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Sharks for the Aquarium and Considerations for Their Selection[1]

Alexis L. Morris, Elisa J. Livengood, and Frank A. Chapman[2]

Introduction

Sharks are magnificent animals and an exciting group of fishes. As a group, sharks, rays, and skates belong to the biological taxonomic class called Chondrichthyes, or cartilaginous fishes (elasmobranchs). The entire supporting structure of these fish is composed primarily of cartilage rather than bone. There are some 400 described species of sharks, which come in all different sizes from the 40-foot-long whale shark (*Rhincodon typus*) to the 2-foot-long marble catshark (*Atelomycterus macleayi*).

Although sharks have been kept in public aquariums since the 1860s, advances in marine aquarium systems technology and increased understanding of shark biology and husbandry now allow hobbyists to maintain and enjoy sharks in their home aquariums, and they are becoming increasingly popular as pet animals. The proper care and display of sharks requires great attention to details. The following information is intended for use by home aquarists and those working in small public aquaria. We provide critical points aquarists must consider in deciding whether or not to include sharks in their aquaria. A table of the most popular sharks kept in public and home aquariums is provided to facilitate species selection.

The Lore of the Shark

Though it has been some 35 years since the shark in Steven Spielberg's *Jaws* bit into its first unsuspecting ocean swimmer and despite the fact that the risk of shark-bite is very small, fear of sharks still makes some people afraid to swim in the ocean. (The chance of being struck by lightning is greater than the chance of shark attack.) The most engrained shark image that comes to a person's mind is a giant conical snout lined with multiple rows of teeth efficient at tearing, chomping, or crushing prey, and those lifeless and staring eyes. The very adaptations that make sharks such successful predators also make some people unnecessarily frightened of them. This is unfortunate, since sharks are interesting creatures and much more than ill-perceived mindless eating machines.

A shark's giant snout, covered with sensory receptors, is well adapted to smell a drop of blood in one million gallons of seawater and can also detect electromagnetic fields emitted by prey creatures, even those hidden in the sand. Unlike vertebrate animals (those with a backbone), sharks' upper jaws are not attached to their skulls. Their teeth do not develop from gum tissue and are not set firmly into the jaw. A shark's teeth are all impermanent and formed throughout its life in a membrane inside the jaw, which gives the shark multiple rows of "disposable" teeth, a few of which are lost periodically and immediately replaced. Teeth vary in shape

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2. Alexis L. Morris, graduate student, College of Veterinary Medicine, Aquatic Animal Health Program; Elisa J. Livengood, graduate student, School of Natural Resources and Environment; and Frank A. Chapman, associate professor and Extension aquaculture specialist, School of Forest Resources, Program in Fisheries and Aquatic Sciences; Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

and size depending on the species of shark. They are direct adaptations for processing food and are tailored to the type of diet the shark eats. For example, a horn shark has molar-like teeth ideal for crushing crabs and other invertebrates, while the razor sharp teeth of a great white shark are perfect for tearing the flesh of a seal. After a shark attack, it is frequently possible for scientists to identify the species of shark the victim encountered based on the size of the bite mark and the impressions left by the shark's teeth.

Situated on each side of its head, a shark's eyes give it a nearly 360-degree field of vision. Sharks' eyes are relatively large and well-adapted for hunting in low light conditions. In some species, the dark iris and large pupil in the eye blend into one another so that the eye appears solid black, like in the great white shark. Other species have vertical or horizontal slit pupils, sometimes with a contrasting iris (e.g., in the whitetip reef shark *Triaenodon obesus* and angel shark *Squatina californica*) that impart an alien look to them. A layer of reflective tissue in the retina known as the *tapetum lucidum* glows when light shines on it the same way a cat's eye shines in the dark. This membrane gives the shark its excellent night vision. When some species of sharks (e.g., the sixgill shark *Hexanchus griseus*) are photographed with a light source close to the camera lens, the eyes appear to "fluoresce" a green color. Guanine, the same organic compound that causes fish scales to shine, makes the eyes fluoresce. To protect their eyes while attacking their prey, some species of shark have a nictitating membrane that covers the eyeball, and protects the shark's eyes just as human eyelids protect our eyes. However, some species like great white sharks do not have this membrane and instead roll their eyes to the back of their head, exposing just the sclera or white part of the eyeball.

Sharks in motion are visualized as having a characteristic swimming posture. How different species of sharks swim and where they are typically found or live is determined by the way they breathe. For convenience, sharks are divided into three ecological types based on their geographic distribution, history, biology, habitat, and ecological factors. There are the benthic or bottom-dwelling sharks, those that live on or near the bottom; the pelagic sharks, those living primarily in the open ocean (or pelagic zone); and the semi-pelagic sharks, those sharks living in the water column but mostly associated with coastal zones or waters next to the land or inland waters. A unique characteristic of bottom-dwelling sharks (e.g., white-spotted bamboo shark *Chiloscyllium plagiosum*) is that they can breathe by pumping water across their gills while resting on the floor of the ocean or the bottom of a tank (called buccal breathing). Not all sharks possess this ability. Pelagic sharks are "obligate ram ventilators," which means that in order to breathe they must force (ram) water over their gills. Because they must swim forward constantly in order to breathe, pelagic sharks such as the great white shark (*Carcharodon carcharias*) and the shortfin mako (*Isurus oxyrinchus*) frequent the open ocean and have large ranges that can span thousands of miles around the globe. (A team of researchers tracked a great white shark on a trip that started off in South Africa and ended in Australia, spanning over 7,000 miles). Most sharks, however, have adopted both types of breathing and can alternate between buccal breathing and ram ventilation. Benthic sharks (e.g., the white spotted bamboo shark, *Chiloscyllium plagiosum*), and semi-pelagic sharks (e.g., great hammerhead shark, *Sphyrna mokarran*), can inhabit a wider range of habitats and are more closely associated with coral reefs and shallower waters than strictly pelagic sharks.

The increasing popularity of sharks is causing people to travel to exotic destinations around the world in order to dive with sharks, like the great white shark, and experience these predatory creatures in their natural environments. Sharks have also become popular in public aquariums, and now, with technological advances in life support systems and increased knowledge in the biology of sharks, we are able to maintain a wide variety of sharks in captivity, including the home aquarium.

Criteria and Special Considerations for Species Selection: Shark Biology, Husbandry, and Aquarium Systems

Three basic considerations can help aquarists determine whether to acquire a shark and choose among shark species to get the best one for a given aquarium. **Species hardiness** refers to the relative ease with which a given species of shark will adapt to a captive environment and indicates how much maintenance the species will require. **Shark availability** describes the relative difficulty of obtaining a certain shark species. It's usually determined by the shark's ability to breed in captivity or its abundance in the wild. For example, some sharks like the swellshark (*Cephaloscyllium ventriosum*) are most abundant on the west coast of the United States and thus are displayed in aquariums in those areas more frequently. Finally, **shark compatibility** indicates whether or not a shark species is likely to be aggressive towards non-shark tank-mates. Compatible sharks work well in tanks with other fish and invertebrates; incompatible

sharks will eat all the fish and invertebrates in the tank and therefore should be kept with other sharks only.

Aquarists should be aware that sharks require special accommodations to adapt successfully to life in an aquarium, and depending on the species, these can be expensive. Aquarists must accommodate shark species' spatial requirements and develop expertise in shark handling, shark dietary requirements and feed management practices in order to adapt a solid aquarium life support system that will maintain healthy sharks. Other considerations, such as ease of transport from wild capture to aquariums, and the relative expense of maintaining species will help determine the right species.

Transporting pelagic sharks from the wild to captivity is now possible because life support systems have been built that can continually pump water over their gills in order to help them breathe. With larger sharks, husbandry expertise and specialized equipment (like stretchers) are needed to manually lift or restrain the fish without causing injury. Extreme care must be taken when handling sharks to protect their internal organs as they can be injured from the weight of their own bodies. The cartilaginous "skeleton" of a shark allows it a greater range of movement, but it provides less support than the skeleton of a bony fish.

Sharks come in all different sizes from the smallest 2-foot marble catshark (*Atelomycterus macleayi*) to a 40-foot whale shark (*Rhincodon typus*). Designs for shark tanks must take into account the need to accommodate an animal that may grow to a large size. The development of acrylic tanks, structurally stronger than the old glass tanks, has allowed aquarists to keep pelagic shark species. The new acrylic tanks can be built large enough to accommodate big sharks and provide them enough room to swim constantly and maintain the flow of water over their gills. Large tanks use a greater volume of water and necessitate a larger filtration system. Most aquariums will have a biological filter to deal with the high organic load produced as a result of metabolic wastes, and at least some type of mechanical filtration system (usually a sand filter or a bead filter) coupled with a protein skimmer and ozonation to optimize water clarity. Because of the difficulty and expense of making and filtering such large volumes of saltwater, many aquariums are located on the coast and use flow-through systems instead of recirculating systems.

Besides the difficulty in meeting the spatial requirements and life-support systems of many sharks, managing the dietary needs of a captive shark has proven difficult as little nutritional research has been done on elasmobranch species. For example, sharks, like all animals, require essential vitamins and minerals which cannot be met if they are fed a pure protein diet of shrimp or fish; therefore, in captivity, sharks must be supplemented with vitamins, like Mazuri SharkTabs®. Captive sharks can develop a wasting disease if they are not fed their proper nutritional requirements. They can develop goiter from iodide deficiency and spinal deformities from vitamin C and/or vitamin A deficiencies. Complicating matters, sharks are notorious for spitting out their vitamins and for being "picky eaters." Therefore, much shark husbandry and care must be focused on meeting the dietary needs of the fish.

Although advancements in marine aquarium systems technology and shark husbandry permit aquarists to successfully maintain a variety of shark species, budgetary limits may determine what species and how many shark species are part of the system. Financially, the rarity of a shark and the difficulty of traveling to its wild habitat can greatly increase the cost associated with the collection of the species. Obviously the cost of obtaining a particular species from half way around the world will be higher than for a local species or one that readily breeds in captivity. Also, there are initial high costs associated with building a life support system for maintaining and displaying the sharks. Aside from materials and labor, the electricity and feeding costs are often the highest in keeping sharks.

Popular Sharks for Marine Hobbyists and Public Aquariums

Marine hobbyists and public aquariums have spent years attempting to find the "right" shark to fit their specific needs; and a wide variety of shark species (some 200) have been kept in captivity. However, only about a dozen species are currently kept successfully in captivity. Again, the small number of success stories is indicative of the difficulty of maintaining the captive sharks' well-being.

Table 1 summarizes the top five shark species common to marine hobbyists and public aquariums, along with maximum species size and considerations for selection. After an extensive literature review (see bibliography) and consultations with hobbyists and professionals from aquariums, the authors feel that the species chosen best reflect sharks with not only the "right look" (predatory hunter) but also the relatively modest husbandry requirements suitable for a hobbyist or public aquarium.

Table 1. Top 5 Popular Sharks for Marine Hobbyists and Public Aquariums. Total length (TL)

Marine Hobbyist			Public Aquariums		
Species Name	**Maximum Size**	**Considerations**	**Species Name**	**Maximum Size**	**Considerations**
Bamboo Shark, *Chiloscyllium spp.*	104 cm TL (3.4 ft)	Two species – whitespotted and brownbanded. Nocturnal. Benthic. Adjusts easily to captivity. Figure 1a.	**Blacktip shark,** *Carcharhinus limbatus*	255 cm TL (8.5 ft)	Pelagic. Difficult to transport and acclimate. Not normally captive bred.
Coral Catshark, *Atelomycterus marmoratus*	70 cm TL (2.3 ft)	Semi-aggressive. Benthic.	**Nurse shark,** *Ginglymostoma cirratum*	270 cm TL (9 ft)	Benthic. Aggressive. Voracious feeder. Figure 2a.
Horn Shark, *Heterodontus francisci*	120 cm TL (4 ft)	Benthic. Difficult to acclimate. Semi-aggressive to tank invertebrates.	**Sandbar shark,** *Carcharhinus plumbeus*	240 cm TL (7 ft)	Pelagic. Difficult to acclimate. Not normally captive bred.
Leopard shark, *Triakis semifasciatus*	150 cm TL (4.9 ft)	Semi-pelagic. Difficult to acclimate. Aggressive. Figure 1b.	**Sand Tiger shark,** *Carcharias taurus*	320 cm TL (10.5 ft)	Pelagic. Aggressive towards other teleosts. Figure 2b.
Port Jackson shark, *Heterodontus portusjacksoni*	137 cm TL (4.4 ft)	Benthic. Difficult to acclimate. Semi-aggressive to tank invertebrates.	**Whitetip Reef shark,** *Triaenodon obesus*	160 cm TL (5.2 ft)	Aggressive towards other teleosts/rays.

Sharks for the Home Aquarium

Marine aquarium tanks kept by hobbyists are usually small, between 180 and 500 gallons, and favor small and docile sharks (Table 1). Ideally, a marine hobbyist is looking for a shark that adapts well to being in captivity, is not aggressive or territorial with tank-mates, is unproblematic to feed, long-lived, and preferably easily bred in captivity. There are only a few shark species that fit these criteria. Most problematic is that many sharks are aggressive to tank-mates, limiting a tank to being a single-species—in some cases a single-animal—aquarium. Bamboo sharks (*Chiloscyllium* spp.; Figure 1a) and horn sharks (*Heterodontus* spp.) are not aggressive towards other fish species, but they are aggressive towards invertebrates because their diet in the wild consists of clams and other bivalve species. Bamboo sharks are easy to acclimate and to feed, while horn sharks are quite difficult.

Unfortunately, sharks that are better suited for smaller systems are most active at night and naturally secretive. Luckily, the marine hobbyist is not limited to benthic, sedentary sharks that do not actively portray a predatory behavior. The leopard shark (*Triakis semifasciata*; Figure 1b) puts on a satisfying show, actively swimming around the tank between its rest breaks on the tank bottom. However, these sharks are prone to jumping out of their tanks if care is not taken to properly cover them. The leopard shark is a subtropical species that lives in water ranging in temperature from 15–20 °C (59–68 °F). It can reach a maximum size of 3.9–4.9 feet, with an average size at maturity for males 2.6 feet and females 3.5 feet.

The subject of maximum size that a species can reach must not be taken lightly. Most sharks are acquired while they are small, and if insufficient forethought is put into the design of the tank, sharks can quickly outgrow it! For example, though the leopard shark may be a desirable species because it has the "right look," this shark will reach a maximum size that many home aquarium systems cannot maintain. A good rule-of-thumb for determining the minimum tank size requirements of a particular shark species is to take the maximum length of the shark and multiply that by three for the length and width of the tank. For example, if a coral catshark reaches a maximum length of 2 feet, the tank should be at least 6 feet long by 6 feet wide. Not many homes can accommodate a tank of that size or weight, which puts sharks out of reach for most home aquarists. To avoid fruitless expense and much heartache, hobbyists must learn about sharks' unique requirements and realistically assess their abilities to provide for those needs before introducing a shark into a home aquarium.

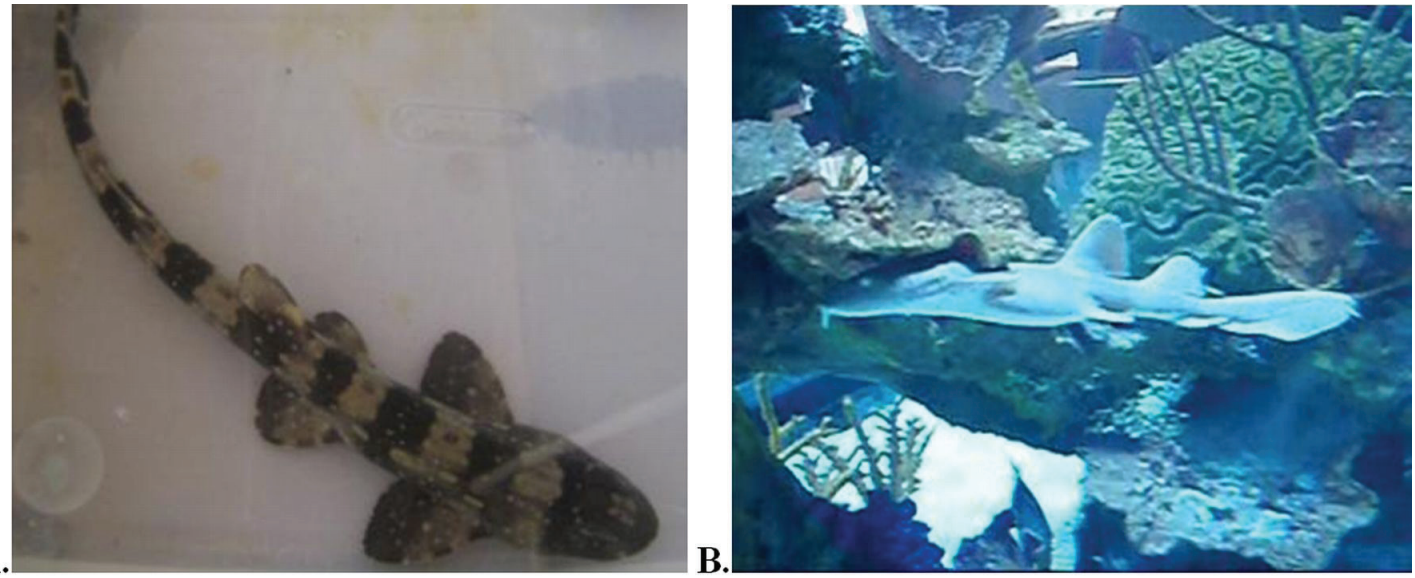

Figure 1. Sharks popular with the home aquarist; (a) white-spotted bamboo shark (*Chiloscyllium plagiosum*), (b) nurse shark (*Ginglymostoma cirratum*).
Credits: A. Morris

Sharks for Public Aquariums

Public aquariums often prefer sharks that exhibit a predatory appearance and display a fierce hunting behavior; often typified by the requiem sharks whose members from the family Carcharhinidae (e.g., blacktip shark, grey reef shark, and sandbar shark) have streamlined bodies that permit a strong and rapid swimming ability (Table 1). They usually look for sharks common to the area that may already have local interest (to facilitate acquiring them and reduce costs), and they search for species that are easy to handle and transport. Most importantly, public aquariums want sharks that are tolerant of captive conditions. Ideally, the shark should do well in multi-species exhibits and breed readily in captivity.

Public aquariums can accommodate enormous tanks, ranging from a few thousand gallons to a million gallons or more, with elaborate life support systems. Big budgets, skilled and experienced caretakers and spacious facilities allow public aquariums to harbor large pelagic sharks, including the sand tiger (*Carcharias taurus*; Figure 2b) and many other species that are beyond the means of home hobbyists.

Due to public demand and the "wow factor," aquariums want to include rarer sharks, such as the great white shark (*Carcharodon carcharias*), tiger shark (*Galeocerdo cuvier*), scalloped hammerhead shark (*Sphyrna lewini*), and whale shark (*Rhincodon typus*), in their exhibits. However, many of these shark species do not adapt to captive life and maintaining them successfully involves tremendous expertise and financial investment. Another species that is often selected for display is the lemon shark (*Negaprion brevirostris*), due to their typified shark appearance, predatory behavior, ease of transport, and ability to acclimate to tank life. However, due to recent fishing restrictions on the fishery in the USA, lemon sharks may be chosen less frequently for display. This brings up the point that shark species must be selected in compliance with current international, federal and state fisheries regulations, as well as conservation efforts for the species.

Besides large spatial requirements, large pelagic sharks also do not adapt well to captivity due to difficulties in feeding them. Because of aggressive behavior towards tank mates and carnivorous nutritional requirements, many sharks are hand fed using feeding prongs. Hand feeding also ensures that captive sharks receive proper nutrition because the food can be supplemented with vitamins and the feeder can control the amount fed. Though there are many benefits to hand feeding, in captivity some sharks do not easily take to eating fish from feeding prongs and may still eat their tank mates from time to time.

Another consideration is the difficulty of acquisition and transport of new sharks. These large sharks are difficult to capture and transport from the wild to the aquariums. Since they are ram-ventilating sharks, the life support system on the transport tanks must provide water that can continually flow over their gills. Despite being tough and rugged, the skins on these sharks are easily susceptible to abrasions that can become points of entry for parasitic, bacterial or fungal infections.

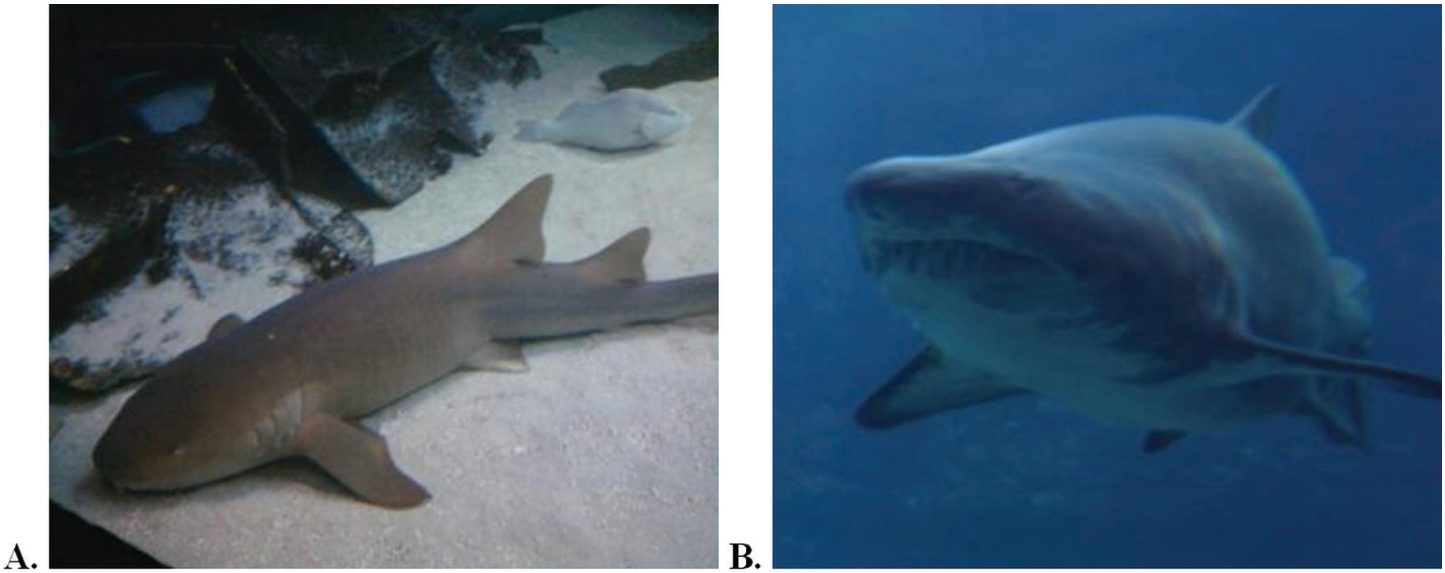

Figure 2. Sharks popular in public aquariums; (a) nurse shark (*Ginglymostoma cirratum*), (b) sand tiger shark (*Carcharias taurus*).
Credits: A. Morris

Shark Conservation

Despite the increased popularity of sharks in both wild and captive settings, shark populations continue to decline worldwide. Many sharks die when they are caught as by-catch in fishing nets and lines, and millions more each year are caught by shark finners. Shark finners capture sharks, remove their fins, and dump them back into the ocean, usually still alive. Without their fins, sharks cannot swim and the pelagic species cannot breathe, so they suffocate or slowly drown. On the Asian market, shark fins go for 25–30 USD per pound and are used in shark fin soup. One bowl of shark fin soup may sell for 100–150 USD. Shark fins are believed to increase female fertility and male virility and they have cultural importance at Asian weddings similar to that of a wedding cake at an American wedding. The high economic value of shark fins combined with the deep cultural value that shark fins have in Asian culture makes eliminating shark finning a complicated issue.

Although the United States government has placed fishing regulations on many shark species, such as the 2009 Shark Conservation Act, which prohibits shark finning in US waters; many foreign countries do not have similar management practices to protect shark populations, nor do they report shark landings. Currently, only five shark species, the great white shark, the whale shark, the basking shark (*Cetorhinus maximus*), the shortnose sawshark (*Pristiophorus nudipinnis*), and the porbeagle shark (*Lamna nasus*) are internationally protected and listed as threatened with extinction and illegal to trade under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). The population status on most shark species is not known and thus a tremendous need exists to determine their vulnerability.

Conclusion

The novice aquarist should not consider maintaining sharks in an aquarium because much experience is necessary to learn how to provide for a shark's well-being and survival. When selecting a species that is appropriate for a particular system, one must consider the shark's hardiness, availability, and compatibility with other tank mates. Though approximately 200 species of sharks that have been held in captivity, success with most has been decidedly mixed. Table 1 in this publication highlights a few "tried and true" species that have become popular due to their relative ease of maintenance. The would-be shark aquarist must not only know the biology and husbandry requirements, but also the conservation concerns and environmental regulations of the species before selecting a particular shark for display in an aquarium.

States have both commercial and recreational fishing regulations for sharks; most are considered game fish and are subject to game fish laws. States also have specific regulations for the possession of specific species of sharks for commercial purposes. Also, there is proposed legislation in Hawaii to prohibit the sale and possession of shark fins. Except for legally protected shark species, most people obtain sharks for display by purchasing them from aquarium and fish supply stores, or from other hobbyists that breed sharks in captivity. We have no knowledge about permits required for the possession and display of sharks commonly kept in home aquaria. Please contact the state fish and marine divisions for any shark fishing and possession regulations, especially since laws and regulations are frequently amended.

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Web Resources

http://www.CITES.org - Convention on International Trade in Endangered Species of Wild Fauna and Flora website.

http://www.fishbase.org - Comprehensive database of information about fish.

http://www.sharkalliance.org – Global, not-for-profit coalition of non-governmental organization for the conservation of shark species.