14$) in diets because *E. entomelas* fed mainly on polychaetes while portunids are the preferential prey of *M. megalops*. In this respect, Varela (1990) points out that diet variations are influenced by availability and abundance of food resources, as well as by the trophic preferences of each species, which allows decreasing food competition between the species in our study and at the same time optimizes the use of resources.

In *E. entomelas* a high overlap ($C\lambda = 0.86$) was found between sexes due to the consumption of bivalves and polychaetes, indicating a good distribution of food resources in Laguna Las Guasimas. In Gerridae, Franco-López *et al.* (2011) found that consumption of resources in different proportion eliminates competition for food among individuals.

The difference in the food components consumed by *E. entomelas* and *M. megalops* suggests there are enough food resources in the lagoon, allowing a higher distribution of the groups of prey and contributing to decreased competition pressure for those resources in the lagoon.

The specimens of *M. megalops* showed sizes from 61 mm to 110 mm FL; 63 of the specimens were juveniles and six were males, suggesting *M. megalops* inhabits the lagoon in this stage for feeding and growth. However, the fact that only six specimens were sexually identified suggests that adults only come into the lagoon occasionally and use the ocean area of the Gulf of California for reproduction (Lopez-Martínez, personal communication). Yáñez-Arancibia & Nugent (1977) mention that fish inhabit the lagoon systems for feeding, growth and reproduction, which is highly relevant and highlights that although the role of the lagoons is obviously for feeding and growth, it is not the case for reproduction because many species inhabiting the lagoons perform reproduction in the ocean (Román-Rodriguez, 2000).

On the other hand, 91% of *E. entomelas* individuals were mature adults, indicating that the species uses the lagoon for feeding and reproduction, which agrees with Yáñez-Arancibia & Nugent (1977) as previously mentioned.

In our work, we found that both predators use the lagoon for feeding, as well as for growth (*E. entomelas*) and for reproduction (*M. megalops*). The lagoon provides food for fish species that inhabit it in any life stage (juvenile, adult). The difference in preferential prey among predators (*E. entomelas* and *M. megalops*) also indicates there is a good distribution of food resources in the Las Guásimas lagoon system.

To corroborate the richness of food in the lagoon, we consider it would be appropriate to conduct a comparative analysis of the available resources in the environment with respect to what is being consumed by the predators inhabiting this system.

ACKNOWLEDGEMENTS

We are grateful to the staff of the Fisheries Laboratory of Centro de Investigaciones Biológicas del Noroeste (CIBNOR Guaymas), where our samples were analysed, to Dr K de la Rosa for her comments to improve our work and to D. Dorantes and A. Arkhipkin for English editing.

FINANCIAL SUPPORT

The current study was funded by the project CIBNOR (EP12) y Ciencia Basica CONACYT (106787).

REFERENCES

Abitia-Cárdenas L.A., Galván-Magaña F. and Muhlia-Melo A.F. (1998) Espectro trófico del marlín rayado *Tetrapturus audax* (Philippi, 1887), en el área de Cabo San Lucas, Baja California Sur, México. *Revista de Biología Marina y Oceanografía* 33, 277–290.

Aguirre-León A. and Díaz-Ruiz S. (2000) Estructura poblacional, madurez gonádica y alimentación de *Eugerres plumieri* (Gerreidae) en el sistema Fluvio-Deltaico Pom-Atasta, México. *Ciencias Marinas* 26, 253–273.

Aguirre-León A. and Díaz-Ruiz S. (2004) Estructura de tallas, madurez gonádica y alimentación del pez *Diapterus rhombeus* (Gerreidae) en el sistema fluvio-deltaico Pom-Atasta, Campeche, México. *Revista de Biología Tropical* 54, 599–611.

Allen G.R. and Robertson D.R. (1998) *Peces del Pacifico Oriental Tropical.* Mexico City: CONABIO, Agrupación Sierra Madre y CEMEX.

Aragón-Noriega E.A., Valenzuela-Quiñones W., Esparza-Leal H., Ortega-Rubio A. and Rodríguez-Quiroz G. (2009) Analysis of management options for artisanal fishing of the Bigeye croaker *Micropogonias megalops* (Gilbert, 1890) in the upper Gulf of California. *International Journal of Biodiversity Science and Management* 5, 208–214.

Arceo-Carranza D., Vega-Cendejas M.E., Montero-Muñoz J.L. and Hernández de Santillana M.J. (2010) Influencia del hábitat en las asociaciones nictemareales de peces en la laguna costera tropical. *Revista Mexicana de Biodiversidad* 81, 823–837.

Arenas-Granados P. and Acero P.A. (1992) Organización trófica de las mojarras (Pisces: Gerreidae) de la Ciénega Grande de Santa Marta (Caribe Colombiano). *Revista de Biológia Tropical* 40, 287–302.

Audeves S., Pérez A.M., Rozo G. and Enríquez F. (1997) Estudio de los moluscos en Bahía Las Guásimas, Sonora. In *Congreso de la Asociación de Investigadores del Mar de Cortés, A.C*, p. 58.

Berg O. (1979) Discussion of methods of investigating the food of fishes with reference to preliminary study of the prey of *Gobiusculus flavescens* (Gobiidae). *Marine Biology* 50, 263–273.

Bertrán C., Jiménez C., Fierro P., Peña-Cortés F., Tapia J., Hauenstein E. and Vargas-Chacoff L. (2013) Alimentación de *Micropogonias furnieri* (Osteichthyes:Sciaenidae) en el lago costero Budi, Sur de Chile. *Revista de Biología Marina y Oceanografía* 48, 193–197.

Bocanegra-Castillo N., Abitia-Cárdenas L.A. and Galván-Magaña F. (2000) Espectro alimentario de la berrugata californiana *Menticirrhus undulatus* de Laguna Ojo de Liebre, Baja California Sur, México. *Ciencias Marinas* 26, 659–675.

Brusca R.C. (1980) *Common intertidal invertebrates of the Gulf of California*. Tucson, AZ: University of Arizona Press.

Burrola-Sánchez M.S., López-Martínez J., Padilla-Arredondo G., Urias-Laborin D. and Padilla-Serrato J. (2008) Influencia de los procesos costeros sobre la distribución de la medusa bola de cañon *Stomolophus meleagris* (Agassiz, 1860) en el golfo de California. In López-Martínez J. (ed.) *Variabilidad Ambiental y Pesquerias de México*. Mazatlán: Comisión Nacional de Acuacultura y Pesca, pp. 161–182.

Cailliet M.G., Love M.S. and Ebeling A.W. (1996) *Fishes: a field and laboratory manual on their structure identification, and natural history*. Belmont, CA: Wadsworth Publishing Company.

Campoy-Favela J.R. and Calderón-Aguilera L.E. (1991) Observaciones ecológicas de las comunidades bentónicas de tres sistemas costeros de Sonora, con énfasis en moluscos y crustáceos. In *Ill. Congreso de la Asociación de Investigadores del Mar de Cortés*. ITESM–Campus Guaymas. 4.

Castro-Aguirre J.L., Espinosa-Pérez H. and Schmitter-Soto J.J. (1999) *Ictiofauna estuarino-lagunar y vicaria de México*. Mexico City: Limusa–Noriega.

Contreras F. and Castañeda O. (2004) La biodiversidad de las lagunas costeras. *Ciencias* 76, 46–56.

Cruz-Escalona V.H., Campos-Dávila L., Abitia-Cárdenas L.A. and Zetina-Rejón M.J. (2010) Repartición de recursos alimentarios entre la ictiofauna dominante de una laguna templada de Baja California Sur, México. *Oceánides* 25, 1–15.

Cruz-Escalona V.H., Zetina-Rejón M.J. and Arreguín-Sánchez F. (2007) Analysis of the ecosystem structure of Laguna Alvarado, western Gulf of Mexico, by means of a mass balance model. *Estuarine, Coastal and Shelf Science* 72, 155–167.

Dawson E.Y. (1966) *Marine alge from in the vicinity of Puerto Peñasco, Sonora, Mexico. Gulf of California Field guide*. Series No.1. Tucson, AZ: The University of Arizona.

Fischer W., Krupp F., Schneider W., Sommer C., Carpenter K. and Niem V.H. (1995) *Guía FAO. Para La Identificación De Especies Para Los Fines De La Pesca*. Rome: FAO.

Franco-López J., Abarca-Arenas L.G., Barrera-Escorcia H., Bedia-Sánchez C.M. and Rivera-Felix V. (2011) Seasonal patterns of food and length–weight relationship of three species of the family Gerreidae in the Alvarado lagoon, Veracruz, Mexico. *Research Journal of Fisheries and Hydrobiology* 6, 59–68.

Garcia S. (2007) *Ecología trófica de la pescadilla de red,* Cynoscion guatucupa *(Pisces: Scianide)* en agua del Atlántico sudoccidental. BSc thesis. Universidad Nacional de Mar del Plata, Argentina.

Giberto D.A., Bremec C.S., Acha E.M. and Mianzan H.W. (2007) Feeding of the whitemouth croaker *Micropogonias furnieri* (Sciaenidae; Pisces) in the estuary of the Rio de la Plata and adjacent uruguayan coastal waters. *Atlântica, Rio Grande* 29, 75–84.

Hacunda J.S. (1981) Trophic relationships among demersal fishes in coastal area of the Gulf of Maine. *Fishery Bulletin* 79, 775–788.

Hauenstein E., Peña-Cortés F., Bertrán C., Tapia J. and Schlatter R. (2008) Comparación florística y estado trófico basado en plantas indicadoras de lagunas costeras de la región de La Araucanía, Chile. *Ecología Austral* 18, 43–53.

Hyslop E.J. (1980) Stomach contents analysis, a review of methods and their application. *Journal of Fish Biology* 17, 411–429.

Jiménez-Valverde A. and Hortal J. (2003) Las curvas de acumulación de especies y la necesidad de evaluar la calidad de los inventarios biológicos. *Revista Ibérica de Aracnología* 8, 151–161.

Kjerfve B. (1994) *Coastal lagoon processes*. Amsterdam: Elsevier.

Krebs C.J. (1989) *Ecological methodology*. New York: Harper and Row.

Liao C.H., Pierce C.L. and Larscheid J.G. (2001) Empirical assessment of indices of prey importance in the diets of predacious fish. *Transactions of the American Fisheries Society* 130, 583–591.

Miller D.J. and Jorgensen S.C. 1973. Meristic characters of some marine fishes of the western Atlantic Ocean. *US Fish and Wildlife Service Fish Bulletin* 71, 301–312.

Ontiveros-Granillo A. (2011) *Variabilidad diurna, estacional e interanual de la comunidad de peces demersales en la laguna Las Guásimas, Sonora, México*. MSc thesis. Centro de Investigaciones Biológicas del Noroeste, S.C. Guaymas, Mexico.

Palomares-Garcia R., Suárez-Morales E. and Hernández-Trujillo S. 1998. *Catálogo de los Copépodos (Crustacea) Pelágicos del Pacífico Mexicano*. Mexico City: CICIMAR-ECOSUR.

Pinkas L., Oliphant M.S. and Iverson L.K. (1971) Food habits of albacore, bluefin tuna, and bonito in California waters. *California Department of Fish and Game Fishery Bulletin* 152, 105.

Rodríguez-Félix D. (2010) *Cambios interanuales en la estructura de la comunidad de peces de una laguna costera semiárida del Golfo de California*. MSc thesis. Instituto Tecnológico de Guaymas, Mexico.

Román-Rodriguez M.J. (2000) Estudio poblacional del chano norteño, *Micropogonias megalops* y la curvina Golfina *Cynoscion othonopterus* (Gilbert) (Pisces: Scianidae), especies endémicas del Alto Golfo de California, México. *Instituto del Medio Ambiente y Desarrollo Sustentable del Estado de Sonora. Informe final SNIB-CONABIO*, no. L298, 143 pp.

Smithsonian Tropical Research Institute (2008) *Shorefishes of the Tropical Eastern Pacific Online Information System*. Available at: http://biogeodb.stri.si.edu/sftep/taxon_option_main.php?lvl=S&id=1042 (accessed 31 January 2014).

Smith P.E. and Zaret M.T. (1982) Bias in estimating niche overlap. *Ecology* 63, 1248–1253.

Stillwell C.E. and Kohler N.E. (1982) Food and feeding ecology of the swordfish *Xiphias gladius* in the western North Atlantic Ocean with estimates of daily ration. *Marine Ecology Progress Series* 22, 239–247.

Solís-Celada F., Quiroga-Brahms C. and Valdés-Guzmán A. (1996) La pesquería de Mojarra la Pesca. In *SEPESCA, Instituto Nacional de la Pesca Pesquerías relevantes de México* (ed.) Tomo II. pp. 539–555.

Tirasin M.E. and Jorgensen T. (1999) An evaluation of the precision of diet description. *Marine Ecology Progress Series* 182, 243–252.

Varela R.A. (1990) *Aspectos tróficos de las mojarras (Pisces: Gerreidae) en tres sistemas costeros de Sonora*. BSc thesis. Universidad Autonoma de Baja California Sur, Mexico.

Winfield I., Cházaro-Olvera S., Ortiz M. and Palomo-Aguayo U. (2011) Lista actualizada de las especies de anfípodos (Peracarida: Gammaridea y Corophiidea) marinos invasores en México. *Revista de Biología Marina y Oceanografía* 46, 349–361.

and

Yánez-Arancibia A. and Nugent R.S. (1977) El papel ecológico de los peces en estuarios y lagunas costeras. *Anales del Instituto de Ciencias del Mar y Limnologia, Universidad Nacional Autonoma de Mexico* 4, 107–114.

Correspondence should be addressed to:
J. López-Martínez
Centro de Investigaciones Biológicas del Noroeste, S.C. Km 2.35 Carretera a Las Tinajas, S/N Colonia Tinajas. Guaymas Sonora, C.P. 85460, Mexico
email: jlopez04@cibnor.mx

https://doi.org/10.1017/S0025315414000198 Published online by Cambridge University Press