

# Feeding habits of the toothed flounder *Cyclopsetta querna* (Paralichthyidae) of the south-east Gulf of California

FELIPE AMEZCUA<sup>1</sup>, ALFONSO PORTILLO<sup>2</sup> AND FELIPE AMEZCUA-LINARES<sup>3</sup>

<sup>1</sup>Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, Joel Montes Camarena s/n, Mazatlán, Sinaloa, 82040, México, <sup>2</sup>Facultad de Ciencias del Mar, Universidad Autónoma de Sinaloa, Paseo Claussen S/N. Mazatlan, Sinaloa, 82000, México, <sup>3</sup>Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, Circuito Exterior, Ciudad Universitaria, México D.F. 04510, Mexico

*Feeding habits of the toothed flounder Cyclopsetta querna caught in the south-east Gulf of California were studied. Specimens were collected via demersal fish surveys. Results of this study show that C. querna is a predator that focuses on fish inhabiting the bottom and in particular on tonguefish (Symphurus sp.), midshipman fish (Porichthys sp.) and moray eels (Muraenidae). The diet of the toothed flounder did not vary significantly throughout the period of study, and neither size nor sex-related variations in diet composition were observed. Simpson's index indicates a limited trophic niche breadth with a diet dominated by a limited number of taxa. The estimated TROPH value for C. querna is similar to that estimated for other demersal top predators from the studied area; therefore, the toothed flounder can be considered a top carnivore from the demersal community in the Gulf of California.*

**Keywords:** *Cyclopsetta querna*, feeding habits, trophic niche, multivariate analyses, trophic level, Gulf of California

Submitted 9 May 2009; accepted 22 February 2010; first published online 2 June 2010

## INTRODUCTION

Feeding is one of the main activities influencing the fitness of fish species, since growth, maturation and mortality depend, directly or indirectly, on food supply (Wootton, 1990). Therefore, data derived from dietary studies can be used in fisheries research through integrating the data with appropriate fisheries models, such as multispecies virtual population analysis, and can be scaled up to the total biomass of predators and prey, information which provides estimates of the total biomass consumed by predators (Jennings *et al.*, 2001).

Moreover, studies on the feeding habits of fish are essential for understanding ecological issues such as resource-partitioning and within- and between-species competition, prey selection, predator–prey size relationships, ontogenetic dietary shifts, habitat selection and invasions (e.g. Harmelin-Vivien *et al.*, 1989; Golani & Galil, 1991; Stergiou & Fourtouni, 1991; Hughes, 1997; Labropoulou *et al.*, 1997, 1999; Labropoulou & Machias, 1998; Pauly, 2000; Scharf *et al.*, 2000).

Finally, if we consider that traditional assessment models and management strategies in fisheries have failed (e.g. Beverton, 1998; De La Mare, 1998; Smith, 1998; Stokes *et al.*, 1999; Stergiou, 2002), feeding-habit studies are necessary for the ecosystem-based management of aquatic resources, through the estimation of trophic levels (Pauly & Christensen, 2000; Pauly & Sala, 2000). Such failures are generally the result of the highly diversified and complex effects of overfishing on

the life histories of individual species and on the ecosystems in which these species are embedded (e.g. Jennings & Kaiser, 1998; Jennings *et al.*, 2001; Stergiou, 2002). Therefore, the compilation of stomach content data seems to be one of the most important steps for the development of ecosystem models through the use of various modelling tools.

The aim of the present work was to study the feeding habits of *Cyclopsetta querna* (Jordan & Bollman, 1890), a widely distributed flatfish species of the tropical and subtropical Eastern Pacific (southern Baja and the Gulf of California to Peru) (Robertson & Allen, 2006). This species inhabits sandy bottoms in the continental shelf at depths of less than 50 m, but it can be found to depths of up to 100 m (Amezcu-Linares, 2009). It is also commercially exploited. In the studied area, the species is caught by trawl and gill net artisanal fisheries all year round (Fischer *et al.*, 1995; Amezcu-Linares, 2009) because of its high abundance and biomass, which also makes it an important component of the bycatch from the shrimp trawl fishery operating in the studied area (Madrid-Vera *et al.*, 2007); according to these authors, *C. querna* accounts for 2.8% in biomass and 2.2% in abundance of demersal fish species in the area. During 2007, landings of *C. querna* were close to 1200 metric tons in the Mexican Pacific; in the area of our study, landings were close to 200 metric tons according to CONAPESCA (National Commission of Aquaculture and Fisheries, Mexico, <http://www.conapesca.sagarpa.gob.mx>).

However, biological information on *C. querna* is scarce. In general, biological data on tropical and subtropical flatfish are very limited (Reichert *et al.*, 2000). Few studies undertaken on this species have focused on aspects of its distribution (e.g. Coronado-Molina & Amezcu-Linares, 1988; Tapia-García *et al.*, 1994). Studies on other biological characteristics

### Corresponding author:

F. Amezcua

Email: famezcua@ola.icmyl.unam.mx

of this species, such as age and growth (Amezcuca *et al.*, 2006), and feeding habits (Perez-España *et al.*, 2005), are scarce, with the last one focused primarily on the trophic interactions of *C. querna* with another nine demersal species, rather than a detailed examination of the diet of *C. querna*. A thorough study into the diet of *C. querna* has yet to be undertaken.

The objective of the present study was to present detailed information on the diet composition, the niche breadth and the trophic level of *C. querna*. Considering the abundance and commercial importance of this species in the south-east Gulf of California, this work, moreover, provides basic data for the development of multispecies assessment models of this area, with the ultimate goal of developing an ecosystem-based management project within the demersal fish community of the south-east Gulf of California.

## MATERIALS AND METHODS

Demersal fishing surveys were carried out by the National Fisheries Institute of Mexico (INAPESCA) during the shrimp closed season, from May to August, on the coasts of Sinaloa (south-east Gulf of California) at monthly intervals. The samples came from surveys undertaken during the closed seasons of 2004 and 2005. A total of 59 stations were surveyed over a period of two weeks on board commercial vessels (Figure 1). At each station, two commercial trawls fitted with a 30 mm liner in the cod end and average door spreads of 34.9 m were towed at 2.3 knots over one hour. A stratified survey design (depth and area) with fixed positions was applied. After each tow collection, individuals of *C. querna* were frozen on board. Additional samples were obtained from the local shrimp fleet during the shrimp open season from September 2005 to March 2006 and from December 2007 to

January 2008 at monthly intervals. The fishing gear of the local shrimp fleet was the same as described above. In the laboratory, total length (TL, cm) and wet weight (g) were recorded for each specimen; each individual was dissected, sexed, and the stomachs were removed. Stomach contents were observed under a stereoscopic microscope. The prey items, identified to the lowest possible taxonomic level on the basis of their digestion state, were counted and weighed to the nearest milligram after removal of surface water by blotting paper.

The vacuity index (VI), used to calculate the rate of feeding activity, gives the proportion of empty stomachs via the formula:

$$VI = \left( \frac{\text{number of empty stomachs/total}}{\text{number of stomachs}} \right) \times 100$$

To assess whether the number of samples analysed was sufficient to describe the diet of this species, a randomized cumulative curve was obtained by plotting the new prey types against the number of non-empty stomachs (Ferry & Caillet, 1996). The PRIMER statistical package, version 5.2.2, was used to estimate a prey species accumulation plot by randomizing the order of the stomachs. On average, 9999 randomizations were performed. To statistically assess whether the curve reached an asymptote, logarithmic and linear regressions were calculated, and their goodness-of-fit coefficients  $R^2$  were compared: the sample size was considered sufficient if the  $R^2$  for the logarithmic curve was higher than that for the linear relationship. The standard deviation was calculated and represented on the graph for every 10th stomach.

To quantitatively express the importance of different prey in the diet of *C. querna*, the frequency of occurrence (%O = (number of stomachs containing prey *i*/total number of stomachs containing prey)  $\times$  100), percentage abundance (%N = (number of prey *i*/total number of prey)  $\times$  100) and percentage weight (%W = (weight of prey *i*/total weight of all prey)  $\times$  100) were calculated (Hyslop, 1980). To assess prey dominance, the index of preponderance (Ip) was used (Marshall & Elliot, 1997). This index ranks prey in order of numerical dominance within the diet and is calculated using the formula:

$$Ip = W_i O_i / \sum (W_i O_i)$$

where  $W_i$  and  $O_i$  are percentage weight and occurrence, respectively. For this analysis, and all those given below, only stomachs that contained food were used; empty stomachs were not used.

To evaluate the niche breadth, Simpson's diversity index ( $D$ ) was used. This index gives the probability that any two individuals drawn at random from an infinitely large community belong to the same species. The form of the index appropriate for a finite community is

$$D = \sum \left( \frac{n_i [n_i - 1]}{N [N - 1]} \right)$$

where  $n_i$  is the number of individuals in the  $i$ th species, and  $N$  is the total number of individuals. As  $D$  increases, diversity decreases; this index is therefore expressed as  $1/D$ , so that the larger its value, the greater the diversity. This index also captures the variance in the species abundance distribution (Magurran, 2004). Confidence intervals for Simpson's index

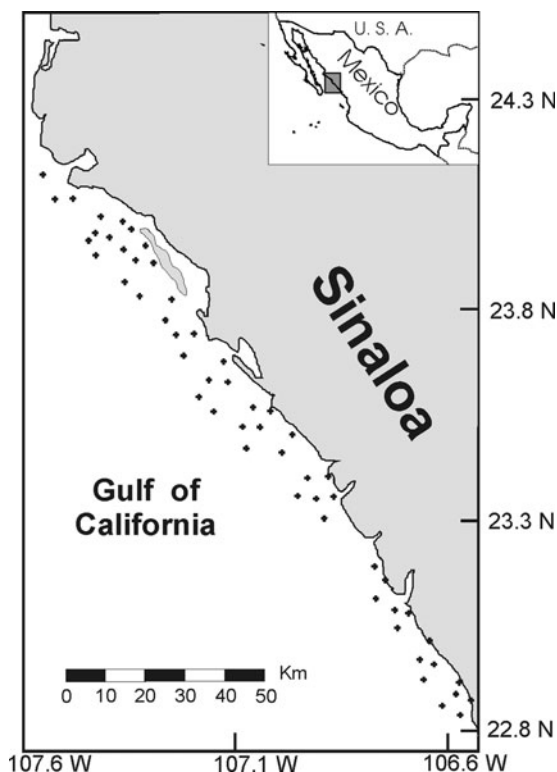


Fig. 1. Map of the studied area showing the sampling locations.

were generated using a bootstrap procedure, which is a technique that allows the estimation of sample variability by resampling from the empirical probability distribution defined by a single sample. A bias-corrected 95% confidence interval was obtained from 1000 bootstrap samples of the species (Efron & Tibshirani, 1993; Haddon, 2001). The calculation of Simpson's index and the bootstrap method were performed using the software Species Diversity and Richness IV (Pisces Conservation Ltd, 2006).

To examine dietary similarities between fish length, sampled months and sex (factors), non-metric multidimensional scaling (MDS) analyses were applied to Bray–Curtis similarity indices between pairs of samples. The data were arranged into a matrix comprising the weight (g) of each prey item, and each stomach was labelled with the sex, month and length group; length groups of 2 cm were formed. The data were fourth-root transformed to reduce the effect of very abundant prey on the analysis while retaining the quantitative nature of the data. All data were standardized to the percentage of total biomass accounted for by each species, to eliminate the effect of differing sample size. Rare prey items (<4% in any sample) were removed (Clarke & Warwick, 1994). A total of three dimensions were used. To check for statistical evidence that the diets differed among sex and season, an analysis of similarity (ANOSIM, PRIMER) was employed using *R*-statistic values for pair-wise comparisons to determine the degree of dissimilarity between groups. *R*-values lie in the range of 0 to 1; values close to 1 show that the composition of the groups are different, whereas values close to 0 demonstrate that the null hypothesis is true and that there is little difference in composition between those groups. A statistical test in which the *P* value was less than 0.05 was deemed as being different (Clarke & Warwick, 1994). A multivariate multiple permutations test, SIMPER (Similarity Percentages, PRIMER), was used in order to determine which prey categories, within each group, accounted for most of the dissimilarities between the compositions of the different sexes and the different months when they were significantly different (Clarke & Warwick, 1994). All the analyses were performed using PRIMER 5 (Clarke & Warwick, 1994; Plymouth Marine Laboratory, 1996).

Finally, diet composition data were also used for the estimation of the trophic level of the toothed flounder, using the TrophLab software (June 2000 version; Pauly *et al.*, 2000). With this software, a trophic level or *TROPH* value is obtained that expresses the position of organisms within the food webs that largely define aquatic ecosystems. To estimate the *TROPH* of fish, we must consider both their diet composition and the *TROPH* values of their food item(s). The *TROPH* of fish species *i* is then estimated from

$$TROPH_i = 1 + \sum_{j=1}^G DC_{ij} \times TROPH_j$$

where  $DC_{ij}$  is the fraction of prey *j* in the diet of consumer *i*,  $TROPH_j$  is the trophic level of prey *j*, and *G* is the number of groups in the diet of *i*. The standard error (SE) of the *TROPH* was estimated using the weight or volume contribution and the trophic level of each prey species to the diet. If such trophic levels are missing, TrophLab uses default *TROPH* values for various prey (based on data in *FishBase*, Froese & Pauly, 2009).

## RESULTS

A total of 404 stomachs of *C. querna* individuals were examined; from these, 84 were males, and 90 were females. The other 230 were small fish below 16 cm in TL, which were assumed to be juveniles, since it was not possible to determine their sex. The length-range of the examined specimens was 6.1 to 33.2 cm.

Of the 404 specimens collected, 148 had completely empty stomachs (vacuity index 36.6%). The same index was performed separately for every sex, with the males showing a vacuity index of 35.7%, the females a vacuity index of 33.3% and the juveniles a vacuity index of 38.3%.

The cumulative prey items curve (Figure 2) for the entire data set fitted better with a logistic curve ( $R^2 = 0.997$ ;  $F_{(2,254)} = 510388$ ,  $P < 0.0001$ ) than with a linear relation ( $R^2 = 0.877$ ,  $F_{(2,254)} = 11306.99$ ,  $P < 0.0001$ ); the sample size was therefore considered sufficient to describe the diet of the toothed flounder.

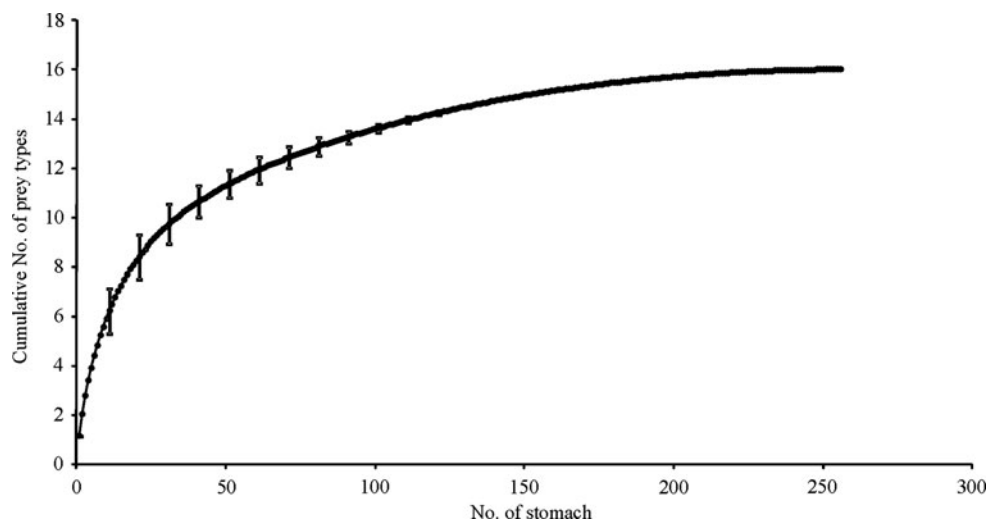


Fig. 2. Prey species accumulation plot as an average of 9999 curves based on different random orders of the stomachs extracted (number of stomachs = 148). Vertical bars represent standard deviation.

**Table 1.** Diet composition of the toothed flounder. Per cent abundance (%N), percentage by weight (%W), per cent frequency of occurrence (%O) and index of preponderance (Ip).

Prey item	%N	%W	%F	Ip
<i>Octopus vulgaris</i>	3.8	5.3	6.6	1.4
<i>Squilla</i> sp.	5.8	1.7	7.9	0.6
Paguridae	1.9	1	3.9	0.2
Unidentified errant polychaete	0.6	0.1	1.3	0.001
Dendrobranchiata	5.1	0.4	5.2	0.001
Portunidae (most likely <i>Callinectes</i> sp. & <i>Portunus</i> sp.)	3.8	0.1	3.9	0.0001
Unidentified eggs	3.2	0.001	2.6	0.001
Unidentified organic matter	0.4	1	16.1	0.001
<i>Symphurus</i> sp.	12.8	21.8	10.5	18.6
<i>Porichthys</i> sp.	11.5	19.4	6.6	11.3
Muraenidae	3.2	1.7	3.9	0.3
Engraulidae	0.6	4.8	1.3	0.3
Sciaenidae	0.6	2.8	1.3	0.1
Haemulidae	0.6	0.4	1.3	0.001
Trichiuridae	0.6	0.6	1.3	0.001
Unidentified teleost	45.5	38.8	26.3	119.8

In total, 294 prey items, belonging to 14 taxa, were identified, plus unidentified eggs and unidentified organic matter. Fish were the most frequent (%F = 52.5), abundant (%N = 75.4), had the highest biomass (%W = 90.3) and the highest values of the Ip. Of the identified fish, the most important prey were the tonguefish (*Symphurus* sp.), which also predominated in terms of percentage by weight, frequency of occurrence and abundance, followed by the midshipman (*Porichthys* sp.) and moray eels (Muraenidae). Other fish prey of the families Engraulidae, Sciaenidae, Trichiuridae and Haemulidae were occasionally recorded. Of the invertebrates, the most important prey according to the all indices and the Ip, was the common octopus (*Octopus vulgaris*), although its importance was much lower than that of the fish. The mantis shrimp (*Squilla* sp.) was also a quite important prey item; its importance was higher than that of some fish. The remaining invertebrates (hermit crabs, shrimps, polychaetes and swimming crabs) showed very low values of all indices and the Ip and were recorded only occasionally (Table 1). The toothed flounder's diet breadth was 4.13 (confidence limits = 2.8–5.7) according to the reciprocal of Simpson's diversity index.

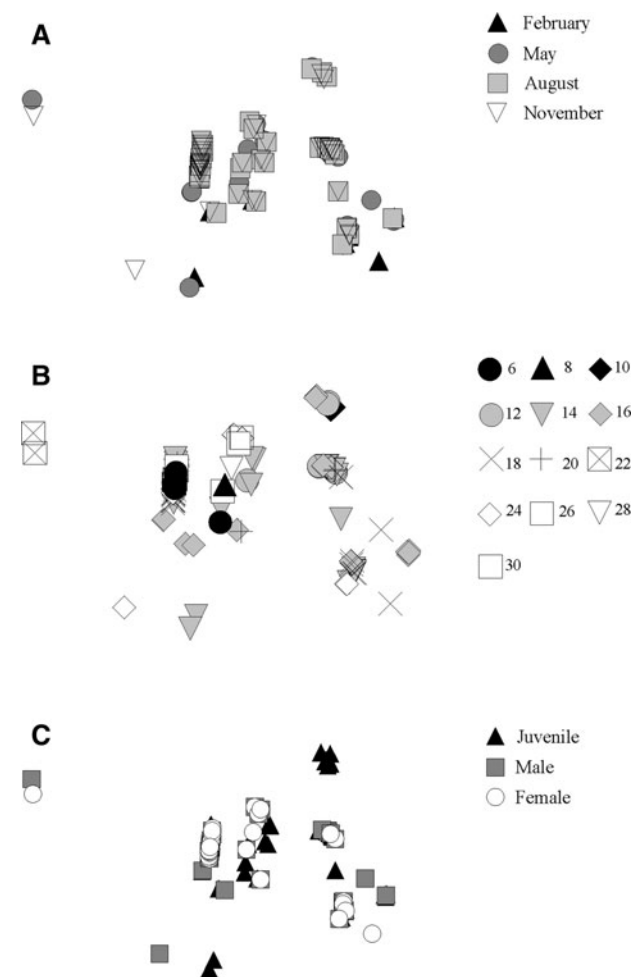
Clear-cut groups between the ordination factors (sex, size and season) were not observed in the MDS plot (stress = 0.01) (Figure 3). On the contrary, all the individuals were mixed together in the groups that were formed, with the exception of one small group comprised only of juveniles (of lengths from 10 cm to 16 cm, although individuals of 14 cm were absent from this group) (Figure 3B, top right).

The ANOSIM confirmed that the diet between sex (juveniles versus males:  $R = -0.006$ ,  $P > 0.1$ ; juveniles versus females:  $R = 0.004$ ,  $P > 0.1$ ; males versus females:  $R = -0.013$ ,  $P > 0.1$ ), size groups (global  $R = 0.049$ ,  $P > 0.05$ ) and seasons of catch (February versus May:  $R = -0.012$ ,  $P > 0.1$ ; February versus August:  $R = -0.002$ ,  $P > 0.1$ ; February versus November:  $R = -0.002$ ,  $P > 0.1$ ; May versus August:  $R = -0.009$ ,  $P > 0.1$ ; May versus November:  $R = -0.004$ ,  $P > 0.1$ ; August versus November:  $R = -0.017$ ,  $P > 0.1$ ) did not differ significantly. Because differences in the diet were not found according to the analysed factors, SIMPER analysis was not performed.

The estimated TROPH value for the toothed flounder was 4.47 (SE = 0.779).

## DISCUSSION

Previous studies on the feeding habits of Paralichthyidae species from the Pacific coast of Mexico are scarce, and for



**Fig. 3.** Two dimensional representation of the non-metric multidimensional scaling analysis based on percentage by weight values (%W) of the 2 cm size-classes. (A) Ordination according to sampling month; (B) ordination according to size-class; (C) ordination according to sex. The stress value was 0.01.

the Gulf of California non-existent. To our knowledge, this is the first study that describes in detail the feeding habits of the toothed flounder, *C. querna*, and is certainly the first study on samples of this species caught in the Gulf of California.

The fringed flounder (*Cyclopsetta querna*) has a diet dominated by demersal fish, which is its most important food source based on both number and biomass, for all individuals, from juveniles to adults, males and females, regardless of the season, and most likely of the area, since the only other work on the diet of this species indicates that demersal fish are also the principal prey of the toothed flounder of the central Pacific coast of Mexico (Perez-España *et al.*, 2005). Other prey such as benthic invertebrates were recorded occasionally. Of these, the most important were the common octopus, followed by the mantis shrimp, which was also important in the study of Perez-España *et al.* (2005), although in that study, the octopus was not identified as an item eaten by the toothed flounder.

Among fish prey, the most important according to all feeding indices were the tonguefish, the toadfish and moray eels—all demersal species with a water column position exclusively at the bottom (Robertson & Allen, 2006). After these prey items, in order of importance, were the common octopus and the mantis shrimp. These five items account for almost 40% of importance with all feeding indices and have the highest values of the index of preponderance, if the unidentified fish is not taken into account, because in this category is the most important prey item. However, it can be assumed that all the unidentified fish prey are in the same proportion of the fish that we were able to identify.

From these results it can be concluded that the toothed flounder is an active predator that preys almost exclusively on the bottom, but that has the capability to prey on other fish species that exclusively inhabit the water column, such as fish species of the family Engraulidae and family Sciaenidae, possibly when these species approach the bottom, probably to search for prey themselves.

Ambushing a continuing supply of fish and invertebrate prey seems to be the preying strategy of the toothed flounder, since the most important prey items are active species, such as swimmers (fish and octopus) or errant organisms (mantis shrimp). Feeding on other prey items such as polychaetes or crabs might require the fish to move around in search of this type of prey, possibly increasing the risk of predation. On the other hand, ambushing is energetically more beneficial and may reduce predation risk (Reichert, 2003).

Our results are in accordance with those reported by Perez-España *et al.* (2005) for the same species on the Central Pacific coast of Mexico, where they found that the family Congridae and the flatfish *Syacium ovale* accounted for 88.5% of the diet. These prey species also exclusively inhabit the bottom.

To quantitatively measure the niche breadth of the toothed flounder, we used the inverse of Simpson's index ( $1/D$ ), which is sensitive to the level of dominance in a community and is considered one of the most meaningful and robust diversity measures available (Magurran, 2004). Unfortunately, this index has not been widely used to describe the diversity and evenness of the prey assemblage, so comparison with other works could not be made. However, the reciprocal of Simpson's index can reach values of more than 9 (Magurran, 2004), so the observed value for this index (4.13) might indicate that the diet of this species focus only on a few items of those available in the system that the population inhabits. This may be why it ambushes only certain prey

types, probably as a way of resource partitioning with other sympatric species.

The multivariate analyses allowed us to determine that the diet of the toothed flounder does not vary significantly according to the season, sex or length. The main prey items for this species are mainly tonguefish, toadfish and moray eels, leaving the invertebrates and other fish species as marginal prey. Therefore, the MDS and ANOSIM could not detect statistical differences in the diet, because although differences may exist, these are minimal.

Although information on the trophic levels of other demersal fish species from the studied area is scarce, our results indicate that the toothed flounder is a top predator in the system. Usually in marine ecosystems, consumers have *TROPH* values that range between 2.0, for herbivorous/detritivorous organisms, and 5.0, for piscivorous/carnivorous organisms (Cortés, 1999). Demersal and benthopelagic inhabitants in the studied area from which *TROPH* values have been estimated have values that range from 2.5 for species such as the flathead mullet (*Mugil cephalus*) to 4.5 for species such as the Pacific sierra (*Scomberomorus sierra*) and the Mexican barracuda (*Sphyraena ensis*) (Froese & Pauly, 2009). Even the Pacific sharpnose shark (*Rhizoprionodon longurio*) and the scalloped hammerhead (*Sphyrna lewini*), both inhabitants of the studied area, have smaller *TROPH* values (4.2 and 4.1 respectively) (Froese & Pauly, 2009).

In our study, the *TROPH* value of 4.47 found for the toothed flounder is practically the same as those of the Pacific sierra and the Mexican barracuda, the top predators of the studied area, according to the available information. Hence, the toothed flounder can be considered one of the top predators in the demersal and benthopelagic ecosystem of the Gulf of California according to the *TROPH* results.

The detailed information presented in this study will be useful in ecological modelling as we move toward multispecies assessments and a better understanding of the interactions among top predators and their prey, which would eventually result in a better representation of the trophic flows associated with demersal fish in the Gulf of California. Nevertheless, to achieve this it will be necessary to continue with these types of studies for other species inhabiting the area, as well as monitoring activity regarding fishery landings, fishing efforts and variations in biotic and abiotic factors in the area over a long period, so as to fulfil the requirements of an ecosystem approach to fisheries.

## ACKNOWLEDGEMENTS

The National Institute of Fisheries (INAPESCA), through the Regional Centre of Fisheries Research in Mazatlan (CRIP-Mazatlan) donated to us samples for this study. This work was funded by the research project PAPIIT-IN217408-3.

## REFERENCES

- Amezcuca F., Martínez-Tovar I., Green-Ruiz Y. and Amezcua-Linares F. (2006) Use of otoliths to determine age and growth of a tropical flatfish *Cyclopsetta querna* (Paralichthyidae) from the southeast coast of the Gulf of California, Mexico. *Ichthyological Research* 53, 70–74.
- Amezcuca-Linares F. (2009) *Peces Demersales del Pacífico de México*. México: Instituto de Ciencias del Mar y Limnología, UNAM.

- Beverton R.** (1998) Fish, fact and fantasy: a long view. *Reviews in Fish Biology and Fisheries* 8, 229–249.
- Clarke K.R. and Warwick R.M.** (1994) *Change in marine communities: an approach to statistical analysis and interpretation*. Plymouth: PRIMER.
- Coronado-Molina C. and Amezcua-Linares F.** (1988) Demersal fishes from the coast of Guerrero, Eastern Pacific: distribution and abundance [In Spanish with an English summary.]. *Anales del Instituto de Ciencias del Mar y Limnología* 15, 67–94.
- Cortés E.** (1999) Standardized diet compositions and trophic levels of sharks. *ICES Journal of Marine Science* 56, 707–717.
- De La Mare W.K.** (1998) Tidier fisheries management requires a new MOP (management-oriented paradigm). *Reviews in Fish Biology and Fisheries* 8, 349–356.
- Efron B. and Tibshirani R.** (1993) *An introduction to the Bootstrap*. New York: Chapman & Hall.
- Ferry L.A. and Caillet G.M.** (1996) Sample size and data analysis: are we characterizing and comparing diet properly? In MacKinlay D. and Shearer K. (eds) *Proceedings of the Symposium on the Feeding Ecology and Nutrition in Fish, 14–18 July 1996*. San Francisco: American Fisheries Society, pp. 71–80.
- Fischer W., Krupp F., Schneider W., Sommer C., Carpenter K.E. and Niem V.H.** (1995) *FAO Species Catalogue for the Identification of Species for Fishing Goals. Mid West Pacific*. Rome: FAO.
- Froese R. and Pauly D.** (2009) *FishBase. World Wide Web electronic publication*. www.fishbase.org, version (05/2009).
- Golani D. and Galil B.** (1991) Trophic relationships of colonizing and indigenous goatfishes (Mullidae) in the eastern Mediterranean with special emphasis on decapod crustaceans. *Hydrobiologia* 218, 27–33.
- Haddon M.** (2001) *Modeling and quantitative methods in fisheries*. Boca Raton, FL: Chapman & Hall.
- Harmelin-Vivien M.L., Kaim-Malka R.A., Ledoyer M. and Jacob-Abraham S.S.** (1989) Food partitioning among scorpaenid fishes in Mediterranean seagrass beds. *Journal of Fish Biology* 34, 715–734.
- Hughes R.N.** (1997) Diet selection. In Godin J.G.J. (ed.) *Behavioural ecology of teleost fishes*. Oxford: Oxford University Press, pp. 134–162.
- Hyslop E.J.** (1980) Stomach contents analysis—a review of methods and their application. *Journal of Fish Biology* 17, 411–429.
- Jennings S. and Kaiser M.J.** (1998) The effects of fishing on marine ecosystems. *Advances in Marine Biology* 34, 201–352.
- Jennings S., Kaiser M.J. and Reynolds J.D.** (2001) *Marine fisheries ecology*. Oxford: Blackwell Science.
- Labropoulou M. and Machias A.** (1998) Effect of habitat selection on the dietary patterns of two triglid species. *Marine Ecology Progress Series* 173, 275–288.
- Labropoulou M., Machias A., Tsimenides N. and Eleftheriou A.** (1997) Feeding habits and ontogenetic shift of the striped red mullet, *Mullus surmuletus* Linnaeus, 1758. *Fisheries Research* 31, 257–267.
- Labropoulou M., Machias A. and Tsimenides N.** (1999) Habitat selection and diet of juvenile red porgy, *Pagrus pagrus* (Linnaeus, 1758). *Fishery Bulletin* 97, 495–507.
- Madrid-Vera J., Amezcua F. and Morales-Bojorquez E.** (2007) An assessment approach to estimate biomass of fish communities from bycatch data in a tropical shrimp-trawl fishery. *Fisheries Research* 83, 81–89.
- Magurran A.E.** (2004) *Measuring biological diversity*. Oxford: Blackwell.
- Marshall S. and Elliot M.** (1997) A comparison of univariate and multivariate numerical and graphical techniques for determining inter- and intraspecific feeding relationships in estuarine fish. *Journal of Fish Biology* 51, 526–545.
- Pauly D.** (2000) Predator-prey ratios in fishes. In Froese R. and Pauly D. (eds) *FishBase 2000: concepts, design and data sources*. Manila: ICLARM, p. 201.
- Pauly D. and Christensen V.** (2000) Trophic levels of fishes. In Froese R. and Pauly D. (eds) *FishBase 2000: concepts, design and data sources*. Manila: ICLARM, p. 181.
- Pauly D. and Sala P.** (2000) Estimating trophic levels from individual food items. In Froese R. and Pauly D. (eds) *FishBase 2000: concepts, design and data sources*. Manila: ICLARM, p. 185.
- Pauly D., Froese R., Sala P.S., Palomares M.L., Christensen V. and Rius J.** (2000) *TrophLab Manual*. Manila: ICLARM.
- Perez-España H., Saucedo-Lozano M. and Raymundo-Huizar A.R.** (2005) Trophic ecology of demersal fishes from the Pacific shelf off central Mexico. *Bulletin of Marine Science* 77, 19–31.
- Reichert M.J.M.** (2003) Diet, consumption, and growth of juvenile fringed flounder (*Etropus crossotus*); a test of the ‘maximum growth/optimum food hypothesis’ in a subtropical nursery area. *Journal of Sea Research* 50, 97–116.
- Reichert M.J.M., Dean J.M., Feller R.J. and Grego J.M.** (2000) Somatic growth and otolith growth in juveniles of a small subtropical flatfish, the fringed flounder *Etropus crossotus*. *Journal of Experimental Marine Biology and Ecology* 254, 169–188.
- Robertson D.R. and Allen G.R.** (2006) *Shorefishes of the Tropical Eastern Pacific: an information system*. Balboa: Smithsonian Tropical Research Institute.
- Scharf F.S., Juanes F. and Rountree R.A.** (2000) Predator size–prey size relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic niche breadth. *Marine Ecology Progress Series* 208, 229–248.
- Smith T.D.** (1998) Simultaneous and complementary advances: mid-century expectations of the interaction of fisheries science and management. *Reviews in Fish Biology and Fisheries* 8, 335–348.
- Stergiou K.I.** (2002) Overfishing, tropicalization of fish stocks, uncertainty and ecosystem management: resharpening Ockham’s razor. *Fisheries Research* 55, 1–9.
- Stergiou K.I. and Fourtouni H.** (1991) Food habits, ontogenetic diet shift and selectivity in *Zeus faber* Linnaeus, 1758. *Journal of Fish Biology* 39, 589–603.
- Stokes T.K., Butterworth D.S., Stephenson R.L. and Payne A.I.L.** (1999) Confronting uncertainty in the evaluation and implementation of fisheries-management systems. *ICES Journal of Marine Science* 56, 795–796.
- Tapia-García M., García-Abad M.C., González-Medina G., Macuitl M.C., De Guevara M. and De Guevara G.C.L.** (1994) Composition, distribution and abundance of the demersal fish community in the Gulf of Tehuantepec, Mexico. *Tropical Ecology* 35, 229–252.
- and
- Wootton R.J.** (1990) *Ecology of teleost fish*. London: Chapman & Hall.

#### Correspondence should be addressed to:

F. Amezcua  
 Instituto de Ciencias del Mar y Limnología  
 Universidad Nacional Autónoma de México  
 Joel Montes Camarena s/n, Mazatlán  
 Sinaloa, 82040, México  
 email: famezcua@ola.icmyl.unam.mx