

PALEONTOLOGICAL NOTE

Local extinction of sharks of genus *Carcharias* Rafinesque, 1810 (Elasmobranchii, Odontaspidae) in the eastern Pacific Ocean

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ABSTRACT

Fossil record has shown that the genus *Carcharias* and probably species *C. taurus* Rafinesque, 1810 occupied the western coast of South America during the Miocene and part of the Pliocene. The genus is absent in the area today. It is suggested that its local extinction was the consequence of a drop of global temperatures during the middle Pliocene and Pleistocene and the coeval lowering of sea level that shranked the area of distribution to the northern areas and provoked the disappearance of suitable environments when the shelf area became extremely reduced. After approximately 3 Ma it would have not been possible for the species to migrate from the north to the region due to the establishment of the Panamanian isthmus.

Key words: Odontaspidae, *Carcharias*, Local extinction, Miocene, Pliocene, South America.

RESUMEN

Extinción local de tiburones del género *Carcharias* Rafinesque, 1810 (Elasmobranchii, Odontaspidae) en el Océano Pacífico oriental. El estudio del registro paleontológico indica que la distribución de *Carcharias* y posiblemente *C. taurus* Rafinesque, 1810, durante el Mioceno y parte del Plioceno, habría incluido la costa oeste de Sudamérica, donde hoy se encuentra ausente. Se propone que su extirpación de esta zona habría sido provocada por el abrupto descenso de las temperaturas durante el Plioceno medio y Pleistoceno y la consiguiente caída del nivel del mar, lo que habría reducido notablemente el ambiente de plataforma, hábitat natural de este taxón. Posteriormente a los 3 Ma aproximadamente, al restablecerse el nivel del mar, la recolonización desde el norte no habría sido posible debido al establecimiento del istmo de Panamá.

Palabras claves: Odontaspidae, *Carcharias*, Extinción local, Mioceno, Plioceno, América del Sur.

INTRODUCTION

Neoselachians sharks are included in the class Chondrichthyes, a very ancient clade which perhaps ranges from the Ordovician but certainly from the Devonian. Sharks, very important fishes in the economy of the sea today, include the most ancient vertebrate recent genera. A family of relatively large sharks, Odontaspidae, is known since the Aptian (early Cretaceous; *Carcharias striatula* (Dalinkiewicz, 1935); Cappetta *et al.*, 1993). Today it includes the genera *Odontaspis* Agassiz, 1838 and *Carcharias*. Genus *Carcharias* is monospecific today but it had several fossil species (Cappetta, 1987). Recent species *C. taurus* (Rafinesque, 1810) is wide-ranging in warm-temperate and tropical coastal waters of the Atlantic Ocean, Mediterranean Sea, and Indo-West Pacific Ocean but is absent from the Central Pacific and eastern Pacific oceans (Compagno, 2001; Lucifora

et al., 2003; Fig. 1). However, the fossil record has shown that the distribution of the genus *Carcharias* and possibly the species *C. taurus* occupied the western coast of South America during the Miocene and at least part of the Pliocene. The World Conservation Union considers *C. taurus* as a vulnerable species today, with its populations seriously depleted (Compagno, 2001). It is critically endangered in New South Wales, Australia, after large numbers were killed in sports and commercial fisheries and by divers (Compagno, 2001). Cione and Azpelicueta (2002) described several cases of extirpation of fishes in the Atlantic Ocean. In this paper, the occurrence of genus *Carcharias* in the eastern Pacific is reviewed and a hypothesis for explaining its local extinction is proposed.

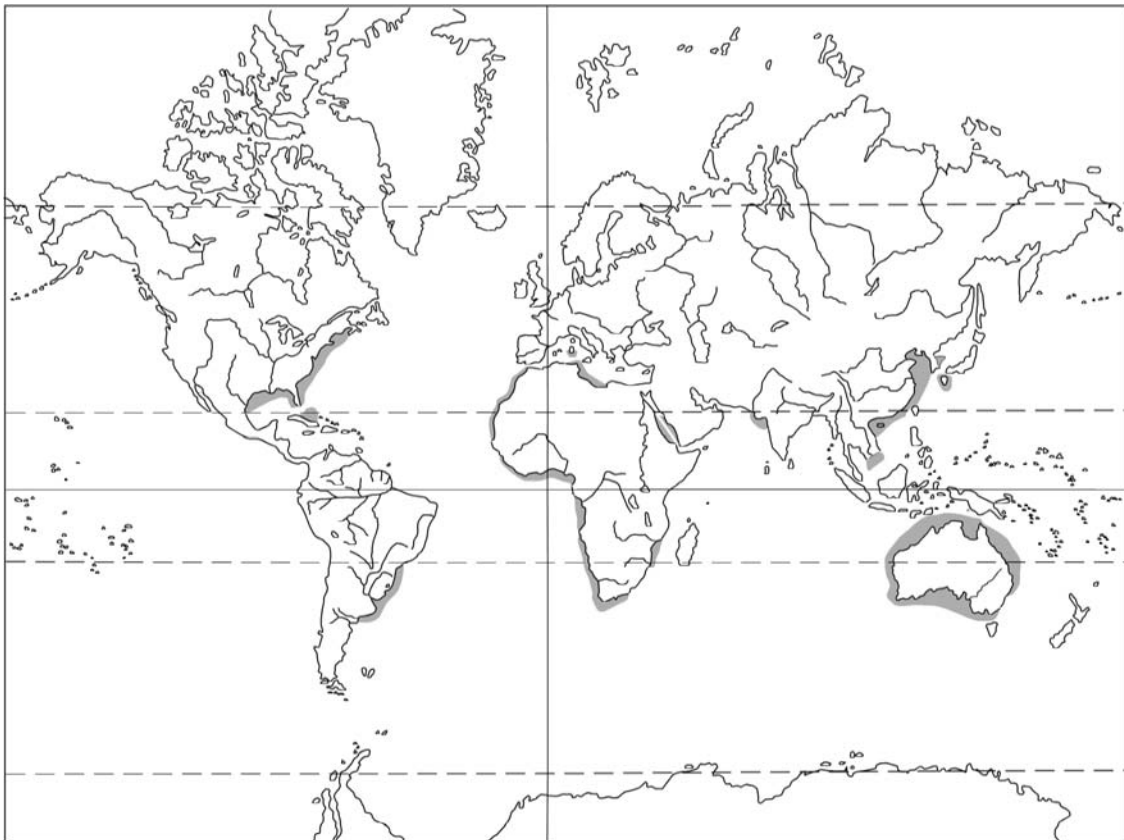


FIG. 1. Present distribution in gray of *Carcharias taurus* (Rafinesque, 1810, modified from Compagno, 2001).

OCCURRENCE IN THE SOUTHEASTERN PACIFIC DURING THE CENOZOIC

Teeth that could correspond to the genera *Striatolamia* Glückman, 1964 or *Carcharias* (Rafinesque, 1810) were reported from Eocene beds in different localities (Lota, Lebu, Puchoco, Buen Retiro) of southern Chile (Oliver-Schneider, 1936; Arratia and Cione, 1996; Fig. 2). The material was not figured. *Striatolamia* traditionally was considered to be an Odontaspidae. However, Siverson (1995) suggested that it could pertain to another lamniform family, Mitsukurinidae. However, specimens certainly assignable to the odontaspidid genus *Carcharias* were described from Miocene to Pliocene beds (Fig. 2):

Carcharias acutissima (Agassiz, 1843), formerly described as *Odontaspis acutissima*, from transitional strata between Borbon and Onzole formations in Ecuador (Longbottom, 1979; Figs. 3-4). Both were formerly considered Miocene in age but presently are referred to the Pliocene (Aalto and Miller, 1999). The localities are CRB 123, a sea stack at Punta La Colorado (0°37.6'S, 80°27.6'W) and CRB 123b is the cliff at Punta La Gorda (0°38.2'S, 80°28'W).

Carcharias (as *Synodontaspis* White, 1931) aff. *taurus*, in the Sacaco vertebrate level (SAO) in the upper part of the Pisco Formation at Sacaco, Perú (near the Peruvian coast, 15°32'S; de Muizon, 1981; de Muizon and DeVries, 1985). The material was identified as such (Cappetta, H., oral comm., 1983,

to de Muizon) but not figured. The bearing level corresponds to the *Anadara* Zone and is Early Pliocene in age. A K-Ar date of 3.9 Ma was obtained in a tuff located several meters below the SAO level at Sacaco (de Muizon and DeVries, 1985). No unconformity is yet known between the tuff and SAO level so it can be reasonably assumed that the SAO level is late Early Pliocene (de Muizon and DeVries, 1985).

Carcharias cuspidata (Agassiz, 1843) has been identified in the Navidad Formation (Early Miocene), at about 150 km from Santiago, in the VI Region, Cardenal Caro Province, Central Chile (Suárez and Encinas, 2002).

Another occurrence of *Carcharias* sp., is from the Bahía Inglesa Formation in the Mina La Fosforita, Bahía Inglesa, Región de Atacama, Provincia de Copiapó, Chile (27°00'S, 70°45'W-28°00'S, 71°00'W), in levels dated as Late Miocene-Middle Pliocene because of the presence of *Carcharodon carcharias* (Walsh and Hume, 2001; Suárez *et al.*, 2004).

These records have demonstrated that individuals of *Carcharias*, probably *C. taurus*, inhabited the occidental shelf of South America until at least about 3-4 Ma. Besides, teeth assigned to the genus *Carcharias* have been reported from the Middle Miocene beds of California, USA (J. Bourdon¹).

DISCUSSION AND CONCLUSIONS

Odontaspidids were more widely distributed during the Cenozoic than today. They inhabited Antarctica until at least the Eocene and southern South America until at least the Early Miocene (Leriche, 1936; Cione *et al.*, 1977; Long, 1992; Cione and Reguero, 1994; Arratia y Cione, 1996). The present authors studied morphological variations in different areas (Lucifora *et al.*, 2003) and the distribution of Cenozoic specimens from different localities of Argentina (Cione *et al.*, 2000). Distribution of some fishes is hard to explain according to vicariance and migration. However, their extirpation from high latitude cold seas is explained because of the global temperature

drop during the late Cenozoic (Cione, 1978; Cione and Azpelicueta, 2002).

The distribution of *Carcharias taurus* is patchy today (Lucifora *et al.*, 2003). The species is more frequent in relatively temperate areas although it also occurs in some equatorial waters (Fig. 1). It is an inshore and offshore, littoral shark that occurs from the intertidal less than 1m deep down to at least 191 m, and mostly at depths of 15 to 25 m (Compagno, 2001).

In South American coasts, several biogeographic marine provinces have been proposed. In the western coast, the Magallanian (from about 56°S

¹ Active in 2006. Sharktooth Hill Miocene Sharks and Rays. http://www.elasmo.com/frameMe.html?file=paleo/sth/shrkhill.html&menu=bin/menu_fauna-alt.html

to 40°S), Peruvian (from 40°S to 4-6°S), and Panamic (from 4-6°S to the North) provinces (López, 1964). In the eastern coast, the Magallanian (from about 56°S to about 42°S), the Argentinean (from 41°S to 23°S), and the Western Indian (from 23°S to the north) provinces (López, 1964). *Carcharias taurus* ranges from approximately Cabo Frio in Brazil to southern Buenos Aires Province in Argentina (Fig. 1). Consequently, it is a typical element of the Argentinean province, of warm temperate waters (López, 1964). Compagno (2001, p. 59) includes *C. taurus* in the Magallanian province in the southern Atlantic; however we do not know of any record there. *Carcharias taurus* is a migratory shark in shelf areas (Compagno, 2001) that reaches the coast of Buenos Aires Province in the early summer and migrates northward in early fall.

The present oceanic circulation was established in the Miocene (Beu *et al.*, 1997). A branch of the West Wind Drift, the Chile Current, runs along the South American western coast and carries Subantarctic water from the Austral Ocean approximately to 20°S where it turns west (Molina-Cruz and Herguera, 2002). Northwest of the backwater, along the Peruvian coast, flow towards the Equator also occurs: the Perú Current. However, according to faunal data, temperatures in Perú from the Miocene to the early Pliocene were higher than present (de Muizon and DeVries, 1985). Early Pleistocene assemblages indicate a rather sudden shift towards modern cooler conditions along the southern Peruvian coast (de Muizon and DeVries, 1985). Substantial cooling occurred in middle and high latitudes in the western North Pacific Ocean as well as the western North Atlantic Ocean between 3 Ma and 2.4 Ma (Cronin and Dowsett, 1992; Tsuchi, 2002). During the Middle and Late Pleistocene temperature drop was very important in the area (Clapperton, 1993; Kim *et al.*, 2002). Populations of sharks such as *C. taurus* could be displaced northerly looking for more optimal temperatures causing that the species distribution shrank.

The continental shelf is presently extremely reduced in western South America (Fig. 2). At the latitude of Bahía Inglesa (Chile) or Sacaco (Perú), localities where *Carcharias* Miocene and Pliocene specimens were found, the present continental shelf is about 10 km and 20 km wide respectively. Oscillations between glacial and interglacial climate conditions over the past 3 million years occasioned important sea level drops (Lambeck *et al.*, 2002). The area between the present depth of 120-140 m (Rohling *et al.*, 1998;

Lambeck *et al.*, 2002) and that of 200 m in the western South America surely represented an extremely reduced belt when the sea level was low. At the latitude of Bahía Inglesa and Sacaco, the belt could be as narrow as 1 km and 3 km respectively. On the contrary, when *Carcharias* inhabited the area during the Miocene and Pliocene, sea level was higher and shelf related organisms had a relatively wider area to inhabit (for instance, in Ecuador, where marine localities of this type and age are 20 km from the present coast; Bianucci *et al.*, 1993). Reduction of the habitat occasioned by sea-level drops severely altered the surface area of ecologically critical zones over the continental shelves and generate important population stress (Smith *et al.*, 2001). In western South America, the suitable habitat for a shelf shark such as *Carcharias taurus* was destroyed by the sea drop. It is considered that this drove the species to local extinction after attaining its extinction point.

During the interglacial periods, when the sea level rised, recolonization from the north was not possible because the Panamanian isthmus was already established (3.7-3 Ma, perhaps later; Duque-Caro, 1990; Cione and Tonni, 1995; Hagelberg, 1996; Ibaraki, 1997).

Recolonization from the Atlantic ocean was also not possible through the Cape Horn area due to the low temperatures in the Drake area (contrary the opinion of Reif and Saure, 1987).

Apparently, the higher temperatures that occurred during the interglacial periods in the Pleistocene have not been enough to permit a transit from the Atlantic to the Pacific oceans (Moy *et al.*, 2002). Local temperature and productivity variations did not altered the biogeographic situation (Loubere, 2002).

Extirpation (or remarkable reduction in distribution area) due to causes different from the global Cenozoic cooling trend is known from the Atlantic ocean for the shark families Heterodontidae, Pristiophoridae and the hemigaleid genus *Hemipristis* Agassiz, 1843, the teleost family Oplegnathidae, and the mammalian families Dugongidae and Monachinae (Cione and Azpelicueta, 2002). In Chile, there are several nominal selachian taxa reported (without description or illustration) from the Bahía Inglesa and Navidad formations that do not inhabit the eastern Pacific ocean (Suárez *et al.*, 2002; Suárez and Encinas, 2002; Suárez *et al.*, 2004). They could correspond to additional pseudoextinctions in the area.



FIG. 2. Localities with fossil odontaspids in the Pacific coast of South America. 1. Lebu (Chile); 2. Punta La Colorada and Punta La Gorda (Ecuador); 3. Sacaco (Perú); 4. Navidad (Chile); 5. Bahía Inglesa (Chile). The present South American continental shelf is in gray.

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