

# Abundance of whale shark (*Rhincodon typus*) preferred prey species in the southern Gulf of California, Mexico

by

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**ABSTRACT.** - In the last decade, the whale shark, which occurs in the Gulf of California, has become an important touristic attraction. However, there is still no program of protection and management for this shark in the Mexican waters because the lack of biological information. The present study concerns an aspect of the biology of the whale shark in the bay of La Paz: its feeding habits, analyzed by the identification and quantification of its preferred preys. Several planktonic surveys were carried out in 2001 and 2002 in areas where aggregations of whale sharks are known. High planktonic concentrations were observed in these areas. The samples were mainly composed of copepods, representing 12 genera; the most abundant ones being *Acartia*, *Undinula* and *Corycaeus*. In the bay of La Paz, the whale shark feeds mainly on these copepods.

**RÉSUMÉ.** - Abondance des espèces-proies préférentielles du requin-baleine (*Rhincodon typus*) dans le sud du golfe de Californie, Mexique.

Au cours de la dernière décennie, le requin-baleine, présent dans le golfe de Californie, est devenu une attraction touristique importante. Cependant, il n'existe aucun programme de protection, ni de gestion, de ce requin dans les eaux mexicaines, du fait du manque de données biologiques. La présente étude concerne un aspect de la biologie du requin-baleine dans la baie de La Paz : son régime alimentaire, analysé en identifiant et en quantifiant ses proies préférentielles. Plusieurs campagnes de récoltes planctoniques ont été réalisées en 2001 et 2002 dans les zones connues de rassemblements du requin-baleine. Des concentrations planctoniques élevées ont été trouvées dans ces zones. Les échantillons prélevés étaient constitués principalement de copépodes, représentés par 12 genres, les plus abondants étant *Acartia*, *Undinula* et *Corycaeus*. Dans la baie de La Paz, le requin-baleine se nourrit donc principalement de ces copépodes.

Key words. - Whale shark - *Rhincodon typus* - ISE - Gulf of California - Mexico - Feeding habits - Copepods.

The whale shark (*Rhincodon typus* Smith, 1828), the largest fish in the sea, is a suction filter feeder that targets dense concentrations of planktonic and nektonic prey, including aggregating crustaceans such as copepods and euphausiids, and schooling baitfish such as sardines and anchovies (Compagno, 1984).

In the coastal waters off Ningaloo Reef, Western Australia, whale sharks aggregate from March to June. The aggregation is believed to be related to a seasonal abundance of food (Taylor and Pearce, 1996). In other parts of the world, the presence of whale shark is not correlated with coral spawning. In some areas, whale sharks are valued by the large commercial fishing industry. In the Peng Fu islands (Taiwan), the whale shark is caught all year round (Clark and Nelson, 1997).

The Gulf of California is an area where many sightings of whale shark occur (Wolfson, 1987), especially off the southern Gulf of California peninsula from Cape San Lucas to the bay of La Paz. Peak sightings of whale sharks are from May to June and from September to November (Ketchum, 2003). Clark and Nelson (1997) observed the feeding behaviour of the whale shark, and sampled plankton, con-

sisting mostly of copepods, of which 95% were *Acartia clausi*.

Nelson (2004) analyzed plankton samples from the bay of Los Angeles, in the north of the Gulf of California, where the zooplankton was mainly composed of copepods, however he did not identify them at the specific level.

In our study, sea surface plankton samples were taken during presence and absence of whale sharks in the bay of La Paz, Mexico (Ketchum, 2003) to determine its composition.

## METHODS

The planktonic surveys were performed in May, June and from August to November 2001 and in October-November 2002 in the southwest part of the Gulf of California (24°10'N to 24°47'N and 110°20'W to 110°44'W). Plankton samples were collected at four stations throughout the bay: station A off El Bajo, station B in the bay of La Paz, station C off Mogote and station D off Punta Prieta (Fig. 1). These stations were selected according to previous observations

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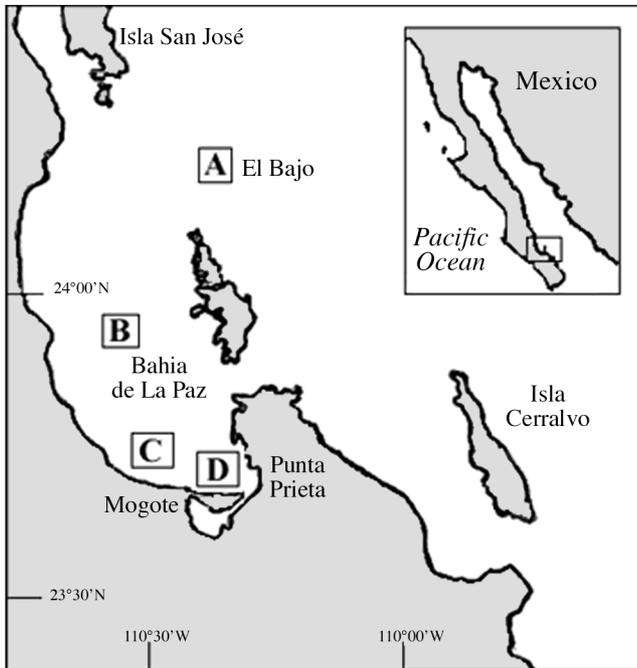


Figure 1. - Study area and localities where plankton tows were made. **A:** El Bajo de Espiritu Santo (EBES); **B:** Centre of the bay of La Paz; **C:** Mogote; **D:** Punta Prieta. [Zone d'étude et localités où les traits de plancton ont été réalisés.]

made by Clark and Nelson (1997) and Ketchum (2003) establishing that these areas are feeding grounds for the whale shark.

To sampling plankton, we used a 330 $\mu$ m net of 60 cm mouth diameter and 1 to 1.5 m length, with a flow meter. Tows were conducted at the surface and lasted 5 minutes. A total of 15 tows were conducted: 4 at station A (2 in the presence of whale sharks in August 2001 and October 2002, and 2 in their absence in May and September 2001), 4 at station B (2 in the presence of whale sharks in June and August 2001, and 2 in their absence in May and June 2001), 5 at station C (in the presence of whale sharks in November 2002) and 2 at station D (1 in the presence of whale sharks in October 2001 and 1 in their absence in November 2001).

Plankton samples were treated according to Beers (1976). The copepods were identified with specific keys (Mori, 1964; Palomares-García *et al.*, 1998).

The organisms were counted and their densities were expressed in numbers of individuals per 10<sup>3</sup> m<sup>3</sup> of water. Data were analyzed using non-parametric statistics. ANOVA analysis was used to test statistical differences between copepod densities for the years 2001 and 2002, for tows made in the presence and absence of whale sharks, and for comparisons between the stations. Statistical analyses were conducted using STATISTICA v. 5.5.

## RESULTS

In 2001, the density of copepods peaked in November with 267,932 ind./10<sup>3</sup> m<sup>3</sup> and was lowest in May with 3,757 ind./10<sup>3</sup> m<sup>3</sup>. In November 2002, the density of copepods was 837,500 ind./10<sup>3</sup> m<sup>3</sup> (Fig. 2).

In May 2001, whale sharks were observed feeding in a passive way (Ketchum, 2003) near locality B (centre of the bay), but copepod density was low (3,757 ind./10<sup>3</sup> m<sup>3</sup>) as in station A where a whale shark was present but not feeding.

In November of 2001 and 2002, active feeding behaviour was observed (Ketchum, 2003) around stations C and D where the maximum copepod densities were recorded.

Statistical analysis showed significant differences in copepod densities between years 2001 and 2002 ( $F_{1,122} = 5.152$ ,  $p < 0.02$ ); between May and June of 2001 ( $F_{1,24} = 10.4317$ ,  $p < 0.0035$ ); between June and August ( $F_{1,24} = 6.8710$ ,  $p < 0.2$ ) and between September and October ( $F_{1,27} = 16.9128$ ,  $p < 0.0003$ ). However, copepod densities showed no significant statistical difference between October and November 2001 ( $F_{1,28} = 1.42$ ,  $p > 0.05$ ).

Copepod densities between the northern and southern part of the bay (localities A and B vs localities C and D) are significantly different ( $F_{1,122} = 31.625$ ,  $p < 0.05$ ).

A total of twelve copepod genera were identified in this study: *Icaria* spp. (Dana, 1846), *Undinula* spp. (Scott, 1909), *Calanus* spp. (Leach, 1819), *Paracalanus* spp.

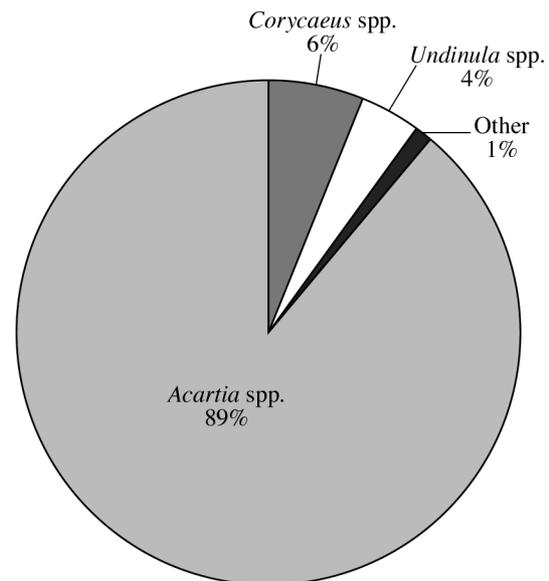


Figure 2. - Average copepod density and sea surface temperature during 2001 and 2002 surveys in the bay of La Paz, Mexico. [Densité moyenne des copépodes et température de surface observées au cours des campagnes réalisées en 2001 et 2002 dans la baie de La Paz, Mexique.]

Table I. - Copepod families and genera identified as preferred prey of the whale shark, *Rhincodon typus*, during the 2001 and 2002 surveys in the bay of La Paz, Mexico. [Genres de copépodes identifiés comme proies préférentielles du requin-baleine, *Rhincodon typus*, au cours des campagnes menées en 2001 et 2002 dans la baie de La Paz, Mexique.]

Family	Genera
Acartidae	<i>Acartia</i> spp.
Calanidae	<i>Undinula</i> spp.
Calanidae	<i>Calanus</i> spp.
Paracalanidae	<i>Paracalanus</i> spp.
Corycaeidae	<i>Corycaeus</i> spp.
Pontellidae	<i>Labidocera</i> spp.
Temoridae	<i>Temora</i> spp.
Oithonidae	<i>Oithona</i> spp.
Eucalanidae	<i>Rhincalanus</i> spp.
Centropagidae	<i>Centropages</i> spp.
Oncaeiidae	<i>Oncaea</i> spp.
Pontellidae	<i>Pontellopsis</i> spp.

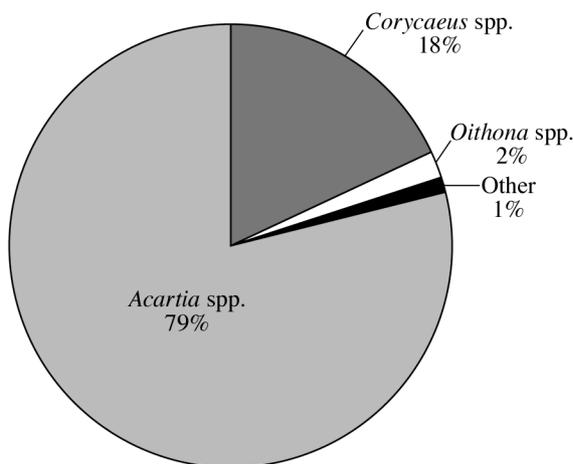


Figure 3. - Copepod composition in the presence of whale shark during the 2001 and 2002 surveys in the bay of La Paz. [Composition des copépodes en présence de requins-baleines au cours des campagnes réalisées en 2001 et 2002 dans la baie de La Paz, Mexique.]

(Boeck, 1865), *Corycaeus* spp. (Dana, 1846), *Labidocera* spp. (Lubbock, 1853), *Temora* spp. (Baird, 1843), *Oithona* spp. (Baird, 1843), *Rhincalanus* spp. (Dana, 1852), *Centropages* spp. (Kroyer, 1859), *Oncaea* spp. (Philippi, 1843), and *Pontellopsis* spp. (Brady, 1883) (cf. Tab. I).

The most abundant genus was *Acartia* spp. with average density of 135,280 ind/10<sup>3</sup> m<sup>3</sup>; the largest densities were found at station C (28,779,305 ind./10<sup>3</sup> m<sup>3</sup> in November 2002) where a whale shark was feeding, at station A (3,724,196 ind/10<sup>3</sup> m<sup>3</sup> in October 2001) and at station D (2,138,971 ind/10<sup>3</sup> m<sup>3</sup> in November 2001). The second most abundant genus was *Corycaeus* spp. with average density of

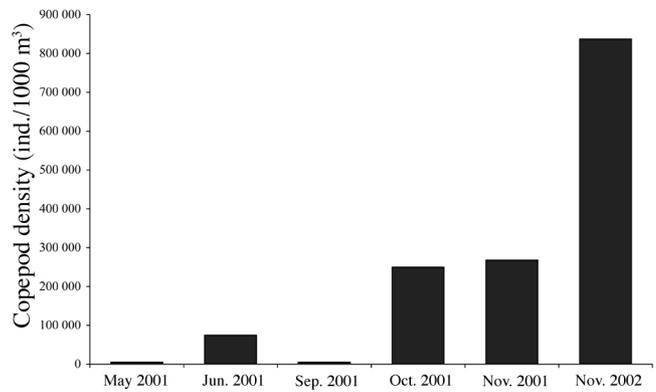


Figure 4. - Copepod composition in the absence of whale shark during the 2001 and 2002 surveys in the bay of La Paz. [Composition des copépodes en absence de requins-baleines au cours des campagnes réalisées en 2001 et 2002 dans la baie de La Paz, Mexique.]

8,280 ind/10<sup>3</sup> m<sup>3</sup> at stations A and B. The third most abundant genus was *Undinula* spp. with average density of 6,735 ind/10<sup>3</sup> m<sup>3</sup> at stations A and B in May and June 2001 (Fig. 3).

In September 2001, in the absence of whale sharks, the most abundant copepods were *Acartia* spp. (27,542 ind/10<sup>3</sup> m<sup>3</sup> at station B), *Corycaeus* spp. (8,567 ind/10<sup>3</sup> m<sup>3</sup>) and *Oithona* spp. (1,013 ind/10<sup>3</sup> m<sup>3</sup>) (Fig. 4).

**DISCUSSION**

Out of the twelve copepod genera, only the genus *Acartia* has been reported as food for the whale shark (Clark and Nelson, 1997). They mentioned that whale shark sightings in the bay of La Paz coincide with blooms of the copepod *Acartia clausi* in the south and southeast parts of the bay during fall.

The high concentrations of *Acartia* spp. observed in the southern part of the bay in November 2001 and 2002, agreed with Palomares's results (1996) that reported high densities of copepods, mainly *Acartia clausi*, in the southern area of the bay during fall season. González-Navarro and Saldierna-Martínez (1997) mentioned that copepod community in the inner part of the bay of La Paz is represented mainly by *Acartia clausi*, *Acartia lilljeborgii* and *Paracalanus parvus*, which occur throughout the year, in areas where tide currents have lower intensity. Palomares (1996) also mentioned that the abundance and diversity of this community decline from spring to winter.

The relative importance of copepod blooms as food resources for whale sharks is unknown. However, our results show that the high planktonic concentrations, and particularly those of the copepod genus *Acartia* spp., are observed when the whale sharks are present and feed on them. So these copepods constitute the main components of the diet of the whale shark in the southern Gulf of California.

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