# Evaluación del canibalismo en el calamar gigante *Dosidicus gigas* en el Golfo de California

# Cannibalism assessment of jumbo squid *Dosidicus gigas* from the Gulf of California

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Ibarra-García L. E., S. Camarillo-Coop and C. A. Salinas-Zavala. 2014. Evaluación del canibalismo en el calamar gigante *Dosidicus gigas* en el Golfo de California. *Hidrobiológica* 24 (1): 51-56.

## RESUMEN

En el calamar gigante *Dosidicus gigas* se ha reportado una alta incidencia de canibalismo. En general, la mayoría de los estómagos que se han revisado para determinar su dieta, provienen de áreas donde se realiza la pesca, lo que probablemente esté influyendo en una sobreestimación del canibalismo en los calamares. En el presente estudio, se analizaron un total de 236 contenidos estomacales de *Dosidicus gigas,* los cuales fueron recolectados tanto en áreas de pesca como de no pesca en el Golfo de California y costa occidental de la península de Baja California, a bordo de siete cruceros realizados entre 2005-2010. Los estómagos se analizaron siguiendo la metodología estándar y los restos de calamar (pedazos de manto, ventosas, picos y lentes oculares) fueron separados y pesados lo que se denominó peso del canibalismo (% W). La longitud de manto de los calamares varió entre 7-86 cm. Las tallas más grandes se encontraron en las zonas de pesca, donde el canibalismo fue mayor. En las áreas de pesca la proporción del peso del canibalismo (%W) y el peso total del contenido estomacal (TW) fueron mayores que en las zonas de no pesca, pero no hubo diferencia significativas en el porcentaje de frecuencia de ocurrencia de canibalismo (%FO) entre zonas y tampoco entre sexos, aunque las hembras mostraron un mayor %W que los machos. Las tallas mayores presentaron una mayor %FO. Los resultados sugieren que las actividades pesqueras, tienen una gran influencia en el comportamiento caníbal de la especie, por lo que debe considerarse este sesgo en las muestras provenientes de sitios en donde ocurre la pesca.

**Palabras clave:** Alimentación, calamar gigante, canibalismo, *Dosidicus gigas*, pesca.

## ABSTRACT

In the jumbo squid *Dosidicus gigas* has been reported a high incidence of cannibalism. The majority of the stomachs reviewed for determining squid diet have been obtained from fishery areas, therefore cannibalism in squids may be overestimated. In this study, a total of 236 *Dosidicus gigas* stomach contents were analyzed, these were taken from both fishing and non-fishing areas in the Gulf of California and San Carlos (west coast of the Baja California Peninsula) onboard seven cruises carried out between 2005 and 2010. Stomachs were analyzed following the standard methodology and the remains of squid (mantle pieces, suckers, beaks and eye lenses) were separated and weighted and that was called cannibalism weight (% W). Squid mantle length varied from 7 to 86 cm. Bigger sizes were found in fishing areas where cannibalism had major values of cannibalism. The cannibalism weight percentage (%W) and total weight of stomach content (TW) was high in fishing areas, but no significant difference in the frequency of occurrence (%FO) between areas and sex where found. Females presented a higher value of %W than males. The largest sizes had a greater %FO. Results suggest that fishery activities have an important influence in the cannibalism behavior on *Dosidicus gigas*, therefore this bias should be considered in diet studies when samples are taken from areas where fishing occurs.

**Key words:** Cannibalism, *Dosidicus gigas,* feeding, fishing, jumbo squid.

## INTRODUCTION

Cannibalism or intraespecific predation is the process of killing and eating an individual of the same species which is common in various taxa and occurs for various reasons. It is a widespread process with a great impact in the biology of many species and may influence population structure and dynamic, life history, behavior and competition for mates and resources (Polis, 1981).

Cannibalism occurs mainly with high population density and under food scarce conditions (Fox, 1975; Ibáñez & Keyl, 2010), so it provides an advantage by reducing competition and population size, it also increases growth rate due to more food available per individual (Polis, 1981). Likewise it allows some individuals to get easily the ideal proportion of nutrients contained in a conspecific and it provides enough energy for vital processes (Meffe & Crump, 1987).

Cephalopods are an important key in the marine ecosystem worldwide due to their predator-prey relationship. They are voracious, rapid, active and versatile opportunistic predators with high metabolic rates that feed on live prey (Rodhouse & Nigmatullin, 1996; Boyle & Rodhouse, 2005). Stomach content analysis is commonly used to describe and quantify dietary items in cephalopods (Nesis, 1983; Nixon, 1987). High incidence of cannibalism has been reported for many cephalopod groups of both octopus and squids, but it may be overestimated, especially if the information comes from samples taken with fishing gears, like jig or trawls, which can cause bias in the diet (Boyle & Rodhouse, 2005).

The jumbo squid *Dosidicus gigas* (D' Orbigny, 1835) is the largest and one of the most abundant nektonic squid and is endemic to the eastern Pacific (Nigmatullin *et al.,* 2001). The northern boundary of its range reaches central California (37 °N) and the southern boundary lies off southern Chile (47 °S), but the main part of its range is from Baja California to northern Chile (Nesis, 1983).

The jumbo squid diet has been described widely through its distribution range mainly in the Gulf of California (Mexico), Peru and Chile. In the Gulf of California the common preys in its diet are fish (mainly sardine and nyctoepipelagic myctophids), molluscs (pteropods and squids including cannibalism) and crustaceans (shrimps and red crabs). Cannibalism in this region had been reported to achieve large percentages from 30 to 68% by weight in *Dosidicus gigas* stomach contents (Ehrhardt, 1991; Markaida & Sosa-Nishizaki, 2003; Markaida *et al*., 2008).

In Peru they feed on fish, cephalopods and crustaceans. In the former group, mesopelagic fish and myctophids are the principal prey. In the next group cannibalism is observed due to the dominance of *Dosidicus gigas* in the stomach contents (Rosas *et al*., 2011).

Also in Chile the principal groups are fishes (mainly mackerel, hake, small pelagic and myctophids), squids, crustaceans and benthic prey (Nesis, 1983; Ibáñez *et al.,* 2008); although cannibalism was an important part of the jumbo squid diet reaching 99% of the relative importance index (RII) inside the phylum Mollusca (Cubillos *et al.*,2004; Ulloa *et al.,* 2006). However it has been argued that main prey in *D. gigas* stomach contents are strongly influenced by the fishing gear used in sampling due to the opportunistic behavior of the species (Ibañez *et al.,* 2008).

*Dosidicus gigas* is the only ommastrephid in Mexican commercial catches. The fishery is focused mainly in the central Gulf of California, off Guaymas from November to May and off Santa Rosalia from May to October (Markaida & Sosa-Nishizaki, 2003) where the capture of this resource is linked to very dense areas and it is carried out by artisanal fleets using hand jigs. As the cannibalism is thought to be an induced behavior due to commercial fishery activities and considering that most of the stomachs reviewed to determine the diet in this species came from commercial fishery areas, the present study pretends to corroborate if the cannibalism is present also in samples taken in non commercial fishing areas inside the Gulf of California, located in the west coast of the Baja California Peninsula.

## MATERIAL AND METHODS

Samples of *Dosidicus gigas* were taken with jigs at several locations onboard seven R/V cruises on different years in the Gulf of California and in one locality in the west coast of Baja California Peninsula. For all squids, the mantle length (ML) was measured to the nearest cm and sex was observed. A total of 236 frozen stomachs contents were analyzed in the laboratory. The samples were grouped in two, those from fishing areas (localities where the fishery takes place when samples were taken) and those from non fishing areas (localities without fishery activities when samples were taken). Stomachs from fishing areas were collected on July 2005, March and July 2006, July 2007 and March 2010 whereas stomachs from non fishing areas came from April 2005, February 2008, March and May 2010 (Fig. 1).

The process of stomach content analysis followed Markaida & Sosa-Nishizaki (2003). The stomach contents were weighted with a digital balance (to the nearest 0.1 g) and stored in a freezer at –20 °C until their subsequent analysis. Once the samples were defrost, the total stomach content was weighted and then the squid remains as muscle, suckers, beaks and eye lenses were separated using a stereomicroscope Stemi DV4 Zeiss and weighted in a digital balance. The beaks were identified to specific level following Clarke (1986).

All mantle lengths were grouped in three size classes: small (5-30 cm ML), medium (31-55 cm ML) and large (56-86 cm ML). Differences in size between sexes were substantiated with a t-student test. Differences in size between locations were evaluated through a Wilcoxon test.

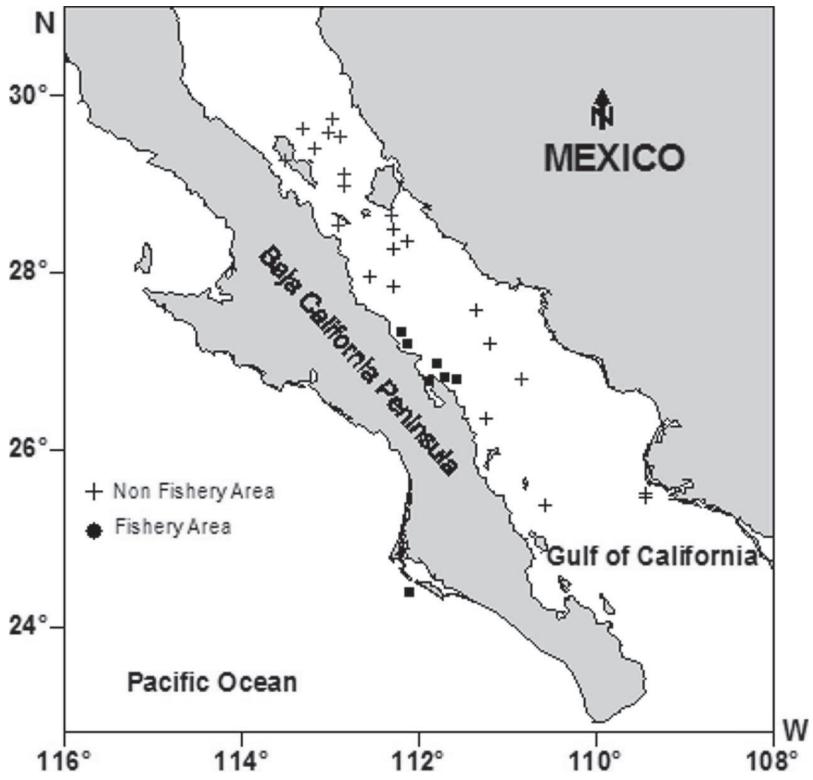


Figure 1. Sites where squids were collected for stomach content analysis. • Fishery area. + Non fishery area.

The cannibalism weight represented as the weight of *Dosidicus gigas* pieces in percentage from the total stomach content was calculated as:

$$\%W = (P_c / P_T)\,(100)$$

Where *%W* is the cannibalism weight, $P_c$ is the total weight of the cannibalized remains and $P_T$ is the total weight of the stomachs content. Differences in W% between sites, sexes and size groups were evaluated with a proportion test. Total stomach content weight (TW) was compared between sites and sexes through a Wilcoxon test.

Cannibalism frequency of occurrence (%FO) was calculated as the percentage of jumbo squid showing cannibalism with respect of all squid as:

$$\%FO = (n*100)/N$$

Where *n* is the number of squids with cannibalism and *N* is the total number of jumbo squid caught. To compare the %FO between size classes, sexes and fishing areas a proportion test was used.

## RESULTS

A total of 236 stomachs were examined of which 100 had evidence of cannibalism. Mantle length of the squids varied between 7cm and 86 cm with an average of 55.2 ± 16.6 cm. The sex ratio was 1:1 and no difference in ML between sexes was found (t= 0.23, $p > 0.05$). Significant difference in ML were found between areas, with larger sizes in fishing areas (Z= 4.5, $p< 0.05$) (Fig. 2).

In fishing areas 39.5% of the total stomach content corresponds to cannibalism (%W) and the remaining 60.5% corresponds to other jumbo squid preys, while in no fishing areas the %W was lower with only 3.8% (z=–23.2, $p<0.05$). Also, the TW in the fishing areas was higher than in no fishing areas (Z=4.8, $p<0.05$). The %W in females was slightly higher than in males (z=2.8, $p<0.05$); the same was found for TW, however no significant difference was found in TW between sexes (Z=1.3, $p<0.05$). Nevertheless, the highest %W was found in medium size group, followed by the large group, and the small group presented the lowest value. The three size classes were statistically different (z=–4.2, $p < 0.05$ small VS medium; z=–2.1, $p < 0.05$ small VS large; z=7.7, $p < 0.05$ medium VS large).

No differences were found in %FO between areas or sexes (z= –0.25, $p > 0.05$; z= 0.1, $p > 0.05$, respectively). On the other hand, the %FO increased with squid size and significant differences were found between size groups (z=–2.48, $p < 0.05$ small VS medium; z=–4.45, $p < 0.05$ small VS large; z=–2.09, $p < 0.05$ medium VS large). All the results are summarized in Table 1.

Table 1. Frequency of occurrence (%FO) and weight of cannibalism in the squid *Dosidicus gigas* samples. Number of stomachs with cannibalism contents are in brackets.

| | Sex | | Area | | Size | | |
|---|---|---|---|---|---|---|---|
| | Female | Male | Fishing area | No Fishing area | Small | Medium | Large |
| Stomachs | 94 (39) | 98 (42) | 143 (60) | 99 (39) | 20 (12) | 55 (28) | 114 (43) |
| Size range (ML, cm) | 22-86 | 22-73 | 28-86 | 7-78 | 7-30 | 31-55 | 55-86 |
| ML mean and SD | 56.2 ± 16. 8 | 56.7 ± 14.1 | 55.35 ± 14.6 | 55 ± 19.3 | 24.1 ± 5.5 | 41.4 ± 6.1 | 67.4 ± 5.0 |
| %W | 26.2 | 21.7 | 39.5 | 3.8 | 4.8 | 47.7 | 22.3 |
| TW | 13.9 ± 24.9 | 16.2 ± 43.9 | 15.2 ± 41.1 | 13.3 ± 20.1 | 1.3 ± 0.9 | 3.3 ± 12.0 | 23.6 ± 43.9 |
| %FO | 43.6 | 42.8 | 43 | 41.4 | 6.9 | 14.8 | 23.3 |

## DISCUSSION

Cephalopods feeding studies are highly influenced by biases in the sampling mainly due to fisheries operations, this has already been remarked in a few studies (Markaida & Sosa-Nishizaki, 2003; Ibáñez *et al.,* 2008). Biases may be the result of the voracious behavior present in this group caused by its rapid growth and high metabolic demands that result in feeding frenzy during catches (Rodhouse & Nigmatullin, 1996).

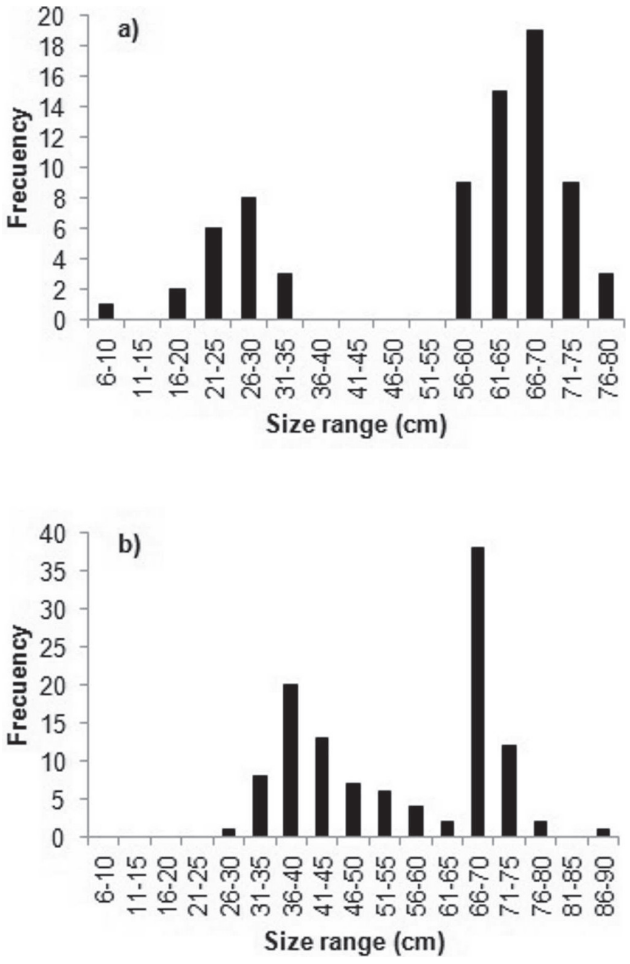


Figure 2. Squid frequency size distribution in both areas: *a)* no fishery and *b)* fishery areas.

High cannibalism values have been reported for *Dosidicus gigas* from the Gulf of California, up to 30% of its diet, and have been attributed to prey scarcity (Ehrhardt, 1991), however this conclusion has been obtained from samples taken from commercial vessels, and this means that fisheries could be influencing the feeding behavior of the animals. The same occurs in other areas, such as Chile, where cannibalism presents values from 96 to 99% in the relative importance index (RII) by prey inside the Phylum Mollusca (Cubillos *et al.*, 2004; Ulloa *et al.,* 2006), In both studies , samples were taken during fisheries, however they do not consider the stress caused by these activities and this could be the reason for their high cannibalism values. On the other hand Rosas-Luis (2007) reported that cannibalism is not an important part of the trophic spectrum in samples taken from two research cruises in no fishing areas from the west coast of Baja California peninsula. The %W value obtained for fishing areas in this study is as high as that presented by Ehrhardt (1991) and in no fishing areas this value is much lower. The differences obtained between the two types of areas point out that cannibalism has been overestimated as a natural behavior in this species and also indicate that fishing activities are influencing the results. Also other reports of cannibalism weight, %W (between 34 and 68%), have suggested that high values are the consequence of the fishing gear, feeding frenzy and catching stress (Markaida & Sosa-Nishizaki, 2003; Markaida, 2006; Ibáñez *et al.,* 2008; Markaida *et al.,* 2008).

Even though the results of this study did not show significant differences between areas in %FO, the values of %W and TW represented better the differences in cannibalism between areas; then, agglomeration and feeding frenzy induced by these activities may be the reason of the presence of more voracious behavior, that is reflected in a higher cannibalism stomach proportion and a higher stomach filling due to organisms feeding at the time of capture. Nonetheless other authors have already reported high values for cannibalism frequency of occurrence, %FO (between

26 and 77%) (Markaida & Sosa-Nishizaki, 2003; Markaida, 2006; Ibáñez *et al.,* 2008; Markaida *et al.,* 2008).

In our samples a higher amount of fleshy pieces were observed in the stomachs of individuals caught in fishing areas, mainly in Santa Rosalia, in contrast with ones caught in no fishing areas. These fleshy pieces represented an important part of the total stomach content and generally these pieces are quickly digested so their presence indicates recent ingestion, probably during catches (Ibáñez *et al.,* 2008; Markaida & Sosa-Nishizaki, 2003). Coupled with this, squids with bigger sizes were registered in fishing areas, where cannibalism was found to be higher, so this behavior could have some effects on organism's growth because a conespecific is an energy supply with a lower predation effort since they are easily available while fishing occurs, being that it have been reported that cannibalism interferes in animals growth (Fox, 1975).

*Dosidicus gigas* presents sexual dimorphism; females are bigger than males, however compared with other large-size species of the same family, this difference is negligible (Nigmatullin *et al.,* 1991). As cannibalism is the result of large sizes dominance over smaller ones, it is expected that females exhibit this behavior more frequently than males, in addition females have more energetic requirements due to the reproduction (Ibáñez & Keyl, 2010). Our results showed that females had a higher proportion of cannibalism in their stomach, despite the size was equal for females and males, possibly females were more voracious at the moment of capture. On the other hand Markaida and Sosa-Nishizaki (2003) showed that larger variations in diet were due to spatial or seasonal differences more than to squid size or sex.

Cannibalism %FO increased with squid size, this coincides with previous feeding reports for the species (Shchetinnikov, 1989; Markaida & Sosa-Nishizaki, 2003). Generally, in cannibalistic events bigger and older squids attack smaller and younger ones, which is the reason why bigger sizes present a higher cannibalism frequency. However Boyle and Rodhouse (2005) suggest that adults and juveniles do not match in the same habitat and in this sense cannibalism and competition is avoided but when different cohorts get together cannibalism may occur, as it happens during migrations and fishing events.

*Dosidicus gigas* is an opportunistic organism with a wide spectrum of prey, it captures abundant and available species, so its diet could be very variable (Hanlon & Messenger, 1996; Markaida & Sosa-Nishizaki, 2003), this leads to the cannibalistic behavior of the species during catching stress because fishing activities conglomerate a high number of conespecifics that are easy prey available.

Finally the results of this study agree with previous reports that argue that cannibalism is being influenced by fishing gears, the opportunistic behavior that causes attacks over vulnerable and abundant organisms, the stress during fishing operations and the feeding frenzy due to clustering in the areas where these activities occur. The results of this study proof that fishing operations cause an important bias in feeding studies of the species in the Gulf of California and San Carlos, Baja California Sur. Due to the fact that samples come from areas where these activities are taking place, cannibalism results obtained should be considered with caution.

## ACKNOWLEDGMENTS

We thank the crews of the Carmelita, Santa Catalina, BIP XII, PUMA and Don José for their kind cooperation in the course of research cruises. We are grateful to Arminda Mejía, the cephalopods team and the rest of the people who participated in the review of the samples.

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*Recibido*: 2 de febrero de 2012.

*Aceptado*: 14 de mayo de 2013.