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Food habits of the yellow snapper *Lutjanus argentiventris* (Peters, 1869) (Percoidei: Lutjanidae) in La Paz Bay, Mexico

Hábitos alimenticios del pargo amarillo *Lutjanus argentiventris* (Peters, 1869) (Percoidei: Lutjanidae) en la Bahía de La Paz, México

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Resumen.- Se analizaron 304 estómagos del pargo amarillo *Lutjanus argentiventris* recolectados bimestralmente de abril 2003 a abril 2004, de los cuales 44% presentó alimento (44%). Se identificaron 54 tipos de presa. De acuerdo con el índice de importancia relativa (IIR), los huevos de peces (62%) y los peces *Harengula thrissina* (23%), *Porichthys margaritatus* (3,3%) y *Abudefduf troschelii* (2,3%) fueron las presas de mayor importancia en su dieta. En los juveniles, las presas de mayor importancia fueron la materia orgánica no identificada (32%), los crustáceos *Upogebia pugettensis* (29%) y los camarones peneidos (6,5%), así como los huevos de peces (5,2%). El índice de Levin determinó que la amplitud de la dieta fue baja (*Bi*= 0,0002), siendo considerado un depredador selectivo, mostrando un consumo preferencial por los huevos de peces y *H. thrissina*. El mismo resultado se obtuvo para machos (*Bi*=0,0002) y hembras (*Bi*=0,0009). Los juveniles mostraron una baja amplitud de dieta, consumiendo principalmente materia orgánica no identificada y *U. pugettensis*. El índice de Morisita-Horn mostró un traslapo significativo en la dieta por sexo, ($C\lambda$>0,6), mientras que para juveniles y adultos se registró un traslapo bajo ($C\lambda$<0,6), reflejando la diferencia de su hábitat.

Palabras clave: Pargo amarillo, espectro trófico, presas importantes, Golfo de California

Abstract.- A total of 304 yellow snapper *Lutjanus argentiventris* stomachs were sampled bimonthly from April 2003 to April 2004, of which 44% contained food. We identified 54 prey species. From the index of relative importance (IRI), fish eggs (62%), *Harengula thrissina* (23%), *Porichthys margaritatus* (3.3%), and *Abudefduf troschelii* (2.3%) were the prey of greatest importance in its trophic spectrum. In juvenile snappers, the most important preys were unidentified organic matter (32%), the crustacean *Upogebia pugettensis* (29%), penaeid shrimp (6.5%), and fish eggs (5.2%). The Levin index determined that the diet breadth was low (B_i=0.0002), indicating that it is a specialist predator showing preference for fish eggs and *H. thrissina*. The same result was found in males (*Bi*=0.0002) and females (*Bi* = 0.0009). Although juveniles also showed a low trophic breadth, they preferred unidentified organic matter and *U. pugettensis*. The Morisita-Horn index showed considerable overlap in diet between genders ($C\lambda$>0.6), though diet overlap was low between juveniles and adults ($C\lambda$<0.2) reflecting feeding habitat differences between them.

Key words: Yellow snapper, trophic habits, main prey, Gulf of California

Introduction

The fish of the family Lutjanidae, commonly known as snappers, are a fishing resource of great importance in the Gulf of California, mainly along the southeastern coast of Baja California Sur (Rodríguez *et al.* 1994). In La Paz bay the yellow snapper *Lutjanus argentiventris* (Peters, 1869) is an important fishery resource, yielding close to 8 t per year (Ramírez 1996). Their high quality meat is sold fresh or frozen (Berdegué 1956, Fischer *et al.* 1995).

Lutjanus argentiventris is a demersal species with adults inhabiting rocky and coral reefs or in caves between rocks. The juveniles live mainly in mangroves, where they form small aggregations (Fischer *et al.* 1995, Thomson *et al.* 2000).

Several studies on the trophic biology of fish of the family Lutjanidae showed that snappers are predators with variable feeding habits. All are carnivores, feeding mainly on fish and benthic crustaceans, e.g. decapods, cephalopods, and gastropods (Allen 1987, Díaz 1994, Sierra *et al.* 1994, Rojas 1997, Thomson *et al.* 2000). They are also known to eat seaweed, sponges, salps, and worms (Díaz 1994, Sierra *et al.* 1994).

For the yellow snapper, Maeda (1981) found that *L. argentiventris* feed on decapods, fish, and amphipods in the lower Gulf of California. Also, Leventhal (1982) and Funes & Matal (1989) mentioned that this snapper feeds on crustaceans, mainly penaeid shrimp, stomatopods, xanthids, and portunids. The knowledge of snapper trophic biology is incomplete and the present study contributes on the trophic dynamics of this species.

Material and methods

The yellow snapper was sampled bimonthly from April 2003 to April 2004 in estuaries and fishing camps in La Paz bay, mainly off El Portugues, El Saladito, San Juan de la Costa, La Gaviota, and Espiritu Santo Island (San Gabriel and El Cardonal) (Fig. 1).

The fish were caught using various devices including line and hook, trawler nets, harpoon, and traps. The total length (TL), standard length (SL), weight (g), and gender of each specimen were recorded. The stomachs were extracted and preserved in 10% formalin. The fullness was determined following the methodology of Stillwell & Kohler (1982).

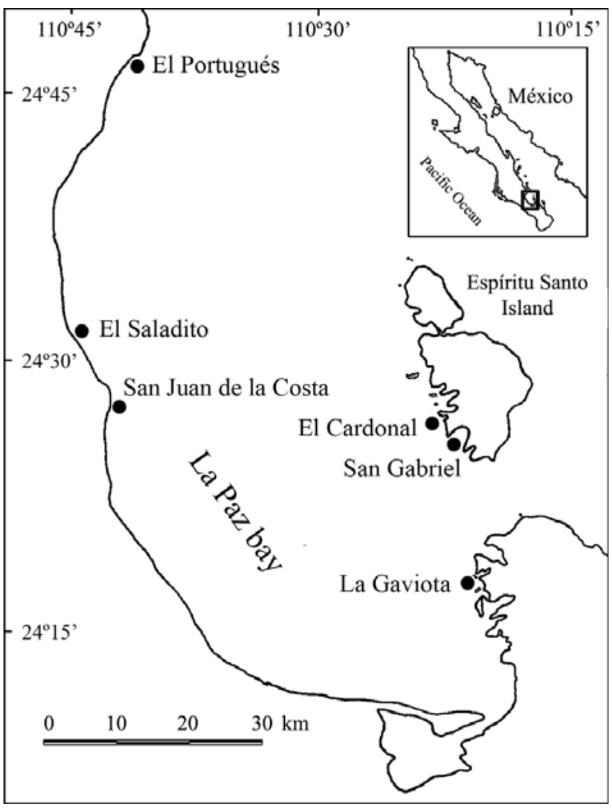

Figure 1

La Paz bay and sampling locations

Localización de Bahía de La Paz y áreas de muestreo

Prey species were identified to the lowest possible taxon, using specialized literature and keys. For fish in a minimum state of digestion, the keys of Miller & Lea (1972), Eschmeyer *et al.* (1983), Allen & Robertson (1994), and Fischer *et al.* (1995) were used. For fish in an advanced state of digestion, we used the keys of Clothier (1950) and Miller & Jorgensen (1973). The fish skeleton collection from the Laboratorio de Ecología de Peces del Centro Interdisciplinario de Ciencias Marinas (CICIMAR) at La Paz, Mexico, was useful for prey verification. Crustaceans were identified using Brusca (1980) and Fischer *et al.* (1995). Worms were identified with Bastida (1991), and cephalopods with Iverson & Pinkas (1971).

The diet was analyzed by calculating three methods for each prey taxon. We calculated (1) frequency of occurrence (%*FO*), (2) by using gravimetric methods (%W), and (3) numerical (%*N*) following Hyslop (1980). We also combined these methods to calculate the index of relative importance of Pinkas *et al*. (1971). IRI is a commonly used measure that provides a summary of dietary composition (Cailliet *et al*. 1986).

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

where % N is percentage of number of organisms, % W is percentage of weight; % FO is percentage of frequency of occurrence.

By using the absolute values of the numeric method, the diet breadth was calculated using the Levin standardized index (Krebs, 1989) following Labropoulou & Eleftheriou (1997)

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

where B_i is the Levin Index for predator *i*; *pij* is the proportion of the diet of predator *i* that is made up of prey *j*, and *n* is number of prey species.

This index assumes values from 0 to 1. When B_i is near zero, the predator is a specialist because it has a preference for only a few prey species. A value of B_i near 1 is a generalist predator, which consumes a higher prey species without a preference for any specific one.

Trophic overlap between gender and between juvenile and adult organisms was analyzed using the Morisita-Horn Index (Smith & Zaret 1982) as

$$C\lambda_{i=l}^{n} = 2\sum(Pxi \times Pyi)/(Pxi + \sum_{i=l}^{n} Pyi)$$

where $C\lambda$ is the Morisita-Horn index, *Pxi* is the proportion of prey *i* of the total of prey used by predator *x*, and *Pyi* is the proportion of prey *i* used by predator *y*. The possible values of $C\lambda$ are from 0 to 1. The scale proposed by Langton (1982) was used in which $C\lambda$ values between 0 and 0.29 indicate low overlap, 0.30 and 0.59 indicate moderate overlap, and a $C\lambda$ greater than 0.6 indicates high overlap. A value of 1 indicates that all prey items are shared in the same proportion by gender or length, indicating a total overlap.

Results

A total of 304 individuals of *L. argentiventris* were collected, of which 44% of the stomachs contained food. The standard lengths of yellow snappers were from 5.4 to 63 cm. We found 54 prey taxa belonging to four general categories; crustaceans (28), fish (22), cephalopods (1), and worms (1). Unidentified organic and plant matter were also found (Table 1).

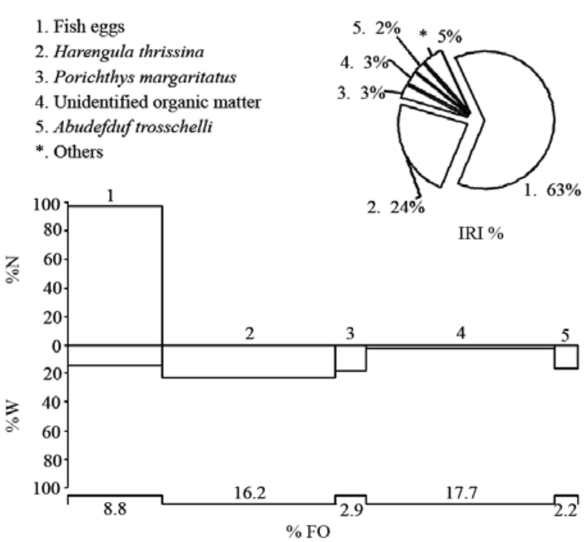

Figure 2

Yellow snapper (*L. argentiventris*) trophic spectrum in La Paz bay, Mexico, using number (N), weight (W), frequency of occurrence (FO) and index of relative importance (IRI)

Espectro trófico del pargo amarillo (*L. argentiventris*) en Bahía de La Paz, México, expresado en valores absolutos y porcentuales de los métodos numérico (N), gravimétrico (W), frecuencia de aparición (FO) e índice de importancia relativa (IRI)

According to the IRI, fish were the most important source of food in the diet of yellow snapper, where fish eggs (63%) appeared to be most important prey item, followed by the sardine *Harengula thrissina* (24%) (Fig. 2).

We found three groups by developing stage: a) male adult, b) female adult, and c) juvenile. A total of 32 males contained 32 prey species. According to the IRI, fish were 96% to the diet of the adult males. The most important prey types were fish eggs (56%), *H. thrissina* (21%), and the toad fish *Porichthys margaritatus* (16%) (Fig. 3). The 39 adult females fed on 21 prey species, including fish eggs (68%) and *H. thrissina* (24%) (Fig. 3).

In the 64 juveniles we found twenty-one prey species. The IRI indicated that crustaceans (46%) were the main food for juveniles, followed by unidentified organic matter (32%), fish (21%), and worms (0.1%). The most important components in the juvenile diet were unidentified organic matter (32%), followed by the mud shrimp *Upogebia pugettensis* (29%), penaeid shrimp (7%), and fish eggs (5.3%) (Fig. 3).

The trophic breadth was low (B_i = 0.0002), which indicates that this species is a specialist because it fed mainly on only a few prey; fish eggs and *H. thrissina*. The same diet pattern was found in the male (Bi = 0.0002), female (Bi = 0.0009), and juvenile snapper (B_i = 0.027). The juveniles ate mainly unidentified organic matter and *U. pugettensis*.

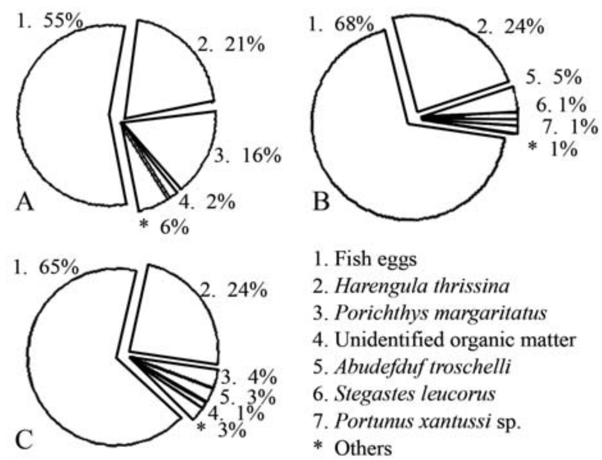

Figure 3

Main preys in the food by sex of *L. argentiventris* using % IRI. A) Adult males, B) Adult females and C) Juveniles

Presas más importantes en la dieta por sexo de *L. argentiventris*, de acuerdo al % IRI. A) Machos, B) Hembras y C) Juveniles

Table 1

Prey composition of yellow snapper of *Lutjanus argentiventris* in La Paz bay, using percentage values of the number (N), weight (W), frequency of occurrence (FO) and index of relative importance (IRI) methods

Espectro trófico del pargo amarillo *Lutjanus argentiventris* en la bahía de La Paz, expresado en valores porcentuales de los métodos numérico (N), gravimétrico (W), de frecuencia de aparición (FO), e índice de importancia relativa (IRI)

Item	%FO	%N	%W	IRI	%IRI
Annelida					
Lumbrineris spp.	1.48	0.006	0.0005	0.010	0.0007
Crustacea					
Stomatopoda					
Squilla tiburonensis Schmitt 1940	0.74	0.003	0.545	0.406	0.025
Squilla hancocki Schmitt 1940	0.74	0.003	0.049	0.038	0.002
Pseudosquillopsis marmorata	0.74	0.003	0.175	0.132	0.008
Penaeidae	11.85	0.059	0.474	6.320	0.398
Metapenaeopsis spp.	2.22	0.049	0.171	0.490	0.030
Litopenaeus spp.	1.48	0.006	0.011	0.026	0.001
Farfantepenaeus spp.	0.74	0.003	0.115	0.087	0.005
Sicyioniidae					
Sicyonia disedwardsi	0.74	0.003	0.080	0.061	0.003
Brachyura					
Portunus xantusii	7.41	0.072	1.360	10.611	0.668
Eurytium affine	2.22	0.016	0.066	0.185	0.011
Panopeus purpureus	1.48	0.013	0.023	0.054	0.003
Leptodius spp.	0.74	0.003	0.017	0.015	0.000
Trapezia spp.	0.74	0.003	0.005	0.006	0.000
Mitras spp.	0.74	0.003	0.191	0.144	0.009
Callinectes bellicosus	1.48	0.006	0.067	0.110	0.006
Herbstia camptacantha	1.48	0.006	0.063	0.103	0.006
Xanthidae	0.74	0.003	0.047	0.037	0.002
Brachyuran remains	5.93	0.046	0.238	1.685	0.106
Anomura					
Porcellanidae	0.74	0.003	0.002	0.004	0.0003
Pleuroncodes planipes	0.74	0.003	0.039	0.031	0.002
Thalassinidea					
Neotryphaena spp.	2.96	0.013	0.250	0.781	0.049
Upogebia pugettensis	10.37	0.088	0.302	4.051	0.255
Excirolana spp.	2.222	0.009	0.027	0.083	0.005
Nerocila californica	1.481	0.019	0.033	0.078	0.004
Cirolana spp.	1.481	0.003	0.047	0.074	0.004
Amphipoda	2.963	0.049	0.022	0.211	0.013
Mysidacea	2.963	1.244	0.166	4.180	0.263
Leptostraca					
Nebalia spp.	2.222	0.052	0.012	0.144	0.009
Subtotal	**70.370**	**1.792**	**4.607**	**30.160**	**1.900**

Table 1. continued

Item	%FO	%N	%W	IRI	%IRI
Mollusca					
Cephalopoda					
Dosidicus gigas	0.740	0.003	2.223	1.649	0.103
Osteichthyes					
Clupeidae					
Harengula thrissina	16.296	0.101	22.995	376.393	23.715
Synodontidae					
Synodus spp.	0.740	0.003	2.020	1.498	0.094
Myctophidae					
Benthosema spp.	2.222	0.009	0.378	0.862	0.054
Batrachoididae					
Porichthys analis	0.740	0.016	0.094	0.082	0.005
Porichthys margaritatus	2.963	0.013	18.165	53.862	3.393
Belonidae					
Platybelone argalus pterura	0.740	0.003	1.225	0.910	0.057
Hemiramphidae					
Hyporhamphus unifasciatus	0.740	0.003	1.536	1.140	0.071
Holocentridae	1.481	0.006	0.517	0.776	0.048
Syngnathidae					
Syngnathus auliscus	0.740	0.003	0.017	0.015	0.000
Scorpaenidae					
Scorpenodes xyris	0.740	0.003	0.047	0.037	0.002
Serranidae	0.740	0.003	0.075	0.058	0.003
Sparidae	0.740	0.003	0.165	0.125	0.007
Pomacentridae					
Abudefduf troschelii	2.222	0.009	16.679	37.087	2.336
Stegastes leucorus	2.963	0.013	3.594	10.689	0.673
Gobidae	4.444	0.023	0.645	2.972	0.187
Bathygobius spp.	2.963	0.016	0.121	0.409	0.025
Gobulus spp.	0.740	0.003	0.056	0.044	0.002
Tetraodontidae					
Sphoeroides spp.	0.740	0.003	1.303	0.9682	0.061
Diodontidae					
Diodon spp.	0.740	0.003	4.081	3.025	0.190
Fish eggs	8.888	97.770	14.346	996.592	62.791
Fish larvae	1.481	0.039	0.000	0.058	0.003
Fish remains	10.370	0.046	1.821	19.364	1.220
Subtotal	**64.444**	**98.099**	**89.888**	**1506.97**	**94.949**
Unidentified organic matter	17.777	0.078	2.623	48.048	3.027
Vegetation	2.222	0.013	0.123	0.303	0.019
TOTAL		**100**	**100**	**1587.14**	**100**

The Morisita-Horn index showed high overlap between female and male groups, indicating that both genders consumed the same prey (fish eggs and *H. thrissina*). We found a low overlap ($C\lambda < 0.2$) when we compared the diets between adults and juveniles.

Discussion

Other studies about the snapper diet showed they feed more on crustaceans and some fish (Claro & Lapin 1971, Claro 1981, Guevara *et al.* 1994, Duarte & García 1999). Also in our research we found that fish eggs were consumed by adults, and crustaceans by juveniles. Claro (1983) found in Cuban waters that snapper distribution and diet diversity suggest a general reliance on a wide spectrum of food resources, which ensures considerable resilience to trophic habitat disturbances.

Duarte & García (1999) found 106 prey species in *L. analis*. However the diets of other snapper species are not very broad, including *L. colorado* with 30 items (Rojas 1997), *L. synagris* (30 items) (Sámano *et al.* 1998), *L. guttatus* (27 items) and *L. griseus* (22 items) (Sámano *et al.* 1998), *L. guttatus* (28 items) (Rojas 1996-1997), *L. guttatus* (88 items) (Rojas & Chiappa 2002), *L. apodus* (11 items) (Rooker 1995). We found 54 prey items in the yellow snapper (*L. argentiventris*) from the lower Gulf of California, which represents a wider trophic spectrum when compared to other snappers, except with the prey number from *L. guttatus* (Rojas & Chiappa 2002) and from *L. analis* (Duarte & García 1999). The trophic spectrum for *L. argentiventris* indicates that it is a carnivorous-omnivorous predator, which consumes mostly benthic organisms, e.g. *P. analis*, *P. margaritatus*, *Synodus* spp., penaeid shrimp, *Squilla tiburonensis*, *S. hancocki*, etc. and a few pelagic species (*Portunus xantusii*). In general the yellow snapper is an opportunistic species that concentrates on prey with high availability. This trophic plasticity also has been observed in other species such as *L. guttatus* (Maravillas 2001) and *L. synagris* (Sámano *et al.* 1998).

Funes & Matal (1989) characterized the yellow snapper as a carnivorous-omnivorous predator that feeds continuously on crustaceans throughout the year. The present work also indicated this high consumption of crustaceans throughout the year though crustaceans constitute the most important prey only for juveniles. The adults fed mainly on fish, represented mostly by fish eggs and the sardine *H. thrissina*.

Lutjanus argentiventris co-occurs with many of its prey species, such as *Upogebia pugettensis* in mangrove roots, and the *Mithrax* spp. and *Herbstia camptacantha* in coral reefs (*Porites* spp.) and these are found as important prey in their stomachs. Although the importance of brachyurans in the yellow snapper diet is evident, they could be underestimated because of the advanced state of digestion of some prey (Duarte & García 1999). This is true mainly in juvenile snappers, because the unidentified organic matter is the most important food item found and could be remnants of crustaceans. The brachyurans are bottom dwellers and weak swimmers, which indicate that the yellow snapper it is a benthic predator (Duarte & García 1999).

The yellow snapper does not have strong teeth for breaking the hard shells of bivalve mollusks (Claro 1981), however we did find some bivalve mollusks in the yellow snapper diet. Rojas (1997) found low rates of bivalve mollusks, echinoderms, and annelids consumed by other snapper species.

Algae and other vegetation were occasionally found in the yellow snapper stomachs, which could indicate ingestion of plants consumed by secondary prey (Rojas 1997, Duarte & García 1999) or incidental ingestion during predation in habitat with algae. Other authors also report the presence of seaweed in snapper stomachs, at a low frequency of occurrence, ranging from 2% to 23%. The role of seaweed in the nutrition of these animals is unknown (Duarte & García 1999).

The high consumption of fish eggs by the yellow snapper indicates a high trophic specialization involving energy advantages. This high percentage of an abundant valuable food should also reduce search time and energy cost. This is consistent with the optimum foraging theory, where a predator consumes prey of high energy content to increase in size more rapidly (Duarte & García 1999). The fish eggs have high energy content (proteins and lipids) and are easy to consume. This is the first study in snappers where fish eggs were the major food type.

The trophic overlap was high ($\lambda = 0.99$) between male and female adult yellow snapper because of the consumption of 14 prey types. The most important prey types for adults were fish eggs, mysidacea, and the sardine *H. thrissina*. In contrast, the diet overlap was low between adults and juveniles, probably because of differences in feeding habitats between juveniles and adults. Zaret & Rand (1971) asserted that such differences in habitat use promote coexistence through partitioning of food and space.

The presence of 54 food items in the yellow snapper showed their ability to feed over a wide range of prey with a preference for certain prey types as fish eggs. The high consumption of fish eggs (62%), and *Harengula* *thrissina* (23%) indicated that yellow snapper is a selective predator, choosing prey according to food requirements. In this sense, this predator would be considered a plastic predator, which feeds on abundant prey to maximize consumption and energy use (fish eggs). However, when the food is limited, it feeds on available prey.

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