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Feeding Habits of Dwarf Goatfish (*Upeneus parvus*: Mullidae) on the Continental Shelf in the Gulf of Mexico

L. Campos-Dávila, V. H. Cruz-Escalona, L. A. Abitía-Cárdenas, F. Galván-Magaña, and E. F. Balart

Feeding habits of dwarf goatfish on the continental shelf off Alvarado, Veracruz, Mexico, were analyzed to determine seasonal variation and size-class changes in diet composition and trophic overlap between size classes. Food was found in 63% of the 1,437 dwarf goatfish guts analyzed. The 52 dietary items identified consisted mainly of crustaceans, with *Solenocera vioscai* being the most important prey. Dwarf goatfish exhibited seasonal and size-class changes in prey consumption. Despite the high number of prey items, low values of diversity and diet breadth were found in the trophic spectrum. A high trophic overlap between size classes was observed in the north-winds season between length classes (92–111 vs 112–130 mm) (λ = 0.81) and (92–111 vs 131–150 mm) (λ = 0.80), and (112–131 vs 131–150 mm) (λ = 0.67). In the rainy season high overlaps were obtained between (92–111 vs 112–131 mm) (λ = 0.73) and (112–131 vs 131–150 mm) (λ = 0.84) length classes. Dwarf goatfish appear to be opportunistic carnivorous predators that impact benthic and epibenthic invertebrates.

The Mullidae (goatfishes) differ from other percoid families in a number of structural features. The most notable of these is a pair of highly developed hyoid barbels; probably all goatfishes use their two barbels to detect food items on or slightly below the surface of the substrate (Gosline, 1984). Each pair is independently movable and bears numerous sense organs (Sato, 1937). When a goatfish is not feeding, the barbels are folded back under the rims of the chin and covered by the gills. During feeding, the barbels are lowered under the fish to touch the bottom (Gosline, 1984; Golani and Galil, 1991). Goatfish are carnivorous, feeding on benthic invertebrates, including worms, shrimp, fishes, amphipods, brittle stars, urchins, crabs, and mollusks (Wahbeh and Ajiad, 1985; Golani and Galil, 1991; Vassilopoulou and Papaconstantinou, 1993; Kuiter, 1994). Although a small number of species occur in temperate seas at depths of 5–140 m, mullids are bottom-dwelling species inhabiting sandy and muddy substrata principally in tropical and subtropical environments (Munro, 1976; Kuiter, 1994). Dwarf goatfish are distributed from North Carolina to Venezuela (Fischer, 1978). Trawling in shallow waters of the continental shelf of the Gulf of Mexico indicated that the dwarf goatfish are one of the most abundant demersal fish species in these waters (Yañez-Arancibia et al., 1985).

Despite their high incidental catches in the shrimp fishery, there is no information on the biology of the dwarf goatfish. Mullid studies around the world reported seasonal and size-related changes in dietary composition. Lee (1973) examined the stomach contents of red goatfish (*Upeneus moluccensis*) on fishing grounds near Hong Kong and concluded that red goatfish fed on benthic organisms, with crustaceans, polychaetes, and fish being the main food groups.

Feeding habits and diet composition of two mullids, *U. asymmetricus* and *U. moluccensis,* and two indigenous goatfish, *Mullus barbatus* and *M. surmuletus,* in the eastern Mediterranean have been investigated by Golani and Galil (1991). They found that *Leptochela pugnax,* a pasiphaeid crustacean of Red Sea origin, was the most important prey of all the mullids studied, resulting in high trophic overlap between all species.

The main objective of this study is to determine the ontogenetic and seasonal dietary changes and trophic overlap of dwarf goatfish over the continental shelf off Alvarado, Veracruz, Mexico.

Material and Methods

Dwarf goatfish were collected from Sep. 1994 to Aug. 1995 (except in May and June 1995) from the commercial shrimp fishery on the continental shelf off Alvarado, Veracruz, Mexico (Fig. 1). Three seasons are usually recognized in the study area: dry season (Feb.–May), rainy season (June–Sep.), and north-winds season (Oct.–Jan.).

The commercial shrimp fishery uses a standard twin otter trawl (20-m length; 10-m width

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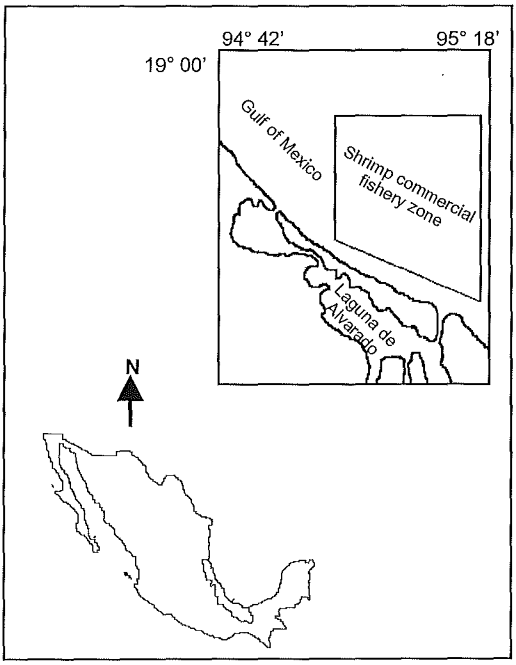

Fig. 1. Study area. Commercial shrimp fishery zone off Alvarado, Veracruz, Mexico.

with 4.5-cm mesh size). Fish were separated from the bycatch and immediately injected with a buffered solution of 10% formaldehyde and sodium borate into the abdominal cavity to stop the digestive processes. The fish were then stored in bags with 10% formaldehyde and transported to the Laboratory of Ecology in the UNAM campus of Iztacala in Mexico City.

Dietary Analyses

In the laboratory, each specimen was washed with flowing water and preserved in 70% ethanol. The dwarf goatfish were thawed, and standard length was measured to the nearest 1.0 mm. Body length measurement followed definitions from Fischer (1978). Stomach contents were removed and stored in 50% isopropyl alcohol until identification and analysis could be completed. Stomach contents were sorted, counted, and identified to the lowest taxon. In most cases, the retention of hard parts was required to identify items to species, and many items could be identified only to family or order. Most fish remains could only be identified as fish remains from vertebrae or scales.

The prey were quantified by number, weight, and occurrence frequency; then, diet was described by percent frequency of occurrence (%F), percent number (%N), and percent weight (%W) of each dietary item (Hyslop, 1980). Gut contents of males and females were pooled.

Cumulative prey curves were constructed to determine if an adequate number of fish had been collected to characterize the diet, according to the methodology proposed by Ferry et al. (1997), where gut contents were analyzed by randomizing 50 times, and the mean number of new prey species found consecutively in the guts was plotted against the number of guts analyzed. Standard deviation was also plotted for each gut to determine if the curve was asymptotic, and a sufficient number of samples had been analyzed.

Five size-class subgroups were selected for analysis as separate size classes: (<73–92 mm), (93–111 mm), (112–131 mm), (131–150 mm), and (>150 mm). Cumulative prey curves were constructed to determine if there were enough guts analyzed to describe the feeding habits of each subgroup.

The percentage contribution by weight of the various dietary items by season and length class was calculated. Species diversity of the prey in the diet was calculated for each season and size class using the Shannon–Wiener index (Krebs, 1989). Levin's standardized index was used to assess the diet breadth (Krebs, 1989). This index ranges from 0 (specialist diet) to 1 (generalist diet) (Krebs, 1989; Labropoulou and Eleftheriou, 1997).

The degree of similarity among the dietary compositions of each length class in all seasons was assessed using the Morisita–Horn overlap index (Krebs, 1989), in which values range from 0 (no overlap) to 1 (complete overlap).

Results

Overall dietary composition.—Stomach contents were found in 909 (63%) of the 1,437 guts of the dwarf goatfish sampled. Cumulative prey for all guts containing food items, based on all prey categories (Table 1), reached an asymptote in all three seasons (Fig. 2). When the five size classes were analyzed independently for sampling periods, most curves quickly reached an asymptote, suggesting that a sufficient number of fish were collected in each class for consideration as separate size classes.

Fifty-two dietary items were identified, most of them crustaceans (Table 1), of which 50% were recorded in the north-winds season, 80% in the rainy season, and 60% during the dry season. The next group of prey that was con-

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TABLE 1. Percentage contribution by weight (%W), frequency of occurrence (FO), and number (%N), of the prey taxa and species to total diets by season in the dwarf goatfish *Upeneus parvus* in the continental shelf off Alvarado, Veracruz, Mexico.

	North-winds season			Rainy season			Dry season		
Prey	%W	%F	%N	%W	%F	%N	%W	%F	%N
Crustacea									
Decapoda	—	—	—	0.8	1.59	0.3	—	—	—
Portunus spinicarpus	7.3	35.14	27.22	3.8	16.83	18.18	23.55	64.86	28.13
Callinectes sapidus	—	—	—	0.0	1.59	0.4	0.0	1.18	0.6
Farfantepenaeus aztecus	1.6	4.5	3.5	14.75	15.24	7.0	6.0	12.97	8.5
Solenocera vioscai	30.65	35.14	28.40	25.70	38.41	16.88	17.67	25.00	10.05
Xiphopenaeus spp.	2.0	0.9	0.5	12.89	3.49	2.2	0.3	0.71	0.5
Sicyonia dorsalis	11.37	2.7	2.3	6.1	5.71	1.5	2.2	3.54	1.2
Trachipenaeus constrictus	6.4	6.3	5.3	17.14	4.13	2.4	10.23	4.48	2.1
Squilla chydea	0.1	0.9	0.5	0.4	1.90	0.4	—	—	—
S. empusa	—	—	—	0.0	0.63	0.1	0.5	0.71	0.2
Lucifer spp.	0.2	0.9	0.5	0.0	0.32	0.0	0.0	0.94	0.5
Calappa sulcata	1.1	4.5	2.9	3.0	7.62	10.03	10.14	13.92	5.0
Partenope spp.	0.5	1.8	1.7	0.0	0.32	0.0	—	—	—
Leiolambrus nitidus	0.4	1.8	1.1	0.0	1.27	0.0	—	—	—
Synaplheus spp.	—	—	—	0.1	0.95	0.2	—	—	—
Palemon spp.	—	—	—	1.6	7.62	5.9	—	—	—
Sylarus vioscai	—	—	—	0.1	0.95	0.2	—	—	—
Macrobrachium spp.	—	—	—	0.2	1.90	0.6	2.7	4.72	2.6
Brachycarpus spp.	—	—	—	0.1	0.63	0.2	—	—	—
Diogenidae				—	—	—	0.0	0.24	0.0
Majidae	—	—	—	0.1	0.95	0.3	—	—	—
Iliacantha subglobosa	—	—	—	0.2	2.22	0.9	2.0	12.97	8.9
Axiidae	—	—	—	0.0	0.32	0.0	—	—	—
Processa spp.	—	—	—	4.1	5.08	3.5	2.7	3.54	2.1
Raninoides laevis	—	—	—	—	—	—	0.0	0.24	0.0
Alpheidae	—	—	—	0.0	0.32	0.0	—	—	—
Panopeus spp.	—	—	—	—	—	—	0.0	0.24	0.0
Pinnixa spp.	—	—	—	0.0	0.32	0.0	—	—	—
Xanthidae	—	—	—	1.7	3.81	12.48	—	—	—
Gammaridae	—	—	—	0.0	0.32	0.0	—	—	—
Ampelisca spp.	0.0	0.9	1.1	0.1	10.48	3.9	0.0	5.90	3.0
Caprellidae	—	—	—	0.0	0.32	0.1	—	—	—
Copepoda	—	—	—	0.0	0.32	3.0	—	—	—
Isopoda	0.0	1.8	1.1	0.0	0.32	0.0	0.0	0.94	0.3
Ostracoda	—	—	—	0.1	0.63	2.4	0.001	0.24	0.0
Podobothrus spp.	—	—	—	0.0	0.32	0.1	—	—	—
Chaetognata	—	—	—	0.0	0.32	0.0	—	—	—
Tanaidacea	—	—	—	0.0	0.32	0.0	—	—	—
Sipunculida	—	—	—	—	—	—	0.0	0.24	0.0
Echinodermata	—	—	—	—	—	—	0.0	0.47	0.1
Ophiuridae	0.3	1.8	2.9	—	—	—	—	—	—
Mollusca	—	—	—	—	—	—	—	—	—
Gastropoda	0.2	2.7	1.7	0.3	1.59	0.3	0.0	1.65	2.9
Macoma spp.	0.0	0.9	0.5	0.0	1.59	1.0	1.7	7.08	8.5
Loligo spp.	6.6	2.7	1.7	—	—	—	2.0	0.24	0.0
Aplysia spp.	—	—	—	0.0	0.32	0.0	—	—	—
Annelida	—	—	—	—	—	—	—	—	—
Polychaeta	2.5	4.5	3.5	0.2	2.22	0.5	2.3	4.48	2.1
Actinopterygii									
Bregmeceros cantori	20.91	12.61	10.06	5.1	10.79	2.8	14.82	21.46	10.73
Ophidium graelsi	5.5	1.8	1.1	—	—	—	—	—	—
Microdesmidae	—	—	—	—	—	—	0.1	0.47	0.2
Myrophis punctatus	—	—	—	0.1	0.32	0.0	—	—	—
Fish remains	1.4	1.8	1.1	0.1	1.26	0.2	0.2	2.12	0.6

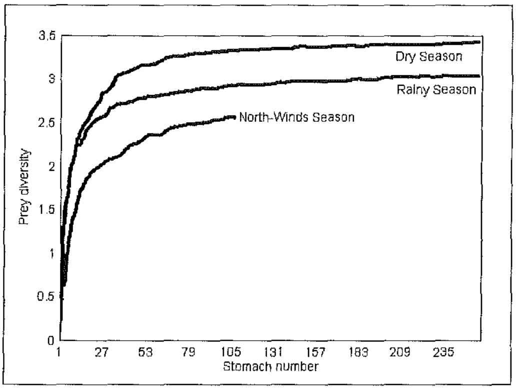

Fig. 2. Randomized cumulative prey curve for all fish with gut contents analyzed.

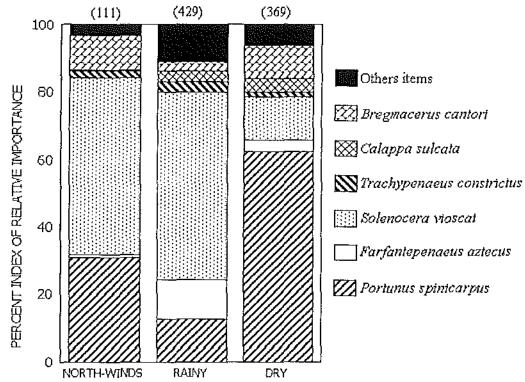

Fig. 3. Seasonal variation of the major prey species in the diet of the dwarf goatfish *Upeneus parvus* determined by index of relative importance (IRI) over the continental shelf of the Gulf of Mexico.

sumed the most was fishes, followed by mollusks and worms.

During the north-winds season, 21 food items were consumed. The decapods, *Solenocera viosacai* and *Portunus spinicarpus,* and the fish *Bregmaceros cantori* dominated the diet in number (28, 27, and 10% respectively), weight (30, 7, and 20%), and frequency of occurrence (35, 35, and 13%). During this season, these three abundant species accounted for at least 55% of the total diet (Fig. 3).

During the rainy season, 42 food items were consumed. However, only a few prey species, mostly decapods, were found at high percentages in the diet (Table 1). The most important prey by weight were *S. vioscai* (26%), *Trachypenaeus constrictus* (17%), *Farfantepenaeus aztecus* (15%), and *Xiphopenaeus* spp. (12%). The higher contributions by number were accounted to *P. spinicarpus* (18%), *S. vioscai* (17%), Xanthidae (12%), and *Calappa sulcata* (10%). In this season *S. vioscai* (38%) was the most frequent food item in the diet of dwarf goatfish; the major fish species in the diet of dwarf goatfish was *B. cantori,* which was, however, of less importance compared with crustaceans (Table 1).

In the dry season 28 food items were consumed. The most common prey (65%) in the diet of the dwarf goatfish was *P. spinicarpus,* dominating the diet in number (28%) and weight (24%). Secondary prey by number were *S. vioscai* (10%), *B. cantori* (11%), *Iliacantha subglobosa* (9%), and *F. aztecus* (8%). Secondary prey by weight were *S. vioscai* (18%), *B. cantiori* (15%), *T. constrictus* (10%), and *C. sulcata* (10%).

Ontogenetic changes, dietary breadth, and dietary overlap.—During the north-winds season, *P. spinicarpus, S. vioscai,* and *B. cantori* dominated the diet of the first three size intervals (92–111, 112–130, and 131–150 mm), contributing almost 60% of the total dietary weight. Additionally, *F. aztecus* contributed between 8 and 10% in the first two length classes. *Trachypenaeus constrictus* made a high contribution (21%) to dietary weight in the 131- to 150-mm size class (Fig. 4a).

In the rainy season the Xanthidae family, *S. vioscai,* and *P. spinicarpus* dominated the diet of 92- to 111-mm individuals; other secondary diet items were *F. aztecus* and *C. sulcata.* In the 112- to 130-mm length class the contribution of Xanthidae decreased to 4%, and *S. vioscai* and *P. spinicarpus* increased their contribution; *C. sulcata* also made a major contribution (17%) to dietary weight. Most fish >130 mm preyed mainly on *F. aztecus* (42%) and *S. vioscai* (36%).

During the dry season, the diet of 92-mm or smaller individuals was dominated (>95% gut content weight) by the prey *P. spinicarpus, F. aztecus, B. cantori, S. vioscai,* and *C. sulcata,* with small percentages of *T. constrictus* and other items (Fig. 4c). As dwarf goatfish increased in length, the prey *C. sulcata* and *F. aztecus* contributed less to the diet, and *T. constrictus* and *S. vioscai* increased their contribution.

Values of Shannon's index (H′) and Levin's index (Bi) among all length classes of dwarf goatfish were <3 bits/individual and <0.6, respectively. Diversity prey values and dietary breadth were lowest during the rainy season (Table 2). Values in this range suggest that this predator could be categorized as having opportunistic feeding habits.

In general, dietary overlap values between size classes were high. The overlap was most

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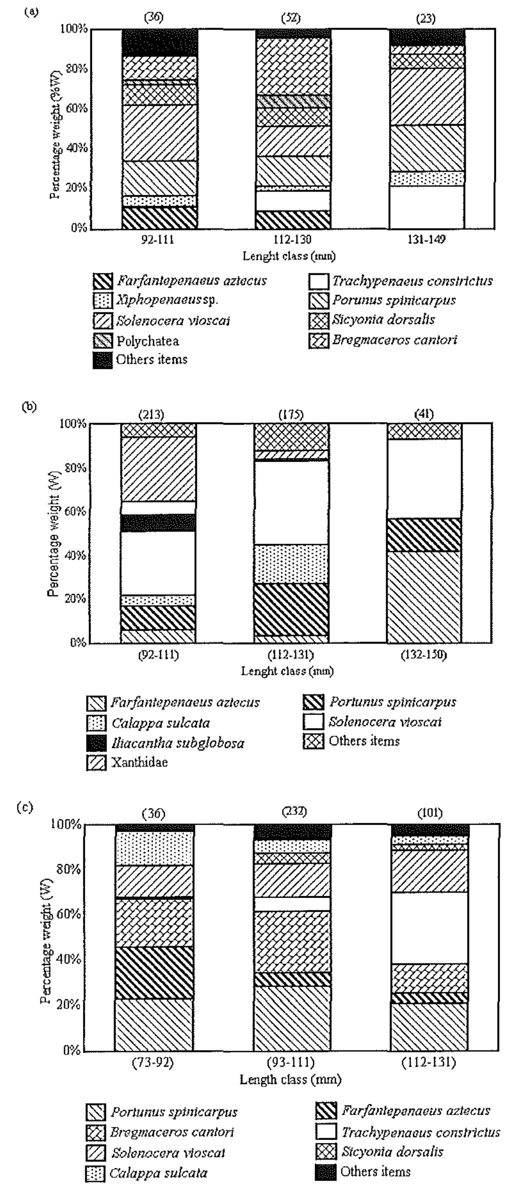

Fig. 4. Percentage contribution of the most important food item toward wet weight of the gut contents found in the dwarf goatfish (*Upeneus parvus*) in the western Gulf of Mexico. Each bar represents a fish size class: (a) north-winds season, (b) rainy season, and (c) dry season.

evident during the north-winds season between length classes (92–111 vs 11 2–130 mm) (λ = 0.81), (92–111 vs 131–150 mm) (λ = 0.80), and (112–131 vs 131–150 mm) (λ = 0.67). In the rainy season high overlaps were obtained between the (92–111 vs 112–131 mm) (λ = 0.73) and (112–131 vs 131–150 mm) (λ = 0.84) length classes. During the rainy season, low overlaps were observed.

Discussion

A large number of dwarf goatfish stomachs were empty, which could be caused by the sampling method used. During trawling, fish are under stress (Harden, 1957; Haight, 1993) and probably regurgitate their food; however, the stomach number to represent the diet of this species was adequate according to the methodology of Hoffman (1978) (Fig. 2).

We consider that in coastal waters of the continental shelf off Alvarado, Veracruz, Mexico, dwarf goatfish are carnivorous, feeding on several benthic and epibenthic invertebrates, mostly crustaceans. Our findings generally agree with published information on the food habits of other mullid species (Lee, 1973; Wahbeh and Ajiad, 1985; Golani and Galil, 1991; Labropolou and Eleftheriou, 1997; Platell et al., 1998).

In general, dwarf goatfish exhibited a varied diet, with only seven species representing the bulk of its diet. The main dietary items were crustaceans (*S. vioscai, P. spinicarpus, T. constrictus, F. aztecus*) and one fish (*B. cantori*). These prey inhabit sandy and muddy substrates and have sedentary habits or limited movements.

Seasonal differences were observed. *Solenocera vioscai* dominated the diet of dwarf goatfish collected in the north-winds and rainy seasons, whereas *P. spinicarpus* was the most important prey in the dry season, making up to 60% of the diet by index of relative importance (IRI). The importance of each food item in the diet of any predator is a function of two factors: a) the predator size, which allows the predator to eat prey of different size, and b) the prey availability, which is related to the environmental conditions (e.g., Daan, 1973; Klemetsen, 1982).

We suspect that seasonal prey changed by season as a result of changing prey availability. However, there are no studies regarding the abundance of invertebrates on the continental shelf off Alvarado, Veracruz, Mexico, to verify the seasonal changes in the main prey of dwarf goatfish.

The low values of diversity and diet breadth were controlled by the predominance of small prey in the trophic spectrum. According to Vega-Cendejas et al. (1994), each species has a different niche breadth depending on its morphological and physiological changes. Gerking (1994) defined this variation as "phenotypic

TABLE 2. Seasonal variation in ecologial attributes in the diet of the dwarf goatfish on Alvarado, Veracruz, Mexico.

Size class	North-winds season			Rainy season			Dry season		
	H'	J'	Bi	H'	J'	Bi	H'	J'	Bi
<73–92 mm							2.4	0.8	0.6
93–111 mm	3.0	0.8	0.4	2.6	0.8	0.4	2.8	0.9	0.4
111–131 mm	2.9	0.8	0.5	2.5	0.6	0.2	2.6	0.8	0.4
131–150 mm	2.6	0.8	0.5	1.8	0.6	0.2	1.8	0.7	0.5
>150 mm	0.6	0.6	0.4						

plasticity," in which prey preference changes according to body and growth needs.

The high values of the Morista–Horn indexes overlap between *U. parvus* length classes. The higher dominance of *S. vioscai* in the diet of all size classes of *U. parvus* would explain the highest overlap values obtained. Golani and Galil (1991) found a high overlap in the diets of some Mullids from the Mediterranean: *U. asymmetricus, U. moluccensis, M. barbatus,* and *M. surmuletus.*

In summary, crustaceans are the most important prey items of dwarf goatfish on the continental shelf off Alvarado, Veracruz, Mexico. Within the benthic crustaceans, the incidence of *S. vioscai, P. spinicarpus,* and *P. aztecus* is caused by their demersal lifestyle in comparison with that of the faunal species prey found: polychaetes, mollusks, cumacea, and isopods. The prey seasonal availability was an important factor in the differences found by season.

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