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Feeding Habits of the Panama Brief Squid (*Lolliguncula panamensis*) in the Gulf of California, Mexico

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ABSTRACT

The feeding habits of the Panama brief squid, *Lolliguncula panamensis* (Berry, 1911), it inhabits off Peru until Gulf of California, was determined by examining the stomach contents of 657. Panama brief squid were collected from the incidental catch of shrimp trawling fishery during 2003-2006 and 2008, along the Gulf of California, Mexico. Most of the stomachs were empty and those that contained food presented highly digested prey items. Eight taxa were identified in the stomach contents and the index of relative importance indicated to juvenile of Pacific sardine (*Sardinops sagax*), the most important prey, this prey bring 99.6% IRI. Results suggest that *L. panamensis* is a highly opportunistic predator foraged primarily in coastal and epipelagic waters, whose diet reflect the local abundance of potential prey species, mainly small pelagic fishes.

Key words: Opportunistic predador, neritic, Panama brief squid, trophic spectrum, Gulf of California

INTRODUCTION

The Cephalopoda class is widely distributed in oceanic and benthic marine habitats worldwide. Cuttlefish, squids and octopuses are typically dominant predators present in any marine environment. Many of the large, schooling, neritic and oceanic squids are targets for commercial or for artisanal fisheries (Hochberg and Couch, 1971). The Panama brief squid (*Lolliguncula panamensis* Berry, 1911) inhabits neritic and oceanic zones and is distributed along the continental shelf and slope of the Eastern Pacific Ocean from the Gulf of California, Mexico to Peru (32°N to 3°S).

The greatest abundance of *L. panamensis* within its distribution range has been established between the 12°N and 24°N latitudes (Squires and Barragán, 1979; Fischer *et al*., 1995; Sánchez, 2003). Because the incidence of *L. panamensis* as by catch in traditional shrimp bottom trawl fishing has become important, fishery managers should be concerned about the potential predatory impact of the Panama brief squid on shrimp fishing stocks and other species such as the Pacific sardine and other small pelagic fishes (*Engraulis mordax*).

Historically, the capture of *L. panamensis* has been incidental and only by means of shrimp bottom trawl fishery when the abundance of this species has been high (Sánchez, 2003). Recently, the incidence of the Panama brief squid as by catch (percentage in weight) by industrial vessels has ranged between 0.3 to 2% (Roper *et al.*, 1984; Hernández-Vázquez, 1987; Alejo-Plata *et al.*, 2001). Nevertheless, the trophic ecological impact on fish populations is unknown.

The feeding habits of *L. panamensis* have been studied in only a few parts of its distribution range (Barragán, 1977). The most common prey items according to Barragán (1977) are shrimp penaeids, unidentified crustaceans and fish remains. Squids represent an important functional group for energy transfer from zooplankton to higher trophic levels (Dawe and Brodziak, 1998; Dos Santos and Haimovici, 2001). However, little information is known about the biology of the Panama brief squid found in the Eastern Pacific Ocean and particularly in the Gulf of California. The objective of this study in this context was to describe the diet of *L. panamensis* found in the northern and eastern Gulf of California, recognized as an area with great species abundance.

MATERIALS AND METHODS

Samples of *L. panamensis* were obtained from random stratified research bottom trawl surveys in the Gulf of California (between 25°N and 31°N) during February 2003, September, October and November of 2004, January, March, April and May of 2005, February, July, August and September 2006 and August 2008. The sampling area consisted of 96 stations defined by location and depth (Fig. 1). The net shrimp bottom trawl was towed at each station at a speed of 2.5 knots. *L. panamensis* were caught and sampled at 65 of 96 stations, at depths maximum of 160 m

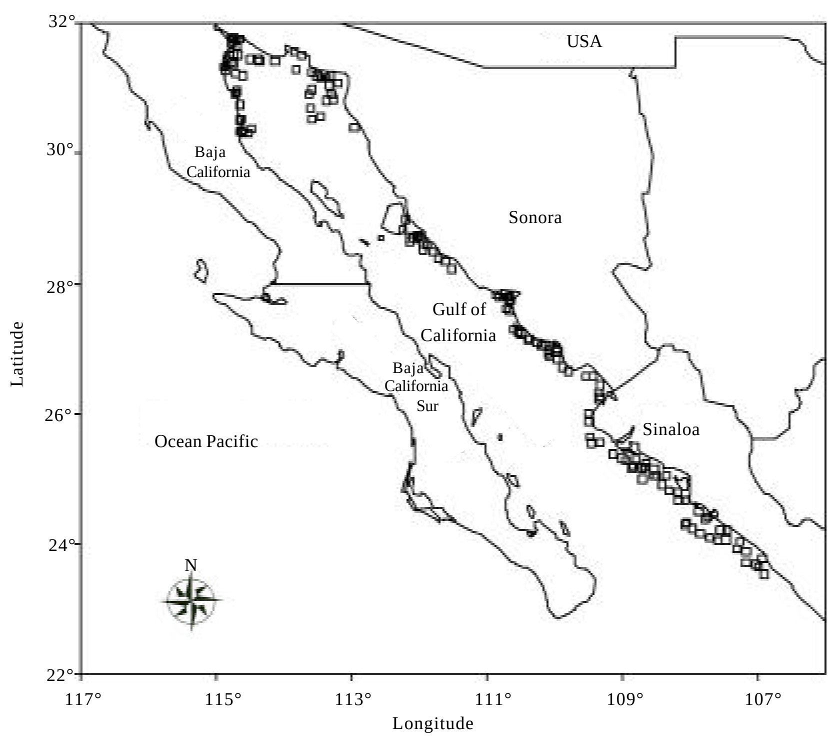

Fig. 1: Study area indicating the geographical position of sampling stations in the Gulf of California

(Fig. 1). On deck, a random sample (40-45 kg) was taken from the catch. The sample was separated by taxonomic groups (cephalopods, crustacean and fish) and frozen at -20°C. In the laboratory *L. panamensis* specimens were identified from the cephalopods group. The sex, the dorsal mantle length (DML; to the nearest mm) and the total weight (to the nearest g) were recorded for each individual. A total of 657 individuals between 20 and 115 mm DML were measured and the stomachs were removed. The wet weight of both the entire stomach and contents were recorded to the nearest 0.1 g and a qualitative assessment was made of stomach fullness (i.e., empty; trace,¼ to ¾ full; full). The stomach contents were removed and rinsed with water through a 500 µm steel sieve to remove fluid and fine material and the wet weight of empty stomachs were recorded to the nearest 0.1 g.

Recognizable prey remains were then identified to the lowest possible taxon under a stereo microscope using reference guides. The fish macerated or digested beyond visual recognition were identified, if possible from their otoliths and other hard structures through specialized guides for this purpose (Clothier, 1950; Monod, 1968; Miller and Jorgensen, 1973). The crustaceans were identified using the guide of Brusca (1980). Squid beaks consumed by *L. panamensis* were identified using guidebooks (Wolff, 1984) as well as laboratory reference collections.

For each prey category, the number of individuals was estimated and the wet weight recorded to the nearest 0.01 g after the removal with blotting paper of surface water. A fragmented prey count was based on the number of eyes, heads, mouth parts, tails, telsons, paired otoliths, or other anatomical parts traceable to a single specimen.

Numerous indexes have been described to quantify the importance of different prey items in the diets of aquatic species (Berg, 1979; Hyslop, 1980; Tirasin and Jorgensen, 1999).

Those used in the present study were: The percentage of frequency of occurrence (%OF), referred as the frequency of occurrence of prey items within the total number of non-empty stomachs:

$$\text{OF (\%)} = \left(\frac{\text{No. of stomachs including a prey item}}{\text{No. of non-empty stomachs}}\right)\times 100$$

The numerical percentage of abundance (%N), referred as the prey item abundance within the total number of prey items identified in the total number of non-empty stomachs:

$$\text{N (\%)} = \left(\frac{\text{No. of prey items}}{\text{Total No. of prey items}}\right)\times 100$$

The gravimetric composition percentage (%W) is the wet weight of prey items found within the total wet weight of non empty stomachs:

$$\text{W (\%)} = \left(\frac{\text{Weight of prey items}}{\text{Total weight of prey items}}\right)\times 100$$

The hierarchization of food items was established using the Index of Relative Importance (IRI) of Pinkas *et al.* (1971), as modified by Hacunda (1981), which provided an optimal balance of the three indexes (Liao *et al.*, 2001):

$$IRI = \%OF \times (\%N + \%W)$$

This index has been expressed as:

$$IRI(\%) = (IRI / \Sigma IRI) \times 100$$

RESULTS

A total of 657 Panama brief squid had an average the dorsal mantle length 67±17 mm and an average weight 16.9±10.3 g were analysed. Both the mantle length and body weight of *L. panamensis* were significantly different between the months (one-way ANOVA, $F_{10,646}$= 15.28 p<0.001; $F_{10,646}$= 6.73, p>0.001, respectively) (Table 1). The number of empty stomachs was high (Table 2) and the weight of the stomach contents was significantly different between the months (one-way ANOVA, $F_{3, 43}$= 15.4, p<0.001).

From the total of examined organisms 59 (9%) contained identifiable prey items allowing the diet to be assessed and 598 (91%) had empty stomachs. From the 59 stomachs, 36% contained only trace prey amounts and 25% were classified as full stomachs (Table 3). No obvious relationship between sizes of the squid (DML) and the presence or absence of food could be detected. Unidentifiable prey items were totally composed of digested flesh.

Eight prey taxa were grouped in three large categories: cephalopods (one item prey), crustaceans (five item prey) and fish (two item prey). Item preys were grouped into three families,

Table 1: Data of dorsal mantle longitude (mm) and weight (g) expressed in values: minimal, maximum, mean and standard deviation

		DML (mm)				Weight (g)			
Months	n	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
February-03	22	33	90	67.9	17.2	2.00	39.3	18.6	10.7
September-04	1	-	-	-	-	-	-	-	-
October-04	10	43	82	67.5	15.6	5.00	28.1	17.8	8.5
November-04	11	30	65	44.5	9.5	2.30	11.1	5.3	2.5
January-05	56	32	90	61.9	13.6	2.80	37.5	14.6	8.3
March-05	11	50	87	70.9	15.3	7.50	27.2	16.1	6.9
April-05	167	35	100	76.2	15.7	2.60	37.5	18.7	9.1
May-05	19	54	90	74.7	9.4	6.50	24.3	15.1	4.9
February-06	15	43	100	79.0	15.1	5.10	47.6	29.9	13.1
July-06	192	27	94	59.9	15.1	1.332	41.7	14.5	9.1
August-06	143	40	105	66.7	14.9	2.80	58.0	18.0	11.8
September-06	2	72	87	79.5	10.6	16.70	34.5	25.6	12.6
August-08	8	56	95	76.4	15.9	12.10	41.8	26.9	11.9
Total	657								

Table 2: Variation in the fullness degree of stomachs used to describe the diet of Panama brief squid *Lolliguncula panamensis* in the Gulf of California, Mexico

Fullness degree	Female	Male
Empty	355	137
Trace	21	36
1/4-3/4	13	22
Full	25	42
Total	414	237

Table 3: Prey found in *L. panamensis* stomach contents from the Gulf of California, expressed as percentages of number (N), weight (W), frequency of occurrence (OF) and index of relative importance (IRI)

Prey item	N	N (%)	W	W (%)	OF	OF (%)	IIR	IIR (%)
Amphipoda	1	1.7	0.001	0.005	1	1.7	2.9	0.02
Crustacea	1	1.7	0.7	3.2	1	1.7	8.4	0.06
Copepoda	2	3.4	0.0001	0.0005	1	1.7	5.8	0.04
Peneidae	1	1.7	3.3	15.0	1	1.7	28.8	0.20
Brachyura	1	1.7	0.27	1.2	1	1.7	5.0	0.03
Cephalopoda								
Lolliguncula panamensis	1	1.7	0.27	1.23	1	1.7	5.0	0.03
Chordata								
Osteichthyes								
Clupeidae								
Sardinops sagax	51	86.4	16.87	76.9	51	87.9	14359	99.6
Gerreidae								
Eucinostomus gracilis	1	1.7	0.54	2.5	1	1.7	7.2	0.05
Total	59	100	22	100	58	100	14422	100

three genera and three species. The analyses of stomach contents revealed 59 individual prey items. In concert having a total weight of 22 g. From the total number of non-empty stomachs the number of prey items per stomach contained only one single prey item. Different types of fish (mainly *Sardinops sagax*) were the most important prey category, occurring in OF = 87.9% of the stomachs and accounting for 79.4% of the prey weight, followed by the Peneidae in 15.0%, Crustaceans at 19.4% and *Eucinostomus gracilis* at 2.46% (Table 2). Crustaceans occurred with considerable less frequency in the diet (OF = 6.7%). Squids also occurred in OF = 1.7% of the stomachs, but they contributed little to the prey weight (W = 1.23%). The most important prey item according to the IRI was the *S. sagax* (IRI=99.6%). It was not possible to analyze composition variations between size and sex, due to the small number of food containing stomachs.

DISCUSSION

The feeding studies based on qualitative indexes (dominance or prey item occurrence) and /or comparisons of the percentages of food containing stomachs have some limitations (Hyslop, 1980; Tirasin and Jorgensen, 1999). For example: (1) they do not consider the volume of food ingested and (2) they do not consider the time differences for the digestion of each prey item. These limitations are particularly valid in the case of cephalopods; for example, squids crush their prey and usually expel the hard parts, which are very useful for identification (Bidder, 1966; Dos Santos and Haimovici, 2001). However, there might be a biased result when heads are not consumed in larger prey (Field *et al.*, 2007) and the presence and number of these structures lead to underestimated results. On the other hand, the accumulation of beaks in the stomachs overestimates the number of prey (Vaske and Rincon, 1998) whereas otoliths do not accumulate in the stomachs of marine piscivores and any otoliths found represent solely the remains of the most recent feeding bout (Jobling and Breiby, 1986).

In the case of cephalopods, Castillo *et al.* (2007) recommend the use of cumulative prey curves to determine whether a sufficient number of samples have been collected to describe precisely the diet of a particular predator and, Ibáñez *et al.* (2008) recommend the use of a presence-absence matrix of prey-predators to describe the diet by calculating the frequency of occurrence and composition gradients. In our study, it was not possible to implement these recommendations due to: (1) A high number of empty stomachs that were found and because the number of non-food components was greater than one in each of them, therefore cumulative curves prey were not developed; (2) the lack of information on the predator abundance of the Panama brief squid, necessary to estimate the frequency of occurrence and composition gradients.

However, we are confident that our results as well as the empirical evidence mentioned in the literature has shown that the gut content analysis was adequate to enable our dietary description of *L. panamensis* and that despite of the small number of food containing stomachs it was possible to identify the most important prey items. The diet composition of *L. panamensis* determined in this study was consistent with previous studies of this species in other regions of the Eastern Tropical Pacific Ocean. For example, the Colombian Pacific medium size specimens (34-110 mm DML) feed mainly on fish and crustaceans, whereas fish and cephalopods occur more frequently in the larger specimens (Squires and Barragán, 1979; Hanlon and Messenger, 1996).

It has been documented that every squid species are active predators and that cannibalism is common in most of them (Squires and Barragán, 1979; Hanlon and Messenger, 1996). Ibáñez and Friedemann (2010) indicate that cannibalism in cephalopods is density-dependent due to their predatory aggressiveness; it also depends upon local and temporal food availability and upon the reproductive season. Whereas cannibalism has been reported as a common behavior amongst squid, we did not find any evidence of this practice. In the total number of food containing stomachs, only one of them contained a squid specimen. Cephalopods are generally restricted in their ability to store energy. Therefore, it is assumed that cannibalism is part of a population energy storage strategy enabling cephalopod populations to react to both favorable and adverse environmental conditions by increasing and reducing their numbers (Ibáñez and Friedemann, 2010).

The spatial distribution of important prey items of *L. panamensis* is partially known, Quiñonez-Velázquez *et al.* (2000) and Nevárez-Martínez *et al.* (2001) described the temporal and spatial distribution of *S. sagax* in the Gulf of California concluding that the greater abundance of the Pacific sardine is concentrated in coastal waters. Unfortunately, no time series is available referring to the abundance of the Panama brief squid, or of the most important prey item consumed. Therefore, our assumption of considering the Gulf of California as a feeding area should be supported with future information on the distribution and abundance of *L. panamensis* prey. In synthesis, our results indicate that the feeding habits of *L. panamensis* are determined by the prey items availability in the environment and are similar to other loliginid squids, which forage primarily on prey found in neritic waters.

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