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Short Communication

Feeding of blue marlin *Makaira nigricans* off Mazatlan, Sinaloa, Mexico

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ABSTRACT. We analyzed the stomach contents of 52 blue marlins caught between October 2002 and October 2004 by the sport-fishing fleet of Mazatlan, Sinaloa, in the gulf of California, Mexico. Blue marlin feed on 15 food items. According to the index of relative importance (IRI), the most important prey were the frigate or bullet mackerel *Auxis* spp. (52%) and jumbo squid *Dosidicus gigas* (30%).

Keywords: blue marlin, *Makaira nigricans*, feeding habits, gulf of California, Mexico.

Alimentación del marlín azul *Makaira nigricans* del área de Mazatlán, Sinaloa, México

RESUMEN. Se analiza el contenido estomacal de 52 marlines azules capturados por la flota de pesca deportiva que operó en el área de Mazatlán, Sinaloa, en el golfo de California, México, durante el periodo octubre 2002 a octubre 2004. El marlín azul se alimenta de 15 categorías alimenticias (ítemes), de las cuales las más importantes de acuerdo al índice de importancia relativa (IRI), fueron el pez melva *Auxis* spp. (52%) y el calamar gigante *Dosidicus gigas* (30%).

Palabras clave: marlín azul, *Makaira nigricans*, hábitos alimenticios, golfo de California, México.

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Blue marlin *Makaira nigricans* (Lacépède, 1802), is a large predator distributed in the tropical and temperate oceans, inhabiting surface and subsurface waters of the open ocean. It is the most oceanic from all istiophorids, usually remaining far away from coastal waters, except where the continental shelf is narrow (Nakamura, 1985; Joseph *et al*., 1988). Around the Mexican Pacific (included Mazatlan, Sinaloa) are common three billfish species: sailfish *Istiophorus platypterus*, striped marlin *Tetrapturus audax* and blue marlin *Makaira nigricans*, in order of abundance.

Studies of blue marlin food habits in Mexican Pacific ocean are difficult, because this specie is not very abundant to obtain representative samples. Only two studies has been done in the Mexican waters: Eldrige & Wares (1974), identified the stomach contents of 15 blue marlin caught by sport fishermen off Buena Vista, Baja California Sur, Mexico with samples from 1970, and Abitia-Cárdenas *et al.* (1999), reviewed 204 blue marlin caught by the sport fishing fleet in Cabo San Lucas, Mexico.

The blue marlin samples were obtained between October 2002 to October 2004 from the sport fishing fleet that operates offshore from Mazatlan, Sinaloa, Mexico (22º40'-23º38'N, 105º50'-106º45'W). This fleet use trolling with live bait (mainly black skipjack *Euthynnus lineatus*), or with jigs. The mean postorbital length of 52 blue marlin was 192.6 ± 20.4 cm (standard deviation) and the mean weight was 91.7 ± 40.1 kg. Of those specimens sampled, seven (13.5%), had empty stomachs and five (9.6%) had regurgitated their stomach contents. The 40 stomach (76.9%) contents were examined and prey items were separated by taxonomic group and identified to the lowest possible taxon, depending on digestion state of the remains. For complete undigested fish, we used

the keys of Fischer *et al*. (1995a, 1995b) and Thomson *et al.* (2000) for identification. Also the vertebral characteristics were used to identify fish remains with keys of Clothier (1950), Monod (1968) and Miller & Jorgensen (1973). We identified cephalopods prey from mandible remains with the keys of Wolf (1982) and Clarke (1986).

The diet was analyzed using the methods by frequency of occurrence (FO), number (N), weight (W) (Hyslop, 1980), and we also combined these methods to calculate the index of relative importance (IRI) of Pinkas *et al*. (1971) to represent the most important prey.

A total of 15 food items were identified, that comprised fish and cephalopods. Only seven prey items could be identified to species (Table 1). By frequency of occurrence, fishes were the most important food in the diet of blue marlin (80%), where the frigate or bullet mackerel *Auxis* spp. (42.5%), finescale triggerfish *Balistes polylepis* (15%), flathead mullet *Mugil cephalus* (10%) and Pacific sierra *Scomberomorus sierra* (10%) had more occurrences in stomach contents. Cephalopods occurred in 45% of stomach contents, with the jumbo squid *Dosidicus gigas* (37.5%) as main cephalopod prey.

A total of 293 prey organisms were enumerated, where 159 (54.3%), were fishes and 134 (45.7%) cephalopods. The dominant prey by number were: *D. gigas* (21.8%), *Auxis* spp. (18.4%), *B. polylepis* (15.7%) and the paper nautilus *Argonauta* spp. (15.4%).

The total accumulated weight of prey in stomachs was 22,257.52 g, where fishes contributed 15,238.07 g (68.5%), mainly *Auxis* spp. (45.6%), *S. sierra* (6.5%), common halfbeak *Hyporhamphus unifasciatus* (2.9%) and *E. lineatus* (2.7%); whereas, cephalopods in biomass comprised 6331.95 g (28.4%), with *D. gigas* as the most important prey with 20.4% of the total weight.

Acoording to IRI, the most important prey were fishes (63.8%), mainly *Auxis* spp. (52.1%), *B. polylepis* (4.8%) and *S. sierra* (2.1%). The cephalopods occupied 35.3% of IRI, where *D. gigas* was 30.3% of the total weight.

Examination of the diet by sex of 40 blue marlin with stomach contents, included 32 females (80%) and 8 males (20%). The diet of female had 15 food items and according to IRI, fishes were the most important food (71.1%), followed by cephalopods (27.8%). The prey *Auxis* spp. (59.3%) and *D. gigas* (23.0%) were the most important prey. The diet of males included nine food items, the most important prey were the cephalopods (63.9%), mainly *D. gigas* (47.9%), and the fish (36.1%), where *E. lineatus* (17.5%) was the most important prey (Fig. 1). The records of black skipjack *E. lineatus* in the blue marlin stomach contents would be associated as bait; however the advanced digestion state of this prey indicated that was a natural food in blue marlin.

Studies of blue marlin feeding ecology are difficult because the species is not very abundant in the coast of Mazatlan thus it is difficult to obtain representative

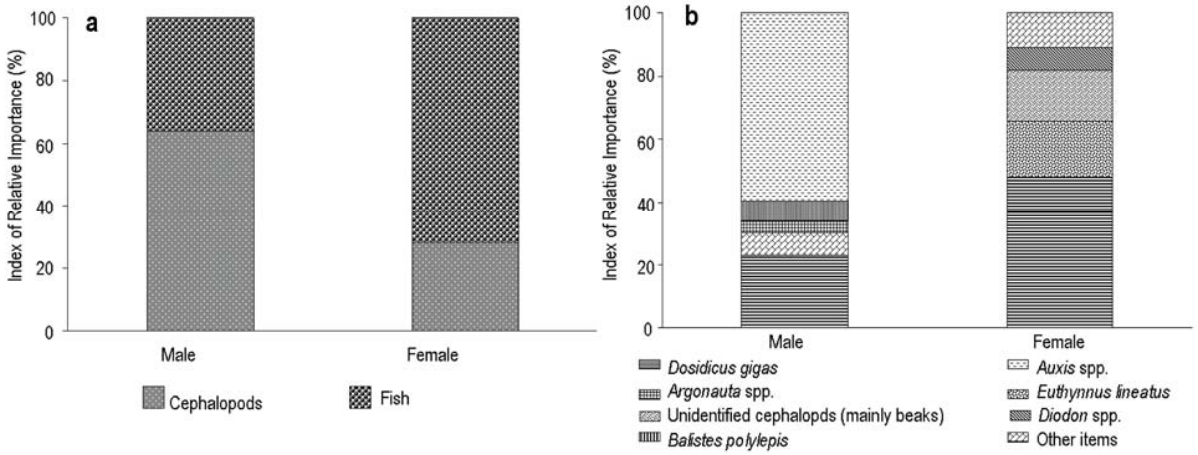

Figure 1. Diet of male and female of blue marlin, expressed as percentages of Index of Relative Importance (% IRI), where a) Corresponding food categories, and b) the major prey species.

Figura 1. Dieta de macho y hembra de malin azul, expresada como los porcentajes de Índice de Importancia Relativa (% IRI), donde a) Categorías correspondientes de alimentos, y b) la especie de presa principal.

Table 1. Taxonomic composition of the prey found in blue marlin *Makaira nigricans* stomach contents (n = 40) from Mazatlan, Sinaloa, Mexico, expressed as percentages based on frequency of occurrence (FO), number (N), weight (W), and Index of Relative Importance (IRI).

Tabla 1. Composición taxonómica de las especies presa encontradas en los contenidos estomacales del marlin azul *Makaira nigricans* (n = 40) del área de Mazatlán, Sinaloa, México, expresado como porcentaje de la frecuencia de aparición (FO), número (N), peso (W) e Indice de Importancia Relativa (IRI).

Prey	FO	% FO	N	% N	W	% W	IRI	% IRI
Mollusca								
Cephalopoda								
Ommasptrephidae								
Dosidicus gigas	15	37.5	64	21.8	4543.68	20.4	1584.64	30.3
Argonautidae								
Argonauta spp.	3	7.5	45	15.4	1777.50	8.0	175.08	3.4
Unidentified cephalopds beaks	4	10.0	25	8.5	10.77	0.1	85.81	1.6
Chordata								
Actynopterygii								
Mugiliformes								
Mugil cephalus	4	10.0	6	2.1	511.41	2.3	43.45	0.8
Beloniformes								
Hemiramphidae								
Hyporhamphus unifasciatus	2	5.0	13	4.4	653.10	2.9	36.86	0.7
Perciformes								
Carangidae								
Decapterus macrosoma	3	7.5	4	1.4	483.20	2.2	26.52	0.5
Caranx spp.	2	5.0	5	1.7	374.70	1.7	16.95	0.3
Scombridae								
Scomberomorus sierra	4	10.0	13	4.4	1454.82	6.5	109.73	2.1
Auxis spp.	17	42.5	54	18.4	10156.21	45.6	2722.57	52.1
Euthynnus lineatus	3	7.5	3	1.0	605.17	2.7	28.07	0.5
Tetraodontiformes								
Balistidae								
Balistes polylepis	6	15.0	46	15.7	236.30	1.1	251.42	4.8
Diodontidae								
Diodon spp.	3	7.5	15	5.1	176.90	0.8	44.36	0.9
Vertebrae of fish	1	2.5			4.20	0.0	0.05	0.0
Unidentified fish	9	22.5			582.06	2.6	58.84	1.1
Unidentified organic matter	6	15.0			687.50	3.1	46.33	0.9
Total			293	100	22257.52	100	5230.69	100

samples, in these sense the 40 stomach is enough to characterize the general diet of this species, but this sample size was considered insufficient to describe the temporal variation of the trophic spectrum.

The low diversity of prey species find in blue marlin from the Mazatlan area, comparing with the highest prey diversity recorded in other studies (Brock, 1984; Abitia-Cárdenas *et al*., 1999; Shimose *et al*., 2006), and the high consumption of the prey *Auxis* spp. and *D. gigas*, indicated a high food specialization from this billfish. This conclusion also was reported by Brock (1984) in Hawaii and Abitia-Cárdenas *et al*. (1999) close to Baja California, Mexico, where in both studies the autor mentioned that neverthless the high prey number predated by blue marlin, this predators select a small number of prey from epipelagic and demersal habitat.

In general, the most important prey species reported in our trophic analysis with blue marlin, also were found in other geographic areas (*e.g.* Strasburg,

1970; Rivas, 1974; Eldrige & Wares, 1974; Brock, 1984; Abitia-Cárdenas *et al*., 1999; Shimose *et al*., 2006).

However we must consider the high abundance of the frigate or bullet mackerel *Auxis* spp. and *Argonauta* spp. in the eastern Pacific ocean, where is also the most important prey in the yellowfin tuna (Olson & Boggs, 1986), sharks, dolphinfish, wahoo (Galvan-Magaña, 1999; Olson & Galván-Magaña 2002) and billfish (Abitia-Cárdenas *et al*., 2002; Arizmendi-Rodriguez *et al*., 2006). *Auxis* spp. is a very common fish in the eastern Pacific ocean and particularly in the gulf of California (95% of larval catch), according to Klawe *et al.* (1970) and Olson & Boggs (1986).

In relation to *D. gigas*, this cephalopod specie is an important commercial resource in the eastern Pacific ocean (Markaida, 2006). In the gulf of California the jumbo squid support the artisanal fishery with an annual catches over 100,000 ton between 1995 and 1997 (Markaida & Sosa-Nishizaki, 2001). Also, Nevárez-Martínez *et al.* (2006), reported that during 2001 and 2002 were the years with the higher capture of *D. gigas* than other years in the gulf of California.

The high abundance of this cephalopod species can be associated with the occurrence of tropical water masses at the entrance of the gulf of California and with the presence of large schools of epipelagic prey from the neritic and oceanic zones, which are common prey consumed by the jumbo squid (Erhardt *et al*., 1986; Abitia-Cárdenas *et al*., 1999; Markaida & Sosa-Nishizaki, 2003). Also the decreased shark population in the gulf of California (Galván-Magaña, 2009), caused by overfishing, would be the cause of the high abundance of jumbo squid, which were the main prey of sharks in the gulf of California (Galván-Magaña *et al*., 1989).

In summary, the blue marlin could be consider an apex predator in the Mexican Pacific ocean which feed on a reduced number of prey from the epipelagic and demersal zone. Also is showed evidence of the high degree of food specialization by the high consumption of some prey as frigate or bullet mackerel *Auxis* spp. and jumbo squid *Dosidicus gigas.*

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