Impalement of marine turtles (Reptilia, Chelonia: Cheloniidae and Dermochelyidae) by billfishes (Osteichthyes, Perciformes: Istiophoridae and Xiphiidae)

John G. Frazier[1], Harry L. Fierstine[2], Sallie C. Beavers[3,4], Federico Achaval[5], Hiroyuki Suganuma[6], Robert L. Pitman[3], Yuichiro Yamaguchi[7] & Carlos Ma. Prigioni[5]

[1] *Centro de Investigación y de Estudios Avanzados del IPN – Unidad Mérida Apartado 73 'Cordemex', Mérida, Yucatán, C.P. 97310, México, and Conservation Research Center, National Zoological Park, Smithsonian Institution, Front Royal, VA 22630, USA;* [2] *College of Science and Mathematics, California Polytechnic State University, San Luis Obispo, CA 93407, USA;* [3] *Southwest Fisheries Science Center, National Marine Fisheries Service, P.O. Box 271, La Jolla, CA 92038, USA;* [4] *Present address: Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331, USA;* [5] *Museo Nacional de Historia Natural, C.C. 399, Montevideo, Uruguay and Instituto de Biologia, Facultad de Ciencias, Universidad de la República, Tristán Narvaja 1674, Montevideo 11200, Uruguay;* [6] *Ogasawara Marine Center, Byobudani, Chichijima Ogasawara-mura, Tokyo 100-21, Japan;* [7] *Yamagata Mura 3286, Higashichikuma gun Naganoken, Japan*

Key words: Fish aggregation devices, FADs, Rostrum, Spearing

Synopsis

Billfishes have long been known to impale a great variety of objects, but there are only two brief, obscure records of marine turtles being speared. Details are presented on these two, as well as on two other confirmed records; data from two additional unconfirmed records are also presented. In total, three species of marine turtles are known to have been impaled by three species of billfishes; a fourth species of fish and a fourth species turtle are listed in an unconfirmed case. Records come from the eastern and western Pacific as well as the eastern Atlantic. Of the four confirmed cases, the turtles survived in two, and apparently died as an effect of the spearing in the other two. In three confirmed cases only the impaled rostrum was encountered, and in one confirmed case the entire fish was found, with its rostrum piercing the turtle. There is no obvious advantage – or clear disadvantage – involved in impaling turtles. It is argued that these attacks are accidental, and the result of attempts made by the billfish to capture prey that are near the turtle. These spearings indicate that the chelonians serve as shelters for prey animals on the high seas, and thus, are further evidence of the pelagic existence of marine turtles. The impalings are evidence of a singular ecological role of the turtles – as live fish aggregation devices.

Introduction

Billfishes have captivated biologists, fishermen and mariners for centuries. These fishes of the families Istiophoridae and Xiphiidae are renowned not only for their large size, elongated rostrum ('bill', 'spear' or 'sword'), and value as sport and commercial fish, but also for their highly active, specialized and aggressive behavior (Gudger 1940). An incredible variety of objects in pelagic environments have been

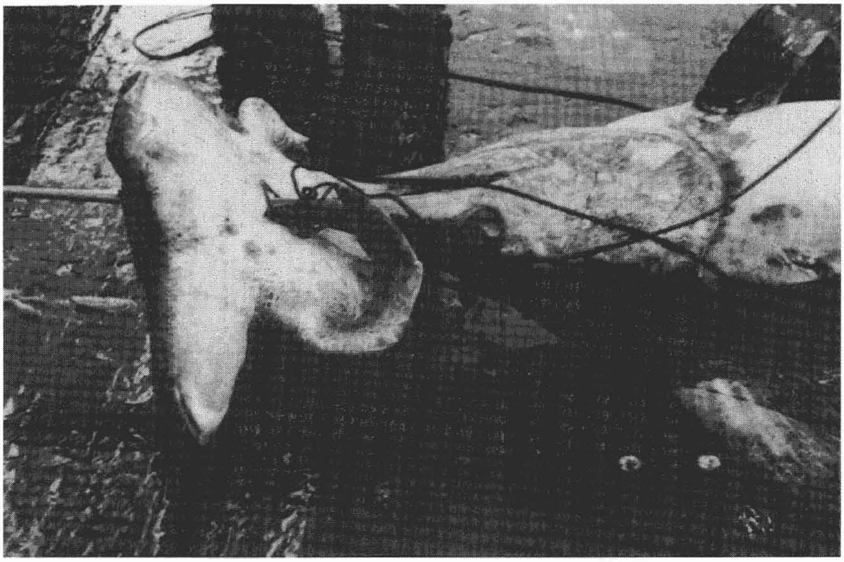

Fig. 1. Marine turtle (probably *Lepidochelys olivacea*) speared by *Xiphias gladius* off Cape San Lucas, Baja California, in September 1965 (photo by Captain Yamashita).

reported as being impaled by billfishes. In broad categories, the list of speared objects includes: large fishes, including other billfish (Voss 1953, Wisner 1958, Stark 1960, Talbot & Penrith 1962, Tinsley 1964, Strasburg 1969, Evans & Wares 1972, Goadby 1975, van der Elst & Roxburgh 1981, Nakamura 1983, 1985), whales (Jonsgård 1959, Tinsley 1964, Major 1979, 1981), inanimate objects at the surface, such as bales of rubber, boats, and ships (Townsend 1924, Walford 1937, Gudger 1940, Wisner 1958, Tinsley 1964, Mather 1976, Achaval & Prigioni 1988[1]), deep-diving vessels (Anon. 1967, Mather 1976), and people, including a deep-sea diver (Gudger 1940, Tinsley 1964, Anon. 1966), as well as a near miss of a skindiver (van der Elst & Roxburgh 1981). It is therefore remarkable that there are but two known published records of billfishes impaling marine turtles: one is only a photograph (Yamaguchi 1973 [published again in Yamaguchi 1989]), and the other is a brief resume (Achaval & Prigioni[1]). Furthermore, both of these records are in obscure sources.

[1] Achaval, F. & C. Prigioni. 1988. Reporte de colisión de 'Marlin' (*Makaira nigricans*) a una tortuga Laud (*Dermochelys coriacea*). V Reunión Iberoamericana de Conservación y Zoología, Vertebrados, Montevideo, 26–30 julio 1988. Resumen p. 93.

The following account provides unpublished details on these two records, as well as data on two other confirmed records and two additional unconfirmed records. It also discusses why these attacks occur, as well as the relevance of the spearings to both billfishes and marine turtles.

Case studies

Confirmed cases

Case A

In September 1965, the tuna long-line fishing vessel *Seiryû-maru* was off of Cape San Lucas, Baja California, México, with baited lines set at depths of 50 to 170 m. 'Many turtles were hooked' (incidentally) in this area, and one day at about 1300 h, a sea turtle which had been hooked in the mouth was hauled aboard, together with the billfish which was skewered in it (Yamaguchi in litt. 21.5.1990).

In a report on long-line fishing techniques, Yamaguchi (1974: 541. Pl. 4, Fig. 4-1-13) included a photograph (Fig. 1) of this spearing as evidence of the manner in which billfishes treat their prey. Other than the fish's identity, no details were given about either the fish or the turtle. The photograph was re-

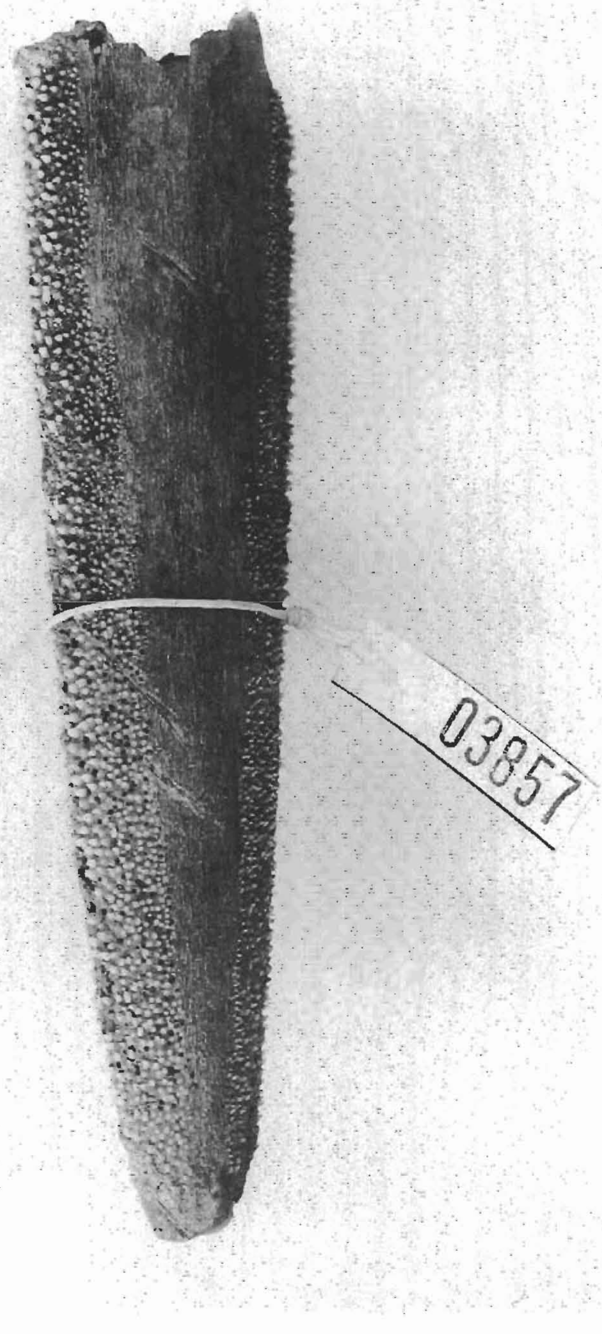

Fig. 2. Fragment of rostrum of *Makaira nigricans* removed from the carapace of a *Dermochelys coriacea* near Kiyú Seaside Resort, San José Department, Uruguay, in November 1983 (deposited in Herpetology Section, Museo Nacional de Historia Natural, Montevideo, number 3857).

published in another study of fishing gear (Yamaguchi 1989; Fig. 7[c]), without further details.

Figure 1 shows a relatively small cheloniid turtle impaled through the plastron, slightly right and anterior of the center (at the position of either the humeral or pectoral scute). The fish's rostrum exits from the left side of the carapace, anterior to the widest part of the shell. The ventral color of the tur-

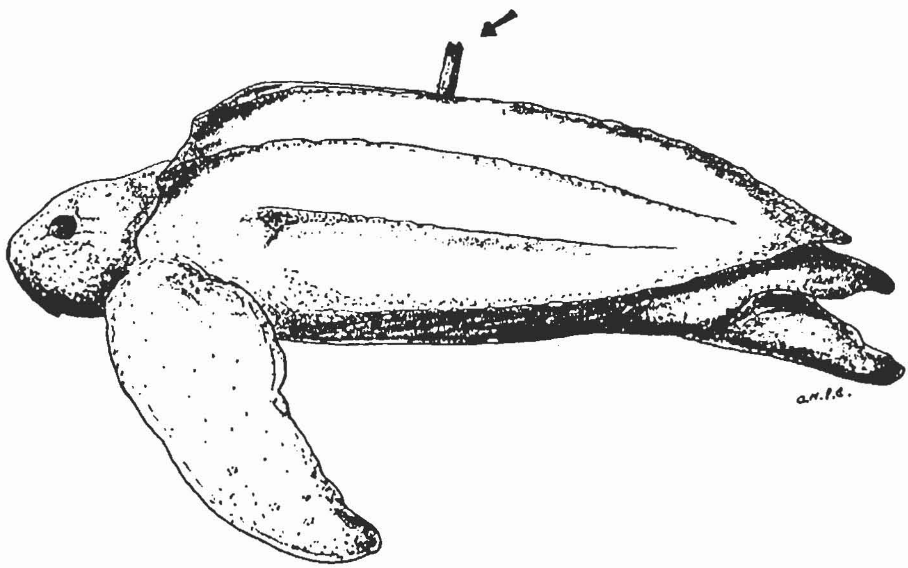

Fig. 3. Sketch of *Dermochelys coriacea* with rostral fragment of *Makaira nigricans,* near *Kiyú Seaside Resort, San José Department, Uruguay, in November 1983 (by C. Prigioni).*

tle is light, evidently not gray; its mandible is clearly visible, relatively wide and v-shaped.

Based on these characters, especially the beak, the turtle was identified as an olive Ridley, *Lepidochelys olivacea* (Eschscholtz). The fish, as identified by Yamaguchi (1974), is a swordfish, *Xiphias gladius* L., with the diagnostic flattened rostrum.

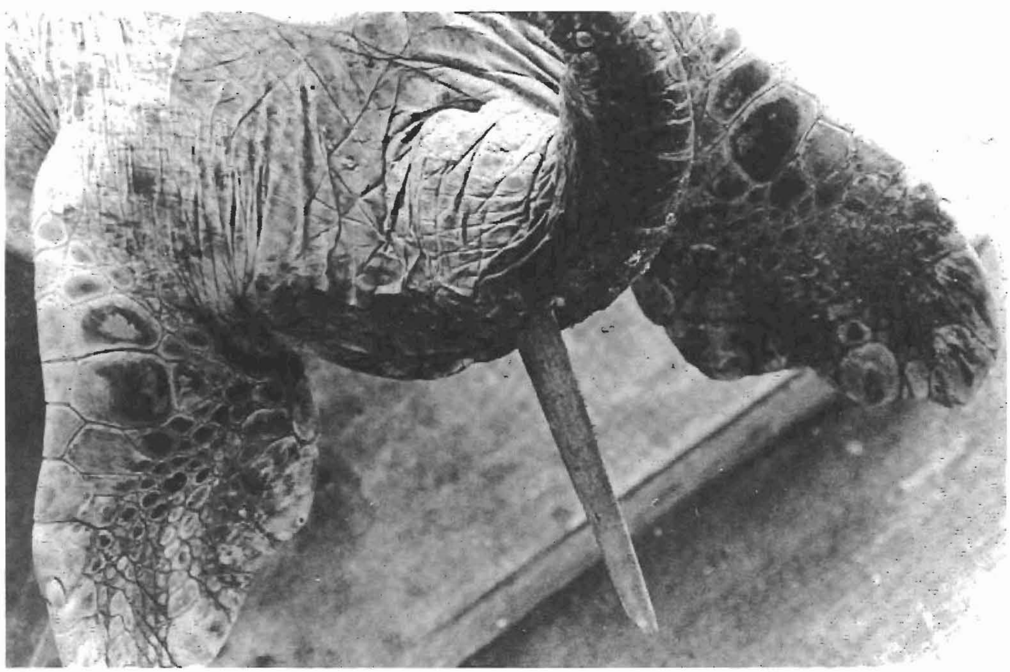

Fig. 4. Tail of male *Chelonia mydas* caught on 21 May 1987 at Otouto-jima, Ogasawara, Bonin Islands, Japan, showing impaled fragment of rostrum of *Xiphias gladius* (photo by H. Suganuma).

Fig. 5. Plastron of male *Chelonia mydas* caught on 21 May 1987 at Otouto-jima, Ogasawara, Bonin Islands, Japan, showing punctures and small impaled bone fragments, presumably from the rostrum of *Xiphias gladius* (photo by H. Suganuma).

Relative to other objects in the photograph, both the turtle and the fish appear to be of adult size.

Case B

In November 1983, a leathery turtle, *Dermochelys coriacea* (L.), was caught in a trammel net set in Rio de la Plata, near Kiyú Seaside Resort, San José Department, Uruguay (Achaval & Prigioni[1]). While boarding the turtle, a 'pole' protruding from its carapace was broken, part remaining in the animal. The chelonian was brought ashore, and died several days later.

The fragment of the 'pole', removed from the dead turtle, is the distal tip of a bony rostrum (Fig. 2); it is 9.3 cm long, 2.2 cm wide and 1.3 cm high at its proximal end. The ventral and lateral surfaces are ornamented with denticles, which are larger along

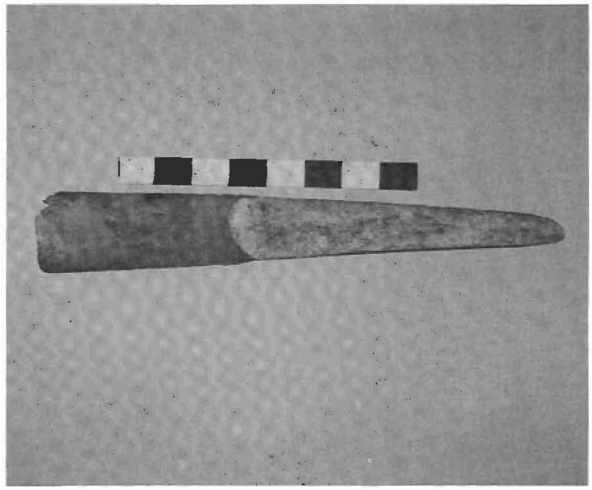

Fig. 6. Fragment of rostrum of *Xiphias gladius* removed from the tail of a male *Chelonia mydas* caught on 21 May 1987 at Otouto-jima, Ogasawara, Bonin Islands, Japan, showing highly eroded surface on distal end, which was projecting from the tail, and uneroded proximal end, which was embedded within the tail (scale 2 cm).

the lateral margins; there is a well-demarcated, denticle-free dorsal surface along its entire length. This specimen (Herpetology no. 3857, Museo Nacional de Historia Natural, Montevideo, Uruguay) is identical in size, shape and form to the terminal rostrum of a blue marlin, *Makaira nigricans* Lacépède, estimated to have weighed between 100 and 140 kg.

A sketch made later (Fig. 3) shows the turtle as large, possibly adult. A fragment of rostrum is shown protruding almost vertically from the center of the carapace, indicating that considerably less than the 9.3 cm had penetrated the turtle.

Case C

On 21 May 1987 at Otouto-jima, Ogasawara (Bonin Islands), Japan (27° 09'N, 142° 11' E) a male green turtle, *Chelonia mydas* (L.), was harpooned while copulating. The straight carapace length (SCL) and width (SCW) were 89.3 and 72.0 cm, respectively, and body weight was 96 kg.

A billfish rostrum approximately 17 cm long protruded from the base of the turtle's tail. It had entered from the ventral side, near the midline, about 10 cm from the posterior edge of the plastron (infra-anal scale) and exited postero-dorsally, right of the midline (Fig. 4). An area about 10 cm in diameter at

Fig. 5. Plastron of male *Chelonia mydas* caught on 21 May 1987 at Otouto-jima, Ogasawara, Bonin Islands, Japan, showing punctures and small impaled bone fragments, presumably from the rostrum of *Xiphias gladius* (photo by H. Suganuma).

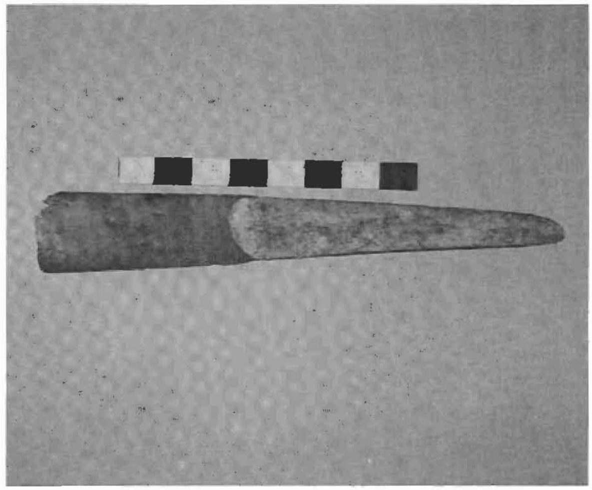

Fig. 6. Fragment of rostrum of *Xiphias gladius* removed from the tail of a male *Chelonia mydas* caught on 21 May 1987 at Otouto-jima, Ogasawara, Bonin Islands, Japan, showing highly eroded surface on distal end, which was projecting from the tail, and uneroded proximal end, which was embedded within the tail (scale 2 cm).

Relative to other objects in the photograph, both the turtle and the fish appear to be of adult size.

Case B

In November 1983, a leathery turtle, *Dermochelys coriacea* (L.), was caught in a trammel net set in Rio de la Plata, near Kiyú Seaside Resort, San José Department, Uruguay (Achaval & Prigioni[1]). While boarding the turtle, a 'pole' protruding from its carapace was broken, part remaining in the animal. The chelonian was brought ashore, and died several days later.

The fragment of the 'pole', removed from the dead turtle, is the distal tip of a bony rostrum (Fig. 2); it is 9.3 cm long, 2.2 cm wide and 1.3 cm high at its proximal end. The ventral and lateral surfaces are ornamented with denticles, which are larger along the lateral margins; there is a well-demarcated, denticle-free dorsal surface along its entire length. This specimen (Herpetology no. 3857, Museo Nacional de Historia Natural, Montevideo, Uruguay) is identical in size, shape and form to the terminal rostrum of a blue marlin, *Makaira nigricans* Lacépède, estimated to have weighed between 100 and 140 kg.

A sketch made later (Fig. 3) shows the turtle as large, possibly adult. A fragment of rostrum is shown protruding almost vertically from the center of the carapace, indicating that considerably less than the 9.3 cm had penetrated the turtle.

Case C

On 21 May 1987 at Otouto-jima, Ogasawara (Bonin Islands), Japan (27° 09'N, 142° 11' E) a male green turtle, *Chelonia mydas* (L.), was harpooned while copulating. The straight carapace length (SCL) and width (SCW) were 89.3 and 72.0 cm, respectively, and body weight was 96 kg.

A billfish rostrum approximately 17 cm long protruded from the base of the turtle's tail. It had entered from the ventral side, near the midline, about 10 cm from the posterior edge of the plastron (infra-anal scale) and exited postero-dorsally, right of the midline (Fig. 4). An area about 10 cm in diameter at

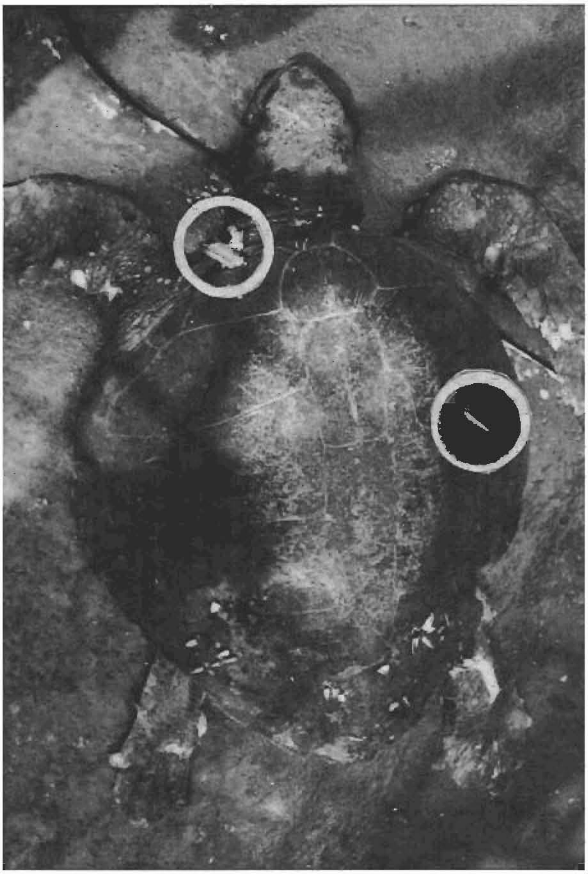

Fig. 7. Female *Lepidochelys olivacea* found floating dead southwest of Acapulco, Mexico, on 5 September 1989; a fragment of rostrum of *Istiophorus platypterus* protrudes (circles) from both sides of the carapace (photo by S. Beavers).

the site of entry had necrotic tissue at the surface. Internally, there was no evidence of damage to the caudal vertebrae.

In addition, on the right side of the plastron, there were four large puncture wounds with small areas of bone exposed in them: at the anterior edge and also at the lateral-posterior edge of the right pectoral scute; at the lateral edge of the right thoracic scute; and near the center of the third right infra-marginal scute. At least five additional smaller punctures were in the same area of the plastron (Fig. 5)..

The rostrum is a distal fragment, 27.8 cm long, 4.2 cm wide and 1.0 cm high at its proximal end. It is dorso-ventrally flattened, diagnostic of *Xiphias gladius*, and is similar in size to rostra from 45–80 kg swordfish. The distal 17 cm which protruded from the turtle's tail was eroded to the bone and well-worn, whereas the proximal 11 cm which was embedded in the turtle remained covered with the fish's skin (Fig. 6). The rostral specimen is deposited in the Ogasawara Marine Center, Chichijima, Ogasawara-mura, Tokyo, Japan.

Case D

On 5 September 1989 at 14° 20.1′N, 99° 19.7′W (about 150 km SW of Acapulco, México), during a research survey of the NOAA Research Vessel *David Starr Jordan*, the carcass of a female olive Ridley turtle was found floating at sea. The carapace measured 63.1 cm SCL and 56.5 cm SCW. The carcass was fresh, with conspicuous fat bodies, and the ovaries contained enlarged follicles.

A fragment of billfish rostrum protruded from both sides of the turtle's carapace; it had entered on the left through the anterior edge of the first left costal scute and exited on the right, near the center of the third right costal scute (Fig. 7). Internally, three cervical vertebrae had fractured zygapophyses and transverse processes. The two external wounds were surrounded by necrotic tissue, but it appeared as if scar tissue had started forming.

The fragment of rostrum measures 36.7 cm long, 2.0 cm wide and 1.0 cm high at its proximal end and has denticles on its dorsal as well as lateral and ventral surfaces. In cross section, the specimen has relatively high nutrient canals, as compared to the height of the rostrum itself. These feautures, especially the relatively slender bill, are characteristic of a sailfish, *Istiophorus platypterus* (Shaw & Nodder), estimated to have weighed 30 to 40 kg. The exposed ends of the rostral fragment are considerably more worn than the portion which was inside the turtle. Both the carapace and the rostrum fragment are deposited at the Southwest Fisheries Science Center, La Jolla, California (collection number D0004).

Unconfirmed cases

Case E

On 23 October 1989, a 13° 26′N, 100° 24′W, approximately 480 km SSW of Acapulco, México, a turtle was photographed at the surface, as it swam away from the bow of the research vessel. The photo (Fig.

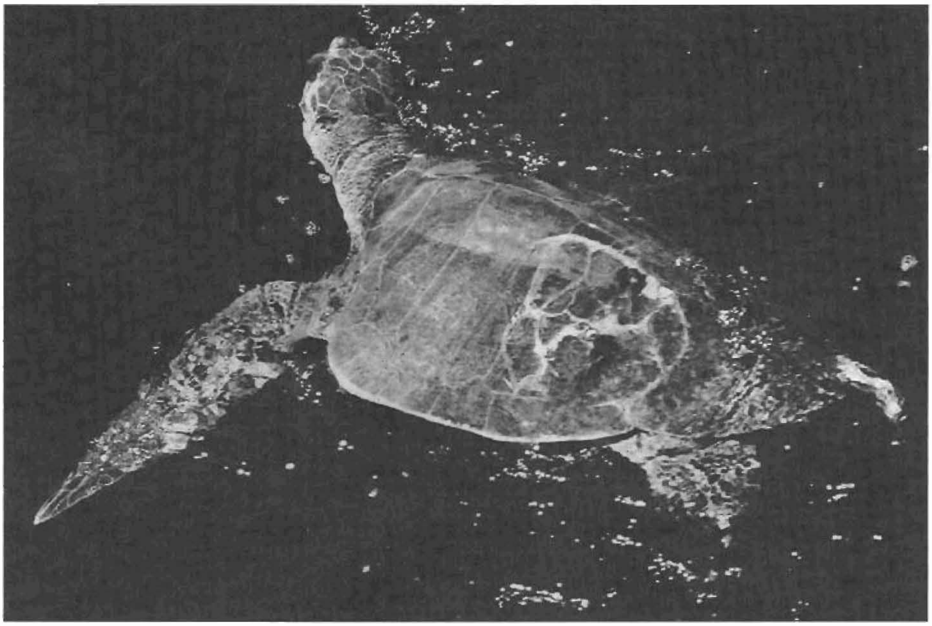

Fig. 8. Adult sized *Lepidochelys olivacea* sighted at 13° 26'N, 100° 24'W, approximately 480 km SSW of Acapulco, Mexico, on 23 October 1989; showing imploded area of left posterior of the carapace with a network of conspicuous white (fracture) lines; this area is estimated to be 20 cm in diameter. In the center is a white semicircle, presumed to be the broken end of an istiophorid bill (photo by R. Pitman).

8) shows an olive Ridley of adult size. On the left posterior of the carapace is an approximately circular area with a network of conspicuous white lines, this circular area is estimated to be 20 cm in diameter.

The original color slide was examined with a microscope, under low magnification. It is clear that the circular area was idented and had been impacted by a strong blow, the white lines resulting from subdermal tissues exposed from multiple fractures of the carapace. Two large *Lepas* sp. barnacles were affixed to a white line at the medial edge of the circular area. In the center, and deepest part of the impacted carapace is a distinctive white semicircular shape.

This semicircle appears to be the cross section of an istiophorid (not swordfish) rostrum, which snapped off after the fish speared the turtle approximately perpendicular to the carapace (Fierstine in litt. 11.8.1992). The impact of the fish's head apparently punched in the carapace, with the bill in the center and deepest part of the indentation. Based on the area of the carapace impacted, and apparent angle of penetration, the rostrum is likely to have penetrated most or all of the turtle's body.

Case F

On 21 April 1992 a loggerhead turtle , *Caretta caretta* (L.), was recovered from a gillnet which had been set off Ventura, California (34° 07'N, 119° 16'W). The carapace measured 50.5 cm curved carapace length, and the only conspicuous external injury was a healed (bite) wound 5×3 cm on the trailing edge of the right rear foot. Internal examination revealed testis and a moderate amount of body fat; there was little sign of decomposition and no obvious injuries.

At the juncture of the second and third right costal scutes, near a marginal scute, was a healed scar. Immediately inside the carapace, below the scar, and laying directly ventral to and in-line with a rib, was a fragment of bone 12 cm long, 1.5 cm wide and tapering at the end closest to the turtle's vertebral column. Connective tissue completely encased this bone fragment, attaching it firmly to the ventral surface of the carapace. When the connective tissue was cut away, the fragment fell out, showing that it had not been fused to the rib, or any other bone of the turtle.

The bone fragment showed signs of partial resorption. Although it could not be positively identified, it was almost certainly the distal end of the rostrum of an adult istiophorid billfish. The dimensions indicated either a large-sized striped marlin, *Tetraptus audax* (Philippi) or a moderately-sized blue marlin, *Makaira nigricans*. Neither the turtle nor the bone fragment were saved.

Discussion

The localities reported in these cases of billfish spearings are consitent with what is known of the geographic distributions of these 4 species of billfishes (Nakamura 1983, 1985), as well as the 4 species of marine turtles: *Caretta caretta* (Pitman 1990), *Chelonia mydas* (Suganuma 1988, 1989), *D. coriacea* (Frazier 1984) and *L. olivacea* (Pitman 1990). Nonetheless, the spearings may have occurred at localities distant from where each turtle was found.

In Case B, *M. nigricans,* like other istiophorids, normally inhabits oceanic waters away from land, except for coastal areas with steep drop-offs (Robins et al. 1986). Rio de la Plata, relatively shallow and turbid, is not where this fish would be expected to occur. Furthermore, since *D. coriacea* can disperse thousands of km across open ocean (Pritchard 1980), and the turtle was caught alive with only the impaled rostral fragment, it could have been speared a considerable distance from the capture site in Uruguay.

Likewise, in Case C, the *C. mydas* may have received its many puncture wounds and been impaled far from its collection site in the Bonin Islands. Clearly the spearing had occurred some considerable time before capture: the entry site of the rostrum was surrounded with old necrotic tissue, there was no bleeding – despite a deep puncture wound, the exposed end of the rostral fragment was well-worn and the turtle was mounted in copula when captured, evidently having recovered from the trauma of the spearing.

In Case D, although the wounds on the *L. olivacea* carcass were surrounded by necrotic tissue, scar tissue was evidently forming. Furthermore, the exposed ends of the rostral fragment had been worn, but the carcass was relatively fresh. Clearly, the turtle survived the spearing, and died some time after; mobility of the head and neck had evidently been impaired by the injury. This specimen had time to move and/or drift some distance after having been speared; surface currents in the region where it was found can be as much as 22 km per day (Feidler et al. 1991).

Similar arguments apply to unconfirmed Cases E and F. In the latter, evidently a considerable time (probably years) passed between the suspected spearing and the final capture of the *C. caretta* in a gill net.

The only locality where the speared turtle can be assumed to have been attacked is off Cape San Lucas, Baja California, and in this case (A) the longlining site is not recorded with precision. Likewise, only for Case A is there information on the position in the water column where the spearing occurred: between the surface and 170 m deep, with a greater probability in the range of 50 to 170 m – the depth where the long line was set. This is well within the known depth distribution of *X. gladius* (Nakamura 1983, 1985), but little is known about the depth distribution of oceanic *L. olivacea.*

The consequences of a stabbing may be fatal for the turtle (evidently Case D and probably Case A, in which the rostrum traversed through the center of the body). However, in half of the confirmed cases reported herein (Cases B and C) the stabbed animal was not only alive, but apparently well. Of the two unconfirmed cases, case E may have involved a fatal injury, and Case F seemed to have no major effect on the turtle.

For the billfish, the consequences of stabbing a large object are also variable. Clearly, if the fish cannot detach itself from the impaled object, by pulling out or breaking the rostrum, it has little chance of survival – unless the speared object is relatively small and insignificant, e.g. part of a cosmetic tube (Nakamura 1983). The *X. gladius* in Case A, as well as another swordfish which rammed the submersible Alvin (Anon 1967, Mather 1976), are clear examples of the risk involved to the fish in not being able to detach from the impaled object.

A billfish which breaks its rostrum cannot, as far as known, regenerate another. The significance of this loss, which is most likely to occur as a consequence of an aggressive encounter, is not clear, especially since there is no agreement about the primary function of this organ. Numerous workers conclude that the bill serves an important hydrodynamic function, notably by reducing total drag forces (Wisner 1958, Walters 1962, Ovchinnikov 1970, Aleyev 1977, Blake 1983, Hebraud 1987, Joseph et al. 1988, Davie 1990). Walters (1962: 148) even suggested that 'the bill may be nothing more than an incidental result of boundary layer mechanics which dictates a concave profile' and Aleyev (1977: 237) simply stated that 'The basic function of a rostrum is hydrodynamic.'

This is consistent with the argument that the bill is not primarily adapted for feeding (e.g. Wisner 1958, Rivas 1975). Various authors have concluded that although the bill may occasionally be used in feeding, it is not essential (Voss 1963, Ueyanagi & Wares 1975, Aleyev 1977). Frequently the stomach contents of these fishes show no signs of having been speared, slashed or mauled by the bill (Hubbs & Wisner 1953, Voss 1953).

In contrast, many other authors discount the hydrodynamic role and conclude that food capture is a major function of the rostrum. These conclusions are based on observations of feeding behavior and/or the presence of slashed or gored prey in the stomach contents (Townsend 1923, 1924, Earle 1940, Gudger 1940, Vos 1953, Wisner 1958, Talbot & Penrith 1962, Scott & Tibbo 1968, Evans & Wares 1972, Yamaguchi 1974, van der Elst & Roxburgh 1981, Nakamura 1983, 1985, see also photo in Brock 1987).

Both roles are evidently important, and the choice of one function over the other may simply reflect the author's specialized interest. Although it could be assumed that a broken or damaged bill would result in impaired high-speed locomotion, and/or reduced feeding efficiency, there is no such evidence. There are numerous records of apparently healthy billfishes with damaged, or malformed, or missing rostra (Gudger 1940, Morrow 1951, Wisner 1958, Ovchinnikov 1970, Goadby 1975, Mather et al. 1975, Rivas 1975, Ueyanagi & Wares 1975, Davie 1990, Yamaguchi in litt. 25.10.1991). Nevertheless, the elongated istiophorid rostrum has been in the fossil record since at least the Eocene (Fierstine 1990). As Wisner (1958) stated, this indicates that it has an adaptive value, and he even suggested (without further elaboration) a third possible function: that of a 'weapon of defense for attack'. Whatever the function of the elongated rostrum, spearing large objects, like marine turtles, would appear to be distinctly disadvantageous for billfishes.

An extended debate has centered on the reasons why billfish stab large objects which they cannot eat (for examples of these objects, see the references cited above, in the Introduction). Since billfish swallow their prey whole, it is difficult to understand how even the largest and hungriest of these fish could attempt to eat an adult-sized marine turtle, especially when viewing the chelonian from perpendicular to the plastron or carapace. There is no evidence of turtles, of any size, occurring in the diets of any billfishes (Earle 1940, Gudger 1940, Hubbs & Wisner 1953, Voss 1953, Scott & Tibbo 1968, Evans & Wares 1972, Yamaguchi 1974, Mather et al. 1975, Rivas 1975, Nakamura 1985, Brock 1987, Yamaguchi in litt. 15.4.1992).

In the eastern tropical Pacific, both marine turtles (especially *L. olivacea,* but not *Dermochelys coriacea*) and prey animals of billfish, notably smaller fishes, are frequently found associated with floating objects (Pitman 1990, 1992a). In these pelagic aggregations, turtles are found in the company of billfish more often than not; and with marlin and some other billfishes this difference is statistically significant (Arenas & Hall 1992).

Because the turtles are commonly at the surface (especially at midday), the chelonians themselves are potential shelters under which prey may accumulate. This is the case in the eastern tropical Pacific, where floating sea turtles are often closely accompanied by small fishes, which in turn attract larger predatory fishes, such as tunas, mahi mahi and sharks (Hunter 1968, Balazs 1981, Pitman 1993). This concentration of fishes may attract feeding billfish (Hunter 1968, Brock 1985).

In Case C, the *C. mydas* at Ogasawara had multiple punctures in the plastron, in addition to a gored tail, indicating that repeated billfish, 'attacks' had been made. However, since the plastron was only superficially perforated, and it was the periphery of the turtle – the tail – which had been deeply stabbed, it would appear that the turtle was not the target, although evidently the predator(s) rushed repeatedly in the direction of the reptile.

Kawamura et al. (1981) argued that marlins have well developed optical tecta and retinae, but poorly developed olfactory lobes, and that these fishes respond mainly to visual, not chemical, stimuli. Their studies of swordfish and three species of marlin, showed that these animals are adapted to low light intensity, yet they are fundamentally diurnal; these fishes (notably marlins) lack color vision and shape discrimination, but are stimulated primarily by rapid movements. In general, a marine turtle would not provide the stimuli (rapid movements) to elicit a predatory response from a billfish – but prey animals milling around the reptile clearly would.

Gudger (1940) compiled 100 pages of evidence and discussion on the topic of billfish spearings, and concluded that 'unprovoked attacks' occurred not because the fish are pugnacious, but rather because while swimming at high speed they accidentally collide with objects about which prey fishes are hiding. Other authors have also concluded that spearing attacks are accidental (Townsend 1923, 1924, Wisner 1958, Jongsgård 1959, Starck 1960, Rivas 1975, Aleyev 1977, Major 1981, Yamaguchi in litt. 25.10.1991). An account of a marlin chasing after a wounded fish which hid behind a diver, and nearly skewering the diver (van der Elst & Roxburgh 1981), is a vivid example of how objects used as shelter by prey fish are liable to be impaled. How many 'unprovoked attacks' by billfish on unusual items cam be explained with this argument is unknown, but to date it is the most parsimonious.

In summation, it is unlikely that marine turtles are purposely impaled by billfishes (c.f. Yamaguchi 1974; 541). As Gudger (1940) concluded half a century ago, the spearing of large, inedible objects (e.g. sea turtles) is evidently an accident which occurs during active feeding attempts by billfishes.

Records on marine turtles being speared by istiophorids and xiphiids reinforce the conclusion that these chelonians have a substantial pelagic existence (Pitman 1990, 1992a), but the significance of this deduction goes beyond the autoecology of the turtle. Two singular, symbiotic roles are played by these reptiles in epipelagic situations. Turtles at the surface evidently provide roosting sites for various species of marine birds in the open ocean (Pitman 1992b, 1993). At the same time, turtles at the surface attract fishes, both prey and predatory species.

There is considerable discussion about the reasons why fishes are attracted by floating objects (Richards 1989). As Rountree (1989) summarized: although there are many explanations, the most widely held hypothesis is that by associating with an object at the surface, the fish are provided with some form of protection from predators. Objects at the surface which serve as foci for fishes are known as fish aggregating devices, or FADs.

The stimuli and mechanism involved in the aggregation response are not clear. Size of the FAD and its length of time at the surface are positively related to the number of fishes which assemble under it (Hunter 1968, Rountree 1989). In some cases, the biomass of fishes associated with a FAD can be several hundred tons; aggregations may remain with a particular FAD for several weeks, and some individual fishes show strong fidelity to a particular FAD (Hunter 1968, Brock 1985). Fishes close in rapidly around a FAD with the approach of a predator, or foreign object, e.g. diver, skiff or ship: this aggregation response can be remarkably strong with the approach of a predatory billfish (Hunter 1968).

In pelagic settings, marine turtles – as well as being part of the FAD community – may actually serve as FADs (Hunter 1968, Balazs 1981, Pitman 1993). In the context of several basic points discussed above, this translates to the following generalizations: large numbers of fishes may aggregate around a turtle at the surface, and they could stay with it for weeks (at least if it remained at the surface); the approach of a billfish may result in an increased concentration of prey fishes close to the turtle; and actively feeding billfishes may attack prey fishes sheltering close to a turtle. Each of these phenomena increases the chances of the turtle – whether it is part of the FAD community, or the FAD itself – being visited by a feeding billfish, and subsequently, being accidentally speared.

In this light, it is remarkable that there are so few documented records of marine turtles having been impaled by billfishes. It is noteworthy that the Inter-American Tropical Tuna Commission has records of more than 6000 cases of pelagic fauna in association with floating objects in the Eastern Tropical Pacific, and more than 4000 reports of sea turtles in the pelagic environment. They do not have a single record of a sea turtle having been impaled or of a billfish spearing anything else (Arenas in litt. 22.6.1992).

As with any instantaneous biological event (e.g. an act of predation or a spearing), the chances of witnessing the incident are minuscule. Yet, a spearing does not have to be directly observed in order to be demonstrated: the fish's rostrum may break off and remain in the live turtle for a considerable time. More careful and systematic observations of marine turtles in pelagic situations may yield additional records of billfishes impaling turtles, but until further reports come to light, we can only underscore the remarkable paucity of such records.

Acknowledgements

Y. Yamashita, of the *Seiryû-Maru*, generously allowed us to use the photograph of the impaled turtle in Case A (Fig. 1); L. Lucián sent in the rostrum in Case B; and S. Eckert provided information on Case F. Special thanks to R. Brill, D. Cupka, P. Davie, J. Femenias, G. Greenwald, R. McKay, J. Pepperell, P. Pristas, P. Speare, J. Squire, S. Tibbo and A. van der Heiden for providing skeletal material of billfish. N. Suzuki and K. Horikoshi kindly made translations of Yamaguchi (1974), and J. Musick and I. Olmsted critically read the paper. The Pacific Ocean Research Foundation (Kailua-Kona, Hawaii) generously provided facilities for HLF to prepare billfish skeletons during several summers.

References cited

Aleyev, Y.G. 1977. Nekton. Dr W. Junk Publishers, The Hague. 435 pp.

Anonymous. 1966. Fish's sword removed from sea-diver's skull. Medical World News (September 30): 38–39.

Anonymous. 1967. Alvin leads an active, exciting life – catches swordfish, finds its own arm, discovers lost aircraft. The Seahorse (published by Hydro Products, Division of Dillingham Corporation, San Diego, California) 3: 1, 4.

Arenas, P. & M. Hall. 1992. The association of sea turtles and other pelagic fauna with floating objects in the Eastern Tropical Pacific Ocean. pp. 7–10. *In:* M. Salmon & J. Wyneken (compilers), Proceedings of the Eleventh Annual Workshop on Sea Turtle Biology and Conservation. NOAA Tech. Memorandum NMFS-SEFSC-302.

Balazs, G.H. 1981. Sea turtles as natural fish aggregating devices. Hawaii Fishing News 6: 5.

Blake, R.W. 1983. Fish locomotion. Cambridge University Press, Cambridge. 208 pp.

Brock, R.E. 1985. Preliminary study of the feeding habits of pelagic fish around Hawaiian fish aggregation devices or can fish aggregation devices enhance local fisheries productivity? Bull. Mar. Sci. 37: 40–49.

Brock, R.E. 1987. A contribution to the trophic biology of the blue marlin (*Makaira nigricans* Lacépède, 1802) in Hawaii. Pac. Sci. 38: 141–149.

Davie, P.S. 1990. Pacific marlins: anatomy and physiology, Massey University Press, Palmerston North. 88 pp.

Earle, S. 1940. The white marlin fishery of Ocean City, Maryland. U.S. Fish Wildl. Serv., Spec. Sci. Rep. 6: 1–15.

Evans, D.H. & P.G. Wares. 1972. Food habits of striped marlin and sailfish off Mexico and southern California. U.S. Dept. Interior, Fish and Wildl. Serv., Bureau Sports Fisheries and Wildl. Res. Rep. 76: 1–10.

Feidler, P.C., V. Philbrick & F.P. Chavez. 1991. Ocean upwelling and productivity in the eastern tropical Pacific. Limnol. Oceanogr. 36: 1834–1850.

Fierstine, H. 1990. A paleontological review of three billfish families (Istiophoridae, Xiphiidae, and Xiphiorhynchidae). pp. 11–19. *In:* R.H. Stroud (ed.) Planning the Future of Billfishes, Part 2, Contributed papers, Proceedings of the Second International Billfish Symposium, Kailua-Kona, Hawaii, 1–5 August 1988, Savannah.

Frazier, J. 1984. Tortugas marinas en el Océano Atlántico Sur-Occidental. Boletin de la Asociación Herpetológica Argentina. Serie Divulgación 2: 1–22.

Goadby, P. 1975. Big fish and blue water: gamefishing in the Pacific. Angus and Robertson, Sydney. 334 pp.

Gudger, E.W. 1940. The alleged pugnacity of the swordfish and the spearfishes as shown by their attacks of vessels. Mem. Royal Asiat. Soc. Bengal 12: 215–315 +9 pl.

Hebraud, F.P.D. 1987. Contribution à l'etude des marlins de genre *Makaira* et de l'espèce *Tetrapturus audax*. Thèse pour le Doctorat Vétérinaire, Diplôme D'Etat Université Paul-Sabatier de Toulouse, l'Ecole National Vétérinaire de Toulouse, Toulouse. 101 pp.

Hubbs, C.L. & R.L. Wisner. 1963. Food of marlin in 1951 off San Diego, California. California Fish and Game 39: 127–131.

Hunter, J.R. 1968. Fishes beneath flotsam. Sea Frontiers 14: 280–288.

Jonsgård, A. 1959. New find of sword from swordfish (*Xiphias gladius*) in blue whale (*Balaenoptera musculus*) in Antarctic. Norsk Hvalfangst-tidende 48: 352, 355–356, 359–360.

Joseph, J., W. Klawe & P. Murphy. 1988. Tuna and billfish – fish without a country. Inter-American Tropical Tuna Commission, La Jolla. 69 pp.

Kawamura, G., W. Nishimura, S. Ueda & T. Nishi. 1981. Vision in tunas and marlins. Memoirs Kagoshima University Research Center for the South Pacific 2: 1–47.

Major, P.F. 1979. An aggressive encounter between a pod of whales and billfish. Sci. Rept. Whales Res. Inst., Tokyo 31: 95–96.

Major, P.F. 1981. Combat on the high seas. Sea Frontiers 27: 280–286.

Mather, C.O. 1976. Billfish. Saltaire Publishing, Sidney. 272 pp.

Mather III, F.J., H.L. Clark & J.M. Mason, Jr. 1975. Synopsis of the biology of the white marlin, *Tetrapturus albidus* Poey (1861). pp. 55–94. *In:* R.S. Shomura & F. Williams (ed.) Proceedings of the International Billfish Symposium, Kailura-Kona, Hawaii, 9–12 August 1972, Part 3, Species Synopses, NOAA Tech. Rep. NMFS SSRF 675.

Morrow, J.E. 1951. A striped marlin (*Makaira mitsukurii*) without a spear. Copeia 1951: 303–304.

Nakamura, I. 1983. Systematics of the billfishes (Xiphiidae and Istiophoridae). Publ. Seto Mar. Biol. Lab. 28: 255–396.

Nakamura, I. 1985. FAO species catalogue. Vol. 5. Billfishes of the world. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Fish. Synop. 5: 1–65.

Ovchinnikov, V.V. 1970. Swordfishes and billfishes in the Atlantic Ocean. Ecology and functional morphology. Atl. Sci. Res. Inst. Fish. Oceanogr. 77 pp. (English translation by Israel Program for Scientific Translations, 1971; Department of Commerce, National Technical Information Service, Springfield, VA, TT-71-50011).

Pitman, R.L. 1990. Pelagic distribution and biology of sea turtles in the eastern tropical Pacific. pp. 143–148. *In:* T.H. Richardson, J.I. Richardson & M. Donnelly (compilers) Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation, NOAA Tech. Memorandum NMFS-SEFC-278.

Pitman, R.L. 1992a. Sea turtle associations with flotsam in the eastern tropical Pacific Ocean. p. 94. *In:* M. Salmon & J. Wyneken (compilers) Proceedings of the Eleventh Annual Workshop on Sea Turtle Biology and Conservation, NOAA Tech. Memorandum NMFS-SEFSC-302.

Pitman, R.L. 1993. Sea bird associations with marine turtles in the eastern Pacific. Pac. Seabird Group Bull. 19: 52–53.

Pitman, R.L. 1992c. Sea bird associations with marine turtles in the eastern tropical Pacific. Colonial Waterbirds (in press).

Pritchard, P.C.H. 1980. *Dermochelys coriacea.* Catalog of American Amphibians and Reptiles 238: 1–4.

Richards, W.J. (ed.) 1989. Fourth International Conference on Artificial Habitats for Fisheries, November 2–6, 1987, Miami, Florida. Bull. Mar. Sci. 44: 527–1073.

Rivas, L.R. 1975. Synopsis of biological data on blue marlin, *Makaira nigricans* Lacépède, 1802. pp. 1–16. *In:* R.S. Shomura & F. Williams (ed.) Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9–12 August 1972, Part 3, Species Synopses, NOAA Tech. Rep. NMFS SSRF 675.

Robins, C.R., G.C. Ray, J. Douglas & R. Freund. 1986. A field guide to Atlantic coast fishes of North America. Houghton Mifflin Co., Boston. 354 pp.

Rountree, R.A. 1989. Association of fishes with fish aggregation devices: effects of structure size on fish abundance. Bull. Mar. Sci. 44: 960–972.

Scott, W.B. & S.N. Tibbo. 1968. Food and feeding habits of swordfish, *Xiphias gladius,* in the Western North Atlantic. J. Fish. Res. Board Can. 25: 903–919.

Starck II, W.A. 1960. Spear of swordfish, *Xiphias gladius* Linaeus, embedded in a silk shark, *Eulania floridana* (Schroeder and Springer). Quart, J. Florida Acad. Sci. 23: 165–166.

Strasburg, D.W. 1969. Billfishes of the Central Pacific Ocean. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Circular 311: 1–11.

Suganuma, H. 1988. Green sea turtles in the Ogasawara Islands. International symposium on sea turtles '88 in Japan, pp. 125–127.

Suganuma, H. 1989. The green turtle (*Chelonia mydas*) in Ogasawara Islands, Japan. Proceedings of the Second Western Atlantic Turtle Symposium. NOAA Tech. Memorandum NMFS-SEFC-226, Panama City. p. 344.

Talbot, F.H. & J.J. Penrith. 1962. Spearing behavior in feeding in the black marlin, *Istiompax marlina.* Copeia 1962: 468.

Tinsley, J.B. 1964. The sailfish, swashbuckler of the open seas. University of Florida Press, Gainesville, 216 pp.

Townsend, C.H. 1923. The swordfish and thresher shark delusion. Bull. N.Y. Zool. Soc. 26: 76–80.

Townsend, C.H. 1924. Why swordfish strike ships. Bull. N.Y. Zool. Soc. 27: 39–40.

Ueyanagi, S. & P.G. Wares. 1975. Synopsis of biological data on striped marlin, *Tetrapturus audax* (Philippi, 1887). pp. 132–159. *In:* R.S. Shomura & F. Williams (ed.) Proceedings of the International Billfish Symposium, Kailua-Kona, Hawaii, 9–12 August 1972, Part 3, Species Synopses, NOAA Tech. Rep. NMFS SSRF 675.

Van Der Elst, R.P. & M. Roxburgh. 1981. Use of the bill during feeding in the black marlin (*Makaira indica*). Copeia 1981: 215.

Voss, G.L. 1953. A contribution to the life history and biology of the sailfish, *Istiophorus americanus* Cuv. and Val., in Florida waters. Bull. Mar. Sci. Gulf Caribb. 3: 206–240.

Walford, L.A. 1937. Marine game fishes of the Pacific coast from Alaska to the equator. University of California Press, Berkeley. 205 pp, 70 pl. (reprinted 1974).

Walters, V. 1962. Body form and swimming performance in the scombroid fishes. Amer. Zool. 2: 143–149.

Wisner, R.L. 1958. Is the spear of istiophorid fishes used in feeding? Pac. Sci. 12: 60–70.

Yamaguchi, Y. 1974. Studies on the mechanism of tuna long-line fishing. Journal of Faculty of Fisheries, Prefectural University of Mie. 9: 511–605.

Yamaguchi, Y. 1989. Tuna long-line fishing II: Fishing gear and methods. Mar. Behav. Physiol. 15: 13–35.