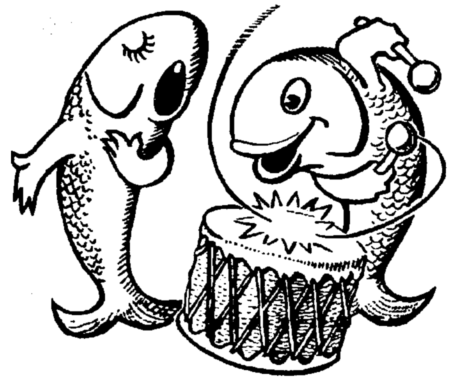
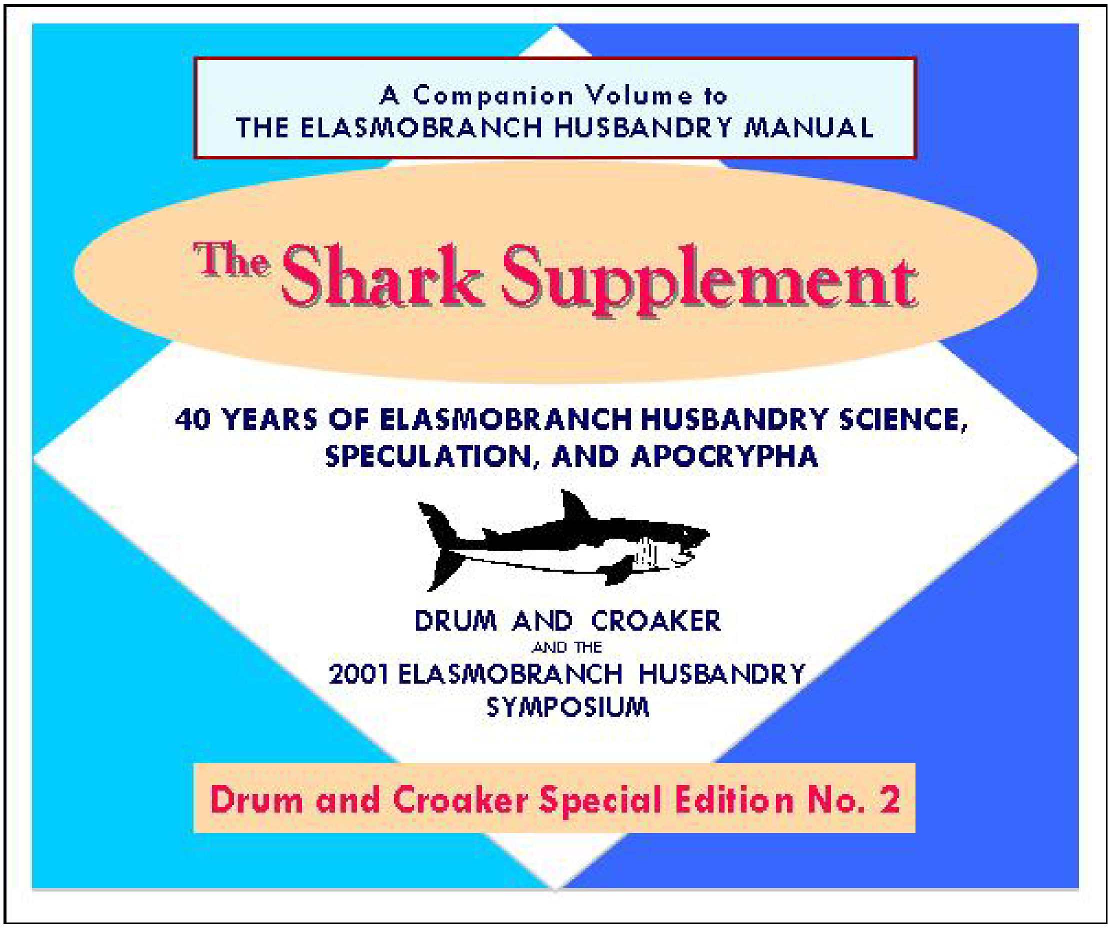
DRUM and CROAKER



A Highly Irregular Journal for the Public Aquarist

Special Edition No. 2 — *December 2004*



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EXHIBITRY AND DESIGN

Preface

This special edition of *Drum and Croaker* is intended as a companion volume to the Elasmobranch Husbandry Manual (EHM) scheduled to be published by the Ohio Biological Survey (Columbus, Ohio) in December 2004.

Special Edition #2 serves two functions. First, it is a reservoir for many valuable papers that were presented at the Elasmobranch Husbandry Symposium (EHS), subsequently submitted to the EHM, but ultimately not included due to space limitations. Second, it serves as a convenient archive of all elasmobranch papers appearing in *Drum and Croaker* from its inception in 1958 through 2004. Many of these articles are cited throughout the EHM, but the original paper copies are extremely rare and not easily available to the scientific or aquarium communities. This volume will replace the barely legible 10th generation Xerox copies that exist in many a curator's reprint collection. While I intend to eventually archive all of these materials on the *Drum and Croaker* website in their original format (many reside there now), it seems extremely useful to have this paper collection, spanning 45 years, available in one accessible location.

I scanned each article as bitmap images from original copies of *Drum and Croaker*. I then used Optical Character Recognition (OCR) software to capture the text from these images, and manually edited and reformatted each reconstruction for accuracy. Images imbedded in the original text were processed separately to retain as much clarity as possible

For this special edition, all of the text obtained from the EHM editors has been converted into the standard *Drum and Croaker* page format. Tables however are inserted as they were provided by the EHM editors; as Microsoft Word Objects from Excel. This is the first publication of these EHS papers. All citations of these works should refer directly to this volume and use the page numbers on which they actually appear. All *old Drum and Croaker* papers have also been reformatted to match the modern page format. The original reference, including page numbers, is given for each article. Please use these original volume and page numbers, as given under the authors' information, when citing these papers. It may be appropriate to also add "reprinted in: The Shark Supplement, Drum and Croaker Special Edition number 2, 2004.", or some similar attribution.

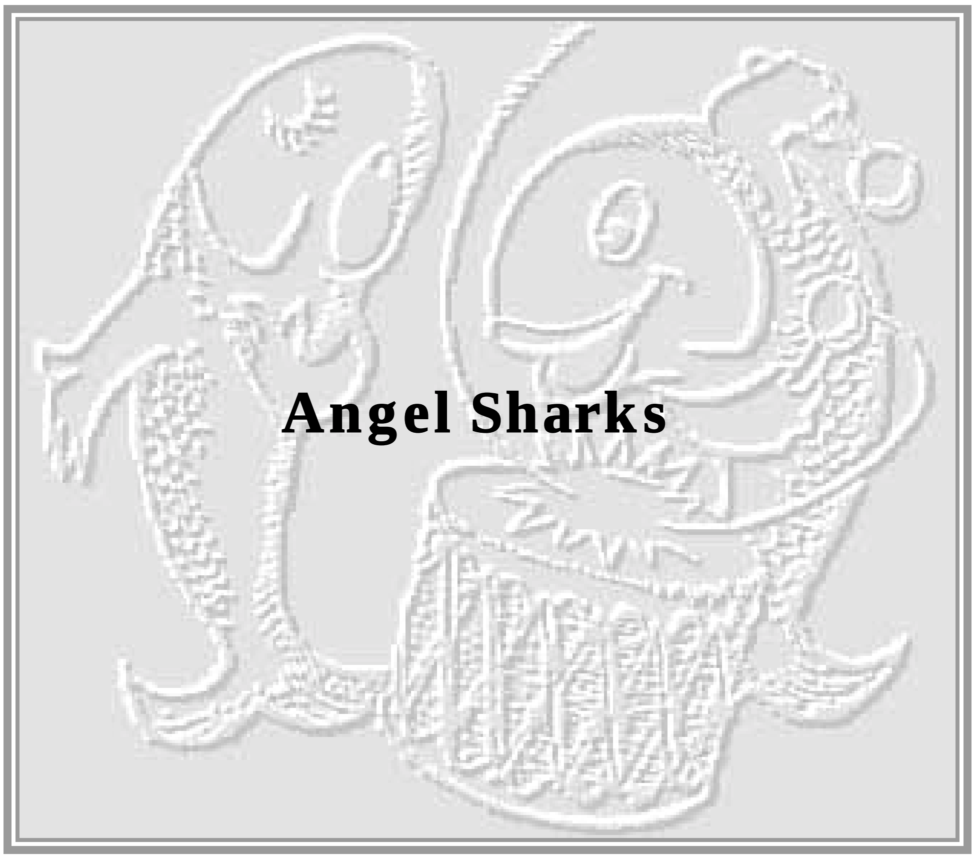
The EHS and *Drum and Croaker* papers are organized together by topic and chronology. When EHS papers are included in a section, they appear first. *Drum and Croaker* contributions follow in order of their original publication in the periodical.

Readers will note that there are frequent grammatical and spelling errors in some of the old material. Remember that *Drum and Croaker* was started as a timely means of informally sharing information. Some of the typewriter work was quick, dirty, and probably executed between frenetic episodes of exhibit maintenance. "Spell check" did not become available until this periodical had existed for more than a quarter of a century. While I have occasionally made corrections in spelling where the author's intent was obvious, I have not otherwise altered the text of these documents. "As is" they provide a unique window into the history of public aquariums in the later half of the 20th century. Although many would consider Drum and Croaker to be "grey literature", it contains a wealth of otherwise unpublished technical information and observational records that are still of tremendous value to aquarists and shark biologists today.

I would like to express my thanks to all of those who have supported *Drum and Croaker* over the years. All pre-1993 articles included here were restored using the archival techniques that I have previously used to rescue many old volumes of *Drum and Croaker*. Initial funding for the archival process was provided in the form of a 1999 grant from the Columbus Zoo and Aquarium. Since 2001 the archive has resided on the *Drum and Croaker* website, also hosted by that institution, at http://www.colszoo.org/internal/drumcroaker.htm. Mike Brittsan (Curator) and Greg Bell (Finance and IT Director) are the institutional supporters that have made the site possible, while Kevin Bonifas (Web Developer) built and continues to update the pages. Doug Warmolts (Assistant Director of Living Collections) was an important advocate for the archiving project. George Buehner and Nick Zarlinga at the Cleveland Zoo, as well as another anonymous benefactor from the Cleveland area, loaned me many of the original copies of *Drum and Croaker* that have been used for both the archiving process and the creation of this volume.

Pete Mohan
Kent, Ohio, USA
November 11, 2004

Angel Sharks



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HUSBANDRY OF PACIFIC ANGEL SHARKS AT CABRILLO MARINE AQUARIUM

Michael S. Schaadt, Exhibits Director
Jeffrey Landesman, Chief Aquarist

Cabrillo Aquarium, Los Angeles, CA

Drum and Croaker 28: 3-5. January 1997

On May 18, 1993, a local fisherman hauled in an adult Pacific angel shark (Squatina californica) which immediately pupped six offspring on the boat's deck. The fisherman placed the newborns in a bait tank and turned them over to Terminal Island Seafood Company which eventually offered them to CMA.

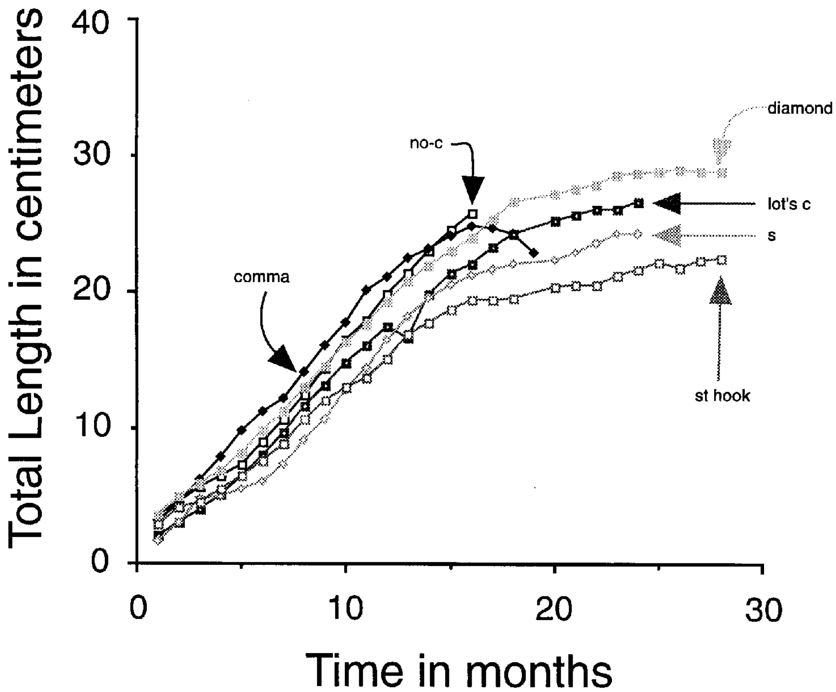
The baby angels were put into holding tanks where they started to feed on live anchovies that were presented to them on a long fork. The food was presented by moving it anteriorly starting at the tail to the head about 4 inched above the shark. The food was eaten whole. It was surprising to see the large size of prey that these small sharks would engulf. Video footage was taken of the feeding and is on file at the CMA video library.

After doing well and feeding for 6 to 7 months in holding, the sharks were put on public display in the schooling fish tank in the exhibit hall. At that time there were only three aquariums in the world that displayed Pacific angel sharks based on a survey of 114 Aquariums by the American Elasmobranch Society. Dimensions of the tank are 5 feet wide by 5 feet long by 3 feet deep and it holds approximately 550 gallons of sea water. Sharing the tank with the sharks were a mixed school of northern anchovies (Engraulis mordax) and Pacific sardines (Sardiops sagax caeruleus) that kept disappearing on a regular basis presumably due to predatory activity by the sharks.

Each of the pups had distinctive markings which were used to identify individuals. These markings remained unchanged as the sharks grew. If the markings stay through adulthood they could provide a method of identification for researchers in the field. During the shark's stay at CMA they were measured monthly to record their growth rates (Figure 1). The data is comparable to that reported by Natanson & Cailliet (1990). Of the original six pups donated three were returned to the ocean, two were donated to the Stephen Birch Aquarium/Museum (La Jolla, CA) which had larger tanks and one died of unknown causes while on display.

Previously, two other attempts to display Pacific angel sharks at CMA were less successful (as reported in Natanson & Cailliet, 1990). They ate only cut mackerel and squid and they developed scrapes on their undersides presumably from the coarse coral shell sediment used in CMA tanks at that time. This time the tank where they were put was modified to have sandy sediment more closely approximating their natural habitat and the food (anchovies and sardines) was presented live or was available swimming above them in the tank. The availability of prey at night presented a more natural feeding opportunity to these nocturnally active animals (Pittenger, 1985).

Their sandy color with mottling and their habit of folding their fins over, making themselves essentially flat, then covering themselves with sand, made it difficult for visitors to view and presented a challenge for the exhibit team. A sign was put on front of the tank with "buried in the sand are baby Pacific angel sharks" which seemed to help visitors find the animals. A graph depicting their growth rates was mounted alongside the tank and was updated monthly. A display of their slow, regular growth pattern presented a valuable educational opportunity.



<u>Figure 1</u>. Growth of angel shark (*Squatina californica*) at the Cabrillo Marine Aquarium from birth to 29 months.

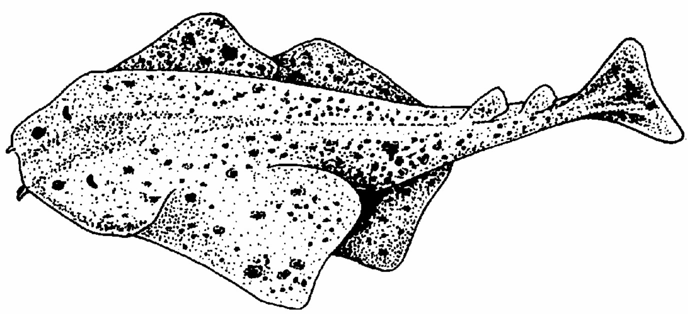
Pacific angel sharks live near shore in cold to warm-temperate waters (Compagno, 1984). Adults can reach about 5 feet in length and weight up to 60 pounds (Miller and Lea, 1972). They are bottom dwellers, burying themselves in sand and waiting to grab unsuspecting fish venturing close to their powerful, needle-sharp teeth-filled jaws. Main prey in the wild include croakers, halibut and squids. Care should be taken when handling Pacific angel sharks since they can whip their heads and snap with incredible speed when touched or provoked and can inflict painful lacerations.

Current evidence indicates that sexual maturity is not reached until six or seven years of age. Mature females have litters of about seven pups, which after a 10 month gestation period, are pupped at approximately 10 inches in length (Natanson & Cailliet, 1986). They are born live (ovoviviparous) and appear as miniature adults, not undergoing a series of metamorphosis so characteristic of newly hatched fish. Since their reproduction is more reminiscent of large land mammals and there is a robust fishery for angel sharks in California, it is wise to regulate fishing pressure as to not deplete this valuable resource.

We believe Pacific angel sharks to be a great animal to have on public display. Its morphology, habits and ecology make great educational opportunities for people to learn more about ocean life.

Acknowledgments:

The authors gratefully acknowledge and thank the staff and volunteers of Cabrillo Marine Aquarium for their support and encouragement. We especially thank Nino at Terminal Island Seafood for donating the sharks, summer interns Deron Fields and Joel Correa who were instrumental in helping ensure the feeding of the sharks in the early stages of this study and Evie Templeton for her illustration of the angel shark.



Literature Cited

Compagno, L.J.V. 1984. Sharks of the world. Part 1. Hexanchiformes to Lamniformes. FAO Fisheries Synopsis No. 125, Vol. 4, Part 1: 144-145.

Miller, D.J., and R.N. Lea. 1972. Guide to the coastal marine fishers of California. Calif. Dep. Fish Game, Fish. Bull. 157: 35.

Natanson, L.J. and G.M. Cailliet. 1986. Treproduction and development of the Pacific angel shark, Squatina califonica, off Santa Barbara, California. Copeia 1986 (4): 987-994.

------------------------------------- 1990. Vertebral Growth Zone Deposition in Pacific angel sharks. Copeia 1990(4): 1133-1145.

Pittenger, G.G. 1984. Movements, distribution, feeding and growth of the Pacific angel shark, Squatina californica, at Catalina Island, California. Unpubl. M.S. thesis, California State University, Long Beach.

CAPTURE AND FEEDING TECHNIQUES FOR PACIFIC ANGEL SHARKS, *Squatina californica*

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Kevin Lewand, Aquarist

Monterey Bay Aquarium, 886 Cannery Row, Monterey, CA 93940-1085

Drum and Croaker 34: 3-4. January 2003

Abstract

Pacific angel sharks, *Squatina californica,* are seldom exhibited long-term in captivity due to the difficulties of inducing them to feed. We developed a capture method and a feeding protocol that has allowed us to successfully exhibit these unusual sharks. Using these methods we have been able to train Pacific angel sharks to eat either live or dead food, and we have successfully maintained individual sharks for more than two years in captivity.

Introduction

As part of an on-going program at Aquarium of the Bay (ABay) in San Francisco, California, focused on displaying challenging or seldom-seen animals in captivity, we developed a selective-capture technique and a protocol for rod-feeding Pacific angel sharks. These techniques, modified from field techniques described by Fouts and Nelson (1999), have been used successfully at ABay since 2000, and have subsequently been implemented at the Monterey Bay Aquarium.

The Pacific angel shark is an unusual, flattened shark, similar in appearance to rays. In the United States, they range from southern Alaska to Baja California. Typically, Pacific angel sharks grow to 1.5 m (5 ft) and up to 27 kg (60 lb). Historically known as monkfish because the shape of their heads resembles a monk's hood, Pacific angel sharks were once common. Currently, their population numbers appear to be declining due to heavy fishing pressure.

Collection

Pacific angel sharks are collected during the late summer and fall in Bodega Bay harbor, 65 miles north of San Francisco. They are found adjacent to riprap, cryptically buried in the sand. To capture the sharks, three SCUBA Divers approach the targeted animal with two large nets and one large plastic bag. The diver with the bag positions the opening of the bag below the shark's head while the other two divers move the shark into the bag. This might involve gentle hand pressure or a quick, yet oh-so-careful, bear hug. Once the shark is inside the bag, the divers move the shark to the surface. The shark is then transferred to an igloo cooler for transportation to the aquarium.

Acclimation

The temperature and pH in the transport container are slowly adjusted to match the exhibit tank. Prior to introduction to the tank, the sharks receive a praziquantel bath inside the transport container (either 20 ppm for 1.5 hours or 10 ppm for 3 hours) and are visually inspected for other ectoparasites, especially leeches on or around the eyes.

Feeding Protocol

During the initial rod-feeding training, only live food is offered. Appropriate food is a live, juvenile sand dab, anchovy, sardine or other small, benthic fish supplemented with a multiple vitamin. Food is offered twice a week. The food fish is skewered on a thin, 30”, clear acrylic rod with a small piece of electrical tape on one end. The tape prevents the food from sliding off the end of the rod. The rod is threaded through the mouth and out the operculum of the food fish.

The diver stealthily approaches the shark and positions him or herself on its anterior or posterior or lateral side. The diver controls the live food with the acrylic rod by moving food to the distal end of the rod and places the food above the shark’s mouth at about the same distance as the length from its mouth to its pectoral girdle (typically 10-15 cm [4-6 in]), and perpendicular to the mouth. The food is wiggled back and forth until the shark lunges at and swallows it. This may take from five seconds to 15 minutes. If no eye movement is observed during the feeding attempt, the shark probably will not eat regardless of the duration of the feeding attempt. The food must be placed at the very end of the rod to help prevent the shark from biting and holding onto the rod. If the shark bites the food item and has also bitten down on the rod, the diver does not pull the rod away from the shark. The diver must wait until the shark either releases the rod or weakens its hold to the point where the rod can be carefully slid from its mouth. Typically it takes from two to eight weeks to train the sharks to eat from the rod. Once they are trained, the sharks can be switched from live to dead food.

Behavioral Considerations

The sharks will not eat if they are swimming in the water column; they must be settled in the sand. Also, the sharks will not feed if other large fishes are swimming in the immediate area (closer that one meter). If a feeding attempt is unsuccessful and the shark swims away, the shark will not eat until it resettles itself. Divers swimming after sharks in an attempt to cajole them to eat have not been successful. After a feeding fails, the next feeding is usually not attempted for at least 24 hours.

Although a non-feeding safety diver is always present during the feeds, the sharks have never displayed any aggression towards either the feeder or the safety diver.

Acknowledgements

The authors would like to thank the Husbandry Staff at Aquarium of the Bay and the Elasmobrach Team of the Monterey Bay Aquarium for their support. Also, we would like to acknowledge the assistance of J. Manuel Ezcurra, William R. Fouts, Michael J. Howard, Jeff Landesman, Colby Lorenz, Mike McGill, Andrew Sim, Freya Singer, and Reid P. Withrow.

References

Eschmeyer, W. N. and E. S. Herald. 1983. A field guide to Pacific coast fishes. Houghton Mifflin.

Fouts, W. and D. R. Nelson. 1999. Copeia. No. 2.

Slager, C. J. 1999. Amazing sharks. Ripley Entertainment.

Taylor, L. (ed.). 1997. Sharks and rays. Time-Life Books.

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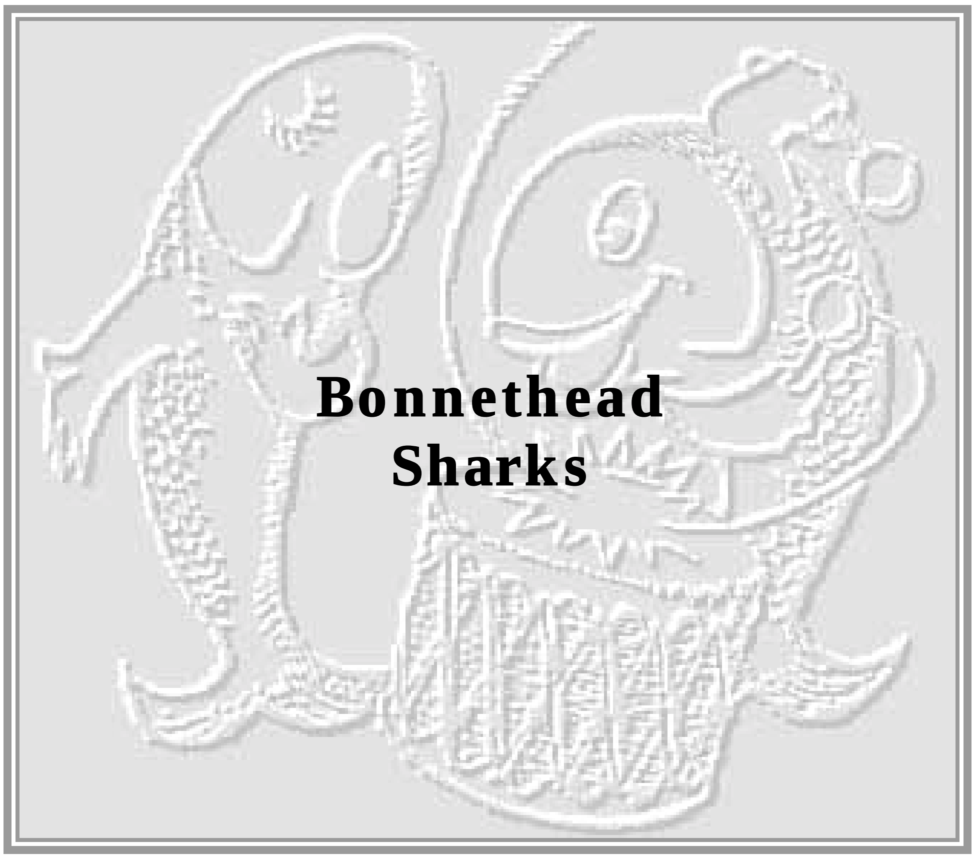

Bonnethead Sharks

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BONNETHEAD SHARK (*Sphyrna tiburo*) IN CAPTIVITY

Gerrit Klay
The Cleveland Aquarium

Drum and Croaker 69(1): 1-5. January 1969

The author has been experimenting with the collecting, shipping and maintaining of sharks of a number of species for several years. Since joining the staff of The Cleveland Aquarium, he shipped in 1967 and 1968 two specimens of *Sphyrna tiburo* to the Aquarium from the Gulf Coast of Florida. These are held in artificial sea water. Following are his observations, opinions and suggestions pertaining to captive bonnethead sharks.

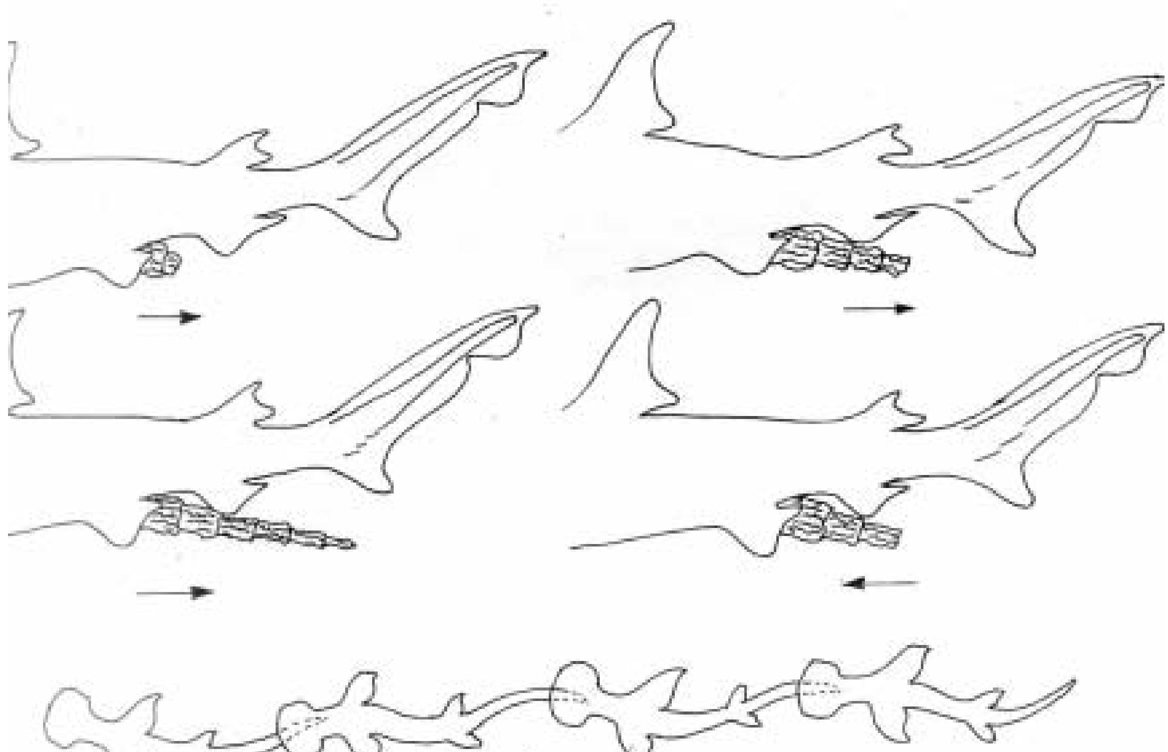
A newly obtained bonnethead shark should be handled with extreme care. A pH difference between shipping container and tank is almost sure to throw the animal into shock. A round plastic swimming pool about nine feet in diameter will accommodate an adult bonnethead. When first introduced in the pool, some will swim from the start and others will rest on the bottom for a short while. I have found "walking" the shark will put it in worse condition. When the shark is allowed to rest undisturbed on the bottom, it usually starts swimming by itself before long. After a couple of days in the pool, it can be released on display if in good condition. (Continued resting on the bottom of the pool indicates poor condition.)

Light intensities should be reduced, as bonnetheads are very nervous and prone to light shock. After being conditioned to its artificial environment, however, this species becomes relatively tolerant. A bonnethead will adjust very nicely to captivity if handled properly when collected and shipped. I never used anesthetics of any kind except during my preliminary experiments. For some reason unknown to me, the sharks collected and shipped with drugs seem to be retarded compared to the ones on which drugs were not used.

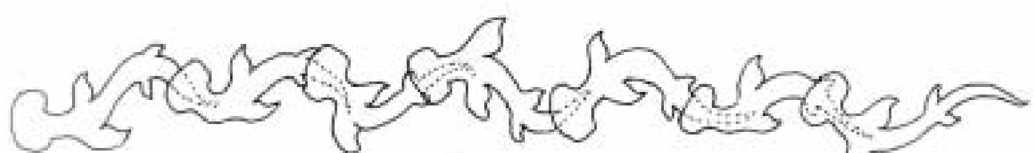
The body color of the bonnethead shark changes frequently, depending on its mood, from light gray to almost dusky brown. Color changes occur on smaller individuals more frequently than in the larger specimens. There are small black spots on the sides which differ in size and number in each individual.

Our larger bonnethead (36") seems to be vicious in its habits. It killed a 24" cow-nose ray and damaged a few other fishes which were in its tank. It also attacked a friend of mine and me while we were guiding a bull shark. I was bitten on one, toe and bled copiously. My friend was attacked four times. He was bitten in the underarm, once on the neck and once on his face plate. Luckily, he was wearing a wet-suit jacket, which was shredded at the points of attack, but through which the shark's teeth did not penetrate.

About once a month, for each of our bonnetheads, I have observed what was at first an alarming habit. What appears to be the gut is extruded, inside-out, from the anus, and extends back as far as the lower caudal lobe. During a period of from four to five seconds, the shark's body vibrates and the normal swimming undulations (fig. A) become exaggerated (fig. B). During this interval of snake-like swimming and vibration, small particles are seen to fly off the gut lobes, after which time the gut is retracted, and normal swimming resumes.



A



B

The Cleveland Aquarium's two bonnetheads measure 36" and 24". These sharks currently share a hexagonal tank (6,500 gallons) with one three-foot lemon shark and a nurse shark of similar length. There are also two smaller groupers in this tank. The nurse shark rests on the bottom most of the time. The lemon shark habitually uses the bottom half of the tank. The smaller bonnethead occupies the bottom 2/3, while the larger uses the top 1/3. Only during feeding do they ordinarily intrude in each others territory. When undisturbed, they swim in large circles, sometimes at high speed, close to the walls, changing direction rarely, except when startled by visitors.

The larger of the two bonnetheads will, when panicked, "hydroplane" near the surface with all of its head out of the water, yet still avoiding the walls.

For the first two or three weeks after being in captivity, bonnetheads may refuse food. Eventually they will almost invariably show interest and then begin feeding voluntarily. After the shark eats its first piece of cut shrimp or smelt it can be expected to eat readily. Much individual variation is to be seen among bonnetheads in this aspect. Whole smelt which float will often be bumped first, and eaten on the second pass. Smaller pieces will generally be swallowed without hesitation before reaching the bottom. When a large amount of food is dropped into the tank the shark will follow the smelt down, swimming in circles and swallowing a piece at a time. Once a week we add a multiple vitamin capsule to the cut fish. A small amount of shrimp is fed as a supplement to the smelt. Live goldfish have been offered, but never taken by the bonnetheads.

One of the most common injuries results from bumping the snout on the tank wall as a result of pounding on the glass by visitors. These injuries will usually heal in a relatively short time. Bad bruises show up on rare occasions--with our sharks only once. Treatment: Leave the shark where it is. If it still eats, add Vitamin C (100 mg. tablets) to its daily food to help the blood clot. The bruise should close up within two weeks.

Severe bruises are first noticeable when the underside of the bonnethead turns red, after which part of the bonnet starts deteriorating and the bare cartilage shows. For this we use the same addition of Vitamin C in the daily food.

Perhaps as a result of a common trace element difficiency and the lack of iodine in some artificial sea waters some sharks develop a goiter under the jaw which will grow and sometimes develop into a bloody ulcer. Iodine is added to the food or placed in the water as part of a trace element supplement which we add to the water once a month. So far, our bonnetheads apparently have a normal thyroid glands.

It has been my experience that bonnethead sharks kept in copper-treated water do not long survive.

SWIMMING BEHAVIOR OF THE BONNETHEAD (*Sphyrna tiburo*) IN SHALLOW WATER

Gerrit Klay

Shark-Quarium Experimental Station, Marathon, Florida 33050

Drum and Croaker 11(2), aka 70(2): 23-26. May 1970

In a previous issue of DRUM AND CROAKER (1969, #1), we communicated some observations on the maintenance and behavior patterns of Bonnethead sharks, *Sphyrna tiburo*, in the Cleveland Aquarium. Since that time Bonnethead sharks shipped by the author have been successfully maintained by major aquariums in New England, the Midwest, and the West Coast.

The present communication concerns itself with some data on the collection of Bonnethead sharks in various coastal locations bordering the Gulf of Mexico. Additional field Observations are described under various conditions of their natural habitat.

The accompanying map (Fig. 1) indicates locations along the Gulf of Mexico where Bonnethead sharks have been collected by the author. Clearly, the Bonnethead shark is common and widely distributed in coastal water. The Bonnethead has been observed at all times of the day. Its swimming pattern seems to depend on the tides and the depth of water in which they are found.

Of the locations indicated above, behavior observations could be carried out most satisfactorily on the Atlantic side of the Florida Keys in the region of Marathon (Vaca Key and Boot Key). Although sharks were frequently sighted and captured in all the indicated locations, the Atlantic side of Boot Key provided best field observations due to calmness and relative clarity even in the shallow water.

Two basic types of swimming patterns have been observed. The usual cruising pattern is customarily observed in relatively deeper waters (three feet and deeper) and consists of linear forward motion. The second and much more interesting swimming pattern is more frequently observed in much shallower water. This type of swimming usually occurs in areas of relatively sheltered flats with the bottom consisting of patches of mud, grass, and sand. This swimming pattern follows a weaving or zig-zag path. This occurs with sharks swimming either singly or in groups as large as half a dozen. Each animal's head also swings back and forth as it cruises a course two-foot laterally paralleling a sand bar or turtle grass ledge for a distance of several hundred feet. The dorsal fin frequently protrudes from the water and can be seen from some distance. The accompanying diagram (Fig. 2) depicts a typical swimming pattern by two sharks. The observer was standing at Point A where deviating loops probably represents the response of the sharks when first noting the observer. After deviating briefly from their original course, they resumed previous direction of travel. Periodically, the smooth weaving pattern is interrupted by episodes of frenzied activity. One or several animals swim in a circular or erratic pattern

Fig. 1. Areas (+) where author has observed and collected Bonnethead Sharks (*Sphyrna tiburo*).

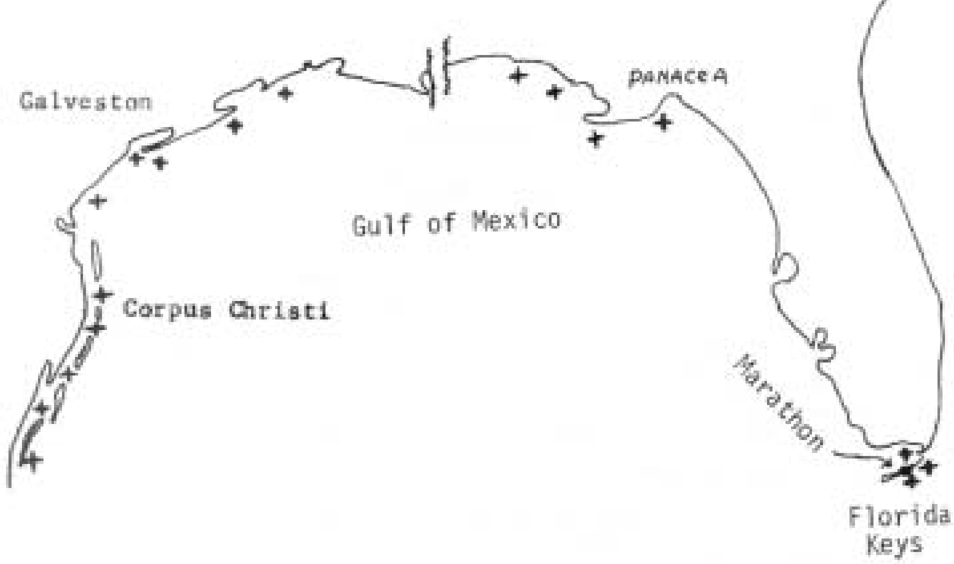
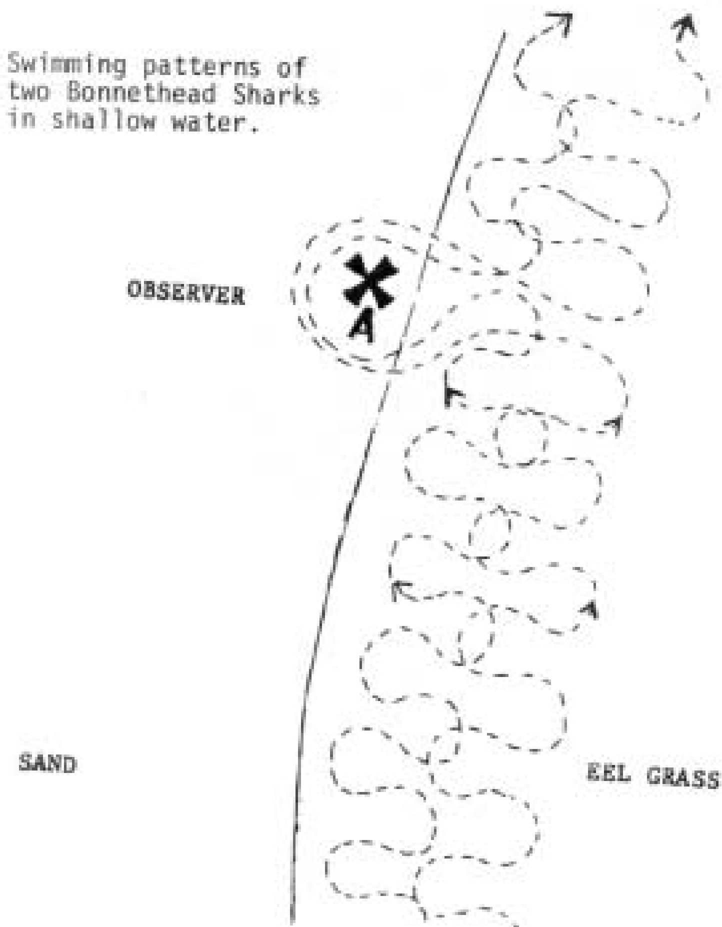


Fig. 2. Swimming patterns of two Bonnethead Sharks in shallow water.



occasionally splashing the surface as their caudal fins break the water. This frenzied activity is thought to represent an encounter with a blue crab or other crustacean. Upon examination of thirty specimens 80 percent contained fresh portunid crab remains. This type of pattern was usually observed at low tide when portunid crabs leave the emerging mangrove thickets and enter surrounding waters. It is assumed, therefore, that the weaving swimming pattern represents a search behavior pattern of Bonnethead sharks.

It is during this shallow water swimming that Bonnethead sharks are most accessible to capture by nets with least injury to the animal. A shark caught in this manner may be unharmed and vigorous if it is rapidly transported to an appropriate holding facility. The author has routinely maintained and air-shipped Bonnetheads in specially designed containers to public aquariums or research institutes. Bonnetheads lend themselves particularly well to aquarium displays, due to their moderate size, very striking appearance, as well as their resemblance to the other hammerhead sharks. It is a very active and constantly swimming shark. The Bonnethead shark is ideally suited for research purposes, particularly along the lines of behavioral studies and demonstrates complicated, "purposeful" and directed behavior oriented to its natural habitat in shallower waters. It, therefore, does well in captivity if appropriate preparations are taken.

Further studies along these lines are under way at the newly established Shark-Quarium Experimental Station using Bonnetheads, Bull Black Tips, and Lemon sharks.

EXPERIENCE IN BLUE
(SHARKS)

Louis Garibaldi, Acting Assistant Curator
Ronald Lloyd, Biological Technician

National Aquarium, Washington, D.C.

Drum and Croaker 12(1), aka 71(1): 3-5. January 1971

Returning from a collecting trip to the Florida Keys, Louis brought back two baby bonnethead sharks, *Sphyrna tiburo*. The two sharks were among eight born early on the morning of August 21 in a holding tank maintained by Gerrit Klay at Sharkquarium, Grassy Key, Florida,

All of the youngsters measured approximately 260 mm in length at birth and all appeared to be feeding well in Gerrit's open-system, 4 ft. deep portable swimming pool.

Upon arrival at the National Aquarium on September 2 the young sharks were measured again. One we shall call "A" measured 262 mm. The other, "B" measured 279 mm in length. It appeared that the smaller of the two sharks was thinner and possibly had not been eating.

One of the first steps taken by Ronald Lloyd, who was given care of the sharks, was to attempt to get the youngster to eat. Small strips of smelt, mackerel, squid, beef heart, and chunks of shrimp and clams were tried unsuccessfully. Appetite stimulant, amino-plex, was also tried with no success. Needless to say we were beginning to worry.

The two baby bonnetheads had been placed in a one-thousand gallons tank, approximately 6 ft. x 6 ft. x 4 ft. deep. The tank was one of eight fiberglass units of that dimension and a larger 2,500 gallon tank designed as marine aquariums and included in a recent renovating of the existing National Aquarium. The pigment of these tanks is an aqua-blue and they all have a six-inch inward recurve at the top to reduce splashing.

Upon initially being released into the 1,000 gallon tank both sharks began swimming at the surface near the edge of the tank with the head partially out of the water and the body sloping at approximately a 25° angle. However, there seemed to be no signs of distress. They were swimming strongly, but in swimming along the edge of the tank they were constantly bumping the sides of their heads against the wall. It appeared they were trying to turn into the wall. On occasion they would attempt to swim straight up the wall only to run into the overhanging lip.

The surface swimming was not a major concern since observations of this behavior had been made by Gerrit Klay. The wall bumping behavior did concern us. Toxic substances were ruled out by a series of tests. Placing one of the sharks ("A") into the 2,500 gallon tank yielded the same behavior and ruled out close confinement as the cause. The two sharks were again reunited in the 1,000 gallon tank. By this time (eight days after arrival) shark "B" had begun to take food with a preference for shrimp. On the tenth day shark "A" was found dead at the bottom of the tank. The only apparent cause of death was shock induced by a nutritional deficiency. It is possible that this animal had never eaten since birth.

Since we had solved the feeding problem for shark "B" we next tried to stop the head bumping. Several techniques were tried in order to keep the surviving shark from running along the walls. Artificial plants were hung along the walls and the light intensity was concentrated in the center of the tank so that the walls were darkened but with no positive results.

The next approach was that of color. Possibly the blue walls were attracting the shark. A panel of black plastic sheeting was hung in one of the corners and it was noticed that as the small bonnethead passed the black patch he moved away from the wall and then returned to the wall after passing that area.

This positive evidence led us to place a black strip of plastic under the lip and extending down six inches below the water level. Immediately the shark's swimming behavior was altered as he began swimming 3-4 inches away from the walls. Somehow the difference in color apparently elicited a change in behavior patterns.

Shark "B" continued to do well until on October 11 when he was accidentally killed when a small sawfish in the same aquarium pinned the bonnethead against the wall. He had grown to 290 mm in the 5 weeks we had kept him. We believe we could have kept him indefinitely had not the accident occurred.

The significance of aqua-blue or blue aquariums should warrant further investigation. Possibly the dogfish we have all seen in aquariums with worn down noses were trying to swim into blue walls. Possibly animals which frequent murky waters may mistake bluish walls for murky waters. The bonnethead had never known the open ocean, but only the inside of an algae-encrusted swimming pool before being placed in our blue tank. He appeared to instinctively avoid dark walls such as those of the pool and our black border, but to him blue was something to turn toward.

If anyone has had similar or conflicting experiences we would all appreciate hearing about it.

SHARK BIRTHS ON VIDEO TAPE

The Staff of Sea World Marine Science and Conservation Center

Drum and Croaker 22(1): 3-5. Summer 1989

The actual birth of a bonnethead shark *(Sphyrna tiburo) is* a rarely observed phenomenon. It usually occurs at night and individual births are widely spaced. At Sea World Marine Science and Conservation Center we consider ourselves doubly fortunate to have recently observed numerous bonnethead births, and at the same time to have video-taped them for later review.

The bonnethead shark is common on the grass flats and in the shallow bays near our facility at Long Key in the Florida Keys. Solitary adolescents and adults are often seen searching for food in 0.5-2.0 meter depths, and occasionally during the winter months congregations of as many as fifty adults are seen in small bays of 2-4 meter depth where no concentration of food is apparent.

Bonnetheads pup annually. The gestation period is approximately five months in the Florida Bay area, and litter size is usually eight to ten pups. Pupping usually occurs at night during the first half of August. Infertile eggs are exceptional in Florida Bay but are not uncommon in some geographic areas. The sex ratio is 1:1. The pups average 25 cm total length (TL) at birth and 60 cm TL after one year. They reach sexual maturity at two to three years of age and attain a maximum TL of approximately 100 cm; though runts are not uncommon in the captive situation.

The stomach contents of free ranging bonnetheads reveal a diet of cephalopods and crustaceans with a healthy percentage of seagrasses. (We are not certain if grasses are ingested incidental to feeding or whether they constitute part of the diet).

Each July gravid females are collected so the pups will be available for display and research. Bonnetheads have difficulty coping with the stress of capture during higher summer water temperatures (+30°C) however, we minimize stress with speedy capture methods and immediate transport to the facility's 500,000 gallon system of outdoor interconnected pools. Freshly captured females exhibit a non-feeding behavior for several days but no signs of long term stress are seen.

1985 was a typical year for our husbandry efforts. Water temperatures in the Bay and our facility fluctuated near 30 °C. Ten gravid females had been collected in late July and by the 16th of August eight females had produced approximately sixty pups. At 1:30 p.m. on the l6th it was noted that one of the females was slightly more active than the other. The difference was quite subtle but closer observation revealed an umbilical cord trailing from the birth canal of the more active female and an obviously newborn pup was found in the pupping area.

Thirty minutes after this discovery the tip of a caudal fin could be seen at the birth canal of this female. At 2:30 p.m. the female was transferred by net to a nearby 15,000 gallon observation tank and at that time two half exposed caudals could be clearly seen at the birth canal. By 3:00 p.m. the entire caudal fins were exposed, and it was observed that while one fin was right side up, the other was upside down. At 3:30 p.m. during a two-minute lapse in observation, two pups were born and a clear, lightly tinted, tube-shaped tissue (the remnants of the egg case) had been expelled. More umbilical cords could be seen trailing from the birth canal.

By 3:45 p.m. another caudal fin was half exposed. By 4:15 p.m. this caudal fin was entirely exposed. Nothing unusual occurred for the next hour and fifteen minutes except that the caudal appeared to make occasional independent motions.

During her entire stay in the observation tank the female swam easily back and forth between the end walls, swimming up at each end to near surface then turning and swimming near the bottom to the other wall. Because of the long time interval between births we assume the pups are scattered widely during the normal pupping process. (We have ever observed a concentration of pups in the wild).

This relaxed swimming continued until approximately 5:30 p.m. when a few moments of agitated swimming were followed by very agitated, erratic swimming, and the immediate birth of a fourth pup. Actual pupping occurred in a matter of 2 to 3 seconds. Pupping was followed in a few minutes by the half emergence of two more caudals; again, one was upside down.

By 6:20 p.m. these two caudal fins were nearly completely exposed when normal swimming was again interrupted by a few moments of agitated swimming followed by very rapid movement and a fifth pup. Within two minutes a sixth pup was born, again after the same unusual swimming. Immediately after the sixth birth two more caudals were partly exposed and within the next ten to fifteen minutes the last three pups were born. Video tapes reveal that at least one pup was upside down at the moment of birth.

At least two of the egg case remnants remained in the water column after pupping. They were probably not expelled at the moment of birth but the exact timing could not be ascertained. The placenta and umbilical cords were expelled intact overnight.

The pups were born with very light grey dorsal coloration except for the head area which was pinkish-grey and slightly translucent. Ventral areas were nearly white. At birth the dorsal fin was flaccid and curved backwards approximately one half its height. Within 24 hours it had attained its normal height and stabilizing action. The pectoral fins were immediately used for guidance. The head appeared laterally curved upward at the edges at birth, but within a day it became quite flat. The head became opaque after about a week. At birth swimming was coordinated but the pups appeared disoriented and swimming occasionally stopped. Within an hour after birth swimming was more routine and was not interrupted, however some initial swimming was done at the surface with a large portion of the head exposed. In previous seasons a few of the pups continued this activity sporadically for several weeks.

This litter was typical of years past. The pups show no feeding interest for the first two or three days of life. They swim constantly, as do the adults, and are easily frightened by underwater noises and by any encounter with an object. They are quite responsive to sounds but do not appear visually stimulated unless the object is very close. When feeding begins it appears to be more stimulated by olfaction than vision. In our captive situation the feeding efforts of one pup apparently stimulates the others and all begin swimming vigorously searching for food. Newborns exposed to direct sunlight begin tanning and take on a charcoal gray dorsal coloration with a light ring around the eye. This tan is temporary and does not occur under artificial light.

Bonnethead husbandry has proven to be uncomplicated. A few losses occur from premature births induced by capture, and with predation and the other usual problems associated with a captive environment; about a 10% mortality is experienced during the first year. Unexplained losses are rare.

Filtered Bay water is pumped through our system of ponds during the warm water months (April-December) and is recirculated and heated to 20°C during the winter, but an entirely closed aquarium system has proven adequate for bonnethead maintenance. We feed both pups and adults squid, capelin and shrimp once a day to satiation.

Density does not appear to be a problem. We routinely maintain as many as 100 pups in a pool 10m x 4m x 1m. We have maintained four pups in a 2m diameter circular tank for three months with no signs of stress. In fact, on one occasion a visiting researcher accidentally left ten pups overnight in a 3m x 1m x 0.5m enclosure at the facility. When found, the pups appeared no worse off for the experience. Light colored tanks walls should be avoided as they are poorly perceived by bonnetheads.

Although parasites are a major problem with many sharks we have seen no parasitic infestations of bonnetheads in, or out of captivity.

As display animals bonnetheads are a compact version of the hammerhead. They are active and hearty. As research animals they are plentiful, ship well, are easy to maintain, and can be observed from birth to maturity.

We would like to thank Glenn R. Parsons of the University of South Florida whose study of the bonnethead shark has provided much of the data included here.

BONNETHEAD SHARKS BORN AT SEA WORLD

Daniel LeBlanc, Director, Public Relations

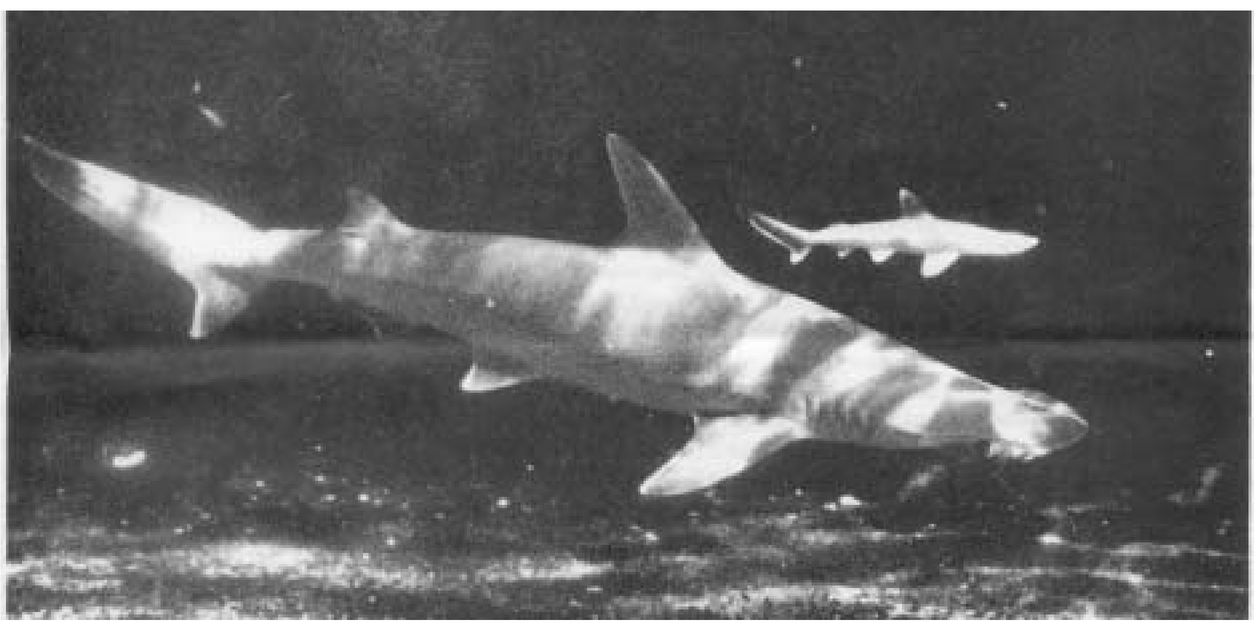
Sea World of California

Drum and Croaker 22(3): 8-9. Winter 1989

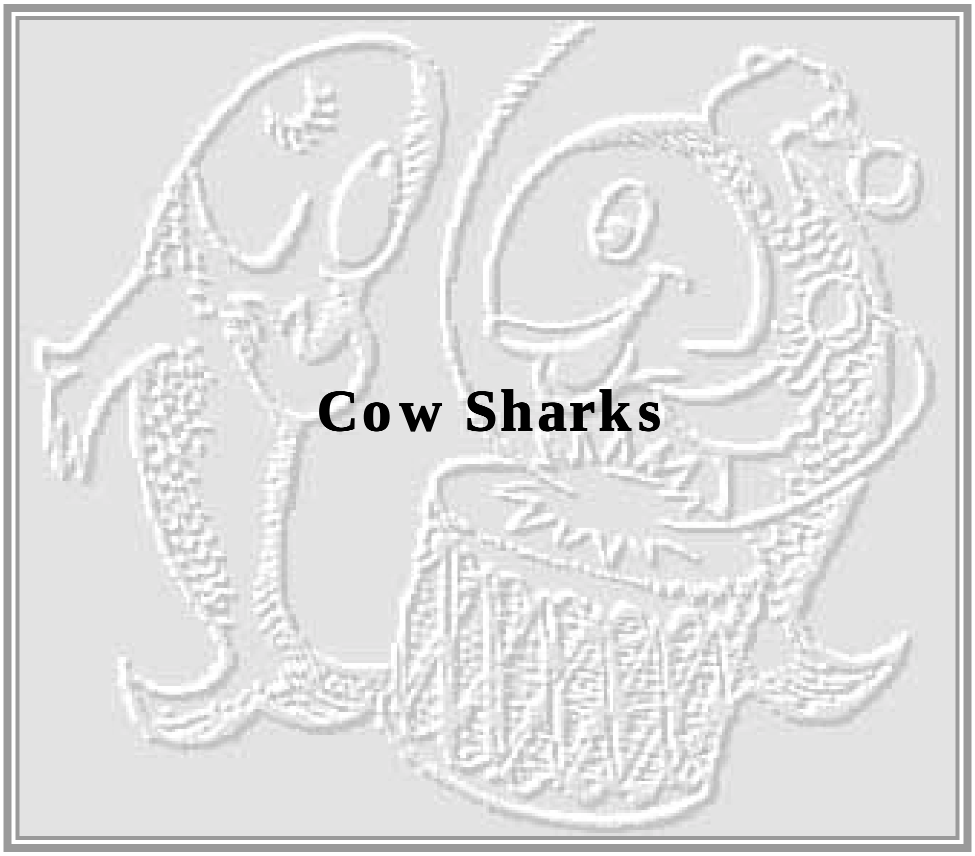
Twenty (20) bonnethead shark pups (*Sphyrna tiburo*) were born at the Shark Exhibit at Sea World of California on 24 October 1989. The pups were born to a female bonnethead who also gave birth to 16 pups in 1987 and to 20 pups in 1988.

As of 6 November 1989, 16 of the pups remain alive and in good condition. Their initial food of preference was krill *(Euphausia superba),* and they are now starting to eat other foods including pieces of shrimp and fish.

Bonnethead sharks are the smallest of the nine species of hammerheads. They inhabit inshore coastal waters, bays and estuaries. They range from San Diego to Peru on the West Coast and from New England to Brazil on the East Coast. Bonnethead sharks are live bearers (rather than egg layers). Pups are born in late summer and early fall. There are usually 4 - 20 pups in each litter. Adults may reach 5 feet in length. Pups measure from 8 to 12 inches. For further information. contact: Mike Shaw, Curator of Fishes, Sea World of California, 1720 South Shores Road, San Diego, California 92109 (619) 222-6363, ext. 2412



BONNETHEAD BIRTHS ... Sea World of California's Shark Exhibit has several new inhabitants. On Tuesday, October 24, 1989, twenty bonnethead sharks were born at the marine life park. The eight-inch long pups are the offspring of a female bonnethead shark who has given birth for three consecutive years. The pups, pictured next to the adult bonnetheads, could each as much as five feet in length.



Cow Sharks

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EXPERIENCES WITH SIXGILL SHARKS (*Hexanchus corinum*) AT THE SEATTLE MARINE AQUARIUM

Eric Friese, Curator

Drum and Croaker 65(1): 17-19. March 1965

Being faced with the problem of what to display in an empty 75,000 gallon outside marine mammal pool and the approach of the busy tourist season, an immediate solution had become imperative. Initially this pool was planned for a display of local porpoises (Harbour or Dall Porpoises), or as an alternative an enlargement of our show facilities, but because of organizational difficulties and the acute lack of time neither one of the two planned projects could be realized. We decided, finally, to convert this pool (32 by 48 feet, 5 feet deep) into a shark pen.

Next we had to consider what species to collect, and what collecting method to apply. Since our opening we have had the common Pacific dogfish (Squalus suckleyi) on display, but now we needed something different and of course something considerably larger. Clemens and Wilby list about ten different shark species in FISHES OF THE PACIFIC COAST as being native to our waters. Yet, only the sixgill shark (Hexanchus corinum) has occasionally been caught in the lower Puget Sound area. Accurate catch records were not available, and general reports about this species had been very infrequent and their reliability doubtful. Only the Point Defiance Aquarium in Tacoma has made serious attempts in the past to collect and display H. corinum. With Cecil Brosseau and Don Goldsberry's advice we finally decided to go after the six-gill shark.

Precise data about the availability of this species in the waters around Seattle was also unobtainable. For some preliminary tests we selected Elliott Bay as the collecting location. This bay covers an area of approximately 4 1/2 to 5 square miles, and is surrounded to the east by downtown Seattle, to the south by West-Seattle and Duwamish Head and to the north by Magnolia with its Navy piers and facilities. The 5000 yard opening to the west leads into the main flow of Puget Sound, which extends north and south, parallel to the city of Seattle. The actual bay area measures about 7500 yards in its longest north to south extension, and about 4500 yards from the edge of Puget Sound to downtown Seattle. The depth does not exceed 73 fathoms, and normally averages about 30 to 50 fathoms.

There had been some doubtful and unconfirmed reports that H. corinum had been taken in Elliott Bay on some rare occasions, but again reliable a data was not available. Local fisheries experts, who were consulted, expressed considerable skepticism, mainly in view of the relatively shallow water (previously sixgill sharks had seldom been taken in less than 100 fathoms) and the high fresh-water inflow from the Duwamish River and the city and industry sewage.

Nevertheless, we went ahead with our project and laid our first set line (1/4 inch manila hemp rope, with 6 foot 1/8 inch steel cable leaders and 6 inch shark hooks, spaced at about 12 to 15 foot intervals). To avoid the heavy commercial and recreational maritime traffic we selected a location about 500 yards into Elliott Bay north/east from Duwamish Head. The line was baited at night and checked the following morning. The first two mornings the bait was partly taken (apparently by Squalus, since we caught two badly mutilated ones), but no sixgill sharks. The third night we also laid an additional line right off Pier 56, in other words right in our "back yard". The following morning, May 21, success was ours. The line off Duwamish Head produced a shark, 8 feet 9 inches long and about 350 lbs. Since this was the first time that such a large shark had been caught publicly in Seattle, this event was given considerable coverage in all local news media. Thousands of people showed up to see this "giant shark", and most of these people just simply could not believe that such large sharks existed right here in Seattle. With all the excitement of our first shark we did net get a chance to check our second line. This was done the following day, but the line appeared to be snagged at the bottom. Two skindivers went down to salvage the line, but much to our surprise two more sharks were hooked on this line and neatly wrapped around an underwater telephone cable. Upon surfacing, these two specimens measured 9 feet 4 inches and 10 feet 4 inches, with an exact weight (we used a large industrial scale) of 400 lbs. and 540 lbs. respectively. Two sharks caught just 500 feet away from Route 99, the largest and busiest interstate highway in the State of Washington!!

Unfortunately, neither one of those three specimens lived any length of time. We have a rectangular pool, with a wire fence partition on one side. The sharks used to get washed up against this fence or into a corner of the pool by the current of the incoming water, and they were unable to free themselves. An occasional push from our attendants used to get them swimming again for a little while until they hit another obstruction and were stranded again. Finally, after 6 or 7 days all three sharks were dead. Autopsies performed immediately upon death did not reveal anything. None of the vital organs or body tissue was ruptured, torn or otherwise forcefully dislocated, thus leaving no clues for the possible cause of these fatalities.

The handling of these sixgill sharks was done with the utmost diligence and attention. The time these sharks were actually out of water was kept to an absolute minimum, never exceeding 10 to 15 minutes. Immediately upon surfacing, these sharks were guided into a specially designed sling, and in this sling they were carried right into the pool. If unwilling or unable to swim, the well known shark walking method was applied until the sharks were able to swim under their own power.

To comply with the sudden, overwhelming demand from our local public to see sharks, we had to continue collecting sixgill sharks. However, the results were inevitably the same. The sharks would always die within a few days. Thirteen sharks of various sizes have been caught so far. This may seem a rather insignificantly mall number, but we are neither equipped nor prepared to handle mom than one or two of these sharks at one time. All handling, including the transfer into and out of the pool has to be done exclusively by muscle power and elbow grease! In fact, the last sixgill shark caught- the 750 pounder - was almost beyond our physical capabilities. The set lines were purposely kept down to no more than about ten hooks. But even with this gear limitation, a line was occasionally lost, presumably -and often with strong evidence - that one or more sharks were already hooked.

This may have possibly lead to an interesting occurrence. The last shark off Duwamish Head was caught on 3 July. About a week prior to this date, two set lines were lost in that general area. After this date fishing was continued until early August, but no more sharks were caught there. Also, coinciding with this above occurrence is another interesting event. Because of some organizational problems we had to dispose of a couple of dead sharks right off Pier 56. We followed the example set by the many fish canneries along the Seattle waterfront, and dumped the carcasses back into the bay. The waste from the canneries - even though It increases the already bad pollution problem - provides excellent hook and line fishing for a number of different species of fish in this general area. However, since we disposed of the dead sharks we have not been able to get any more of these sixgill sharks in this vicinity until this very day (3rd week in August).

Grantedly, the evidence presented is far from being conclusive, nevertheless, it strongly resembles the various instances quoted by Dr. Perry Gilbert in his book SHARKS AND SURVIVAL. Dr. Gilbert lists a number of occurrences, reported by reliable sources, where either shark lines with a number of sharks on them were lost, or dead sharks left on the beach for the tides to wash away, have completely "burned out" the fishing grounds. It may sound unbelievable that the decomposition of shark flesh might act as a repellent, but the evidence seems to speak for itself. At the same time, however, Squalus fishing continued to be productive at its all time high!

Realizing our failure, we have currently discontinued our efforts to collect and display Hexanchus corinum, until we can come up with a solution that promises to be more successful. One of the deteriorating factors in our shark maintenance procedures may have been the extremely shallow water, thus exposing these essentially deep water fish to the bright sunlight. Another possible factor may have been the use of a rectangular tank, which seemed to offer too many obstructions to the swimming pattern of this shark. The Point Defiance Aquarium, for instance, has kept this species for several weeks, but there a large circular indoor pool is utilized.

Obviously we have not succeeded in solving a scientific mystery, yet our success in collecting this species so "close to home" has certainly stirred up the undivided interest of some local fisheries experts, and work on this shark may shortly be continued on a larger basis, at which time we will also resume our efforts. In the meantime, however, I would like to appeal to my learned readers and other skilled and experienced shark experts for any and all constructive advice available. All hints and possible "secrets" will be gratefully accepted.

THE IMOBILISATION OF SPOTTED SEVENGILL SHARKS (*Notorynchus Cepedianus*) TO FACILITATE TRANSPORT

L. Vogelnest, D.S. Spielman and H.K. Ralph

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Drum and Croaker 25: 5-6. January 1994

The capture, sedation and immobilisation of elasmobranchs (sharks) for transport to, from or between aquariums is difficult and complicated. In order to minimise stress and trauma to the animal and personnel, detailed attention has to be paid to immobilisation, capture and transport technique (Smith 1992).

In order to sedate or immobilise elasmobranchs drugs would have to be administered orally or intramuscularly. Other routes such as immersion or intraperitoneal are generally impractical. There is limited information on the efficacy of orally and intramuscularly administered drugs in elasmobranchs (Harvey et al 1988; Smith 1992; Stoskopf 1992). Immobilising drugs that have been used include alphadolone/alphaxalone, tiletamine/zolazepam, ketamine and ketamine/xylazine.

A number of techniques have been used to inject elasmobranchs. These include hand injection, pole syringe and the use of a laser aimed underwater dart gun (Harvey et al 1988). The ideal area to inject intramuscularly is above the lateral line in a saddle region extending from behind the gill slits to the anterior aspect of the second dorsal fin. This area is heavily muscled and is free of vital structures (Stoskopf 1992).

A number of anaesthetic dose rates for elasmobranchs have been quoted in the literature. A dose of 0.3-0.5 ml/kg of alphadolone/alphaxalone has been used (Harvey et al 1988). For ketamine doses of 12-20 mg/kg have been used (Stoskopf 1992) and for ketamine/xylazine 12-15 mg/kg plus 6 mg/kg respectively (Stoskopf 1992; Smith 1992). Some concern has been expressed over the use of xylazine in elasmobranchs because of its cardiovascular effects and certainly should be avoided in teleosts (T. Williams personal communication).

This article reports the attempted immobilisation of two male spotted sevengill sharks (*Notorynchus cepedianus*) held in an aquarium. They were to be removed from a very large, mixed tank, transported and released back into the ocean. Sevengill sharks are a pelagic species belonging to the order Hexanthiformes. They differ from most other sharks in that they have seven gill slits (most have five) and a single dorsal fin (there is no anterior fin). There is nothing published in the readily available literature on the immobilisation of sevengill sharks.

It was estimated that the two individuals weighed between 30-35 kg. Lyophilised ketamine was reconstituted to 200 mg/ml and 500 mg administered, by hand injection, to each animal. The success of delivery appeared to be complete. There was little effect after 45 minutes. A further 400 mg ketamine plus 180 mg Xylazine was then given. There was no further effect one hour after the second injection.

Recommended dose rates for ketamine in reptiles are 55-88 mg/kg (Bennett 1991) and for amphibians, 50-100 mg/kg (Crawshaw 1989). In the light of this it was considered more appropriate to use a higher dose rate in these sharks. Williams (personal communication) suggested 66-88 mg/kg ketamine in elasmobranchs.

Three days after the first attempt, one of the sharks was killed by a Grey nurse shark (*Carcharias taurus*). It is unlikely that he was affected by the procedure or drugs, although this cannot be ruled out. He weighed 27 kg and was 2.1 metres long.

For the second attempt ketamine was used at 80 mg/kg. Lyophilised ketamine was reconstituted to 270 mg/ml and 2470 mg was administered in a 10 ml Telinject dart with a 2 inch barbed needle, stabbed into the animal by a diver. Delivery was complete and the dart remained in the animal.

An initial effect was noticed after 5 minutes when the shark started bumping into objects. Within the next 45 minutes the shark's swimming slowed and he became less responsive to being touched. After 60 minutes there was no further effect and the shark was easily caught in a net, brought to the surface and transferred to a sling. It weighed 29 kg and was 2.2 m long. The shark struggled slightly but not to a degree that would cause physical stress. It was then transferred to a holding tank with oxygen supersaturated water for transport. It was transported in this tank for one hour, then released back into the ocean. He swam off showing no sign of sedation. This higher dose was only just adequate for capture and transport.

The wide variety of elasmobranchs and their differing metabolism and sensitivity to immobilising agents makes prediction of the effects of drugs difficult, particularly when dealing with less common and primitive species.

Acknowledgments

The authors would like to thank the staff of Sydney Aquarium, Darling Harbour for their assistance.

References

BENNETT, R.A. (1991); A review of Anaesthesia. and Chemical Restraint in Reptiles, Journal of Zoo and Wildlife Medicine 22, 282-303.

CRAWSHAW, G.J. (1989); Medical Care of Amphibians. Proceedings of the American Association of Zoo Veterinarians 155 pp.

HARVEY, B., DENNY, C., KAISER, J. & YOUNG, J. (1988); Remote intramuscular injection of immobilising drugs into fish using a laser-aimed underwater dartgun. Veterinary Record 122, 174-177.

SMITH, M.F.L. (1992); Capture and Transportation of Elasmobranchs, with Emphasis on the Grey Nurse Shark. Australian Journal of Marine and Freshwater Research 43, 325-343.

STOSKOPF, M.K. (1992); Shark Pharmacology and Toxicology. Fish Medicine. (Saunders: Philadelphia) 809 pp.

Atlantic Nurse Sharks

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BABY NURSE SHARKS

Warren Zeiller,Curator of Fishes

Miami Seaquarium

Drum and Croaker 68(2): 29-31. May 1968

The diver working in the Main Seaquarium tank paid little attention to the seven-foot nurse shark as it swam slowly by. The shark had been caught the day before in 35 feet of water south of Biscayne Bay, Miami, Florida. She was a fine, fat, and healthy specimen which seemed to be quite at home in this half-million-gallon artificial environment.

A small brown sphere covered with tiny black dots caught the diver's eye as it ejected from the shark with amazing force. It tumbled over and over for several feet and then, much to his surprise, a newborn baby untangled itself and swam slowly to the bottom; a miniature polka-dotted image of its mother. By the end of the day, an additional three had been born.

During the next four days the number of births increased to a total of seventeen. The nine female and eight male babies ranged in size from 9 1/2 inches to 11 3/8 inches. Some still had a small external yolk sac, possibly indicating that they were premature. A week later a second birth sequence took place in the same tank. This nurse shark had been caught on the same day and in the same locale as the other. The twenty-two babies born of this female were all about twelve inches in length, probably full-term. All the young were removed from the large tank and placed in one of the 500-gallon display aquaria where they are viewed by the public.

Nurse sharks (Ginglymostoma cirratum) are ovoviviparous; their eggs resemble large skate eggs (often referred to as the Mermaid's Purse), but are retained within the body of the female until the young are hatched, expelled, and swim away. The divers searched the main tank daily for several weeks for remnants of the leathery keratin egg cases, but none were found. Perhaps they had been reabsorbed by the parent.

The small, nearly harmless baby nurse sharks do not enjoy parental care. Apparently, such protection for them is unnecessary for survival. Often, during the course of many dives in Florida waters, I have been surprised to find a juvenile nurse shark living in harmony with a green moray. The young shark could be taken only after the moray had been driven away from its niche in the reef. This may be a case of commensalistic symbiosis, where the shark baby finds a ready-made, well-protected home in which to live until it is large enough to roam safely alone. I do not sea that the shark's presence in the moray's lair adds to the well-being of the latter. The newborn nurse shark is just “bite size” for the moray, why is it not eaten?

Emil Hanson, Captain of the Seaquarium collecting boat, has reflected similar phenomena. The Seaquarium Shark Channel contains numerous bull (Carcharhinus leucas) and lemon (Negaprion brevirostris) sharks, as well as nurses. Bulls and lemons born in the channel are consumed immediately by any larger than themselves. Even the parent may join the frenzied feast. Newborn nurse sharks are another story. Captain Hanson has observed this a number of times and has reported that at birth the nurse shark babies simply drop to the bottom of the channel, poke about, and are bypassed by the others as what night best be described as inedible fare. Why?

Captain William B. Cray, Seaquarium Director of Collections and Exhibits, vividly describes similar instances from his many years of observations. Specimens such as groupers measuring less than three feet are now displayed in other aquaria, but some years ago these were housed in the Main Seaquarium with morays, sharks, rays, sawfishes and the bottle-nosed dolphins. "I watched through the underwater viewing windows as the boat crew introduced a very heavy female nurse shark into the tank. She no sooner entered the water than she started dropping babies all over the place. I thought they would all be goners because the groupers were right there rolling their eyes at those little nurse sharks. They would swim right up to one and open their mouth as if to inhale the little fellow in one gulp--and stop! No sir, they did not take one! Those babies just found a rock or something under which to hide and everything went about its business as if nothing at all had happened. Even the dolphins, which generally will engage in rough play with or eat any small specimens, passed them by without a glance." Why?

Total lack of interest of larger species in the baby nurse sharks was observed again during the most recent births. Other fishes of equivalent size would have been fair game for the larger creatures. What is there about juvenile nurse sharks that seems to bestow upon them a high degree of immunity from predation? Individuals and corporations investigating shark repellents would do well to give thought to this enigma which may have bearing on man's ability to survive in what is still the hostile environment of the sea.

MORE ON BABY NURSE SHARKS

Warren Zeiller, Curator of Fishes

Miami Seaquarium

Drum and Croaker 69(3): 17. September 1969

The old aquarium favorite of the shark family is *Ginglymostoma cirratum*, the nurse shark. They are colorful, interesting, look "fearsome" enough to satisfy vicarious thrills sought by the public ... and, unlike other sharks, will survive years of captivity. They may even reward our efforts further by producing 15 or 30 offspring, each ejected live from its parent like a polka-dotted cannon-ball before the viewer's eye. I was fortunate to be able to describe two such birth sequences in the May 1968 issue of DRUM AND CROAKER.

Within the uterus, each embryo is encapsulated within a keratinous egg case. There are no umbilical attachments to the uterine wall; nurse sharks are ovoviviparous. Few have the opportunity to see, much less photograph, the living embryo within its leathery pouch. Two of 32 eggs were removed from a pregnant nurse shark and brought to Seaquarium August 3, 1969, by a local fisherman. The embryos were alive and wiggling in a manner identical to that of the roundel skates (*Raja texana*) whose sequential embryological development has been photographed in the past.* Outer layers of one egg case were peeled away with scalpel and tweezers to a point where nothing remained, but a frail, clear amber "window." Executed with care, the procedure is harmless and permits an unobstructed view of the fascinating activity within.

The two embryos in this case did not survive. Neither did those of *Raja texana* on first attempt, but from such frustrations, challenges are created which, with acquisition of additional eggs, I hope to report on in the future.

Photographs--Miami Seaquarium

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*Eggs Into Animal (Roundel Skate); Sterling Communications, Inc.;
309 W. Jackson Boulevard, Chicago, Illinois 60606; Color, 12-minute film.

NURSE SHARK - 300 POUNDS OF HELL

Gerrit Klay

Shark-Quarium

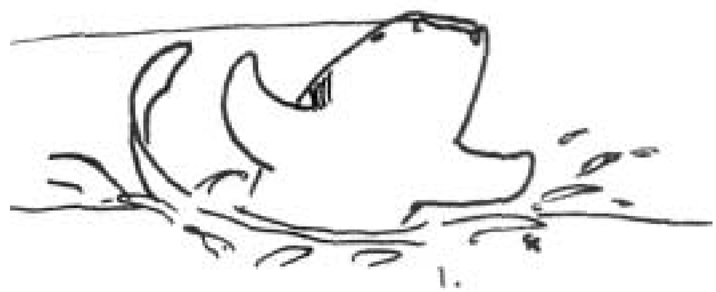
Drum and Croaker 13(2): 28-29. July 1972

It is known that the Nurse shark (c Cirratum) is a shark with a docile nature and is usually stacked on top of other sharks of same species, when you have more than two together.

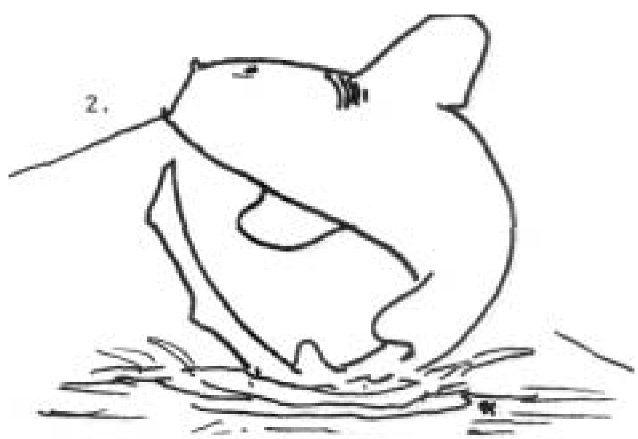
It is also known to be harmless and not at all a game fish for the angler. However, when one is hooked on a set line such as is used by Shark-Quarium which consists of 1 block, 30 ft. of nylon rope, 1 large float, 6 ft. of nylon, 1 small float, and 6-8 ft. of steel wire and a hook, total withstanding 2,000 pounds of pull, all hell breaks loose .... especially if the animal is over 8 ft., which is usually the case.

To describe what happens would take too long, but to the people who have seen it and even attempted to land "just a Nurse shark", memories of burning hands, slapping tails, and a small but ferocious mouth snapping at every possible object, will come back. And, for those who have handled one, a respect for the docile shark is quite likely.

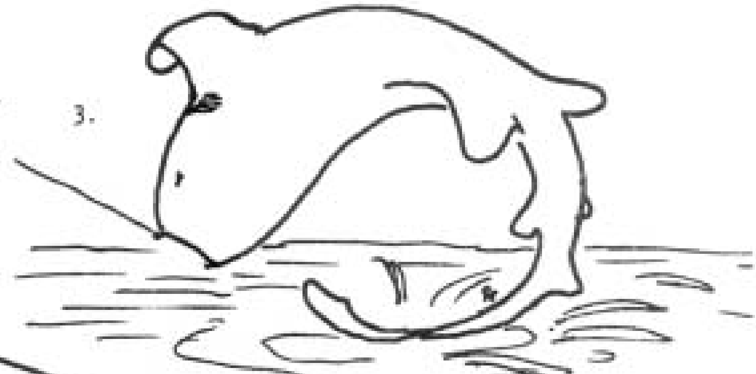
1. Approach Run Position - Usually causes the person holding the other end to let go. Burn marks are left on palms of hands.



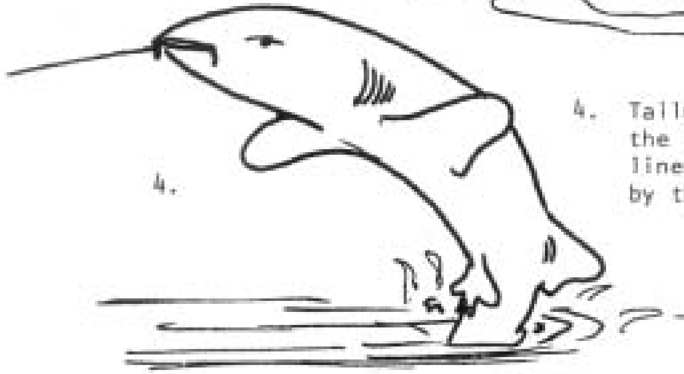
2. Back Flip Position - At the end of the maneuver a slam against the transom of the boat or the lower part of the person hauling in the line. This maneuver usually occurs within 6 ft. of the boat.



3. Forward Flip Position - This also occurs within 6 ft. of the boat with the terrifying result of beaching the boat and the unlucky catcher.



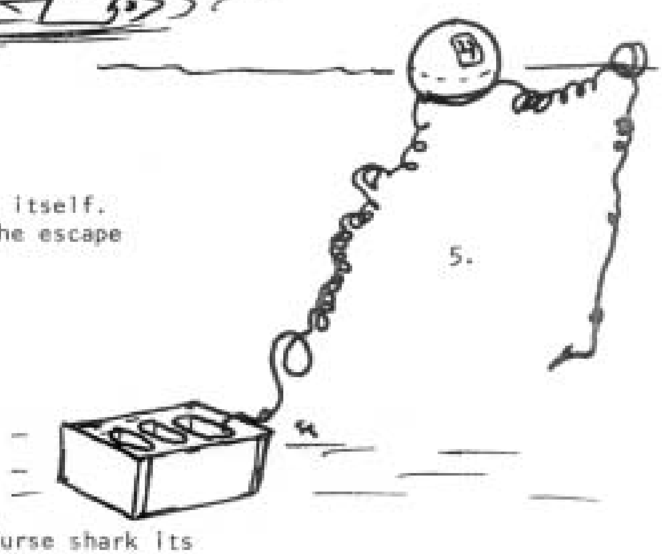
3.



4.

4. Tailwalk - This results in the catcher letting go of the lines and a successful escape by the shark.

5. This position speaks for itself. This could be known as the escape position.



5.

6. The most popular position - which gives the Nurse shark its reputation of laying around harmlessly.

6.

DEVELOPMENT OF THE BITE MANIPULANDUM FOR USE IN THE CONDITIONING OF THE NURSE SHARK (*Ginglymostoma cirratum*)
A behavioral paper presented to Naval National Science Awards Competition

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Drum and Croaker 23(1), aka 22(4):3-5. Summer 1990

Abstract

In the 1960's it was a common belief that sharks were extremely primitive creatures that operated on pure instinct. Therefore, it was thought sharks weren't capable of learned responses (Myberg, 1976). It was later found that shanks were capable of being "instrumentally conditioned" to perform simple associative actions (Ellis, 1976).

The purpose of this experiment was to modify the bite manipulandum designed by V. Strength, D. F. McCoy and L. Hull for use with the nurse shark (*Ginglymostoma cirratum*). The bite manipulandum was used in operant conditioning as a reliable response detection system.

The experiment included two phases. Phase I used light as a stimulus and Phase II used a stimulus of an electric field to condition the shark. The purpose of conducting two phases was to determine whether a stimulus of light or a stimulus of electric current would effectively condition the nurse shark and which was more effective.

The results gathered from Phase I and Phase II showed that the nurse shark was capable of responding to the device when a stimulus was presented. The data further proved that either light or an electric current could be used with the bite manipulandum, in the conditioning of the nurse shark.

Introduction

Over the past decades there has been, very little research done on the behavior of sharks held in captivity. In the 1960's, there was a belief that sharks were inferior to bony fish and higher vertebrates in the extent to which their behavior could be modified through the learning process. Recent work has shown that young nurse sharks and lemon sharks could be trained as easily as many mammals. These sharks retained their learned tasks for considerable periods of time (Myberg, 1976). This showed that sharks were capable of being "instrumentally conditioned," and of being trained to perform simple associative actions.

Misconceptions about the shark and its abilities exist. Two new findings will be addressed in this research.

One belief that has been disproved was the image of the shark as a "swimming: nose." It was believed that they did not have good vision and that sharks used their sense of smell as a guide for mobility. Over the past years there has been some research done on the vision of sharks. It's been determined that sharks are capable of differentiating colors and patterns (Ellis, 1976). The role of vision in the shark's life is virtually unknown, but visual adaptations are so sophisticated that the impression is given that vision must play and important role in their lives (U.S. Navy, 1975).

A discovery made in 1971 found that sharks can find their prey and orient themselves in the open sea by the detection of electric fields. The nurse shark is capable of responding to field of voltage as low as 100 millionths of a volt per centimeter with the use of their Ampullae of Lorenzini (Kalmijn, 1978).

This paper will deal with the development of the modified bite manipulandum for use with the nurse shark. The research had several purposes. The first was to prove that the modified bite manipulandum will give reliable response data and to determine whether a stimulus of light or a stimulus of electric current produces the best response. The second purpose was to show that the nurse shark is capable of being instrumentally conditioned.

The first step of the research involved the modification of the bite manipulandum designed by V. Strength, D. F. McCoy and L. Huff. The bite manipulandum was used in operant conditioning as a reliable response detection system and made it possible to obtain schedule of reinforcement data (Strength, 1981).

The next step was to actually train or condition the shark to come to the manipulandum and bite the nipple.

Methods and Materials

The shark used for this research was the nurse shark (*Ginglymostoma cirratum*).

A tank holding 300 gallons (1363.83 liters) of salt water housed the shark. A salt water mix of Marine Environment Dual Phase Formula was mixed with fresh water to achieve a salinity level of 24-28 parts per thousand needed for the survival of the nurse shark. The water temperature was maintained at 78° F (25.5° C). Water parameters were monitored at 0.6 ppm for ammonia, 8.0-8.5 for pH, 0.75 ppm for nitrite, and 100-200 ppm for nitrate.

Water quality was maintained by recirculation of the water through a wet/dry filter. Two light fixtures were placed on mechanical timers to give the shark 12 hours of light per day with no allowance for seasonal changes.

The bite manipulandum designed by Vernon Strength, D. F. McCoy, and Larry Hull was modified with use with the nurse shark.

The original manipulandum had a rubber lamb's nipple mounted on clear 0.24 in. (0.64 cm) plexiglass with silicone cement. Two holes were drilled in the plexiglass to allow rear access to the nipple chamber. One hole was for a flexible feeding tube (outside diameter 0.44 in. or 1.1 cm). The other hole was for an adaptor for the air tubing. The tip of the nipple was cut off', the cut end was inverted and stretched over the end of the feeding tube. The area of contact between the nipple and the feeding tube was sealed with silicone to achieve an airtight chamber. The inversion of the nipple allowed the end of the feeding tube to be recessed within the nipple so that the tip of the manipulandum was sensitive to compression.

One end of the air tubing fit over the adaptor and the other end passed through a hole drilled in a 0.5 in (1.27 cm) sheet of plexiglass until the tip of the tubing extended out the other side about 1 cm. A four inch 8 ohm acoustic speaker was bolted face down on another sheet of plesiglass and scaled. When mounted and sealed, the bite manipulandum and speaker form separate airtight chambers connected by air tubing. Compression of the nipple by a fish bite displaced the speaker membrane so that the speaker acted as a pressure transducer. The signal from the speaker was processed by a circuit (Strength, 1981).

To make the bite manipulandum suitable for use with the nurse shark, several modifications had to be made.

The first modification was the mounting of a rubber cow's nipple onto a 0.38 in (0.97 cm) plexiglass box. The second modification was to increase the size of air tubing. This allowed an increase in the air volume sent to the speaker. A piece of regular air tubing was connected by silicone cement to a 0.75 *(2004 editor's note: should this be 7.5?)* in (19.91 cm) piece of tubing. Because of the increase in air volume an electronic amplifier was not needed to register the signal to the speaker. A 4 in 8 ohm speaker was placed in an airtight chamber to keep air from seeping through the speaker chamber. To register each signal from the speaker, a DC Milliampere Voltmeter was used. For use with Phase I, a stimulus projection area was placed about the cow nipple. Behind this area, a flashlight used as the light source for the stimuli was placed. The flashlight was connected to two D Duracell batteries. A plexiglass control panel located beside the speaker contained the voltmeter, light switch, and battery pack. The last modification was made before Phase II with the addition of an electric current switch connected to the Duracell batteries. The switch generated the flow of electric current through bell wire, covered with plastic, to be turned off and on. The bell wire was wound around the tip of the nipple.

The next step of the research was to train the nurse shark to bite the nipple on the bite manipulandum. The techniques used in the conditioning of the shark were shaping and chaining. Shaping refers to the process of developing sequence. Chaining is the process of connecting each learned act with reinforcement. Positive reinforcement was given after each successful trial. Reinforcement is a means of strengthening a tendency to perform a certain action. Primary reinforcement is something of first and greatest importance; is absolutely necessary for survival such as food or water. This kind of reinforcement creates the strongest incentive to learn. Food was used as the reinforcement in the research. A continuous schedule of reinforcement is the giving of reinforcement each time a desired behavior occurs. Partial reinforcement is not giving reinforcement continuously (McMahan, 1990).

Two phases were completed in this research with multiple trials in each. Each trial had a set time for the test.

Phase 1. Phase one included Trials I, II, and III. A stimulus of light was used in Trial II and III.

Trial I was the first step of the chaining technique. To attract the shark and condition it to eating food out of the nipple on the bit manipulandum, a dummy nipple was used. Fifty tests were run in Trial I. Each test was terminated after 30 second or one response, whichever came first.

Trial II was the second step of the chaining technique. For this trial the bite manipulandum was placed in the water. Food was once again placed in the end of the nipple. As soon as food was placed in the end of the nipple the light was turned on. This stimulus signaled the availability of food. A voltmeter was used in this trial to register when the shark actually bit or blew into the nipple to receive the reinforcement. Seventy-five tests were conducted in Trial II. Each test was terminated after 1:00m minute or one response, whichever occurred first.

Trial III was the last step of the chaining technique. For this trial the bite manipulandum was once again placed in the water. This time only the scent of food was placed through the feeding tube. The scent was used to attract the shark to the manipulandum. For discrimination, as the scent of food was placed in the water, the light (stimulus) was turned on randomly to signal the availability of food. This allowed the data to be analyzed to determine if the shark learned that reinforcement would be given when the light was on. No reinforcement was given for a response that occurred when the fight was not on. To read and record each response of the shark, an oscilloscope was connected to the manipulandum. After each successful response, food was given as a primary positive reinforcement. One hundred and fifty tests were conducted for Trial III. Each test was terminated after 1:00 minute or one response. There was about a 30 second period between each test.

Phase II. This phase used a stimulus of an electric current on the tip of the nipple. The purpose of this phase was to determine how effective the electric current would be as a stimulus. The scent of food was placed in the water to attract the shark to the manipulandum. As the scent was placed into the water, the electric current was turned on. Food was given as positive reinforcement after each successful response. Each test was terminated after 1:00 minute or one response. One hundred and fifty test were conducted for Phase II. The oscilloscope was used to record each bite made by the shark.

Results and Discussion

Phase I . Overall, Phase I showed that the nurse shark (Ginglymostoma cirratum) was capable of being "instrumentally conditioned."

Trial 1. The data collected from Trial I showed that the nurse shark was able to learn that food would be given each time a bite to the bridge (dummy nipple) occurred. Out of the 50 tests conducted in Trial I only six tests were terminated before a response occurred. The six terminated tests happened within the first three days of tests. The first day the bridge was used to feed the nurse shark and the shark seemed leery of approaching the nipple. Almost all of the tests took between 20-30 seconds for a response to occur. By the last couple of days of testing, the shark had learned it would receive food if it bit the nipple. The tests also happened much quicker.

Overall, the shark bit the nipple 88% of the time during the five days of testing. This trial showed that the nurse shark was capable of learning to bite the nipple to receive food.

Trial II. The data from Trial II showed the nurse shark was capable of learning to bite the nipple on the bite manipulandum. Also, the tests showed that the shark was capable of biting the nipple hard enough to register a response on the voltmeter. The first day the bite manipulandum was placed in the water, the shark was very leery of the machine. Only four tests were successfully completed. The time of the shark's response was very slow. After the four successful tests, the shark continued to run into the manipulandum box for five minutes. Finally, the shark laid in the corner and ignored the machine. By the third day of tests, the shark was learning how to approach the nipple and receive, the food. Responses happened much quicker and the shark was starting to bite the nipple hard enough to make the bit register on the voltmeter. Out of 75 tests, only 13 had to be terminated without a response. Overall the shark bit the nipple and received reinforcement 83% of the time.

Trial III. The data from Trial III indicated the nurse shark had learned to bite the manipulation nipple when a stimulus of light was present. Early in Trial III, the shark nudged or bit the nipple when the light was not on. The stimulus of light was present and reinforcement given in 75 tests. The shark bit the nipple 100% of the time during the reinforced tests. Seventy-five non-reinforced tests were conducted. Out of these 75 tests, the shark reacted correctly 93.3% of the time by not biting the nipple. The shark bit the nipple only five times. All five non-reinforced bites occurred during the first three days of testing. A t-test was run comparing the reinforced and non-reinforced tests in Trial III. The statistics were significant to the.001 level. This trial showed that the nurse shark learned to bit the nipple when a stimulus of light was present and the nurse shark also showed progress in recognizing when reinforcement was available.

Phase II. The data collected from Phase II indicated that using an electric current as a stimulus was very effective. Out of the 150 tests conducted, 75 were non-reinforced tests. The shark bit the nipple only twice during the non-reinforced trials. During the reinforced trials the shark bit the nipple 100% of the time. A t-test was run comparing the reinforced and non-reinforced tests in Phase II. The data was significant to the.001 level.

Conclusion

The research completed in Phase I showed that the nurse shark (*Ginglymostoma cirratum*) could be "instrumentally conditioned" for a learned response. Also, the research showed that the modified bite manipulandum could be successfully used to train the nurse shark and obtain reliable response data.

Trial III in Phase I showed that the nurse shark had leaned to bite the manipulandum nipple to receive food. This trial also showed the nurse shark was making progress in determining when reinforcement was given.

Comparing testing completed in Trial III of Phase I with Phase II indicated that either a stimulus of light or an, electric current could be used effectively with the bite manipulandum in gaining reliable response data.

Further research will be conducted to determine whether variables such as hunger, smell, or location influence the sharks response and response time. Research will also be conducted to determine if there are any additional stimuli that would be effective in conditioning the nurse shark.

References

Cousteau, Jacques-Yves and Philippe Cousteau. 1970. The Shark - Splendid Savage of the Sea, A&W Publishers, New York N.Y.

Ellis, Richard. 1976. The Book of Sharks, Grosset & Dunlap, New York, N.Y.

Kalmijn, Adrianus and Kenneth Rose. 1978. The Shark's Sixth Sense, National History, Vol. 87:3, pp. 76-81.

McMahan, Frank B., J. McMahan, and T. Romano. 1990. Psychology and You, West Publishing Company, New York

Myrberg, Arthur A. 1976. Behavior of Sharks - A Continuing Enigma. pp. 510.

Strength, Vernon, D. P. McCoy, and Larry Hull. 1981. A Bite Manipulandum for the Development of Operant Behavior in Predacious Fishes. Behavior Reseach Methods & Instrumentation. Vol. 13(l). pp. 43-45.

U.S. Navy, Office of Naval Research. 1975. Shark Research: Present Status and Future Direction. Vol. ACR 208. PP. 11-14.

A LOG OF CAPTIVE BIRTHS BY AN ATLANTIC NURSE SHARK, "SARAH"

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Drum and Croaker 31: 22-23. February 2000

(Editors note: This contribution is in log form and the narrative begins on November 9, 1998 with a recap of prior observations.)

Sarah the nurse shark, an inhabitant of Animal Encounters, was discovered to be pregnant at the end of the month of September, 1998. [The Animal Encounters is a big lagoon where visitors can snorkel or dive with stingrays and reef fish. They can also feed lemon and nurse sharks that are separated by a fence and big Plexiglas windows with holes in it]. Sarah is approximately 7 ft in length with an estimated weight of 300 lbs(?). After she was moved to the isolation aquarium (Aquarium # 27) on October 1st it was observed that she was swimming in circles. Sarah was rubbing her belly on rocks and on the sandy bottom in the aquarium. At first she did not eat, most likely due to the stress of the movement because after a few days she got a strong appetite.

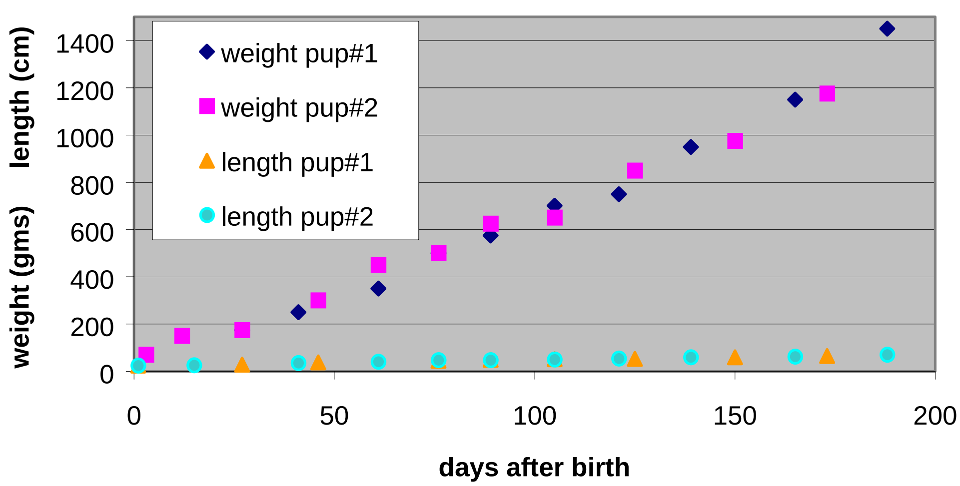
<u>Figures 1 & 2</u>: One of the newly born Nurse shark pups hold by Amy Messbauer (intern-marine biologist)(right), and a comparison of the first born pup and a newly born about one month (left).

At the 3rd of October the first egg cases appeared in the aquarium. Through the whole month of October Sarah dropped approximately 16-22 empty egg cases, she was fed everyday, and her appetite appeared normal. Observed behaviors: rubbing belly on rocks and sand, erratic swimming ("bending in half"), cloaca opening and closing.

The first pup was born two days after full moon, the 6th of November between 12.30 – 2.30 p.m.. It was a male, 24 cm. long and around 75 grams. Sarah had a very strong appetite and nobody was sure whether she would eat her pups or not (does anybody have more information on this?). We decided not to take any risks and the pup was moved to a different aquarium to observe. Since then two or three more egg cases were found. Sarah's appetite was good, she ate mostly squid and mackerel, occasionally she wouldn't eat for one day. She would alternate between resting on the bottom and swimming circles during the day and was also rubbing her belly on a rock. In some cases she would arch her back and open her cloaca for a little while.

Two weeks later at the 21st of November the second pup was born at about 11:00 a.m.. It was a female again (24 cm and about 75 grams - our scale is not very accurate). She was put together with the first pup. Sarah didn't eat for that day. After a good meal the next day, a third pup (male) was born two days later at the 23rd of November. Sarah again didn't eat that day. The pups were eating the same day or one day after birth. They immediately attack the food like an adult shark. The food was given on little sticks and mainly consisted of pieces of squid and sardines.

Two more males was born at December 1 and 4. At December 6 Sarah didn't eat and was still restless. Another male was born the 7th and three more pups were born the 9th (two males and a female. They were all between 19 and 26 cm and weighted around 75 grams. Then Sarah started to eat again. A big male pup was born the 10th , 24cm and 90 grams, but three days later a female pup was born that looked underdeveloped and died the next day.



<u>Figure 3</u>. Growth of the two first-born nurse sharks *(Ginglymostoma cirratum)*

At the 17th of December the firstborn was 35 cm. long and weighed 250 grams. The second born was 28.5 cm. long and weighed 175 grams.

Nine days after the birth of the big pup, at December 22 pup #12 was found, he looked very small and weak, was 24 cm. and about 60 grams. Fortunately he ate very well and gained weight quickly. Pup # 13 was born the 26th , a female of 25 cm, and only 50 grams. The last pup, of December, #14, was born sometime during the night at the 29th. It was female, 24 ½ cm and about 75 grams.

In January (6-9-11-11-13-14 and 18) 7 more pups were born: 2 females and 5 males. Sarah slimmed down and became extremely hungry during that time. Most pups weighed not more than 50 grams and were between 23.5 and 26cm long. They all ate very well and only one

more pup died two weeks after it's birth. The last one, born at January 18 was a strong pup again,
75 grams and 28 cm. Sarah went back to her lagoon after three months at the 3rd of February.

In total 7 females and 14 males were born. The two first born seemed to grow faster than those born later. Female pup #18 of litter was born on January 11th. She was 23.5 cm long and weighed ~40 grams when she was born. She gained 160 grams in almost 2 months. The first born gained 150 grams in first two months.

The following is a detailed record of growth of the first two pups (also graphed in Fig. 1).

January 13: Pup #1 weighed 500grams and was 47 cm. long. Pup #2 weighed 450g and was 36 cm. long.

February19: Pup #1 weighed 700g and was 50 cm long. Pup #2 weighed 625g and was 49 cm long.

March 23: Pup #2 weighed 850 grams and is 52.5 cm long. Pup #1 weighs 950 grams and is 59.5 cm long.

April 20: Pup #2 is 59 cm and weighs 975 grams. Pup #1 weighs 1150 grams!!! and is 62 cm. I haven't been logging but all pups have been eating well and seem to be doing fine. Haven't noticed any "toads".

May 13: Pup #1 weighs 1450 grams and is 70.5 cm long. Pup #2 weighs 1175 grams and is 65 cm long.

The pups have to have light meals some days because they grow fat easily. Four pups have been sent to Rotterdam Zoo in Holland where they will become part of a new shark aquarium

Final note: On October 24, 1999 Maureen reported that it was likely that "Sarah" was pregnant again, and that she hoped to make further observations.

Sand Tiger Sharks

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OBSERVATIONS ON THE BEHAVIOR OF CAPTIVE SAND TIGER SHARKS, *Carcharias taurus*, (RAFINESQUE, 1810)

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Elasmobranch Husbandry Symposium

Abstract

A size-dependant dominance hierarchy was implied in a population of three sand tiger sharks, *Carcharias taurus*, held at the Oceanworld Aquarium, Dingle, Ireland. Ram ventilation was used in preference to active ventilation by sand tiger sharks held at the Oceanworld Aquarium and the Blue Planet Aquarium, Cheshire, United Kingdom, when swimming rate exceeded 40 FPM (R^2=0.6628; n=8). Artificial stimuli (i.e. diver presence and elevated illumination) appeared to influence active ventilation rates (VPM) in sand tiger sharks at both aquaria.

Introduction

Synonymy

Carcharias taurus, *Eugomphodus taurus*, and *Odontaspis taurus* are synonyms for the sand tiger shark. It is commonly known as the sand tiger shark, sandtiger shark, or sand shark in the USA; the grey nurse shark in Australia; and the spotted ragged-toothed shark, or "raggy", in Africa (Pollard et al., 1996). The sand tiger shark is of the order Lamniformes and family Odontaspididae (Compagno, 1984). The Australian grey nurse shark may not be synonymous with the sand tiger in the USA (Martin, 1999). Should they become widely accepted as distinct species, *C. arenarius* would have priority for the former species and *C. taurus* would be retained for the latter (Martin, 1999). The sand tiger is regarded as vulnerable world-wide and the Australian representative of the genus is considered to be "vulnerable to extinction" and "critically endangered" on the west and east coasts of Australia, respectively (Anon, 2001). The sand tiger sharks used in this study were from the Eastern coast of the USA. These specimens were therefore considered to be "true" *C. taurus*.

General Biology of the sand tiger

The sand tiger is a large bulky shark with a flattened conical snout. The sand tiger can grow to a length of 3.2m (Compagno, 1984) although lengths of 4.3m have been reported (Pollard et al., 1996). Sand tigers inhabit shallow bays, sandy coastal waters, and rocky or tropical reefs from shallow waters down to about 200m (Compagno, 1984). They are commonly found in depths of 5-12m (Gilmore et al., 1983).

There is little literature on the population biology and behavioral ecology of the sand tiger shark. Divers have historically observed large aggregations of sand tigers around rocky outcroppings in offshore waters. The sand tiger is active at night tending to remain on the seabed during the day (Compagno, 1984). It is the only species to use intrauterine cannibalism (adelphophagy) as part of its reproductive strategy (Martin, 1999). Sand tigers can maintain neutral buoyancy by swallowing air, allowing them to "hang" almost motionless in the water column. It is also known that they are able to switch from respiratory pumping or active ventilation, when at rest, to "ram" ventilation while cruising, and thereby save energy (Myrberg, 1999).

Sand tigers were once thought to be man-eaters and slaughtered by the hundreds, but they have since been shown to be of no threat to humans unless provoked (Compagno, 1984). The sand tiger is susceptible to over-fishing due to its low fecundity and late maturation (Branstetter and Musick, 1994). The future of the sand tiger in Australia and other parts of the world is uncertain. Dwindling numbers are under increasing pressure from directed fisheries, as by-catch of commercial fisheries, and from the aquarium trade. Researchers in Australia are examining the feasibility of breeding sand tigers in captivity as an indemnity against their possible extinction in the wild (Parker, personal commun.). Only one article examining the captive biology of this species could be found in the literature (Gordon, 1993). More studies of this species are required to better understand their basic biology, improve the chances of developing a successful breeding program, and hopefully increase their chances of survival into the future.

Objectives

The objectives of this study were as follows:

1. Investigate evidence for social (dominance) hierarchies within small populations of sand tiger sharks.

2. Investigate the relationship between breathing technique and swimming behavior in the sand tiger shark.

3. Make a qualitative examination of captive sand tiger behavior and suggest husbandry strategies to improve animal welfare.

Methods

Observations for this study were recorded at the Oceanworld Aquarium, Dingle, Co Kerry, Ireland and the Blue Planet Aquarium, Cheshire, United Kingdom. The Oceanworld Aquarium is a pentagonal shaped exhibit of dimensions 10m long x 10m wide x 3m deep and has a volume of 380m^3. During the study Oceanworld Aquarium held a population of three sand tiger sharks, OF, SOF, and OM (where O = Oceanworld Aquarium; F = female; M = male; and S = small). The Blue Planet Aquarium is a rectangular exhibit of dimensions 36m long x 24m wide x 3.5m deep and has a volume of 2,500m^3. During the study Blue Planet Aquarium held a population of eight sand tiger sharks, BF1, BF2, BF3, BF4, BM1, BM2, BM3, and BM4 (where B = Blue Planet Aquarium; F = female; and M = male).

Sampling Protocol

A protocol of continuous sampling was used in both aquaria as this method provides the most complete and accurate data for analyzing animal behavior (Lehner, 1996). Due to the rarity of interactions a continuous observation period of 1h was adopted. This was considered a favorable rate for comparison. The Oceanworld Aquarium has eight large windows at the front of the exhibit where it was possible to always observe all the sand tiger sharks. Unfortunately there was no position at the Blue Planet Aquarium where it was possible to continuously observe all the sharks. Observations were therefore recorded at a point halfway through the first section of acrylic tunnel. It had previously been determined that this position would yield the highest mean rate of observations.

Incident at the Oceanworld Aquarium

Data collection was interrupted during this study as the result of an incident at the Oceanworld Aquarium on the evening of the 20th of January 2000. Unbeknownst to the staff, water temperature within the exhibit rose to 33°C (11.1°C in excess of the 21.9°C set point) when a negative feedback controller failed to turn off the heating system. When staff arrived the next morning all three sand tigers (OF, SOF, and OM) were lying on the bottom of the exhibit, mouths agape. The temperature was corrected (i.e. returned to 24°C by the following evening) and the sharks treated with an injection of adrenaline and simulated "ram" ventilation by bringing the animals to the surface and pumping water into their mouths. OF and OM recovered, but unfortunately SOF succumbed to the trauma (Scanlon, personal commun.). For a period of 12 days following the incident OF and OM did not eat and were observed to be "yawing". This was not consistent with their normal behavior and although speculative they were considered to be in a state of "post-incident trauma" (**Table 1**). Thereafter the sharks appeared to resume normal feeding and behavior patterns. Subsequent observations were therefore considered to take place during a "post-incident trauma" recovery period.

Dominance Hierarchy

The first experiment examined evidence for the existence of dominance hierarchies within the sand tiger population at the Oceanworld Aquarium. When two sharks were swimming toward each other and one yielded the right of way, with the second shark maintaining both direction and velocity, the former was referred to as the subordinate (i.e. lost the interaction) and the latter as the dominant (i.e. won the interaction) (Myrberg and Gruber, 1974). This behavior was referred to as a "give-way" interaction. Allee and Dickinson (1954), and Myrberg and Gruber (1974) used this behavior to rank a colony of smooth dogfish (*Mustelus mustelus*) and bonnethead sharks (*Sphyrna tiburo*), respectively. Additional interactions were considered to be indicative of a dominance hierarchy: "avoiding", "touching", and "tailing" (**Table 1**). During 37 x 1h observations, 106 dominance interactions were observed (59 in the 14 x 1h observations prior to the over-heating incident and 57 in the 23 x 1h observations following the over-heating incident).

Swimming and Ventilation rates

The second experiment examined the relationship between swimming rates and active ventilation rates in both populations of sand tigers. Swimming rate was defined as the number of "tail flicks" observed per 60s (FPM) (**Table 1**). Active ventilation rate was defined as the number of single ventilation cycles (i.e. mouth opening and closing, and gill covers flaring) observed per 60s, or breaths per minute (VPM). Swimming rates were taken at the same time or directly after corresponding ventilation rates were recorded. A total of 16 observations were made for two of the sharks at the Oceanworld Aquarium (post over-heating incident), while 37 observations were recorded for six of the sharks at the Blue Planet Aquarium. The relationship between swimming rate to active ventilation rate was examined.

Table 1

Behavioral repertoire of sand tiger sharks, *Carcharias taurus* , observed at the Oceanworld Aquarium and Blue Planet Aquarium.

Behavior	Definition
Gaping	Mouth consistently open more than normal (i.e. agape).
Give-way	Shark alters swimming direction to avoid oncoming conspecific.
Loss	Shark yields the right of way during a "give-way" interaction.
Post-incident trauma	A period of "gaping", "yawing" and inappetance (observed for 12 days following the over-heating incident at the Oceanworld Aquarium).
Swimming rate	Number of "tail flicks" per minute (FPM)
Tail flick	One half stroke of the tail (from the shark's mid-line to the extreme left or right and back to the mid-line) during normal locomotion (i.e. 2 "tail flicks" = 1 tail beat).
Tailing	Shark closely follows conspecific, restricting tail movement of lead shark.
Twitching	An uncontrolled contraction of the musculature resulting in a repeated, jerky movement of the tail.
Ventilation rate	Number of active ventilation cycles per minute (VPM)
Win	Shark maintains direction and velocity during "give-way" interaction.
Yawing	Shark tilts laterally and moves head from side-to-side with each "tail flick".

Results

The behavioral repertoire of the sand tiger sharks observed during this study has been summarized in **Table 1**.

Collected data was non-normally distributed. As sample sizes were small, transformations to "normalize" the data were not undertaken and non-parametric tests were used. Statistical analyses were performed using Instat 3 and Excel.

Interactions between sand tigers at the Oceanworld Aquarium were analyzed and summarized in a dominance hierarchy matrix (**Table 2**). OF had the highest percentage of "wins" while OM had the lowest. The over-heating incident did not appear to affect this relationship. SOF had the second highest percentage of "wins" prior to the over-heating incident (**Table 2**).

Swimming rates and active ventilation rates were compared for sharks at the Oceanworld Aquarium (R^2=0.8184; n=2), sharks at the Blue Planet Aquarium (R^2=0.6987; n=6), and for both aquaria where a significant correlation was observed (R^2=0.6628; n=8) (**Figure 1**).

Discussion

By necessity, small sample sizes were used during this study. Extreme caution should therefore be exercised when interpreting the results.

Dominance Hierarchy

Many examples of complex behaviors (e.g. dominance hierarchies, adaptive learning, etc.) have been observed in various shark species (Bres, 1993; Gordon, 1993). OF demonstrated a similar percentage of "wins" over OM both before and after the overheating incident suggesting that the presence of SOF had little influence on interactions between the larger animals. Although OM only "won" 6% of interactions with the much larger OF, he "won" 30% of interactions with the only moderately larger SOF. This suggests that size may influence the chances of success (i.e. "win") during "give-way" interactions. At no time during the study was direct aggression as a means to display dominance observed. This finding is in agreement with the conclusions of other workers (Allee and Dickinson, 1954; Myrberg and Gruber, 1974; and Gordon, 1993).

Table 2

Dominance hierarchy matrix for sand tiger sharks (*Carcharias taurus*) held at the Oceanworld Aquarium showing number of "wins" (columns), number of "losses" (rows), and percentage of "wins". Figures in parenthesis refer to data taken following the "post-in

	OF	**SOF**	**OM**
OF	-	22	6 (8)
SOF	78	-	30
OM	94 (92)	70	-
% of Wins	86% (92%)	46%	18% (8%)

Swimming and Ventilation rates

Swimming rates, active ventilation rates, and temperature ranges (i.e. 20-23°C) were comparable in both the Oceanworld Aquarium and the Blue Planet Aquarium. Swimming and ventilation rate data were therefore combined (**Figure 1**). Ventilation rates in undisturbed sand tiger sharks were similar to those observed by Smith (1992). As swimming rate exceeded 38FPM active ventilation rate decreased significantly, in some cases ceasing altogether (**Figure 1**). This decrease appeared to be the result of a transition between active ventilation and ram ventilation (where movements of the mouth and gills are absent).

Active ventilation was more frequently observed than ram ventilation during this study. It is possible that the animals were "resting" during periods of observation. This possibility is consistent with the fact that sand tiger sharks are more active at night.

Swimming and ventilation rates changed during feeding sessions. During feeding sessions at the Oceanworld Aquarium sand tiger active ventilation rates dropped considerably by the time feeding was completed. For example, active ventilation in OF dropped from 20VPM to <0.25VPM during a typical feeding session. At the end of the session OF was swimming quickly and ram ventilating. Ventilation rate returned to 20VPM approximately 30min after the feeding session. Feeding appeared to waken the sharks from their normal routine of relaxed swimming and accompanying active ventilation. Ram ventilation may have been the result of an increasing oxygen demand with increased activity. However, it could have been a simple case of the animals taking advantage of induced currents resulting from increased swimming speeds.

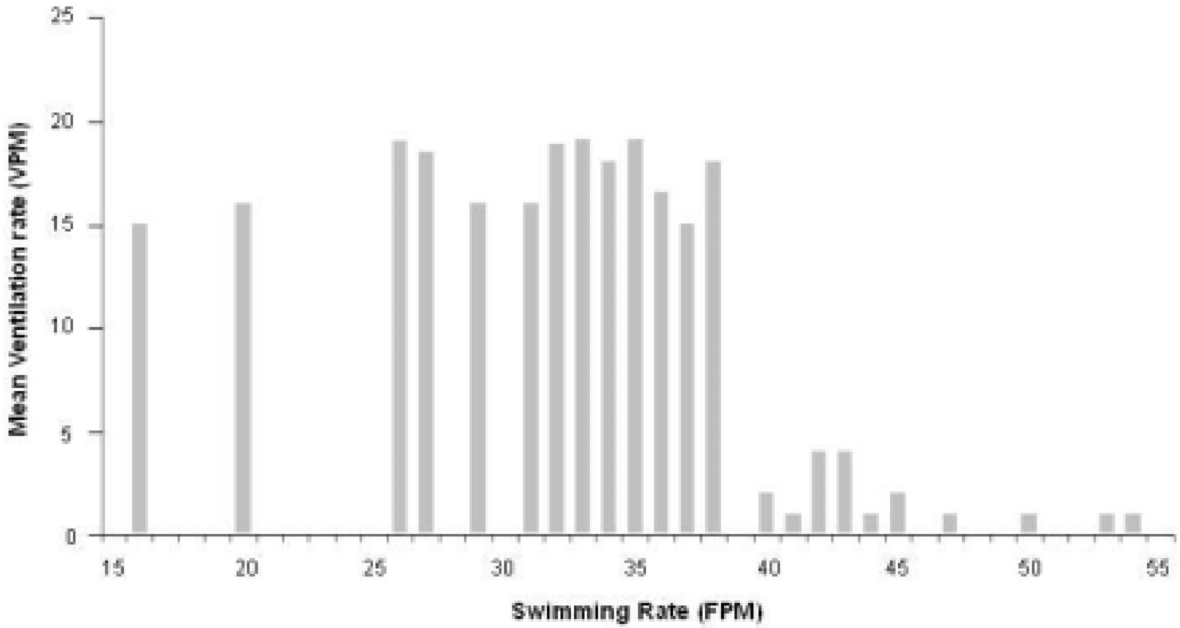

Figure 1. Relationship between swimming rate and active ventilation rate in sand tiger sharks (*Carcharias taurus*) observed at the Oceanworld Aquarium and the Blue Planet Aquarium.

<u>The influences of Artificial Stimuli</u>

On the rare occasions that divers entered the Oceanworld Aquarium, shark swimming and active ventilation rates were recorded. It was observed that ventilation rates frequently dropped from 20VPM to <15VPM, in many cases reaching 0VPM. After divers exited the exhibit active ventilation rates returned to 20VPM. It appears as if diver presence aroused the sharks from their typical quiescent swimming behavior, inducing them to rely more heavily on ram ventilation. This finding is consistent with previous studies that demonstrate a reaction by sand tiger sharks to diver presence (Gordon, 1993; Richards, 2000).

During her study of sand tigers at the Blue Planet Aquarium, Richards (2000) observed that sand tigers were less active in the morning, remaining in apparently favored sections of the aquarium. During the afternoons and evenings, the sharks appeared to swim in a more random fashion and Richards (2000) hypothesized that this was the result of diver activity. Certainly while workers were in the water, sharks tended to avoid the divers, swimming higher in the water column. It is therefore possible that diver presence influenced the rate of interactions between individual sand tigers during the current study.

The behavior of sand tiger sharks at the Oceanworld Aquarium was frequently observed during the period before and after (i.e. 1h each) artificial lighting was raised to full illumination (i.e. from two to five lights). These observations indicated that intraspecific interactions were more frequent when illumination was low. For example, on day 1 and day 2, six intraspecific interactions were observed when illumination was low and only one interaction was observed on each day when lighting was normal. “Tailing” occurred more frequently during low lighting and was rarely seen at normal levels of illumination. Copulation has only been observed in this species, in aquaria, during periods of low illumination (Garner, personal commun.). This may account, in part, for an apparent partiality toward dominance behaviors during nocturnal periods.

Excessive illumination and/or changes to normal illumination appeared to influence the behavior of the sharks. During a film shoot at the Oceanworld Aquarium eight overhead lights were illuminated (three more than the five lights normally used to illuminate the exhibit). Camera lighting was also employed. During the film shoot one of the sand tiger sharks (OM) developed a violent “twitch” just anterior to its caudal fin. The shark continued to “twitch”, with a 1s frequency, for approximately 90s. A sandbar shark (*Carcharhinus plumbeus*) occupying the exhibit was observed “twitching” on three separate occasions during the same period of elevated illumination. As all other parameters remained constant it appears as if the higher illumination, or electro-magnetic fields associated with the lighting, was responsible for this phenomenon. This was the only time that “twitching” behavior was observed in any of the sharks.

Swimming Patterns and Stereotyped Behavior

The sharks at the Oceanworld Aquarium rarely used the lower part of the exhibit. OF typically swam in an anticlockwise direction within the upper portion of the water column, only breaking the surface at the front, right-hand corner. Her dorsal fin appeared to be permanently bent to the left and was unaffected by swimming direction. Conversely, OM swam clockwise around the exhibit and avoided the surface at the front, right-hand corner. OM's dorsal fin was bent to the right. SOF did not swim in a particular direction and did not have a bent dorsal fin, suggesting some relationship between the stereotyped swimming patterns and physical changes to the dorsal fins of both OF and OM.

Richards (2000) noted that the sharks at the Blue Planet Aquarium frequented certain limited areas of the exhibit and repeated definite swimming patterns. Klay (1977) claimed that once a shark was fully adapted to adequate captive conditions it would use the whole space and alternate its swimming direction at will. It is possible that the sharks in both the Oceanworld Aquarium and the Blue Planet Aquarium have not fully adapted to captivity or alternatively that the facilities are not entirely adequate for the species. Although other factors may be responsible it is suggested that environmental enrichment programs (such as multiple feeding techniques) may be of use in helping to extinguish these stereotypic behaviors.

Conspecific vigilance

The sand tiger sharks at the Oceanworld Aquarium appeared to be aware of the swimming pattern of conspecifics. For example, OM appeared to avoid areas recently occupied by OF. Following the "post-incident trauma" period, OF returned to her typical swimming pattern forcing OM to alter a swimming pattern he had adopted (near the surface of the exhibit) immediately following the over-heating incident. There were many examples of OM avoiding OF when she was in close proximity. In addition, the swimming behavior of OM was suggestive of a constant vigilance for OF, consistent with the possibility that visual cues may play a role in intraspecific social interactions (Bres, 1993).

Post-incident trauma

Oceanworld Aquarium's large female (OF) relied heavily on active respiration during the "post-incident trauma" period. It appeared that she did not have sufficient energy for the swimming rate required to achieve ram ventilation. Conversely, the male (OM) relied more on ram ventilation and appeared to be more active. During the "post-incident trauma" period both animals "gaped" and swam with a weaker tail-stroke, resulting in "yawing" (**Table 1**). The sharks did not appear to have sufficient energy to maintain an elegant, efficient swimming stroke. This was the only time these behaviors were observed.

Observations for improved husbandry

If surface skimmers remained operating during feeding sessions, surfactants were removed and sent to water treatment systems before they became hydrolyzed. This resulted in superior water quality. It is suggested that such practices should be encouraged during all feeding sessions.

It is common practice to add remora (*Remora remora*) to aquaria that have a collection of sharks. However, remora appear to unduly disturb sand tiger sharks and it is recommended that they not be introduced into an exhibit with this species (Walker, personal commun.).

On two occasions OM dropped his pectoral fins vertically, raised the front of his body 45° to the horizontal plane, twisted his entire body from side-to-side, and repeatedly opened and closed his mouth. This behavior, observed during feeding sessions, is possibly related to digestion and should not be confused with agonistic displays (Garner, personal commun.).

The over-heating incident recorded at the Oceanworld Aquarium was most unfortunate. It is the responsibility of aquarium staff to ensure that such problems are minimized and appropriate contingencies are adopted. It is hoped that an explanation of this incident will help prevent future such errors in other aquaria. At the very least other aquaria should note that any mechanical and/or logic control units should have suitable back-up and alarms systems.

Future Research Ideas

1. Do size and/or gender influence dominance hierarchies in the sand tiger shark?

2. What determines the change from active ventilation to ram ventilation in the sand tiger shark?

3. Do excessive artificial stimuli (e.g. constant diver presence, high or rapidly changing levels of illumination, etc.) have an adverse affect on sharks in aquaria?

4. Does stereotypical behavior exist in captive sharks? If so, what forms of enrichment can be undertaken to extinguish such behaviors should such be indicated?

5. Do sand tiger sharks monitor the location of nearby conspecifics?

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References

Allee, W. C., and Dickinson, J. C. Jr.
1954. Dominance and subordination in the smooth dogfish *Mustelus canis*, (Mitchell). Physiol. Zool., 27, 356-364.

Branstetter, S., and Musick, J. A.
1994. Age and growth-estimates for the sand tiger in the north-western Atlantic Ocean. Transactions of the American Fisheries Society 123(2), 242-254.

Bres, M.
1993. The behaviour of sharks. In: Reviews in Fish Biology and Fisheries Vol. 3. Chapman and Hall Press. pp. 133-159.

Compagno, L. J. V.
1984. Food and Agricultural Organization of the United Nations (FAO) Species Catalogue (Vol. 4), Parts 1 & 2 - Sharks of the World. pp. 655.

Gilmore, R. G., Dodrill, J. W., and Liney, P. A.
1983. Reproduction and embryonic development of the sand tiger shark (*Odontaspis taurus* (Rafinesque)). Fish. Bull., 81(2), 201-225.

Gordon, I.
1993. Pre-copulatory behavior of captive sand tiger sharks, *Carcharias taurus*. Environmental Biology of Fishes, 38(1-3), 159-164.

Klay, G.
1977. Shark dynamics and aquarium design. Drum and Croaker, 17, 29-32.

Lehner, P. P.
1996. Handbook of Ethological Methods (2nd Edition). Cambridge University Press. pp. 672.

Myrberg, A. A.
1999. Shark behavior. In: Sharks - An illustrated Encyclopedic Survey by International Experts (Ed: Stevens, J. D.) Weldon Owen Pty. Ltd. Press. pp. 84-96.

Myrberg, A. A., and Gruber, S. H.
1974. The behavior of the bonnethead shark, *Sphyrna tiburo*. Copeia, 1974(2), 358-374.

Pollard, D. A., Lincoln Smith, M. P., and Smith, A. K.
1996. The biology and conservation status of the grey nurse shark (*Carcharias taurus*, Rafinesque 1810) in New South Wales, Australia. Aquatic Conservation: Marine and Freshwater Ecosystems, 6(1), 1-20.

Richards, L. S.
2000. An investigation into swimming patterns and hierarchy in captive sand tiger sharks in Blue Planet Aquarium. Unpublished B.Sc. (Hons.) thesis for Hull University, U.K.

Smith, M. F. L.
1992. Capture and transportation of elasmobranchs, with emphasis on the grey nurse shark (*Carcharias taurus*). Aust. J. Mar. Freshwater Res. (Sharks: Biology and Fisheries), 43(1), 325-43.

Personal Communications

Anon
2001. Status of Grey Nurse shark worsens to critically endangered on the East coast. http://www.hsi.org.au

Garner, R.
Queensland, Australia.
E-mail: rodgarner@powerup.com.au

Martin, R.
1999. Sand tiger Vs Grey Nurse:
http://www.reefquest.com/topics/gnurse_v_sand tiger.htm

Parker, P.
Fisheries Technician II, NSW Fisheries, NSW 2316, Australia.
E-mail: parkerp@fisheries.nsw.gov.au

Scanlon, T. J.
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A TAG AND RELEASE PROGRAM FOR GREY NURSE SHARKS.

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Drum and Croaker 28: 17-19. January 1997

Since 1993, Sea World Australia on the Gold Coast, has operated a tag and release program for Grey Nurse sharks *(Carcharias taurus).* The Grey Nurse shark makes up a significant part of Sea World's "Shark Encounter" dive show which encompasses a history of SCUBA diving along with and environmental message as to the plight of the much maligned shark.

The Grey Nurse shark once had a poor reputation as a man-eater in Australia but this is due to confusion with other species (Compagno, 1984). However, the Australian Shark Attack File (as of 14 February 1991), states that there have only been 4 positively identified cases of attacks by Grey Nurse shark, none of which were fatal (West, 1991).

This species is found in many areas around the world and is strongly migratory in parts of its range. Polewards migrations occur in summer and equatorial movements in autumn and winter (Compagno, 1984). In the Atlantic and off South Africa the Grey Nurse make seasonal migrations associated with reproduction (Last & Stevens, 1994). Locally, on the east coast of Australia it is thought that the Grey Nurse sharks migrate north from New South Wales to area within Southern Queensland waters during winter and south again for the summer months.

Individual animals are thought to be residential returning to similar area year after year and diving operations are attempting to verify this by identification of individual animals according to the small brown pigment spots on the body of each animal. These spots are individual to each animal and if "mapped", they can be as individual as the tail fluke of a whale.

Presently in Australia, the Grey Nurse shark is only protected in New South Wales (the first elasmobranch in the world to receive this status), and is currently under review for protection in Commonwealth waters of Australia (waters outside the 10 mile State limit). So in Queensland, where a percentage of the population migrate to, the Grey Nurse shark is a prime target for fisherman, as the jaws and fins of one animal can be sold for hundreds of dollars. Steps are being taken to have Grey Nurse shark protected in Queensland waters.

It is known that the Grey Nurse shark frequent the Flat Rock area (off North Stradbroke Island) during the months of July-October. During these months Sea World conducts their tag, release, and capture program. The sharks that have spent months in the Sea World Oceanarium are transported in specially designed shark boxes north to Flat Rock where they are tagged with spaghetti tags and released. These tags are very successful for animals that are recaught but not for those seen during dive trips as they are small and have small identification numbers. A different spaghetti tag (one with 5 coloured beads) will be trialed next winter. These coloured beads are site and individual specific and can be seen by a diver up to 20 meters away.

Once the animals have been tagged and released, a team of 3 divers gear up and set out to find a new animal. They use a large aluminum hoop (see figure 1) with a rope clipped to the inside of it to “lasso” the shark. The head passes through the hoop and the rope is tightened and hence released from the hoop. The rope tightens around the animal anterior to the pectoral fins (see figure 2).

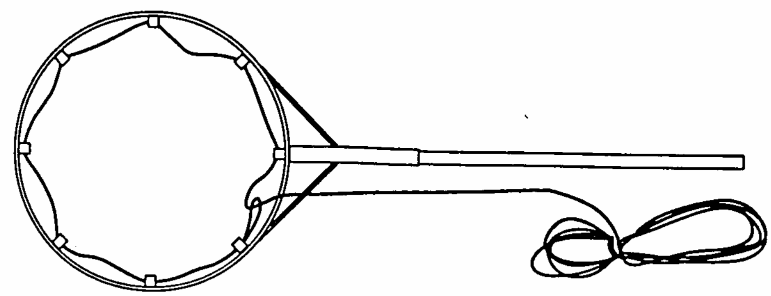

Figure 1. Hoop and position of rope in hoop (from Smith, 1992).

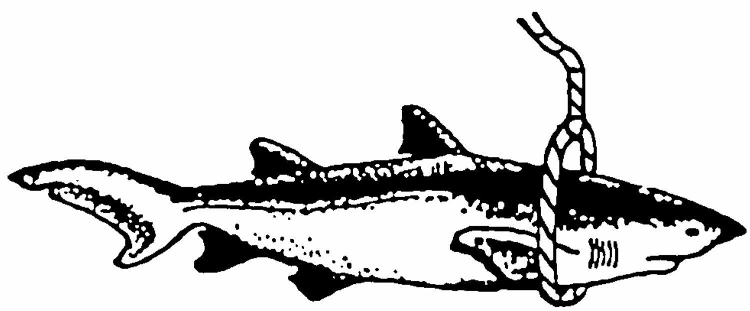

Figure 2. Position of tightened rope.

The sharks first reaction is “flight” but they tire easily and lie relatively stationary in the water column. As Grey Nurse are unique in their buoyancy regulation mechanisms, i.e. they gulp air from the surface and hold it in their stomach, they must be “belched”’ at depth, to prevent bloating of their stomach and organ damage on surfacing.

They are raised and lowered from the bottom using the rope around the front of their pectoral fins in approximately 5-6 m of water. This aggravates their stomach and they belch the air. They can then be brought slowly to the surface where they are slide onto a stretcher and winched onto the boat, into the transport box.

The transport of animals is closely monitored with blood samples to look at glucose and other levels in the blood. With enough of these blood pictures we should manage to get some good base line data for Grey nurse sharks during transport without drugs. It was once the norm to transport the Grey Nurse using drugs, such as ketamine hydrochloide and xylazine hydrochloride (Smith, 1992), but recent years have shown that transport with adequate water exchange and sufficient dissolved oxygen levels is more than satisfactory to transport these animals for up to 4 hours and possibly longer.

The Grey Nurse (Ragged tooth or Sand Tiger shark) was once abundant in Australian waters but due to human impact, their populations are steadily decreasing and it is easy to see why. The nurse has a relatively slow reproductive rate with gestation taking 9-12 months. Sexual maturity in both sexes is attained at about 220cm length but the age is unknown. Pups are born at 100cm and can grow to 318cm (Last & Stevens, 1994). Reproduction is oviphagous, where single embryo cannibalizes the other ova in both uteri (Compagno, 1984). This leaves two pups to develop as siblings.

When unprovoked the Grey Nurse shark is a slow moving, even shy creature that will turn away from divers calmly and swim slowly away. Divers can get very close to these animals in the wild even close enough to touch the individuals. This however, made them easy targets for spearfisherman and before they were protected in New South Wales they were vulnerable to deluded human heroics and the population declined rapidly.

Very little is known of this or any other large shark in the ocean. The grey nurse shark is becoming a popular tourist attraction with divers and shark enthusiasts and hopefully by protecting this species we can discover more about it before we humans wipe yet another species from earth.

References:

Compagno, Leonard J.R., 1984. FAO Species Catalogue. FAO Fisheries Synopsis No. 125, Vol. 4, Part 1.

Last, P.R. & J.D. Stevens, 1994. Sharks and Rays of Australia. CSIRO Australia.

Smith, Mark F.L., 1992. Capture and transportation of Elasmobranchs, with emphasis and the Grey Nurse Shark *(Carcharias taurus).* Aust. J. Mar. Freshwater Res. 43: 325-343.

West, J.G., 1991. The Australian Shark Attack File with notes on preliminary analysis of data from Australian waters. Shark Conservation Workshop, Taronga Zoo, 1991.

A CASE HISTORY OF A SEVERE BITE WOUND AND ITS REPAIR IN A JUVENILE SAND TIGER, *Carcharias taurus*

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Drum and Croaker 31: 25-26. February 2000

On 11/6/99 we were called in to assess the condition of a juvenile sand tiger shark, *Carcharias taurus*, that had been bitten by a tank mate during the night. The shark had three 10 cm diameter shark bite wounds on the right side behind the pelvic fin. Two of the bites were fairly superficial and the third was approximately 4 cm deep into the ventral musculature of the tail. This wound produced a flap that was connected to the body only at its lower edge.

The injured animal weighed 9.1 kg and her total length was 1.19 m as of 10/27/99. The sand tiger shared a 9.1 m diameter, 0.7 m deep, pool with another juvenile sand tiger, a 1.5 m, captive born, sub-adult sandbar shark (*Carcharhinus plumbeus*), two 1 m, captive born Pacific blacktip sharks (*C. melatopterus*), a 1.3 m white-tip reef shark (*Triaenodon obesus*), and a spotted wobbegong (*Orectolobus maculatus*).

The animal was corralled using a small transport stretcher and removed from the pool where it was placed in a large Xytec® cargo box for anesthesia. After 15 minutes immersion in 50 ppm Finquel® (Tricane Methanosulfonate = MS-222, Argent Laboratories) the shark was only slightly sedated and was still very active if handled. Additional MS-222 was added to the box to bring the concentration to 65 ppm and within 5 minutes the animal was quiet and unable to right itself when inverted. A tank lid (PVC frame with ½" poly mesh) was used as an improvised stretcher/operating table above the Xytec ® box. Barrels of 50 and 65 ppm MS-222 were set up nearby using water from the holding pool. Small submersible pumps were used to deliver these solutions and untreated pool water to the operating area.

Once removed from the water and placed on the tank lid, the sand tiger's gills were alternatively flushed with the 65 ppm solution and clear water. As gill movements were slowing to a near-stop, we then switched to the 50 ppm solution and continued alternating with untreated water for a few minutes. Fifteen to twenty minutes after the animal was placed on the lid we stopped alternating with untreated water, and the animal was maintained on 50 ppm MS-222 for the remainder of the 70 minute procedure.

It was determined that the large avulsed flap of skin and muscle should be reattached. Surgical repair of the deep muscle tissue was difficult because the muscle was friable and would not hold sutures well. Four to five simple interrupted, 3-0 vicryl sutures were placed in the muscle tissue. The largest flap was reapposed using horizontal mattress and simple interrupted suture patterns with 2-0 nylon suture material. The two smaller wounds on the right side, and another wound on the ventral surface behind the pelvic fins, also required a few sutures. A total of 35-40 sutures were placed (Fig. 1).

A procedure of this length creates special challenges. At the end of the repair, when the animal was moved from its left to right side, gill movement abruptly ceased. Several minutes of clear water were required to re-establish gill activity and the animal was returned to the pool and walked for 5 minutes until it was sufficiently active to swim on its own. It is possible that the 50 ppm MS-222 dose is higher than needed. It is also possible that after lying on its side for over an hour, the downside (left) gill became paralyzed due to compression against the lid, or had not been fully oxygenated. Placing the lower gill over a window in the stretcher material might prevent this effect. PJM also wonders whether a slightly lower dose of MS-222 (45 ppm) would be more suitable for long term anesthesia in juvenile sand tigers.

The shark was given Baytril® IM at a dose of 10 mg/kg during the surgery (split into two locations). A second injection was given after 48 hours, and subsequent injections were given at 72 hour intervals for one month. The 100 mg/ml concentration of Baytril® was used so that the dose could be contained within the 3 cc syringes our pole spear is designed to accept.

Dr. Tobi Pledger completes the reattachment of the flap created by the bite wound.

Some of the sutures fell out within two days and the flap of reattached tissue appeared to be raised at least 0.5 cm off the normal body outline of the animal for a period of over two weeks. Three weeks after the procedure, the flap was nearly flush with the surrounding tissue and granulation tissue was covering all previously “raw” sites. The animal began to feed occasionally within a week, and its appetite returned to normal within 2 to 3 weeks. The external stitches were removed after four weeks.

In order to prevent a reoccurrence of the injury we identified the species that had caused the wound using sheets of neoprene to take bite impressions. *Carcharhinus melanopterus* of this size (10 cm bite radius) leave tooth impressions approximately 1 cm apart, while *T. obesus* teeth are spaced much more closely. Although we suspected the whitetip to be the aggressor, the black tips were implicated by the neoprene impressions. They were isolated from the sand tigers, along with the wobbegong and whitetip, which we felt might be attracted to the wound.

Our experience with bite wounds on sharks had been previously limited to sandbar (brown) sharks, and in these cases the healing process was remarkable. Large, deep wounds usually heal without any obvious scarring. We are not sure what to expect with this sand tiger, but are encouraged by her progress to date and hope to see an equally good result in this species.

WORLDWIDE REVIEW OF THE GREY NURSE SHARK, *CARCHARIAS TAURUS*, AS A CONTRIBUTION TOWARDS ITS CONSERVATION IN AUSTRALIA. A BIBLIOGRAPHY

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AFONSO, P., PORTEIRO, F.M., SANTOS, R.S., BARREIROS, J.P., WORMS, J. & WIRTZ, P. 1999. Coastal marine fishes of São Tomé Island (Gulf of Guinea). Arquipélago. Life and Marine Sciences 17A: 65-92 (p68).

AITKEN, K. 1991. Australia's Grey Nurse: The Seal, the Nurse and the Fisherman., p. 20-24. *In:* Sportdiving in Australia and the South Pacific. Issue. 27.

—. 1998. Sharks - Australia, the Indo-Pacific and Asia., p. 9. *In:* SportDiving Magazine. April/May, Issue. 67, 1998.

ALEXANDER, R. L. 1998. Blood supply to the eyes and brain of lamniform sharks (Lamniformes). Journal of Zoology. 245: 363-369.

ALLEN, B. & PEDDEMORS, V. 2000. Raggedtooth sharks (*Carcharias taurus*) @ Aliwal : a research update. Vol. 2001. Sancor Newsletter. Issue 164, August. http://www.botany.uwc.ac.za/sancor/Issue%20164%20pg%2010.htm

ALLEN, G. R. 1997. Marine Fishes of Tropical Australia and South-East Asia., p. 40-41. Western Australian Museum.

ALLEN, G. R. & SWAINSTON., R. 1988. The Marine Fishes of North-Western Australia: A Field Guide for Anglers and Divers., p. 20-21. Western Australian Museum.

ANDREWS, J. C. & SNADER, R. 1989. The collection and transport of sharks at the National Aquarium in Baltimore. *In:* American Elasmobranch Society 1989 Annual Meeting., San Francisco, California.

ANON. 1987. *Carcharias* Rafinesque, 1810 (Chondrichthyes, Lamniformes): conserved. Bulletin of Zoological Nomenclature. Vol. 44, Issue 3, Opinion 1459 : 216-217.

—. 1992. Review of the operation and maintenance of shark meshing equipment in Queensland waters. Department of Primary Industries, Brisbane. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

—. 1993. Grey Nurse Shark Births Update., p. 1. Vol. 2, UnderWater World "NewSplash" Newsletter.

—. 1996a. Comments in support of the nomination of the Grey Nurse shark, *Carcharias taurus* and the Great White shark, *Carcharodon carcharias* to be included in Part 2 of Schedule 1 of the Commonwealth Endangered Species Act, 1992. Taronga Zoo. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

—. 1996b. Listing of Grey Nurse and White Sharks as Vulnerable under the Endangered Species Protection Act, 1992. Fisheries Department of Western Australia. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

—. 1996c. Public nomination of Grey Nurse shark, *Carcharias taurus* to the *Endangered Species Protection Act, 1992.* Bureau of Resource Sciences, Fisheries and Aquaculture Branch. Fisheries Advice Note 446. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

—. 1997a. Report to the Minister - Public nomination to the Endangered Species Protection Act, 1992: Great White shark and Grey Nurse shark - recommended by the Endangered Species Scientific Subcommittee in the Threatened Species and Communities Section. Environment Australia. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

—. 1997b. Sea World plays role in Shark Protection., p. 6, Newsletter of the Sea World Research and Rescue Foundation Inc.

—. 1999b. *Carcharias taurus* Rafinesque, 1810. FAO. http://www.fao.org/WAICENT/FAOINFO/FISHERY/sidp/htmls/sharks/cs_ta_ht.htm

—. 1999c. Conservation of Threatened Aquatic Species. http://www.fisheries.nsw.gov.au/pages/conservation/df71publ.htm

—. 1999d. Grey Nurse shark, p. 1-4p (p4). *In:* Marine Parks News - The Newsletter of the Marine Parks Authority. Vol. 1., Issue 1.

—. 1999e. Sand Tiger shark. Mystic Aquarium. http://www.ife.org/Internet/animals/sandTigerShark.cfm

—. 1999f. Shark Attacks in Florida. Florida Sea Kayaking Association, USA. http://www.jacksonville.net/~dldecker/Shark.htm

—. 1999g. Sharks: Thyroid Hormone Balance in Sharks. http://www.ife.org/Internet/research/sharks.cfm

—. 2000a. Draft Recovery Plan for Grey Nurse Sharks, *Carcharias taurus,* in Australia, p. 1-26. Environment Australia. http://www.ea.gov.au/marine/species_protection/greynurse.htm

—. 2000b. FAO/SIDP Species Identification Sheets - *Eugomphodus taurus*. FAO. http://www.fao.org/fiservlet/org.fao.fi.common.FiRefServlet

—. 2000c. Grey Nurse Shark Numbers Plummet: Strong Recovery Plan Needed. Community Biodiversity Network, Nature Conservation Council of New South Wales, Australia. http://www.nccnsw.org.au/member/cbn/projects/LifeLines6.2/TS_GreyNur.html

—. 2000d. Grey Nurse Shark Submissions Needed. Humane Society International. http://www.hsi.org.au/GreyNurse_Alert.html

—. 2000e. Sand Tiger Sharks : The Facts. Nautilus Productions. http://www.nautilusproductions.com/sandtigersharks/facts.html

—. 2001a. Candidate Species - Sandtiger Shark (*Odontaspis taurus*). NOAA Fisheries - Office of Protected Resources. http://www.nmfs.noaa.gov/prot_res/species/fish/sandtiger_shark.html

—. 2001b. The Grey Nurse Shark, (*Carcharias taurus*). Abyss Scuba Diving. http://www.abyss.com.au/nurse.html

—. 2001c. Sand Tiger. Canadian Shark Research Laboratory. http://www.mar.dfo-mpo.gc.ca/science/shark/english/stiger.htm

—. 2001d. Sand Tiger Shark, *Carcharias taurus*. Coastal Shark Fishing. http://www.coast-shark.com/beachbum/coast-shrk/Pic_Pages/SandTiger/

—. 2001e. Sandtiger or Grey Nurse shark, *Carcharias taurus*. The Shark Trust, UK. http://web.cyberia.net.lb/lebscuba/Sharks/English/greynurse.html

—. 2001f. Species Summary for *Carcharias taurus*, Sand tiger shark. Fishbase. http://www.fishbase.org/Summary/SpeciesSummary.cfm?ID=747&genusname=Carcharias&speciesname=taurus

—. 2001g. Statistics of Shark Attacks on Divers. Ichthyology at the Florida Museum of Natural History. http://www.flmnh.ufl.edu/fish/Sharks/scuba/Shark/Shark.htm

—. 2001h. Status of Grey Nurse shark worsens to critically endangered on the East coast. Humane Society International. www.hsi.org.au

APPLEGATE, S. P. 1965. Tooth Terminology and Variation in Sharks with Special Reference to the Sand Shark, *Carcharias taurus* (Rafinesque). Los Angeles County Museum Contributions in Science. 86: 3-18.

BAILLIE, J. & GROOMBRIDGE., B. 1996. 1996 IUCN Red List of Threatened Animals. 378p. IUCN, Gland, Switzerland.

BALLARD, J. 1999. Captive Birth Event with *Carcharias taurus* in 1998. (R. Garner *pers. comm.*). SeaWorld, KwaZulu-Natal, South Africa.

BALON, E. K. 1990. Epigenesis of an epigeneticist: the development of some alternative concepts on the early ontogeny and evolution of fishes. Guelph Ichthyological Review. (1): 1 - 48 (p24).

BANNISTER, K. 1993. The book of the shark. Quintet Publishing Ltd, London. pp.81-84.

BASS, A. J. & BALLARD, J.A. 1972. Buoyancy Control in the Shark, *Odontaspis taurus* (Rafinesque). Copeia. 3: 594-595.

BASS, A. J., D'AUBREY, J.D. & KISTNASAMY, N. 1975. Sharks of the East Coast of Southern Africa IV. The Families, Odontaspididae, Scaponorhynichidae, Isuridae, Cetorhinidae, Alopiidae, Orectolobidae and Rhiniodontidae., p. 7-17 (p12-17). Oceanographic Research Institute, Durban, South Africa, Investigational Report 39.

BASS, A. J. & COMPAGNO, L.J.V. 1986. Odontaspididae. *In.* Smith, M.M. & Heemstra, P.C. (eds.) Smiths' sea fishes. Springer-Verlag., Berlin. pp.104 -105.

BAUMANN, P. 1997. Beyond the Grey Nurse?, p. 81-82. *In:* Sportdiving in Australia and the South Pacific. Issue. 61.

BERZINS, I. K., JESELSON, K., WALSH, M., MURRU, F., CHITTICK, B., MUMFORD, S., MARTEL-BOURBON, H., SNYDER, S.B., RICHARD, M.J., LANE, H. & LERNER, R. 1998. Kyphoscoliosis in Sand Tiger Sharks, *Odontaspis taurus*., p. 525-526. *In:* Abstract from 1998 Proceedings AAZV and AAWV Joint Conference.

BIANCHI, G., CARPENTER, K.E., ROUX, J. -P., MOLLOY, F. J., BOYER, D. & BOYER, H.J. 1993. FAO species identification field guide for fishery purposes. The living marine resources of Namibia. FAO., Rome. pp.68,73 & 206.

BICSKOS, A. A. 1985. Grey Nurse in perspective., p. 43-44. *In:* Underwater. Issue. 14.
BIGELOW, H. B. S. & SCHROEDER, W.C. 1948. Family Carchariidae - Sand sharks, p. 576pp (p98-108). *In:* Sharks - Fishes of the Western North Atlantic. H. B. Bigelow, Schroeder, W.C. & Farfante, I.P. (ed.). Memoir Sears Foundation for marine research, Yale University, New Haven.
BOSCHUNG, JR. H. T. & COUCH, J. 1962. A Record of the Sand Shark, *Carcharias taurus*, off Pensacola, Florida. Copeia. Vol.2 : 456-457.
BOWMAN, P. 1995. Grey Nurse Shark Migration Project., p. 17. *In:* Neville Coleman's Underwater Geographic. Issue. 40. July/August, 1995.
BRANSTETTER, S. 1990. Early life-history implications of selected Carcharhinoid and Lamnoid sharks of the Northwest Atlantic. NOAA National Oceanic and Atmospheric Administration Technical Report NMFS 90 National Marine Fisheries Service.
BRANSTETTER, S. & MUSICK, J.A. 1994. Age and Growth Estimates for the Sand Tiger in the Northwestern Atlantic Ocean. Transactions of the American Fisheries Society. Vol. 123: 242-254.
BRAY, R. A. 1984. Some helminth parasites of marine fishes and cephalopods of South Africa: Aspidogastrea and the digenean families Bucephalidae, Haplosplanchnidae, Mesometridae and Fellodistomidae. Journal of Natural History. 18 (2) : 271-292.
BRITO, A. 1991. Catalogo de los pesces de las Islas Canarias. Francisco Lemus, la Laguna. 230p (p25). www.fishbase.org
BUDKER, P. 1971. The life of sharks. Weidenfeld & Nicolson, London. 222p.
BURGESS, W. E., AXELROD, H.R. & HUNZIKER, R.E. 1990. Dr. Burgess's Atlas of marine aquarium fishes. T.F.H. publications Inc., USA. p.37.
BURNHAM, B. 2000. The Sand Tiger shark. Rosen Publications, Powerkids Press, New York, USA.
CADENAT, J. 1956. Note d'ichtyologie ouest-Africaine. XIV. - Remarques biologiques sur le Requin-sable *Carcharias* (Odontaspis) *taurus* Rafinesque, 1810. Bull. Inst. Fr. Afr. Noire. 18: 1249-1256.
CALLARD, I. P., PUTZ, O., PAOLUCCI, M. & KOOB, T. 1995. Elasmobranch reproductive life-histories : Endocrine correlates and evolution, p. 204-208 (p206). *In:* Fifth International Symposium on the Reproductive Physiology of Fish. F. W. T. Goetz, P. (ed.). Fish Symposium 95, Austin, The University of Texas at Austin, Austin, Texas, USA.
CAPPETA, H. & NOLF, D. 1991. The selachians of the lower Pliocene from Le-Puget-sur-Argens (Southeastern France). Palaeontographica Abteilung A Palaeozoologie Stratigraphie. Vol. 1-3, Issue. 218 : 49-68.
CAPUTI, N., EDMONDS, J.S. & HEALD, D. I. 1979. Mercury content of shark from south-western Australian waters. Marine Pollution Bulletin. 10 (11) : 337-340.
CARRICK, C. 1977. Sand Tiger Shark. Clarion Books, NY, USA.
CASTRO, J. I. 1983. Family and Species descriptions, p. 79-81. *In:* Sharks of North American Waters. J. I. Castro (ed.). Texas A&M University Press, College Station, USA.

CASTRO, J. I., WOODLEY, C.M. & BRUDEK, R.L. 1999. A preliminary evaluation of the status of shark species. FAO Fisheries Technical Paper. No.380, 72p (p21-22) (4.2.16 Sand Tiger sharks - Family Odontaspididae).

CERVIGÓN, F. F., W. 1979. INFOPESCA. Catálogo de especies marinas de interes economico actual o potencial para América Latina. Parte 1. Atlántico centro y suroccidental. FAO/UNDP, SIC/79/1., Rome. 372p (p203). www.fishbase.org

CLARK, E. 1963. The maintenance of sharks in captivity, with a Report on their instrumental conditioning., p. 115-149. *In:* Sharks and survival. Vol. Chapter 4. P. W. Gilbert (ed.). D.C. Heath and Company, Boston.

CLARO, R. 1994. Características generales de la ictiofauna. Ecología de los peces marinos de Cuba. In R. Claro (ed.) Instituto de Oceanología Academia de Ciencias de Cuba and Centro de Investigaciones de Quintana Roo. p.55-70. www.fishbase.org

CLIFF, G. 1989a. The Breeding Migration of the Sand Tiger Shark, *Carcharias taurus* in Southern African Waters., p. 1-12. *In:* Unpublished manuscript.

—. 1989b. Breeding migration of the Sand Tiger shark in Southern *Carcharias taurus* African waters. *In:* American Elasmobranch Society 1989 Annual Meeting, San Francisco, California.

—. 1989c. Raggedtooth Shark., p. 67-76. *In:* South Africa's Second Underwater Handbook. A. J. Venter (ed.). Ashanti Publishing Ltd., Johannesburg, South Africa.

COLEMAN, N. 1980. Australian Sea Fishes South of 30'S., p. p20. *In:* Australian Sea Fishes South of 30'S. N. Coleman (ed.). Doubleday Australia Pty Ltd.

COLVOCORESSES, J. A., & MUSICK, J. A. 1988. Comparative food habits of subtropical sharks in the Chesapeake Bight. *In:* American Elasmobranch Society 1988 Annual Meeting, Ann Arbor, Michigan.

COMPAGNO, L. J. V. 1978. Odontaspididae. *In:* FAO species identification sheets for fishery purposes. Western Central Atlantic (Fishing Area 31),. Vol. 5., Fischer, W. (ed.). FAO., Rome.

—. 1984. FAO Species Catalogue. Volume 4, Sharks of the World. FAO Fisheries Synopsis. Vol. 4, Part 2, Section 8, No. 125 (Carcharhiniformes. Section.8, Order Lamniformes - Mackerel Sharks, Family Odontaspididae) : 212-222 (p216).

—. 1997. Odontaspis vs Carcharias. http://www.elasmo.com/frameMe.html?file=selachin/misc/lc-sndtg.html&menu=bin/menu_topics-alt.html

—. 1999. Checklist of living elasmobranchs. *In*: W.C. Hamlett (ed.) Sharks, skates, and rays: the biology of elasmobranch fishes. John Hopkins University Press, Maryland. John Hopkins University Press., Maryland. pp. 471- 498 (p477).

COMPAGNO, L. J. V., EBERT, D.A. & SMALE, M.J. 1989. Guide to the sharks and rays of southern Africa. New Holland (Publ.) Ltd., London. pp. 158 (p40).

COMPAGNO, L. J. V. & FOLLETT, W. I. 1986. *Carcharias* Rafinesque, 1810 (Chondrichthyes, Lamniformes): proposed conservation by the use of the relative precedence procedure. Z.N. (S.) 2414. Bulletin of Zoological Nomenclature. 43 (1) : 89-92.

COMPAGNO, L. J. V. & NIEM, V.H. 1998. Odontaspididae. Sand tiger sharks. p1264 - 1267 (p1266). *In:* FAO identification guide for fishery purposes. The Living Marine Resources of the Western Central Pacific. FAO, Rome. K. E. N. Carpenter, V.H. (eds.).

COPPLESON, V. M. 1958. Chapter 14 : 'Meeting the menace' - The known and reputed man-killers. p223. *In:* Shark Attack. A study of swimmers, surfers, skindivers, shipwreck survivors and sharks. V. M. Coppleson (ed.). Angus & Robertson Ltd, Halstead Press, Sydney.

CORREIA, J. P. 1999. Tooth loss rate from two captive sandtiger sharks (*Carcharias taurus*). Zoo Biology. 18: 313-317.

CORTÉS, E. 1999. Standardized diet compositions and trophic levels of sharks. ICES Journal of Marine Science. 56: 707-717 (p711).

CROPP, B. 1964. Shark Hunters. Rigby, Adelaide. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

—. 1974. Handbook for Skindivers. Jack Pollard Sportsmaster. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

CUNNINGHAM, S. B. 2000. A comparison of isolated teeth of early Eocene *Striatolamia macrota* (Chondrichthyes, Lamniformes), with those of a Recent sand shark, *Carcharias taurus*. Tertiary Research. 20 (1-4) : 17-31.

—. 2001. Tooth Study of a Recent Sand Tiger Shark, *Carcharias taurus* (Rafinesque, 1810). http://www.baltobluegrass.com/News.html

DAHL, G. 1971. Los peces del norte de Colombia. Instituto de Desarrollo de los Recursos Naturales Renovables, Bogota. 391p. (p10). www.fishbase.org

DAVIES, D. H. 1964. Dangerous sharks of the Natal region, p. 61-62. *In:* About Sharks and Shark Attack. Brown Davis and Platt Ltd, Durban, South Africa. pp 61-62.

DEBELIUS, H. 1998. Fischführer Mittelmeer und Atlantik. Jahr Verlag GmbH & Co., Hamburg. 305p. (p38). www.fishbase.org

DEMSKI, L. S. & NORTHCUTT, R.G. 1996. The brain and cranial nerves of the white shark: an evolutionary perspective., p121-130 (p125). *In:* Great white sharks: the biology of *Carcharodon carcharias*. A. P. A. Klimley, D. G. (ed.).

DIAW, A. A. 1976. Un vocabulaire Wolof de la faune au Senegal. Les Langues Nationales au Senegal No. 67. Centre de Linguistique Appliquee de Dakar. 22p. www.fishbase.org

ECKERSLEY, Y. 1996. Shark meshing is the net result justifiable?, p. 17-26. *In:* GEO Australia. Vol. 18 (5). http://www.environment.gov.au/marine/species_protection/sharks/references.htm

EDGAR, G. J. 1997. Australian Marine Life : The Plants and Animals of Temperate Waters. p394. *In:* Australian Marine Life; The Plants and Animals of Temperate Waters. G. J. Edgar (ed.). Reed Books., Victoria, Australia.

EDWARDS, H. 1997. Shark : The shadow below. Harper Collins, Sydney. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

ELLIS, R. 2001. Sand Tiger (*Carcharias taurus*). http://www.postmodern.com/~fi/sharkpics/ellis/sandtigr.htm

EMOKPAE, A. O. & ANEKWE, G. E. 1983. Characterization of the non-saponifiable fraction of the liver lipids of shark *Carcharias taurus* by mass-spectrometry. Comparative Biochemistry and Physiology B Comparative Biochemistry. 74B (3) : 661-665.

ESCHMEYER, W. N. 1990. Catalogue of the genera of recent fishes. California Academy of Sciences. San Francisco, USA. 697 p., San Francisco, USA.

FERGUSSON, I. K. 1999. Shark Trust: Sandtiger or Grey Nurse Shark (*Carcharias taurus*). http://www.ds.dial.pipex.com/sharktrust/sandtiger.shtml

—. 2000. Note on the declining status of the Sandtiger shark, Carcharias taurus Rafinesque, 1810, in the Mediterranean sea. Vol. 2001. Mediterranean Shark Site. http://www.zoo.co.uk/~z9015043/abstracts.html

FISCHER, W., SOUSA, I., SILVA, C., DE FREITAS, A., POUTIERS, J.M., SCHNEIDER, W., BORGES, T.C., FERAL, J.P. & MASSINGA, A. 1990. Fichas FAO de identificaçao de espécies para actividades de pesca. Guia de campo das espécies comerciais marinhas e de águas salobras de Moçambique. Publicaçao preparada em collaboraçao com o Instituto de Investigaçao Pesquiera de Moçambique, com financiamento do Projecto PNUD/FAO MOZ/86/030 e de NORAD. FAO., Roma. 424p. (p250). www.fishbase.org

FISH, F. E. & SHANNAHAN, L.D. 2000. The role of the pectoral fins in body trim of sharks. Journal of Fish Biology. 56 (5) : 1062-1073.

FRITZSCH, B. & MOLLER, P. 1995. A history of electroreception., p. p39 - 55 (p51-53). *In:* Electric Fishes: history and behaviour. Fish and Fisheries series 117. P. Moller (ed.). Chapman & Hall., London.

GARBUTT, R. 1995. Sharks under attack. Grey Nurse numbers take a dive in fishing conflict., p. 26-38. *In:* GEO Australasia. Vol. 17 (4).

GARNER, R. J. 1997. Shark Breeding Success. p. 11. No.35, December 1997. Australasian Regional Association of Zoological Parks & Aquaria (ARAZPA), Australasian Regional Association of Zoological Parks & Aquaria (ARAZPA) Newsletter.

GARRICK, J. A. F. & SCHULTZ, L.P. 1963. A guide to the kinds of potentially dangerous sharks, p50-52. *In:* Sharks and survival. P. W. Gilbert (ed.).

GELSLEICHTER, J., MUSICK, J.A. & NICHOLS, S. 1999. Food Habits of the Smooth Dogfish, *Mustelus canis*, Dusky Shark, *Carcharhinus obscurus*, Atlantic Sharpnose Shark, *Rhizoprionodon terraenovae* and the Sand Tiger, *Carcharias taurus* from the Northwest Atlantic Ocean. Environmental Biology of Fishes. 54 (2) : 205-217.

GERT DE COUET, H. & SMITH, A. 1992. Sea Science: Grey Nurse Sharks - A Natural History, an Unnatural Fate., p. 10-13. *In:* Scuba Diver. October/November, 1992.

GILBERT, P. W. 1981. Patterns of shark reproduction. Oceanus. 24 (4) : 30-39.

GILMORE, R. G. 1991. The reproductive biology of lamnoid sharks. Underwater Naturalist. 19(4) & 20(1): 64-67.

—. 1993. Reproductive Biology of Lamnoid Sharks. Environmental Biology of Fishes. 38 (1-3) : 95-114.

GILMORE, R. G., DODRILL, J.W. & LINLEY, P.A. 1983. Reproduction and Embryonic Development of the Sand Tiger Shark, *Odontaspis taurus* (Rafinesque). U.S. Fish and Wildlife Service Fishery Bulletin. 81 (2) : 201-225.

GLOERFELT-TARP, T. & KAILOLA, P. J. 1984. Trawled fishes of southern Indonesia and northwestern Australia., p. 407p (p10). Australian Development Assistance Bureau, Australia, Directorate General of Fishes, Indonesia and German Agency for Technical Cooperation., Federal Republic of Germany. www.fishbase.org

GODKNECHT, A. & RITTER, E. 2001. *Carcharias taurus*. Shark Foundation. http://www.shark.ch/cgi-bin/Sharks/spec_conv.pl?E+Carcharias.taurus
GOMON, M. F., GLOVER, J.C.M. & KUITER, R.H. 1994. The Fishes of Australia's South Coast, p. 147-149. *In:* The Fishes of Australia's South Coast. M. F. Gomon, Glover, J.C.M. & Kuiter, R.H. (ed.). State Print, Adelaide, Australia.
GORDON, I. E. 1992. Preliminary Report on Captive Pre-Mating Behaviour of Grey Nurse Sharks (*Eugomphodus taurus*)., p. 1-7. *In:* Unpublished Manuscript.
—. 1993. Pre-Copulatory Behaviour of Captive Sandtiger Sharks, *Carcharias taurus*. Environmental Biology of Fishes. 38 (1-3) :159-164.
GOVENDER, A., KISTNASAMY, N. & VAN DER ELST, R.P. 1991. Growth of Spotted Ragged-Tooth Sharks, *Carcharias taurus* (Rafinesque) in Captivity. South African Journal of Marine Science. 11:15-19.
GOWAN, L. K., REINING, J.W., SCHWABE,C., BEDARKAR,S. & BLUNDELL, T.L. 1981. On the primary and tertiary structure of relaxin from the sand tiger shark (*Odontaspis taurus*). FEBS (Federation of European Biochemical Societies) Letters. 129(1): 80-82.
GRANT, E. 1987. Fishes of Australia. E. M. Grant Pty Ltd, Scarborough, QLD. p20-21.
GRUBER, S. H. & KEYES, R.S. 1981. Keeping sharks for research. *In:* Aquarium Systems. Chapter 14. A. D. Hawkins (ed.). Academic Press, London.
HALSTEAD, B. W., AUERBACH, P.S. & CAMPBELL, D.R. 1990. A colour atlas of dangerous marine animals. Wolfe Medical Publications Ltd, W.S. Cowell Ltd., Ipswich, England. 192p (p22).
HAMLETT, W. C., EULITT, A.M., JARRELL, R.L. & KELLY, M.A. 1993. Uterogestation and placentation in elasmobranchs. The Journal of Experimental Zoology. 266: 347-367 (p359).
HAMLETT, W. C. & HYSELL, M. K. 1998. Uterine specializations in elasmobranchs. Journal of Experimental Zoology. 282 (4-5) : 438-459.
HAMLETT, W. C. J. 1983. Maternal-fetal relations in elasmobranch fishes. Chapter 3 - Oophagy and Adelphophagy in the Sand Tiger shark, *Eugomphodus taurus.* p137-158. Clemson, South Carolina.
HAMLETT, W. C. & KOOB, T.J. 1999. Aplacental viviparity with oophagy and intrauterine cannibalism, p 420-421. *In:* Sharks, Skates and Rays.
HAMMOND, P. 2001. Extinction fear for Grey Nurse shark, p. 4. *In:* The Courier Mail, Brisbane, QLD. Tuesday July, 31st, 2001.
HARDING, J. H. 1990. Return of the Gray Nurse Shark., p. 30-33. *In:* Sea Frontiers. July\August, 1990 Vol. 36 (4).
HEIM, B. & BOURDON, J. 1997. Carcharias RAFINESQUE, 1810. http://www.elasmo.com/frameMe.html?file=heim/bh-c_tau.html&menu=bin/menu_topics-alt.html
HILL, R. 1997. Media Release - Australia Sounds Shark Alert. The Hon. Robert Hill, Leader of the Government in the Senate & Minister for the Environment, Media Release & Speech 17th December, 1997 (150/97). http://www.environmentgov.au/portfolio/minister/env/97/mr17dec97.html

—. 1999. New campaign to protect the Grey Nurse shark. http://www.erin.gov.au/minister/env/99/mr4dec99.html

HILTON -TAYLOR, C. 2000. 2000 IUCN red list of threatened species. IUCN, Gland, Switzerland. http://www.redlist.org

HOENIG, J. M. & WALSH, A.H. 1983. Skeletal Lesions and Deformities in Large Sharks. Journal of Wildlife Diseases. 19 (1) :27-33.

HOGANS, W. E. & TRUDEAU, D.J. 1989. *Alebion crassus* Wilson, 1932, Copepoda: Caligoida, from the Sand Tiger Shark, *Eugomphodus taurus* (Rafinesque), in the Upper Bay of Fundy. Canadian Journal of Zoology. 67: 774-775.

HORTON, M. 1996. Sea World Shark Program, p. 11. *In:* ARAZPA (Australian Regional Association of Zoological Parks & Aquaria) Newsletter, Issue 27.

—. 1997a. Shark protection in Queensland, p. 11. *In:* ARAZPA (Australasian Regional Association of Zoological Parks & Aquaria) Newsletter. February, Issue 30.

—. 1997b. A Tag and Release Program for Grey Nurse Sharks. Drum and Croaker. 28:17-19.

—. 1999a. Grey Nurse sharks, p. 15. *In:* ARAZPA (Australasian Regional Association of Zoological Parks & Aquaria) Newsletter. February, Issue 41.

—. 1999b. The Vulnerable Grey Nurse Shark. Sea World Research & Rescue Foundation Newsletter, 1999. pp. 7

HUSSAIN, S. M. 1989. Buoyancy Mechanism and Density of Sand Tiger Shark, *Eugomphodus taurus*. Indian Journal of Fisheries. 36 (3): 266-268.

—. 1991. The Behaviour of Sharks in Captivity. Indian Journal of Fisheries. 38 (3): 151-156.

HUTCHINS, B. & SWAINSTON, R. 1986. Sea Fishes of Southern Australia: Complete Field Guide for Anglers and Divers. p22-23. Swainston Publishing., Perth, Australia.

IRELAND, D. 1984. The Grey Nurse Shark., p. 10-13. *In:* Underwater. Vol. 11.

IRION, R. 1994. Killer Siblings., p. 42-47. *In:* International Wildlife. Vol. 24, Issue 2.

JOHNSON, J. 1998. Wildlife Guide to Moreton Bay: Wildlife and Habitats of a beautiful Australian coast - Noosa to the Tweed., p. 263. *In:* Wildlife Guide to Moreton Bay: Wildlife and Habitats of a beautiful Australian coast - Noosa to the Tweed. P. Davie *et al.* (ed.). Queensland Museum., South Brisbane.

JOHNSON, M. D. & ST. AUBIN, D.J. 1995. Tissue Distribution and Serum Levels of selected Enzymes in five species of sharks: *Sphyrna lewini, Prionace glauca, Carcharias taurus, Carcharhinus plumbeus* and *Isurus oxyrinchus*. *In:* Proceedings of the 26th Annual Conference of the International Association for Aquatic Animal Medicine. http://www.ife.org/Internet/research/sharks.cfm

JOYCE, W. N. 1999. Management of shark fisheries in Atlantic Canada. FAO Food and Agriculture Organization of the United Nations Fisheries Technical Paper. 378, Part 1: 74 -108.

KEMP, N. R. 1991. Chapter 15 : Chondrichthyans in Cretaceous and Tertiary of Australia, p. 497-568. *In:* Vertebrate Palaeontology of Australasia. N. R. Kemp (ed.). Pioneer Design Studio, Monash University Publication, Lilydale, Victoria.

KISTNASAMY, N. 1975. Raggedtooth Sharks in the Aquarium. The Tale of Bess and George. p. 27-30. Vol. 11, South African Association for Marine Biological Research, Bulletin.

KROGH, M. 1994. Spatial, seasonal and biological analysis of sharks caught in the New South Wales protective beach meshing programme. Australian Journal of Marine and Freshwater Research. 45: 1087-1106.
KROGH, M. & REID, D. 1996. Bycatch in the protective shark meshing program off South-eastern New South Wales, Australia. Biological Conservation. 77: 219-226.
KUITER, R. H. 1993. Coastal Fishes of South-Eastern Australia., p13-14. *In:* Coastal Fishes of South-Eastern Australia. R. H. Kuiter (ed.). Crawford House Press., Bathurst, NSW Australia.
LAST, P. R. & STEVENS, J.D. 1994. Sharks and Rays of Australia., p. 144-147. *In:* Sharks and Rays of Australia. P. R. S. Last, J.D. (ed.). CSIRO Division of Fisheries.
LIMBAUGH, C. 1963. Field notes on sharks, p72. *In:* Sharks and survival. P. W. Gilbert (ed.). D.C. Heath and Company, Boston.
LUCIFORA, L. O., MENNI, R. C. & ESCALANTE, A. H. 2001. Analysis of dental insertion angles in the Sand Tiger shark, *Carcharias taurus* (Chondrichthyes: Lamniformes). Cybium. 25 (1) :23-31.
LONG, J.A. 1995. THE RISE OF FISHES. UNSW PRESS, SYDNEY. 223PP.
LUMNITZER, A. 2000. The Grey Nurse shark. Fish & Critters., p. 86-87. *In:* Sport Diving, December\January.
MANIGUET, X. 1991. The jaws of death : Shark as predator, man as prey. Random House Value Publishing, New Jersey, USA. p293-294.
MARES, R. J. 1995. Rod-cone ratios and cone characteristics of various chondrichthyan species. *In:* 1995 American Elasmobranch Society Abstracts, Annual Meeting., Edmonton, Alberta.
MARSH, N. 1995a. A Grey Future for the Grey Nurse Shark. Part 1, p. 39-42. *In:* Underwater Geographic. Issue 39, April\June.
—. 1995b. A Grey Future for the Grey Nurse Shark. Part 2, p. 41-43. *In:* Underwater Geographic. Issue 40, July\August.
MARTIN, R. 2001a. Family Carchariidae: Sandtiger Shark - 1 species. ReefQuest Expeditions. http://www.reefquest.com/shark_profiles/carchariidae.htm
—. 2001b. Grey Nurse vs Sandtiger. ReefQuest Expeditions. http://www.reefquest.com/topics/gnurse_v_sandtiger.htm
—. 2001c. Intrauterine Cannibalism in Sharks. ReefQuest Expeditions. http://www.reefquest.com/topics/intrauterine_cannibalism.htm
—. 2001d. Life History and Behaviour of Lamnoid Sharks. ReefQuest Expeditions. http://www.reefquest.com/lamnoid_profiles/c_taurus.htm
—. 2001e. Sandtiger - the Current State of Ignorance. ReefQuest Expeditions. http://www.reefquest.com/topics/sandtiger1.htm
—. 2001f. The Tangled Taxonomic History of the Sandtiger Shark. ReefQuest Expeditions. http://www.reefquest.com/topics/sandtiger_taxonomy.htm
MASUDA, H., K. AMAOKA, C. ARAGA, T. UYENO AND T. YOSHINO,. 1984. The fishes of the Japanese Archipelago., p. 437p (p7). Vol. 1. Tokai University Press., Tokyo, Japan.

MASUDA, H. & ALLEN, G.R. 1993. Meeresfische der Welt - Groß-Indopazifische Region. Tetra Verlag, Herrenteich, Melle. p528 (p24). www.fishbase.org

MCCORMICK, H. W., ALLEN, T. & YOUNG, W.E. 1963. Shadows in the sea. Sidgwick & Jackson, London. 415p.

MCGROUTHER, M. 2001. Australian Fishes in focus - Grey Nurse shark, *Carcharias taurus* Rafinesque, 1810. Australian Museum. http://www.amonline.net.au/fishes/students/focus/grey.htm

MENZIES, S. J. & GORDON, I.E. 1989. Feeding Biology of Grey Nurse Sharks, (*Eugomphodus taurus*) in Captivity., p. 1-8. *In:* Paper presented to the American Elasmobranch Society Seminar on Captive Elasmobranchii, June 1989., Monterey Bay, San Francisco.

MICHAEL, S. W. 1993. Reef sharks and rays of the world. A guide to their identification, behaviour, and ecology. Sea Challengers., Monterey, California. 107p (p48).

MOHAN, P. J. 1996. Using Fisheries Data to Manage the Diets of Captive Elasmobranchs., p. 265-273. *In:* American Zoo and Aquarium Association Annual Conference Proceedings.

MOLLET, H. F. 2001. Demography of the Sandtiger Shark, *Carcharias taurus* (Rafinesque, 1810). http://homepage.mac.com/mollet/Ct/DemographyCt.html

MORRISSEY, J. F. 1995. A summary of ten years of shark taxonomy. *In:* American Elasmobranch Society 1995 Annual Meeting, Edmonton, Alberta, CANADA.

—. 1997. *Odontaspis* vs *Carcharias*. http://www.elasmo.com/frameMe.html?file=selachin/misc/lc-sndtg.html&menu=bin/menu_topics-alt.html

MOULTON, J. M. 1954. The Sand Shark, *Carcharias taurus* from Casco Bay, Maine. Copeia 4 : 296.

MUSICK, J. A., BRANSTETTER. S. & COLVOCORESSES, J. A. 1993. Trends in shark abundance from 1974 to 1991 for the Chesapeake Bight region of the U.S. mid-Atlantic coast. NOAA National Oceanic and Atmospheric Administration Technical Report NMFS 115 National Marine Fisheries Service : 1-18.

MUSICK, J. A., HARBIN, M.M., BERKELEY, S.A., BURGESS, G.H., EKLUND, A.M., FINDLEY, L., GILMORE, R.G., GOLDEN, J.T., HA, D.S., HUNTSMAN, G.R., MCGOVERN, J.C., PARKER, S.J., POSS, S.G., SALA, E., SCHMIDT, T.W., SEDBERRY, G.R., WEEKS, H. & WRIGHT, S.G. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries. 25 (11) : 6-30 (p8).

MUSICK, J. A., TABIT, C. R. & EVANS, D. A. 1990. Body surface area in galeoid sharks. Copeia. 4: 1130-1133.

NAKAYA, K. 1984. Odontaspididae. *In:* Fishes of the Japanese Archipelago. H. Masuda, K. Amaoka, C. Araga, T. Uyeno and T. Yoshino (eds.) Tokai Univ. Press, Tokyo, Japan. 437 p (p7), 370 pls., Tokyo, Japan. www.fishbase.org

NELSON, J. S. 1994. Fishes of the World, p. 51. *In:* Fishes of the World. J. S. Nelson (ed.). John Wiley & Sons, Inc., Edmonton, Alberta, Canada.

OFORI-ADU, D. W. 1988. List of fishes, shellfishes and other marine food resources in the Ghanaian coastal waters. Marine Fisheries Research Technical Paper. Issue 1. : 43p. www.fishbase.org

OGILBY, J. D. 1911. Descriptions of new or insufficiently described fishes from Queensland waters. Annals of the Queensland Museum. 10: 36-58.

OLIVIER, P. A. S., DIPPENAAR, S.M., KHALIL, L.F. & MOKGALONG, N. M. 2000. Observations on a lesser-known monogenean, *Udonella myliobati*, from a copepod parasite, *Lepeophtheirus natalensis*, parasitizing the spotted ragged-tooth shark, *Carcharias taurus*, from South African waters. Onderstepoort Journal of Veterinary Research. 67: 135-140.

OTWAY, N. M. & PARKER, P.C. 1999. Save our sharks, p. 39. *In:* Fisheries NSW. Autumn Edition.

—. 2000. A draft code of conduct for scuba diving with Grey Nurse sharks, p. 1-7, including Survey. NSW Fisheries - Office of Conservation, Port Stephens Research Centre.

OTWAY, N. M. & PARKER, P.C. 1999a. A review of the biology and ecology of the Grey Nurse shark (*Carcharias taurus*) Rafinesque 1810. New South Wales Fisheries Research Report Series 1, New South Wales Fisheries Research Institute: 1-36.

—. 1999b. The distribution and abundance of Grey Nurse sharks in the coastal waters of NSW in November - December, 1998.

OVERSTROM, N. A. 1991. Estimated Tooth Replacement Rate in Captive Sand Tiger Sharks, *Carcharias taurus* (Rafinesque, 1810). Copeia. 2: 525-526.

PARKER, P. 1999. A study of Grey Nurse Sharks (*Carcharias taurus*) in Northern New South Wales., p. 1-60, Southern Cross University, Lismore.

PARKER, P. & BUCHER, D.J. 2000. Seasonal variation in abundance and sex ratio of Grey Nurse (Sand Tiger) Sharks *Carcharias taurus* in Northern New South Wales, Australia: a survey based on observations of recreational scuba divers. Pacific Conservation Biology. 5 (4) : 336-346.

PATERSON, R. A. 1990. Effects of long-term anti-shark measures on target and non-target species in Queensland, Australia. Biological Conservation. 52: 147-159.

PAXTON, J. R., HOESE, D.F., ALLEN, G.R. & HANLEY, J.E. 1989. Zoological Catalogue of Australia, Volume 7, PISCES, Petromyzontidae to Carangidae., p63-64. *In:* Zoological Catalogue of Australia, Volume 7, PISCES, Petromyzontidae to Carangidae. J. R. Paxton, Hoese, D.F., Allen, G.R. & Hanley, J.E. (ed.). Australian Government Publishing Service., Canberra, Australia.

PEDDEMORS, V. 1995. Diver impact on raggedtooth shark distribution and behaviour on the Aliwal Shoal, KwaZulu-Natal., p. 26-27. *In:* Proceedings of the Aliwal Shoal Workshop. M. H. Schleyer (ed.), Amanzimtoti Town hall on 8th June 1995.

PEDDEMORS, V. & ALLEN, B. 2001. Ragged-tooth sharks and recreational scuba diving: socio-economic and environmental implications at the Aliwal Shoal, Umkomaas, KwaZulu-Natal, South Africa. http://www.africam.com/Articles/Features/Conservation/RaggedToothSharksvsHumanDivers/raggedtoothsharksvshumandiversindex.html

PEDDEMORS, V. M. 1996. The Raggies of Aliwal Shoal., p. 50-54. *In:* Divestyle. Sept\Oct.

PEDDEMORS, V. M. & PIENAAR, A. 1997. Raggies to Riches., p. 68-71. *In:* Divestyle. Sept\Oct

PEPPERELL, J. G. 1992. Trends in the Distribution, Species Composition and Size of Sharks caught by Gamefish Anglers off South-Eastern Australia, 1961-1990. Australian Journal of Marine and Freshwater Research. 43: 213-225.

PEPPERELL, J., WEST, J., & WOON, P. 1993. "Sharks Down Under", Proceedings of an International Workshop on the Conservation of Elasmobranchs held at Taronga Zoo, Sydney, Australia, 24 February 1991. Zoological Parks Board of NSW. 147p.

PEREIRA, R. 1982. Peixes de nossa terra. Livraria Nobel, Sao Paulo, Brazil. 129p (p116). www.fishbase.org

PLEDGER, T. & MOHAN, P. 2000. A case history of a severe bite wound and its repair in a juvenile Sand Tiger, *Carcharias taurus.* Drum and Croaker. 31: 25-26.

POLLARD, D. 1998. Shark management and conservation. *In:* Gibble, N.A., McPherson, G. & Lane, B. (eds). Proceedings from the Sharks and Man workshop of the Second World Fisheries Congress, Brisbane, Australia, 2nd August, 1996. Department of Primary Industries, Queensland. p81-85.

POLLARD, D. A. 1990. The Conservation Status of Australian Marine Fishes, Protected fish species in New South Wales with particular emphasis on the Black Cod and the Grey Nurse Shark., p. 28-29. *In:* Australian Society for Fish Biology's Seventeenth Annual Conference, August,1990. Vol. 20 (2). Australian Society for Fish Biology Newsletter, Lorne, Victoria.

—. 1991. Grey Nurse - the World's First Protected Shark? *In:* Sharks Down Under. Woon, P. & Pepperell, J. (ed.). Conference Schedule and Abstracts of the "Sharks Down Under" Conference, February-March, 1991, Taronga Zoo, Sydney.

POLLARD, D. A., LINCOLN SMITH, M.P. & SMITH, A.K. 1996. The Biology and Conservation Status of the Grey Nurse Shark, *Carcharias taurus*, Rafinesque 1810, in New South Wales, Australia. Aquatic Conservation : Marine and Freshwater Ecosystems. 6 (1) :1-20.

POLLARD, D. & SMITH, A.1999. Sand Tiger - Candidate species - *Odontaspis taurus*. The Office of Protected Resources : National Marine Fisheries Service. http://www.nmfs.gov/prot_res/candidate/sandtiger.htm

PRATT, H. L. JR. & CARRIER, J.C. 1998. The Reproductive Behaviour of Elasmobranchs. *In:* 1998 American Elasmobranch Society abstracts, Annual Meeting., Guelph, Ontario, Canada.

PRATT, H. L. JR. & CASEY, J.G. 1990. Shark reproductive strategies as a limiting factor in directed fisheries, with a review of Holden's method of estimating growth-parameters. NOAA National Oceanic and Atmospheric Administration Technical Report NMFS National Marine Fisheries Service. 90: 97-109.

PRATT, H. L. JR. & TANAKA, S. 1994. Sperm storage in male elasmobranchs: A description and survey. Journal of Morphology. 219 (3).

PURDY, R. W. 1990. A Key to the Common Genera of Neogene Shark Teeth. Smithsonian National Museum of Natural History. http://www.nmnh.si.edu/paleo/sharkteeth/

QUEROT, J. C. 1984. Fishes of the North-eastern Atlantic and Mediterranean., p. 75-83. *In:* Fishes of the North-eastern Atlantic and Mediterranean. Vol. 1. P. J. P. Whitehead, Bauchot, M. L., Hureau, J.C., Nielson, J. & Tortonese, E. (ed.). UNESCO., Paris. www.fishbase.org

RAFINESQUE, C. S. 1810. Caratteri di alcuni nuovi generi e nuove specie di Animali e Piante della Sicilia, con varie osservazioni sopra i medisimi. Part 2 (with slightly different title, pp71 - 105). Palermo.:105p. www.fishbase.org

RANDALL, J. E. 1963. Dangerous sharks of the Western Atlantic, p. 356-357. *In:* Sharks and survival. Chapter 11. P. W. Gilbert (ed.). D.C. Heath and Company, Boston.

RANDALL, J. E., ALLEN, G.R. & STEENE, R.C. 1990. The Complete Divers & Fishermen's Guide to Fishes of the Great Barrier Reef and Coral Sea. p. 16. J. E. Randall, Allen, G.R. & Steene, R.C. (ed.). Crawford House Press., Bathurst, NSW, Australia.

RANDALL, J. E., IDA, H., KATO, K., PYLE, R.L. & EARLE, J.L. 1997. Annotated checklist of inshore fishes of the Ogasawara Islands. National Science Museum Monographs (11): 1-74 (p5).

RASMUSSEN, J. M., GARNER, M. M. 1999. Presumptive volatile organic compound intoxication of sharks and teleost fish in a newly constructed aquarium. (Or why fish and paint fumes just don't mix). p. 51-52. *In:* American Zoo and Aquarium Association Annual Conference Proceedings., Minnesota Zoo, Minneapolis, Minnesota.

RASMUSSEN, L. E. L. &. MURRU, F.L. 1992. Long-term Studies of Serum Concentrations of Reproductively Related Steroid Hormones in Individual Captive Carcharhinids. Australian Journal of Marine & Freshwater Research. 42: 273-281.

REID, D. D. & KROGH, M. 1992. Assessment of catches from protective shark meshing off New South Wales beaches between 1950 and 1990. Australian Journal of Marine and Freshwater Research. 43: 283-296.

REINER, F. 1996. Catálogo dos peixes do Arquipélago de Cabo Verde. Publicações avulsas do IPIMAR. Issue 2. 339p (p35). www.fishbase.org

REINIG, J. W., DANIEL, L.N., SCHWABE, C., GOWAN, L.K., STEINETZ, B.G. & O'BYRNE, E.M. 1981. Isolation and characterization of relaxin from the sand tiger shark (*Odontaspis taurus*). Endocrinology. 109 (2): 537-543.

RIEDMAN, S. R. & GUSTAFSON, E.T. 1969. Focus on sharks. Fitzhenry & Whiteside Ltd, Toronto. 256p

RITTER, E. K. 2000. Fact Sheet: Sand Tiger Sharks. International Media Services. http://www.sharkinfo.ch/SI1_00e/ctaurus.html

ROBINS, C. R., BAILEY, R.M., BOND, C.E., BROOKER, J.R., LACHNER, E.A., LEA, R.N. & SCOTT, W.B. 1980. A list of common and scientific names of fishes from the United States and Canada. American Fisheries Society Special Publication (12): 1-174.

ROBINS, C. R. & RAY, G.C. 1986. A field guide to Atlantic coast fishes of North America. Houghton Mifflin Company, Boston, U.S.A. 354p (p18).

ROUGHLEY, T. C. 1966. Fish and Fisheries of Australia. Angus & Robertson Ltd, Sydney. 246p http://www.environment.gov.au/marine/species_protection/sharks/references.htm

RUSSELL, B. C. & HOUSTON, W. 1989. Offshore fishes of the Arafura Sea. Beagle. 6: 69-84 (p79).

RUSSELL, S. J. 1993. Shark Bycatch in the Northern Gulf of Mexico Tuna Longline Fishery, 1988-91, with Observations on the Nearshore directed shark fishery. NOAA National Oceanic and Atmospheric Administration Technical Report NMFS 115 National Marine Fisheries Service.: 19-29.

SABALONES, J. 1995. Considerations on the husbandry of sharks for display purposes. International Zoo Yearbook. 34: 77-87.

SADOWSKY, V. 1970. On the dentition of the Sand Shark, *Odontaspis taurus*, from the Vicinity of Cananeia, Brazil. Bolm Inst. Oceanogr. S. Paulo. 18 (1): 37-44.

SANCHES, J. G. 1989. Nomenclatura Portuguesa de organismos aquáticos (proposta para normalizaçao estatística). Publicaçoes avulsas do I.N.I.P. Issue 14 : 322p (p125). www.fishbase.org

SANFORD, A. M. 1984. Sharks : An introduction for the amateur naturalist.

SANGER, A. 2000. Notice of proposed recommendation - Carcharias taurus - Grey Nurse shark. NSW Government Reference No. PR9, File No. FSC 99/22. (Sanger, A. Chairperson for the NSW Fisheries Scientific Committee). http://www.fsc.nsw.gov.au/recommend/pdf/grey-nurse-shark.pdf

SAUER, W. H. H. & SMALE, M.J. 1991. Predation patterns on the inshore spawning grounds of the squid, *Loligo vulgaris reynaudii* (Cephalopoda: Loliginidae) off the South-Eastern Cape, South Africa. South African Journal of Marine Science.: 513-523.

SCHMID, T. H., MURRU, F.L. & MCDONALD, F. 1990. Feeding Habits and Growth Rates of Bull (*Carcharhinus leucas* (Valenciennes)), Sandbar (*Carcharhinus plumbeus* (Nardo)), Sandtiger (*Eugomphodus taurus* (Rafinesque)) and Nurse (*Ginglymostoma cirratum* (Bonnaterre)) Sharks Maintained in Captivity. Journal of Aquariculture and Aquatic Sciences. 5 (4): 100-105.

SCHWABE, C. 1990. Relaxin, Sharks, and Geneology. *In:* 1990 American Elasmobranch Society Annual Meeting Abstract., Charleston, South Carolina.

SCHWARTZ, F. J. 1991. A Second Record of a Urogenital Sinus Urolith in the Sandtiger Shark, *Odontaspis taurus*. Northeast Gulf Science. 12 (1): 73-74.

SHARPE, A. 1993. Shark downunder : Shark attacks in Australian waters. The Book Company International Pty Ltd. p137-138.

SIMPFENDORFER, C. 1999. Management of shark fisheries in Western Australia. FAO Food and Agriculture Organization of the United Nations Fisheries Technical Paper. 378 Part 1: 425-455.

SIVERSON, M. 1995. Revision of the Danian Cow sharks, Sand Tiger sharks and Goblin sharks (Hexanchidae, Odontaspididae and Mitsukurinidae) from Southern Sweden. Journal of Veterbrate Paleontology. 15 (1): 1-12.

SKINNER, S. 1991. NSW's Grey Nurse Sharks face extinction. *In:* Sun Herald Newspaper, 25th August,1991., Sydney.

SMITH, A. K. & POLLARD, D. A. 1999a. Threatened fishes of the world: *Carcharias taurus* (Rafinesque, 1810) (Odontaspididae). Environmental Biology of Fishes. 56: 365.

SMITH, C. L. 1997. National Audubon Society field guide to tropical marine fishes of the Caribbean, the Gulf of Mexico, Florida, the Bahamas, and Bermuda. Alfred A. Knopf, Inc., New York. 720p (p256-257).

SMITH, M. F. L. 1989a. A case history of shark capture and transportation., p. 1 - 4. Unpublished Report.

—. 1992. Capture and Transportation of Elasmobranchs, with Emphasis on the Grey Nurse Shark (*Carcharias taurus*). Australian Journal Marine & Freshwater Research. 43 (1): 325-343.

—. 1998. Isolated Grey Nurse Shark Pathogens showing Antibiotic Sensitivity. Unpublished Report, R. Garner (*pers. comm.*).

SMITH, M. F. L., FAY, F. MARSHALL, A.L. 1989b. The Use of Ketamav 100 (Ketamine Hydrochloride), Anased (Xylazine Hydrochloride), Reversine (Yohimbine Hydrochloride) and Sodium Bicarbonate in the Immobilization and Transport of the Grey Nurse shark (*Eugomphodus taurus*) and Black Whaler (*Carcharhinus macrurus*)., p. 1-9. Unpublished Report, Sea World Australia Ltd, Surfers Paradise, Queensland Australia.

SMITH, M. L. 1999b. Chapter 17 : Reef sharks and rays., p. 149-157. *In:* Under Southern Seas : The Ecology of Australia's Rocky Reefs. N. Andrew (ed.). University of NSW Press.

SOLJAN, T. 1975. I pesci dell'Adriatico Arnoldo Mondadori Editore, Verona, Italy. www.fishbase.org

SOMMER, C., SCHNEIDER, W. & POUTIERS, J. -M. 1996. FAO species identification field guide for fishery purposes. The living marine resources of Somalia., p. 376p (p62), FAO, Rome. www.fishbase.org

SPRINGER, S. 1948. Oviphagous Embryos of the Sand shark, *Carcharias taurus*. Copeia. 3: 153-157.

—. 1963. Field observations on large sharks of the Florida-Caribbean region., p. 112. *In:* Sharks and Survival. Chapter 3. P. W. Gilbert (ed.). D.C. Heath and Company, Boston.

—. 1990. Odontaspididae, p. 81 - 82 (p81), In : J.C. Quero, J.C. Hureau, C. Karrer, A. Post, & L. Saldanha (eds.) Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). JNICT, Lisbon; SEI, Paris; and UNESCO, Paris. www.fishbase.org

SPRINGER, V. G. & GOLD, J.P. 1989. Sharks in question : the Smithsonian answer book. Smithsonian Institution Press, USA. 187p.

STEAD, D. G. 1963. Grey Nurse and Goblin shark, p. 56-61. *In:* Sharks and Rays of Australian seas.

STEEGE, K. F., MORRISSEY, J.F. & GRIMES, G.W. 1995. Presence of an Incipient Swim Bladder in the Stomach of Sand Tiger Sharks, *Carcharias taurus*. *In:* American Elasmobranch Society 11th Annual Meeting Abstracts, 1995., Edmonton, Alberta, Canada.

STEEL, R. 1991. Common Sand Shark, p. 14. *In:* The concise illustrated book of sharks. Brian Trodd Publishing House Ltd.

—. 1994. Sharks of the World, p. 119-120. Blandford Press Ltd, London.

STEVENS, J. D. 1997. Sharks. Weldon Owen Pty Ltd, Sydney, NSW. 240p.

STOSKOPF, M. K. 1990. Shark diagnostics and therapeutics: A short review. Journal of Aquariculture and Aquatic Sciences. 5(3): 33-43.

STOSSELL, T. 1993. Investigation of the International shark fin trade. http://www.environment.gov.au/marine/species_protection/sharks/references.htm

STRIBLING, M. D., HAMLETT, W.C. & WOURMS, J.P. 1980. Developmental efficiency of Oophagy, a method of viviparous embryonic nutrition displayed by the Sand Tiger Shark, *Eugomphodus taurus*. Bulletin of the South Carolina Academy of Science. 42: 111.
TANIUCHI, T. 1970. Variation in the teeth of the Sand Shark, *Odontaspis taurus* (Rafinesque) taken from the East China Sea. Japan Journal of Ichthyology. 17(1): 37-44.
TAYLOR, R. & TAYLOR, V. 1994. Sharks : Silent hunters of the deep. Reader's Digest, Surry Hills, NSW. 208p.
TAYLOR, V. 1978. The Vanishing Grey Nurse, p. 60-65. *In:* Great Shark Stories. R. Taylor, Taylor, V. & Goadby, P. (ed.). Bantom Books, New York.
THOMPSON, K. S. 1976. On the heterocercal tail in sharks. Paleobiology. 2(1) : 19-38.
TORRES, F. S. B., JR. 1991. Tabular data on marine fishes from Southern Africa, Part I. Length-weight relationships. Fishbyte. 9(1) : 50-53.
TRICAS, T. C., DEACON, K., LAST, P., MCCOSKER, J.E., WALKER, T.I. & TAYLOR, L. 1997. Sharks and Rays. Reader's Digest, Surry Hills, NSW. 288p.
VAN DER ELST, R. 1993. A guide to the common sea fishes of southern Africa. (3rd Ed.). Struik Publishers., Cape Town, South Africa. 398p (p62).
VAN DER ELST, R. P. & ADKIN, F. 1991. Marine linefish: priority species and research objectives in southern Africa. Oceanographic Research Institute Spec. Publication No.1: 132p.
VISSER, J. 1996. The capture and transport of large sharks for Lisbon zoo. International Zoo News. 43: 147-151.
WALSH, M. T.& MURRU, F.L. 1987. Urogenital Sinus Calculi in a Sand Tiger Shark (*Odontaspis taurus*). Journal of Wildlife Diseases. 23(3) : 428-431.
WARNER, C. 1992. Capture Report 13.07.92 - Species *Eugomphodus taurus* (Grey Nurse). Unpublished Report.
WEST, J. 1991. The Australian Shark Attack File with notes on preliminary analysis of data from Australian waters. Shark Conservation Workshop, Taronga Zoo, 1991. http://www.environment.gov.au/marine/species_protection/sharks/references.htm
WHITLEY, G. P. 1940. The fishes of Australia. Part I Sharks, rays, devil-fish, and other primitive fishes of Australia and New Zealand. Royal Zoological Society of New South Wales, Sydney. 280p.
—. 1991. Australian Sharks. O'Neil and other by Claremont Books (1991), Victoria. p33-34.
WINTNER, S. 1996. Tagging at the Natal Sharks Board. NEWSLETTER OF THE IUCN SHARK SPECIALIST GROUP. Shark News 7, September. http://www.flmnh.ufl.edu/fish/Organizations/SSG/7Newsletter/shark7news19.htm
ZANEVELD, J. S. 1983. Caribbean Fish Life. Index to the local and scientific names of the marine fishes and fishlike invertebrates of the Caribbean area (Tropical Western Central Atlantic Ocean). E.J. Brill / Dr. W. Backhuys, Leiden. p2. www.fishbase.org
ZANNOU, L. H. 1985. Liste de quelques espèces animales des eaux marines de la République populaire du Benin., (Manuscript, p6.). Projet des Pêche Maritime Artisanale., Direction des Pêches, Cotonou, Benin. www.fishbase.org

USING GARLIC AS AN APPETITE STIMULANT IN SAND TIGER SHARKS (*Carcharias taurus*)

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Drum and Croaker 35: 59-61. January 2004

Abstract:

For many years, fish keepers have been using supplemental garlic in their fish food for parasitic control and more recently as an appetite stimulant. This study was conducted to observe if supplemental garlic would increase food intake in two anorectic sand tiger sharks (*Carcharias taurus*).

Introduction:

Throughout the centuries, garlic seedpods, *Allium sativum,* have been said to be an effective parasitic control and an old Chinese goldfish remedy (Herwig, 1979). Allicin a.k.a. Diallyl thiosulfinate (*Allium sativum*) is the active pharmaceutical ingredient in garlic. Allicin has anti-bacterial, anti-viral, and anti-fungal properties and controls pathogenic protozoans such as *Cryptocaryon irritans* in saltwater fishes (Cortes-Jorge Jr., 2000), protozoans in freshwater fishes (Bauer, 1958) and internal nematodes (Bartelme, 2003). Garlic also appears to be an appetite stimulant when added to foods (Bartelme, 2003). There are various new food products containing garlic available to aquarists. Garlic Xtreme™, which is 99% *Allium sativum*, is advertised as "a natural attractant for fish and will help cause finicky eaters to take food" (Kent Marine Inc., 2001). Garlic flavor is also being used in sport fishing to attract game fish (Robbins, 2001).

Background information:

The shark exhibit at SeaWorld Adventure Park Orlando is a 660,000 gallon oblong aquarium. The water temperature is kept between 25 and 27 degrees Celsius and the salinity is 30 parts per thousand. The lighting cycle fluctuates with park hours, but the lights are generally left on for about 15 hours per day. The exhibit is home to 50 elasmobranchs, including 19 sand tiger sharks, *C. taurus*. The animals are tong fed twice a week and all feeding data is recorded.

Reviewing the feeding records revealed that two sand tiger sharks, *C. taurus*, were below their weekly targeted food amount. Results from the annual shark physicals confirmed that each shark had lost weight. Because of their low captive-to-wild weight ratio percentage, these animals were chosen for the study. The wild weight was calculated based on the formula:

$$Wt = 2.594\ (10^{-6}) * TL^{3.168}$$

where Wt is the shark's body weight in kg and TL is the total length in cm (Mohan, 2000). Each shark's actual weight was divided by the calculated wild weight to determine the captive-to-wild weight percentage. Sand tiger sharks with captive-to-wild weight percentages between 95% and 120% were considered within the acceptable weight range.

The largest weight for sand tiger A was 108 kg in 1990. Although there were periods of weight gain since 1990, the shark's weight had slowly declined, especially in the last three years. Between March 3, 2002 and April 4, 2003, sand tiger A lost 14 kg. At the start of this study, the shark weighed 73 kg and had a captive-to-wild weight percentage of 80%.

The largest weight for sand tiger B was 74.5 kg in March 2002 with an approximate captive-to-wild weight percentage of 90%. One year later, the shark's weight decreased to 70.6kg with a captive-to-wild weight percentage of 85%.

Procedure:

The study was conducted in the late spring/early summer and the weekly feeding data from January to March 2003 (pre-study) was compared to the weekly feeding data during the study (April to July 2003).

The targeted food amount for these two sharks is 4% of their body weight per week. For sand tiger A, the amount is 3.2 pounds per feeding and, for sand tiger B, 3.1 pounds per feeding.

Prior to feeding, approximately 1 cc of minced garlic (Spice World Minced Garlic; Spice World, Inc. Orlando, FL 32809 and McCormick California Style Minced Garlic; McCormick & Co., Inc Hunt Valley, MD 21031-1100) per pound of food was injected to the prepared whole fish food. The prepared fish food included salmon (*Salmo salar*), bonita (*Katsuwonus pelamis*), herring *(Clupea sp.*) and Pacific mackerel (*Scomber japonicus*). The prepared food was supplemented with Mazuri™ vitamins (Type: Maz Vit-Zu Sharks/Rays II; Product # 0053454; Address: 1050 Progress Drive, Richmond, IN 47374) then fed to the two sand tigers on the normal feeding schedule. During the study, behavioral observations of the sharks feeding as well as the amounts fed were recorded. This protocol was followed for 13 weeks.

Results:

Sand tiger A began eating on day one of the study almost immediately as the food entered the water. After consuming the food with minced garlic, the shark continued to eat during the entire feeding. Throughout the entire study period, sand tiger A continued to eat near or above its targeted food amount. It refused to eat only once on the day it was weighed, which was almost two months into the study period.

Sand tiger B declined to eat any food during the first month of the study and never consistently ate its targeted food amount. When the shark did eat, it would consume the garlic-injected food and return for more. Because of sand tiger B's continued inappetence, approximately two months into the study, the animal was given an oral steroid (Prednisone, 2.3mg/kg) as an appetite stimulant. The steroid did not appear to affect its feeding behavior.

Although minced garlic continued to be injected into the food, the shark's appetite remained sporadic.

Tables: Sand tiger food consumption. Jan-March = before garlic was introduced (pre-study). April-July = the study period.

Total amounts of food consumed

Sand tiger	Target amt. for 13 weeks	Jan-March total	April-July total
A	83.2 lbs	46.5 lbs	75.9 lbs
B	80.6 lbs	43.9 lbs	31.6 lbs

Average amount of food consumed per feeding

Sand tiger	Target amt. per feed (4%)	Jan-March avg. amt.	April-July avg. amt.
A	3.2 lbs/feed	1.8 lbs/feed	3.0 lbs/feed
B	3.1 lbs/feed	1.7 lbs/feed	1.3 lbs/feed

* Sand tiger B did not eat during the first 5 feedings of the study.

Average amount consumed excluding fasting days

Sand tiger	Jan-March avg. amt	April-July avg. amt.
A	2.4 lbs/feed	3.0 lbs/feed
B	2.1 lbs/feed	2.4 lbs/feed

Conclusion:

During this 13-week study period, Sand tiger A increased the frequency of feeding days and increased the amount of food per feeding when offered garlic-injected food. Sand tiger B also increased the amount of food consumed on certain individual days but overall decreased its food intake. Since the cessation of the garlic additions, Sand tiger A has continued to consume its targeted food amount during most weeks. Sand tiger B has continued to eat sporadically.

Acknowledgements:

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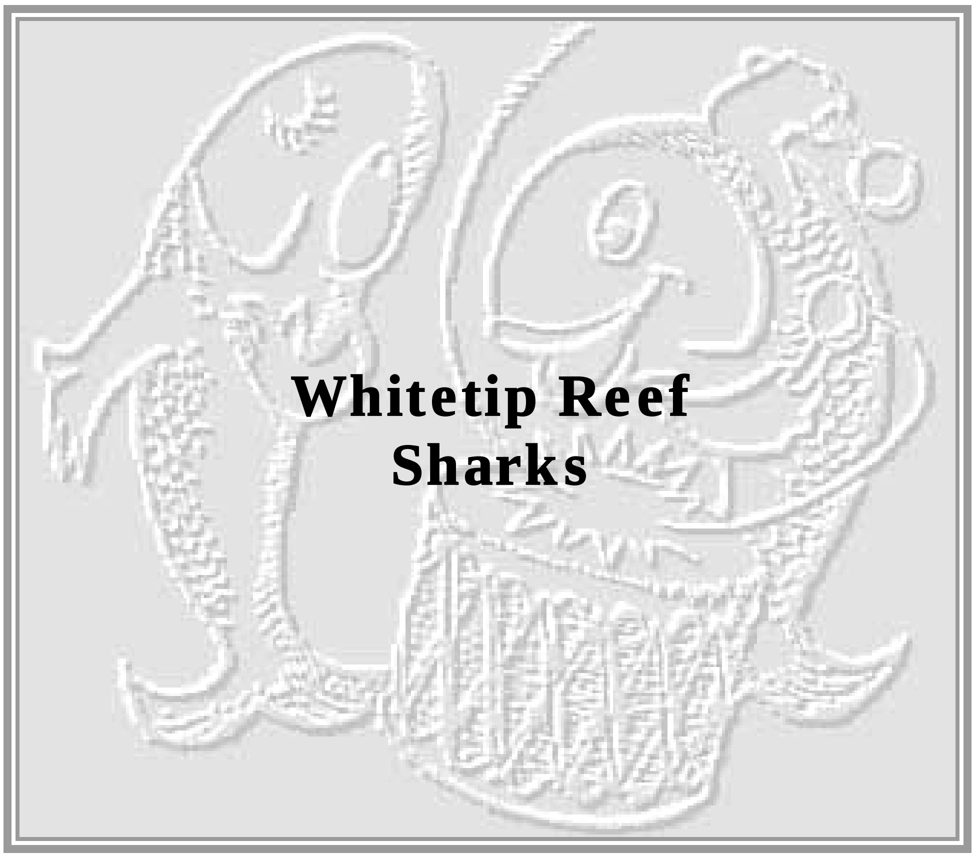

Whitetip Reef Sharks

SECOND GENERATION WHITETIP REEF SHARKS AT SEAWORLD SAN ANTONIO

Joe Keyon, Curator of Fishes

Drum and Croaker 33: 30. February 2002

Four whitetip reef sharks (*Triaenodon obsesus*) – three female and one male – were born on the evening of June 17, 2001. This is a significant event for us because the mother was born under our care back in July 1995. *T. obsesus* are viviparous and have 1 to 5 pups per litter, ranging in size from 50 – 60 cm. Adults reach sexual maturity at about 110 cm and can grow to be roughly 160 cm.

The pups, which averaged 50 cm at birth are fed daily with a variety of shrimp and cut fish. Since 1998 we have had over 30 whitetip pups, but this is the first group of second-generation whitetips at our park. Other births this year have included a pair of spotted eagle rays (*Aetobatus narinari*).

OBSERVATION OF WHITETIP REEF SHARK (*Triaenodon obesus*) PARTURITION IN CAPTIVITY

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Drum and Croaker 35: 13-17. January 2004

Abstract

At the Steinhart Aquarium a female whitetip reef shark (*Triaenodon obesus*) gave birth to four pups while under 24 hour video monitoring system observation. The birthing process is described for three of the four pups including the pup presentation at the adult cloaca through expulsion of placenta and umbilical cords. Included is a record of adult female parturition behavior during birthing, time of significant birthing processes and time of initial presentation of pups.

Introduction

Reproduction of placental and aplacental viviparous elasmobranches in captivity is becoming more prevalent (Uchida et al., 1990; Michael, 2001). However, there is a paucity of information describing captive elasmobranch parturition and accompanying behavior in detail. This paper addresses a normal captive parturition which could be used as an aid to guide husbandry and veterinary staff in what to expect before, during and after parturition both for the adult female and neonates. The birth would be considered normal because all pups were born alive and the female had no complications during birth.

A majority of captive whitetip reef shark parturition occurs overnight (Uchida et al., 1990; Garner, 1998). This means the observation of parturition is infrequent due to the low number of staff in facilities at night. Under these circumstances, the ideal way to observe captive parturition includes the following equipment: an underwater camera designed for low light, some low light over the tank and a video recording system.

A 24 hour underwater video camera system with 87 degree field of view (Subsea Video Systems, Inc, Elizabeth City, North Carolina 27909, USA) and a 24 hour time lapse video cassette recorder that imprints the date, hours, minutes and seconds on tape (Sanyo Electric Co., LTD., Japan, Model TLS-924) was professionally installed at the Steinhart Aquarium. The husbandry staff was able to observe a shark birth without human interference thanks to the installation of this underwater video monitoring system. The described observations and behaviors are a result of watching the recorded birth on camera.

Shark Transfer/Birthing Pool

The decision that the female whitetip reef shark was gravid was made based on observed mating wounds from May 2nd to May 10th of 2002 and a subsequent swelling of her abdomen.

Mating in the whitetip reef shark has been observed both in the wild and captive environments (Uchida et al., 1990; Tricas and Le Feuvre, 1985) and was determined to have occurred in this adult female due to open wounds seen on her gill slits and surrounding skin.

The female was caught from the main shark exhibit, transferred and isolated in a 44,000 liter pool on March 25, 2003 to prevent predation on the female and expected pups. The shark birthing pool was 6 meters in diameter and 1.5 meters deep. The water quality was maintained at 25.6 degrees Celsius with a pH of 7.1-7.2, salinity of 32-34 ppt and the water was tested for ammonia, nitrite and nitrate with no trace amounts detected. A set of five PVC pipes were placed in the tank in order for the pups to hide after the adult's parturition. On July 4th, 2003 the female whitetip reef shark gave birth to four well developed female pups.

Parturition Observations

At 10:38pm the female was observed swimming with a swollen, dilated cloaca and her pelvic fins noticeably farther apart. She was swimming at her normal speed and her condition remained the same until 10:45pm when she stopped swimming and lay down to rest, she was not seen resting again until after completion of the birthing process. At 10:47pm she resumed swimming and by 10:49pm the first sign of embryonic material was seen being eliminated from the cloaca. From 10:49pm to 10:55pm there were several occasions of the female twisting quickly, swimming in quick bursts of speed and occasions of body contortion resulting in hitting her abdomen on the pool floor.

At 10:53pm the first sign of a pup was apparent with the cloaca expanded to allow for the pup's caudal fin to protrude. The pup presented itself upside down with the ventral surface in contact with the birthing female's ventral surface. The pup's caudal fin and body continued to slowly protrude farther out of the adult's cloaca especially after bursts of visible torsion of her body. The female's behavior included some violent 180 degree turns, occasional bursts in increased swimming velocity and occasional physical contact with the pool bottom. At 10:59:38pm, the caudal, anal, second dorsal and pelvic fins were apparent (see images below).

At 11:03pm, the first pup was expelled with an accompanying quick patterned swim of the adult. The pup landed head first onto the pool bottom and within two minutes it began to swim. The umbilical cord and placenta were not attached to the pup. Both of the pup's pectoral and pelvic fins were slightly folded towards the pool bottom. The pup initially swam with irregular patterns mostly in the mid-water column. However, the pup's swimming quickly

became more patterned with several minutes of swimming and then several minutes of resting on the bottom. The pup's behavior only changed when the female came close to it, then the pup swam quickly away from the female. There was no attempt from the female to consume the pup.

At 11:05pm the second pup became apparent at the female's cloaca with only the pup's caudal fin exposed. By 11:09 pm the second pup's caudal fin was exposed then with a quick movement the pup's anal fin and second dorsal became exposed. The chorionic membrane was seen trailing with the pup's caudal/anal fins from the birthing female's cloaca (the chorionic membrane looks like brown cellophane). At 11:10pm the female was contorting her body and shaking with very quick bursts of swimming speeds. On occasion she was observed hitting her abdomen and the exposed part of the pup's body onto the pool floor.

By 11:18:23pm the second pup was almost entirely hanging out of the birthing female's cloaca. The female continued to swim in occasional quick bursts, occasionally rolling on her side and hitting her abdomen and pup onto the pool floor (see right image). The female performed an abrupt 180 degree turn and at 11:18:39pm the second pup was born and landed onto the bottom of the pool. There was no initial attempt made by the pup to swim or avoid hitting the bottom of the pool. Within one minute the second pup was observed swimming with pectoral and anal fins folded slightly towards the pool bottom.

At 11:19pm the third pup's caudal fin was seen protruding from the cloaca. The adult continued to swim in clockwise circular patterns with less variation than previously observed. There were many occasions of her swimming out of camera view and she did not stop her circling for several minutes. At 11:23 pm the caudal, anal and second dorsal fins became apparent. Due to her swimming patterns the birth of the third pup was off camera and there was no observation of the actual birth.

The fourth pup's caudal fin and body were seen protruding at 11:32pm. The adult's behavior became repetitive almost pacing along the sides of the pool, although she performed a quick 180 degree turn. The pup was shaken and pushed farther out the cloaca during this turn. She did not appear to rub on the bottom of the pool, and her swimming direction did not appear to vary.

At 11:42pm the fourth pup was expelled from the cloaca entirely. The pup quickly fell to the pool bottom with no umbilical cord or placenta attached. The umbilical cords and placenta were expelled by the adult quickly after the pup was completely out of the cloaca. All pups were seen swimming at this time, the first three swam in a normal swimming pattern with fins more erect than previously observed. The fourth pup's head and caudal fin were lower than the dorsal areas and appeared slightly curled towards the pool bottom. The pup's body straightened out within one hour.

The female was removed from the parturition tank at 9:00am. The adult was reintroduced to the exhibit without sustaining injury upon reintroduction and began to voraciously feed within 24 hours. At 10:00am a physical inspection was performed on the pups: they were sexed and an examination of their umbilical wounds was completed. The wounds were superficially open, but no blood, redness or remainder of the umbilical stalk was present. Tonic immobility did not occur, as they struggled even when turned upside down. They were identified by their spots, however, the spots did change in contrast within the next week; some spots became lighter, some became darker. The pups seemed healthy and began to feed on small pieces of fish within four days.

Discussion and Suggestions

Captive breeding of the whitetip reef shark has occurred in several facilities (Uchida et al., 1990; Garner, 1998) and is becoming a more common occurrence. This is due to the improvements in elasmobranch husbandry, tank design and nutritional requirements. If these trends continue, the reproduction of elasmobranches will inevitably need the support of shared communication about birthing cycles. The tendency towards cooperative learning and perhaps improved descriptions of parturition could lead to an increase of survival of adults and pups, not only during normal parturition but also during abnormal births. The more we recognize the trends in normal versus abnormal partition the easier it would be to make an educated decision as to whether there is a need to intervene.

In retrospect, there are a few improvements that could be made with the management of this animal and video system. There were a few times that the female was off camera due to the width of view; this could be remedied by installing a second camera or a camera with a wider lens. The 24 hour system worked for overnight observations, but there was an expected loss of video quality due to the time lapse system. The tapes are also constantly taped over (due to an automatic rewind system) and this also reduces video quality. The use of computer systems hooked up to the underwater camera that could record the video in digital format and saved for review might be more useful, if the computer has enough memory.

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References

Castro, J. and Wourms, J. (1993) Reproduction, Placentation, and Embryonic Development of the Atlantic Sharpnose Shark, *Rhizoprionodon terraenovae*. Journal Morphology 218: 257-280.

Garner, R. (1998) Captive Breeding of the Whitetip Reef Shark, *Triaenodon obesus*. Thylacinus 22(2): 16-17.

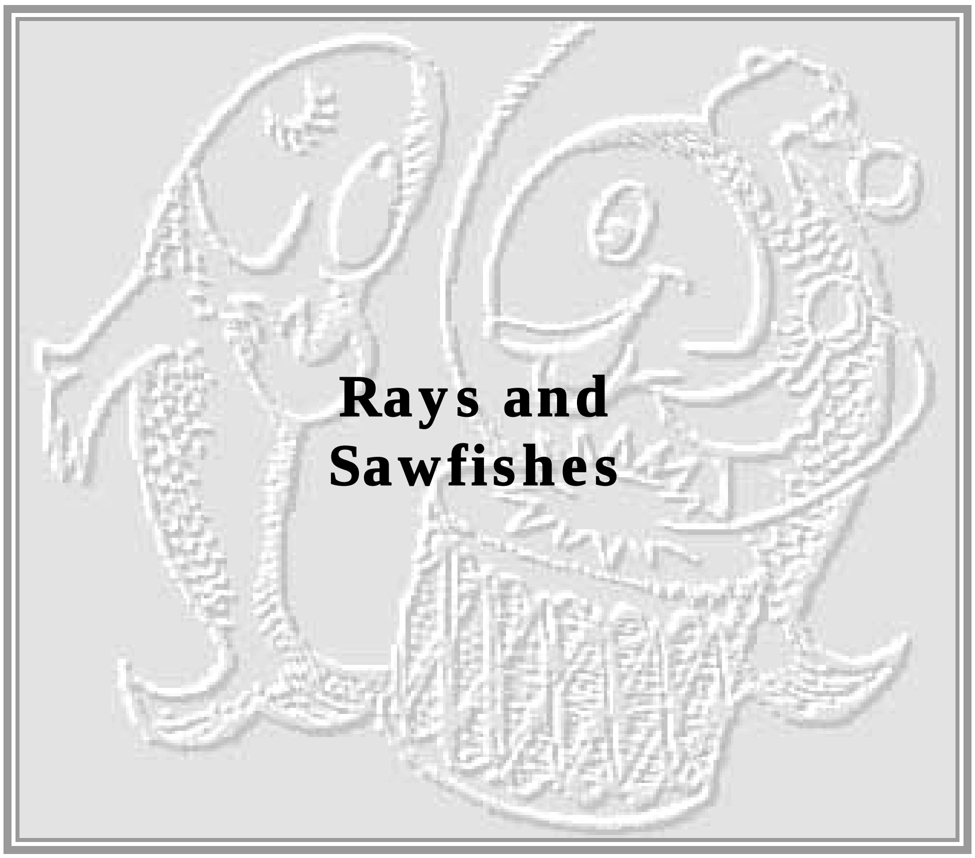
Michael, S. (2001) Aquarium Sharks and Rays. New Jersey: T.F.H. Publications, Inc.

Otake, T. (1990) Classification of Reproductive Modes in Sharks with Comments on Female Reproductive Tissues and Structures. In: Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of Fisheries. NOAA Technical Report 90(1990): 111-130.

Randall, J. E. (1977) Contribution to the Biology of the Whitetip Reef Shark (*Triaenodon obesus*). Pacific Science 31(2): 143-164.

Tricas, T. C. and Le Feuvre, E.M. (1985) Mating in the reef white-tip shark *Triaenodon obesus*. Marine Biology 84: 233-237.

Uchida, S., Toda, M., and Kamei, Y. (1990) Reproduction of Elasmobranchs in Captivity. In: Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of Fisheries. NOAA Technical Report 90(1990): 211-237.



Rays and Sawfishes

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SUMMARY OF THE CAPTURE, HUSBANDRY, AND RELEASE OF MANTA RAYS (*MANTA BIROSTRIS*) MAINTAINED AT ATLANTIS RESORT, BAHAMAS.

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Elasmobranch Husbandry Symposium

Capture of manta rays

The capture of manta rays (*Manta birostris*) was spearheaded and executed by Todd Kemp, senior collector at Atlantis, Bahamas. Capture crews included at least four persons and as many as seven individuals. Many expeditions yielded no sighting of specimens. When sighted, all manta rays were caught within 1.6 km of Rose Island, Bahamas, in <3.0 m of water. Capture conditions have been summarized in Table 1.

Table 1

Collection and release of manta rays (*Manta birostris*) by the team at Atlantis, Bahamas, showing specimen size, date, moon phase, and geographic location.

Specimen	Size (m)	Date	Moon Phase	Operation
1 - "Oscar"	2.13	19.Jul.2000	Waning Gibbous	Collected in "Manta Bay".
	3.43	3.Oct.2001		Released with helicopter.
2 - "Minnie"	1.91	11.Jul.2001	Waning Gibbous	Collected in "Manta Bay".
	1.96	1.Sep.2001		Released.
3 - "Bubbles"	2.36	23.Oct.2001	Waxing Cresent	Collected off Frosty's Cove.
	3.58	24.Sep.2003		Released with helicopter.
4 - No name	2.44	27.Jun.2002	Waning Gibbous	Collected off Frosty's Cove.
	2.26	16.Jul.2002	Waxing Cresent	Collected South of Large Sandbar Reef.
	2.26	9.Aug.2002		Released.
5 - "Rose"	2.08	30.Sep.2003	Waxing Cresent	Collected South of Large Sandbar Reef.

Once spotted, specimens were encircled using a 122 meter multifilament beach seine net. Due to the excessive length of the net, two people would enter the water and purse the section of net containing the manta ray by joining the lead and cork lines. Other members of the crew would then haul in the pursed portion of the net and place the manta ray directly into the boat's live well. Transport times were typically ~1.0 hours.

On arrival at Atlantis, specimens were transferred to the Ruins Exhibit in a plastic tarpaulin stretcher by four crew members. All specimens were a little pallid on introduction. Specimens would bump into obstructions for <0.5 hours and then start to navigate the exhibit without incident thereafter.

Table 2

Husbandry record for manta ray *(Manta birostris)* specimen 1 ("Oscar") maintained at Atlantis, Bahamas.

Date	Day	Husbandry
19.Jul.2000	1	Capture Location: Rose Island Conditions: 3.7 m depth, 0.8 km offshore. Catch gear: 122 m multifilament net Vessel: Anderson 7.6 m. Transport: 2.5 m^3 "livewell" Crew: 6 Specimen Size: 2.13 m Specimen Weight: ~113 kg Gender: Male Exhibit size: 10,200 m^3 Occupants: 13,000 animals, 150 species (e.g., silky sharks, cobia, etc.) Behavior: bumped obstructions for 20-30 minutes, navigated well after ½ hour, jacks flashing on skin
23.Jul.2000	4	Behavior: 1st time ingested food with turkey baster (cloud through gill slits/ open mouth) Food: 1.36 $kg.day^{-1}$ *Euphasia superba* and *E. pacifica* Note: approach - from top / side, scared away - from below / front approach
28.Jul.2000	9	Behavior: entanglement with diver's hoses Note: from here on separated whenever vacuuming
3.Aug.2000	15	Behaviour: feeding with baggie, animal now approaching diver, manta following bubbles, barrel rolls Food: 5.4 $kg.day^{-1}$
12.Aug.2000	24	Behaviour: began luring specimen to surface w/ snorkeller Food: increased to 10.9 $kg.day^{-1}$ (7.3 kg *E.superba* , 3.6 kg *E. pacifica*)
18.Aug.2000	30	Behaviour: feeding on surface w/ ladle on pole, exhibiting barrel rolls on surface, stomach distended! Food: decrease to 5.4 $kg.day^{-1}$
1.Jan.2001	166	Food: amount became constant 7.3 $kg.day^{-1}$ (4.6 kg *E. superba* , 2.7 kg *E. pacifica*) (for 9 mos)
6.Apr.2001	261	Behaviour: rope entanglement Note: healing time ~2 weeks
6.Aug.2001	383	Food: Increased to 9.1 $kg.day^{-1}$
3.Oct.2001	441	Released! Catch gear: barrier seine multi filament (9.1 m x 45.7 m) Vessel: Bell 407 helicopter (used for fire fighting, based in Atlanta, Georgia) + 2.4 m diameter SS ring cargo netting stretcher Transport time: 3 min (exhibit to ocean) Specimen size: 3.43 m wingspan + 1.56 m mouth to base of tail + 0.25 m cephalic lobe Specimen Weight: ~340-360 kg

Details of manta ray exhibit

The Ruins Exhibit, where the manta rays were maintained, was an L-shaped exhibit of 10,200 m^3 volume (183 m x 9.1 m x 4.6 m deep). The exhibit contained numerous large "artifacts" as décor, around which the manta rays successfully navigated. Other inhabitants of the exhibit included jacks, snappers, grunts, eagle rays, and pacific blacktip sharks.

Feeding of manta rays

Manta rays were initially fed using a turkey baster, and then a plastic "baggie", with a slurry of krill (*Euphasia pacifica* and *E. superba*). The aquarist feeding the specimen would swim above and slightly ahead of the manta, so the animal would associate food with both staff members and a particular area of the exhibit. Thereafter specimens were lured closer to the surface of the exhibit by feeding from a Tupperware container attached to the end of a 3.1 m aluminum pole. The food was given in a sweeping motion, in front of the manta's open mouth, with care being taken to ensure that no contact was made between the specimen and the feeding pole. The feeding platform was ~4.6 m long and 1.5 m above the surface of the water, allowing a good vantage point to view specimen approach and feeding behavior. Specimen 1 ("Oscar") was successfully feeding at the surface within 30 days, while specimen 2 ("Minnie") was feeding at the surface after only 11 days; similar to the 10-14 days observed by Uchida (pers com.) at the Okinawa Expo Aquarium, Japan.

Specimens were fed twice a day, after the 9:00 AM and 3:00 PM general feeding of the exhibit. Following information from Nishida (pers com.) that a 2.3 m female manta ray at the Osaka Aquarium (Japan) was successfully fed 1.5 $kg.day^{-1}$ for 10 months, food rations were generally started at ~1.5 $kg.day^{-1}$. Food ration steadily increased to a maximum of 4.5-9.0 $kg.day^{-1}$, before specimens became too large for the exhibit and were released.

Tables 2 and 3 give more details of the feeding behavior and feeding rations applied to the first two manta ray specimens maintained at Atlantis. Table 4 gives details of the growth rate of the first manta ray specimen maintained at Atlantis.

Release of manta rays

Manta rays were released while healthy, before they could outgrow the exhibit and harm themselves on the exhibit walls. Two of the larger manta rays (~3.6 m) were released using a helicopter. On two occasions, two specimens were simultaneously maintained on display. On both occasions one of the manta rays had to be released as feeding of a specimen was complicated by the disruptive behavior of the other specimen. The longest period of time that a manta ray was successfully maintained on display was almost two years (Table 1).

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Personal communications

Nishida, K. 2001. Ring of Fire Aquarium, Osaka, Japan.

Uchida, S. 2001. Okinawa Expo Aquarium, Okinawa, Japan

Table 3
Husbandry record for manta ray (*Manta birostris*) specimen 2 ("Minnie") maintained at Atlantis, Bahamas.

Date	Day	Husbandry
11.Jul.2001	1	Capture location: within 18 m of specimen 1 capture site. Vessel: Sea keeper Transport: 7.6 m^3 "livewell" Crew: 5 Specimen size: 1.96 m wingspan Specimen Weight: 90.7 kg Gender: female
16.Jul.2001	5	Behavior: baggie feeding, two personnel required, one to pole feed "Oscar" and another to baggie feed "Minnie" simultaneously Food: 1.8 $kg.day^{-1}$
22.Jul.2001	11	Behavior: surface feeding alternating with larger animal using ladle on pole, observed near collisions with other manta
6.Aug.2001	26	Behavior: abnormal, collision with other manta, bursts of speed, swimming in shallow areas of exhibit Food: Increased to 4.5 $kg.day^{-1}$
1.Sep.2001	52	Released! Behaviour: swam into shallows, bumping and rubbing, quarantined, showed no improvement

Table 4

Growth rate for manta ray (*Manta birostris*) specimen 1 ("Oscar") maintained at Atlantis, Bahamas.

Date	Day	Wingspan (m)
19.Jul.2000	1	2.13
23.Jan.2001	188	3.00
6.Apr.2001	261	3.18
3.Oct.2001	441	3.43

SUCCESSFUL SPOTTED EAGLE RAY (*Aetobatis narinari*) BREEDING PROGRAM AND DETAILS OF AN ASSISTED BIRTH

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Elasmobranch Husbandry Symposium

Abstract

Underwater World Singapore has had a successful eagle ray breeding program for several years, with up to 4 offspring being born each year. The various details of the program will be discussed, and compared with results from the breeding programs at Sea World of Texas and Okinawa Expo Aquarium.

In July 2000 a pregnant female experienced a blocked birth where part of the birth canal was being pushed out of the cloaca. The female appeared distressed so she was removed from the display tank to a small holding area and Dr. Chua examined her. He diagnosed the problem with the birth canal and pushed the herniated tissue back inside the cloaca. The birth occurred soon afterwards. The single offspring was large (54 cm wingspan), and the mother and offspring were healthy with only one correctable complication.

Introduction

Underwater World Singapore has been in operation for over 10 years and is a popular attraction in the area. Our feature attraction consists of two large oceanariums that have an acrylic tube running down the middle. The tanks are both long and thin (roughly 10 meters by 40 meters) providing a long swimming avenue. The smaller one is the 'reef' tank, holding 1.1 million liters and containing mostly small to medium sized reef fishes. The slightly larger one is the 'shark' tank, holding 1.3 million liters and containing larger sharks, rays, groupers, snappers, and jacks. The two tanks are each serviced by 3 large (10x10 meters) gravity sand filters, ozone skimming, and receive a daily change of 20-30% new seawater from the ocean.

Eagle Ray Breeding

One of the more popular features of our large tanks are the eagle rays, *Aetobatis narinari* (Euphrasen 1790). Records on the early handling of the eagle rays are sketchy, but the first births occurred around 1993-4. The eagle rays were initially kept in the shark tank, and unfortunately the first few offspring were lost to predation. Around 1995 some eagle rays were shifted to the reef tank, where the pups were able to survive until removed to quarantine. Out of our current 12 eagle rays, we have two adult females, one with about a 1.6 meter wingspan, the other about 1.8 meters. Two other adult females were lost in the shark tank about 2-3 years ago due to shark attacks. Accurate records have been kept for the last two years, and in that time our larger female has produced 3 litters - unfortunately all were stillborn pups. These pups appeared full size and near-term. In that same time frame the smaller female has produced three live litters, with 188 days between the first and second and 180 between the second and third. It appears that the gestation period is highly variable dependent on temperature, as compared to breeding programs at Sea World of Texas and Okinawa Expo Aquarium (Uchida et al., 1990) in Table 1. Individual differences may also play a part, as the Okinawa and Singapore data are from one adult female each and the San Antonio data are from two adult females. The size of the captive born pups are all larger than reports on wild born pups, while the litter sizes are all smaller. The captive born sizes are shown in Table 1, which differ from published numbers for wild populations, such as Last and Stevens (1994, birth disk width 26 cm, litter size up to 4) and Bigelow and Schroeder (1953, birth disk width 17-36 cm, litter size 6-10).

Table 1

Gestation period, size, and litter size, compared to temperature, for captive born eagle rays.

Aquarium	Temperature	Gestation period	Birth size (disk width)	Litter size
Okinawa Expo Aquarium	19.8 - 29.4°C	331 - 377 days	50-59 cm	1 - 2
Sea World of Texas	24.0 - 27.2°C	270 - 330 days	40-52 cm	1 - 3
Underwater World Singapore	28.1 - 30.1°C	180 - 188 days	48-54 cm	1 - 3

Until July 2000 all births in Singapore occurred at night so no births had previously been viewed. The newborn eagle rays were generally observed the next morning and were removed to quarantine. They were placed in a 3.5m x 2.3m x .85m quarantine tank. The newborns are initially fed cockles (*Anadara granosa*), a small local bivalve. The cockles are deshelled and force fed to the newborns until they become accustomed to feeding from the aquarist's hand. They are gradually shifted to crushed cockles, then whole cockles with squid and fish added to the diet.

Once they are very comfortable being hand fed, we transferred them to our reef tank. We watch the newborns closely for any injuries and ensure they are feeding. They initially like to stay right at the water inlet for the tank, which makes individual feeding convenient, as that is next to the walkway. A basket of cockles is left next to the inlet and the newborns quickly learn to feed there, in addition to feeding from the aquarist's hand. Their habit of continually swimming into the water inlet uses a lot of energy and even when they are feeding well they get thin, so we will transfer them back to the quarantine tank to get their weight back up. They gradually get accustomed to swimming throughout the tank and feeding from the diver, which means competing with all the other fish in the tank. Since we started this system we have lost only one of the four live born pups.

One strange occurrence is that all the pups born in the last two years, and the two surviving captive born eagle rays from before, are males. Sea World of Texas experienced a mixture of sexes, so the cause of this biased sex ratio is unknown.

Assisted Birth

In July 2000 our smaller female eagle ray appeared to be near term based on the abdominal distension. On 18 July a small piece of dark tissue (finger sized) was trailing from the cloaca. On the next day the extending tissue had enlarged to about fist size, and other fish in the tank were biting at it, causing bleeding. By early afternoon the female appeared distressed and the decision was made to remove her for examination. She was herded into our holding area and allowed handling with little struggling. Frederic Chua, our Veterinarian, diagnosed that the dystocia (difficult birthing) was due to congestion of the reproductive canal wall, leading to inversion of the canal lining out from the cloaca. He pushed the herniated tissue back inside the cloaca, smoothing out the birth canal with a 500 cc glass bottle. The opening of the reproductive tract had not dilated enough for immediate birth, so she was moved to an empty dolphin holding tank, a move that took about 2 minutes. The reproductive tract opening apparently dilated during the move as she gave birth about 1 minute after being released. The single pup was large (54 cm wingspan) and had his whip tail threaded through his gills and knotted up at the end, and this was preventing him from swimming properly . Dr. Chua cut off the end of the tail and pulled the tail out of the gills. It appears fortunate that assistance was needed for the birth because if the birth was at night it is questionable that the pup would have survived until morning. Both mother and pup are now healthy with no lasting problems.

Acknowledgements

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Bibliography

Bigelow, H. G., and Schroeder, W. C.
1953. Fishes of the western North Atlantic. Part 2. Sawfishes, guitarfishes, skates and rays: Chimaeroids, Sears Found. Mar. Res., New Haven 464-465 pp

Last, P.R., and Stevens, J.D.
1994. Sharks and Rays of Australia, Australia: CSIRO, 513 pp

Uchida, S., Toda, M., and Kamei, Y.
1990. Reproduction of Elasmobranchs in Captivity n Elasmobranchs as Living Resources: advances in the biology, ecology, systematics, and the status of the fisheries (Eds. Pratt Jr., H.L., Gruber, S.H., and Taniuchi, T.) NOAA Technical Report NMFS 90, 211-237 pp

HISTORY OF FRESH-WATER STINGRAYS, GENUS POTAMOTRYGON, AT CHESTER ZOO AQUARIUM

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Elasmobranch Husbandry Symposium

Introduction

Prior to the late 1970s only marine stingrays were kept by British public aquaria. Very few fresh-water stingrays were imported into the UK until the mid-1980s. Chester Zoo Aquarium was one of the first collections to exhibit Fresh-water Stingrays. In 1984, the Zoo received the Meritorious Award from The National Federation of Zoological Gardens of Great Britain and Ireland for the first recorded breeding of Fresh-Water Stingrays (species *Potamotrygon reticulatus*) in the UK.

Fresh-Water Stingrays at the Aquarium

The first fresh-water stingray kept at Chester was a lone male *Potamotrygon hystrix*, which arrived in the late 1970s. He grew to a length of 45 cm within a year. The mixed exhibit also contained three South American Arowana (*Osteoglossum bicirrhosum*) and was very popular with the public. After the death of the first ray in the early 1980s, the Zoo obtained 0.2 *P.reticulatus*. One died soon after arrival from a severe infection of the tail tip, a common problem with newly imported rays.

Diet

Adults: prawns, mussel, sprats, lean beef heart and earthworms.

Juveniles can be difficult to get started sometimes going for two weeks without feeding after birth. They will eventually accept small earthworms and once feeding well, are gradually weaned onto the same diet as the adults.

Husbandry

1.2 *P. motoro* are housed in a 50 sq. foot (4.6 sq meters) tank with a water depth of 2.5 ft (0.75 cm). This Aquarium can be viewed by the public from two sides and is part of a 4000 Imperial gallon (18000l) system. Juveniles are housed in a variety of tank sizes, dependant on body size and number of young.

Temperature is kept between 76-82 F (24-28 °C). pH is 7.5 and nitrates are kept below 25 ppm by over-head trickle filtration and a continuous water exchange system.

Breeding program

In order to set up a breeding programme, we obtained 2.0 Fresh-water stingrays, which were later identified as *P. hystrix*. Two further rays were purchased, which were identified as *P.reticulatus*. Chester Zoo now held 2.0 *P.hystrix* and 1.2 *P.reticulatus.* This time, no health problems occurred, and all rays were feeding well on earthworms. After a few weeks, the animals' diet was changed from earthworms to strips of lean beef heart and sprats. *P. reticulatus* fed well on the new food, while *P. hystrix* refused everything except earthworms. Over the next few months, it became apparent that *P. hystrix* could not compete with *P. reticulatus* at feeding times and the animals began to lose condition. Soon after, we lost both male *P. hystrix*.

In July 1982, both female *P. reticulatus* stingrays gave birth for the first time on the same night. Six young were reared from this breeding.

Together with the original female stingray they were sent to London Zoo Aquarium.

The breeding pair of *P. reticulatus* continued to produce 4-8 young every 23-26 weeks. Although remnants of the yolk sac were still visible at 23 weeks - a possible site of infection, all 26-week old young survived.

The last time the pair produced offspring at Chester was in October 1988 when they gave birth to 16 young. In August 1990, the pair, which had not bred for nearly two years, were exchanged with Stapley Water Gardens for two juvenile female *P. motoro*. The pair at Stapley started breeding again after another two years at this collection. A further 1.2 *P. motoro* were received in February 1991 and settled in well with the previous two.

The first young were born in July 1993 and the pair produced a total of 44 young at Chester Zoo (see Table 1).

One of the original female *P. motoro* was returned to Stapley in March 1996 and another female died in October 1997. No births were recorded in the years 1996 and 2000. In June 2001, two of the females born on 01/17/99 were sent to London Zoo Aquarium.

The young male was removed from the tank on the 13/02/01 as soon as sexual interest in his sisters was noticed. 18 weeks later on the 18/06/01, however, young were found unexpectedly, which were the result of the sibling mating.

Of the two remaining adult female *P. motoro*, only one breeds. The other, much larger female is possibly a different morph, *P. garrapa* or *P. henleyi* (see Ross R.A. & Schafer F. (2000) SuBwasserrochen = Fresh-Water Rays.ASC Glaser, Germany).

Two female *P.motoro*, born in 1999, will be kept at Chester, and an unrelated male will be acquired. Breeding them will improve the genetic integrity of the UK population, and allow Chester Zoo to carry on with its breeding success with these fascinating animals.

Table 1

Freshwater rays of the Genus Potamotrygon born at the Chester Zoo Aquarium between 1993 and 2002.

Date of pupping	Male	Female	Unknown	Total of litter
30 Jul 1993	2	3		5
18 Dec 1993	4	1		5
19 Apr 1994	2	2		4
24 Aug 1994			3	3
25 Nov 1994	1	1		2
13 Aug 1995			1	1
25 Nov 1995	2	3		5
13 Aug 1997	1	1		2
23 Jul 1998	3	2		5
01 Jul 1999	1	4		5
18 Jun 2001	3	4		7
Totals	**19**	**21**	**4**	**44**

AMPUTATION OF A FRACTURED SNOUT IN A GIANT SHOVELNOSE RAY (*Rhinobatos typus*) USING CRYOSURGERY

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Elasmobranch Husbandry Symposium

Abstract

A partial amputation of the snout was performed to solve an open fracture in a captive giant shovelnose ray (*Rhinobatos typus*). A mixed technique, cryosurgery and conventional surgery, was used successfully.

Introduction

Cryosurgery is the controlled use of cold temperature to induce cellular death. It is a useful addition to conventional therapy because of its speed, predictability, and avoidance of general anesthesia in many settings. Cryosurgery is commonly used in neoplasia treatment, both in human and in veterinary medicine, but other applications (e.g., treatment of non-neoplasic skin lesions or bumble foot-lesions affecting the feet or toes of birds) are reported.

In fish surgery, conventional techniques are adequate for most situations. In this case due to the peculiar characteristics of the tissues involved it was useful to use cryosurgery as an adjuvant technique.

Case History

In July of 1999 a captive giant shovelnose ray (*Rhinobatos typus*), held in a 5000 m^3 exhibition tank, exhibited an open fracture, localized in the caudal third of the snout.

After being transferred to a big rectangular holding tank (volume: 100 m^3), manual reduction and immobilization with a splint was performed unsuccessfully. Amputation of the snout, anterior to the fracture, was thus considered necessary for continued survival of the specimen.

Due to the nature of the tissues involved-bilateral, poorly-irrigated soft cartilage and central, more-irrigated, denser cartilage, both without skin to aid suturing—a mixed approach was planned. Tissues were destroyed by cryosurgery, with subsequent excision by conventional surgical techniques. In each session, manual restraint was used, with affected tissues out of the water, and no apparent signs of discomfort were observed.

The cryogen was liquid nitrogen using a Cryojem™ applicator. Both probe and spray freezing of the lateral cartilage and spray freezing (size 18) of the central tissues was used. To evaluate tissue reaction, a small semicircular area of the lateral cartilage was submitted to two consecutive freeze:thaw cycles (~2:10 minutes). Within seven days, treated areas became paler and fell off.

Treatment consisted of four sessions at 3-4 week intervals. In each session, nitrogen was applied at 2-3 freeze:thaw cycles (~2:5-10 minutes) and necrotic tissues excised. Nitrogen was applied after larger excisions. These excisions were covered with Vetbond™ tissue adhesive (3M).

Enrofloxacin (Baytril®, Bayer) was administered EOD (every other day) at 15 $mg.kg^{-1}$ IM during the period of major tissue manipulation (until the third session).

The lateral soft cartilage and central thicker cartilage showed different responses to freezing. Lateral tissues became paler in 7-10 days and when excised, showed no signs of hemorrhaging. The denser, central tissue became reddish and formed a thick white scar. Scar tissue fell off in 10-15 days leaving a granulation area with no signs of infection.

Conclusion

A portion of the snout, 10 cm in length, was successfully removed without major infection and with complete cicatrisation of the central area within 1 month.

Freezing the tissue before excision appeared to reduce hemorrhaging and the temporary scar protected the surgical wounds against infection.

References

Stoskopf. M. K. 1993. Fish Medicine. W. B. Saunders Company.

Lewbart, G. A. 1998. Self-Assessment Colour Review of Ornamental Fish. Manson Publishing Ltd.

Withrow, S. J., and MacEwen, E. G. 1998. Small animal clinical oncology. 2nd ed. W. B. Saunders Company.

Carpenter, J. W., Mashima, T. Y., and Rupiper, D. J. 2001. Exotic animal formulary. 2nd Ed. W. B. Saunders Company.

Altman, R. B. 1997. Avian Medicine and Surgery. W. B. Saunders Company.

SAGA OF A SAWFISH

K. Gilbey Hewlett, Curator

Vancouver Public Aquarium

Drum and Croaker 17(1, mislabeled as “2”): 41-43. April 1977

In 1967 a smalltooth sawfish (Pristis pectinatus) was caught in a beach seine near Galveston, Texas. The specimen was four feet long. After a few months at SeaArama the sawfish was moved to the Dallas Aquarium where Jeff Moore showered it with tender loving care for nine years. The sawfish thrived and doubled its length. By the fall of 1976, Jeff decided the animal was getting a bit large and it was time to provide a larger tank. At this point, he arranged to give it to the Vancouver Aquarium.

Gerritt Klay, who had escorted three lemon sharks from Florida to Vancouver in September was commissioned to transport the sawfish. All was arranged. Using one of Gerry's 8' shark boxes, complete with 12 volt submersible pump, batteries and O2 cylinders, the sawfish departed Dallas November 22, 8:00 p.m. with expected arrival in Vancouver 3:00 p.m. Tuesday, November 23. All went according to plan until Los Angeles. It arrived at 10:00 p.m. and was to leave for Seattle at 8:00 a.m.

Gerry Goldsmith of Marineland in Los Angeles met the sawfish at the airport with a tanktruck and 300 gallons of fresh, warm seawater. He stayed the night at the airport with Gerrit and the sawfish. At 6:00 a.m. he called it a night and went home.

As morning rolled around, fog rolled in and the morning flight was canceled. Gerrit sent an SOS to Jerry at Marineland. Back with the truck to take the sawfish, still in its box, to Marineland. Unfortunately, Marineland had no warm reserve seawater tank large enough for the sawfish to get out and "stretch its fins." So the Gerrys gerry-rigged a system to circulate seawater through the shipping box.

Meanwhile back in the frozen north, staff sat and waited, wringing their collective hands trying to figure out what to do and how to do it, and not being able to do anything. In addition, a crew of three waited somewhere in Seattle with a big truck, trying to keep a water change warm in anticipation of meeting the sawfish at Sea Tac Airport and then driving it to Vancouver. Eventually they bought a dozen 50-watt aquarium heaters to keep the water warm.

It was now the evening of the second day (Tuesday, November 23) and preparations were being made at Marineland to take the fish to the airport for a 6:00 a.m. departure an Wednesday morning.

Wednesday morning arrived, the sawfish was ready to be loaded, the fog arrived, the flight was canceled -- again.

The Gerrys returned to Marineland with the sawfish and again rigged up a water system. It was the afternoon of the third day.

Back in the frozen north (Vancouver) after dozens of frantic phone calls, we were prepared for the worst. The sawfish had been in its 8' x 2' x 2' box for 48 hours and was not even half way to its destination.

Finally, at midnight, the sawfish and Gerritt departed Los Angeles for San Francisco where the Steinhart Aquarium staff met the plane with another water change. It was the morning of the fourth day.

Meanwhile in Seattle, the Vancouver Aquarium staff was beginning to show signs of waiting at the airport without money, toiletries, or a change of clothes for three lays. (Under the original plan, they would have been gone 8 hours.)

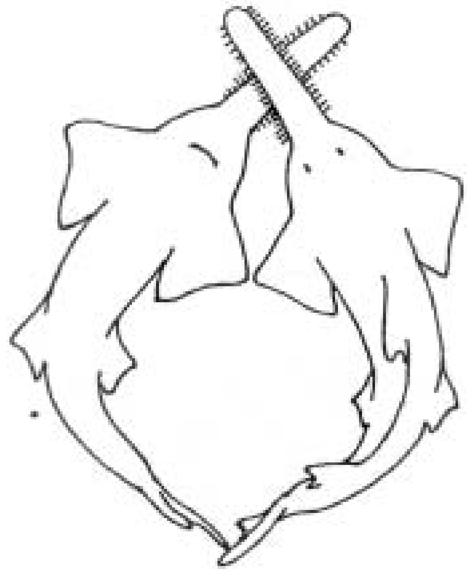
Back in the frozen north (Canada), we had discovered Thursday, November 25, was American Thanksgiving. We found most Americans, including customs brokers were home enjoying turkey dinner. We were frantic to find that, yes, the sawfish would be able to cross the border; however, we would have to leave the box, pumps, water, etc. behind until the customs offices opened the next day.

By now we were prepared to go to the President! Through some high-level international negotiations we convinced the powers that be that United States-Canadian relations will be threatened if the box and water did not come through with the fish.

FINALLY, at 7:30 p.m., Thursday, November 25, the sawfish arrived at the Vancouver Aquarium, 80 hours in transit and ALIVE. By this time the sawfish was a local hero and the press gave it a hero's welcome.

The sawfish is now on display and doing well in a 30,000-gallon pool with three lemon sharks, two jewfish, five nurse sharks and assorted damselfishes. The fact that the sawfish is alive and well today is a credit to the fantastic help it received from so many aquarists along the way.

Royal Order
of the
Sawfish Survival Society Ass.



Bestowed upon Jerry Goldsmith on this
first day of the twelfth month in the nineteen
hundred and seventy sixth year of our Lord
for
outstanding devotion, patience and sobriety in
the face of overwhelming odds and
Los Angeles smog.

Awarded by the staff of the Vancouver
Aquarium, Vancouver, Canada.

HUSBANDRY OF FRESHWATER STINGRAYS

James K. Langhammer, Curator of Fishes

Belle Isle Aquarium, Detroit Zoological Park

Drum and Croaker 19(2): 31-33. Winter 1979

As professional animal exhibitors, you are all aware of the need to establish exhibits which subjectively provide intrigue and titillation for the viewer while simultaneously offering educational and, when possible, recreational outlets. At the Belle Isle Aquarium, we have found the South American freshwater stingrays (*Potamotrygon motoro*) to be perhaps the best all-round exhibit which we have.

Among the positive features of their exhibition are:

1. The family Potamotrygonidae contains the only truly freshwater elasmobranchs in the world.

2. The representative species are the most feared and dangerous freshwater fishes in South America - and perhaps the world.

3. They are large - females being slightly in excess of 70 centimeters in disc diameter as adults - and are very active on exhibit. (A frequent and apparently independently derived observation of viewers is that "they look like flying saucers.")

4. Lastly, we can capitalize on local pride in that Belle Isle has the only captive-bred colony in the world.

The only detraction in their exhibition is that the species are notoriously difficult to maintain in captivity. Which is the purpose of this presentation - to share the experiences which we have had with these rays.

Freshwater rays are very sensitive to the buildup of nitrogenous metabolites in solution. Much failure with them is directly attributable to inadequate water changes. Attention to water changes of no less than 25 percent once per week is perhaps the most important element in the management of freshwater systems for fishes and amphibians. Such water changes are far easier and more economical than reliance on adsorptive materials for contaminant removal. Most adsorptive materials are usually effectively nonfunctional long before they are replaced or reactivated in common practice.

I believe our practice of regular water changes has been the basis of our success with these rays. Our major setback occurred when a new low-pressure blower system was installed to replace our air compressors. Apparently an organic evaporate--either from the PVC tubing or the linkage sealants--poisoned the rays in three different areas of the building. The adult breeders died overnight, and two tanks of juveniles were seriously distressed until massive water changes were made.

These rays are easily sexed, even at birth. Males have the inner edge of the pelvic fins rolled into copulatory claspers. In juveniles, these claspers can be seen in ventral view, but in adults they are enlarged sufficiently to be seen from lateral and even dorsal views.

Copulation has never been observed and recorded in this family, but the onset of breeding is usually evidenced by prominent bite marks around the edges of the female's disc. Breeding activity has usually been during the months of October and November with births following in the spring. Gestation appears to be between four and five months' duration. There have been six litters born at Belle isle, consisting of 20 offspring. Litters have ranged from two to five in number, with the most frequent number being three (i.e., 2,3,4,3,5,3).

These rays can be difficult to induce to feed. Acclimated individuals eagerly eat redworms, nightcrawlers, and fish either alive or dead. Newborn and recently imported specimens pose special problems. The only food our newborns have initially accepted has been mashed minnows. Oddly enough, dead whole or chopped minnows are not accepted until they have been mashed. Once feeding begins, new items are quickly accepted by the babies. Larger rays usually begin feeding on diced whole fish. Established rays are quite proficient at catching live fish between their disc and the tank walls. Interestingly, stomach analyses of wild rays give no indication that fish are ever eaten.

Captive rays are gluttonous feeders, and care must be exercised that all rays are satiated. The slightest hint of the pelvic girdle protruding on the dorsal surface signals trouble. As a precaution, water changes should be increased and the ray watched closely to be sure it receives its share of the food. Rays quickly become tame and will beg for food by splashing at the tank surface. Many rays accept food offered by hand.

Although the bony sting or barb is a formidable weapon, its utilization in captivity probably would require considerable provocation. Most human injuries occur when rays are stepped on by waders. Occasionally, though, while being netted, a frantic ray has been known to embed its barb deeply into a wooden net handle. The force of embedment, the serrated edges of the barb, and the associated venom make resultant human injuries of serious medical concern. Without expert medical care, many deaths have occurred in remote parts of South America due to shock and associated infections.

All things considered, the freshwater stingrays can be important display animals in any aquatic menagerie. However, emphasis must be again placed on the importance of regular water changes to reduce the effect of organic pollution and nitrogenous metabolites on these delicate fish.

BABY STINGRAYS *Dasyatis americana* BORN AT CORAL WORLD

Jim Mayer, Aquarium Director & Curator

Coral World, Coki Point, St. Thomas

Drum and Croaker 21(1): 39-45. May 1984

November 12, 1982

On October 29, 1982, a rare birth occurred in captivity at Coral World, St, Thomas.

"Frisbee", an Atlantic Southern Diamond Stingray (Dasyatis americana) one of Coral World's original residents of the 50,000 gallon reef tank, gave birth to four, nearly perfect shaped "Frisbees" with tails. The pups, two male and two female, measures at birth:

1) wingspan - 24½ cm (9 ½")
2) body (head area to base of tail) - 23 cm (9")
3) tail - 29½ cm (11½")
4) overall body length - 52½ cm (19½")
5) claspers - 1½ cm
6) spine 3½ cm
7) weight 452g (almost 1 pound, 454g-1 lb.)

Coloration of the newborn stingrays shows white juvenile dots on a background of light gray with almost a silver highlighting.

Frisbee, the mother, has a wingspan of approximately 4' 6", is one of four female Diamond Stingrays in Coral World's reef tank. Only six months prior to the birth of the pups, were we able to collect a male, its approximate wingspan is three feet, Frisbee is probably as domesticated as is possible for a stingray. Her behaviour and habits are relatively predictable. However, the last month or so, before giving birth, she had been feeding with voracious aggression - in retrospect, feeding for the future "family".

Two weeks prior to the birth in order to protect the anticipated pups, Frisbee was moved from the reef tank which houses many predators, to a 7,000 gallon octagon isolation tank.

Early morning of October 29, we found four baby stingrays alive and healthy. The pups were perceived to be relatively active and showed interest in feeding.

Two days later, on the morning of October 31, one male was found dead. Apparently, Frisbee had killed this individual pup . Bite marks were found on the dorsal side between the juvenile's eyes. Frisbee was removed from the rest of the pups.

The remaining three juvenile rays are doing well and have accepted eagerly a diet of shrimp and scallop. Frisbee, herself, feeds mostly on different types of fish such as Sprat, Dolphin (the fish, Coryphaena), Bonito, and occasional handouts of shrimp.

At present, Coral World is considering releasing Frisbee. We are curious about Frisbee's adaptability back to the wild. Perhaps, Frisbee will stay around the observation tower at Coral World. If she stays around the tower, and appears not to be doing well, recapture would be easy. Discussions with local Conservation and Fish and Wildlife about proper tagging of this animal are being considered. We, at Coral World, hope that Frisbee's release will be successful and that she in fact, will adapt to her "Natural Hone".

Coral World is involved with many research programs. We have released and tagged many sharks such as Lemons (Negaprion brevirostris), Reefs (Carcharhinus springeri), Tigers (Galeocerdo cuvieri), Silkys (Carcharhinus falciformis), Atlantic Sharpnose (Rhizoprionodon porosus), Blacktips (Carcharhinus limbatus), and Nurse (Ginglymostoma cirratum). The shark captures and taggings are part of a program run in conjunction with National Marine Fisheries Service (NMFS). Many of these animals have been kept at Coral World for various periods of time before release. In addition to sharks, several Spotted Eagle Rays (Aetobatus narinari), have been released without tags. All of these animals, except for the nurse sharks, have been released at sites several miles north of St. Thomas. The release is between Thatch Cay and Little Tobago, latitude and longtitude respectively: 18° 22.5'N, 65° 52.5'W approximately. The nurse sharks are released outside of Coral World's observation tower. Most of the nurse sharks released have been observed frequently outside Coral World's underwater observatory, indicating that these sharks prefer to stay around the observatory for food handouts when our divers feed the fish outside the underwater observatory. Coral World has also released numerous juvenile sea horses in the National Park areas of St. John, U.S.V.I. Other programs at Coral World include Sea Turtle "Head Start" research. Approximately 100 Florida Green Sea Turtles (Chelonia mydas) have been tagged and released in the National Parks of St. John. We hope to find out if these Florida laboratory incubated turtles will "imprint" on St. John's protected beaches or migrate back to Florida beaches.

Earlier this year, Federal authorities brought nine (9) newly hatched Hawksbill Sea Turtles (Eretmochelys imbricata) to Coral World. These individual turtles could not find their way to the sea. Some became stranded in mangrove roots while others were too weak for the journey from beach to sea. Except for the largest Hawksbill, all will be released on St. John beaches around the turn of the year. The remaining Hawksbill will be kept for further growth studies. Developmentally, all of the turtles have done extremely well. Coral World displays all sea turtles to the general public to heighten awareness of this animal's plight.

If we can provide any further information of interest, particularly in this part of the Caribbean, please contact:

Jim Mayer, Aquarium Director & Curator
Coral World, Coki Point, St. Thomas, U.S.V.I. 00802-3299

We are more than willing to improve the state of the art in aquarium sciences.

November 29, 1982

Young of *Dasyatis americana*, Follow-up

We are pleased about the interest, that our announcement has raised, concerning the young of Dasyatis americana. Several inquiries were made about the white spots, temperature at birth, and feeding.

All of the pups showed white spots up until ten days after birth. The main body color of the rays changed from a light gray to a sandy gray the next day. Two days later, the rays assumed a sandy brown color, essentially matching the color of the isolation tank where they were held for a period of two weeks. The juvenile markings transformed from a sequence of white spots to a pale brown before finally fading completely to match the main body color ten days later. Four days later, the three remaining pups were moved to a display pool with a bottom substrate of natural brown sand. The rays have copied this color very closely.

The water temperature at birth and now remains a constant 27°C. Our intake water supply originates at a depth of 60 feet, where the water temperature fluctuates from 26°C. to 28°C., winter to summer respectively.

The three pups seem to live in a dominance related hierarchy. This is most notable at feedings. The most dominant pup (Alpha) is the most aggressive feeder. This particular animal started feeding by hand seven days after birth. After Alpha slows feeding, the second most aggressive pup, (Beta) moves in to feed. This particular animal started feeding by hand 16 days after birth. The least aggressive pup, (Omega), at this point is still reluctant about feeding from our hands.

(continued on next page)

All the pups have grown. One month after birth, the two females and one male measured:

	Alpha	Beta	Omega
1) wingspan	28.1 cm (11")	28.1 cm (11")	26.1 cm (10¼")
2) body (head area to base of tail)	26.1 cm (10¼")	26.1 cm (10¼")	24.8 cm (9 ¾")
3) tail	33.0 cm (13")	32.3 cm (12 ¾")	28.7 cm (11¼")
4) overall body length	59.6 cm (23 ¾")	57.0 cm (23")	53.5 cm (21.0")
5) claspers	N/A	N/A	N/A
6) spine	4 cm	3.8 cm	3.6 cm
7) weight	680g (1½ lbs)	645g	525g

I referred to the white spots on the stingray pups as juvenile markings. It has been noted that adult forms of Rhinoptera develop white spots on the body when subjected to cold water temperatures. I have observed many Elasmobranchs especially many species of sharks to show either light or dark "juvenile" spots. I have never observed these spots in adult forms. However, I have very limited experience with these animals in cold water conditions. While measuring our juvenile Dasyatis americana, their juvenile markings reappeared as faint light tan spots on a dark background. I imagine this coloration showed through as part of a stress situation while taking measurements.

Jim Mayer
Aquarium Director and Curator

OBSERVATIONS OF ROSTRAL TOOTH REGROWTH IN SMALLTOOTH SAWFISH, *Pristis pectinata*

David H. Clippinger, Senior Aquarist
The Living Seas, EPCOT Center, Walt Disney World Resort

Drum and Croaker 24(1): 31-33. January 1993

Sawfish are characterized by a distinctive rostrum armed with a row of slender blade-like teeth on each side. This weapon-like appendage is used to capture fish with side to side sweeps or to rake shellfish from the bottom. Unlike sawsharks whose rostral teeth are constantly replaced by developing teeth arranged in a regular sequence behind the primary tooth, sawfish are born with the number of rostral teeth they will have as adults (Slaughter and Springer, 1968). Sawfish teeth are attached within sockets which are connected to the circulatory canals of the rostrum. This socket arrangement allows for continuous growth of the tooth. (Schaeffer, 1963, Slaughter and Springer, 1968, Shellis and Berkovitz, 1980). There is no apparent means of replacing a tooth if it is totally lost (Schaeffer, 1963). Slaughter and Springer (1968), using preserved Pristis rostrums, observed that damaged teeth often retained a pointed tip but remained shorter than adjacent teeth.

The objective of this study was to observe and document changes in the rostral teeth of smalltooth sawfish to determine if damaged teeth regrow to normal size and shape. Previous studies have relied on dried museum specimens or one-time observations of capture-release animals which do not allow for observing changes that occur over time. The unique environment of The Living Seas reef aquarium provided the opportunity to study three Pristis pectinata in a large simulated habitat.

Methods

The three smalltooth sawfish (Pristis pectinata) used for this study were transported from the Florida Keys to The Living Seas at EPCOT Center in Lake Buena Vista, Florida. The three sawfish, two males and one female, are maintained as part of the Caribbean reef display, a twenty-two thousand cubic meter artificial sea water aquarium at The Living Seas. Observations of the rostral teeth were documented bi-monthly over a twelve month period using sketches and underwater photography. All observations were made using SCUBA to avoid handling the animals. The rostral teeth were not deliberately altered or broken.

Observations

There were eighty-one recorded broken teeth over the twelve month study. Most of the breaks occurred at the back of the crown without damaging the pulp cavity. When only a small portion of the tooth was broken with the remaining tooth half retaining a pointed shape, regrowth of the crown took as little as one month. A broken tooth begins to regenerate itself by first forming a new tip. The progression of tooth regrowth can be observed in Figure 1. The broken end of the tooth thickens and lengthens from the pulp cavity. If the crown is missing, a new crown is generated from the pulp center. The new crown and base lengthen until the size of the repaired tooth is comparable to an adjacent tooth. Only nineteen of the 81 recorded breaks involved the pulp cavity portion of the tooth. Crown formation was delayed in this case until the

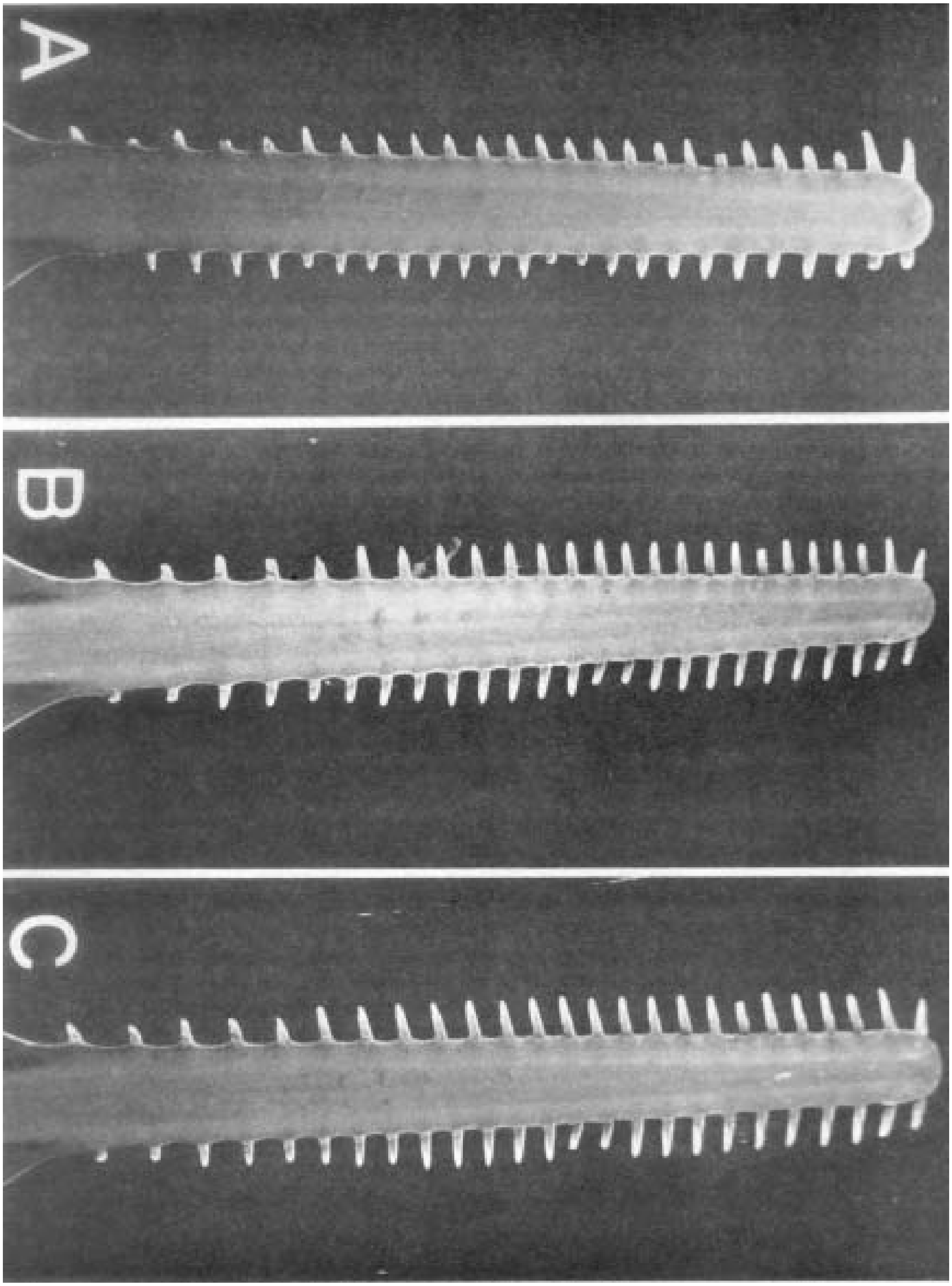


Figure 1: Photographs of smalltooth sawfish (Pristis pectinata) rostral teeth. A: April, B: October, C: December. Actual rostrum length approximately 65-71 cm.

base sufficiently lengthened to re-establish the pulp cavity. The base portion of the tooth lengthens more slowly than the crown. Regrowth of a damaged tooth appeared faster than the continuous growth of undamaged neighboring teeth.

The rate of regrowth was not uniform. Teeth on the anterior of the rostrum grew faster and to a greater length than posterior teeth. Regrowth was slower if many teeth in one area were broken. Injury to the rostrum or tooth socket also delayed tooth regrowth. Although very slow in some cases, no damage occurred that was severe enough to prohibit tooth regrowth. It is not known if regrowth is possible if the entire tooth is lost.

Conclusions

In sawfish, continuous tooth growth and regrowth of damaged teeth takes the place of successional tooth replacement found in sawsharks. Growth may be reduced as a tooth reaches an optimum size, partially explaining how a damaged tooth can grow to the length of a neighboring tooth. Older, longer teeth that are prone to breaking tend to fracture at a point above the pulp cavity where the crown can be regrown in a short period of time. Damage to the tooth base, to the extent that regrowth is not possible, is probably so rare that true tooth replacement is not necessary.

Acknowledgements

I am grateful to the technical staff of The Living Seas, Dr. L. Brooks and C. Davis for their assistance and support.

Literature Cited

Schaeffer, B. 1963. Cretaceous fishes from Bolivia, with comments on pristid evolution. Am. Mus. Novit. No 2159, 20 pp.

Shellis, R.P. and B.K.B. Berkovitz. 1980. Dentine structure in the rostral teeth of the sawfish Pristis (Elasmobranchii). Archs. of Oral Bio. vol 25(5):339-349.

Slaughter, B.H. and S. Springer. 1968. Replacement of rostral teeth in sawfishes and sawsharks. Copeia 1968(3):499-506

FEEDING TECHNIQUES FOR THE PACIFIC TORPEDO RAY, *Torpedo californica*

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Drum and Croaker 34: 19-21. January 2003

Abstract

Pacific torpedo rays, *Torpedo californica,* are seldom exhibited long-term in captivity due to the difficulties of inducing them to feed. We developed a feeding protocol that has allowed us to successfully exhibit these unusual rays. Using these methods we have been able to train Pacific torpedo rays to eat either live or dead food, and we have successfully maintained individual rays for over two years in captivity.

Introduction

As part of an on-going program at Aquarium of the Bay (ABay) in San Francisco, California, focused on displaying challenging or seldom-seen animals in captivity, we developed a protocol for feeding Pacific torpedo rays. These techniques have been used successfully at ABay since 2000, and have subsequently been implemented at the Monterey Bay Aquarium.

Pacific torpedo rays (also known as electric rays) possess a kidney-shaped electric organ located on each side of their flattened disc. These electrogenic organs are used to capture prey and fend off predators. Torpedo rays are obligate piscivores. (Bray and Hixon, 1978). They capture and orient their prey head first during ingestion. Maximum electric organ discharge (EODs) for one torpedo ray in the field is 45 V (Lowe, Bray, and Nelson, 1994). In the Eastern Pacific, they range from British Columbia to Baja California with a depth range between 3–196 m, and attain a maximum length of 1.4 m (Michael, 1993). They are ovoviviparous with an estimated fecundity up to 17 young per litter. Maximum age is estimated at 24 years (Neer, 1998). They have no known predators, but there is a small fishery for neurological studies (Love, 1996). Long-term studies of this species have been unsuccessful due to their refusal to eat in captivity (Michael, 1993; Neer, 1998). Therefore, developing feeding techniques in aquarium and laboratory settings would be beneficial to learning more about this species.

Collection

Pacific torpedo rays are collected as bycatch from local fishermen using lompara or purse seine nets. Juveniles are also collected via SCUBA using plastic nets in Monterey Bay.

Acclimation

The temperature and pH in the transport container are slowly adjusted to match the exhibit tank. Prior to introduction to the tank, the rays receive a praziquantel bath inside the transport container (either 20 ppm for 1.5 hours or 10 ppm for 3 hours) and are visually inspected for other ectoparasites.

Feeding Protocol

During the initial rod-feeding training, only live food is offered. Appropriate foods for smaller rays are live anchovies or other small, benthic, fish, and for larger rays, sardines or surfperch are offered. All food is supplemented with a multiple vitamin. All prey must be offered with its head facing the mouth of the ray (they always swallow fish in this direction). Food is offered two times a week.

To feed adult rays in Abay's larger display (350,000 gallons), a monofilament line is threaded into the feeder fish via the animal's mouth and exits the operculum. One end of the monofilament line is tied to a black PVC pole held in one of the diver's hands; the other hand holds the end of the monofilament line. The prey is offered to the ray while it is resting on the sandy bottom. The prey is placed under the ray, near its mouth. The ray senses the food underneath using its ampullae of Lorrenzini and begins to release EODs as it undulates its body over the prey. The ray cups its pectoral fins over the prey, continuing until the food has been consumed. After two weeks of feeding live food, we switch to frozen sardines and use a 48" tong for feeding. The diver must hold the fish so the head faces toward the mouth of the ray, and the diver must continually move the food to simulate a live food item. (Note: It is very important to keep the prey moving while feeding frozen food or the ray will not swallow the food.)

To feed smaller rays in smaller tanks (*i.e.* 8-ft. cylinder tanks), the ray is initially lifted up in the water column using a soft net. The feeder uses 20" tongs to hold the prey offered. This is accomplished by clamping the tongs near the caudal peduncle of the prey. The feeder then offers the prey head first underneath the ray near its mouth. The ray will sense the prey and begin cupping the food into its mouth as described above. Again, frozen food needs to be moving in order for the ray to swallow the prey completely. If the ray still refuses to feed after many attempts, the feeder can invert the ray into a small, soft net and place the food into the mouth. The ray will slowly ingest the food on its own.

Behavioral Considerations

If larger torpedo rays (total length greater than 60 cm [23 inches]) are placed in smaller tanks they do not seem to survive long term, possible due to the rays need to roam and forage frequently. Rays that discontinue feeding should be checked and treated for parasites, especially monogenetic flukes within the gill filaments. Larger rays placed in tanks with other species may injure and possibly kill cohabitants. Divers must be aware of their location within the tank while doing maintenance, as rays will deliver a minor shock to the unsuspecting diver.

Acknowledgements

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References

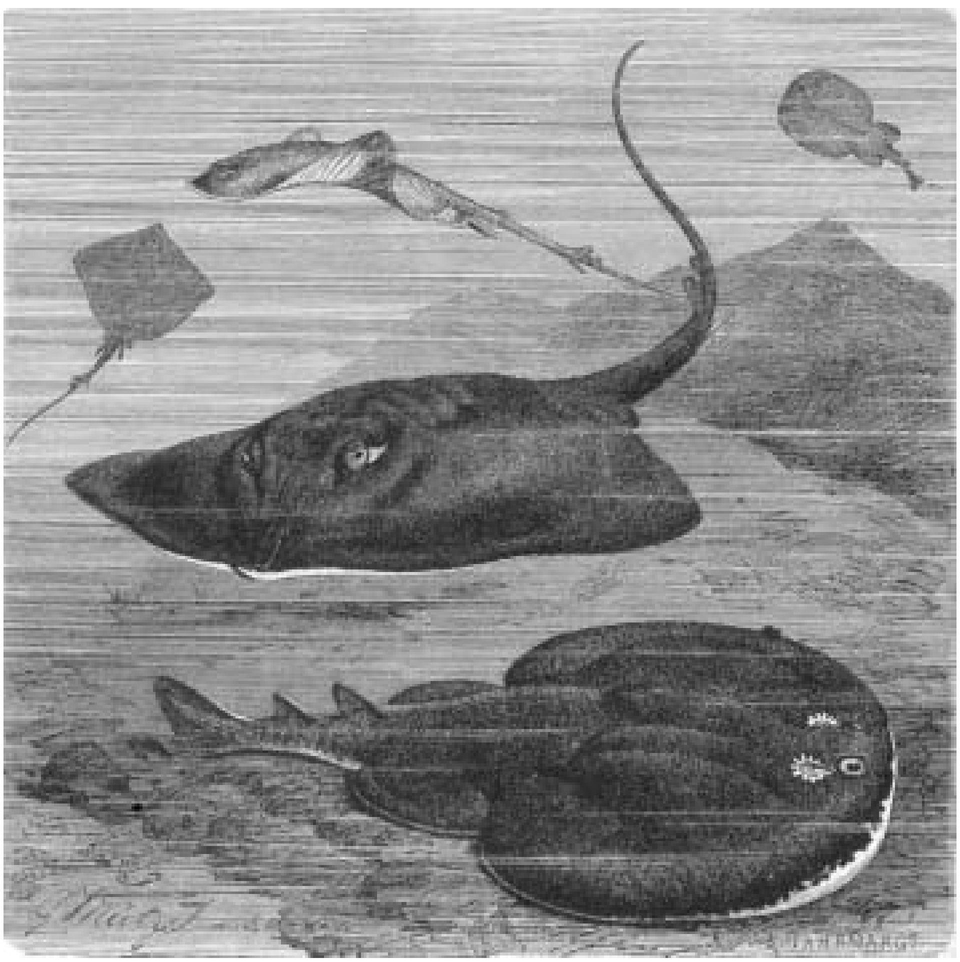
Bray, R.N. and M.A. Hixon. 1978. Night-shocker: Predatory behavior of the Pacific electric ray (*Torpedo californica).* Science 200:333-334.

Love, R.M. 1996. Probably more than you want to know about the fishes of the Pacific coast. 2nd edition. Really Big Press, Santa Barbara. 381pp.

Lowe, C.G., R.N. Bray, and D.R. Nelson. 1995. Feeding and associated electrical behavior of the Pacific electric ray, *Torpedo californica* in the field. Marine Biology 122(1):

Michael, S. W. 1993. Reef Sharks & Rays of the World. Sea Challengers, Monterey, CA. 107pp.

Neer, J.A. 1998. Life History of the Pacific Electric Ray, *Torpedo californica* (Ayers), in central and southern California. Unpub. M.A. thesis, San Jose State University, Moss Landing Marine Laboratories. 71pp.



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Other Species:
Hammerhead, Lemon, Tiger, and Silky Sharks

COLLECTION AND TRANSPORT OF HAMMERHEAD SHARKS, WITH EMPHASIS ON THE GREATER HAMMERHEAD, *Sphyrna mokarran*.

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Elasmobranch Husbandry Symposium

Introduction

Hammerhead sharks are one of the most unusual sharks in both appearance and highly specialized adaptations for moving through the water. Their unique morphology presents numerous challenges to the aquarist looking to collect, transport and display this family of sharks and until recently, there have not been any long distance and time period transport of these animals.

There are special circumstances and procedures that must be considered when collecting and transporting hammerheads and all other species of totally pelagic sharks (Arai, 1997.) The most significant aspect that must be part of the equation is to provide ample swimming room for the animal following capture and during transportation (Young, et al 2001). Hammerhead sharks cannot be transported under the current state of technology unless they are allowed to swim and normally respire under conditions that allow them to ram-ventilate (Young, et al. in press).

Once this is well understood, the basis for successful transport then becomes how small one can get that container to be to fit it into a transport vehicle, for example a truck or an aircraft, while still allowing the shark the means to respire by this essential swimming action. The majority of this chapter deals with the great hammerhead due largely to the fact that this work has been almost 100% successful. However, most, if not all, of the techniques can be used successfully to transport *S. lewini* (Young et al. in press) and *S. tiburo* (Klay, 1977.)

Materials and Methods

A total of seven great hammerheads (*Sphyrna mokarran*) were caught aboard the 42 foot power catamaran, F.V. Katrina. All captures occurred between the months of May and August in either the Atlantic Ocean or the Gulf of Mexico. Rod and reel or long line was the preferred method of capture. Immediately when the shark is hooked on the fishing line, it is brought up to the surface; pulled out of the water by a large dip net and placed into a circular live well.

The dimensions of the live well were 2.5 meters diameter by 65 centimeters high and there was a constant exchange of fresh seawater. The sharks were then transported to the laboratory and holding facility located at Dynasty Marine Associates, Inc. in the Florida Keys and placed in an elliptical staging tank with the dimensions of 22' x 57'x 4'. The average temperature and salinity of the holding tank were 27o Celsius and 36ppt respectively. During the staging process, the *S. mokarran* were fed, observed, and cared for from 8 weeks to approximately 4 months.

All transports from Dynasty Marine Associates, Inc. to final destination aquariums, occurred in custom-made fiberglass tanks (as per Young, et al, 2002). The tank dimensions were 250.0cm diameter and 60.0 cm high and could hold 3000 liters of seawater. The opening of the tank was 112 cm by 112 cm with a perforated Plexiglas plate, 4cm thick, that was placed on the opening as a splash guard/baffle. A square column 46-cm high surrounded the opening where the perforated Plexiglas was placed. The water level was maintained at 6 cm above the baffle.

Located on the baffle was a filter cartridge filled with activated carbon. A spraybar was located on the outside of the filter. Below the baffle was a submerged pump (Model 27D, Rule ITT) to pull the seawater up into the filter canister and spray it onto the baffle to enhance gas exchange and CO2 liberation. Excess seawater not going through the spraybar was pushed out a small nylon elbow extending through the Plexiglas baffle to produce circular flow. Federal Aviation Administration (FAA) approved 12 volt sealed batteries (Model 800s Optima, USA.) powered the pump via water tight connectors.

The seawater was saturated with pure oxygen between 110-140%. The oxygen was introduced to the water through airline hose attached to a pressurized oxygen cylinder of 7.98m3 capacity. The saturation was maintained at the high level by adjusting the flow from the cylinder.

Water quality was administered throughout duration of all transports. Dissolved oxygen concentrations, ammonia concentrations and pH were tested approximately every hour. An ammonia detoxifier (AmQuel, Kordon-Novalek Inc, USA.) was added when ammonia concentrations were higher than 0.5 mgl-1. The amount of AmQuel added was 420.0 ml dose precalculated to neutralize 1.0 mgl-1 of ammonia in 3.20 m3 of water. When the pH was lower than 8.0, 50g of sodium bicarbonate was added.

A mock shipment of a *Sphyrna mokarran* first took place before an actual transport occurred. The mock transport lasted 6 hours, approximately the length of time it would take to get to Atlantis Resort, Paradise Island, Bahamas. After 6 hours in the transport vessel, the shark was hand caught out of the transport vessel (with great effort) and placed back into the holding facility for 1 month. The shark was fed, and ate, one day following the mock shipment and each day thereafter until it was time to withhold food prior to the actual shipment.

In all transports the sharks were fasted for at least 7 days before the shipment occurred, no anesthesia was used at any time, and the sharks swam freely in the transport containers at all times.

Each transport tank was packed onto a single aluminum aircraft pallet and placed onto the aircraft by forklift. All transports were by air in chartered aircraft. All transports from airport to final destination were via flatbed truck.

Results

Six *Sphyrna mokarran*, the greater hammerhead, have been transported by Dynasty Marine Associates, Inc. Table 1 describes the shipping results of each transport. All sharks to be transported were between the sizes of 1.1 to 1.5 meters except for one that was 2.1 m (**Table 1**).

Table 1

The result of six *Sphyrna mokarran* transports. Temperature shown is for the final destination holding tank

Number of Specimens	Size meters	Date Of Transport	Length Of Transport	Final Destination	Tank Temperature	Status
1	1.5	Sep-01	12 Hours	Atlantis Resort	27-30°C	Alive
2	1.3 & 1.6	Jul-01	7 Hours	Atlantis Resort	27-30°C	Alive
2	1.1 & 1.4	Aug-01	18 Hours	Shark Reef Mandalay Bay	23°C	Alive
1	2.1	Aug-01	2 Hours	Dynasty Marine	27-30°C	Deceased

The 2.1 m shark died within 2 hours and its final destination was to be Mandalay Bay's Shark Reef. This shark was also only held at the Dynasty holding tank for 1 week unlike all other sharks that were held for 8 or more weeks. Note: It was later judged by the authors that the transport container was too small to allow adequate ventilation/respiration and recovery in between power strokes of shark based upon it significantly larger size and turning radius.

Although some rubbing did occur, the sharks were able to avoid physical injuries in the transport vessel. Except for the larger *S. mokarran* that died within the first 2 hours of transportation, the sharks displayed no extreme exertion during transport. Water quality was regulated and remained high throughout all transports.

The first *S. mokarran* transport was to Atlantis Resort. After the 12 hour transport, the shark was placed directly into the Ruins tank which had many simulated artifact-type obstructions displayed. The shark collided with these artifacts continuously. A slight discoloration and heavy breathing was displayed. Many of these obstructions were subsequently removed as they posed risk to the health of the shark.

The shipment to Shark Reef at Mandalay Bay Resort in Las Vegas was the longest term and distance transport of 18 hours. The sharks did very well on this transport. There was slight disorientation when the sharks were initially placed into the holding tank from the transport tank, but this resolved after less than one hour. The initial temperature of the holding tank was 23 °C and was increased to 28 °C over time period of a few weeks. After approximately two weeks of holding and observations, the 1.4 meter shark was introduced into an approximately one million gallon tank with 37 larger sharks consisting of Sandbar sharks (*Carcharhinus plumbeus*) and

Sandtigers (*Odontaspis taurus*). The temperature of this tank was approximately 22-23 °C. This *S. mokarran* was found dead approximately 10-12 weeks after being introduced into the large display tank. All other great hammerhead sharks that were transported are still alive to this day.

Discussion

Based upon the result of four years of work on these species, a lot of relatively new information has been added to the husbandry of this family. It is especially significant to note that the primary basis for success in collecting and transporting these sharks is recognizing the special nature of their physiology and the essential requirement that they be allowed sufficient room to swim during ALL aspects of their captive maintenance. While the size of the tank or transport vessel can be reduced for a finite period of time, during which time the shark is subjected to great stress, successful maintenance and captive husbandry of this species requires giving these sharks the necessary room to swim un-impeded. There is no other condition that has more importance than this one.

A secondary consideration that also appears to have great importance is to recognize that these are a largely tropical species. It is the authors' unproven hypothesis that these animals rarely venture into cool waters and only do so in an effort to migrate to warmer areas or in search of food. They are not found within range of operations based in the subtropical Florida Keys, except for the warmest months of the year.

Husbandry success or the lack thereof, appears to be directly related to keeping them at or about the optimum temperature, which appears to be 28 to 29 C. There appears to be a direct relationship between optimal tank temperature, metabolism of the shark, its ability to navigate in the tight confines of the aquarium and the ability to compete adequately with tankmates. The authors observed great hammerhead sharks actively competing with larger carcharhinids for food on numerous occasions. It is significant to note that all other anecdotal evidence has been contrary to this observation. Based upon these observations and results, the authors strongly recommend that combinations of these tropical sharks not be mixed with temperate species such as the sand tiger shark (*Odontaspis taurus*).

Handling in a typical shark stretcher is not recommended. There is considerable eye trauma that is caused by this procedure. The use of a nylon fabric or tarp to restrain the shark directly behind the head and wrapped around the rest of the body is the preferred method and eliminates most of the eye contact injuries that were experienced with the first *S. mokarran* transport.

Acknowledgments

The authors would like to thank co-contributors to this paper, Joao P.S.Correia, Steve Kajiura, and Mark Smith, who provided the drawing of the container, along with the technical and scientific expertise to support our activities. They should be listed as co-authors. Special thanks to Gerard Visser for setting us on this path in the first place.

We sincerely and gratefully acknowledge the support, assistance and advice of Yoshitataka Abe, Hiroshe Arai, Monica Brazel, Ray Davis, Jack Jewell, Steve Kaiser, Glenn Kelly, Michelle Liu, Allan Marshall, Frank McHugh, John Rupp, John O' Sullivan, David C. Powell, Gary Violetta, Dave Wert, Marty Wisner and many others without whom, we could not have done this work.

Bibliography

Arai, H.
1997. Collecting, transporting and rearing of the scalloped hammerhead. Proc. Fourth International Aquarium Congress, 87-89.

Klay, G.
1977. Shark dynamics and aquarium design. Drum and Croaker 17: 29-32

Young, F. A., Kajiura, S. M., Visser, G. J., Correia, J. P. S., and Smith, M. F. L.
2002. Notes on the long-term transportation of the scalloped hammerhead shark, *Sphyrna lewini*. Zoo Biology, 21 (3), 242-251.

Young, F. A., Lerner, R., and Powell, D. C.
2001. The Transportation of Live Silky Sharks (Carcharhinus falciformis) on Standard Palletized Aircraft Cargo Positions for Long Distance and Time Period Transports. Drum and Croaker 32: 5-7

NIGHT LIGHTS IN THE AQUARIUM
FROM OBSERVATIONS MADE WITH A CAPTIVE LEMON SHARK

Colin Grist

Poole Aquarium, Dorset

Drum and Croaker 20(1): 20-21. January 1982

To the best of my knowledge, pelagic or semi-pelagic species of sharks, Elasmobranchii have never been successfully maintained in captivity in Britain. Smaller, generally bottom-dwelling, sharks are normally kept, like the various tropical catsharks, *Hemiscyllium*, etc. and occasionally the Nurse Shark, *Ginglymostoma cirratum*, but this species grows far too large for most aquaria to handle (maximum length approximately 14 feet). British coastal species are usually kept, but, even amongst these only the dogfishes, *Scyliorhinus*, seem to thrive. Tope, *Galeorhinus galeus*, and Smooth Hounds, *Mustelus mustelus*, etc., do not survive for long in tanks. Sharks damage very easily because they only have a cartilagenous skeleton which does not give protection to the internal organs. Catching and transporting techniques have yet to be perfected in a way not to harm the animals. If this is achieved, there may be a better chance of maintaining the specimens.

For the past two years, I have been working with a young 4 ½ foot male Lemon Shark, *Negaprion brevirostris*, that shares the 6,000 gallon tank at Poole Aquarium with a 4 foot Nurse Shark, *Ginglymostoma cirratum*. Both these sharks were caught off the Florida Keys. The Lemon Shark is a coastal species that is semi-pelagic when young, but becomes more pelagic later in life. They are by no means a bottom-dweller, but juveniles will spend quite a bit of time resting on the sand. Lemons are rated at 5th most dangerous shark in the world, and they are notoriously aggressive in captivity, however, our specimen is reasonably docile most of the time.

There are numerous problems to be overcome when keeping large sharks and there are various husbandry techniques and aspects of tank design, in relation to shark dynamics and habits, which should be employed if even a modicum of success is to be achieved. The number of problems to deal with increase when attempting to keep these creatures in a closed system as we use at Poole.

I could write volumes on these problems and possible ways to solve them, but, the real purpose of this article is to relay a simple idea that came to my mind as a direct result of trying to solve many of the problems I have had trying to maintain this Lemon Shark. It is basically to do with light at night.

For many months I had continually found the Lemon Shark to be lying on its back, at the bottom of the tank, first thing in the morning. It became a daily chore having to 'kick start' the creature to make it swim. In fact, I had to lift the shark to the water's surface by using a long pole. If half way up the shark slid off the pole, it would spiral in an attempt to start swimming, but always it would end up on the bottom again. It seemed to be totally disorientated and appeared to be having an epileptic fit. However, when I finally succeeded in getting the shark to the surface, it would manage to orientate itself and swim normally for the rest of the day. At first it was thought that the shark was suffering from brain damage, but, this was ruled out when it was observed that the shark would spiral in any direction. If there was any brain damage, spiraling would most likely be in one direction only. The next suggestion was that there might be a build up of fats caused by over feeding. It is easy to over feed a shark as, due to its dynamics it is probably the most efficient swimmer in the seas, it needs little food in relation to its body weight. So I stopped feeding for nearly two weeks, but this really made matters worse if anything. So that idea was dismissed. Also a build up of gases was a possibility and this would certainly be an answer to why the shark was rolling over onto its back. However, the shark was sinking to the bottom and if gas was the problem, the shark would eventually become more buoyant and float to the surface. The mostly likely of all the suggestions made is that there has been damage to the 'inner ear'. This would cause disorientation and unbalancing and also spiraling in any direction.

The tank that the sharks are housed in contains a number of large rocks and a sunken boat which have been obstacles for the Lemon when disorientated. Some damage has occurred to the shark's skin tissue, particularly around the snout area, due mostly to crashing into the boat. One day it occurred to me that, because the aquarium building does not have any windows around the exhibition areas, at night there is complete blackness.

I had often thought about the fact that it never gets totally dark on coral reefs, apart from in deep caverns, but, these thoughts had never before registered enough to make me go into the subject any deeper. When diving in the Red Sea, I was surprised at how far you can see underwater at night once your eyes become use to the dark. The water in the Red Sea is crystal clear as other coral reef areas. So I wondered whether slight illumination over the shark tank during the night would help the Lemon Shark's ability to pick out the basic shapes of the boat and rocks. As I have already mentioned, Lemons are as a rule a coastal species in areas where illumination throughout the night is quite good. So I rigged up a low wattage night light and have not had any problems with the Shark ever since. He swims well, feeds well and never goes down to the bottom any more.

I also wondered, and I am sure that I am not the first to do so, whether this idea if put into practice would be generally beneficial to the wellbeing of other aquatic animals. Even in most bodies of freshwater it does not get totally dark at night; at least not in the shallow areas where the majority of organisms live, as on the coral reefs also. So perhaps in a room where there is an aquarium tank the curtains should be left open through the night; or low wattage light bulb, possibly one coloured blue, left on. I know that it is unlikely to have the same sort of problems, bumping into objects in the dark, with most aquarium fishes, but it seems that a night light can help to cut down levels of stress, particularly in coral fishes.

I am sure that our Lemon Shark has got some sort of damage to the ' inner ear' , but, with this illumination the creature is no longer damaging itself, which, had it been allowed to continue, would ultimately have made the problem very serious.

HUSBANDRY OBSERVATIONS, AND TREATMENT OF FUNGAL INFECTION IN A TIGER SHARK, *Galeocerdo cuvier*

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Drum and Croaker 29: 9-13. February 1998

Introduction:

Tiger sharks, *Galeocerdo cuvier*, are rarely displayed in public aquariums and little is known about their behavior and health in the captive environment. Omaha's Henry Doorly Zoo had the opportunity to display this species for a year and a half, from March 1995 to August 1996. The purpose of this material is foremost to relay the information gained from the experience in regard to keeping tiger sharks in captivity. Secondly, to address a fairly successful treatment for fungal infections in elasmobranchs, which was used on this individual.

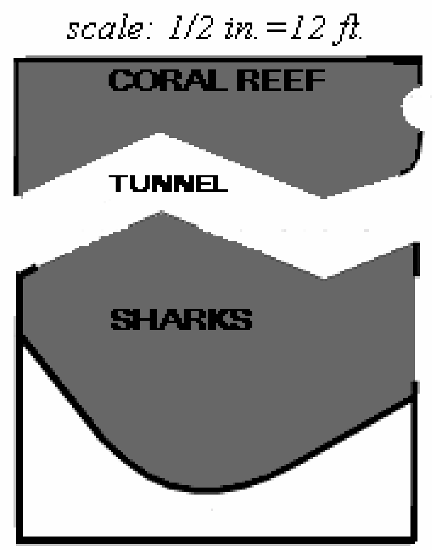
Transport:

A female tiger shark arrived in Omaha, via direct air transport, from Nomad Marine in the Florida Keys on March 15, 1995. Before shipping, the shark was kept in an oval shaped holding tank on an open system, for approximately nine months. In this holding tank the shark swam the perimeter constantly, due to the size and shape of the area. The transport went fairly well, except for the fact that the shark vomited en route. Total travel time from the Keys to Miami, and then to Omaha, was approximately six hours.

The most difficult part of the transport was the release of the shark. She was acclimated for about an hour and a half in her shipping box, which had a circulating pump, as well as an oxygen supply. When the temperatures were finally in equilibrium she was released into the 900,000 gallon closed system, display tank where she darted away, but then quickly became disoriented and sank to the bottom. Aquarists then had to pick her up off the bottom and swim her around the exhibit to ventilate her. This was a very slow process. After being pushed for several minutes the shark would take off on her own and swim for a short duration, but would then sink to the bottom again, apparently very disoriented and exhausted. Originally, there was some concern about the excessive handling removing her slime layer and compromising her health, but it did not seem to cause any complications. The swimming process took over two hours until she finally acclimated and began successfully navigating the tank by herself. The shark was watched all night, along with the six sandbar sharks, Carcharhinus plumbeus, that arrived. Due to the complicated manner of the transportation and acclimation, accurate measurements were not taken, but the tiger shark arrived at an approximate total length of 152 cm and an estimated weight of 35 kg.

Behavior:

Behaviorally, she quickly developed a pattern of swimming the perimeter of the tank, but seemed not to rub with her pectoral fins or ventral surface. She may have adapted quickly to this pattern due to the fact that she was kept in a rectangular holding pool with no structure for months before her arrival at the Henry Doorly Zoo. At the time when the sharks arrived to the facility, the aquarium was not yet open to the public and the shark exhibited fairly normal swimming behavior, with times of swimming out in the middle of the display, as well as periods where she continually swam the perimeter. The Shark/Reef Exhibit at the Henry Doorly Zoo has a seventy-foot long tunnel, which zigzags, down the center of the tank. As soon as the aquarium opened to the public, the tunnel became filled with thousands of visitors per day, creating an extremely high amount of noise, which in turn reverberated off the acrylic tunnel. At this point in time the tiger shark's behavior changed, to the point that during visitor hours she would swim along the smooth perimeter wall, the farthest area from the tunnel. At night however, she was routinely noticed to come out and swim a lot in the middle of the display, even crossing over and around the tunnel. It was also noted that when the dissolved oxygen was elevated over 100% her behavior and swimming greatly improved. An elevated D.O. was possible by using a total dissolved gas meter to ensure gas bubble disease was not a problem. The shark would have benefited greatly if a D.O. of 105%-110% could have been maintained on a constant basis.



Problems:

By swimming the back perimeter wall the shark began to develop abrasions on her pectoral fins and her mandible. As noticed previously this behavior is somewhat common and frequently leads to pathogen entry (Crow and Hewitt, 1998). These abrasions were successfully treated with enrofloxacin (Baytril) orally in food at an original dose of 10 mg/kg every other day for three treatments, and then later treatments at 5 mg/kg daily for five days. These abrasions routinely reappeared due to the rubbing, but were all treated with enrofloxacin and improved.

The only other medication used for these abrasions was an oral treatment for ten days of trimethoprim and sulfadiazine (Di-Trim) at a dose of 10 mg/kg. Di-Trim was used so that a resistance would not build up towards enrofloxacin, and also the shark's swimming became very sluggish. By the sixth day of this treatment there was a marked improvement in the animal's swimming and her appetite greatly increased.

Observations:

Initially the diet was 3.4 kg of blue runner *(Caranx crysos)* and mackerel, fed weekly in two feedings, but that was periodically increased as the shark grew. The food was supplemented with Mazuri shark and ray multi-vitamins, at a dose of one tablet per half pound of food.

During this time frame the shark was very inquisitive, and would always come over to investigate divers while they were in the water. The shark never exhibited any aggressive behavior. Baffles and bumpers were used to try to modify the tiger shark's swim pattern, but none of these worked for very long. A curtain of air bubbles was even tried along the back wall, which kept her away for about two days, but then later she began to swim in and out of the bubbles unaffected. The shark continued to do well in this environment, with the exception of the occasional skin abrasions, until February of 1996, when a white cottony fungus was noticed on the lower section of the caudal fin.

Fungal infection:

The fungal infection was believed to be of the genus *Fusarium* (Stoskopf, 1993). Along with the fungal infection a decline in the shark's swimming behavior was observed, as she began swimming with her tail slouched downwards. Skin abrasions were also noticed in conjunction with the fungus, so enrofloxacin was again prescribed to prevent any secondary infections. Again the enrofloxacin was effective against the skin abrasions, but as expected did nothing to combat the fungus. By April 13 the fungal infection had worsened with the area on the caudal fin getting larger, and the appearance of the fungal infection spreading to the abraded margins of the pectoral fins. A treatment of ketaconizol at a dose of 5 mg/kg was given daily for 41 days orally in the food. During this treatment the affected areas seemed to reduce greatly in size, and disappear completely from the pectoral fins. In addition to the visual decrease in size of the affected area, the shark also began to display greatly improved swimming behavior and an increased appetite.

New diet:

On June 1 it was decided to greatly increase the shark's food intake, because she was starting to look quite thin and was clearly expending more caloric energy than she was bringing in. Food intake was increased to 6.3 kg per week, and later 7.6 kg per week, in daily feedings. The diet was supplemented with 100 mg vitamin B1, 400 IU vitamin E, and ten to fifteen fish oil gel tabs daily, in addition to the normal Mazuri vitamins, to improve the nutritional and energy content. This improved feeding regiment was used for about a month with remarkable success. The shark filled out in size and her swimming improved greatly, with the most noted improvement being less tail drag swimming. At this point the shark appeared healthier than she had ever looked, with the exception of the remnants of the fungal infection on her caudal fin.

Complications:

On July 2 however, this all took a drastic change for the worse. The shark exhibited very labored and exaggerated tail dragging, with frequent periods where she would stop and sink to the bottom, then she would gill very hard for a short while and get back up and repeat the cycle. After observing this a few times, the shark was caught up in a stretcher and brought to the surface. Blood was drawn and there was an attempt to get a fungal scrape, which later showed no results. As precautionary measures, injections of amikacin and later rocephin (50 mg/kg) were administered. During this procedure the shark vomited. She did not actively swim by herself after this, and after failed attempts to swim start her, she was moved to the reserve tank where ram ventilation was possible on the effluent return of the display pumps. The ram ventilation process lasted about two hours until she regained enough energy to be re-released into the display. Once back in the display the shark seemed somewhat lethargic, but was managing to swim all right.

Hypothesis:

The first probable cause that was examined was a *Vibrio carchariae* (Stoskopf, 1993) infection due to the manner in which she was seeming to have equilibrium problems and how the shark repeatedly crashed to the bottom of the exhibit. Secondly, was the thought that this might be a complication of the fungal infection becoming systemic. And thirdly, the question arose of a possible vitamin overdose from the increased feeding schedule.

Treatment:

The director and the veterinary staff decided to address the possible *Vibrio* infection first, and began an IM treatment with rocephin at a dose of 50 mg/kg given with a pole syringe daily for seven days. These rocephin injections frequently caused the shark to stall and roll violently then sink to the bottom, and then take off again normally. This seven-day treatment was given twice with very little noticeable improvement.

By August 5 there was no significant improvement, and the shark had basically quit eating during this period. Attempts to treat the fungal infection were thus totally ineffective. A second type of treatment was administered at this time to combat the possible *Vibrio* infection. Florfenical was applied at a dose of 20 mg/kg with an IM injection via pole syringe for five consecutive days. Again nominal improvement was noticed.

Further complications:

On August 22 the shark was seen on the bottom of the tank struggling to get up and swim. Again she was caught up and blood samples were taken and she was treated with enrofloxacin. She was moved to the back holding area once again to be ram ventilated. Several attempts were made to tube feed the shark, but she vomited the food within a half-hour of each feeding. The shark was held in the back over strong current for over 48 hours when the decision was made to euthanize her, due to the decrease in her activity and her lack of responsiveness.

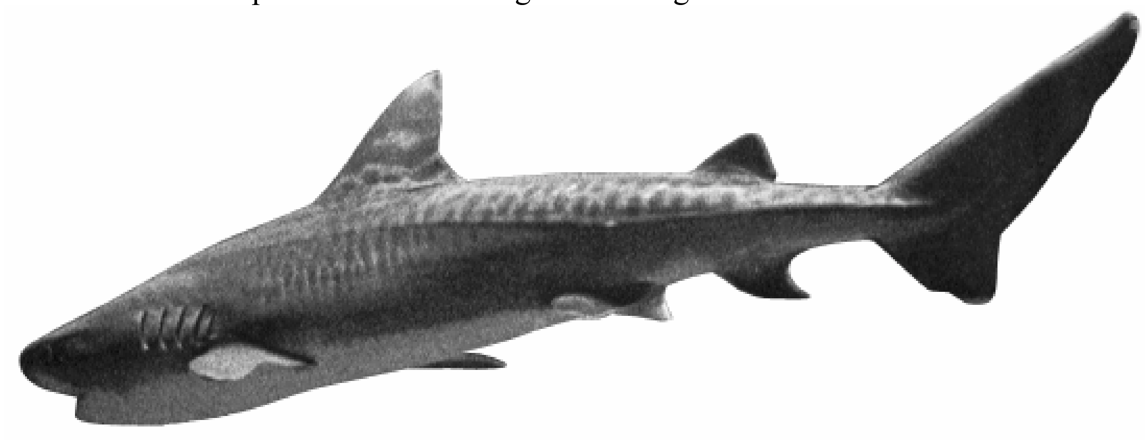
Necropsy results:

Initial necropsy revealed a large fold in the posterior section of the stomach, with multiple gastric ulcers, which did not perforate the stomach. Multiple mucosal ulcerations were also noticed around the entrance to the spiral valve. Many of the ulcers were quite large.

Upon histopathology, large numbers of fungal hyphae were found in the gastric lesions and in multiple blood vessels. No lesions were found on the brain or spinal cord, and no fungal or bacterial organisms were isolated from the cerebrospinal fluid.

Conclusion:

At the time of the tiger shark's death, her total length was 241 cm with an estimated weight of 100 kg, which was far less than she had been a month before. Based upon necropsy results, the hypotheses for these events were primarily that the fungal infection led to the initial crash of the shark. During the time of this first episode the shark vomited while being restrained, and it is believed that this could have caused the stomach to fold on itself after being everted. It is thought that this fold caused, or complicated, the ulcerations. From this point, due to lack of eating from these complications, the shark was severely compromised and became weaker. Vibrio infection was thus ruled out due to the lack of bacterial or viral organisms in the cerebrospinal fluid. Even though vitamin overdose could not be totally ruled out, it was considered to be not a factor due to normal blood values. Although the fungal infection was not fully eliminated with the treatment, it is believed that clinically, it greatly improved the external infection as well as improved the swimming and feeding behavior of the shark.



The staff at the Henry Doorly Zoo firmly believes that tiger sharks can be kept successfully in captivity. Currently, Atlantis Resort in Nassau, Bahamas has had one for approximately two and a half years. Evidence observed at the Henry Doorly Zoo and information obtained from consulting with other facilities that have kept tiger sharks, points to the benefits of obtaining these animals at a small size of about 122 cm. It also appears that there is advantage to keeping these animals in displays with uneven rockwork on the walls, rather than smooth surfaces. Another important factor is an increased diet, because these sharks tend to exhibit binge and starve eating behaviors. Although this shark is a very difficult species to maintain, the future looks hopeful for long-term captivity of the tiger shark, *Galeocerdo cuvier*.

References:

Stoskopf, Michael K. Fish Medicine. Philadelphia, PA, W.B. Saunders Company, 1993.

THE TRANSPORTATION OF LIVE SILKY SHARKS (*Carcharhinus falciformis*) ON STANDARD PALLETIZED AIRCRAFT CARGO POSITIONS FOR LONG DISTANCE AND TIME PERIOD TRANSPORTS

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The silky shark, *Carcharhinus falciformis*, is a species that has only recently been displayed in public aquariums, and to date, little information has been compiled on its behavior and husbandry requirements. As far as the authors are aware, this species has only been collected and displayed by Steve Kaiser, Dave Wert and Glenn Kelly at Atlantis Resorts, Paradise Island, Bahamas, Jerry Crow at Sealife Park, Hawaii and Kiyonori Nishida at the Osaka Aquarium Kaiyukan. Atlantis' and Sealife Park's proximity to the open sea obviously minimizes the transportation difficulties that most aquariums face in acquisition and acclimation of display animals. The transport to Osaka was by sea and truck and was relatively short in its time period. Nonetheless, the work done at the three institutions with pelagic sharks has been quite impressive.

The silky shark is quite similar to the blacknose shark, *C. acronotus'* capability to survive brief capture stress and brief transportation times to the quarantine system. In total, about 60 to 90 minutes represents the maximum time from capture (by rod and reel) to introduction into a 7m by 20m by 1.5m holding tank where mostly all animals that are captured, will survive. The author suspects that longline capture is even more stressful as it greatly increases the "in water stress" time period. Once the silky shark is acclimated to captivity it seems to be a hardy and visually impressive husbandry candidate.

Until the present time, they have not ever been transported over any significant distance or transported in an aircraft (David C. Powell, pers. com). It was the hypothesis of the authors, that the methods that we have developed at Dynasty Marine Associates, Inc., that considers the basic spatial and dynamic requirements of similar species such as *C. acronotus* and the more challenging blacktip shark, *C. limbatus*, would also work for *C. falciformis*.

This approach was developed during experimentation that was initiated in the desire to provide captive specimens of small pelagic sharks, especially *Carcharhinus limbatus*, *C. acronotus* and bonnethead shark, *Sphyrna tiburo*, and the scalloped hammerhead, *Sphyrna lewini* to public aquariums. Small Caribbean carcharhinids, specifically *C. limbatus* are extremely sensitive, obligate ram-ventilators and are difficult to collect and transport. On board the collecting vessel, maintenance of totally pelagic, obligate ram-ventilators requires highly specialized methods and holding containers.

All totally pelagic shark species have a great degree of difficulty recognizing and negotiating barriers in their swim path and the resultant stress levels caused by repeated container contact is an extreme major obstacle to their adaptation to immediate captivity. The energy budget required to negotiate these tight turns in rectangular boxes very quickly depletes the energy reserves of the shark, especially when the animal is already arriving on board the boat in a highly stressed condition from being caught on a baited hook, fought on the tackle and landed at the boat. The staff at Dynasty Marine Associates has for some time been developing and modifying a large, round holding tank system (hammer paper in press) that takes into account the initial difficulties for these species. The primary obstacle is that the size of the container is limited to the size and carrying capacity of the boat.

The results that have been achieved bear out the merit of the hypothesis. Collections of two 1m *C. falciformis* were made on two separate collecting trips and they were acclimated in the holding system for about three weeks. During this time, the sharks were fed daily and ate ravenously on squid and cut mackerel at about 2% of total body weight/ day.

Once the sharks were adequately acclimated, food was withheld for four days and the authors shipped them via truck to Orlando and from there by cargo aircraft to Denver. The transport containers that were previously developed for transporting hammerheads were used (hammer paper in press) and one 1m shark was shipped in each of two 2.5 m diameter containers. Total transportation time from holding tank to aquarium was about 26 hours. Both sharks swam in the containers during the entire trip and ate the day after the transport.

One shark developed a slightly cloudy eye, presumably from contact with the transport container in route. An oral Baytril regimen was administered and this cleared up the injured eye within 10 days. Slight rostral damages, also presumably from perhaps either capture injury and or container contact were also observed and these healed completely within 30 days from the time of transport. This is not unusual in small pelagic carcharhinids or sphyrnids.

The ideal temperature for the species seems to be above 25°C. and below 28 °C. There were several low pressure weather systems that occurred during the holding and acclimation period and the resultant cool water in the semi-open system with temperatures below 23° significantly slowed swimming speeds and overall activity levels. Feeding was also sporadic below 23°C. and did not occur much at all below 21°C. The senior author has since observed feeding in *C. falciformis* twice in about ten observations at about 20°C. It is interesting to also note that the senior author has noted several mortalities in *C. acronotus* below 18 and 19°C. that for lack of any other factor that could be found have been attributable to the cold temperatures. In the sea, these species are never found in water below about 22 or 23°C.

The short term conclusions indicate that medium length transports of duration's of 24 to 36 hours present slight risk of mortality the principal risk is of equipment failure, transport mishandling by the airlines or flight cancellations. It is also the authors' conclusions that transport durations up to as much as 48 hours are possible with only slightly elevated risk. Also, the transport of two sharks per container is quite likely to represent a minimal risk on shorter duration transports of 24 hours or so transports.

The senior author recently supervised a 38 hour transport of two, one meter sized *C. acronotus* with no mortalities, a thirty hour transport of three *C. acronotus,* where one mortality was observed out of six animals transported and up to six, 50cm to 60cm *C. limbatus*, for transports up to 56 hours with a high degree of success. The risk of stress and mortality is always minimized if fewer animals are transported in the same container and is always recommended.

It is the authors' conclusion that many other species of small and medium size, totally pelagic sharks can be collected and transported by these methods and that their husbandry will be researched in detail during the next few years. Up until this time, very few species of visually impressive sharks were available for aquariums to display. These have been primarily the brown shark, *Carcharhinus plumbeus* and the sand tiger shark, *Odontaspis taurus*. With the increase of availability and interest in other new and sometimes smaller, pelagic species, new displays are sure to follow, especially those that more easily accommodate the requirements of the smaller species.

Diet Management

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SHARK NUTRITIONAL REQUIREMENTS IN CAPTIVITY

Gerrit Klay

Shark-Quarium, Marathon, Florida

Drum and Croaker 17(1, mislabeled as “2”): 19-22. April 1977.

Contrary to popular belief, sharks are not indiscriminate feeders. Sharks, like many other animals, have particular dietary preferences and distastes. For example, a healthy shark will reject anything not fresh. Successful maintenance of captive sharks depends, therefore, on the provision of fresh or fresh-frozen food. In many cases, pieces of food fish are spit out after a taste bite, indicating that the fish was not fresh enough. This behavior is misinterpreted by many aquarists to mean that the shark is not hungry. In fact, indications point to the ability of sharks to quickly identify spoiled fish. Even "fresh fish" by human standards might be unacceptable to a shark. In many cases when fish are defrosted from the same box, some will be eaten while others will be rejected. Freshly defrosted fish should therefore be carefully separated in grades, by the condition of the skin being tough or mushy. The mush fish should not be used since the shark might reject it, and create water management problems. Such considerations make the nutritional maintenance of a shark a lot harder than the average person might think.

Sharks also show preferences for particular species and parts of food fish. Excellent fare for captive sharks includes: Bonito, Mackerel, Bluefish, Mullet, Smelt, Shark liver, Sting Rays. Sharks' liver is preferred above all, but very messy as a daily food. Blue runner may be included among these preferred items except that most commercially available blue runner is not up to the shark's standards. It acquires a preference for a single food, and this can vary among individual sharks. This should be avoided; over a weekly period, a diversified diet will give each shark its needed share of nutrients.

There are further problems confronting the aquarium manager. For example, in a group of captive sharks, the pack leader will eat up to 80 % of the food put in the tank. If this shark concentrates on one preferred food item, it can cause the other sharks to have less than their nutritional requirements. Therefore, more than needed food must be placed into the tank to satisfy the others, thus adding to water management problems.

A variety of fish is necessary in a daily feeding to cover:

1) The preferences among individuals

2) Economy in feeding costs without jeopardizing nutritional value

3) Water management problems.

Selections of food fishes must take a multitude of factors into account. For example, fish scales do not digest and will end up clogging filters and pipes. Thus, small-scaled species are preferable to large-scaled forms in this regard. Mullet, for instance, though a good food fish for sharks, are large-scaled and thus are more likely to lead to filtering problems than would, say, the small-scaled blue runner. Therefore, the blue runner is more preferable for water management control. The fish used should be cut into small enough pieces that the shark does not have to tear it. This will reduce the release of small particles of food into the water.

Vitamins and minerals should be added to the shark's diet which are not available in fresh dead fish. The vitamins used are 500 mgr multiple vitamin capsules. These are provided daily. Here again it is up to the aquarist to outsmart the most aggressive shark in the tank. Each week 500 mgr calcium tablets are added. Trace element replacements are done on an annual basis. Iodine, necessary to avoid goiter, should be introduced in quantities recommended by most artificial seawater manuals, or in tablet form to the individual shark if goiter appears.

The nutritional requirements of captive sharks vary among species, depending on their natural habitats. Inshore and offshore sharks are as different as night and day in their feeding habits. Inshore sharks are much less active in captivity than in the wild state. Therefore, their food intake should be greatly reduced in captivity to prevent the shark from getting too fat. (Most sharks in captivity do become overweight and need to be on a diet.) A reasonable formula which I have developed over many years of aquarium management is:

> 1.65 kilos for 100 kilos of shark a day. Reduction to 1.00 kilo is applied when the shark seems to get too fat, in which case it needs to be put on a diet.

Offshore species of sharks in captivity cannot achieve their normal cruising speeds. They will burn up many calories with eventual loss of appetite, after which the shark will quickly waste away. The inshore sharks can either rest on the bottom, or have a low stalling speed and can cruise and maneuver within their environment without exhaustion. Offshore sharks have a rest-glide period which differs between size and weight in distance of rest-glide and recovery to regular speeds. For instance, a six-foot blue shark or black tip shark has a minimum requirement of 60 ft. of rest-glide distance in a straight line. There must be sufficient room beyond this to allow cruising speed and turning. Most tanks within the U.S. or elsewhere used for captivity have not even a 30-foot rest-glide and recovery distance. This, therefore, forces the shark to swim with optimum power to avoid stalling. These sharks then must continuously apply braking power to keep from slamming into the wall. The combination of full thrusting power and braking power compares to an airplane landing with power on, flaps down, and burning up more fuel than it would at normal cruising speed. In the shark's case, the animal will physically burn up its calories and cannot replenish them fast enough. This theory replaces the theory that pelagic sharks cannot comprehend the walls and therefore must have a circular tank in order to live. Over the years I have kept pelagic species in square tanks which were calculated for the size of shark kept, and they have lived for years.

There are a number of shark species which have been kept in captivity. Among the inshore species successfully maintained as captives are the bull shark, lemon shark, nurse shark, bonnethead shark, brown shark and dusky shark. Offshore species have so far been kept successfully only at Shark-Quarium. They are the black tip shark, black nose shark, Cuban night shark, and the hammerhead shark. In one case we kept a great white shark of approximately 5' 4" length.

There are problems of feeding when multiple species are kept together. Probably to everyone's surprise, the 5' 4" great white had a hard time competing with a 4' black tip which was faster and more aggressive in feeding. The lemon and bull shark were also the underdog when kept together with black tip sharks. Large amounts of food had to be dumped into the tanks to give tidbits to the others, while black tips took the lion's share. This illustrates that when choices have to be made as to which to keep together in captivity compatibility among different species must be found.

EXPLANATION TO TABLE I

An example of shark feeding preferences. The data are derived from observations on four lemon sharks, designated as individuals A, B, C, and D. The observations covered an eight-month period with the sharks being fed daily. At each feeding, four or more categories of fish were fed the sharks, in randomly mixed lots. The table shows the responses of the sharks to the food. An interested shark will often approach food by touching it with its snout. If the food is still potentially acceptable, the shark will raise the snout slightly, and lower it on the food, giving it a gentle push downward. From this point, a shark might bite the food--taste it. If still interested, but nevertheless cautious, the shark may circle the food, and then either eat or reject it. Following the touch, the more actions (push, taste, circle) occurring before actual acceptance, the more hesitant is the shark. For instance, the javelin fish was accepted outright by Shark C after the push, while Shark D required a taste and circling movement before rejection. Shark A rejected it without a touch, and Shark B rejected it after the push. For Shark C, javelin fish was relatively high as an acceptable food fish, while it was totally unacceptable to Shark A.

SHARK A, B, C, D

TABLE I

	TOUCH	PUSH	TASTE	CIRCLE	EAT	REJECTION
Bonito	ABCD	ABCD	BCD	C	ABCD	
Amberjack	ABCD	ABCD	ABCD	A D	ABCD	
Blue Runner	ABCD	ABCD	ECD	CD	CD	AB
Black mullet	ABCD	BCD	CD	C	CD	AB
White mullet	ABCD	BCD	CD	CD	CD	AB
Yellowtail	ABCD	ABCD	A CD	A CD	C	AB D
Grunt	BCD	B D	B D	B D	D	ABC
Snapper	ABCD	AB	AB	AB	B	A CD
Javelin	BC	BC	D	D	C	AB D
Blue Fish	ABCD	ABCD	BCD	BCD	ABCD	
Mackeral	ABCD	ABCD	ABCD	AB	ABCD	
Fresh	ABCD	ABCD	ABCD	ABCD	ABCD	
90°	ABCD	ABCD	ABCD	ABCD	B D	A C
60°	ABCD	ABCD	B D	B D		ABCD
20°	ABCD	B D				ABCD
Bad	BC					ABCD

SOME LENGTH-WEIGHT RELATIONSHIPS FOR SHARKS AND THEIR USE IN HUSBANDRY PROGRAMS

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I have found that a knowledge of the "normal" weights for sharks of a given length has enabled me to effectively deal with obesity in sand tiger sharks (*Carcharias taurus*), and anorexia in sandbar sharks (*Carcharhinus plumbeus*) (Mohan 1996). When fed ad libitum mature sand tiger sharks can easily consume 3.5% of their body weight per week (%BW/wk). While this might be an acceptable ration for a subadult, such a diet will result in obesity in older animals. I have continued to observe that fully grown animals kept at 22-23°C will maintain weights somewhat higher than a wild shark even at rations averaging 1%BW/wk. I personally feel it is important to regulate food intake to maintain each animal's weight within a range that does not significantly exceed what might be seen in the wild. While high weights are a concern with sand tigers, I have found low weights to be more of an issue in juvenile and subadult sandbar sharks. Occasionally these animals will stop eating after being bitten by another exhibit animal or when suffering from some sort of systemic infection. When a sandbar masses below it's expected weight, as determined using a table generated from a length-weight equation, we prepare to intervene medically if necessary.

Table 1 contains length-weight (L-W) equations for a number of sharks commonly kept in public aquariums, and for a few species whose captive husbandry is not well established. Multiple records are provided for a species when more than one region has been sampled. Each equation can be used to generate a table of predicted weights using a spreadsheet program such as Microsoft's Excel®. It is a fairly simple matter to enter a series of target lengths into a spreadsheet column using intervals of one or five centimeters. Always start with a length at the low end of the size range for which the equation is valid, and end with a highest valid length. These values correspond to the smallest and largest sharks used to generate the equation. Attempting to use the equation for animals that do not fall within the valid size range may result in significant errors in estimating weight. For example: When Branstetter and Musick's (1994) formula is used to generate a predicted weight for a 100 cm sand tiger (outside of the 165-270 cm valid range), the result is at least 25% lower than what has actually been reported for wild neonates. The formula I built using capture data from SeaWorld and Ripley's, as well as a few neonate data points from the literature, produces a somewhat closer match to what should be seen in young sharks. The "function wizard" in Excel allows you to solve the L-W equation for each target length and produce a column of predicted weights.

Each equation is in the form of: Wt = #.## ($10^{-\#}$) * $\text{Length}^{\#.\#\#}$

I've found it convenient to do the math in two steps, first figuring the #.## ($10^{-\#}$) part and then multiplying the numbers in the resulting column by the second half of the equation. Once you have entered a formula for the first row of the column, just drag down on the square dot (handle) at the lower corner of the highlighted box to copy the equation for all of the other rows. The help menu in Excel adequately explains how to do this.

Attention should be paid to the units used in each L-W equation (usually, but not always, kilograms and centimeters), to the type of length measurement taken [total (TL), fork (FL) or precaudal (PCL)], and to the physical method the original author or source used to manipulate the measuring tape. The various types of length measurements are defined by a drawing on p. 10 of Compagno (1984). A number of techniques have been used to physically measure length (Table 1). While Branstetter and Musick's, and my own L-W formulas for sand tigers, used different methods of obtaining total length, they produce weights that vary by little more than one percent when compared at the valid size range for the former authors' L-W equation (165-270 cm). Although this (perhaps) fortuitous agreement between the two *C. taurus* formulas seems to indicate that measurement technique is not important, the opposite may be true in some cases. However, I doubt that differences in measurement technique would produce differences in L-W relationships that would be large enough to have a significant effect on husbandry protocols. Shark weights, like most other biological parameters, will normally vary substantially for a given length anyway. The question may simply be whether the approximate weight given by the formula lies above or below the actual mean for wild sharks of a given length. A few kilograms one way or the other is not biologically significant from a husbandry point of view.

You may wish to use an index of fish condition known as "relative weight" (W_r) to express the ratio of actual to predicted weight as a percentage. Relative weight is simply the observed weight of a shark divided by the expected weight generated by a L-W equation, and then multiplied by 100 to obtain a percent.

I would have liked to include equations for other species in Table 1. Other relevant papers certainly exist and remain to be found, however, age and growth studies often fail to gather or report weight data because their principal goal is to compare vertebral aging data with length. Species for which L-W equations would be useful include virtually all of the Indo-Pacific and temperate species that we display. I would urge anyone collecting sharks to record length and weight at capture so that this data may be pooled in the future. If you are collecting data on a species whose L-W relationship is **not** already described in the literature, I would recommend the length measurement method used by Castro (1996), as it seems to be the most error-proof. Drop perpendiculars to the nose and tail from a horizontal bar that is parallel to the body axis of the shark. Stretch The tail out along the line of body axis as far as it will go. If you are collecting species already studied, particularly sand tigers, it is important to use the same measurement technique used previously so your data can be pooled with, or compared to, existing sets. I urge anyone collecting young sand tigers (90-160 cm TL) to measure and weigh all animals upon capture. I will add these data to the pool I already have on hand for larger animals, and distribute a corrected L-W equation to anyone who sends me data.

Additional Resources:

The annual American Elasmobranch Society captive census provides a list of species for which additional husbandry information would be desirable (contact Beth Firchau at bfirchau@city.virginia-beach.va.us for a copy). It would be useful to generate L-W equations for bonnethead, sharpnose, Caribbean reef, Pacific blacktip, reef whitetip, and bull sharks, to name just a few species.

A length-weight calculator is posted on the NMFS's Apex Predator Program website (http://www.na.nmfs.gov/sharks/lw/calc.html), and can be used to quickly determine projected weights for sandbar sharks and a variety of other Atlantic species.

Table on following pages.

Table 1. Length-weight equations reported for a variety of sharks, and conditions under which each formula is valid.

Species	Sampling area	Length - Weight Equations, Sample Size, Size Range for Which Equation is Valid, and Other Notes	Length Measurement Method	Source
sand tiger *Carcharias (a.k.a.: Odontaspis, Eugomphodus) taurus*	Delaware Bay, USA (neonate data from various Atlantic US sites)	Wt(kg) = 2.594 (10^{-6}) * TL (cm)$^{3.168}$ N=25 103 - 278 cm TL 3 neonate data points are from Gilmore et al 1983, 174-278 cm data is from public aquarium capture records (SeaWorld Orlando, Ripley's), one data point from healthy neonate in captivity for 4-8 weeks before receipt at SeaWorld Cleveland.	End of tape on nose, laid over dorsal surface, and stretched from top of peduncle to end of extended tail.	Pete Mohan, SeaWorld Cleveland (see L-W notes to left).
sand tiger *Carcharias taurus*	Vicinity of Chesapeake Bay, USA	Wt(kg) = 1.62 ($10^{-6)}$ * TL(cm)$^{3.24}$ N= 69 ~165 - 270 cm TL (formula was tested, and found invalid for, smaller animals) Formula in paper is a typographical error. Above correction was sent to P. Mohan via Henry Mollet (MBAq). FL = .845 TL - 2.97	Perpendicular dropped to nose and tail. Tail in natural position.	Correction to: Branstetter and Musick 1994
lemon *Negaprion brevirostus*	Bahamas	Wt(kg) = 2.069 (10^{-5}) *PCL(cm)$^{2.892}$ N=53 44 - 215 cm PCL (data set was primarily juveniles and includes 8 adults)	Tape stretched over dorsal surface, but kept nearly straight, with perpendiculars dropped to the nose and peduncle.	Henning-sen 1989
Sandbar (Brown) *Carcharhinus plumbeus*	Entire Atlantic Coast of USA	Wt (kg)=1.0885 (10^{-5})*FL(cm)$^{3.0124}$ N=1,548 44 - 201 cm FL FL = .8175 TL + 2.5675	Tape in straight line along body axis	Kohler et al. 1995

Species	Sampling area	Length - Weight Equations, Sample Size, Size Range for Which Equation is Valid, and Other Notes	Length Measurement Method	Source
Dusky *Carcharhinus obscurus*	Entire Atlantic Coast of USA	Wt (kg)=3.2415 (10^{-5})*FL(cm)$^{2.7862}$ N = 247 79 - 287 cm FL FL = .8396 TL - 3.1902	Tape in straight line along body axis	Kohler et al. 1995
tiger *Galeocerdo cuvier*	Entire Atlantic Coast of USA	Wt(kg) =2.5281(10^{-6})*FL(cm)$^{3.2603}$ N = 187 92 - 339 cm FL FL = .8761 TL - 13.3535	Straight line along body axis	Kohler et al. 1995
white *Carcharodon carcharias*	"Mostly from California"	WT(kg) = 4.34 (10^{-6}) * TL(cm)$^{3.14}$ 127 - 554 cm TL	not given	Compagno 1984 (original reference not specifically cited)
white *Carcharodon carcharias*	Entire Atlantic Coast of USA	Wt(kg) =7.5763 (10^{-6})*FL(cm)$^{3.0848}$ N = 125 112 - 493 cm FL FL = .9442 TL - 5.7441	Straight line along body axis	Kohler et al. 1995
blue *Prionace glauca*	Entire Atlantic Coast of USA	Wt(kg) =3.1841 (10^{-6})*FL(cm)$^{3.1313}$ N = 4,529 52 - 288 cm FL	Straight line along body axis	Kohler et al. 1995
Atlantic nurse *Ginglymo-stoma cirratum*	Florida Keys, USA	Males (N = 87): Wt (kg) = 3.44 (10^{-5}) * TL(cm)$^{2.595}$ Females (N =63): Wt (kg) = 4.093 (10^{-5}) * TL(cm)$^{3.037}$ ~30 - 180 cm TL	Not given	Carrier and Luer 1990

Species	Sampling area	Length - Weight Equations, Sample Size, Size Range for Which Equation is Valid, and Other Notes	Length Measurement Method	Source
Atlantic blacktip *Carcharhinus limbatus*	Atlantic coast: Northern Florida and South Carolina, USA	Wt(kg) = 2.512 (10^{-9})*TL(mm)$^{3.1253}$ Note that length is given in millimeters. N = 183 65 - 195 cm TL FL(mm) = .8301 TL - 29.00425 PCL(mm) = .74493 TL - 23.13766	Perpendiculars dropped to nose and tail. Tail at it's max. extension.	Castro 1996
Atlantic blacktip *Carcharhinus limbatus*	Northwestern Gulf of Mexico	Wt (kg) =1.44 (10^{-5}) * TL(cm)$^{2.87}$ N ~ 70 ~60 - 180 cm TL TL = 1.16 FL + 5.71	Perpendiculars dropped to nose and tail. Tail in natural position.	Branstetter 1987b
spinner *Carcharhinus brevipinna*	NW Gulf of Mexico	Wt (kg) =7.51 (10^{-6}) * TL(cm)$^{2.97}$ N = 29 ~60 - 210 cm TL TL = 1.17 FL + 3.05	Perpendiculars dropped to nose and tail. Tail in natural position.	Branstetter 1987b
oceanic whitetip *Carcharhinus longimanus*	Pacific Ocean	Males (N = 133): Wt(kg) = 3.077 (10^{-5})* PCL(cm)$^{2.860}$ Females (N = 128): Wt(kg) = 5.076 (10^{-5})* PCL(cm)$^{2.761}$ ~50 -195 cm PCL TL = 1.397 PL	not given	Seki et al 1998
scalloped hammerhead *Sphyrna lewini*	Northwest Gulf of Mexico	Wt(kg) = 1.26 (10^{-5}) * TL(cm)$^{2.81}$ N = 43 ~105 - 235 cm TL	Perpendiculars dropped to nose and tail	Branstetter 1987a
scalloped hammerhead *Sphyrna lewini*	Entire Atlantic Coast of USA	Wt(kg)= 7.7745 (10^{-6})*FL(cm)$^{3.0669}$ N = 390 79 - 243 cm FL FL = .7756 TL - .3132	Tape in straight line along body axis	Kohler et al. 1995

References:

Branstetter, S. 1987a. Age, growth and reproductive biology of the silky shark, *Carcharhinus falciformis*, and the scalloped hammerhead, *Sphyrna lewini*, from the northwestern Gulf of Mexico. Envir. Biol. of Fishes 19(3): 161-173.

Branstetter, S. 1987b. Age and growth estimates for blacktip, *Carcharhinus limbatus*, and spinner, *C. brevipinna*, sharks from the northwestern Gulf of Mexico. Copeia 1987(4): 964-974.

Branstetter, S. And J. Musick. 1994. Age and growth estimates for the sand tiger in the northwestern Atlantic Ocean. Trans. Amer. Fish. Soc. 123: 242-254.

Carrier, J. And C. Luer. 1990. Growth rates in the nurse shark, *Ginglymostoma cirratum*. Copeia 1990(3): 686-692.

Castro, J. 1996. Biology of the blacktip shark, *Carcharhinus limbatus*, off the southeastern United States. Bull. Mar. Sci. 59(3): 508-522.

Compagno, L. 1984. FAO Species Catalogue. Vol. 4: Sharks Of The World. Part 1 - Hexanchiformes to Lamniformes. United Nations Development Programme, Food and Agriculture Organization of the United Nations, Rome, Italy. 249 pp. (see 238-241)

Gilmore, G., J. Dodrill, and P. Linley. 1983. Reproduction and embryonic development of the sand tiger shark, Odontaspis taurus (Rafinesque). Fish. Bull. 81(2): 201-226.

Henningsen, A. 1989. Annual production in the juvenile lemon shark, *Negaprion brevirostrus* (Poey), in a shallow Bahamian lagoon. M.S. Thesis. Department of Biology and Living Resources, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami. Miami, FL. 112p.
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Kohler, N., J. Casey, and P. Turner. 1995. Length-weight relationships for 13 species of sharks from the western North Atlantic. Fish. Bull. 93: 412-418.

Mohan, P. J. 1996. Using fisheries data to manage the diets of captive elasmobranchs. Annual AZA Conference Proceedings. Waikiki, HI. Sept. 17-21. pp. 265-273.

Seki, Tomoko, T. Taniuchi, H. Nakano, and M. Shimizu. 1998. Age, growth and Reproduction of the oceanic whitetip shark from the Pacific Ocean. Fisheries Sci. 64(1): 14-20.

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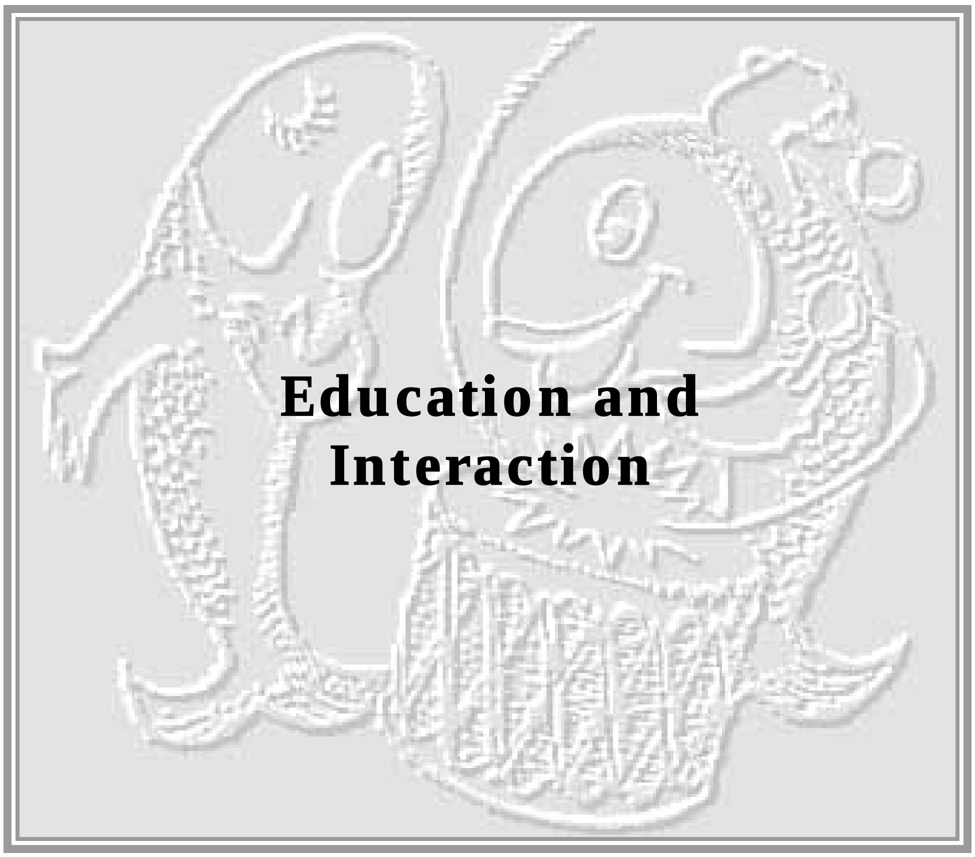
Education and Interaction



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COMMUNITY RELATIONS AND ELASMOBRANCHS IN PUBLIC AQUARIA

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Elasmobranch Husbandry Symposium

The Public Understanding of Sharks

A couple of years ago, the 'Weekly World News' devoted most of its front page to a fearsome photograph of the great white shark. Overprinted was the attention-grabbing headline:

> '…Castro's evil plot to terrorize our beaches! – CUBA LAUNCHES SHARK ATTACK ON U.S.!....'

The inside pages carried more details of the plot by 'depraved dictator' Fidel Castro. Marine biologists at an isolated laboratory had developed the killing machines –

> '…Ichthyologists, geneticists and other scientists, and animal behavioral experts working at the secluded laboratory bred several generations of various shark species before developing the dreadful killer species that now patrols America's coastlines…'

Apart from the fact that this story reinforces the public belief that all scientists are manipulating nature to create monsters and/or developing weapons of mass destruction it also sums up the popular belief that all sharks are malevolent, calculating killers bent on wreaking vengeance on the human race. Despite the fact that the same newspaper also carried a story about a 3-breasted woman and a 3-armed man who between them produced a 3-legged baby, an awful lot of people would want to believe the story is, or could be true. Indeed it is very difficult to find any story in the popular press or on the media that does not pander to and hence give credibility to the wholesale perception that all sharks are dangerous at best and man eaters at worst. The mythology, of course, makes for very good headlines and sells newspapers. A more recent 'serious' article reported the capture off Cornwall, UK of a 'baby killer shark'. The species reported, the Mako shark, has been implicated in injurious encounters with humans but even though the journalist was told that the shark was in fact a Porbeagle, he chose to run with the 'better' story. Stories are often embellished to 'give them teeth', but it is just as likely that a better story is gained by omission. The report of a Mediterranean great white repeatedly attacking a small boat was covered by all news media and seemed to strengthen the vindictive nature of sharks but neglected to mention that the shark was on the end of a fishing line and was understandably trying to defend itself.

This fascination with the blood and guts element of sharks is a self-perpetuating myth. The media generate the stories in response to the blood lust of their audience, which in turn is fed by the stories and so on. Even credible 'blue chip' TV programs dwell upon this aspect of sharks. We are still at the point where nobody wants a shark story unless it has a high 'gore content' – breaking the chain is a real challenge. So from an educational point of view we have a huge challenge but also much potential.

A rough survey of attitudes towards sharks has a predictable outcome. Ask most people to draw a shark and it will have large, sharp teeth. Sharks are used in advertising to swim menacingly around boats and islands awaiting an incautious arm or leg, they leap out of the sea to 'snap up bargains' at the January sales. They are used to depict the human occupations we love to hate – they often take the place of tax inspectors and traffic wardens in cartoons. It is no surprise then that the over-riding impression is of a calculating predator bent on ridding the seas of humans – and this is exactly what fascinates people.

Even dead sharks hold a fascination for people. The trophy shark on the quayside is a decreasingly common sight as attitudes gradually change. Perversely but predictably it is the very people who hunt sharks that are starting to champion their cause. But sharks still come ashore and when they do they still generate a huge amount of interest. Watching people around a dead shark can teach us much. They are fascinated and want a closer look, they see the animal in the flesh as an incredible creature - it is they, not the shark, who become hooked. Any 'expert' close by is bombarded with questions about what it is, where it came from, what age, sex, species it is. If female, has it left its babies out at sea, will they die without her? The over-riding emotion is not the revulsion and disdain you might expect but rather, concern and respect. The glaringly obvious reason for this contradiction is the proximity of the real thing. Most people never see a shark so close, even a dead one, but when they do they see it for what it is, not what they have been told it is. Proximity of sharks is where aquariums gain, time and time again – they can provide a unique view of the marine world and the animals it contains.

Forget being purist and cash in on the widespread interest, awe, fascination and unwarranted but genuine fear that sharks generate. There is no doubt that for the majority of our visitors, sharks are a high point of their stay in any aquarium. The sharks that we hold, in trust, in captivity are ambassadors for their kind and for the marine environment as a whole. We can use them to inspire appreciation and concern through the way they are presented and interpreted.

The 'Jaws' connection is an important tool for gaining attention. In the UK our National Curriculum majors on a few subjects, of which mathematics and literacy are key elements. Sharks provide ideal subjects to address the needs of schools whilst providing us with the vehicle for dispelling myths. A group of children (or adults!) can be encouraged to see sharks as perfect swimming machines and to look at them as flying creatures – the underwater equivalent of birds of prey or even airplanes. Measurements of the 'engine' – the tail movements can be related to different species and different lifestyles. Any gill slit movements can be associated with activities. Sharks can thus be studied by numbers.

The language of sharks is varied and colorful. A group of visitors, asked through word association, can generate a shark vocabulary in a very short time. At the first mention of the word shark they respond with ‘bite, fear, blood, teeth, man-eater, jaws, killer, cold-blooded, etc’. This provides the educator with the perfect material to ‘put the record straight’. Simply sitting and watching and asking what visitors know about sharks is an excellent method of bringing out the truth, and surprisingly many children and adults know much of the truth – it simply needs raising to the surface. Often in a group there will be one who is more knowledgeable and concerned than the others and they become a champion of the cause. It is never long before the vocabulary changes to include the words ’sleek’, ‘misunderstood’, ‘elegant’, ‘endangered’, ‘beautiful’, ‘amazing’, and so on.

Sharks suffer too

The end product of all of our outputs has to be a greater understanding of sharks, which will in turn lead to more sensible and sustainable management and conservation. Most of our visitors have little understanding of the frequency of shark attacks, the figures for global mortalities, or the relative risk of shark attack. They certainly have little appreciation of the numbers of sharks that humans kill each year, whether by accident or design, whether for malicious pleasure or economic need. The figure of 100 million shark deaths per annum is an oft-quoted one and a staggering one. This equates to over one quarter of a million sharks each day – about three sharks each second . Such staggering numbers are perfect for making the point. Timing a talk and translating it into shark deaths, or having a death counter totting up the total is both immediate and very powerful.

The Future – Organizations and Attitudes

Not so many years ago the idea of a conservation organization specifically for sharks would have been met with derision. After all, the prevailing attitude was that the only good shark is a dead shark. Now we have the Shark Trust in the UK, the European Elasmobranch Association, and many others established throughout the world. The real strength of these organizations is that they have been born of necessity rather than sentiment. They have grown from scientific beginnings rather than from a fluffy ‘feel good factor’. They can only go from strength to strength as more people are converted to the cause. There is a growing understanding of sharks and their importance in their environment. There is a growing awareness of the threats that sharks face worldwide. There is a growing appetite for information about sharks and there is a great opportunity to accelerate the changes in attitude that are taking us from killing to conservation. Aquariums should be at the vanguard of this turning tide, they have a huge part to play in replacing shark fiction with shark fact. They are ambassadors for the seas and their species. We all have a duty to make them welcome, treat them well, and help our visitors understand the truth rather than the fiction about them.

SCIENCE AND AESTHETICS: AN EDUCATIONAL INSIGHT

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Elasmobranch Husbandry Symposium

Science and Aesthetics

The general public has a polarized view of the arts and science. This is probably born of our schooling experience, where each discipline is kept quite apart from the other. There is however incredible beauty in the discoveries of science, and a lot of science behind the creation of art. This may be taken as referring to the practicalities of each discipline-- for example the order that emerges from the study of fractals in computing, or the ingredients of pigments and their behavior under light; but more-so I see this as pertaining to the mental approach to both. The process of observation, questioning and interpolation of information for art's sake is, in my view, exactly the same as that of scientific research. Further, a real sense of creativity is required to explore the mysteries of the natural world.

The beauty of public aquaria is that they have the opportunity and the freedom to inspire a deeper interest and understanding in those who are skeptical of the arts or the sciences by using one to promote the other. I have found that no captive marine creature is better placed as a tool through which to achieve this than the shark. Capturing instant curiosity, the functionality behind the simple beauty of the shark presents a perfect tool for promoting the arts and sciences in an exciting and an entertaining way. To explain why the shark presents itself as such an ideal subject I must first take a personal detour into my past and sources of inspiration.

As a young child I was attracted to the graceful lines of aircraft and sharks quite unaware of any link between the two. This innate sense of the good aesthetics of objects in the world around me influenced my tastes and interests quite subconsciously. This has since proven to shape my career in a most dramatic fashion. I bought a poster of the space shuttle 'Columbia' on her maiden voyage because the shape of the orbiter was pleasing to my eye. Ironically, written beneath it were the words 'From our wildest dreams come our greatest endeavors'. Equally inspired by the aesthetics of sharks, it became my dream to see wild sharks and to learn to accurately draw them. I found a simple pleasure in mapping out the sweeping lines of their form. That dream was fulfilled when I came to Florida to work for Dr. Samuel Gruber as part of a scientific illustration degree. I found myself regularly using the 'guide to terms and measurements' at the front of the FAO species catalogue1 to distinguish tricky shark species such as *Carcharhinus limbatus* from *C. brevipinna*. The use of morphometrics to identify species revealed to me a system for accurately drawing sharks. This system was very much a technical drawing procedure that used standard reference points from which to measure proportions. I found that using this technique, I could teach children to instantly draw accurate representations of sharks where previously they could not draw anything that even closely resembled these fine fish. In drawing certain features I asked myself, and was asked by others, what are these for?

I noted that pilots often say of an aircraft, 'if it looks good it flies well'. Good design solutions seem naturally to take on the best aesthetic appearance. Many years later the opportunity presented itself for me to study the Space Transportation System (the US space shuttle). I was interested to learn what the function was behind the orbiters' unusual shape, what had failed in a technical sense to the shuttle 'Challenger' on the doomed STS-51L mission, and to understand the nature of the human impact.

I learned that the technical failure was caused by localized human complacency that let down the efforts of the greater team and the hopes of an entire nation. All this was summarized by a large banner that I found hanging in one of the orbiter processing facilities at the Kennedy Space Centre, it read:

"It takes a team to build a dream."

It takes 20,000 individuals to safely launch the space shuttle. It demands perfection from all, the best in communication, total cooperation, regardless of, and sometimes precisely because of, the vast mix of personalities, skills and beliefs; a human success story that gets the world's most complex machine to repeatedly fly safely.

Returning to sharks I saw an awe-inspiring beauty, but one which represented a successful 'design' solution, this time by nature. My artistic mind could not help but ask what the challenge was that this solution so perfectly overcame, and so before I could notice, I was thinking like a biologist. My starting point had been shark illustration, I progressed to study their basic biology, and no sooner had I grasped the unusual reproductive strategies of elasmobranchs than I found myself turning to conservation issues - the one just led to the other.

A bit like space, the oceans are free of the boundaries and divisions that we are used to working with on land. I quickly applied my lessons from the Space Transportation System to marine conservation. If ever people needed to demonstrate the ability to work as a team across all borders – real or imagined, using our whole diversity of skills, it was in exploring the oceans and managing them in a sustainable way across the globe.

The thought of taking on the issues that affect our oceans is as mind-boggling to most, as trying to quantify outer space. Most of the problems start at the bottom of the food chain, affecting creatures that simply do not have common names and that sadly do not inspire most people. We need flagship species to communicate conservation messages to the layperson. Cetaceans are not kept by many aquaria. In fact, they are perhaps already too familiar. People think they know them already and aren't really listening when you try to present the truth. Most aquaria can and do keep sharks, and sharks instantly captivate the audience, albeit perhaps for the wrong reasons.

In my current presentations I literally draw the parallels between the hydrodynamics of sharks and the aerodynamics of aircraft and formula one cars using fin structures, pre-caudal pits, corrugated tails, caudal keels and the pitted skin. The relationship between form and function is dramatically conveyed. Further, the lessons we can learn from nature are well portrayed through the use of products that function like their natural counterparts. Such examples present selfish reasons for conserving elements of the natural world. Conversely, the increasing importance of technology to marine research can be introduced. More and more, advancements in diving equipment, satellite telemetry, sonar, and remote sensors of all kinds are supporting biologists in their work. It simply is no longer possible to divorce the creative approach of the scientist from that of the artist/designer. Whichever you are, you will achieve little if you work alone and do not feed off the inspiration and passion of others.

Sharks in an aquarium may play the most pivotal role in inspiring visitors to think about the oceans in a new way and to recognize relationships where before they saw none. It no longer seems ethical for aquaria to keep sharks purely to thrill. In accepting that sharks have such a key educational role I believe it is important that the appropriate species are selected to maximize this potential. Sand tiger sharks (*Carcharias taurus*) have the 'nasty' teeth that fit the misconceptions of most visitors, but they really do not move in a way, or exhibit the fluid form that is typical for sharks. I argue therefore that they do not make the ideal exhibit. Any species that bumps its nose and is left looking less than perfect is also not appropriate for projecting the right messages. I have seen many a Sandbar (*C. plumbeus*), Tope (*G. galeus*), and Spiny dogfish (*S. acanthias*), that simply could not live up to the shark talk, taking place in front of it. Of course, we should only exhibit the species that we know we can maintain correctly, but of those let us then only select the species that will best serve the interpreters, for that is why the sharks are there, isn't it?

After word

All of these thoughts came together in a new context when the delegates of the 1st International Elasmobranch Husbandry Symposium gathered in Orlando in early October 2001. The tragic events of the previous month threatened to keep many away and to throw a shadow over proceedings. However, they did not, and so as a part of my presentation I chose to read from some simple notes I made while flying to the conference. At the request of the editors I have copied word for word the conclusion of my presentation.

" … 1500hrs eastern standard time. We're at 36,000ft and, while no-one's saying it, we're all looking out the starboard window at Long Island for some misty view of New York and what is not there. It's like somehow it will become real. All we have though, is some hazy smudge that is probably New York.

I dreamt last night with contrasting, crystal clarity, that I visited 'ground zero' as they call it. The site where the World Trade Centre stood. The dream feels more real than the 3000 bodies smudged to nothingness down there, outside the window, in seconds, by one of these airplanes… and yet, as we took off today I smiled at the wonder of this beautiful plane, still able to separate the excitement, the amazing human endeavor of this 747-400 from the 'flying bomb' the world now sees them only to be. The world is still a big and beautiful place. Everything below me will be influenced by what happened out there, as big as it seems; and we all will have some part to play in what happens next. But every-one who is not a victim must see themselves, now, as a ‘survivor’ in a terrorist war; it ‘could’ have been us. So we will all be responsible for keeping the world a beautiful place and we shall achieve that through our love for each other and our world, more able to achieve for the extra strength we find in each other. We change our world one way or another not because of what we see, but because of what we feel. The view may be bleak sometimes, but if we feel good in our hearts that is what will prevail. I wish these passengers would stop looking for the answers out of the window for the answers are in us … ”

“ … Take pride in what you do in each day of your working life and do not lose sight of the value to other people in what you do regardless of world events. When people lose faith in their fellow human beings and the human world that they live in they often turn to their pets, wild animals, the natural world, for comfort and re-inspiration. You can’t get CNN at 40m on a reef or hanging under a canvas wing at 1000ft spotting buzzards and bobcats; or more likely, visiting the aquarium – fish are restful. The work that you do offers a distraction to people, but then also an opportunity for people to contribute in many things, in making things better, especially when they feel vulnerable or helpless. They can make a difference, be that in their observations, their signatures, or simply their money. The results of this conference are an important part of bonding our team, striving for perfection, feeding our thirst for knowledge, to indulge our own passions and find the means to best communicate your passion to others. We in the animal husbandry and natural science world are ultimately in the business of making people happy, giving them a wow every now and again, and a wow that will be repaid with environmental awareness to the good of everything … ”

DISCOVER SCUBA: DIVE WITH THE SHARKS PROGRAM AT DEEP SEA LEISURE

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Elasmobranch Husbandry Symposium

Introduction

Like many public aquariums, Deep Sea Leisure plc. (DSL) offers the public an opportunity to dive in the main displays. DSL is not the first aquarium company to offer this type of experience; guest divers have been diving in various establishments around the globe since the early 1980's (pers. com.), and possibly earlier.

DSL currently operates two aquarium attractions in the UK, with an average annual visitation of 850,000. Phil Crane, (Managing Director, DSL. 1992 – 2000) believed that interaction between staff and visitors was the key to success for public aquaria in the UK. Company culture focuses on the three E's; the Environment, Education & Entertainment. A team of up to 24 employees is available to interact with the public at all stages of their voyage through Blue Planet. 'Edutainment' allows DSL to fulfill the visitor's desire to be inspired and entertained by providing an informative personal experience.

Public dives at DSL began in early 1998, as a result of managerial and public pressure. Like all visitor attractions DSL strives to offer a unique visitor experience, not only to exceed visitor expectation, but also to encourage visitors to share the experience and help educate others for sometime after the visit.

The main dive site at Blue Planet is the Caribbean reef display, a 3.8 million liter system averaging four meters deep. There is a 71meter walk through tunnel and a 4m by 4.5m acrylic window in the Aquatheater for public shows. The main inhabitants are:

8 Sand tigers, *Carcharias taurus*
3 Nurse sharks, *Ginglymostoma cirratum*
2 Lemon sharks, *Negaprion brevirostris*
7 Southern stingrays, *Dasyatis americana*
1500 Caribbean fishes.

Diving in the UK

Diving Operations in the UK are governed by the Health and Safety Executive (HSE), under the Diving At Work Regulations 1997. Divers must have a commercial scuba diving qualification, or minimum of PADI Divemaster (or equivalent) to work as a diver in the UK.

The dive team must have First Aid at work and Oxygen Administration certifications, and an annual HSE approved medical assessment.

Diving operations must be supervised at all times by the allocated dive supervisor with a dive tender present. The Dive Supervisor is legally responsible for the health and safety of the divers in their care, whilst the Dive Contractor (the employer) is legally responsible for the provision of the appropriate equipment and all dive operations undertaken by their employees.

Maintenance dives

Minimum dive team of four, (two in water, two at the surface). Open lines of communication between divers and the supervisor, and the supervisor and the duty manager are maintained at all times. Maintenance dives are carried out from 11.00am to 5.00pm each day. Each diver completes three hours in the water per day, and dives on average, three days a week. Tasks include maintenance, public shows and feeding. Although the animals are encouraged to associate divers with food, it is essential that they don't expect food during non-feeding dives. Therefore each target species identifies a separate set of cues to obtain food. The cues relate to: (1) a specific place; (2) specific time; (3) specific technique.

Public dives

As with daily operations open lines of communication must be maintained. All guest divers must be negatively buoyant. No guest divers are permitted to dive until all feeding is completed for the day (after 5.00pm). Guest divers cannot physically enter the designated shark feed area. If any diver attempts to touch the inhabitants the dive is instantly aborted, all diving operations are immediately cancelled and staff divers face disciplinary procedures.

<u>Dive Nights for qualified divers</u>***:***

Requirements:

Maximum of 12 participants, 3 groups of 4 divers.
Minimum qualification: PADI Advanced.
Minimum 12 logged dives ..
Last logged dive within 3 months.
Certified medically fit to dive..
Blue Planet Dive team of 4 (2 in water, 2 surface support).
Ratio of 2 staff diver to 4 guests..

Participants receive:

15min group briefing.
5min safety briefing..
30min dive..
30min debrief.

Dive clubs usually stay until every member has completed the dive. Each participant averages two spectators, and the average spectator retention time is three hours.

Discover Scuba for unqualified divers*:*

Requirements:

Maximum of 6 participants, 3 groups of 2 divers.
Minimum, 16 years of age.
Certified medically fit to dive.
Blue Planet dive team of 5 (3 in water, 2 surface support).
Ratio 3 staff divers to 2 guests.

Participants receive:

30mins theory (basic diving skills).
30mins skills practice (mask clearing, etc)
15min briefing (don't touch).
30min dive.
10min debrief.

Spectators depart as soon as their friend or relative has completed the dive. Participant averages three spectators, and the average spectator retention time is four hours.

Discussion

Initial investigations suggest that diving does not significantly change the swimming behavior of the sharks tested. This may be due to the busy diver maintenance schedule and implies that the elasmobranchs have been conditioned to the presence of divers, and furthermore suggests that stress induced by the presence of divers is minimal.

DSL shark feed records indicate that despite seasonal fluctuations feed rates have not changed significantly since the Discover Scuba program was started. A research project has been set up with Manchester University to compare the behavior of our sharks (*C. taurus* and *G. cirratum*) in three different time periods, which reflect the intensity of diving operations.

Divers present (daily operations).
A dive function (DS or DN).
After dark (no divers present).

Each shark was observed for a total of six hours, in fifteen minute blocks (24 blocks in total, with 8 blocks in each time period). Location, swimming speed, and maneuvers were timed and documented. An ethogram of common Behavioural traits was made with each shark. Analysis is ongoing to test the hypothesis that if visitor divers and staff divers are not affecting the behavior of the sharks there will be no significant difference in observations for each time period.

Pending statistical analysis, results suggest that there is no difference in behavior of the sharks over the three different time periods (with the exception of feeding). The recent birth of four *D. americana* pups supports this suggestion, and results from this study will be available June 2002. Ideally, further investigation is required to identify a suitable method of quantifying and qualifying stress indicators in captive elasmobranchs.

It is generally considered (Veverka. 1994) that the average person remembers:

10% of what they hear
30% of what they read
50% of what they see
90% of what they do

Diving within the exhibit allows the general public to 'see' and 'do' the aquatic environment. Diving provides an ideal starting point for raising awareness by provoking interest and relating the interest to a personal experience.

Conclusion

Due to the informal, relaxed atmosphere and long visitor retention times provided by the Discover Scuba program, staff can interact with the visitors on a more personal level to give them an unforgettable informative experience. Although controversial, diving in the exhibits allows us to provide the general public with an entertaining, interactive experience. This provides the stimulus for a better understanding and appreciation of the conservation issues affecting the aquatic environment over the longer term.

Bibliography

Veverka, J. A.
1994. Interpretive Master Planning. Falcon Press Publishing Co., Inc. Helana, Montana, USA.

ELASMOBRANCH COMMON NAME USE IN MARINE AQUARIUM EDUCATION

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Elasmobranch Husbandry Symposium

Introduction

The use of a genus and species name to describe an organism is the basic or classical method of biological classification. We humans are inveterate classifiers, labelling plants & animals using either a common name for general descriptive purposes or a scientific Latin name obtained from the system of classification used by biologists. This is based on a hierarchical scheme devised by Swedish naturalist Carl von Linné (often Latinised to Linnaeus, a.k.a. Carolus Linnaeus). In the 10th edition of his Systema De Naturae (published in 1758), Linné listed every type of animal known to him, organising them into groups based on overall similarity and it is considered the starting point of modern (Western) systematics. Previously there had been no clear-cut distinction between the name of a species and its description. Species names are based on type specimens; these are the specimens an author used in describing a particular species.

The rules governing scientific nomenclature of animals are codified in the International Code of Zoological Nomenclature (3rd edition) published by the International Commission on Zoological Nomenclature or ICZN in 1985. The purpose of these rules is to ensure that the names given to groups of animals are unique and therefore unambiguous. Other groups of organisms, such as plants and bacteria, have their own codes of nomenclature.

However, the use of Common Names does not follow any particular method or format, which has led and can lead to considerable confusion. It generally lacks consistency from place to place, country to country, person to person, because, as we know, one man's 'German Shepherd' is another man's 'Alsatian'. The common name of a species should be that which best describes its appearance or pertains to the vernacular, idiom, cultural or indigenous name appropriate for that species in any given culture, country or region.

Why worry then?

We use common names to describe or identify species because these name titles are usually easier to remember and they provide a much more simple name to identify a particular species, in place of their scientific name, which, on many occasions, is long and/or hard to pronounce.

Claiming that common names of sharks & rays are one of their most important attributes is an understatement. In fact, common names are all that most people know to identify sharks as shown by the fact that most people accessing FishBase (www.fishbase.net) on the Internet do so by common name. Hence, FishBase would not be complete without common names. This fact was considered very early in the design of FishBase (Froese, 1990), which has resulted in the compilation of over 100,000 common names, probably the largest collection of its kind.

The purpose of this paper (originally presented as a poster) is to suggest that as a collective group, we adopt an appropriate World Zoological Elasmobranch Common Name Database or system, which reduces confusion and assists those responsible for education to use the most appropriate common name for a species in their region.

However, limited by their resources all public aquariums will make some attempt to educate their visitors in the sense of imparting information about their holdings and about aquatic life in general. The future of humankind greatly depends on extensive and effective environmental and conservation education (IUDZG, 1993). We need to ensure and reduce the incidence of incorrect or inappropriate common names being labeled on captive elasmobranch species.

What is their common name then?

It was only as a result of my captive breeding research of the Brown-banded Bamboo shark, *Chiloscyllium punctatum* (Garner, 1998) that I first became aware of such confusion surrounding the use of common names. This particular shark species was often referred to by the media, aquarium curatorial and education staff as a Catshark and not a Bamboo shark. For taxonomy comparison the first difference between these two shark species is that the genus *Chiloscyllium* is designated within the family Hemiscylliidae ie. Epaulette & Bamboo Sharks (Last & Stevens, 1994) and the Catshark is the designated common name for the sharks from the family Scyliorhinidae and several other families (Yearsley, et al.1997).

"We preferred to use the common name of Grey Carpet Shark to distinguish it (*Chiloscyllium punctatum*) from the Catsharks (Scyliorhinidae). The common name Bamboo presumably refers to the banded appearance of juveniles, again a bit misleading as the adults are brown-grey. That's the problem with common names, they can cause lots of confusion" (Dr. John Stevens, pers.comm.). Although this species (*Chiloscyllium punctatum*) is often referred to as the "banded catshark" in the aquarium trade, it is not a catshark, which are members of the family Scyliorhinidae (Michael, 1999). I think it best to use the most apt commonly used name for the area, as long as it is not misleading" (Jeff Johnson, pers. comm.).

The shark wheels

The three wheels represented below each show a picture of a shark species and how their name can vary depending on:

1. Regional Common Name Variations - Grey Nurse (Aust), Sand Tiger (USA), Ragged-Tooth (Africa).

2. General Common Name Variations - White Pointer, Great White, White shark

3. Literature Common Name Variations - Brown-banded Bamboo shark, Grey Carpet shark and Banded Catshark

As a further example, inappropriate common names could lead to potential problems regarding conservation strategies such as when the word 'Tiger' appears in the common name of a known shark attack species such as the Tiger shark, Galeocerdo cuvier with that of the Grey Nurse\ Sand Tiger shark, Carcharias taurus which has protected species status.

Conclusions

No common name classificatory system is inherently 'better' than another, but with a uniform approach undertaken through this World Elasmobranch Husbandry Symposium, such an endeavour would contribute towards alleviating these types of common name discrepancies.

Public aquariums have an ethical responsibility for providing their visitors with highly accurate and up-to-date information concerning their holdings. The use of common names falls within this informal education & interpretation responsibility, which could be termed "Captive Education". Through captive education, aquariums have an important captive audience who are there of their own free will and are very often enthusiastic to learn as much as they can. It is therefore paramount and a very important component of an institution's education agenda that this heightened awareness is appropriately fed the most accurate material including the use of elasmobranch common names.

Acknowledgements

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Bibliography

Froese, R.
1990. FishBase: An information system to support fisheries and aquaculture research. Fishbyte 8 (3). pp: 21-24

Garner, R. J.
1998. Preliminary report regarding captive breeding observations of the Brown-banded Bamboo Shark, Chiloscyllium punctatum Muller & Henle, 1838. Thylacinus vol.22, no.1, 1998. Pp: 31-32.

IUDZG/CBSG (IUCN/SSC)
1993. The World Zoo Conservation Strategy; The Role of the Zoos and Aquaria of the World in Global Conservation. In: Chapter 4, Education, Pp. 17-25.

Last, P., and Stevens, J.
1994. Sharks and Rays of Australia. CSIRO, Australia.

Michael, S.
1999. Fishes for the Marine Aquarium; Bamboo and Epaulette Sharks, A shark adventure in your own home. Aquarium Fish Magazine September, 1999. Pp: 20-31.

Yearsley, G. K., Last, P. R., and Morris, G. B.
1997. Codes for Australian Aquatic Biota (CAAB): an upgraded and expanded species coding system for Australian fisheries databases. CSIRO Marine Laboratories, Report 224. CSIRO, Australia.

HANDS-ON AND CHILD FRIENDLY SHARK DISPLAYS

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Elasmobranch Husbandry Symposium

Explore the Wonders of Water

ST. LOUIS CHILDREN'S
AQUARIUM

Introduction

St. Louis Children's Aquarium is committed to learning by experience about aquatic environments and culture (mission). Our core values include accountability, respect for environment, community involvement and making learning fun by personalized experiences. One of the key ways we accomplish our mission is by visitor engagement exemplified by our popular "Pet A Shark Exhibit." There are three key areas to prepare an institution to implement a successful interactive display with elasmobranchs:

1. develop and achieve your educational goals;
2. ensure excellence in the care of the animals; and
3. create a safe environment for the visitors.

Educational Goals

Prior to making a decision to display sharks in a public encounter setting, whether by general display or in a "hands-on" exhibit, exhibit goals must be set. This pedagogy begins by looking pragmatically at the educational goals and missions of the organization. Apply these goals to the "hands-on" exhibit and, if need be, develop new ones. The main purpose of having a touch station is to teach people specific information: about the animal(s), ecosystem and conservation. Learning the academic and curricular requirements of your state and school district, particularly where group experiences are involved, will give your organization's design team a framework for information to be disseminated towards standards. Correlate your exhibit plan to educational goals. Exhibit designs should be simple with some taxonomy and other pertinent ecological information in the background. Physical exhibit height, placement and shape should be planned for small group and individual interaction. Exhibit information panel graphics should be fun, educational and colorful. Filtration and life support systems should be hidden. Formulate pre- and post-tests to insure your guests are learning the information according to goals and standards. This "best practices approach" will allow you to evaluate your exhibit for effectiveness engaged by opinionaires given to general visitors and other educational groups. Curatorial, educational, design and management staff should be consulted on evaluation outcomes regularly to ensure quality.

Animal Welfare

Once a decision has been made to exhibit elasmobranchs in an interactive exhibit, the physical and mental health of the animals must be accounted for in addition to the well being of the visitors. Nurse sharks, Bamboo sharks and Horn sharks are examples of species of sharks that have proven successful in a "touch table" setting (Figure 1). Room and or exhibit temperature may determine which species you select in order to maintain the animal in a more natural environment. Closely monitor the water quality (test for ammonia, nitrites, nitrates and pH) and temperatures daily. Enhanced filtration (protein skimmers, biological and mechanical filtrations) are recommended as well as regular water changes. Have habitat enrichment protocols such as hiding places, manipulative devices like plastic blocks, and/or altered water flow dynamics in place, to help ensure the sharks' mental well being. Nutrition, timeliness of feeding, and behavioral stimulation studies are integral parts of maintaining a healthy touch shark. Feed your shark a diverse diet based on the animal's natural needs, including shark supplements as recommended by your institution's aquatic veterinary specialist. Time feedings so animals are not hungry when they are about to be touched but not touched immediately after eating.

Specific Care Instructions

You will need to make a commitment to keeping the species of shark you have selected for your "hands-on" exhibit. Keep a minimum of six animals for touching so they can be rotated on a regular basis. Maintain your reserve area at the same temperature, salinity and chemical values as your touch exhibit, so rotation provides minimal stress. Sharks are continuously rotated making proper identification essential. Name your sharks, number your sharks, know what makes each one of them distinct from the other. The easiest way is by color, marks, fin nicks and other physical differences. Behavior is another way to differentiate one from another. Spend time observing the sharks both in the touch exhibit and in the reserve area. Keeping a log on each one of the sharks will help when defining behavioral changes while in the touch exhibit. Not all sharks of a given species will be amenable to a "hands-on" situation. Measure, weigh and follow your organization's standards for medical observations and practices. Rotate the touch animals by "number of hands" – how many times has the animal been touched that day or week. Also consider accommodations for the sharks that graduate (outgrow) a touch environment (Figure 2).

Figure 1. Nurse Shark Touch Table.

Figure 2. Nurse Shark Graduation Tank.

Visitor Safety

Safety for the visitor as well as the animal is also a necessary consideration. We find ensuring the best use of the “hands-on” elasmobranch display is done by adhering to the following guidelines:

1. verbally give touching rules to all guests upon arrival;
2. post touch rules on all touch exhibits;
3. for tours, guides review the rules and observe the interaction; and
4. trained volunteers are stationed at touch areas.

These basic safety principles allow our facility’s visitors “Hands-On Success.”

Conclusion

In conclusion, having a “hands-on shark exhibit” is engaging to the visitors in that it gives them a sense of awe and wonderment about these prehistoric and somewhat mythological creatures. However, this type of visitor engagement will also enhance your institution’s ability to achieve the mission and promote its philosophy and educational goals in creating a more conservation-stewardship minded informed citizenry about aquatic environmental issues. Touchable elasmobranch exhibits are only successful when coupled with a study, evaluation and conservation mission(s) for their exhibit and display. Factors for the animals and the visitors should be established by competent professionals and adhered to by all concerned and touching a shark at their institution. Touching a shark in an institutional study should be considered a strong base toward encouraging inquiry-learning processes for developing a more science literate society.

SHARK MYTHS - A PROBLEM FOR MARINE EDUCATION.

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Drum and Croaker 29: 14-15. February 1998

Most people would agree that music has and incredible ability to stimulate a huge variety of emotions, ranging from acute sadness to joyful rapture. There are however a few bars of a well-known film score which has the ability, almost without exception, to strike fear into the hearts of most people. It is probably on a par with the "shower scene" clip from Hitchcock's "Psycho" - it is of course the first few notes of "Jaws". This is quite an incredibly powerful piece of music and although appears simple it has the ability to render the listener almost breathless with terror.

The unfortunate long-term result of the phenomenal box office success of this film has been an overall massive negative portrayal of shark imagery in an almost global basis, and this problem is one in which we as marine educators have a constant battle with trying to persuade members of the public to accept the truth rather than Hollywood generated stereotypes.

As the (Sea Life) Centre here in St. Andrews we keep four species of shark native to the waters around our coasts. The Common Dogfish, *Scyliorhinus canicula,* grows to around 75 centimetres in length, the Greater-spotted Dogfish, *Scyliorhinus stellaris* grows to 1.25 metres, and our two Smooth-hound species, *Mustelus asterias* and *M. mustelus* are no longer than around 80 centimetres. It is obvious from this then that we do not keep anything approaching the size (or apparent temperament!) of our friend *Carchardon carcharias*. Unfortunately however, we are continually besieged by an army of people demanding to know where the "sharks" are. The reaction given upon being told that our specimens are in fact sharks ranges from surprise to outright disbelief. Several years ago I spoke to a woman from California who emphatically stated to me that our species could not possibly be sharks as she came from a country where (and I quote) "sharks eat people all the time and are much larger than these". No earthly amount of explaining by myself would sway her from her convictions, and she marched off, happy that her perception of the Jaws mythos remained irrevocably intact.

Why do we encounter this problem? Are we alone in this country with regard to this failing by members of the general public to accept the scientific truth? Over the years we have armed ourselves with statistics which emphasize the benign side of sharks, such as the fact that 300 people die in the UK every day from smoking related diseases, which equates to around ten times the number of people killed annually by sharks, and the fact that only around 20% of living sharks attain a body length in excess of two metres. On a more positive side many people *do* accept what we tell them and go away with a more realistic image, but there are still many people who are content with their media generated preconceptions. Even as I type this I can hear several people at our reception area who are studying the Talks Programme board and are whispering the words "shark talk" in a state bordering on almost reverential awe. Sharks are blessed by 400 million years of evolution which has honed them into apex predators unrivaled in marine ecosystems, but the trade off has been to be cursed by an appearance which is perceived by the lay person as being not "cuddly". There is global condemnation of the ivory trade yet any eradication programme initiated against sharks can go largely unchallenged. If this state of affairs is left unchecked and uncontrolled it is ultimately ourselves who will pay the price in marine ecological catastrophe. It is our job as marine biologists to *educate* people into the importance of all marine organisms, not just sharks, and especially target children who will ultimately be left to cope with our mistakes.

SHARK TAILS

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Drum and Croaker 30: 8-9. February 1999

Having grown up in the era of Jaws, I thought I had heard all the variations on shark stories that were to be told until I moved to Indonesia. Then I started to hear about large sharks that ate bats. Impossible, one is of water and one is of the air. How would the two ever meet?

It was still the first year after SeaWorld Indonesia opened and finding sharks had not been easy. We had tried transporting Grey Nurse sharks from Australia but they were too old to tolerate the constant higher temperatures that are found in our waters. We had spent a week in Sunda Straits long lining for sharks; only to catch one ray, two groupers and a moray eel. Where were these elusive large sharks that everyone kept telling us about?

So you can imagine my curiosity and excitement when I heard from a number of sources that there was an island between Labuhan and Lampung where the sharks ate bats and these sharks were BIG! I had to see for myself.

As it was a private island, permission was sought to land on the island and a date was set. Before the pale rays of dawn crept over Jakarta, we were already on our way heading west to Merak. The SeaWorld Indonesian collecting boat was standing by, waiting to pick us up and chug us away over to this mysterious island.

Sharks that eat bats? Right. I have read many natural history descriptions of sharks and not once have I seen "bats" listed under their diet! Fish, squid, invertebrates, even marine mammals but never has anyone classified "bats" as a marine mammal.

Anticipation grew as we churned the hour over to Pulau Siangiang. I was ready to see this incredible phenomenon. But nothing is done without ceremony, nothing as momentous as discovering bat-eating sharks and so we began with a leisurely breakfast on the beach with our hosts. Stories were exchanged, donuts passed and the sun rose higher in the sky.

Finally we climbed into the long low perahu to gently motor through mangrove swamps, over to another side of the island where we would be able to land again and easily hike to the caves. This was even more intriguing. We were to see these sharks in caves inland?

It was a long way to come to have someone pull my leg! There must be an explanation.

It was a hot humid half hour hike in coming that explanation. Suddenly, we cleared the bush and descended from a rise to face a large cave. The whine of bats could be heard before we could even see within its depths. And there was water lapping at our feet as gentle waves rolled through the cave. This cave connected with the sea!

We watched the bats, surprisingly active at mid-day, fly from one side of the cave to the other; soaring and gliding. Still, I couldn't imagine how a shark could jump from the water to catch this beast of the air until a large wave came crashing through. An unlucky bat was caught unawares by the wave, wings wet, it fell into the water. Ah! There was a meter long Blacktip reef shark (Carcharhinus melanopterus), patiently waiting for this snack. With a smooth flick of its tail, the shark's jaws opened and closed, consuming the water logged bat.

As we watched for the next hour, twelve bats were eaten by the two sharks that patrolled this cave. Two bats were eaten by the excited dog that had accompanied us on this journey and none were caught by the monitor lizard that was cruising from a rock in the middle of the cave to the side and back.

Now if only the sharks had really been large!

WHITE SHARKS IN SCOTLAND - A CASE OF MISTAKEN IDENTITY?

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Drum and Croaker 30: 24. February 1999

Over the latter part of the Summer I received reports from various sources that a specimen of the Great White Shark, *Carcharodon carcharias*, had been sighted "rampaging through seal colonies" (sic "The Scotsman" newspaper 7th September 1998). This followed on from other reports of the same species which had allegedly been spotted earlier in the year.

The Great White Shark (*Carcharodon carcharias*, Linn, 1758, Order Lamniformes, Family Lamnidae) is considered to be primarily a coastal and offshore species with a coastal and amphitemperate geographical distribution (Compagno 1984). It preys upon a wide range of other species including bony fish, other elasmobranchs, marine mammals including cetaceans (probably as carrion) as well as invertebrates. Maximum total length is quoted as at least 640 cms and possible to over 800 cms, with a length-weight power curve, generated from 98 specimens, of: $WT = 4.34 \times 10^{-6} TL^{3.14}$ (Compagno 1984).

A vast amount of literature has been written concerning this species, mainly resulting from the aftermath of the "Jaws" phenomenon in the 1970's. Unfortunately for every one rational, well researched study there seems to be at least half a dozen articles extolling the apparent ferocity of this shark, and needless to say that as soon as the media get hold of any story concerning such a fish it generates a great deal of interest. Although the nearest authenticated sighting as far as the UK is concerned occurred off La Rochelle in France, there appears to be no reason *in theory* why the White Shark could not occur off the Scottish coast. They seem to prefer the same water temperature range as we get, and there are may seal colonies which could support such an animal. After the initial sighting at the start of the year the general consensus of opinion was that the animal sighted was probably a Porgbeagle, *Lamna nasus*, which was observed pursuing a shoal fish, and not as at first thought, seals. In all likelihood the Porbeagle was after the same food source as the seal, and not the seal itself. It has also been suggested that the more recent sighting was of a Basking Shark, *Cetorhinus maximus*, although I would suggest that skippers of boat crews who have reported these sightings are unlikely to confuse what is a relatively common, slow, benign and massive species with a fast, streamlined pelagic super-predator. Other marine biologists are skeptical and wish to adopt an open minded policy on these sightings. Personally I would love to add White Sharks to the 30 species which are known to occur off the UK, but I am convinced that if such an animal is ever genuinely recorded off our coasts it would open the flood gates for shark hunters hell-bent on adding the animal to their trophy list. It is perhaps best that the Scottish White Sharks adopt a "mystery policy" in line with their famous contemporary water dweller in Loch Ness.

Reference Cited:

Compagno, L.J.V. 1984. Sharks of the World - An Annotated and Illustrate Catalogue of Shark Species Known to Date. Part 1 - Hexanchiformes to Lamniformes. FAO Species catalogue Vol. 4, Rome 249 pp.

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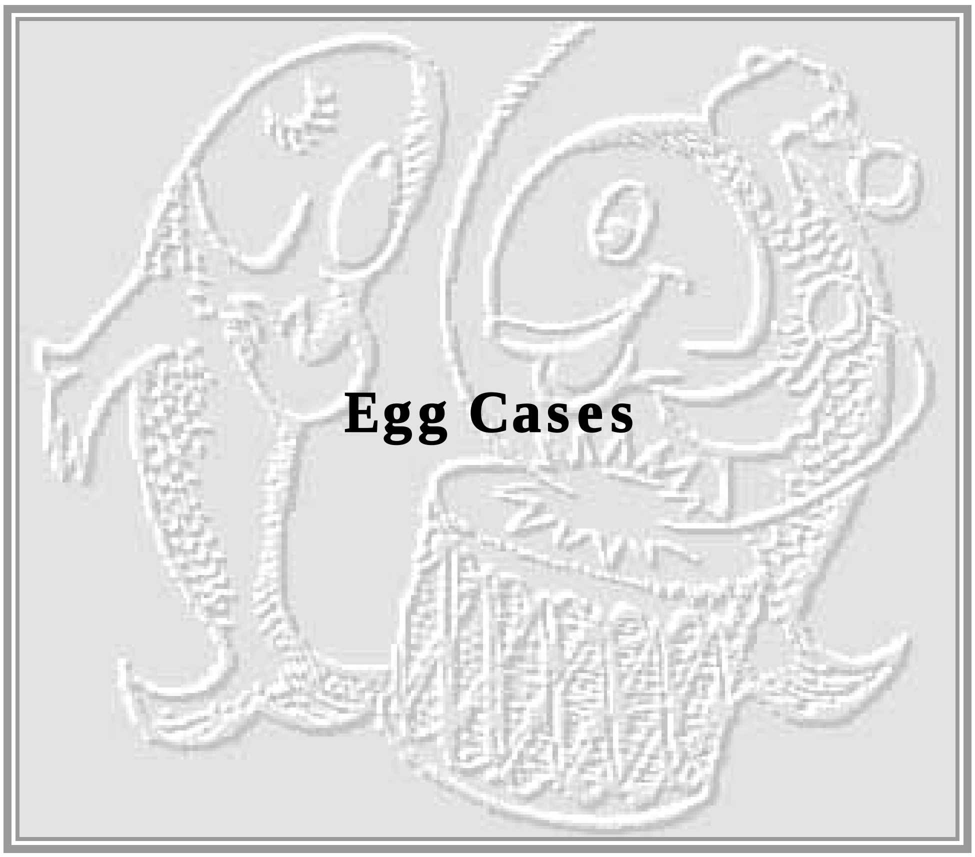
Egg Cases



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OBSERVATIONS ON EGG LAYING IN THE HORN SHARK,
***Heterodontus francisci* (Girard)**

Charles Farwell

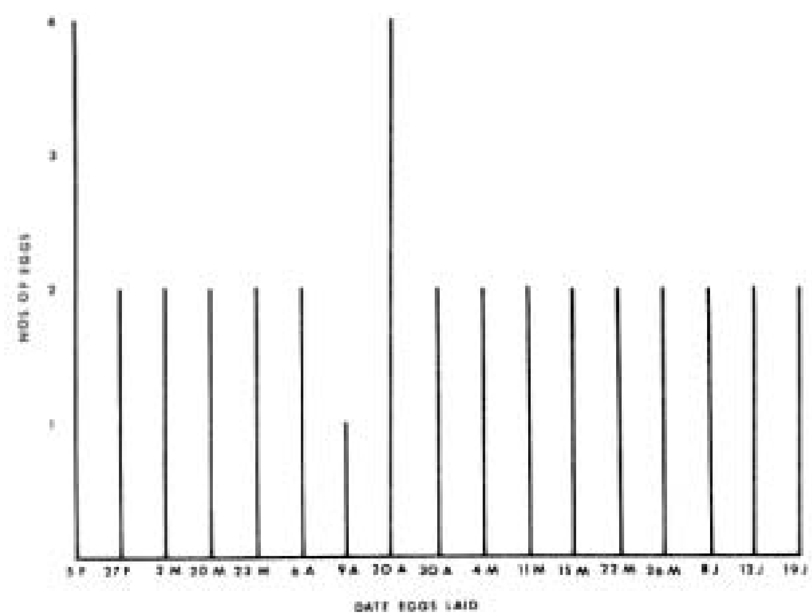
T. Wayland Vaughan Aquarium*

Drum and Croaker 13(2): 20. July 1972

A female horn shark which has been on display at Scripps Aquarium since January 1971 produced 37 eggs in a five month period. The first eggs were laid on the fifth of February and the last on the 19th of June. Both male and female specimens were on display, but were never seen copulating. The male was slightly handicapped in that he had only one clasper.

The eggs were usually found during the morning rounds which may indicate that egg laying in nature is a nocturnal event. Most of the eggs had yolks, but none of them appeared to be fertile. One or both of the sharks were seen on several occasions swimming with an egg case in its mouth which may account for the empty egg cases that were found.

The eggs were laid in pairs with a three or four day period between the laying of a second pair. This sequence was repeated every seven to 22 days, and occurred seven times. On two occasions four eggs were laid on the same day--these cases were not as rigid as the others. A single egg was laid on April 9th, and was followed in eleven days by four eggs laid in one evening.



The eggs were put on display or in a holding tank and watched for developing embryos, however, none were found. The female is still on display, and if a sexually aggressive male can be found, it may be possible to produce a clutch of fertile eggs.

- University of California, San Diego - Scripps Institution of Oceanography

MAINTENANCE OF PRE-TERM EMBRYOS OF THE LESSER-SPOTTED DOGFISH, *Scyliorhinus canicula,* IN ARTIFICIAL EGG-CASES.

Gordon S. Croft

The Sea-Life Center, Scotland

Drum and Croaker 28: 11-12. January 1997

Abstract. Pre-term specimens of lesser-spotted dogfish (*Scyliorhinus canicula* Linn. Class Chondrichthyes, Order Selachii*)* were removed from their natural egg-cases and placed in polythene bags in order to increase ease of observation of their development. There was no apparent increase in mortality in artificially reared embryos compared to natural development in the maternally produced cases.

Embryos of female elasmobranchs tend to have prolonged developmental periods and in general the group have evolved three main reproductive strategies viz.: 1) Oviparous e.g. *Scyliorhinus canicula* Linn 2) Ovoviviparous e.g. *Squalus acanthias* Linn 3)Viviparous e.g. *Sphyrna zygaena* Linn. In oviparous species a few large eggs are produced by the female over a lengthened spawning time. Development of the embryo relies wholly on the reserves of yolk stored within the egg-case and successful completion of development relies on a very tough, stable shell casing.

In general, populations of oviparous sharks and rays exhibit year round reproduction although in *Scyliorhinus canicula* there is a peak breeding season in late winter and spring. The egg capsule itself is produced by a specialized gland which is unique amongst vertebrates called the nidamental or oviducal gland. Cells in the gland make and secrete a large variety of materials such as proteins, carbohydrates and phenol. Early observations suggested that the egg capsules were composed of keratin although recent analysis has produced evidence to suggest that the major structural protein of elasmobranch egg capsules is a molecule resembling collagen.

Some species use the nidamental gland to store sperm from the male and Metten reported finding active spermatozoa in the nidamental glands of every egg-laying *Scyliorhinus* he studied. All the adult female *Scyliorhinus canicula* in our display lay eggs on a more or less constant basis. Normal development takes 6 - 10 months although developmental time is largely temperature dependent with colder water resulting in lengthened developmental time. Upon hatching the juveniles are around 5 - 6 centimeters in length and are miniature versions of the adults. After a period of several months of development in the egg cases the embryos do not tolerate any movement such as transfer from tank to tank, and may abort from the egg cases and expire.

Several embryos were removed from their natural cases and a variety of artificial egg cases were tried in order to demonstrate the yolk-sac system to the general public. Initial trial included the use of small glass jars covered in netting and also perspex boxes but unfortunately none of the embryos survived probably due to inadequate water circulation. Any artificial container must duplicate the features of the natural egg case, e.g. A) resistance to damage and attack by predators and B) adequate circulation of water. Recently small clear "ziplock" plastic bags of size 100mm x 165 mm were used. These had 15-20 holes randomly punched into the bag using a standard paper hole punch (hole diameter - 6 mm) to allow flow-through of water. A short length of standard size aquarium air-line of length 140 mm was filled with lead shavings and water and then formed into a circle with the two open ends joined with a straight connector. This was then placed in the bag and ensured the artificial case rested in a more or less upright position on the tank base.

Pre-term embryos of *Scyliorhinus* were removed when the yolk-sac diameter was around 10 mm by carefully removing one end of the natural egg case and cutting along one side with a pair of surgical scissors. The embryos are obviously extremely delicate and require careful handling with plastic forceps to transfer them to the artificial cases. The filled bags were then placed on the base of the display tank and left until the yolk-sac had been successfully absorbed, upon which the bag was unzipped and the embryos released.

So far this technique has proved successful at St. Andrews although further experimentation is required in order to evaluate the critical time of development before which it is not recommended to remove the embryo from the natural egg case.

References:

Koob, T.J. & Callard, I.P., 1991. Reproduction in Female Elasmobranchs. *Comp. Physiol.* **10**, 155-209.

Metten, H., 1939. Studies on the Reproduction of the Dogfish. *Phil. Trans. R. Soc. London.* **230**, 217-238.

Sumpter, J.P. & Dodd, J.M., 1979. The Annual Reproductive Cycle of the Female Lesser-Spotted Dogfish *Scyliorhinus canicula* L. and its Endocrine Control. *J. Fish. Biol.* **15**, 687-695.

WINDOWS INTO ELASMOBRANCH EMBRYONIC DEVELOPMENT: A METHOD TO INSTALL A WINDOW ON THE EGG CASE OF THE BIG SKATE, *Raja binoculata* (GIRARD 1855), BEFORE THE COMPLETION OF THE FIRST TRIMESTER

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Drum and Croaker 33: 26-30. February 2002

An excellent display for public aquaria is one that demonstrates live elasmobranch embryonic development. Many aquaria have such exhibits and these are usually quite popular with the guests. These types of exhibits demonstrate an interesting physiological phenomenon, have a strong visual impact on guests, and are an excellent opportunity for a glimpse into pre-natal development.

At Aquarium of the Bay in San Francisco, several females of both big skates, *Raja binoculata*, and longnose skates, *Raja rhina*, have deposited eggs in the *Beyond the Golden Gate* exhibit, a 350,000-gallon community display with a sandy bottom and rock outcroppings. Divers recover the eggs, place them in floating baskets in an acclimation tank, and log the date and lay location. Then the data are recorded in a permanent logbook and the eggs are tagged and transferred to a permanent holding system that runs on the same system water. After a certain point in gestation, eggs are selected for display and clear plastic windows are installed to permit unobstructed views of the developing embryos. Eggs are selected based on lay date and several are mounted on acrylic stands in chronological order to demonstrate various stages of development.

The accepted timeline for installing windows on capsules of the genus *Raja* has been to wait until approximately one third of the gestation was complete. At this stage, the jelly has dissolved and there is a complete opening of the four ports allowing an embryo-assisted flow of seawater through the capsule (Long and Koob, 1997). With the temperature of incoming water ranging from 56^0 - 60^0 F, complete dissolution occurred in two to three months after deposition for the big skate capsules and three to four months for the longnose skate capsules. It seems largely dependent on temperature. It is possible that additional variance may be attributed to the predisposition of individual embryos.

To determine if the ports are open, simply lift the capsule from the water and check for an outflow of water from the ports. After the completion of the first trimester, the process of installing windows is straightforward and not difficult to complete successfully. However, the development is quite advanced by the first trimester. For an even more dramatic display, methods were researched to demonstrate earlier stages of development.

Observations on oviparous elasmobranch capsules indicate that they are a nutritionally closed system and the embryo is dependent solely on the yolk for organic materials (Read, 1968). Evidence on the role of egg jelly in the egg capsules of *Raja erinacea* presented by Koob and Straus (1998) supports Read's assessment. Their analysis of the carbohydrate concentrations in the jelly matrix at different stages of development, demonstrates that the jelly serves primarily as a cushion against mechanical stress and does not serve as a nutritional source for the developing embryos. Based on this evidence, it seemed possible that a window could be installed before the ports are opened.

One concern with replacing a significant portion of the egg case with plastic so early in development is whether the change in permeability of the egg will affect the embryos, causing harm or altering the normal development of the embryos. Based on my empirical evidence, it has not been a factor. Perhaps, squeezing out the horn jelly counteracts the loss in permeability to some extent. However, this deserves further study. It appears that the greatest dangers to the embryos are mechanical stress and biological and chemical contamination from the procedure.

Materials and Methods:

Egg cases were selected based on an approximation of current development. Eggs were examined for the presence of holes at the tips of the horns. Holes must be present in at least two horns. The appearance of holes at the tips of the horns seems to correspond with the start of lumen jelly dissolution that Ouang (1931) believes is initiated by enzymes secreted through specialized glands at the heads of the embryos. At this stage in development, the egg is permeable to seawater that begins displacing the lumen jelly. The viscosity of the egg jelly differs depending on its location within the capsule (Koob and Straus, 1998). The lumen jelly, nearest the embryos is relatively low in viscosity and dissolves first. The horn jelly is stiff, comparable to cured silicone, and takes much longer to dissolve.

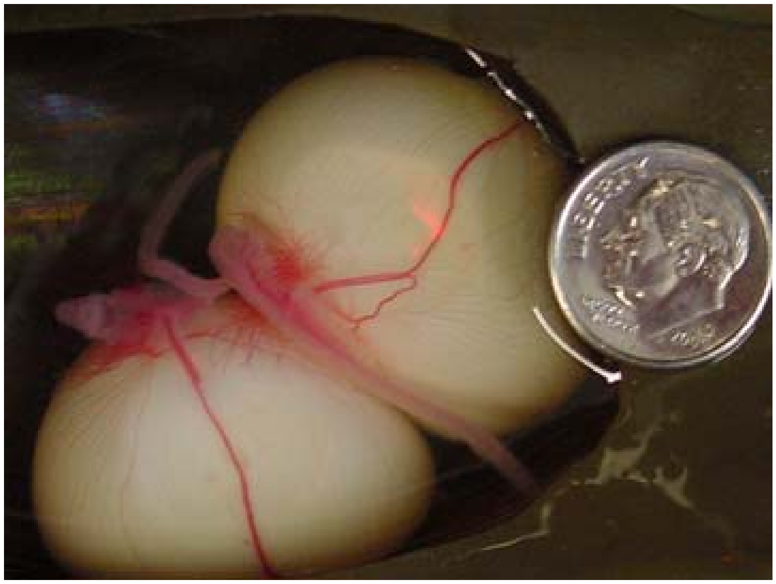
To remove the jelly, first identify a suitable egg case, then support it in one hand with the highly curved dorsal side down and apply pressure with the thumb and index finger at the base of a horn with a hole. Squeeze out the horn jelly by moving the other thumb and index finger outward along the length of the horn. Figure 1 shows horn jelly coming through the open port.

Squeezing out the horn jelly is critical. When the procedure is completed the lumen can be flushed of residual glue vapors, reducing the chance of chemical contamination. Additionally, air bubbles can be burped. While jelly is present in the lumen, the embryos are not able to effectively pump out air bubbles, the presence of which may lead to biological contamination.

Once the horn jelly is cleared from all open horns (note a change in color and viscosity of the jelly emanating from the horn) a piece from the ventral side should be cut. When making the incision, always angle the egg so that the embryos shift to the opposite corner away from the scissors blade. Cut out a piece that will leave a sufficient frame to lay a bead of glue and attach the clear plastic window (Fig. 2 and 3).

<u>Figure 1</u>: Horn jelly (arrow) squeezed out of an egg from *Raja binoculata*.

<u>Figure 2</u>: Open egg, *Raja binoculata*, embryos at 44 days



<u>Figure 3</u>: Close up of embryos, *Raja binoculata,* at 44 days

When the cut is complete, set the piece aside and gently dry the surface of the frame with cotton pads. Depending on the extent of liquefaction of the jelly, it may be wise to remove a portion of the jelly by drawing it into an eyedropper. This reduces the chance of contacting the jelly with glue. As the surface of the frame dries, superimpose the cut piece of egg case on a sheet of clear plastic (document protector sheets work well). Cut the clear plastic slightly larger than the egg case piece. The exact increase in size will depend on how much the frame can accommodate. If the clear plastic is cut too large it will be difficult to set it flush on the frame. If the plastic is cut too small, a greater amount of super glue will potentially contact the jelly. When the plastic is trimmed to size, dry both surfaces and lay a thin bead of super glue on the frame far enough from the edge so that when the plastic is set on top of the egg case it does not draw the glue to the edge of the egg cut. Press the plastic window in place until the surfaces hold. Then allow it to dry for several minutes. The embryos may react by vigorously beating their tails for several seconds. This is a reaction to the glue vapor. When the glue is set, return the egg to the water and burp out any air. After the bubbles are displaced, lift the egg out, allowing water to drain from the egg and refill the egg. There will not be very much water present, so repeat this several times to flush as much of the glue vapors as possible. Following this procedure leaves less room for error than if a window is installed after the first trimester. With the jelly fully dissolved, the lumen is more easily flushed after the window installation.

It will be apparent within 24-48 hours following the procedure whether or not the embryos will survive. Healthy embryos will maintain their color and continue actively wriggling their tails in the capsule, and the external yolk should remain well vascularized. The capsules are now ready to be displayed.

Acknowledgments:

I would like to thank Christina J. Slager of the Monterey Bay Aquarium for her guidance and encouragement in writing this article, and Kevin Lewand and the Husbandry staff at Aquarium of the Bay for assistance in collection of the capsules from the exhibit. Also, I would like to acknowledge Drew A. Haller, Matthew J. Tooley, and Michelle M. Chow for their help with the digital photography.

References:

Koob, T.J., and J.W. Straus. 1998. On the role of egg jelly in *Raja erinacea*. *Bull., Mt. Desert Isl. Biol. Lab.* **37**: 117-119.

Long, J.H. Jr., and T.J. Koob. 1997. Ventilating the skate egg capsule: the transitory tail pump of embryonic little skates *Raja erinacea*. *Bull., Mt. Desert. Isl. Biol. Lab*. **36**: 117-119.

Ouang, T.Y. 1931. La grande de l'eclosion chez les Plagiostomes. *Ann. Inst. Oceanogr*. **10**: 281-370.

Read, L.J. 1968. Urea and trimethylene oxide levels in elasmobranch embryos. *Biol. Bull., mar. biol. Lab. Woods Hole* **135:** 537-547.

SIZE RELATIONSHIPS BETWEEN EGG CAPSULES AND FEMALE BIG SKATES, *Raja binoculata* (GIRARD, 1855)

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Drum and Croaker 33: 31-34. February 2002

Data from the fertilized egg capsules of the big skate, *Raja binoculata*, were analyzed. The data were collected from three different females that mated and laid eggs in captivity. It was determined that the size of the eggs increases with the size of the fish. This finding supports similar data for another species in the genus *Raja* (Templeman, 1982). Additionally, it was observed that individual females lay eggs with a unique, individual shape that remains more or less constant throughout the course of deposition (Figure 1). Aside from dimensional qualities, the differences in egg shape between broods are subtle but definite.

The three female big skates have been maintained in captivity for greater than three years in the *Beyond the Golden Gate* exhibit, a 350,000-gallon community exhibit with a sandy bottom and rock outcroppings. The capsules were removed from exhibit and placed in flow-through plastic bins connected to the exhibit's system water. Eggs were tagged and lay date and location were recorded. After hatchout, neonates were moved to flow-through plastic bins with a fine sand substrate.

On August 19, 2000, a pair of big skate, *Raja binoculata*, egg capsules were recovered from the exhibit. It had been over two years since the last skate egg had been laid at the aquarium. The event came as a surprised because it was not apparent that a mature female was housed in the exhibit. Based on data collected from 68 female big skates captured in Monterey Bay between January 1980 and September 1981, the total length (TL) for sexually mature females was determined to be 1300 mm (Zeiner and Wolf, 1993). The largest female on display at that time was considerably smaller (DW = 670 mm and TL = 940 mm).

The gravid individual was identified by following observations made by Luer & Gilbert (1985) on gravid clearnose skates, *Raja eglanteria*. The capsules within the gravid female were visible externally as a pair of prominent lumps anterior to the base of the tail on her dorsal side, on either side of the midline. A report on twenty egg cases from *R. binoculata* recovered from Puget Sound lists the total lengths ranging from 265 to 305 mm (DeLacey and Chapman, 1935). Eschmeyer, et al. (1983) confirm these data, reporting the egg capsules for big skates to be nearly 300mm in length. These figures contrast those recorded from the eggs recovered from exhibit at Aquarium of the Bay. Total lengths were approximately half the previously reported size, the largest measuring 179mm in TL (Table 1). It should be noted that measured length data on capsules depends on the amount of time elapsed since deposition. As capsules age, the leading edge of the posterior end wears away. This suggests the possibility that the initial lengths (< one week following deposition) on wild caught capsules might be even greater than those reported.

Templeman (1982) observed for thorny skates, *Raja radiata*, that capsule size increases with an increase in fish length. It seems likely that the capsules measured by DeLacey and Chapman and Eschmeyer were laid by females much larger than the spawning female at Aquarium of the Bay. For the little skate, *Raja erinacea*, reproductive tracts are expanded in spawning females, perhaps hormonally regulated (Koob 1981). It seems fair to assume that the skate's reproductive tract also grows larger as the female grows. This growth would provide additional volume within the tract to accommodate the production of larger eggs with each successive spawning season.

After positively identifying the spawning female and noting that her TL and her capsules' TLs were considerably smaller than previously reported for mature females, the eggs were examined more closely. In addition to being quite small, the eggs also seemed structurally weak. The horns were very pliable and the dorsal and ventral plates were not rigid. Among the first dozen eggs, some were laid with long streaming tissue extending from the posterior end. It seemed as though she was working out some "technical difficulties" on the manufacturing end. Her small size and the structural inconsistencies of the first few eggs suggested that this was possibly her first brood of eggs. Perhaps this is indicative of a smaller size limit for sexually mature females for the San Francisco Bay's big skate population.

In June of 2001 two pairs of eggs were recovered on consecutive days, indicating another female had started to lay eggs. The eggs were noticeably larger and much sturdier than the previous set. The typical swellings were observed in a larger skate (DW = 880 mm and TL = 1200 mm), confirming that she was gravid and laying the new eggs.

On June 23, 2001, the last pair of eggs from the first female was recovered from exhibit. Her deposition lasted 10 months. The second female continued to lay eggs. Then, two months later, on August 10, 2001, small eggs were again recovered from exhibit. They appeared very similar in size and shape to the original set but were slightly more rigid. The first female was again laying eggs. In the month following, three pairs of eggs were recovered from exhibit. All were deposited within three days of each other. Additionally, a new stockier, but relatively small egg shape was discovered. A third female big skate (DW = 690 mm and TL = 910 mm) was confirmed to be spawning.

Based on the observations from the big skate eggs recovered in captivity at Aquarium of the Bay, it is clear that the size of the eggs increases with the size of the fish and that individual females lay eggs with a unique, individual shape that remains more or less constant throughout the course of deposition. Also, the size at maturity for female big skates seems to be much smaller than previously reported by Zeiner and Wolf (1993). Further studies on skate reproduction are necessary to clarify these apparent discrepancies. Possible reasons for the discrepancies may include differences in population dynamics at various localities, sport and commercial fishery demands and wild versus captive environments.

Table 1: Total length for spawning females and the measured range for TL and width of corresponding capsules.

Female	TL (mm)	Egg TL (mm)	Egg Width (mm)
1	**940**	**155-179**	**75-90**
2	**1200**	**181-200**	**95-114**
3	**910**	**150-167**	**81-90**

Figure 1: Egg cases, *Raja binoculata*, recovered from exhibit at Aquarium of the Bay.

Acknowledgements:

I would like to thank Christina J. Slager of the Monterey Bay Aquarium for her guidance and encouragement in writing this article and Kevin O. Lewand and the Husbandry staff at Aquarium of the Bay for assistance in collection of the capsules from exhibit.

References:

DeLacey, A. C. and W. M. Chapman. 1935. Notes on some elasmobranchs of Puget Sound, with descriptions of their egg cases. *Copeia*. **2**: 63-67.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. Pacific Coast Fishes of North America. Houghton Mifflin Co., Boston, MA, 336 p.

Koob, T.J., J. Laffan, and I.P. Callard. 1981. Egg-oviduct size relationships in *Raja erinacea*. *Bull., Mt. Desert. Isl. Biol. Lab.* **21**: 46-48.

Luer, C.A. and P.W. Gilbert. 1985. Mating behavior, egg deposition, incubation period, and hatching of the clearnose skate, *Raja eglanteria*. *Environ. Biol. Fishes*. vol. 13, **3**: 161-171.

Templeman, W. 1982. Development, occurrence and characteristics of egg capsules of the thorny skate, *Raja radiata*, in the northwest Atlantic. *J. Northw. Atl. Fish. Sci.*, **3**: 47-56.

Zeiner, S.J. and P. Wolf. 1993. Growth characteristics and estimates of age at maturity of two species of skates (*Raja binoculata* and *Raja rhina*) from Monterey Bay, California, p. 87-99. *NOAA Tech. Rep. NMFS*.

Exhibitry and Design

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SHARK AQUARIUM – ONE OF THE LARGEST ELASMOBRANCH COLLECTIONS

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Elasmobranch Husbandry Symposium

The objective of the Shark Aquarium is to dispel the myth and misconception of sharks and to provide positive information about these animals to the public as well as to establish on-going breeding programs to conserve shark species.

The Shark Aquarium (see Figure 1) was officially opened to the public on December 7, 1990. The construction cost was 40 million Hong Kong dollars. The shark collection consists of over 200 sharks and rays from 30 species. Sources of sharks are mainly from the Indo-Pacific, South Africa and America, as well as from exchange programs with Aquariums in Japan, Singapore, USA and China.

The total water capacity of Shark Aquarium is 450,000 litres. The water in tank is treated by a partially closed water system with daily make-up water replacement and turnover rate of once every 2 hours. A series of pressure sand and granular activated carbon filters are used to remove large suspended particles and organic/inorganic substances respectively. Ultra-violet sterilizers are used to control pathogens as small as bacteria. A heat exchanger and chiller system adjust and maintain constant water temperature while a packed column aerator raises the oxygen level in the water. Water quality tests are performed on a regular basis to ensure optimal water quality. Table 1 shows the acceptable range of water quality parameters for the Shark Aquarium.

The Shark Aquarium is divided into the pre-aquarium (see Figure 2) and post main display area. The two areas are connected by an underwater viewing panel (see Figure 3). There are 2 aquaria at the post main display area for benthic and coldwater shark displays and these are changed regularly to educate visitors about shark diversity. Included is also a display showing the different stages in the development of real shark eggs.

In addition, a Shark Pool (see Figure 4) is located in the post main display area, which is a well-received interactive hands-on display for small tropical benthic sharks and rays that have been captive bred at Ocean Park. All sharks are changed every 3 days to reduce stress to the animals, so a number of animals for each species are required for this rotation. The shark pool has been recognized as a very important and useful tool to convey shark conservation messages in the educational and behind-the-scene tours.

Tuna, Pacific Mackerel, Horse Mackerel and Squid are the major diet and multivitamins are supplemented. The daily quantity of food is equal to 1.3 –1.5 % of the total shark body weight.

Over the years, Aquarium staffs have successfully bred 11 species of shark and 1 species of ray (see Figure 5 – 16 and refer to Table 2). In the history of Shark Aquarium, staffs have had the opportunity to experience keeping a total of 66 species of sharks and rays as detailed in Tables 2a,b.

Table 1

Acceptable range for the water quality parameters measured at Shark Aquarium.

Parameter	Acceptable Range
pH	7.8 - 8.1
Temperature (°C)	24 – 25
Turbidity (NTU)	< 0.16
Salinity (ppt)	29 – 32
Dissolved oxygen (ppm)	6.2 - 6.8
Ammonical nitrogen (ppm)	< 0.058
Nitrite (ppm)	< 0.01
Nitrate (ppm)	< 2
Total alkalinity as CaCO3 (ppm)	110 - 160
Delta P (mmHg) at 1 meter	---
Total heterotrophic bacteria (CFU/ml)	< 900
Vibrios (CFU/ml)	< 500
ORP (mV)	280 - 320
Free Ozone	0
Reactive phosphate (ppm)	< 0.2
Bromine	0

Figure 1. The Shark Aquarium, Ocean Park Hong Kong.

Figure 2. Shark Aquarium pre-aquarium area.

Figure 3a. Entrance of underwater viewing tunnel.

Figure 3b. Underwater viewing tunnel.

Figure 4. Shark pool at the post main display.

Figure 5. Coral catshark (*Atelomycterus marmoratus*)

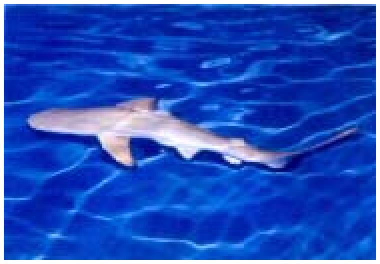


Figure 6. Blacktip reef shark (*Carcharhinus melanopterus*)

Figure 7. Transparent egg case of pygmy swellshark (*Cephlaloscyllium pseudoumbratile*)

Figure 8. Grey bambooshark (Chiloscyllium griseum)

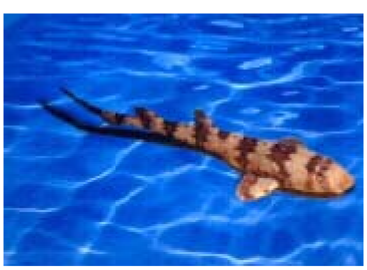


Figure 9. Whitespotted bambooshark (*Chiloscyllium plagiosum*)

Figure 10. Brownbanded bambooshark (*Chiloscyllium punctatum*)

Figure 11. Dark shyshark (*Haploblepharus pictus*)

Figure 12. Striped catshark (*Poroderma africanum*)

Figure 13. Leopard catshark (*Poroderma pantherinum*)

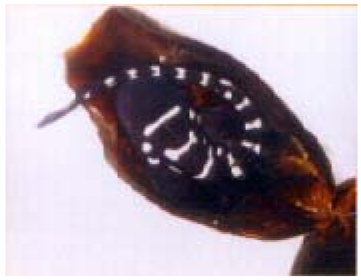


Figure 14. Zebra shark (*Stegostoma fasciatum*)

Figure 15. Whitetip reef shark (*Triaenodon obesus*)

Figure 16. Black spotted sting ray (*Taeniura melanospila*)

Table 2a
List of elasmobranch species maintained throughout the history of Shark Aquarium.

Scientific name	Common name	Currently Exhibited	Currently Breeding
Aetobatus flagellum	Duck-bill Ray		
Aetobatus narinari	Spotted Eagle Ray		
Amphotistius kuhlii	Blue Spotted Sting Ray		
Atelomycterus marmoratus	Coral Catshark	●	●
Brachaelurus waddi	Blind Shark		
Carcharhinus galapagensis	Galapagos Shark		
Carcharhinus melanopterus	Blacktip Reef Shark	●	●
Carcharhinus plumbeus	Sandbar Shark		
Carcharias taurus	Grey Nurse Shark	●	
Cephaloscyllium pseudoumbratile	Pygmy Swellshark	●	●
Cephaloscyllium umbratile	Japan Swellshark	●	
Cephaloscyllium ventriosum	Swellshark		
Chiloscyllium griseum	Grey Bambooshark	●	●
Chiloscyllium plagiosum	Whitespotted Bambooshark	●	●
Chiloscyllium punctatum	Brownbanded Bambooshark	●	●
Chiloscyllium sp.	Burma Bambooshark	●	
Dasyatis gerrardi	Cow Tail Sting Ray	●	
Dasyatis zugei	Sharpnose Sting Ray		
Eucrossorhinus dasypogon	Tasselled Wobbegong		
Galeocerdo cuvier	Tiger Shark		
Ginglymostoma cirratum	Nurse Shark		
Gymnura sp.	Butterfly Ray		
Halaelurus buergeri	Blackspotted Catshark		
Halaelurus natalensis	Tiger Catshark		
Haploblepharus edwardsii	Puffadder Shyshark		
Haploblepharus pictus	Dark Shyshark	●	●
Hemiscyllium ocellatum	Epaulette Shark		
Hemitriakis japanica	Japanese Topeshark		
Heterodontus francisci	Horn Shark		
Heterodontus galeatus	Crested Bullhead Shark		
Heterodontus japonicus	Japanese Bullhead Shark	●	
Heterodontus portusjacksoni	Port Jackson Shark		

Table 2b
List of elasmobranch species maintained throughout the history of Shark Aquarium.

Scientific name	Common name	Currently Exhibited	Currently Breeding
Heterodontus zebra	Zebra Bullhead Shark	●	
Himantura sp.	Leopard Sting Ray	●	
Mustelus californicus	Grey Smooth Hound		
Mustelus griseus	Spotless Smooth Hound		
Mustelus manazo	Starspotted Smooth Hound		
Mustelus mustelus	Smooth Hound		
Narcine brunneus	Electric Ray		
Nebrius ferrugineus	Tawny Nurse Shark	●	
Negaprion brevirostris	Lemon Shark		
Orectolobus japonicus	Japanese Wobbegong	●	
Orectolobus maculatus	Spotted Wobbegong	●	
Orectolobus ornatus	Ornate Wobbegong	●	
Parascyllium multimaculatum	Tasmanian Carpetshark		
Platyrhina sp.	Thornback Ray	●	
Poroderma africanum	Striped Catshark	●	●
Poroderma pantherinum	Leopard Catshark	●	●
Pristis microdon	Sawfish	●	
Raja straeleni	South African Skate		
Rhina ancylostoma	Bowmouth Guitarfish		
Rhinobatos armatus	Shavelnose Ray	●	
Rhinobatos granulatus	Sharpnose Guitarfish		
Rhinobatos hynnicephalus	Angel Fish		
Rhinobatos vincentiana	Australian Ray		
Rhinoptera javanica	Cownose Ray		
Rhychobatus djiddensis	White Spotted Shavelnose Ray	●	
Scyliorhinus torazame	Cloudy Catshark		
Sphyrna tiburo	Bonnethead Shark		
Stegostoma fasciatum	Zebra Shark	●	●
Taeniura lymma	Blue Blotched Sting Ray	●	
Taeniura melanospila	Black Spotted Sting Ray	●	●
Triaenodon obesus	Whitetip Reef Shark	●	●
Triakis scyllium	Banded Houndshark		
Triakis semifasciata	Leopard Shark		
Trygonorhina fasciata	Fiddler Ray		

EXPERIMENTAL TANK FOR PELAGIC SHARKS

David C. Powell, Curator of Fishes

Sea World, San Diego

Drum and Croaker 68(3): 24-26. September 1968

In the past, this spectacular and widespread group of marine animals has never been satisfactorily maintained and displayed in captivity. Because of their potential as a public exhibit and the relatively sparse knowledge of their physiological needs during transport and in captivity, we at Sea World felt that a small, but hopefully adequate shark tank should first be constructed and put into operation. What we learn from this will guide us in the design of a public display complete with underwater viewing of large pelagic sharks such as the white shark, mako, blue shark, thresher, whitetip, blacktip, tiger, etc.

The tank has been in operation for five weeks and at the present time it contains six blue sharks (*Prionace glauca*). These are all feeding and acting well. The first specimen introduced to the tank was a great white shark *Carcharodon carcharias*) that weighed 120 pounds (54kg). It appeared to act well for six days, but deteriorated rapidly and died on the seventh day. The loss of the white shark is believed to have been due to anoxia during the period of transport. Improvements in the transport technique have been tied, and success with a white shark is anticipated in the near future.

In the short period of operation, the tank and its water system seem to be functioning quite well and will be confirmed in the near future with the acquisition of additional species and specimens.

Statistics of the tank:

Diameter	48 ft. (17.5m.)
Depth in center	7 ft. (2.1m.)
Depth at edge	3.5 ft. (1.0m.)
Volume	65,000 gallons (247,000 1)
Pumping rate	450 gpm (1,700 liters per minute)
Filtration	hi-rate pressure sand filters
Aeration	75% of water flow is passed over a rock cascade prior to entering tank.

Chemical treatment - Alum is added continuously prior to the filters at a rate of approximately 0.5 ppm. No copper sulfate is used. Algae and diatoms are controlled by the periodic addition of the algicide 2-chloro-4, 6-bis (ethalamino) s-triazine (brand name Algi-gon).

The concrete tank bottom is finished with a smooth epoxy finish, and the sharks are protected from the hard concrete vertical wall by a smooth nylon reinforced vinyl curtain suspended from the overhanging walkway. In addition to occasionally banging the tank wall when turning around, the blue sharks often swim with their pectoral fins touching the side. To date, the plastic curtain has prevented any noticeable damage to the skin of the sharks and we attribute a great deal of our success to this curtain.

Work is underway on a study of the oxygen consumption and minimum oxygen requirements of the blue and make sharks. This information should contribute greatly to solving the rather haphazard transport methods that have been used in the past.

SHARK-QUARIUM (GROWING UP)

Gerrit Klay

Drum and Croaker 13(2): 16. July 1972

It is always a pleasure to announce a change. In our case, it is incorporation and a shuffling of names.

Shark-Quarium has become a registered trademark, and a Division of S. Q. Oceanographic, Inc., based in Grassy Key, Florida.

Shark-Quarium has moved from the sketching stage to engineering, with its full building plan off the drawing board. It will be located "somewhere in the Keys".

Also, we have recently acquired a 24 ft. collecting boat, with great speed and plenty of room.

This year's visitors include the Sea World, San Diego group - Dave Powell and Bill Erwin. Recent visitors were Lou Garibaldi and crew from the New England Aquarium in Boston, Mr. de la Poype of Marineland of France was here recently; Kenneth Tong from the soon-to-be-built Atlantic Aquarium (which was designed by Shark-Quarium personnel). We've had visitors from several aquariums in Canada this year also. In addition, it is not unusual for a group of university students to drop by. A number of students have been here on various study programs which we were happy to be a part of, because it is always refreshing to see their enthusiasm and interest.

Our most frequent visitor is Dr. Jensen of the U. of Miami Medical School. He takes home Nurse shark blood by the bottle for his research.

It is our policy to assist any aquarium in their efforts to collect and ship species for new exhibits. In our Shark-Quarium plans are lab facilities to assist the serious aquarist, hopefully to experiment with hard to handle species. Cost for rental is going to be kept at a minimum.

We have had a number of sharks born in captivity and kept successfully - they are Lemon sharks, Black Nose sharks, and Bonnetheads (of which one is still on exhibit at the National Aquarium).

This season will carry Shark-Quarium to:
San Francisco Marine World
Boston New England Aquarium
Cincinnati Zoo
London Nord Sea-Aquarium
Paris and Nice France -
Marineland of France

THE STEINHART ROUNDABOUT: AN AQUARIUM FOR FISHES

John E. McCosker

Steinhart Aquarium, San Francisco

Drum and Croaker 16(2), aka 76(2): 1-3. December 1976

Fishes have historically been given the short end of our planetary stick. Since the late Pleistocene, our enlightened species has either eaten, endangered, or been educated by our more than 20,000 vertebrate cousins. To make retribution for past sins against ichthyology, we at the Steinhart Aquarium have devised an aquarium that places people within a cylinder surrounded by piscine viewers, so that, through this role reversal, we might learn something about each other.

This rather unconventional compromise, dubbed the "Roundabout," has a projected completion date of February 1977. Conventional aquarium design has limited aquarium viewers to the experiences of coral reefs, trout streams, farm ponds, and kelp beds, each recreated for better or worse along traditional lines. The greatest of all water environments, however, the open-ocean pelagic realm that covers nearly 70 percent of the surface of our planet, has been beyond the reach of the aquarium world. The limitations of duplicating an open ocean are obvious, but they were overcome in recent years by Aburatsubo Aquarium and Shima Marineland in Japan which were uniquely designed in the shape of a ring or torus. Pelagic fishes neither tolerate nor comprehend confinement, and the end result is usually a dead fish after several high speed collisions with the walls of an aquarium. The novelty of the ring or doughnut-shaped tanks lies in the infinite environment they create -- a current flows within the tank and the pelagic fishes orient themselves and swim upcurrent through an infinite window of water.

The success of the Japanese tanks inspired my predecessor, the late Dr. Earl S. Herald, to construct a similar tank in this country, thereby improving upon the Japanese prototypes and creating the first pelagic fish aquarium in this country. Earl completed the initial planning before his untimely death; Steinhart Curator Dave Powell and I inherited the Roundabout concept after the design was completed, but have made several modifications during the construction phase. In the early planning, Earl christened the new structure "The Roundabout," a British term for a merry-go-round.

Architectural plans for the Roundabout were prepared by the San Francisco firm of Milton T. Pflueger, and the construction was undertaken by the San Francisco firm of Cahill Construction Company. The Roundabout is located on the southwest corner of the Steinhart, adjoining the dolphin tank and the Tropical Marine Fish wing. Entrance is through the Aquarium corridor adjoining Fossil Hall. Upon entering the Roundabout, Aquarium visitors are treated to a breathtaking sight, more reminiscent of the Guggenheim than of a house for fishes. A spiral walkway gracefully encircles a jewel-like tidepool tank. Along the circular walls of the entrance level are located front-lit graphics, which depict life in the sea, the hydrodynamics of pelagic fishes, the oceanic food chain, oceanic fisheries, and the increasing problems of global marine pollution. The rough, natural rock of the Touch Tank erupts from the center of the entrance level, in stark contrast to the subdued beauty of the carpeted surroundings and sweeping helix to the Roundabout viewing level. The Touch Tank, constructed by Carlos Machado, simulates a California tidepool and offers Aquarium visitors the opportunity to handle, under docent supervision, the starfishes, sea urchins, algae, and crabs that live in that wave-washed zone. It is felt that this "wet hands laboratory" adds a new dimension for the viewer, previously separated from the viewee by a pane of glass.

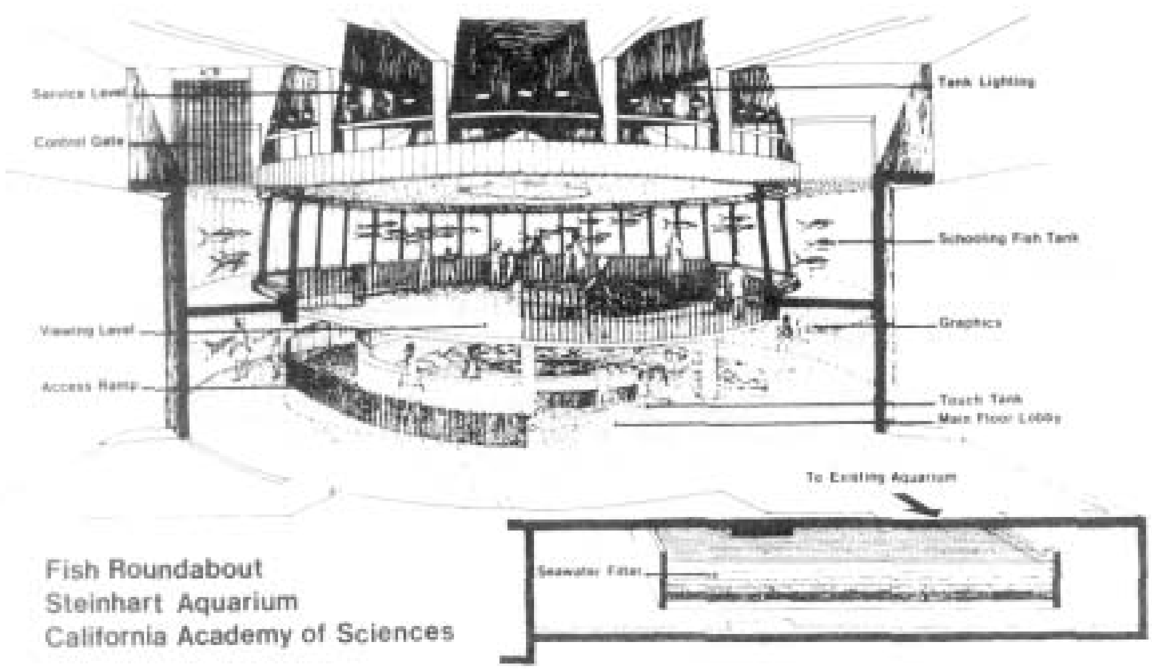
After viewing the entry-level exhibits, the Roundabout visitor then ascends the spiral ramp to become submerged in a sea of blue light and flashing fishes. The viewing level is 10 meters (33 feet) in diameter, surrounded by 36 windows of 7.5-cm. thick (three-inch) plexiglass. The plexiglass is protected from the public by one-quarter-inch plate glass separated by an open air space. The lighting in the viewing area comes primarily from the water and is supplied by 175-watt mercury vapor fixtures. The fish will swim within an endless circular channel, nearly three meters (10 feet) in diameter. Three stainless-steel doors, each weighing nearly 700 kilograms (three-quarters of a ton), can be lowered into watertight tracts separating the tank into sections, in order to remove fishes or work in the tank. The service floor from which the aquarists work is one floor above the viewing level. All work must be done from above, or within the tank by SCUBA divers, because of the novel difficulties associated with the tank design. Introducing fishes into the tank also presents difficulties, particularly when the desired species are large and thrashing sharks or fast-swimming tuna. A hoist is situated above the service level to lift cargo from the aquarium truck, up a three-story stairwell, and into the tank. Filtration is provided by a basement filter room with six sand-gravel biofilters.

During the planning and early construction phases of the Roundabout, the Academy was faced with the material and energy shortages encountered in late 1973. Serious consideration was given to the future energy requirements of the Roundabout, and a decision was made to use unheated rather than heated water for the display. Although the beauty of tropical fishes undeniably surpasses that of drab and less exotic species from cooler, temperate waters, we charted the fuel-conservative course, a decision that will save countless future kilowatts.

The water for this nearly 375,000-liter (100,000-gallon) tank will come from the pipeline already in operation, which brings seawater directly from the beach. Should future technological breakthroughs occur in the development of solar energy gathering, the Roundabout could be converted to a tropical tank.

The Roundabout will provide both the Steinhart staff and research biologists with an opportunity to study fast-moving fishes within arm's reach. The first task for the Aquarium biologists will be to learn which fishes can be captured, transported, and released into the tank. The following, equally critical task will be to decide which of those voracious predators are compatible. Residents of this pelagic bouillabaisse will include such fishes as yellowtails, tunas, horse mackerels, salmon, striped bass, Atlantic bluefish, and sharks. Research biologists from universities and marine fisheries laboratories realize the uniqueness of the Roundabout as a resource facility. The comfort, ease, and savings of studying a fish in the ring tank, rather than on the high seas, as well as the added benefits of recovering the expensive scientific sensors placed on the pelagic animals, should make the Roundabout as popular among researchers as it is for Aquarium visitors.

The pelagic fishes of the world's oceans are major contributors to the food resources of the world. It is hoped that the Roundabout will someday be assisting in making scientific contributions to that field, as well as providing education and enjoyment for millions of future visitors.



Fish Roundabout
Steinhart Aquarium
California Academy of Sciences

SHARK DYNAMICS AND EXHIBIT DESIGN

Gerrit Klay

Shark-Quarium, Marathon, Florida

Drum and Croaker 17(1, mislabeled as “2”): 29-32. April 1977

There have been a number of attempts over the years to exhibit large sharks in captivity. These have ranged from adding sharks to large ocean tanks to the construction of special donut-shaped "shark channels". To date none of these have worked satisfactorily. The common failing appears to be a result of a lack of knowledge and in-depth study of the swimming requirements of sharks. Gerrit Klay of Shark-Quarium has spent many years observing sharks both in captivity and in the unrestrained environment of the ocean. The following is an analysis of the swimming behavior of sharks and how it may be accommodated in a captive situation.

-Louis Garibaldi, Curator, New England Aquarium

The swimming pattern of a shark is composed of several stages that vary from species to species. In all patterns there is a forward power component that can be expressed as one of the following: cruising (long distance swimming); high speed long runs; high speed short runs; attack or feeding runs (very short, high speed bursts).

All power components have three things in common. 1) All have a rest/glide period. 2) All assist in blood circulation, and 3) All burn calories.

Typical follow-through stages in the forward motion sequence are:

1) (A) cruising, (B) rest/glide, (C) recovery, (A) cruising

2) (A) cruising, (B) rest/glide, (C) recovery, (D) high speed burst of speed, (B) rest/glide, (C) recovery.

3) (A) cruising, (B) rest/glide, (C) recovery, (E) turn, (D) high speed, (B) rest/glide, (C) recovery, (A) cruising, (E) turn, and so forth.

In captivity the entire sequence above goes through an abrupt change due either to limitations in the size of the tank or a poorly designed tank shape which does not consider the needs of the shark. When unable to maintain the sequential aspects of swimming, most large sharks die of exhaustion.

The next obvious question is What are the needs of a shark? Sharks need to be able to swim in the most efficient way possible thereby burning the least amount of calories possible for locomotion. They must also be able to swim at random in any direction. Neither of these criteria are available for large sharks in any existing tank. The ability to swim in any direction at will is regulated by the rest/glide-recovery distance which differs for every species of shark and with the size of the shark. The primary effect of being in confinement is that sharks have to turn more often than in the wild. We must understand that any time a shark makes a turn, other than gentle bends and directional changes between rest/ glide-recovery periods, it burns large amounts of calories due to its efforts to maintain its elevation in the water column. In captivity these drastic turns are far more frequent than in nature and therefore the shark has to adapt itself to the new surroundings and the burning of more calories. This calorie consumption is larger than is ever needed in nature. (Keep in mind the existing shark tanks today that don't allow long enough straight distances for adequate rest/glide-recovery periods). The rest/glide periods are limited due to the size, depth and design of existing tanks. Any shark introduced is doomed from the start to burn up excess calories-above those necessary for normal locomotion. This deficit is expressed in reduced red blood cell replacement, tissue repair and general body condition, i.e., exhaustion and inevitable death.

What size exhibit will satisfy a shark's needs? Other than for nurse sharks and lemon sharks, this is a very difficult question to answer. In calculating the size of the exhibit, we must consider 1) The available species, 2) The size range of the species we select, 3) The amount of space available to build the tank, and 4) The amount of money we have in the budget.

However, before going into the tank size and shape, let's take another look at a shark. Aside from ancestry, the main thing that a shark has in common with a fish is that it swims in water and breathes through gills. Otherwise, we should consider them separately from animals we call fish. Sharks are different than bony fish primarily due to their lack of a swim bladder for buoyancy when swimming. The forward motion in a shark not only accomplishes a change in location from point A to point B but also keeps the shark from sinking and helps circulate oxygen in its blood. Let's look more closely at the forward motion of a shark in captivity. Why do we lose the more active, free-swimming sharks when in captivity for only a short time? The answer is simple. In existing exhibits the sharks are literally burning up excess calories regardless of the amount of food they eat. Today's so-called shark exhibits are either 50-foot diameter tanks or racetrack-like "shark channels" of all sizes. None of them are very good for sharks of any variety

Newly introduced sharks seem to fare well for a few weeks and then steadily go downhill to a certain death for the following reasons. To avoid running into the walls, the shark has to swim at a slower speed (much like an airplane during landing) using all its power to stop from sinking. After a few encounters with the walls, the shark will seek the longest straight swimming line which is to hug the outer walls of any round tank. This is not an economical use of energy, similar to an aircraft using more power when circling just to stay at the same altitude.

Moreover, the circular swimming pattern results in an inefficient operation of the gills since one side is partly closed. This requires the shark to increase its speed to satisfy its oxygen requirement. All of these factors shorten the life span of a shark.

Now let's look at a shark under conditions we would like to provide. In general, the swimming behavior of a shark should follow this sequence: a speed burst, turn, glide, recovery period, turn, cruise period, turn, speed burst, glide recovery, turn, etc. Within this generalized sequence the shark can accomplish its normal behavioral patterns: speed bursts, feeding chase, domination and intimidation posturing, and love chasing, all followed by a rest/glide recovery and cruising that we want to look at and the total distance of that behavior. In nature these behaviors are carried on for longer distances because the water is deeper and there is no need to turn. There are limitations imposed by the size and shape of our tanks that restrict these behaviors in captivity.

The distance needed for the sequence of (A) turn, (B) cruise, (C) rest/glide, (D) recovery, (B) cruise, (A) turn, gives us the basic information as to 1) the size of the tank; 2) the depth of the tank (a function of the sink rate during the rest/glide); 3) the species we can accommodate. The number of animals is not a major factor. The A/B/C/D/B/A sequence varies with each species and the size of the shark. Therefore, in designing a shark exhibit we must ask ourselves what species of shark we would like to display and how big. This then must be calculated into the size of the exhibit and compared with the amount of money available.

An example of the difference between species would be to compare a black tip shark (C. limbatus) to a bull shark (C. leucas). The A/B/C/D/B/A length of a four-foot black tip shark is much longer than that of the bull shark. In fact, the distance a four-foot black tip shark must travel to achieve an adequate A/B/C/D/B/A is 72-74 feet. The same sequence for an eight-foot bull shark is approximately 62-64 feet. The length of these previous sequences is calculated for the pattern during an acclimation period. Once the sharks have adjusted to captivity, the sequence becomes abbreviated in length but is performed more frequently to accommodate to the confinement if the shark does not fall into a stereotyped swimming behavior. If the shark is fully adapted to captivity and the tank is adequate, it will utilize the whole tank in swimming and will alternate its direction at will.

Except for the lemon, nurse, bull and sand tiger sharks, sharks over six feet long need an introduction tank up to 100 feet long by 40 feet wide in order to take up a normal swimming pattern and exhibit normal behavior. Understandably, a tank of this size is deadly to a building fund.

To understand the difference in tank size required by different species, one must know it is not simply a matter of saying that if a four-foot black tip needs 72-74 feet then an eight-foot black tip needs double that space. It will come as a big surprise if you build a tank based on that logic and it doesn't work. There is a formula for calculating the requirements of different species which is not being included in this paper. This formula is considered proprietary information by the author who is willing to consult on these matters. *(2004 Editor's note: This formula appears to have eventually entered the public domain and may appear in the "Quarantine and Isolation Facilities" chapter of the Elasmobranch Husbandry Manual, Ohio Biological Survey, 2004)*

Rest/glide studies done on a total of 29 species of sharks indicate all of them are possible exhibit animals which can be kept with success provided the tank is designed properly.

Shark	Size	A	B	C	D	B	A	Total Distance
Black tip	4 ft	4	10-20	20	15	10-20	4	72+
Lemon	8 ft	4-8	10-20	5	5	10-20	4-8	56±
Bull	6 ft	4-8	10-20	10	10	10-20	4-8	60±
Sandbar	4 ft	2-4	10	6	6	10	2-4	54±
Porbeagle	5 ft	2-4	20	20	20	20	2-4	84±
Blacknose	3 ft	2-3	10-15	10	10	10-15	2-3	60±
Tiger	6 ft	4-6	10-20	20	20	10-20	4-6	80±

The figures listed above reflect the conditions required when first introduced. These will change as to each individual demand after a period of acclimation. For instance, after acclimation, the rest/glide periods will decrease in time with a longer cruise distance. During this period the frequency of directional change and the depth of the tank are critical factors. Forced turning during the cruising period is not possible without a loss of elevation and a risk of stalling out, placing stress on the shark. This may result in the shark sinking to the bottom, unable to get up due to exhaustion. Frequent encounters with tank walls also lead to exhaustion due to a loss of momentum and the consequent oxygen deficit that develops.

The keeping of large sharks can no longer be considered a hit-or-miss proposition. Sharks become more predictable as we learn more about them. If we want to display these fascinating animals, more consideration must be given for their needs. Only then will the public be able to appreciate these animals properly as they present themselves in their natural behavior rather than as swimming zombies just waiting to die.