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10. APPENDIXES

10.1 SHARK ATTACK

Introduction : There is no other aspect of the biology of sharks that has attracted more attention than their occasional attacks on human beings. While sharks as a group are poorly known biologically, much anecdotal, emotional and misleading information is available about the minor phenomenon of shark attack. Additionally, a massive corpus of excellent scientific work has emerged centred on the shark attack question but ranging far beyond it. Although a number of important general works on sharks are available, these seem for the most part to be obscessed with shark attack, and overlook or play down the diversity of sharks in their concern with the uncommon misdeeds of a minority of the species. As this Catalogue primarily deals with sharks in a taxonomic and biological light, and as several books and collections of papers as well as numerous articles have been written about the subject, the shark attack 'problem' is not dealt with exhaustively here or elsewhere in these volumes. For much more on this subject see Whitley (1935, 1940, 1951a), Llano (1957), Coppleson (1958), Davies (1964), Follett (1966, 1974), Schultz. (1967), Lineaweaver & Backus (1969), Baldridge (1973, 1974), Ellis (1976, 1983), Klimley (1978), Wallett (1978), Gilbert (1981), Miller & Collier (1981), Nelson (1981), and particularly the excellent collections of papers edited by Gilbert (1963) and Zahuranec (1983).

The writer's viewpoint is that of a biologist specializing in the systematics, morphology and evolution of cartilaginous fishes, and conducting research not on the anthropocentric phenomenon of shark attack, but the selachocentric phenomenon of shark diversity. The writer himself has no special fear of sharks, but maintains, considerable respect for the larger species and has as little interest in the gory details of shark attacks as in those of the far more frequent automobile accidents. To the writer, the popular obsession of people with the subject has seemed to be more of a problem of human psychology and philosophy than a rational reaction to an objectively major and important problem.

Some sharks do attack people, undoubtedly, but the attack rate is very low, much less than the frequency of other aquatic mishaps that afflict people. Baldridge (1973, 1974) estimated that from 1940, attacks on a worldwide basis averaged about 28 a year, in no year up to 1974 surpassing 56, while Gilbert (1981), basing a revised estimate on long experience with the shark attack problem, indicated that about 30 to 50 shark attacks were reported each year worldwide, but at most less than 100 attacks, with 25 to 30 fatalities, occurred worldwide each year. Probably far more important to humans is damage to gear and fish catches by sharks, and time spent dealing with unwanted catches of sharks in those maritime countries where sharks are underutilized fishes.

Nelson (1981), with many years of underwater research on shark behaviour to his credit, notes that a number of species he and other researchers have observed are intraspeciifically quite unaggressive, relative to many other vertebrates, but may show interspecific aggression to other sharks and even people, as dramatically documented with the grey reef shark (Carcharhinus amblyrhynchos). Popular belief has it that shark attacks on people are feeding attacks, but analysis of over 1000 attacks in the International Shark Attack File by Baldridge (1963, 1964) suggested to him and also Nelson (1981) that half to 3/4 of the attacks might have been non-feeding, aggressive attacks; victims of such attacks show single slash-wounds, without substantial removal of flesh. 'Mistaken identity' of humans for pinniped prey (McCosker, 1981) or deliberate 'investigation' and rejection of humans as food items (Miller & Collier, 1981) have been suggested for many white shark attacks, but either hypothesis is hard to separate from aggressive or defensive threat, and there is no compelling reason to eliminate one in favour of any of the others. The important point for the victims of such attacks is that the sharks usually inflict far less damage than they are capable of producing if they were actively feeding.

Fear of sharks and shark attack is a MAJOR phenomenon in many countries, and has resulted in millions of dollars being spent on attack-centred research and anti-shark measures, particularly on shark repellents, anti-shark weaponry, and expensive shark-meshing programmes. On coastlines with popular bathing beaches in some countries a few shark attacks each year may mean an economic disaster for the beachside resorts and communities, and hence funds have been allocated in some places, notably Australia and South Africa, to deal with the problem by shark meshing. Considerable progress has recently been made in repellent research (see Zahuranec, 1983) that may eventually result in non-lethal alternatives to killing sharks to ward against potential attacks. Presumably shark fear has also lead to the massive success of the various JAWS movies in the mid-seventies' and early eighties', portraying a savage, gory-toothed shark archetype of great popular appeal but little resemblance to any of the living species.

The Taxonomy of Shark Attack : As documented in this Catalogue, most sharks are small and harmless to humans, and a number of larger species are confined to deep water where they cannot interact with people. A survey by the writer (Compagno, 1981) showed that about 82% of shark species attained a maximum total length between 20 cm and 2 m, and that the average maximum adult size for sharks was about 1.5 m. Most of the species indicted in shark attacks are large species between 2 and 8 m or more.

"A guide to the kinds of potentially dangerous sharks" was presented by Garrick & Schultz (1963). An updated, abbreviated taxonomic guide to these species is given as follows:

Order Hexanchiformes, Family Hexanchidae : Broadnose sevengill shark, Notorynchus cepedianus. The only large hexanchid that frequents shallow water. Suspected of a few unprovoked, non-fatal attacks on swimmers, it has attacked divers in captivity. Omnivorous habits, size, and aggressiveness when aroused make this species at least potentially dangerous. The larger bluntnose sixgill shark, Hexanchus griseus lives in deep water and does not normally come in contact with people.

Order Squaliformes, Family Squalidae : Greenland shark, Somniosus microcephalus. Old, unconfirmed tales of this very sluggish shark attacking Eskimos in kiyaks have not been verified. The closely related Pacific sleeper shark, S. pacificus, has never been indicted in attacks on people. Both of these large sharks are regarded as potentially dangerous, but minimally so because of their habitat.

Order Squatiniformes, Family Squatinidae : Angelsharks, Squatina species. Angelsharks have strong jaws and needle teeth, and can bite painfully when accosted. They are not regarded as particularly dangerous, however, because of their small size (most below 1.5 m). S. dumeril, S. californica, and an Australian species have been cited as biting people.

Order Orectolobiformes, Family Orectolobidae : Wobbegongs, Eucrossorhinus, Orectolobus, and Sutorectus species. Wobbegongs are collectively infamous for biting people who walk on the coral reefs they frequent, but little is known about their behaviour generally or in regard to attacks. Probably the spotted wobbegong, O. maculatus, has attacked people, and the tasseled wobbegong, E. dasypogon is said to attack and kill people in New Guinea on uncertain evidence, but other species are currently not implicated. Larger wobbegongs should be considered dangerous because of their strong jaws and dagger-like teeth, but they probably do not normally feed on large mammalian prey and may attack primarily when accosted or presented with the limbs of a potential victim.

Family Ginglymostomatidae : Nurse shark, Ginglymostoma cirratum. A large, small-toothed shark credited with several provoked and unprovoked attacks, none fatal. Divers often harass this shark, which may respond by biting them, but nurse sharks are generally unaggressive when left alone. Attacks may be defensive or non-feeding aggression, as this shark normally feeds on small prey.

Tawny nurse shark, Nebrius ferrugineus. Said to be more docile than the nurse shark, and readily allowing handling by divers, but credited with a few provoked attacks.

Family Rhiniodontidae : Whale shark, Rhiniodon typus. Unaggressive to divers but occasionally bumps boats that are reeling in game fishes. Not considered dangerous despite its great size.

Order Lamniformes, Family Odontaspididae : Sand tiger, grey nurse or ragged-tooth shark, Eugomphodus taurus. A large sluggish shark involved in a number of abortive, non-feeding attacks on people, none apparently fatal, generally unaggressive to divers but will steal speared fishes. Feeds on smaller prey, not on mammals; may be mainly dangerous to people when accosted or presented with their limbs only. Two other large species in the family, Odontaspis ferox and O: noronhai, are deepwater sharks with smaller teeth than the sand tiger, and have never been implicated in attacks on people.

Family Alopiidae : Thresher shark, Alopias vulpinus. Two unconfirmed boat attacks may have been due to this species; also, an anecdotal account of a fisherman being decapitated by the tail of a large adult while attempting to land it could not be verified. Probably not normally dangerous; approaches divers without being aggressive. Two other species in the family, the bigeye thresher, A. superciliosus, and the pelagic thresher, A. pelagicus, have never been indicted in attacks on people.

Family Cetorhinidae : Basking shark Cetorhinus maximus. May attack boats when harpooned, but unaggressive to divers and not considered dangerous despite its great size.

Family Lamnidae : Great white shark, Carcharodon carcharias. Currently one of the three most dangerous sharks, and often considered the most dangerous shark by virtue of the number of attacks (possibly between 50 and 100) than can be attributed to it worldwide in this century on swimmers, surfers, divers and boats. Several white shark attacks have been fatal, though most are not due to their abortive or tentative nature. An aggressive, bold species, feeding on large prey, but apparently not living up to its JAWS reputation in regard to humans; sometimes approaches divers, perhaps out of curiosity, and departs without attacking. Should be treated with great caution.

Shortfin mako, Isurus oxyrhynchus. A large, very fast, dangerous species, with a few unprovoked non-fatal attacks on swimmers and rather more on boats, particularly after being hooked. Can be aggressive to divers, gives a figure-8 swimming display and jaw gapes as possible threat, should be treated with caution.

Longfin mako, Isurus paucus. Not indicted in attacks, but should be treated as potentially dangerous because of its size and large teeth. Possibly more sluggish than the shortfin makb.

Salmon shark, Lamna ditropis, and porbeagle, L. nasus. Not indicted for certain in attacks, and probably not particularly dangerous because of their smallish teeth and fisheating habits, but the size of adults should invite respect. Divers have encountered the salmon shark in California waters without incident.

Order Carcharhiniformes, Family Triakidae : Leopard shark, Triakis semifasciata. A small shark once reported as having harassed a diver with a nosebleed; ordinarily flees when approached underwater, and not considered dangerous.

Family Hemigaleidae : Snaggletooth shark, Hemipristis elongatus. A medium-sized fisheating shark with formidable teeth, considered potentially dangerous but never indicted in a shark attack.

Family Carcharhinidae : Silvertip shark, Carcharhinus albimarginatus. A large, aggressive, common, potentially dangerous shark that favours offshore islands but with few if any attacks attributed to it.

Bignose shark, Carcharhinus altimus. A large, fisheating shark found in deepish water, not likely to come in contact with people except for fishermen who catch it.

Graceful shark, Carcharhinus amblyrhynchoides. A narrow-toothed medium-sized fisheating shark similar to C. limbatus, and of a limited potential danger, not implicated in shark attacks.

Grey reef shark, Carcharhinus amblyrhynchos. A common small to medium-sized reef shark, sometimes very aggressive and involved in several attacks on people, at least one fatal. May give a threat display when cornered, and bold in taking speared fish.

Pigeye or Java shark, Carcharhinus amboinensis. A heavy-bodied large inshore shark with no attacks attributed to it but potentially dangerous because of its omnivorous habits, powerful jaws and large triangular teeth. Likely to be confused with the bull shark, C. leucas.

Copper shark or bronze whaler, Carcharhinus brachyurus. A common large shark with a few provoked and unprovoked attacks on swimmers and divers ascribed to it. Probably less dangerous than the bull and tiger sharks because of its relatively slender teeth and primarily fisheating habits.

Spinner shark, Carcharhinus brevipinna. A medium-sized shark with one unprovoked, non-fatal attack ascribed to it; probably not particularly dangerous as teeth are small and diet is largely fish.

Silky shark, Carcharhinus falciformis. A large aggressive oceanic shark, regarded as dangerous or potentially dangerous, although definite attacks cannot be attributed to it. Possibly involved in attacks following air-sea disasters, like the oceanic whitetip shark.

Galapagos shark, Carcharhinus galapagensis. A large, dangerous shark that favours offshore islands, and definitely responsible for one fatal attack on a swimmer; young sharks can be very abundant and aggressive, and have harassed divers to the point of causing operations to be suspended.

Bull, Zambezi or Lake Nicaragua shark, Carcharhinus leucas. An inshore, heavy-bodied shark that ranges widely into fresh water. One of the three most dangerous sharks; several fatal and non-fatal attacks are attributed to it, and it may very well turn out to be the most dangerous shark because of its wide range in the tropics, proximity to human activities and omnivorous habits. Probably at least partly responsible for the bloody reputation of the Ganges shark.

Blacktip shark, Carcharhinus limbatus. A medium-sized dangerous or potentially dangerous shark with at least one attack ascribed to .it; may harass spearfishers and steal their catch, but probably less dangerous than more omnivorous sharks like the bull shark.

Oceanic whitetip shark, Carcharhinus longimanus. A large, bold, dangerous shark of the open seas, with several attacks definitely attributed to it, and perhaps chiefly responsible for a large number of deaths in the aftermath of at least one sinking of a ship by submarine. Has approached divers in the open ocean and stubbornly persisted in investigating and circling them, showing little fear in response to their defensive actions. Probably one of the more dangerous sharks.

Blacktip reef shark, Carcharhinus melanopterus. A small, active fisheating shark, of limited dangerousness; responsible for a number of attacks on spearfishers and waders without major injuries or fatalities; most attacks are on the limbs of people wading in shallow water on coral reefs, and may be a case of 'mistaken identity' for its usual prey.

Dusky shark or black whaler, Carcharhinus obscurus. A large shark that eats mainly fish and invertebrates, involved in a few attacks on people but probably less dangerous than bull or tiger sharks.

Caribbean reef shark, Carcharhinus perezi. A large, little-known dangerous shark involved in at least one abortive attack.

Sandbar shark, Carcharhinus plumbeus. A medium-sized shark that is considered potentially dangerous because of its abundance and large, triangular teeth, but never implicated in an attack on people and unlikely to attack because of its strong preference for fresh fish and invertebrate prey.

Night shark, Carcharhinus signatus. A large semioceanic shark, not implicated in shark attacks and unlikely to be involved in such because of its deepwater habitat and fisheating habits.

Blackspot shark, Carcharhinus sorrah. A small, common active reef shark, feeding on small fishes and not known to have attacked people; has minimal potential danger.

Blacktail reef shark, Carcharhinus wheeleri. Very similar to the grey reef shark, and possibly identical; considered potentially dangerous because of its aggressiveness when divers are spearing fish.

Tiger shark, Galeocerdo cuvier. One of the three most dangerous sharks, involved in several fatal and non-fatal attacks on people and in boat attacks. Perhaps the most omnivorous of sharks, prone to sample unusual items, and sometimes inquisitive and very aggressive underwater. It should be treated with great caution when encountered underwater.

Ganges shark, Glyhis gangeticus. A poorly known medium-sized or large inshore and riverine shark with a frightful reputation as a 'maneater' in the Ganges-Hooghly system of India, which cannot be confirmed because of its rarity and the presence of the bull shark in the same river system.

Speartooth shark, Glyhis glyphis. A poorly known medium-sized inshore shark, with no attacks attributable to it.

Broadfin shark, Lamiopsis temmincki. A poorly known smallish inshore shark with broad triangular upper teeth, potentially of minimal danger but not known to have attacked people.

Sharptooth lemon shark, Negaprion acutidens. A large, heavy shark that is dangerous when provoked. Adults may be unaggressive and flee divers when approached, but if speared, poked or otherwise accosted may respond with a vigorous attack.

Lemon shark, Negaprion brevirostris. Very similar to the sharptooth lemon shark in often responding to abuse with a vigorous attack: Although involved in a few unprovoked attacks on bathers and swimmers, more often recorded as attacking divers and boats after being disturbed or injured.

Blue shark, Prionace glauca. A large, dangerous, often inquisitive oceanic shark with several attacks on boats and divers, often after much circling. More timid than the oceanic whitetip or shortfin mako, and often eating rather small prey.

Reef whitetip shark, Triaenodon obesus. A smallish shark that occasionally attacks divers, especially when excited by spearfishing and baits, but which is regarded as minimally dangerous because of its general timidity and small teeth.

Family Sphyrnidae : Large hammerhead species, including the scalloped or bronze hammerhead, S. lewini, great hammerhead, S. mokarran, and smooth or black hammerhead, S. zygaena. A small number of attacks can be attributed to larger hammerheads, with species identity uncertain. Although all these species are at least potentially dangerous, divers have repeatedly observed scalloped and great hammerheads in unbaited situations and found them to be unaggressive. Hammerheads may be more bold with speared fish about, as with several carcharhinids. Another large species, the whitefin hammerhead, Sphyrna couardi, is poorly known and has never been indicted in attacks on people, but may be considered potentially dangerous.

Summary of Dangerous Species

The sharks surveyed above can be subdivided into the following categories:

A. Sharks that have attacked people or boats = 27.

- **(i)** Very dangerous = 4?: numerous injurious attacks on people, including several fatalities: Great white shark, tiger shark, bull shark, oceanic whitetip shark?
- **(ii)** Dangerous = 17?: one to several attacks on people, capable of inflicting moderate to severe injury or death but few if any fatalities; spotted and tasseled wobbegongs, nurse shark, tawny nurse shark, sand tiger, shortfin mako, grey reef shark, copper shark, spinner shark, Galapagos shark?, blacktip shark, blacktip reef shark?, dusky shark, Caribbean reef shark, sharptooth lemon shark, lemon shark, blue shark?
- **(iii)** Small species that are minimally dangerous or harmless = 4: Pacific angelshark and sand devil, leopard' shark, whitetip reef shark.
- **(iv)** Giant filter-feeders, normally not dangerous to people in the water = 2: whale and basking sharks.

B. Sharks suspected of attacking people = 12: Broadnose sevengill, Greenland shark, Australian angelshark?, thresher shark, silvertip shark, pigeye shark, silky shark, blacktail reef shark, Ganges shark, scalloped, great, and smooth hammerheads.

C. Additional species of potential harmfulness = 28.

(i) Potentially dangerous sharks = 15: Pacific sleeper shark, 5 additional wobbegongs, 2 additional threshers, longfin mako, bignose shark, graceful shark, night shark, sandbar shark, speartooth shark, whitefin hammerhead.

(ii) Sharks of minimal potential danger = 13: 10 additional angelsharks, snaggletooth shark, blackspot shark, broadfin shark.

Of about 21 species involved in shark attacks that are considered dangerous or very dangerous, virtually all are large species between 2 and 8 m or more. Adding about 40 other species that are suspected of harming, regarded as 'potentially or suspected as dangerous' to the 27 indicted species gives a total of slightly below 20% of the known species. A majority of the sharks that have attacked people (56%) belong to the family Carcharhinidae.

The 'Human Attack Problem': Shark attack may not be a major problem for humans, but 'human attack' is a major problem for sharks. The 1976 worldwide FAO shark catch data reported by Kreuzer & Ahmad (1978) was 307 085 metric tons, which is probably a minimal figure. If one assumes that the average shark caught weighed as much as the average human being (about 68 kg, probably too high as most of the fisheries species are lighter than the average human being), the sharks killed by human attack that year were about 4.5 million individuals, not counting those that were injured and lost or those killed and thrown overboard (Compagno, 1981). Assuming Gilbert's (1981) maximum figure of 30 human fatalities a year from shark attack, the shark fatality rate from human attack is minimally about 150 000 times higher than for shark attacks on human.

With many sharks having a reproductive strategy like larger mammals, with low fecundity, long maturation periods, and long gestation periods, the present exploitation level may be depleting the stocks of many species, and even endangering their survival. This in turn would have an uncertain and possibly negative impact on the marine ecosystems that they are a part of. Clearly shark conservation and restricted exploitation of endangered species may become a necessity in the next few decades. Particularly worrisome are those inshore species, like the river sharks, Glyphis species, and the Borneo shark, Carcharhinus borneensis, that are known 'from very few valid records and museum specimens. A major difficulty in accessing the condition of shark populations is a general dearth of knowledge on their population biology. Another problem is that, unlike cetaceans, sharks have no positive popular appeal in many countries, being generally saddled with the obnoxious 'JAWS image' that invites lack of concern for the problems of shark overexploitation.

Advice to People Who are at Potential Risk from Shark Attack : The following advise for people who use waters frequented by dangerous or potentially dangerous sharks is derived and modified from that advocated by Gilbert (1963), Baldridge (1974), and the recent shark issue of Oceanus (1981, vol. 24, no. 4).

1. Remember that shark attack is a minor phenomenon, despite media hyperbole to the contrary. Millions of people use the oceans every year without being attacked, and your chances of being attacked are lower than being hit by lightning. The sea itself is far more dangerous. Also, it may be some comfort to realize that people are far more serious a hazard to sharks than vice-versa.

2. Do not swim, dive or surf where dangerous sharks are known to congregate. In California, for example, white shark attacks have repeatedly occurred in the same small areas favoured by these sharks.

3. Swim, dive or surf with another person or in groups, and do not stray far away from your group. Lone people are more readily attacked than a large and possibly threatening group.

4. Avoid spreading blood or human wastes in the water. Human blood may attract and excite sharks, and divers and swimmers should avoid or come out of the water with bleeding injuries or, for women, when menstruating. Similarly, feces and urine may be attractive, and should not be scattered indiscriminately where one swims or dives. Avoid swimming where raw sewage or slaughterhouse offal is dumped in the water.

5. If possible, do not swim or dive in water with high turbidity and low visibility.

6. If possible, avoid swimming or diving well offshore, in channels, at river or bay mouths or along dropoffs to deeper water where large sharks may occur.

7. If fishes begin to behave erratically or congregate in unusual numbers, leave the water. Large aggregations of fish or squid often have their attendant sharks, and should be avoided.

8. Uneven skin tanning and bright, contrasting swimsuits and wetsuits may be more attractive to sharks, and should be avoided. Some authorities have stated, however, that a black wetsuit makes one look more like a seal and increases the probability of attack by white sharks. Surfboards that contrast with the water surface from below may be more attractive to sharks. In general, low contrast is probably better to avoid attracting or exciting sharks.

9. Do not swim with pets or other domestic animals, which may attract sharks, or swim, dive, or surf too close to seal and sea lion colonies. Apart from increasing your chances of being attacked by an attendant shark near such colonies, the pinnipeds themselves may present a hazard. The near presence of dolphins, porpoises or other small cetaceans is no guarantee of the absence of sharks, contrary to popular belief. A few sharks feed on and may even follow small cetaceans.

10. Before entering the water from shore or a boat take care to scan about for sharks. In open lagoons low tide may trap sharks inside them, and these should be checked. While swimming or diving, keep a regular lookout to the open sea and all around you for approaching sharks. Particularly with divers, alertness has paid in avoiding injuries and decreasing the seriousness of shark attacks.

11. If possible, do not swim or dive at dusk or night when many sharks become more active.

12. A number of surfers have been accosted by sharks in recent years, mainly by great whites. The small paddleboards or bellyboards that are currently popular may give less protection from shark attack than the more traditional large surfboards; one scientist has. suggested that such boards, with the limbs of the surfer hanging down from them, might easily be mistaken for a seal by a great white shark.

13. Attacks on small sportfishing and commercial fishing boats by sharks, mostly great whites and shortfin makos but also tiger sharks, lemon sharks and a few others, occasionally occur, particularly when the sharks are hooked. Makos in particular may wreck havoc with a small boat when hooked, and very rarely both white sharks and makos have demolished them. Boats with leaky, dirty bilges trailing fish juices may contribute to white shark attacks, along with contrasting bottom colours and bright, spinning propellors. JAWS not withstanding, large white sharks are often content to patrol under fishing boats and steal fishes that are hooked. Any large and dangerous sharks should be shot or otherwise subdued before being boarded on a boat, or confined to a penboard area separate from the rest of the deck.

14. Spearfishing increases the chances of shark encounters. If possible do not stay in a limited area for so long that trailing fish juices, or your erratic swimming while pursuing fish, attracts hungry sharks. Generally spearfishing on an outgoing tide, which may attract sharks from offshore to the fishing site, is less safe than fishing on an incoming tide, with fewer sharks likely to be inshore from the site. Do not carry speared fish on your person, or on a stringer or tether, but remove them from the water immediately.

15. Do not provoke or molest any shark by spearing it, poking it, attempting to ride it, or hanging onto its tail, no matter how small or seemingly innocuous. Even small, weak-toothed species will often bite when harassed, and some normally docile large species may defend themselves with vigor when accosted. Do not corner a shark in a place where its escape route may be blocked by you.

16. If a large shark is sighted leave the water as soon as possible. Swim as smoothly as possible to avoid exciting the shark. If diving, keep submerged and watch the shark until exit from the water can be accomplished quickly, to be able to block an attack if the shark chases to do so.

17. If a shark changes its normal smooth swimming to a jerky, rigid, unusual pattern, it may be giving a threat display; you should depart from the vicinity of such sharks as quickly as possible.

18. Divers should carry some tool or object to fend off sharks and keep distance between you and them. A 'shark billy', a 1.2 m long wooden, glass-fibre or metal club with one end roughened to give purchase against the skin of a shark is useful, and a speargun, abalone iron or knife can suffice. Some powerhead designs can double as a shark billy when unloaded, and several divers have successfully kept persistant oceanic whitetip sharks at bay with underwater cameras.

19. Use a shark cage or sharkproof small submersible if sharks in an area persist in harassing diving operations that cannot be conducted elsehwere, or if sharks are to be studied underwater in safety.

20. If a shark approaches closely and seems to be attacking, keep calm and use any object available to you to fend it off. Do not attempt to injure the shark with knife or speargun unless all else fails in deflecting its attack, as injury often makes large sharks more aggressive. Use your bare hands only as a last resort, to avoid cutting yourself on the teeth or skin of the shark.

21. Lethal anti-shark weapons like powerheads or gas guns, as well as ordinary spearguns, have their limitations and may excite a shark, cause other sharks to attack or injure a diver if improperly applied. These should be used with care and as infrequently as possible. With a powerhead or even a speargun, aim for the top of the head between the eyes, or the side of the head right through an eye.

22. Aggressive actions toward approaching sharks may be effective in deterring attacks, but some sharks may not react at all and others may become very aggressive themselves; aggressive actions should be applied judiciously. Rapid limb movements, charging the shark, shouting underwater or blowing bubbles just might abort a possible attack, and poking a shark in the eyes or in its gills has aborted several attacks. Fending off a shark may buy sufficient time to allow a rescue.

23. In most cases, people have recovered from shark attack injuries. If a person is attacked and bitten, all effort should be made to stop bleeding, even before exiting the water, and a physician should be called on to attend the victim as soon as possible.

24. Recent promising results with potential shark repellents may result in salves or ointments that can be used by divers on wet suits and possibly by swimmers on bare skin to deter sharks from biting. At least a squirt-gun applicator to shoot a repellent at an oncoming shark seems possible as a non-lethal anti-shark weapon. Work with an oversuit of stainless steel chain mail for divers suggests that such passive protection may be quite effective against some dangerous sharks, and with further development and possibly different materials against all large species. Practical anti-shark armour and repellents may be available in a few years at most. If you obtain the old US Navy 'shark chaser' repellent or its British equivalent as surplus, remember that these are of limited value at best and should not be depended on to repel a shark.

10.2 PRESERVING SHARKS FOR SCIENTIFIC STUDY

Many countries have natural history museums, and these often have fish collections with sharks and other elasmobranchs in them. In the 18th and 19th centuries museum sharks were often skinned and the skins dried and stuffed, but this was supplemented and largely replaced first by fixation and storage in high concentrations (70% or more) of ethyl alcohol (CH_3CH_2OH) solutions in water. By the beginning of the 20th century fixation in water solutions of formaldehyde gas (CH_20) or formalin, followed by permanent storage in aqueous solutions of ethyl, isopropyl ($CH_3CHOHCH_3$) or n-propyl (CH_3CH_2CHOH) alcohols became the standard mode of preservation. Because of the extreme fire hazard with high concentrations of alcohol in some places (notably Japan, with much seismic activity and a history of large fires) or limited availability or high cost of alcohol, some collections store sharks and other fishes in weak formalin sometimes buffered, but this is far less desirable because of the excessive hardening of soft tissues, brittleness of fins, and decalcification of hard tissues in sharks long stored in formalin. A 1% solution of propylene phenoxcetol with 5% ethylene glycol in water has been used with some success as a substitute for formalin or alcohol storage after formalin fixation.

Although sharks form a relatively small group of fishlike fishes, they are poorly known, and many described species are inadequately represented in museum collections. Also, new species are still being collected at a goodly rate, especially from trawl catches on the continental and insular slopes. It is not impossible that readers of this Catalogue may come upon unusual sharks of rare species interesting to science, or even new species, and may want to preserve them for later identification and deposition in a museum collection. Hence it is desirable to briefly outline methods of preserving sharks.

Most sharks, including small species or small specimens of larger ones a metre or less long, can be preserved readily in the field or laboratory when caught. For best results sharks should be fixed with formalin as soon after death as possible, though they can be frozen or even covered with ice to halt or retard putrefaction until the specimen can be fixed or delivered to a museum for fixation. Excess freezing will dehydrate unprotected specimens, and sharks to be frozen for considerable periods should be sealed with some water in plastic bags. In hot climates it is especially important to preserve (or freeze) specimens quickly, as they can deteriorate in a matter of hours. Specimens should be kept cool, in the shade, and iced or covered with wet cloth or burlap if they cannot be immediately fixed or frozen.

Containers are necessary to fix and house the sharks, such as small barrels, cardboard liquipaks, elongated troughs, plastic garbage pails or whatever is available locally. Formalin will quickly corrode ordinary steel containers, so such should have acid-proof coatings if used for fixation. Ideally a long trough of wood, plastic, fibreglass, stainless steel or other formalin-resistant material should be used for preserving sharks in a straight position, but it may be possible in some situations only to fix and store specimens in cylindrical containers in a curled position. Tools and materials needed include several litres of 40% aqueous (concentrated) formaldehyde, a scalpel or small penknife, a fish filleting knife, a forceps, a pointed metal probe, a 20 to 50 ml hypodermic syringe with large needles (size 16 or larger), rubber gloves, good quality label paper of high rag content that will not tear easily when wet or plastic-impregnated paper that can be written on with pencil, linen or cotton string, and pencils.

To preserve a small shark, prepare a 10% formalin solution by adding 1 part concentrated formaldehyde to 9 parts of water, in a volume enough to, at least, cover the shark in the container selected. Formalin is quite toxic, and should be handled with great care, in a well-ventilated place and with protective clothing and safety glasses. Containers for fixation and temporary storage should ideally have tight-fitting lids to prevent escape of toxic formalin fumes. Make a label for the shark in pencil, with the date, locality and depth of capture, collector, field number (if any), and any other pertinent information, and either tie it to the shark (the caudal peduncle is often used) or place it inside its mouth or inside a gill slit. If a syringe is available inject a quantity of formalin into the body cavity and also the muscle masses of the body, tail, and fin bases, and the head to preserve the brain. Dilute 10% formalin can be used for injection, though higher strength formalin, 1:4, 1:2 or even undiluted concentrated formaldehyde is very effective and preferable in preventing putrefaction in hot climates. If a syringe is unavailable make several small holes or slits on the sides and body cavity of the shark with a knife, scalpel or probe, preferably on the righthand side (left side is generally used for illustration); even when injecting the shark

make at least one small slit on the left side of the body cavity. Position the shark flat on its abdomen with fins spread in the preserving container and add enough dilute formalin to cover it. Fins can be pinned out on pieces of styrofoam or other soft material if necessary. With hot climates and larger sharks it may be desirable to use stronger formalin, up to 1:4, for initial fixation, or add more concentrated formaldehyde to 10% solution if outgassing from putrefaction is evident. Specimens should be fixed for at least two weeks for small sharks below 1.5 m to a month or more for larger specimens. Volume of the shark should not exceed half of the volume of the preserving fluid. If possible specimens should be stored in alcohol, after a brief wash in water to remove excess formalin.

The larger sharks, 1.5 m or more, present special storage problems, and it is often impossible to preserve them intact. However heads, fins and vertebral columns of even large sharks can be readily accommodated in barrels and other containers. To prepare a large shark for compact storage measure its total length and remove its viscera and most of its muscle mass from the pectoral fin bases to the second dorsal and anal fin with a filleting knife, leaving a long dorsal strip of skin connecting the head to the first dorsal fin, second dorsal, caudal peduncle and caudal fin, and a short ventral strip connecting the pelvic fin bases, anal fin and caudal peduncle. Strip the vertebral column of excess flesh and cut it off at the head and caudal peduncle, cut it into sections if necessary, tie labels to it and the rest of the shark, and fix it and the rest of the shark in a suitable container with at least 10% formalin or stronger, injecting the head and tail if possible.

If it is not possible to preserve any parts of a shark take black and white or colour photographs of the entire shark in lateral view and dorsal view, and the underside of its head and pectoral fins, and remove and dry a strip of teeth from the upper and lower jaws. At minimum, record the date, locality, depth, collector and any other significant data for the specimen and take the following measurements as indicated in the first volume of this Catalogue with a metre stick or tape measure: Total length, Preoral length (POR); Head length (HDL); Eye length (EYL); Mouth width (MOW); Pectoral anterior margin (PIA); Pelvic anterior margin (P2A); First dorsal height (D1H); Second dorsal height (D2H); Anal height (ANH); and Dorsal caudal margin (CDM). Take other measurements if possible.

The writer is quite willing to help any readers who have shark identification problems, and photos, measurements and tooth samples or small whole sharks can be sent to him care of FAD.

10.3 CORRECTIONS AND ADDITIONS

It is inevitable with a work of the size and scope of this Catalogue that it should become obsolete as soon as its publication. Due to a tight deadline for submitting the first volume of the Catalogue data from several important papers that appeared at the time could not be incorporated in it. Also because of the deadline, the writer was unable to proofread the galleys for volume 1 (unlike volume 2), and a number of text errors, mostly minor and typographic but with two important omissions, appeared in the first volume. Hopefully these errors will be corrected in a revised version of this Catalogue, but as a present expedient some of the more annoying errors are listed, and summaries of some of the more interesting works that could not be included in volume 1.

Corrections: Page 1, para. 3, Gill (1873) is (1872), Garrick (1979) is (1982), Bass, D'Aubrey & Kistnasamy (1975c) is (1975, a,b,c), Applegate et al. (1981) is (1979). **Page 4,** para. 3, to Eucrossorhinus and Orectolobus add Sutorectus. **Page 15,** para. 6, Compagno (1981) is (1981a). **Page 21,** para. 9, 'specimen' is 'specimens'. **Page 26,** para. 10, Tortonese (1958) is (1956). **Page 34,** Aculeola, Field Marks omitted, is 'blackish brown, no anal fin, small dorsal fin spines, small hook-like teeth in both jaws'; Literature omitted, is 'de Buen (1959a), Kato, Springer & Wagner (1967). **Page 35,** para. 7, Cadenat (1959) is (1959a,b,c). **Page 41,** para. 6, and **page 59,** para. 1, Regan (1908b) is (1908d). **Page 46,** para. 1, Okamura et al. is Okamura, Amaoka & Mitani. **Page 53,** para. 8, Fowler (1949) is (1941). **Page 57,** para. 4, Garrick (1959), is (1959a), Krefft & Stehmann is Krefft & Tortonese. **Page 57,** para. 15, Regan (1906) is (1906b). **Page 58,** para. 5, **page 59,** para. 1, **page 76,** para. 9, **page 85,** para. 10, Krefft (1968) is (1968a). **Page 64,** para. 6, Cadenat & Blache (1982) is (1981). **Page 68,** para. 7, Smith & Radcliffe (1912) is Smith (1912a). **Page 70,** para. 2, **page 101,** para. 10, Nakaya (1982), should be Nakaya (in Okamura, Amaoka & Mitani, 1982). **Page 95,** para. 5, **page 244,** para. 9, Strasburg is Strasberg. **Page 96,** para. 5, Kstanasamy is Kistnasamy. **Page 103,** para. 4, carcharis is carcharias in Squalus and Carcharodon. **Page 123,** Literature omitted, is 'Fourmanoir & Rivaton (1979). **Page 136,** para. 9, nudipinnis not underlined. **Page 138.** Ordinal Citation, Synonymy and Diagnostic Features omitted for Squatiniformes, should be:

Order Squatiniformes Compagno, 1973, J.Linn.Soc.(Zool.), 53, suppl. 1.

Synonymy : Order Asterospondyli, Suborder Rhinae: Gill, 1893. Order Cyclospondyli, Suborder Tectospondyli: Jordan & Evermann, 1896. Order Euselachii, Suborder Squatinoidei: Blot, 1969. Order Lamniformes, Suborder Squatinoidei: Patterson, 1967. Suborder Plagiostomi Tectospondyli: Hasse, 1879 (in part). Suborder Rajiformes: Goodrich, 1909 (in part). Suborder Rhinae: Gill, 1862, 1872. Suborder Rhiniformes: Lozano y Rey, 1928. "Group" Rhinoidei: Garman, 1913. Order Squalea, Suborder Rhinida: White, 1936, 1937. Order Squaliformes, Suborder Squatinoidei: Berg, 1940, Berg & Svedovidov, 1955, Arambourg & Bertin, 1958 (in part). Order Squaloidea, Suborder Squatinoidei: Schultz & Stern, 1948. Suborder Squaloidea: Romer, 1945, 1966 (in part), Norman, 1966 (in part). "Division" Squaloidei: Regan, 1906 (in

part). Suborder Squaloidei: Engelhardt, 1913 (in part). Order Squatinae: Fowler, 1941, Smith, 1949. Order Squatinida, Suborder Squatinoidei: Glikman, 1967. Order Squatiniformes: Rass & Lindberg, 1971, Applegate, 1974, Chu & Wen, 1979. Suborder Squatiniformes: Bertin, 1939. Suborder Squatinina: Matsubara, 1955, Fowler, 1969a. Suborder Squatinoidea: Bigelow & Schroeder, 1948. Suborder Squatinoidei: Lindberg, 1971, Nelson, 1976. Order Tectospondyli, Suborder Squatinoidei: Jordan, 1923.

Diagnostic Features: Trunk greatly depressed and raylike; head greatly depressed and laterally expanded, with a distinct neck between itself and the trunk; 5 pairs of gill slits present on ventrolateral surface of head, with the posteriormost in front of pectoral fin origins; spiracles present and very large, just behind the eyes; nostrils with barbels, poorly developed nasoral grooves and weak circumnarial grooves, very close to mouth, anterior nasal flaps elongated and bordering mouth; eyes on dorsal surface of head, without nictitating lower eyelids; snout very short and truncated, not sawlike and without rostral barbels; mouth large, arched and moderately long, extending behind eyes; labial furrows very large, present on both jaws; teeth moderately differentiated along jaws, without enlarged anterior or posterior teeth and without a gap or small intermediate teeth between anterior and lateral teeth in the upper jaw; two spineless dorsal fins present, the first with its origin opposite or behind free rear tips of pelvic fins; pectoral fins very large, expanded and raylike, with unique triangular anterior lobes that extend forward from the pectoral bases and cover the gill slits laterally; pelvic fins large, with vent separate from the pelvic inner margins; anal fin absent; caudal fin with a moderately long dorsal lobe but with the ventral lobe longer than it; vertebral axis depressed into the ventral caudal lobe; intestinal valve of spiral type.

Page 150, para. 5, Poll (1950) is (1951). **Page 155**, para. 6, Tropidodus Beebe & Tee-van is Tropidodus (original mispelled). **Page 156**, para. 9, '11 to 14 intervals' is '11 to 14 day intervals', para. 10, 'echnoids' is 'echinoids'. **Page 160**, para. 8, 'selections shown' is 'selection is shown'. **Page 161**, para. 6, fin spine' is 'fin spines'. **Page 165**, Definition and Diagnostic Features missing for Orectolobiformes:

Synonymy : Order Asterospondyli: Gill, 1893 (in part), Smith, 1949 (in part), Fowler, 1941 (in part). Order Asterospondyli, Suborder Galei: Jordan & Evermann, 1896 (in part). Superorder Carcharhini, Order Squatinida, Suborder Ginglymostomatoidei: Glikman, 1967. Order Carcharhiniformes: Rass & Lindberg, 1971 (in part). Suborder Carchariina: Fowler, 1967a (in part). Order Euselachii, Suborder Galei: Jordan, 1923 (in part). Order Euselachii, Suborder Galeoidei: Whitley, 1940 (in part), Blot, 1969 (in part). Order Gales, Suborder Isurida: White, 1936, 1937 (in part). Suborder Galei: Gill, 1872 (in part). Order Galeiformes, Suborder Isuroidei: Arambourg & Bertin, 1958 (in part). Suborder Galeiformes: Lozano y Rey, 1928, Budker & Whitehead, 1971 (in part). "Division" Galeoidei: Regan, 1906 (in part). Suborder Galeoidei: Engelhardt, 1913 (in part). Order Lamniformes, Suborder Lamnoidei: Berg, 1940 (in part), Berg & Svedovidov, 1955 (in part), Patterson, 1967 (in part). Suborder Lamnina: Matsubara, 1955 (in part). Order Lamnoidea, Suborder Galeoidea: Schultz & Stern, 1948 (in part). Suborder Lamnoidei: Lindberg, 1971 (in part), Nelson, 1976 (in part). Order Orectolobiformes: Applegate, 1974, Chu & Wen, 1979. Suborder Plagiostomi Asterospondyli: Hasse, 1879 (in part). Suborder Scylliformes: Bertin, 1939 (in part). Suborder Scyllioidei: Goodrich, 1909 (in part). Suborder Squali: Gill, 1862 (in part).

Diagnostic Features: Trunk cylindrical to strongly depressed and somewhat raylike; head conical and slightly elevated to strongly depressed, not laterally expanded; 5 pairs of gill slits present on sides or on dorsolateral surface of head, the last two or more over the pectoral bases; spiracles present and small to very large, behind and below or at level of eyes; nostrils with barbels on the lateral surfaces of the anterior nasal flaps, strong nasoral grooves, and circumnarial grooves present or absent, connected to mouth, with anterior nasal flaps expanded posteriorly and reaching mouth; eyes lateral or dorsolateral on head, without true nictitating lower eyelids but sometimes with a subocular pocket below eyes; snout short to very short and bluntly rounded to truncated, not sawlike and without rostral barbels; mouth moderate to large, arched or virtually transverse and short, well in front of eyes; labial furrows very large, present on both jaws; teeth not strongly differentiated along jaws, without enlarged anterior or posterior teeth, and no small anterior teeth or a gap between anterior and lateral teeth in upper jaw; two dorsal fins, without spines, the first with its origin varying from over the pectoral fins to behind the pelvic fin bases but usually over or behind the pelvic bases; pectoral fins small to moderately large, not raylike and without triangular anterior lobes; pelvic fins moderately large, with vent usually continuous with their inner margins; anal fin present; caudal fin with a moderately long dorsal lobe but with ventral lobe varying from moderately long (but shorter than the dorsal lobe) to absent; vertebral axis raised into the dorsal caudal lobe; intestinal valve of spiral or ring type.

Page 166, para. 5, 'spirale' is 'spiral'. **Page 167**, para. 7, **page 168**, para. 10, **page 169**, para. 7, **page 170**, para. 5, Teng (1959) is Teng (1959a). **Page 173**, para. 14, **page 175**, para. 9, **page 177**, para 2, for 'perinasal' read 'circumnarial'. **Page 179**, para. 3, Compagno (1973) is (1973c), para. 4, Crossohrinus is Crossorhinus. **Page 192**, para. 9, underline griseum. **Page 203**, para. 3, 'pried lose' is 'pried loose'. **Page 206**, para. 7, 'brag' is 'drag'. **Page 207**, para. 9, "La Coquille2, omit 2, add ". **Page 209**, para. 10, 'Rhiodontidae' is 'Rhiniodontidae'. **Page 210**, para. 2, Hubbs, Iwai & Matsubara is Hubbs, Compagno & Follett. **Page 211**, para. 3, 'utilized' is 'utilize', para. 4, 'excited and hooked fishes' is 'excited by hooked fishes'. **Page 213**, para. 1, 'Teeth large, less numerous, and less than 50 rows in each jaw half' to 'Teeth usually larger, less numerous and less than 50 rows in each jaw half (except Cetorhinidae, with over 200)'; also, to 'Internal gill openings without rakers' add 'or with dermal denticle rakers'. **Page 216**, para. 1, White et al. (1962) is White, Tucker & Marshall (1961), 'odontstaspids' is odontaspid's; para. 7, 'absence of labial furrows' is 'presence of labial furrows'. **Page 218**, para. 5, 'sued' is 'used'. **Page 219**,

para. 8, 'Carcharias ferox. Placed on ... ' is 'Carcharias ferox was placed on ... '. **Page 223**, para 7 and 224, para. 5, Uyeno 1976) is Uyeno, Nakamura & Mikami 1976. **Page 224**, para. 2, for 'teleost paddlefishes' read 'chondrostean paddlefishes'. **Page 230**, para. 7, Mizue et al. (1981) is Otake & Mizue (1981). **Page 232**, para. 2, and 246, para. 2, Gillmore (1983) is Gilmore (1983). **Page 234**, para. 1, 2 and 4, Rafinesque (1809) is Rafinesque (1810). **Page 237**, para. 2, Gray 1815 is Gray 1851. **Page 239**, para. 2, 'with light free rear tip' is 'without light free rear tip'. **Page 241**, para. 1, 'divers surfers,' is 'divers, surfers,', para. 2, '0.12' is '0.13', para. 3, 'heard' is 'horde', para. 9, Biegelow & Schroeder is Bigelow & Schroeder, Arnold (1971) is Arnold (1972). **Page 243**, para. 3, to 'teeth with incomplete cutting edges' add 'in young and small adults'. **Page 246**, para. 2, Fourmanoir & Laborde is Fourmanoir & Laboute; Dodrill & Gillmore is Dodrill & Gilmore, para. 3, Compagno (1978, 1981a) is Compagno & Vergara (1978), Compagno (1981a). **Page 248**, para. 1, Uquuhart is Urquhart. **Page 249**, para. 10, Stevens (1983) is Stevens, Dunning & Machida (1983).

Additions: Family Chlamydoselachidae: Chlamydoselachus anguineus was reported from off Surinam and French Guiana by Uyeno, Matsuura & Fujii (1983), the first western Atlantic record.

Family Squalidae: Papers by Yano & Tanaka (1983, 1984, 19840) clarify the status of Scymnodon and Centroscymnus from the western Pacific. Centroscymnus coelolepis is reported from Japan, Scymnodon obscurus from the Atlantic is synonymized on good evidence with the Pacific S. squamulosus, and a new species, S. ichiharai, is described from Japan. S. ichiharai is undoubtedly valid but further bridges the gap between Scymnodon and Centroscymnus, and makes it likely that the two genera will have to be synonymized.

Family Hemiscylliidae: Dingerkus & DeFino (1983) present a comprehensive revision of this family, which must be briefly dealt with here. The species listed in the present account are recognized by these authors with the exception of Chiloscyllium caerulopunctatum, which is synonymized with C. plagiosum, and C. arabicum, which was apparently overlooked. They recognize an Indonesian species, C. hasselti Bleeker, 1852, formerly synonymized with C. griseum, and describe two new species, C. burmensis from Burma and C. confusum from the "Gulf" east to India. C. hasselti and C. burmensis appear to be valid, while C. confusum seems to be a junior synonym of C. arabicum.

Family Odontaspididae: Gilmore, Dodrill & Linley (1983) give a detailed and fascinating account of the reproduction of the sand tiger shark, Eugomphodus taurus, documenting the squence of intrauterine nourishment in this species, in which a successful embryo progresses from using stored yolk through killing and eating other embryos to eating unfertilized eggs, for a 9 to 12 month gestation period.

Family Mitsukurinidae: The goblin shark, Mitsukurina owstoni, was reported from off Surinam and French Guiana by Uyeno, Matsuura & Fujii (1983).

Family Cetorhinidae: Priede (1984) details a successful short-term satellite tracking effort on a radio-tagged basking shark, Cetorhinus maximum. This space-age methodology promises to reveal some of the secrets of the basking shark's seasonal migrations and movements.

Family Lamnidae: Pratt & Casey (1983) estimated the age of the shortfin mako, Isurus oxyrinchus, using four methods. As with Parker & Stott's (1965) work with the basking shark, Cetorhinus maximus, these authors assume two growth rings per year on mako vertebrae from indirect calibration methods.

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