The Elasmobranch Husbandry Manual II:

Recent Advances in the Care of Sharks, Rays and their Relatives

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Chapter 5

Collection, transport and husbandry of the blue shark, *Prionace glauca*

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Abstract: The blue shark, *Prionace glauca* (Linnaeus, 1758), is a common, globally distributed shark species. Although beautiful and graceful it has rarely been maintained in public aquaria, and never for an extended period. The longest survival time for a *P. glauca* in an aquarium was 246 days at Tokyo Sea Life Park. Capture of *P. glauca* is relatively easy using longlines, game fishing gear (i.e., rod and reel) and set nets. These methods allow for the collection of animals in good condition. *P. glauca* can be successfully transported using a round tank with oxygen supplementation and a filtration system. Smaller animals (i.e., <100 cm TL) are optimal display candidates, as they better tolerate the biochemical challenges presented by capture and transport. Small *P. glauca* also seem to be more resistant to handling than larger specimens. Large-

volume exhibits (i.e., over 2,000 m^3), with ample space for swimming and gliding, few obstacles, and no potential predators—e.g., sand tiger sharks, *Carcharias taurus* (Rafinesque, 1810), and sandbar sharks, *Carcharhinus plumbeus* (Nardo, 1827)—are recommended, to provide an appropriate aquarium environment for *P. glauca*. It may be prudent to introduce *P. glauca* into an exhibit before other potential predatory species. *P. glauca* tend to rub their skin, fins and snouts on the smooth walls and windows of aquaria. Optimizing *P. glauca* swimming patterns to minimize contact abrasion is critical to their care in aquaria.

INTRODUCTION

The blue shark, *Prionace glauca* (Linnaeus, 1758), is the only species in the genus *Prionace*, and belongs to the family Carcharhinidae, commonly known as the requiem sharks (Compagno, 1984). This species of shark is found worldwide, often in offshore surface waters, in both temperate and tropical climates. Historically, *P. glauca* has been the most abundant species of large shark found throughout its range (McKenzie and Tibbo, 1964; Casey, 1982). *P. glauca* has an indigo-blue coloration on its upper body, bright blue sides, and a markedly white abdomen (Carwardine and Watterson, 2002). Tagging studies and catch records indicate that *P. glauca* exhibit extensive seasonal migrations (Stevens, 1976; Casey, 1982). *P. glauca* is the most heavily fished large shark species in the world, and bycatch in commercial fisheries, especially long line swordfish and tuna fisheries, accounts for the largest cause of adult shark mortality (Castro et al., 1999). The conservation assessment of *P. glauca* is “near threatened” (www1). Due to its unique shape, color, historical relevance, and conservation status, *P. glauca* represents an attractive species for public display. Yet, few institutions have displayed *P. glauca*, and never for an extended period of time.

This chapter presents an overview of capture and transport methods used for *P. glauca*, as well as basic husbandry methods specific to the species. The information provided is based on experiences drawn from maintaining a *P. glauca* at the Oceanário de Lisboa, Portugal, for seven months, along with information extracted from similar trials by other institutions. The experiences detailed in this article are intended to serve as a point of reference for future attempts at maintaining *P. glauca* in aquaria.

A number of institutions, including Sea World San Diego, Monterey Bay Aquarium, Aquarium of the Bay, Adventure Aquarium, and Tokyo Sea Life Park (Correia, 2004), have attempted to capture, transport and maintain *P. glauca*. The first known trials occurred in 1968 at Sea World San Diego, where a 15 m diameter tank was built to trial the maintenance of pelagic sharks, such as *P. glauca* and mako sharks, *Isurus oxyrinchus* (Rafinesque, 1810) (Powell et al., 2004). In order to understand how these and other scientists approached the capture, transport and maintenance of *P. glauca*, a questionnaire was sent to the nine institutions that have attempted to keep the species. Six questionnaires were returned providing information on more than 20 individual *P. glauca*, which has been summarized in Table 1. Five of the six responding institutions conducted trials with several sharks (3 - 7), some of which were released to the wild after spending variable lengths of time in human care.

SHARK COLLECTION

P. glauca are highly-pelagic, obligate ram ventilators, which prevents the use of any collecting method that does not allow the shark to swim freely. As such, trapping, gill netting, or pelagic trawling are not advisable collection methods, and would almost certainly result in *P. glauca* mortality. In light of these limitations, the use of long lines or standard game fishing gear provides a viable alternative for shark collection. Both of these capture methods allow the animal to swim continuously, even when being reeled in. However, collection in commercial set nets represents the ideal capture method, as the animal is allowed to swim freely, without hyperactivity, before being removed from the water.

For decades, game fishers have captured *P. glauca* using rod and reel, then tagged and released them. This methodology has been used in independent studies, as well as the National Marine Fisheries Service’s (NMFS) Cooperative Shark Tagging Program. Together, these programs list thousands of recaptures (Briggs, personal communication), providing evidence that

P. glauca survive a short struggle with anglers and subsequent tagging and release.

Many *P. glauca* detailed in the survey were caught using long lines, or game fishing rod and reel, although others were caught using set nets. The sharks caught in set nets displayed the highest survivability. Captured shark sizes ranged from 60 - 180 cm total length (TL). Most of the sharks were deemed to be in good condition after capture, with reported cases of post-capture complications predominantly involving larger animals (160 - 180 cm TL).

SHARK TRANSPORT

The majority of successful *P. glauca* transports used round tanks, with diameters ranging from 100 - 240 cm, and volumes up to 3.5 m^3 allowing the sharks to swim freely. Transport regimes typically employed oxygenation, via water replacement, or regulated diffusors fed by compressed gas cylinders, and/or some form of water treatment. Where reported, oxygen was maintained above 100% saturation. Water treatments typically consisted of a mechanical filter (e.g., a cartridge filter filled with pleated paper media), fed by a 12V submersible pump placed on the bottom of the transport tank. These regimens were adequate for transporting *P. glauca*, provided transport times were no longer than 4 h. Post-transport complications reported in the survey were predominantly related to excessively large sharks (160 - 180 cm TL). A shark transported in a rectangular tank did not fare well.

Our experiences transporting *P. glauca* at the Oceanário de Lisboa were consistent with the findings of other researchers. Smaller sharks (i.e., <100 cm TL) were relatively easy to transport using round polyethylene tanks (100 - 240 cm diameter). Mechanical filtration was provided by a canister (Model CFR 50, Jacuzzi, Chino, California) filled with activated carbon and a 50 µm pleated paper filter. Oxygen saturation was maintained as high as 200% using a cylinder of compressed medicinal grade oxygen. Further details of shark transport methods can be found in Correia (2001), Young et al. (2002), Smith et al. (2004), Correia et al. (2008), Correia et al. (2010) and Rodrigues et al. (2012). Multiple trials conducted directly by the team at the Oceanário de Lisboa suggested that 100 cm TL is the upper length threshold for transporting *P. glauca*, over which animals adapt poorly to the confines of a transport tank. For transports of longer duration, or for animals longer than 100 cm TL, a larger round tank with both oxygenation and filtration is strongly advised.

SHARK HUSBANDRY

Aquarium shape and size

As reported in the survey, aquaria used to maintain *P. glauca* varied considerably in shape, including circular, elliptical, and even rectangular. Aquarium volumes ranged from 20 - 157 m^3 for quarantine tanks and 250 - 7,000 m^3 for exhibit tanks. While some facilities maintained *P. glauca* in quarantine or holding tanks, before moving them into a display tank, other institutions maintained sharks in a quarantine tank or an exhibit tank exclusively. Although large-volume aquaria (i.e., >1,000 m^3) are recommended for *P. glauca*, it is suggested that smaller sharks (~70 cm TL) could survive, medium-term (i.e., several months), in smaller aquaria (e.g., 150 m^3). For example, an individual *P. glauca* was maintained at the Oceanário de Lisboa in a quarantine tank of 100 m^3 for a period of 161 days.

Food and Feeding

In general, as reported by survey respondents, initiating feeding in healthy *P. glauca* did not appear to be a challenge. Some *P. glauca* fed from the bottom of the aquarium, while others were induced to eat by target feeding. Two facilities reported a necessity to force-feed anorectic sharks. Food accepted by *P. glauca* included: squid, *Loligo* sp.; hake, *Merluccius* sp.; Atlantic herring, *Clupea harengus* (Linnaeus, 1758); European sprat, *Sprattus sprattus* (Linnaeus, 1758); tuna, *Thunnus* sp.; Atlantic salmon, *Salmo salar* (Linnaeus, 1758); and shrimp of the genera *Litopenaeus* sp. and *Penaeus* sp. Sharks were typically fed 3 - 5% of their body mass (BM) each day. In one case, a single *P. glauca*, which was eating well in a single-species aquarium, became anorectic when moved to a multispecies exhibit (Roche, personal communication). One researcher reported that *P. glauca* tended to swim along the perimeter walls of an aquarium, in some cases forming contact abrasions. Perimeter swimming typically ceased during feeding sessions, then returned once feeding was over (Ezcurra, personal communication).

Rudimentary growth data was reported in the survey for two *P. glauca*. One specimen grew from 60 cm TL to 100 cm TL in eight months (Arai, personal communication), while another shark

Table 1. A summary of attempts, by six institutions, to collect, transport, and maintain blue shark, *Prionace glauca* (Linnaeus, 1758) in aquaria (extended on the facing page).

Institution	Date	Shark Size (cm)	COLLECTION		TRANSPORT		
			Capture method	**Animal condition**	**Transport method**	**Transport time (min.)**	**Animal condition**
Tokyo Sea Life Park	22-06-99	60-70	Fixed fishing net; set-net; longline	Good	1 m^3 tank	120 (car)	Good to Average
	22-06-99						
	22-06-99						
	22-06-99						
	13-07-99						
	13-07-99						
Oceanário de Lisboa	01-10-02	90	Rod & reel; circle hooks	Good	100 cm circular tank; O_2 only	240 (boat)	Good
	01-10-02	90					Good
	24-02-03	120	Set-net	Good	160 cm circular tank; O_2 + filtration		Good
	15-07-03	180	Rod & reel; circle hooks	Poor			Bad
	30-09-04	160			240 cm circular tank; O_2 only		Average
	26-05-11	70	Set-net	Good	240 cm circular tank; O_2 + filtration	300	Good
	17-05-12	100		Good			
L´Oceanografic Valencia	04-08-05	120-150	Surface longline	Good	3.5 m^3 circular tank; O_2 + filtration	540	Good
	04-08-05						
	01-08-05					600	
	01-09-05				1 m^3 rectangular tank; O_2 only	540	Bad
Aquarium de San Sebastián	01-07-06	unknown	Surface longline	Good	Inmobilized with water pump directed into mouth	90 (boat)	Good
						30 (van)	Average
Tunipex, S.A.	01-06-11	100	Set-net	Good	160 cm circular tank	45 (boat)	Good
	14-05-12	100				240 (truck)	
	17-05-12	100				45 (boat)	
Monterey Bay Aquarium	multiple: 1995 - 1998		Handline with baited hook	Good	Vessel transport	60 - 180	Good

grew from 70 cm TL to 92 cm TL in six and a half months (mean ± standard error = 1.04 ± 0.20 cm/week; n = 2)

Longevity

The longest survival times reported in the survey, by Tokyo Sea Life Park, were 164, 224 and 246 days, for three separate *P. glauca* maintained in a large, toroid exhibit tank (dimensions = 28 m outer wall diameter x 20 m inner wall diameter x 7m deep). The *P. glauca* maintained at the Oceanário de Lisboa lived for a total of 194 days in human care. The remaining animals detailed in the survey survived for periods ranging from a few hours to 78 days (Table 1). Some of these animals were subsequently tagged and released (Ezcurra, personal communication; Graça, personal communication).

<table>
<tr><th colspan="3">QUARANTINE TANK</th><th colspan="3">EXHIBIT</th><th colspan="4">FEEDING</th><th rowspan="2">Time in Aquarium</th></tr>
<tr><th>Shape</th><th>Dimensions (m)</th><th>Volume (m^3)</th><th>Shape</th><th>Dimensions (m)</th><th>Volume (m^3)</th><th>Standard feeding</th><th>Target feeding</th><th>From bottom</th><th>Force feeding</th></tr>
<tr><td colspan="3" rowspan="6">N/A</td><td rowspan="6">Deformed toroid</td><td rowspan="6">28 (OD) 20 (ID) x7</td><td rowspan="6">2.2</td><td rowspan="6">Yes</td><td rowspan="6">Yes</td><td rowspan="6">Yes</td><td rowspan="6">No</td><td>246 days</td></tr>
<tr><td>163 days</td></tr>
<tr><td>unknown</td></tr>
<tr><td>unknown</td></tr>
<tr><td>224 days</td></tr>
<tr><td>unknown</td></tr>
<tr><td colspan="3" rowspan="4">N/A</td><td rowspan="4">Cylindrical</td><td rowspan="4">35 x 7</td><td rowspan="4">5</td><td colspan="4" rowspan="4">No</td><td>1 hour</td></tr>
<tr><td>2 days</td></tr>
<tr><td>2 hours</td></tr>
<tr><td>1 hour</td></tr>
<tr><td rowspan="2">Rectangular</td><td rowspan="2">9.6 x 7.0 x 1.5</td><td rowspan="2">100</td><td>Oval</td><td>1.8 x 2</td><td>250</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>194 days</td></tr>
<tr><td>Cylindrical</td><td>35 x 7</td><td>5,000</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>4 days</td></tr>
<tr><td rowspan="3">Circular</td><td rowspan="3">5 x 1</td><td rowspan="2">27</td><td rowspan="2">Elliptical</td><td rowspan="2">80 x 30</td><td rowspan="2">6,000</td><td rowspan="2">Yes</td><td rowspan="2">No</td><td rowspan="2">No</td><td rowspan="2">No</td><td>45 days</td></tr>
<tr><td>51 days</td></tr>
<tr><td>20</td><td>Rectangular</td><td>40 x 30 x 6</td><td>7,000</td><td>Yes</td><td>No</td><td>No</td><td>Yes</td><td>60 days</td></tr>
<tr><td colspan="10">N/A</td><td>0 days</td></tr>
<tr><td>Rectangular</td><td>4 x 5 x 1</td><td>2000</td><td colspan="3">N/A</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>7 days</td></tr>
<tr><td rowspan="3">Circular</td><td rowspan="3">10 x 2</td><td rowspan="3">157</td><td colspan="3" rowspan="3">N/A</td><td rowspan="3">Yes</td><td rowspan="3">Yes</td><td rowspan="3">Yes</td><td rowspan="3">No</td><td>60 days</td></tr>
<tr><td>30 days</td></tr>
<tr><td>30 days</td></tr>
<tr><td colspan="3">N/A</td><td>Oval bowl</td><td></td><td>4,500</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>5 to 78 days</td></tr>
</table>

Survival times reported in the survey depended on multiple factors. The three major causes of mortality were predation, physiological exhaustion and physical injury. All institutions reported challenges accommodating the swimming behavior of *P. glauca*, manifest as contact abrasions on the snout and fins from rubbing against the smooth walls or windows of the aquarium. This behavior has also been described for tiger sharks, *Galeocerdo cuvier* (Péron & Lesueur, 1822) (Dehart, 2004). One possible solution presented by Dehart (2004) was to build exhibits devoid of flat walls, as sharks tend to rub against smooth areas and not against decorative rockwork, an assertion corroborated by Marin-Osorno et al. (this volume). This counterintuitive suggestion contradicts prior assumptions that abundant rockwork along exhibit walls could present a challenge to *P. glauca* and is worth serious consideration by researchers attempting to maintain this species in the future.

KEY FACTORS FOR SUCCESS

To better understand issues contributing to the successful maintenance of *P. glauca* in aquaria, survey respondents were asked to force-rank five key parameters based on their respective experiences. On a scale of “5” to “1”, where “5” was of highest importance, the results were as follows (mean ± standard error; n = 5; ranked by highest to lowest): Specimen size = 5.0 ± 0.0; Aquarium size and shape = 3.8 ± 0.5; Presence of other species = 3.2 ± 0.7; Aquarium hydrodynamics = 3.0 ± 0.9; and Water quality = 2.0 ± 0.8.

The size of *P. glauca* was considered to be critical to transport success, and the success of their long-term maintenance in aquaria. While specimens should be small enough to ease transport challenges, it should also be noted that smaller specimens were more prone to become prey to larger species in a multi-taxa aquarium.

The next most highly ranked factor for success with *P. glauca* was tank size and shape. It is presumed that exhibits needed to be large enough to accommodate the swimming behavior of this highly pelagic species—i.e., an adequate horizontal dimension to allow the shark to swim and glide unobstructed. It should be noted, however, that a *P. glauca* maintained at the Oceanário de Lisboa for 161 days was maintained in a quarantine tank of only 100 m^3. In this case, manipulation of tank hydrodynamics (i.e., altering the direction and height of water currents) may have reduced the impact of smaller tank size, and the correspondingly modest horizontal dimension (a maximum of 9.6 m), on the swimming shark. Tank shape and internal topography was also identified as a determinant of success when maintaining *P. glauca* as the species is challenged by obstacles interrupting their swimming path (Roche, personal communication).

The third most important parameter for successfully maintaining *P. glauca* was the presence or absence of other predatory species. *P. glauca* were identified as susceptible to large predators, especially sandtiger sharks, *Carcharias taurus* (Rafinesque, 1810) and sandbar sharks, *Carcharhinus plumbeus* (Nardo, 1827). Every institution attempting to keep *P. glauca* with larger shark species reported at least one death due to predation. Tokyo Sea Life Park, reporting the longest survival times for *P. glauca*, did not maintain predatory species in the same aquarium.

Aquarium hydrodynamics and water quality were deemed less important for the successful maintenance of *P. glauca*, although elevated noise and elevated illumination were both reported as potential stressors (Murguia, personal communication).

CASE STUDY AT THE OCEANARIO DE LISBOA

This case study describes the capture, transport and husbandry of a *P. glauca* held at the Oceanário de Lisboa between June 22 and December 6, 2011.

Collection and Transport

A 70 cm TL *P. glauca* was captured in a tuna set net off the coast of Olhão (South of Portugal) on 26 May 2011. The shark was transported by boat to a commercial live fish facility (Tunipex S.A.), where it was held in a round staging tank (10 m wide x 1.8 m deep) for 27 days. The *P. glauca* began eating squid (*Loligo* sp.) from a pole two days after collection. Although food was offered several times per day, the shark fed intermittently during the first month. Starting on 1 June 2011 an antibiotic regimen of enrofloxacin (Baytril™ 5%, Bayer Portugal, S.A., Carnaxide, Portugal) was administered orally at a dosage of 15 mg/kg, every other day (EOD) for eight days, to treat abrasions on the snout (Graça, personal communication). Additionally, food was supplemented with six drops of Protovit™ (Bayer Portugal, S.A., Carnaxide, Portugal), a generic multivitamin complex traditionally used for pets, humans and wild animals. On 9 June 2011, as a result of continued intermittent anorexia, a new antibiotic regimen of ceftazidime (Cefortam™, Glaxo Wellcome, Portugal) was administered at a dosage of 30 mg/kg intramuscularly (IM) every three days. The antibiotic regimen was coupled with an injection of methylprednisolone sodium succinate (Solumedrol™ 40 mg/ml, Pfizer, Oeiras, Portugal), at a dosage of 0.5 - 1.0 mg/kg intramuscularly (IM). A mixture of two ointments containing codfish oil and zinc oxide (Mitosyl™, Sanofi Winthrop, Quétigny, France), and Centella asiatica (Madecassol™, Sofex Farmacêutica, Quelux, Portugal), was applied topically to stimulate healing of snout abrasions.

Less than a month after collection (22 June 2011), the *P. glauca* was transported 280 km by road to the Oceanário de Lisboa in a 2.4 m diameter tank with a volume of 3.2 m^3. The tank was equipped with a protein skimmer (Model EV240, Aquatic Ecosystems, Apopka, Florida) and a cartridge filter (Model CFR 50, Jacuzzi, Chino, California), containing activated carbon. Ammonia was maintained at 0.0 mg/L using 25 g of an ammonium quencher (Amquel™, Kordon, Wilbraham, Massachusetts), and pH was stabilized at approximately 8.0 with multiple additions of sodium bicarbonate (100 g) and sodium carbonate (100 g). The water was changed several times during the transport, with a net replacement of two transport vessel volumes (i.e., 6.4 m^3) during the 4 h trip.

Feeding and Body mass

On arrival at the Oceanário de Lisboa, the *P. glauca* was introduced into a rectangular quarantine tank (9.6 m long x 7.0 m wide), with a volume of 100 m^3. The shark exhibited normal swimming behavior and appeared to be in good condition. Although the shark began feeding immediately, the frequency at which it accepted food was inconsistent over the first two months. On four occasions, when the *P. glauca* had been anorectic, the shark was force-fed by manually restraining it in a vinyl stretcher and using a syringe, fitted with a long tube, to administer a mixed paste of fish, shrimp, mussels, tap water and elasmobranch vitamins (PSVO 10/3, Premix™, Viana do Castelo, Portugal). Within a day or two of force-feeding, the shark typically resumed eating normally. At the beginning of the third month the shark began to feed regularly, without further assistance. At this time, preferred food was small squid, “stuffed” with other food items, such as fish, shrimp or clams. Once the *P. glauca* was feeding consistently (10 August - 21 November), the shark was weighed regularly (n = 13) and an increase in body mass was observed from 1.08 to 2.96 kg, an increase of 174% BM during the period observed, or 11.8% BM/week.

Swimming behavior

The swimming behavior of the *P. glauca* was of primary concern to the husbandry team. Constant rubbing of the snout and fins along the wall or window of the tank resulted in numerous contact abrasions, in some cases requiring medical intervention. During its six months in quarantine the shark was readily caught (via plastic bag or stretcher), and regularly handled for the administration of intramuscular injections and/or topical treatments (see below), as well as for weighing and forced feeding, when required.

In an attempt to minimize contact abrasions, the water flow pattern in the quarantine tank was adjusted to disrupt repetitive swimming patterns adopted by the shark, in particular, swimming close to the perimeter walls of the tank. The first change directed incoming water across the surface of the tank, parallel to one of the longer walls, where it had formerly been directed downward at an angle of 45° toward the bottom. This change to water current resulted in an improvement to bilateral contact abrasions on the caudal fin and some other contact lesions elsewhere on the skin. The second hydrodynamic change, made some months later, resulted in water being introduced at the bottom of the exhibit, parallel to the floor and parallel to one of the longer walls of the tank; resulting in an improvement to contact abrasions on the lower lobe of the caudal fin and on the pectoral fins.

Medical management

During the first few weeks in quarantine, the *P. glauca* presented numerous medical challenges, including recurrent anorexia, as well as dermatological and ophthalmological pathologies. When the shark was anorectic, methylprednisolone sodium succinate (Solumedrol™ 40 mg/ml) was administered at a dosage of 0.5 - 1.0 mg/kg IM.

Some weeks after moving the *P. glauca* to the quarantine tank, the shark injured its left eye, presenting as severe traumatic keratitis (corneal inflammation) with a corneal ulcer penetrating to the iris. This condition was accompanied by increased anorexia and signs suggestive of general dehydration. The antibiotic ceftazidime (Ceftazidime 1g powder for injection) was administered at a dose of 30 mg/kg IM, once every two days. In addition, povidone iodine (Betadine™ dermal solution diluted 1:20 in water, Meda Manufacturing, Mérignac, France), in combination with a tobramycin-ophthalmic suspension (Tobrex™, Alcon Cusí, S.A., Barcelona, Spain) and carbomer-ophthalmic gel (Liposic™, Dr. Gerhard Mann Chem.-Pharm., Fabrik GmbH, Berlin, Germany), was applied topically to the eye while the shark was briefly restrained. Topical treatments were continued for more than two months and, despite the severity of the initial injury, the animal responded well to treatment with the cornea completely healing. There was also some regeneration of the iris and partial vision was restored.

While in the quarantine tank, the *P. glauca* regularly presented contact abrasions on the snout, caudal fin and elsewhere on the integument. In some cases, associated tissue inflammation necessitated medical intervention. Abrasions were treated with enrofloxacin (Baytril™ 5%) administered orally at a dosage of 10 mg/kg once every two days, for periods of 6 - 19 days. If little or no improvement was observed, ceftazidime was then administered at a dosage of 30 mg/kg IM, every three days, for periods of 4 - 30 days. Antibiotics were administered until the minimum prescribed treatment course had been met, and thereafter until significant improvement to lesions was observed. In two cases, scrapes of mucous from persistent lesions associated with the nares, gill slits, dorsal surface of the trunk, and the caudal fin, were positive for a protozoan (*Uronema* sp.) and flexibacter-like bacteria. These lesions were treated with antibiotics as detailed above. In addition, an immuno-stimulant (Ergosan™, Intervet/Schering-Plough Animal Health Aquaculture Centre, Essex, United Kingdom) was added to *P. glauca* food, once per day, and all lesions were treated topically with chlorhexidine gluconate (Desinclor™ 5% diluted 1:20 in water, Laboratorios Vaza Sl., Madrid, Spain) and a healing enhancement ointment consisting of codfish oil, zinc oxide (Halibut™, Farmalabor - Produtos Farmacêuticos, S.A., Condeixa-a-Nova, Portugal) and *Centella asiatica* (Madecassol™), which was applied whenever the animal was restrained for IM antibiotic administration.

Death and Necropsy

At the end of November, seven months after collection, the shark was deemed fit to move to the exhibit. At this time the *P. glauca* was feeding consistently, its eye lesion had healed, and contact abrasions had healed or were stable. The exhibit aquarium was a large, flume-like loop tank with a perimeter of 70 m, a width of 1.5 - 2.0 m and a depth of 2.0 m. The flume tank included a comprehensive water treatment system and incoming water created a strong, monodirectional current. When first introduced into the exhibit, the *P. glauca* swam normally, both against and with the water current. However, the shark would not feed. On day three, the swimming behavior of the *P. glauca* became strained and labored, and its swimming behavior and condition deteriorated quickly until its death six days later.

Necropsy revealed a gastric ulceration, as well as a rupture in the cornea of the right eye leaving the animal partially blind. The ultimate cause of death is unclear, but may have been related to chronic stress, the gastric ulceration, infection secondary to the chronic lesions, deterioration of general biochemistry, ante-mortem acidosis, or possibly a combination of some or all of these problems.

CONCLUSIONS

The longest period of time any institution has successfully maintained *P. glauca* in an aquarium is 246 days. Despite the many challenges associated with maintaining *P. glauca* in aquaria, collection and transport is relatively easy for small animals (up to 100 cm TL). Larger *P. glauca* (120 - 150 m TL) have also been transported successfully, but require large, sophisticated transport vessels.

Feeding initiation for *P. glauca* in aquaria does not appear to be a significant challenge, as most individuals commence feeding regularly within a few weeks, or even days, of collection. Nevertheless, during anorectic episodes, force-feeding may be required, and has proven to be a relatively straightforward operation.

One factor critical to the success of maintaining *P. glauca* in aquaria is the provision of ample horizontal swimming distance; allowing this pelagic species to adopt a swim-glide strategy to conserve energy reserves, and to minimize the formation of abrasions from repetitive contact with the perimeter walls of the exhibit. Periodically altering the hydrodynamics within an aquarium may be a helpful strategy to interrupt repetitive swimming behavior by *P. glauca* and reduce the incidence of contact abrasions. It may also be helpful to maintain this species in an aquarium without flat vertical surfaces by installing prominent rockwork along the perimeter walls, dissuading the shark from constantly contacting the otherwise smooth walls (refer also Dehart, 2004; Marin-Osorno, this volume).

P. glauca, especially smaller specimens, appear to be tolerant of handling for medical treatments. Some sharks responded favorably to treatment protocols and demonstrated an ability to recover from lesions and other medical challenges.

P. glauca should not be maintained with larger sharks as experience has shown them to be quite vulnerable to predation. When considering the inclusion of smaller *P. glauca* (<100 cm) in a multi-taxa exhibit, introduction of the sharks, before any other species, may be a useful strategy to reduce loss through predation.

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