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Spectra® fishing twine entanglement of a bottlenose dolphin: A case study and experimental modeling

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ABSTRACT

We report here the first documented case of a cetacean fatality from entanglement in recreational Spectra® fishing twine. Spectra® twine is a relatively new microfilament braided twine that is marketed to replace nylon monofilament twine in rod and reel fisheries. Following the case of this entangled bottlenose dolphin (*Tursiops truncatus*), we conducted tests with Spectra® and comparable monofilament twines on *Tursiops* tissue from stranded animals to compare the abrasion properties of the twines. We found that Spectra® twine was significantly more abrasive on bottlenose dolphin fluke tissue than a similar strength and diameter monofilament. With the same forces applied, the Spectra® twine cut deeper than the monofilament, exhibiting a linear relationship with force applied where the monofilament appeared to reach a maximum depth of penetration of approximately 2 mm. These tests may explain why this bottlenose dolphin was so severely debilitated from carrying a relatively light load of twine over a short period of time (20 days). Future public and corporate outreach will be essential to minimize the effect that this increasingly popular fishing twine will have on non-target species.

1. Introduction

The makers of Spectra® fiber claim that it is one of the world's strongest and lightest fibers. It is comprised of white polyethylene, a durable plastic material. Manufacturers claim it is, pound-for-pound, 15 times stronger than steel and more durable than polyester. The fibers float and exhibit high resistance to chemicals, water and ultraviolet light. They have excellent abrasion resistance and extremely low elongation. For these reasons, Spectra® fibers braided into fine diameter twine is marketed as a premium, high performance, fishing twine for recreational rod and reel enthusiasts. The characteristics that make it an ideal fishing twine also make Spectra® fiber twine potentially deadly to non-target species when they become entangled. We report here the first documented case of a bottlenose dolphin lethally entangled in Spectra® fishing twine near Chincoteague, Virginia, and we test the abrasion characteristics of this twine on cetacean tissue to illustrate our cause for concern about the destructive capability of this product in the marine environment.

Spectra® fiber fishing twine, marketed under names such as *Powerlokt, Diamond Braid* and *PowerPro*, among others, is described by manufacturers as 'microfilament braided twine' and is composed of hundreds of very fine fibers formed into strands and braided together much like high quality larger diameter line. Spectra® twine marketed as 40 lb breaking strength is the same diameter as monofilament twine that is 14 lb breaking strength.

In May and June of 2009, we documented the first case of a live bottlenose dolphin (*Tursiops truncatus*) entangled in Spectra® twine. The case ended in the animal becoming severely emaciated and weakened. Prior to the animal's demise, we partially disentangled it, but subsequently it stranded live and was humanely euthanized. Twenty days elapsed between the initial entanglement report and death. During that time, the entangling twine nearly amputated the dorsal fin and mangled the flukes and caudal peduncle. Here we provide gross and histological descriptions of the entanglement wounds and evidence of Spectra® twine's potential lethality with abrasion testing.

2. Case history and report

The dolphin was first reported to the Virginia Aquarium & Marine Science Center (VAQS) on June 18, 2009, with callers reporting a small *Tursiops* alone in an area where this species has rarely been reported. On June 20, 2009, we received the first photographic confirmation of entanglement and were able to observe a piece of fine twine on the animal's dorsal fin. The twine was beginning to cut into the flesh on the fin's leading edge. In

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the June 20 images, the entangling line did not appear to be bearing much weight or producing much drag. We assumed, from the fine nature of the twine that it was likely to break if it developed a heavy load. Over the next 5 days, however, there appeared to be increasing drag on the twine causing a severe laceration that nearly amputated the dorsal fin. Behaviorally, less of the animal was observed at the surface when it respired. Water visibility in the area was near zero, preventing us from observing other body parts for entanglement. We never observed the dolphin's flippers or flukes. On June 25th, 5 days following the initial images confirming the entanglement, we observed the animal behaving as if it was having trouble surfacing and, with permission from the National Marine Fisheries Service Regional Stranding Coordinator and in consultation with veterinarians, attempted disentanglement.

When the response team first sighted the dolphin, it was moving slowly and the flukes were not visible. It was obviously thin. After initial assessment, the team was able to grapple the fouling gear and remove it. The entangling gear was wrapped around the nearly severed dorsal fin and attached tightly around the right fluke blade and peduncle at the insertion of the fluke. We believed that the only gear left on the dolphin was approximately 5 cm of twine embedded in a lesion on the right fluke. Following disentanglement, the dolphin swam quickly away and the team was unable to re-locate it again that day. The gear that was removed consisted of a very fine multifilament braided twine wound upon itself and fouled with algae. The entire mass weighed <2 kg. The twine was identified as 40 lb test Spectra® twine.

The dolphin was not resighted for 10 days following disentanglement. When sighted on July 5th, its condition had deteriorated. A VAQS team was unable to re-locate the dolphin during an extensive survey of the area on July 7th. The dolphin stranded alive on July 8th. Upon exam, the animal's flukes and peduncle were severely compromised with most of the distal third of the right fluke blade nearly amputated, a deep lesion at the leading edge of the proximal right fluke, and a deep linear lesion spiraling around the peduncle at the fluke insertion. Because it appeared unlikely that the dolphin would retain enough use of its fluke to attempt rehabilitation for release, it was euthanized. VAQS staff collected initial samples and conducted the necropsy on July 9th.

VAQS conducted a detailed necropsy including an assessment of the external entanglement injuries and morphometrics. Data from the external observations were recorded on a Human Interaction Form and all gross observations were recorded on a standardized necropsy form.

At necropsy, the immature, emaciated male had evident traumatic injuries to the dorsal fin and flukes. The flukes and peduncle had three distinct lesion patterns which were labeled as A, B and C (Fig. 1). Lesion A was a circumferential constriction wound around the distal third of the right fluke blade. This wound was 55.5 cm in circumference and cut approximately 4 cm into the flukes to the

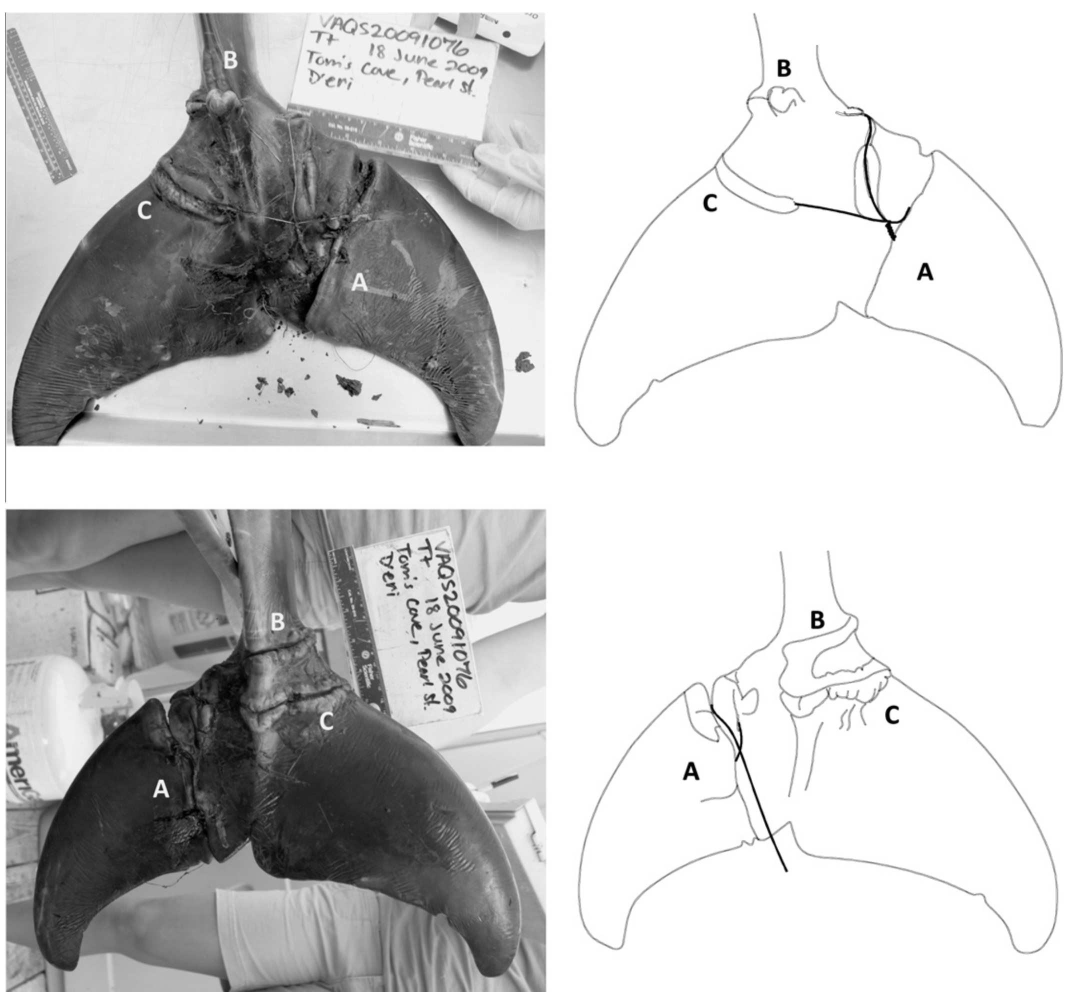

Fig. 1. Dorsal (top) and ventral (bottom) images and illustrations of fluke lesions. Lesion A wrapped around the right fluke blade cutting ~3 cm into both the leading and trailing edges. Lesion B was proximal to lesion A on the right blade and wrapped around the peduncle at the insertion of the flukes and lesion C was caudal to lesion B on the ventral surface of the flukes and cut into the left fluke blade. All three lesions had twine embedded in the tissue.

bone. The second lesion (B) started 3 cm from the insertion of the right fluke and spiraled from the leading edge of the fluke around the ventral keel of the peduncle onto the dorsal keel, ending at the right lateral peduncle. The deepest portion of lesion B was 4.5 cm deep, and the lesion was 30.5 cm long. The third lesion (C) started on the dorsal surface of the left fluke blade 3.1 cm proximal of insertion and wrapped around leading edge of left fluke along the ventral keel. The deepest portion of lesion C was 1.6 cm deep, the length was 20.5 cm. All three lesions were flanked by abundant granulation tissue (proud flesh). Gear was embedded in lesions A–C. Lesion D involved the dorsal fin which was nearly amputated with the caudal 4.5 cm remaining intact. Muscle and collagen/elastin tissue were exposed at the amputation site and edges were discolored a pale gray to white.

There were few remarkable gross observations internally. Significant gross findings at necropsy included gastric Brauniasis, scant gastric and enteric contents, bilaterally thickened adrenal cortex, and firm liver on cut section. Microscopic findings from the skin lesions involved repeatable patterns that varied in severity. Epithelial hyperplasia characterized by a thickened epithelium that ranged from 35 to 40 cell layers and formation of deeply penetrating and arborizing dermal pegs or, arborizing rete pegs or formation of islands of keratinizing (keratin pearls) islands of epithelium within a fibrotic dermis (Fig. 2) was a common finding in all lesions. Ulcerations with the defect filled with abundant numbers of degenerate and viable neutrophils, fibrin, erythrocytes, and bacterial cocci were a component of deeper lacerations. In addition, there was mild to moderate dermal fibroplasia characterized by plump streaming fibroblasts and interspersed vessels and dermal fibrosis were also observed with a mixed pattern in deeper lacerations. Dermal inflammatory infiltrates were observed and ranged from primarily neutrophilic to mixed including lymphocytes, plasma cells, and macrophages denoting a chronic inflammatory response (Table 1).

Other microscopic observations in this animal included lesions in the adrenal gland, liver, lymph node, lung, stomach, intestine, and pancreas. In the liver there was a periportal fibrosis, biliary hyperplasia, and periportal hepatitis suggestive of a response to parasitic migration. In the adrenal gland, there was nodular hyperplasia of the adrenal cortex indicating chronic stress. There was a mild, non-specific interstitial pneumonia. Pancreatic acini had few zymogen granules indicating pancreatic atrophy which is observed in starvation. A mild to moderate, parasite-induced gastroenteritis and mesenteric lymphadenitis was present. No significant findings were observed in all other examined organs including, but not limited to, the heart, kidney, and brain. There was no microscopic evidence of septicemia, though given the depth of lacerations, a route of infection was present. Acute endotoxemia cannot be ruled out.

The speed at which the animal deteriorated may be due to several factors. Possibilities include: (1) The initial entanglement may not have been as severe as the final presentation. Entangled cetaceans have been known to roll and double back and, in the course of these actions, becoming more severely entangled over time (Landry and Wells, pers. comm.); (2) The gear gained weight and thus increased tension over the course of the entanglement period (Moore et al., 2006). The algae entangled in the trailing gear could

Table 1
Histologic findings from entanglement sites samples from VAQS20091076. The following abbreviations are used: U = ulceration, EH = epithelial hyperplasia, F = fibroplasia (active fibrosis), FN = fibrin, H = hemorrhage, D = dermatitis (mixed inflammatory cell infiltrates including macrophages, neutrophils, lymphocytes, and plasma cells), C = epithelial compression, and SR = suppurative (neutrophils) inflammation. All skin sections had a roughened, irregular stratum externum.

Region	Sample number	Description
Dorsal Fin	2, 3, 15	U, EH, F, H, FN, H, SR
	4	EH, F, H, D
Left Fluke	5, 6, 7, 18	C, EH, F, D
	16	U, EH, F, H, FN, H, SR
Right Fluke	9, 12, 17, 20	C, EH, F, D
	10, 19	U, EH, F, H, FN, H, SR
Dorsal peduncle	8	C, EH, F, D
Right peduncle	20	EH, F, D

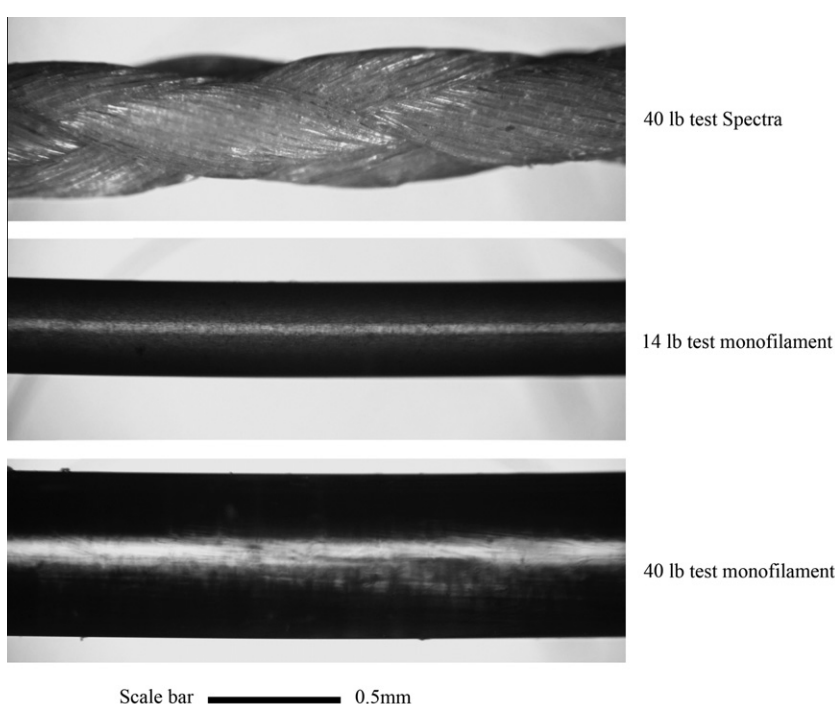

Fig. 2. Line types tested: 40 lb test Spectra®, a similar diameter (14 lb test) monofilament, and a similar strength (40 lb test) monofilament. Note the smooth texture of the monofilament twines compared with the convoluted surface of the braided Spectra twine with its microfilament strands. Images taken at 40× magnification.

have increased the tension on the flukes and peduncle, but the tension on the dorsal fin appeared to be due, at least in part, to twine connecting the dorsal fin and caudal lesion C; (3) The nature of the Spectra® twine may have resisted elongation as tension increased, and the braided nature of the twine may have acted like a saw on the dolphin's tissue.

3. Twine testing

In order to test the abrasive properties of Spectra® compared with monofilament twine, fluke specimens from two stranded bottlenose dolphins (*T. truncatus*) were opportunistically collected and frozen at −20 °C during standard necropsy events along the Virginia coast. The carcasses (1) a 197 cm F (VASQ 20091099Tt) collected on 9/15/2009 in Virginia Beach, VA and (2) a 210 cm M (VASQ20091109Tt) collected on 11/22/09 in Virginia Beach, VA were listed as Code 3 and 2, respectively – moderately decomposed and fresh (Gerasci and Lounsbury, 2005). Samples were thawed for 48 h in a freshwater bath in a 4 °C chiller prior to testing.

A straight pull abrasion test system described in Winn et al. (2008) was used to compare the abrasive impact of three different twine types on *Tursiops* fluke tissue using a standard draw-length and known tension. Twine types included: (1) 40 lb test (18.14 kg) 0.38 mm diameter microfiber Remington Power-Lokt twine with Spectra® core (Remington Fishing, Madison, NC), (2) a similar strength 40 lb test (18.14 kg) 0.60 mm diameter Sufix Superior monofilament twine (Sufix Fishing North America Inc., Greensboro, NC) and (3) a similar diameter 0.36 mm 14 lb test (6.35 kg) Sufix Elite monofilament twine (Sufix Fishing North America Inc., Greensboro, NC) (Fig. 2). Following the Winn et al. (2008) protocol, tissue samples were submerged and clamped in a static freshwater tank with the leading edge of the sample facing downward toward the bottom of the tank. A ¼ hp gear motor was used to pull a standard 3.1 m length of twine unidirectionally across the leading edge of the fluke at a fixed rate of 5 cm/s, inducing a shear load on the tissue. Abrasive impact of each twine type on the tissue sample was tested under four different load conditions: 4.4 N (0.45 kg), 17.8 N (1.81 kg), 35.6 N (3.63 kg), and 53.4 N (5.44 kg) of tension.

Tests were conducted in random order using a clean, previously undamaged site on the leading edge of the fluke blades. Individual test sites on the samples were separated by a minimum distance of 1 cm to isolate test sites and maintain the integrity of the tissue. The resulting tissue indentation and/or damage was assessed following each test. Twine furrow patterns were photographed, and tissue abrasion was compared in two ways: (1) the maximum depth of epidermal/dermal penetration (±0.02 mm) and (2) the length of epidermal penetration (±0.1 cm). Penetration depth was measured using digital calipers while the length of epidermal penetration was measured from the point of twine entry into the epidermis to the point of line exit from the epidermis along the curve of the sample using a flexible ruler.

A substantial difference in abrasion rates was found between the Spectra® and the two monofilament samples. With the fixed 3.1 m draw-length, Spectra® penetrated the epidermal layer with only 4.4 N of tension of the test line. A visible stream of skin particles was noted in the water column just beneath the sample as the line was drawn across the fluke tissue. At the end of the 3.1 m draw, the Spectra® twine had cut completely through the epidermis and was lodged in the dermal tissue. Under these same test conditions, neither monofilament twine broke the skin surface. Instead, they produced small, darkened, superficial indentations or "furrows" on the leading edge of the fluke that faded over time. The stream of skin particles noted in the water column during the Spectra® testing was not observed with the monofilament twines. Increasing the load to 17.8 N produced a more significant indentation, but still failed to cut through the epidermal layer on the leading edge (Fig. 3). A 35.6 N load (8 times the load required by the Spectra®) was sufficient to cut into the leading edge with both monofilament twines.

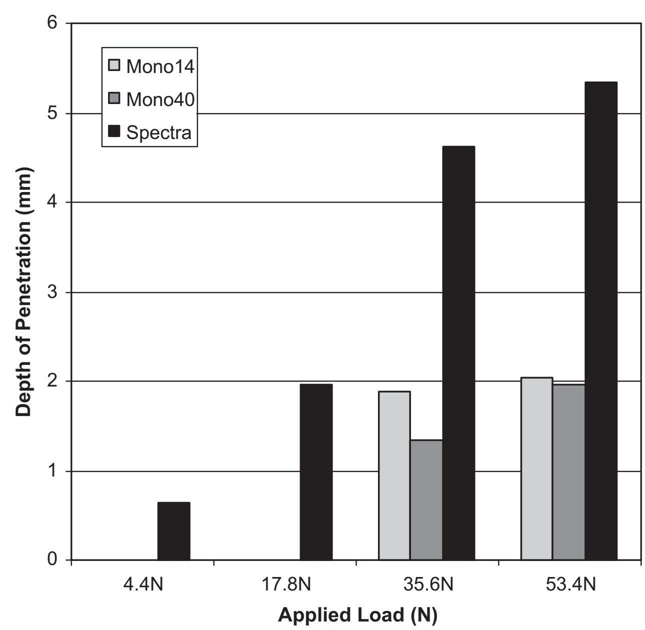

Fig. 4. Depth of epidermal penetration versus applied load for three types of fishing line. Spectra® was the most abrasive of the line types tested with penetration depths more than twice that of the monofilament lines under similar load conditions.

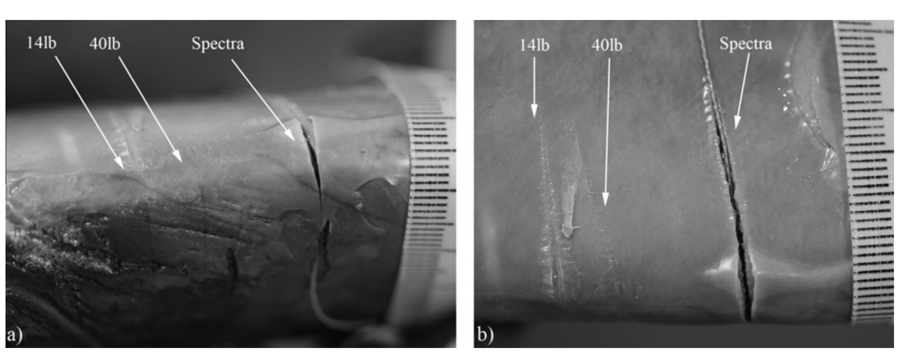

Fig. 3. Abrasion resulting from a unidirectional 3.1 m draw of line across a dolphin fluke sample under a 17.8 N load: (a) view from leading edge of fluke; (b) view of flat plane of fluke blade. Both 14 and 40 lb test monofilament lines left a superficial indentation while the Spectra® line cut through the epidermis and became embedded in the dermal layer. Scale bar on flexible ruler is 1 mm.

As seen in Fig. 4, the depth of cut with the Spectra® twine continued to increase rapidly as the tension on the twine increased, causing the line to penetrate deep within the dermal layer. In contrast to the nearly linear increase in penetration depth with increasing load seen with the Spectra®, the monofilament twine penetration depths remained fairly steady as the load was increased from 35.6 to 53.4 N. The 40 lb monofilament cut depth increased 0.6 mm, while the 14 lb monofilament only increased 0.2 mm. Interestingly, both seemed to approach a maximum penetration depth of approximately 2 mm – slightly greater than the epidermal thickness of the fluke blades (1.58 mm thick for the female and 1.64 mm thick for the male). It may be that the smooth surfaced monofilaments had more difficulty in abrading through the dermis, whereas the texture of the braided microfilament fibers in the Spectra® twine act as a miniature saw blade which can quickly cut through the underlying tissue.

The smaller diameter 14 lb monofilament penetrated slightly deeper into the fluke tissue than the larger diameter 40 lb monofilament twine, likely due to the smaller diameter line concentrating the applied load onto a smaller surface area of skin. When the 53.4 N load was applied to the 14 lb monofilament, there was substantial stretching of the twine as it neared its breaking strength.

4. Summary

The results of the twine testing support the third hypothesis of why the case presented above was so severe. We found that Spectra® twine was significantly more abrasive on bottlenose dolphin fluke tissue than a similar strength and diameter monofilament. Only 1 lb of pressure was required for Spectra® to cut into the tissue. The Spectra® twine cut deeper, with a linear relationship to force applied where the monofilament appeared to reach a maximum depth of penetration of approximately 2 mm under the loads simulated in the lab. The twine testing leads us to conclude that Spectra® twine is significantly more abrasive to dolphin fluke tissue than similar strength or similar diameter monofilament twine. While we cannot determine what the ultimate outcome of the case would have been if the dolphin had been entangled in similar diameter or similar strength monofilament twine, based on our abrasion testing, we speculate that the wounds on the animal would have been significantly less severe over the same time frame.

The case described herein is the second case of Spectra® twine being found on a stranded bottlenose dolphin. The previous case involved a dolphin (VAQS20081060) that stranded on June 2, 2008 with Spectra® twine entangling the right flipper. The entanglement lesion penetrated through the soft tissue to the humerus. The 2008 case involved a moderately decomposed animal and decomposition prevented us from determining if the entanglement was the cause of stranding and/or death. The case of VAQS20091076 is the first where we are confident that the entanglement was pre-mortem and caused the stranding event.

During the 2 years when these two cases occurred, one bottlenose dolphin stranded with recreational monofilament twine and tackle on it, but the entanglement appeared to be post-mortem where a pier fisher accidentally hooked an already dead dolphin. The lack of observed monofilament twine entanglements in the Virginia stranding record suggests that those events may be less lethal than Spectra® entanglements especially since we believe that Spectra® twine is still relatively rare in usage compared to monofilament twine. We suggest that as Spectra becomes more popular throughout the rod and reel market, we will see a higher rate of lethal entanglement with animals such as bottlenose dolphins, loggerhead and kemps ridley sea turtles as well as pelicans and other sea birds known to interact with the recreational rod and reel fishery. Public and corporate outreach will be essential to minimize the effect that this twine will have on non-target species if it becomes more popular and more prevalent in our coastal waters.

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