

body, the time of the year that the wounds are received, and the age of the seal provide a good indication of the cause. During the breeding season, for example, suckling seal pups bear bite marks on the snout, head, and rump, these having been inflicted by adult females (Le Boeuf and Briggs 1977). Weaned pups and adult females bear fresh bite marks of varying severity caused by adult males biting their necks while attempting to mate with them, and breeding-age males inflict a variety of bite wounds on each other during fights to establish dominance (Le Boeuf and Reiter in press). During winter and spring, *Mirounga angustirostris* of both sexes and all ages exhibit fresh wounds inflicted by white sharks, *Carcharodon carcharias*. The shape and serrated edges of those wounds are easily distinguished from the smooth-edged and halfmoon-shaped wounds caused by boat propellers (Le Boeuf et al. 1982; Tricas and McCosker 1984).

The wounds that we discovered were round, hollowed-out craters, smooth edged at the margin, about the size of a tennis ball, and unlike any of the wounds described above. The similarity in appearance of these wounds to scars inflicted by *Isistius* upon cetaceans (Van Utrecht 1959) and fishes (Jones 1971) implicate the cookiecutter shark as the probable cause. The only reported eastern Pacific occurrence of an *Isistius* is that of an *I. brasiliensis* from off the Galapagos (Compagno 1984). However, we have examined additional eastern Pacific specimens of *I. brasiliensis*, including a specimen from off Isla de Guadalupe.

Background information. Northern elephant seals inhabit traditional island and mainland sites from mid-Baja California, Mexico, to central California. Their range at sea along the Pacific coast is from Isla Cedros, Mexico, to the southern Aleutians. Feeding occurs beyond the continental shelf in deep water (Le Boeuf et al. 1986). It is not known how far from shore they go to feed, but some animals have been seen as far as 3,000 miles away on Midway Island in the mid-Pacific (Condit and Le Boeuf 1984). Several islands are used regularly throughout the year (Guadalupe, San Benito, Cedros, and Coronados in Mexico and San Miguel, San Nicolas, Año Nuevo, and the Farallones); the sex and age composition of each colony varies with time of year (Le Boeuf and Bonnell 1980). Late August or early September, when most of the observations reported in this paper were made, is the end of the molt period for adult and subadult males and the beginning of the fall haul-out for juveniles, 1-4 years old. Breeding-age males, observed on land at this time, are completing the annual molt, a process that takes

CRATER WOUNDS ON NORTHERN ELEPHANT SEALS: THE COOKIECUTTER SHARK STRIKES AGAIN

A variety of wounds are observed on northern elephant seals, *Mirounga angustirostris*. We report a new type of wound observed on juveniles, primarily from the Mexican islands west of Baja California and rarely from off California. The form and shape of these wounds, and their similarity to wounds reported from other marine mammals, fishes, and squids, suggest that they were caused by a small, squaloid shark of the genus *Isistius*, commonly known as the cookiecutter or cigar shark.

The shape of wounds, their location on the victim's

30-40 days; they are in the process of returning to sea to feed. As their number declines, juveniles of both sexes begin to haul-out in increasing numbers. They have been at sea for 4 months or more. Census counts of total northern elephant seals are lower at this time than at any other time of the year (Le Boeuf and Bonnell 1980).

Observations and Methods

Most of the observations were made during an expedition to Mexican islands aboard the MV *Mirage* from 20 to 31 August 1986. Islands surveyed included Isla de Guadalupe, Islas San Benito, Cedros, San Martin, and Los Coronados. We censused northern elephant seals at all sites and, in doing so, recorded the incidence of fresh wounds. On 2 September 1986, we censused and recorded wounds on northern elephant seals at Año Nuevo Island off central California. Similar observations and censuses were conducted weekly at Año Nuevo Island during October and November, when peak numbers of juveniles are observed.

Censuses and inspection for wounds were made from an inflatable 6 m boat, approximately 10 m from seals lying on sandy beaches near the water's edge, or from on foot to get closer to the animals. When possible, we inspected both sides of all seals; we made no attempt to turn animals over to inspect the ventrum or to arouse them to better inspect them for wounds. Approximately half of the animals counted were seen from only one side. Thus, the counts of wounded animals we present are clearly underestimates of the true figure. We noted the location of all wounds and estimated their size and freshness.

We examined preserved specimens of *Isistius* housed in the Marine Vertebrates Division of the Scripps Institution of Oceanography (SIO).

Results

We observed fresh wounds on 20 juvenile northern elephant seals on three of the five island groups inspected in August and September (Table 1); there were no elephant seals on Isla San Martin. Four additional wounded juveniles were observed on Año Nuevo Island later in the year. All wounds were fresh, as indicated by their bloody color, and, with one exception, they were of similar size and shape (Fig. 1). The wounds were round and hollowed-out craters; the margin of each wound was smooth. Each wound was about 5-6 cm wide and 3-5 cm deep. One wound, although like the others in most respects, had a flap of skin and blubber still attached. No fresh crater wounds were observed on adult and subadult males.

Most animals had one wound. Wounds were located on various parts of the body (Fig. 1): the side posterior to the flippers, on the ventrum or the back and to either side or on the midline, on the chest and neck, and just behind the ear. Two animals had two wounds and one had three. One animal had two fresh, identical wounds on the dorsal midline at the level of the foreflippers, separated by approximately 3 cm. Another had two wounds 0.3 m apart on its left side. One animal had three wounds: two on the abdomen and one on the ventral surface of the neck.

The incidence of fresh wounds was highest on northern elephant seals inhabiting Isla de Guadalupe (8.4% of the juveniles censused) followed by Isla Cedros and Islas San Benito (Table 1). No wounded

TABLE 1.—Proportion and percentage of fresh crater wounds on northern elephant seals censused on various Mexican and Californian islands during August and September 1986.

Date	Island	Beach or islet	Adult and subadult males	Juveniles
21-24 Aug.	Guadalupe	Pilot Rock Beach	0/34 = 0	7/95 = 7.37
		Barracks Beach	0/19 = 0	3/95 = 8.57
		Twin Canyons	0/10 = 0	6/61 = 9.84
		Sum: all beaches	0/63 = 0	16/191 = 8.38
25-27 Aug.	San Benito	Este	0/10 = 0	1/57 = 1.75
		Centro	0/38 = 0	1/127 = 0.79
		Oeste	0/6 = 0	0/51 = 0
		Sum: all islets	0/54 = 0	2/235 = 0.85
28-29 Aug.	Cedros		0/13 = 0	2/45 = 4.44
31 Aug.	Los Coronados		0/1 = 0	0/14 = 0
2 Sept.	Año Nuevo		0/23 = 0	0/200 = 0

¹Over 90 juveniles were counted but only 57 were observed close enough to document wounds.

animals were observed on Los Coronados during August or on Año Nuevo Island during August and September. However, four juveniles with fresh wounds, among 700 juveniles present, were observed on Año Nuevo Island during four censuses in November (1, 9, and 30 November). One animal, sighted on 1 November 1986, was marked: a 22-month-old juvenile born on Año Nuevo Point on 11 February 1984 and tagged 1 month later.

As mentioned above, through examination of the holdings of the Scripps Institution of Oceanography Fish Collection, we uncovered additional Pacific specimens of *Isistius brasiliensis*. The eight specimens from seven lots included six males and two females. The largest, a 470 mm (standard length) female (SIO 69-345) with jaw width of 38 mm, was collected by IKMT (Isaacs-Kidd midwater trawl) between the surface and 2,000 m from north of Easter Island (lat. 25°58.5'S, long. 108°50.7'W). Another eastern Pacific specimen (SIO 78-183) is from off Isla de Guadalupe (29°26.5'N, 119°44'W) and was collected by phytoplankton net. The other eastern Pacific specimen (SIO 52-413) is from west of the Galapagos (00°00', 100°00'W) and was captured at the surface by dip net.

Discussion

The fresh crater wounds we observed on juvenile northern elephant seals resemble those reported on beaked whales, sperm whales, several species of porpoises, and most of the baleen whales (Mackintosh and Wheeler 1929; Van Utrecht 1959), as well as those from a variety of pelagic fishes (Jones 1971) and a nuclear submarine (Johnson 1978). Jones (1971) and others have demonstrated conclusively that those wounds are the result of bites inflicted by the small squaloid shark, *Isistius brasiliensis*, or possibly by its congener, *I. plutodus*. To date, the only Pacific record of *I. plutodus* is from off Okinawa (Compagno 1984), so we therefore presume that the more wide-ranging and topotypical *I. brasiliensis* is the culprit. *Isistius brasiliensis* is epipelagic to bathypelagic and is known from all tropical oceans, extending northward to off Japan and Baja California and southward to Lord Howe Island. It is typically caught by midwater trawl at depths between 85 and 3,500 m; however, it is occasionally found at the surface at night. The shark is thought to be a diurnal vertical migrator, perhaps traveling a distance as great as 2,000-3,000 m in each direction; in so doing, it apparently encounters feeding *Mirounga*. As noted by Compagno (1984, p. 94), *Isistius* is highly specialized as a facultative ectoparasite in its

dentition, suctorial lips, and modified pharynx that allow it to attach to the side of large prey, drive its sawlike lower jaw teeth into the skin and flesh of its victim, cut a conical plug of flesh, and then pull itself free with the plug cradled by its scooplike lower jaw and held by the hooklike upper jaw teeth. The scar patterns of juvenile *Mirounga* support the scenario described above. A comparison of jaw width of *Isistius* of known size with the scar patterns observed on *Mirounga* suggests that the attacking sharks were at least 50-60 cm long.

Northern elephant seals would appear to be easy prey for *Isistius*. They are slow swimmers, compared with large pelagic fishes, and they spend 85% of their time at sea underwater at depths of 400-650 m (LeBoeuf et al. 1985; Le Boeuf et al. 1986). Juvenile seals that use Isla de Guadalupe during the fall are evidently most prone to being parasitized. Juvenile seals hauling out on other islands, especially those to the north, are evidently not exposed to *Isistius* to the same degree. Until recently, no fresh crater type wounds were observed on seals at Año Nuevo despite 16 years of observations by B. J. Le Boeuf. Some wounds observed may have been old, healing crater type wounds, suggesting that the animals bearing them may have been immigrants from the south, the predominant direction of dispersal (Bonnell et al. 1979). Fresh crater wounds have not been observed on the northern elephant seals at the Farallones since their breeding began in 1972 (H. Huber, pers. commun.¹). Le Boeuf never observed fresh crater wounds on northern elephant seals breeding on San Miguel and San Nicolas Islands during 1968-78, despite annual visits to these islands.

Mexican northern elephant seals of juvenile age fall prey to *Isistius* shortly before they haul-out in late August. Le Boeuf and coworkers never observed crater wounds on seals at these Mexican rookeries during the winter breeding season (13 visits since 1968) or summer molt (4 visits). The juveniles may be exposed to *Isistius* while feeding or while returning to the island. The marked difference in distribution of shark wounds is consistent with the observation that Mexican, southern Californian, and central Californian juveniles feed in different locations, and each "subpopulation" feeds north of its birthplace (Condit and Le Boeuf 1984). Juveniles, trapped in fishing gear, have been caught around 200 m below the surface and captured 16-224 km offshore.

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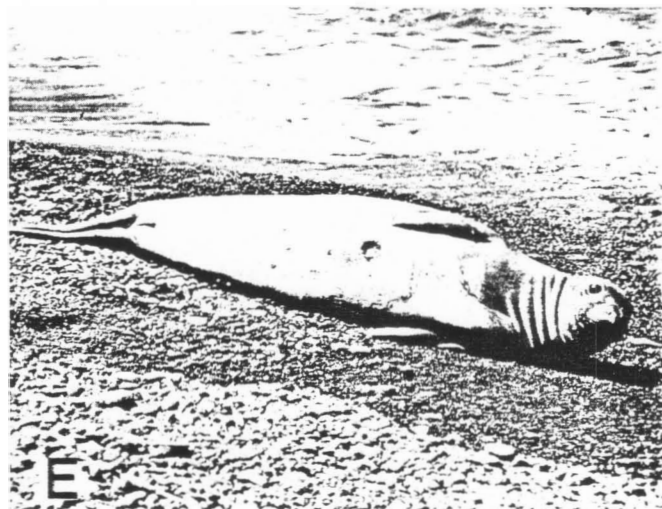
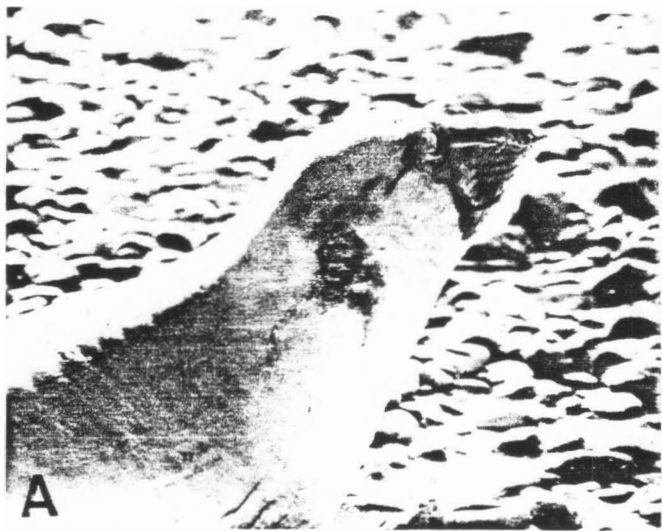
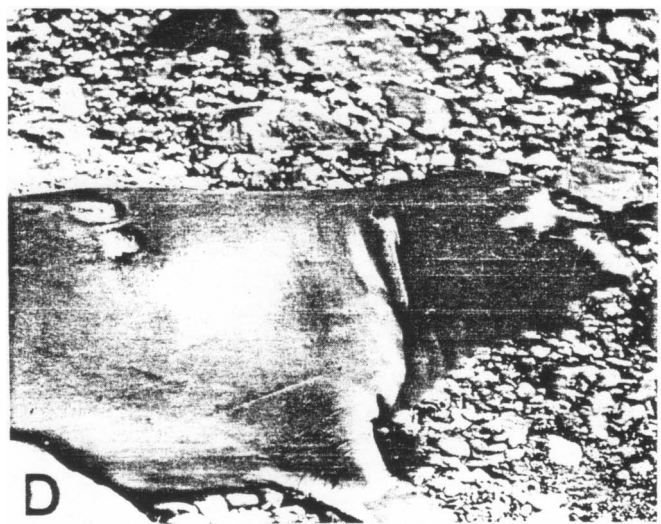
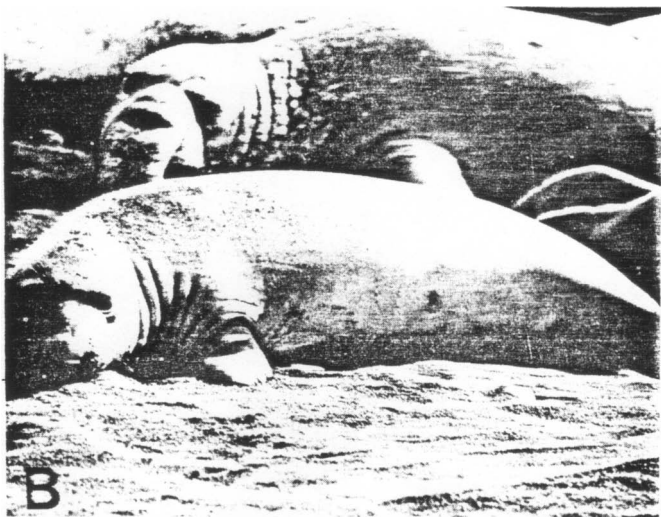


FIGURE 1.—Representative wounds on *Mirotunga angustirostris* caused by *Isistius* attacks. A, B, C—taken at Isla de Guadalupe, Mexico; D, E—taken at Isla Este, Islas San Benito, Mexico; F—taken at Año Nuevo Island, California. Not visible in F are two other healing wounds along the animal's right flank. (Photos A-E by B. J. Le Boeuf; photo F by P. Thorson.)



That only juvenile northern elephant seals exhibit fresh crater wounds may be explained in several ways. It suggests that this age category is the only one exposed by depth or location to feeding *Isistius*; or, it may suggest that older age classes are able to avoid attack. Another interesting hypothesis concerns the common prey of both *Isistius* and *Mirounga*, midwater squid. It has been speculated that the bioluminescent pattern of *Isistius* might simulate the pattern of a large midwater squid and thereby attract squidophagous predators (Jones 1971) upon which it could prey. It seems unlikely that an *Isistius* could outswim a *Mirounga*; attacks by the shark would thus be accomplished either by attracting the seal, perhaps for a closer inspection of the shark, or by attacking the seal by stealth and surprise. The location of attack scars on the head region of *Mirounga* would indicate a frontal approach, whereas the scars on the back and flanks might indicate that the seal was unaware of the impending attack. Both scenarios are likely. It is also possible that juveniles seals are more readily attracted to the display of *Isistius*, not having learned yet to distinguish them from squid. Further insight into these hypotheses will be provided as more data concerning the spatial and temporal distribution of *Isistius* are collected.

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