MARINE MAMMAL SCIENCE, 24(4): 774–794 (October 2008)

DOI: 10.1111/j.1748-7692.2008.00212.x

Consequences of injuries on survival and reproduction of common bottlenose dolphins (*Tursiops truncatus*) along the west coast of Florida

RANDALL S. WELLS
Chicago Zoological Society,
c/o Mote Marine Laboratory,
and
Sarasota Dolphin Research Program,
Mote Marine Laboratory,
1600 Ken Thompson Parkway,
Sarasota, Florida 34236, U.S.A.
E-mail: rwells@mote.org

JASON B. ALLEN
Chicago Zoological Society,
c/o Mote Marine Laboratory,
1600 Ken Thompson Parkway,
Sarasota, Florida 34236, U.S.A.

SUZANNE HOFMANN
KIM BASSOS-HULL
Sarasota Dolphin Research Program,
Mote Marine Laboratory,
1600 Ken Thompson Parkway,
Sarasota, Florida 34236, U.S.A.

DEBORAH A. FAUQUIER
NÉLIO B. BARROS
RUTH E. DELYNN
GRETCHEN SUTTON
VICTORIA SOCHA
Stranding Investigations Program,
Mote Marine Laboratory,
1600 Ken Thompson Parkway,
Sarasota, Florida 34236, U.S.A.

MICHAEL D. SCOTT
Inter-American Tropical Tuna Commission,
8604 La Jolla Shores Drive,
La Jolla, California 92038, U.S.A.

ABSTRACT

Accurate identification of human-induced injuries that lead to death or interfere with reproduction is important for marine mammal management, as deaths exceeding established limits can lead to restrictions on fisheries or vessel operations. The fates of cetaceans last seen swimming with attached gear, particularly in pelagic fisheries, or with vessel strike lacerations, have been difficult to predict. Survival and reproduction data from long-term research on resident common bottlenose dolphins near Sarasota, Florida were examined relative to consequences of fishing gear ingestion, line entanglements, vessel strikes, and amputations of unknown origins. Fishing hooks embedded in the throat, goosebeak, or esophagus, or line wrapped around the goosebeak, generally lead to death. Multiple, constrictive line wraps around fin insertions can lead to amputation, blood loss, impaired mobility, or infection. Dolphins with ingested gear or severe entanglements may swim away with the gear, but likely die later. Propeller injuries involving only soft tissue were often survivable. Some dolphins survived amputations of the distal ends of fins, and continued to reproduce. As a precautionary approach, dolphins with ingested gear or severe constrictive entanglements should be considered mortalities, but extrapolations of findings from coastal bottlenose dolphins to other cetaceans and different gear must be done with caution.

Key words: fishery interaction, vessel strike, entanglement, bottlenose dolphins, *Tursiops truncatus*, serious injury, mortality, amputation.

Cetaceans are subject to injuries from a variety of natural and anthropogenic sources. Predators such as sharks and killer whales (*Orcinus orca*) can remove entire appendages, or parts thereof, or create wounds to the body that eventually form scars. Fishing gear can cause injuries from entanglement or ingestion. Entanglements in line or nets can lead to loss of appendages, or interference with important behaviors such as swimming or feeding. Ingested fishing gear can interfere with feeding, and hooks embedded in the gastrointestinal tract may lead to more serious problems. Vessel strikes have been implicated as sources of injuries on a variety of marine mammals, including large whales (Laist *et al.* 2001) and dolphins (*e.g.*, Wells and Scott 1997) through impacts with hulls and associated equipment, and lacerations from spinning propellers. van Waerebeek *et al.* (2007) present confirmed records of vessel collisions for 18 species of small coastal and pelagic cetaceans worldwide, suggesting the problem is far more widespread than previously reported.

Accurate identification and classification of which human-induced injuries are likely to lead to death are particularly important to management of cetacean stocks in the United States. The National Marine Fisheries Service (NMFS) is tasked with compiling records of mortalities from anthropogenic sources. Observed mortalities are extrapolated to entire stocks, with serious implications for human activities such as shipping or commercial fisheries, should estimated human-caused deaths exceed a calculated stock-specific value for the stock's "Potential Biological Removal" level (PBR) (Wade and Angliss 1997). Although mortality classification can be a reasonably straightforward process when carcasses are recovered or observed, assessing whether a living but injured animal is likely to die is much more challenging.

The NMFS regulations implementing the Marine Mammal Protection Act define "serious injury" as an injury that is likely to lead to mortality (Angliss and DeMaster 1998). When an animal is last seen swimming with attached gear, or with a major laceration from a vessel strike, it is difficult to evaluate the seriousness of the injury and predict whether the animal will survive. Not scoring this injury as a serious injury leading to mortality may lead to underestimates of true mortalities. However, in the absence of a carcass, commercial interests impacted by restrictions resulting from estimated mortality levels exceeding PBR may reasonably contest such a mortality classification.

A workshop was convened by the NMFS in 1997 to develop guidelines for which injuries should be considered serious for marine mammals, including entanglement in nets or pot gear, or hooking or entanglement by longline gear (Angliss and DeMaster 1998). Small cetaceans are rarely caught in lobster pot gear, and they seldom survive net entanglements (Angliss and DeMaster 1998). Thus, the pelagic longline fisheries for tunas and swordfish were considered to be of greatest concern for injuries for small cetaceans, and subsequent observations demonstrate reason for continuing concern in the Atlantic and off Hawaii. Although these fisheries have a low rate of observed mortality, they have a potentially high rate of incidental injury, with estimated takes approaching or exceeding PBR (Garrison 2007, Waring *et al.* 2007, Forney and Kabayashi, 2007). In particular, Risso's dolphins (*Grampus griseus*), pilot whales (*Globicephala* spp.), and false killer whales (*Pseudorca crassidens*) become entangled in longline mainlines or gangions, or may be hooked in the body or mouth. These animals are often released alive and trailing some type of longline gear either from their mouth or from their caudal peduncle. The 1997 workshop participants considered animals to be seriously injured if they ingested hooks, were released trailing gear, or were released and swam away abnormally. Animals hooked externally or that were released and swam away normally were not considered injured. Among the research needs identified for refining these classifications and making them more defensible were: (1) determining survival rates of animals entangled/injured in different types of fishing gear, and (2) surveying existing stranding records for evidence of hook-and-line interactions. Unfortunately, little progress has been made with either of these actions during the ensuing decade because of the inherent difficulties of determining survivorship of small cetaceans in offshore habitats, and because there have been few documented strandings of animals impacted by longlines.

As an alternative to making direct observations of animals injured in offshore habitats, we have been able to obtain relevant data under more tractable circumstances, where it is possible to monitor small cetaceans over time, and to recover some of the mortalities as stranded carcasses. A long-term, multigenerational resident community of common bottlenose dolphins (*Tursiops truncatus*) living in Sarasota Bay, Florida, has been under study since 1970 (Scott *et al.* 1990*a*; Wells 1991, 2003). Research on this community and neighboring estuaries to the south (Charlotte Harbor) and north (Tampa Bay) has provided unique opportunities to learn about the consequences of a variety of injuries, including fishing gear ingestion, line entanglements, vessel strikes, and amputations of unknown origins, on dolphin survival and reproduction. With appropriate qualifications, it should be possible to extrapolate findings from these well-documented populations to other stocks and species in more challenging field situations.

Methods

In order to assess the consequences of injuries, it is necessary to be able to monitor individual animals over time. Working with long-term resident bottlenose dolphins, we have combined longitudinal photographic identifications and observations with health assessment, stranding response, and rescue and rehabilitation efforts to track injury cases.

Research initiated in 1970 using tagging (Irvine and Wells 1972), radio-tracking (Irvine *et al.* 1982), and individual identification techniques (Scott *et al.* 1990*b*, Wells 2002) has found long-term residency for bottlenose dolphins in bays, sounds, and estuaries along the central west coast of Florida (Irvine *et al.* 1981; Scott *et al.* 1990*a*; Wells 1991, 2003; Wells *et al.* 1996*a*, *b*). Overall, the sighting database from 1975 to 2007 includes 32,347 dolphin group sightings, and 91,059 identifications of distinctive individual dolphins, derived from a photographic identification catalog of 3,958 individually identifiable dolphins. Some individuals have been resighted more than 1,100 times, over more than three decades. Most of the research focus has been in the vicinity of Sarasota Bay (Fig. S1). Early research established the long-term, multigenerational residency of the dolphins in the area, with about 25% of the dolphins first identified in 1970–1971 still present in the area in 2007. The community home range of the resident dolphins includes the inshore waters extending southward from the southern edge of Tampa Bay to southern Siesta Key, and offshore several kilometers. Maternal lineages spanning at least five concurrent generations reside in the bay. More than 96% of the approximately 150 dolphins using the bay on a regular basis are recognizable from prior tagging or distinctive natural markings. Photographic identification surveys continue to be conducted on at least 10 d each month.

Demographic and genetic details are known for many of the resident dolphins of Sarasota Bay: 66% are of known age (up to 58 yr) and sex, 10% are of known sex and unknown age, 20% are of known age and unknown sex, and 62% are of known maternal lineage. Detailed records are compiled of the reproductive histories of each of the adult females that use Sarasota Bay on a regular basis. Data include birth dates of calves, calf sex, mother's age at time of birth (including age at first birth in some cases), duration of the mother-calf association, and circumstances leading to separation. The data set through 2007 includes records from 85 resident females and 261 of their calves; some females have been observed with as many as eight different offspring over the course of their lifetime, providing the basis for evaluating reproductive success.

Complementing the observational and photographic data, records of health and body condition are also available for many of the resident dolphins of Sarasota Bay, obtained during brief capture-release operations (Wells *et al.* 2004). Since 1988, blood sample and veterinary examination data have been collected that include 676 sets of measurements from 214 individuals (some sampled up to 14 times). Body condition and morphometric data collected since 1984–1986, including weight, a standard suite of length and girth measures, and ultrasonic measurement of blubber thickness at standard sites, are available for 220 individuals (some measured up to 13 times), with 672 sets of measurements.

Since 1985, Mote Marine Laboratory's Stranding Investigations Program (SIP) has responded to reports of stranded, sick, and injured marine mammals in Sarasota and Manatee Counties, and more recently, in Charlotte and Lee Counties, which includes and extends beyond the Sarasota Bay bottlenose dolphin community home range. Carcasses are examined and necropsied for determination of cause of death and for collection of standardized measurements and biological samples. Through 2007, 427 bottlenose dolphins have been recovered dead from the central west coast of Florida, including 67 with sighting histories.

As necessary, rescues have been performed on entangled dolphins. In some cases, animals have been disentangled in the field, through capture-release or removal of line from free-swimming individuals. In other cases, it has been necessary to bring the dolphins into Mote Marine Laboratory's dolphin hospital for treatment and rehabilitation, followed by release and follow-up monitoring. Both kinds of cases have provided information on the sources and nature of entanglement injuries and allowed for the assessment of wound healing through time.

Injury cases involving fishing gear ingestion, line entanglement, vessel strikes, and amputations of unknown origins were drawn from stranding records, photographic identification databases, rescue and rehabilitation cases, and health assessment capture-release research. Cases were selected largely on the basis of availability of historical records for injured individuals, such that time-series data could provide perspective for the injury and consequences. Causes of death were determined through case reviews by the Mote Marine Laboratory SIP necropsy team. All records were reviewed and standardized by the staff veterinarian (DAF).

Results

Injuries from Fishing Gear

Mote Marine Laboratory's Stranding Investigations Program has compiled cases of stranded and rescued bottlenose dolphins, including ingestion cases involving hooks, monofilament fishing line, and lures, and entanglement cases involving crab trap float lines and monofilament or braided fishing line. All of the gear not associated with crab traps appeared to be from recreational fishing activities. Of the ingestion cases compiled by the SIP during November 1994 through July 2006, 12 involved dolphins for which sighting histories were available. Forty-eight cases of scarring on free-ranging dolphins with sighting histories (from photographic identification surveys and health assessment operations) recorded during June 1984 through June 2007 are believed to have resulted from line entanglement.

Gear Ingestion

Eleven of the 12 ingestion cases involved carcasses associated with gear (Table 1), and the remaining case was based on scarring in both sides of the mouth of a free-ranging animal. For seven of the dolphins, ingestion was considered to be the cause of death. Three of these mortality cases, including two previously reported by Gorzelany (1998), involved line wrapped around the goosebeak, or laryngeal spout, formed by the epiglottis and corniculate cartilages. The other four involved hooks embedded in the mouth, throat, or goosebeak. In three of the mortalities, line extended outside the mouth. In another case, a dolphin with fresh line wounds in the angle of the gape of the mouth was recovered after the line had been removed by the public; cause of death was attributed to a severe shark bite, although emaciation and the wounds suggest ingestion may have played a role in mortality.

In every case in which line was found wrapped around the goosebeak, this internal entanglement was considered to be the cause of death. Although it is not known how the line wraps around the goosebeak, sometimes forming a slipknot, it is suspected that it may result from attempts at regurgitation of the gear. In one case, a partially digested fish was still attached to the hook and line, at the entrance to

Table 1. Summary of fishing gear ingestion cases.

Dolphin ID	MML ID	Sex	Age (yr)	Stranding date	Embedded gear	Non-Embedded gear	Internal entanglement	Cause of death
FB41	9514	F	36.0	27 August 1995		Hook in fish in stomach	Line around goosebeak	Line around goosebeak
SLMS	9523	M	33.0	24 December 1995		Line, lure extending from mouth	Line around goosebeak	Line around goosebeak
1536	0313	M	4.0	6 April 2003			Line around goosebeak, extending from mouth	Line around goosebeak
FB29	9804	F	35.0	25 July 1998	Lure hooks in throat			Lure hooks in throat
FB75	0611	F	32.0	1 May 2006	Lure in mouth, throat			Lure in mouth, throat
FB06	0614	M	22.0	12 June 2006	Hook and line in mouth, lure and circle hook in throat			Lure and circle hook in throat
F100	0619	M	17.0	13 July 2006	Line extending from mouth, hook, lure hooks in throat, goosebeak	2 hooks, line in stomach		Hook, lure hooks in throat, goosebeak
JOSE	0609	F	Adult	12 April 2006	Lure in mouth			Stingray barb in lung
C754	9417	F	0.5	23 November 1994		Line or net in mouth		Shark attack, infection
BRD2	0016	M	1.0	2 August 2006		2 hooks, line in stomach		Vessel strike, severe emaciation
THUV	0332	M	Adult	1 October 2003		2 hooks in stomach		Red tide

the forestomach. In the other two cases, line protruded from the mouth; in one of these, both ends of the line protruded. A repeated cycle of unsuccessful swallowing followed by regurgitation, could bring the fish and associated line around different sides of the goosebeak, leading to wrapping.

Embedded gear, in the form of single hooks or treble hooks from lures, has been found in the mouth, throat, and/or goosebeak of five dolphins, and was considered to be the cause of death in four of these (Table 1). In the fifth case, involving a large lure lodged in the mouth, a stingray barb in the lung was considered to be the primary cause of death, but the lure was also considered to have a possible contributing role to mortality. Embedded gear has not been observed in free-ranging dolphins in the Sarasota Bay area, only in carcasses, suggesting that hooks embedded in the throat or goosebeak are typically fatal. Ingested gear has never been found in more than 600 veterinary examinations during health assessments. The veterinary examinations include examination of the oral cavity, and in recent years have also included insertion of a tube into the stomach to collect small samples of stomach contents for cytology.

Mortality from ingestion of gear was not immediate. Most of the dolphins were emaciated, and in several cases weights were available for comparison. On average, dolphins with embedded gear weighed 27.3% (±6.1% SD, $n = 4$) less than expected. Such dramatic weight loss likely requires a period of weeks. In one case (F100, Table 1), an adult male had been examined in 2006 during regular health assessment operations and found to be in good health (198 kg weight) and free of gear. Thirty-five days later his carcass was recovered with multiple embedded hooks in his throat; he had lost 48 kg since the health assessment.

If hooks are not embedded in tissue, they may not be fatal. Nonembedded single hooks were found in the stomachs of four dolphins (Table 1). These were not considered to be the cause of death in any of the cases.

The final ingestion injury case involves an adult female (F153), first observed with large, well-healed scars in the angle of the gape of the mouth on both sides during her first health assessment at 36 yr of age (Fig. S2). These scars suggest either ingestion or gear wrapped around the gape. As of 2008, at 55 yr of age, she was still alive, and she has produced multiple calves subsequent to the injury.

Gear Entanglement

Injuries from external entanglement were indicated either by direct observation of gear on the dolphin ($n = 12$) or scarring consistent with wounds from lines ($n = 38$). Four dolphins were observed with crab trap float line entanglements (Table 2). Of these, one died from the entanglement, one was freed by fishermen, one cleared the gear on its own within several days, and another was rescued, rehabilitated, and released. The mortality case (C931) involved a young-of-the-year calf with line wrapped around its caudal peduncle. In two other cases (FB16, F118) in which dolphins were observed towing crab traps, the line was removed or came off the animal within days of the first observation of entanglement, and the dolphins were seen for years following the events. One of these two young males, F118, was examined during a health assessment 3.5 mo after the entanglement. Scars from the wounds are clearly visible (Fig. 1).

Muscle injuries from entanglement can require several weeks to heal fully, as indicated by a rescue and rehabilitation case involving an adult male bottlenose dolphin, F300 (Table 2). On 24 June 1992, F300 was removed from a crab trap float

Table 2. Summary of entanglement cases where gear was observed.

Dolphin ID	MML ID	Sex	Age (yr)	Date 1st seen with gear	Intervention date	Entanglement type	Fate
FB16	na	M	7.0	16 December 1988	16 December 1988	Crab trap line around peduncle	Seen for years
F300	9219	M	Adult	24 June 1992	24 June 1992	Crab trap line	Rehabilitated, seen for 16 mo
C931	9807	M	0.9	10 October 1998		Crab trap float line around caudal peduncle	Died
F118	na	M	11.0	26 October 2003		Crab trap float line around caudal peduncle	Escaped, seen for years
C333	9314	F	1.5	6 December 1993		Monofilament line around body and tail	Died
FB03	na	F	7.0	4 June 1996	6 June 1996	484 m of 80-lb test braided Dacron "squidding" line around caudal peduncle	Removed in field, seen for years
FB28	na	M	42.0	22 June 2007	6 July 2007	Monofilament around dorsal fin, right fluke	Cut in field, seen with line trailing from fluke for at least 10 mo
PLAC	na	F	1.0	5 November 2003	14 November 2003	Monofilament in prop cuts	Treated in field, seen for years
F301	0403	F	Juvenile	26 May 2003	9 March 2004	Monofilament line embedded in dorsal fin, multiple embedded wraps around right flipper	Rehabilitated, seen for years
F201	0701	F	1.5	12 December 2006	30 January 2007	3 embedded wraps of monofilament line around peduncle	Rehabilitated, seen 1 mo, died?
F222	na	M	7.0	21 July 2005		Monofilament around right fluke tip	Line off, seen for years
F248	na	M	8.0	29 June 2006	3 August 2006	Bathing suit around torso	Seen for 1.5+ years

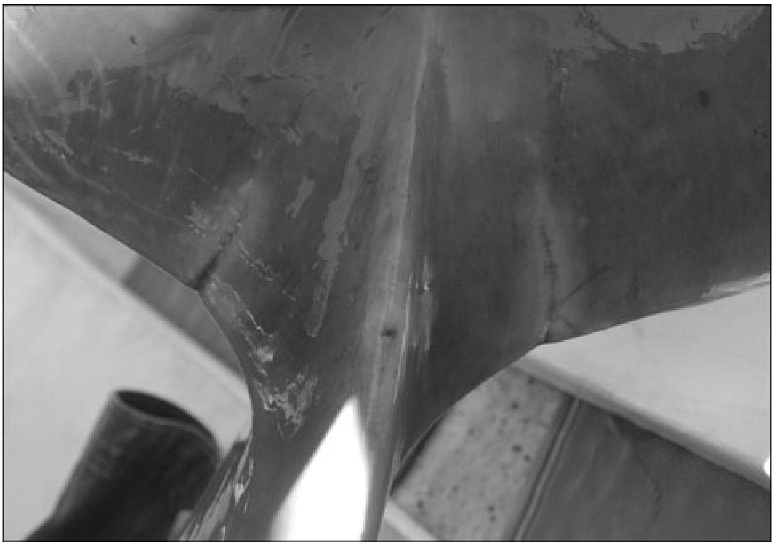

Figure 1. Crab trap entanglement scars on both flukes and dorsal caudal peduncle of F118 as seen during a health assessment on 10 February 2004, 3.5 mo after the entanglement. F118 was still alive years after disentanglement, after clearing the gear on his own.

line, where he was immobilized for an unknown period of time, and brought by pick-up truck to Mote Marine Laboratory for rehabilitation. The dolphin was admitted without any external lesions from the entanglement, but with highly elevated blood values for lactate dehyrogenase (LDH), alanine aminotransferase (ALT), and aspartate aminotransferase (AST). In the absence of elevated bilirubin, such elevated values can be indicative of muscular trauma (Bossart *et al.* 2001). LDH returned to "normal" (<538 U/L) by day 12, but AST did not decline to normal levels (<318 U/L) until day 33, and ALT did not approach normal (<33 U/L) until day 36 (Bossart *et al.* 2001, Wells *et al.* 2004). F300 was subsequently released, and follow-up monitoring recorded sightings of him over the following 16 mo.

Seven dolphins were entangled in fishing line (Table 2). Of these, one died, one shed the line on its own, and five might not have survived without intervention. Another dolphin was rescued from entanglement in a bathing suit. Most severe injuries involved constricting lines and multiple wraps cutting into appendages, a process that likely occurred over periods of weeks to months.

The carcass of dolphin C333 was recovered with large quantities of monofilament fishing line wrapped around its dorsal fin, flippers, and caudal peduncle (Table 2). This 1.5-yr-old female had last been observed 19 d prior, apparently without line. The young age of this dolphin was consistent with the pattern reported by Wells and Scott (1994), describing a disproportionately high number of subadult dolphins in Sarasota Bay with indications of entanglement.

Two resident Sarasota Bay dolphins have benefited from efforts to clear line from them in the field, under free-ranging conditions (Table 2). Seven-yr-old female FB03 was observed trailing several large snarls totaling about 484 m of 80-lb braided Dacron "squidding" line in June 1996 (Wells *et al.* 1998). A rescue team was able to motor alongside the slowly swimming dolphin and cut most of the line free near the

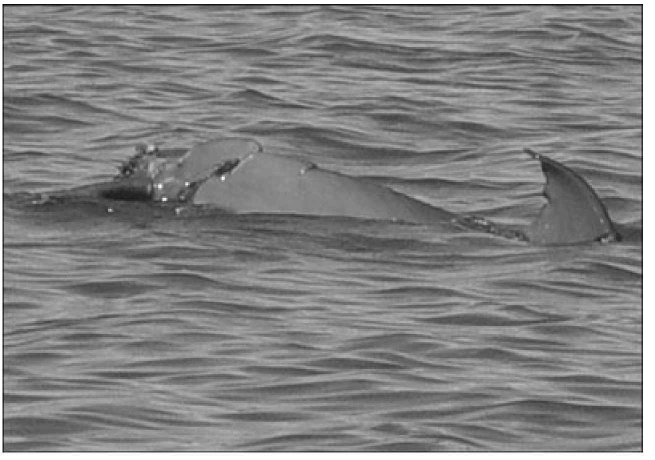

Figure 2. Yearling female dolphin PLAC with trailing monofilament fishing line and algae embedded in apparent boat propeller cuts on the caudal peduncle on 12 November 2003. PLAC was still alive 3 yr later, following disentanglement and field treatment.

caudal peduncle. Subsequent health assessment showed the flukes to be scarred from deep cuts that likely would have severed the flukes if the line had not been removed (see fig. 1 in Wells *et al.* 1998). The dolphin was observed for several years following the injury, and produced two calves.

In June 2007 a 42-yr-old male (FB28) was observed with multiple strands of monofilament fishing line stretched between his dorsal fin and right fluke and cutting into the dorsal fin (Fig. S3). After several unsuccessful attempts, within 2 wk of the first observation rescuers were able to cut the connection between the dorsal fin and flukes, leading to shedding of the line on the dorsal fin, but with line apparently remaining on the fluke. FB28 was observed in May 2008, with a small amount of line trailing from the right fluke, but this was not considered by veterinarians to be life-threatening.

A yearling female (PLAC, Table 2) was observed trailing monofilament fishing line from apparent boat propeller scars on her caudal peduncle (Fig. 2) in November 2003 (Table 2). Within 9 d of first observation, the dolphin was captured, the line and associated necrotic tissue were removed in the field, and the dolphin was released on-site. The dolphin was observed over the following 4 yr.

In two cases, rescue captures of dolphins trailing monofilament fishing line led to the dolphins being admitted to the dolphin hospital at Mote Marine Laboratory due to the severity of the injuries and the degree to which the line was embedded in tissue. A young female, F201 was observed with monofilament fishing line trailing from the insertion of her flukes on 12 December 2006 (Table 2). After subsequent observations indicated that she was unable to shed the line on her own, a rescue capture was conducted on 30 January 2007. Upon examination, it was determined that the line was too deeply embedded for field treatment (Fig. 3), and she was admitted to Mote Marine Laboratory's dolphin hospital. Three constricting wraps of monofilament line down to the level of the bone were removed in two surgeries, and she was released in good health after 3 mo. She was tracked over the following month, and then disappeared unexpectedly.

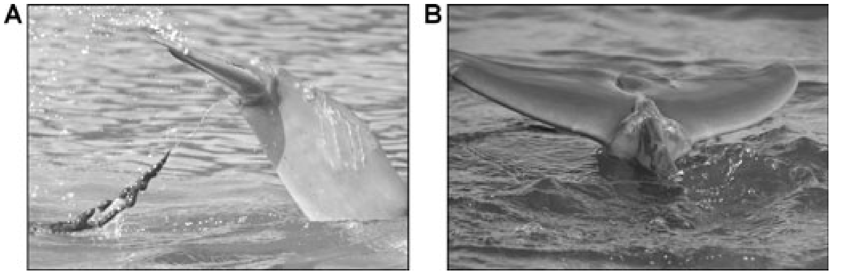

Figure 3. F201 (A) on 19 January 2007, showing monofilament fishing line trailing from the insertion of her flukes; note the diagonal boat propeller scar on her caudal peduncle just above the surface of the water, and (B) on 24 January 2007, showing the extent of tissue reaction from the embedded line. F201 was rescued, disentangled, treated, released, and tracked for about 1 mo before she disappeared.

Another subadult female (F301) was observed by Florida Fish and Wildlife Conservation Commission Marine Mammal Pathobiology Lab staff in May 2003 in Tampa Bay with monofilament line embedded in her dorsal fin (Fig. 4A). In February 2004, the same dolphin was next seen in Bull Bay, 106 km to the south in Charlotte Harbor, with line more deeply embedded in the dorsal fin, algae fouling the line (Fig. 4B), and lesions on the right flipper. Upon capture 17 d later, the flipper lesions were

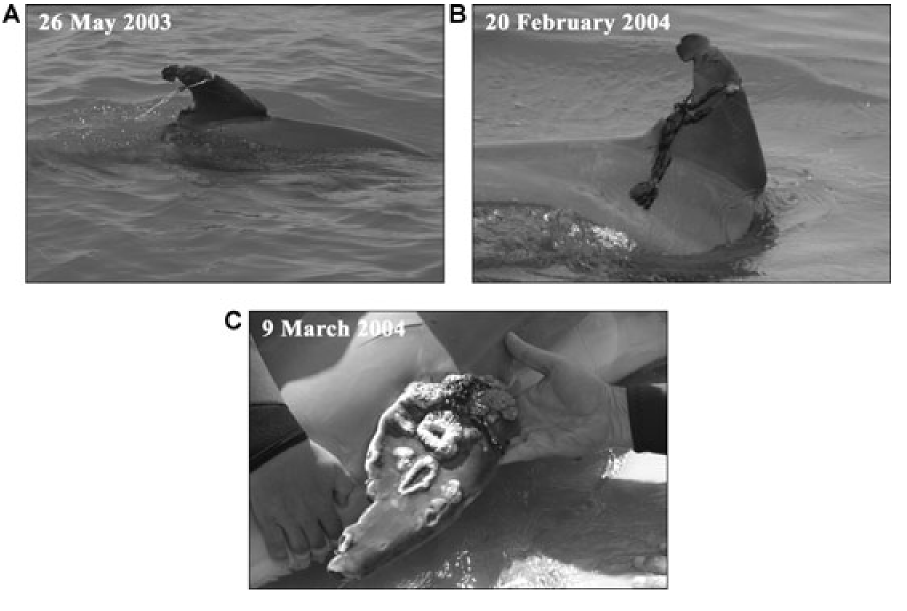

Figure 4. Subadult female F301: (A) Initial report of dorsal fin entanglement from Tampa Bay, 26 May 2003 (photo by A. Costidis, FWC), (B) in Bull Bay on 20 February 2004, and (C) upon capture for disentanglement and treatment at Mote's dolphin hospital on 9 March 2004, showing lesions and line wrapped around the right flipper. F301 was still alive at least 2.3 yr after release.

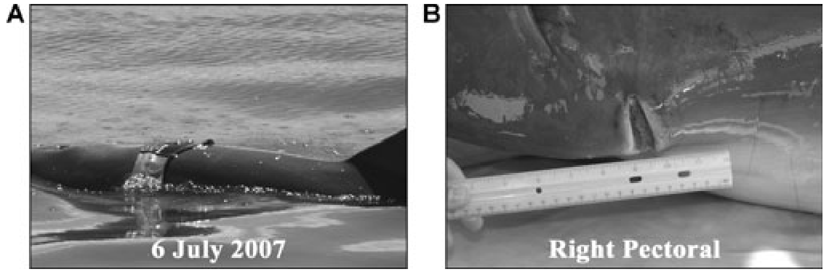

Figure 5. F248: (A) Men's bathing suit stretched across his back and around his torso on 6 July 2006, and (B) with wounds from bathing suit to anterior insertion of right pectoral flipper at the time of his rescue and disentanglement. F248 was still alive more than 1.5 yr after rescue.

found to be due to multiple constrictive wraps of monofilament down to the bone, requiring surgery for removal (Fig. 4C). After 2 mo of rehabilitation, the dolphin was released and survived for at least 2.3 yr.

Entanglement injuries have been documented from more than just line. On 6 July 2006 an 8-yr-old male (F248) was observed in Sarasota Bay with fabric stretched across his back (Fig. 5A, Table 2). After several weeks, it was evident that the fabric was not going to be shed without assistance, so a rescue capture was conducted on 3 August 2006. Upon examination, the fabric was determined to be a large men's bathing suit made of synthetic material. The material was cutting through the anterior insertions of both flippers, to a depth of about 1 cm on each side, and maintaining open raw wounds (Fig. 5B). The bathing suit was not wrapped tightly around the animal's torso. With assistance, it slid off the animal with little effort, suggesting that the force of water flowing over the animal was sufficient to cause the bathing suit to saw through the tissue below. The wounds were cleaned, an injection of antibiotic was given, and the dolphin was released at the capture site. F248 has been observed frequently for more than 1 yr subsequently, in good condition.

Not all entanglements resulting in injuries were fatal or required intervention for successful resolution. In one case, a 7-yr-old male was observed with monofilament fishing line wrapped around and trailing from the distal portion of its right fluke (Fig. S4A) over a period of at least 1 mo. By the next time the fluke tip was observed, 8 mo later, the line was gone, leaving a disfigured but apparently functional fluke (Fig. S4B). The dolphin has been observed for more than 2 yr since the entanglement, without apparent complications.

Based on scarring from injuries, 38 other well-known dolphins were believed to have been entangled at some point in their lives, but were free of the gear when first observed. Most of the scars were at the anterior insertions of the pectoral flippers, dorsal fin, and/or flukes, and did not appear to have been wrapped completely around the appendage or to result in severe injuries. Nine of 10 adult females observed with entanglement wounds or scars subsequently produced calves (Fig. S5).

Vessel Strikes

Ten cases of apparent vessel strikes have been recorded, based on the occurrence of deep, evenly spaced, parallel cuts and/or indications of severe blunt trauma

Table 3. Summary of vessel strike cases.

Dolphin ID	MM ID	Sex	Age at injury (yr)	Date 1st seen with injury	Fate
C331	8810	M	2 d	22 June 1988	Perinatal death, boat involvement unclear
BRD2	0016	M	4.0	2 August 2000	Died from boat strike; emaciated, fish hooks in stomach
F177	0526	F	3.0	12 September 2005	Died from boat strike; red tide intoxication?
FB78	na	M	11.0	2 July 1983	Fresh wounds; disfigured, seen for 25+ yr
F108	na	M	6.0	24 June 1984	Fresh wounds; healed, seen for 23+ yr
FB09	na	F	12.0	9 July 1996	Fresh wounds; disfigured, seen for 12+ yr; reproduced
F111	0229	F	29.0	16 July 1997	Fresh wounds; healed, seen for 5 yr; reproduced
F103	9221	F	3 mo	8 July 1988	Fresh wounds; disfigured, seen for 4 yr
PLAC	0335	F	1.0	5 November 2003	Disfigured, seen for 4 yr; entanglement
F201	0701	F	1.5	12 December 2006	Disfigured, seen for 4.5 mo; entanglement

(Table 3). Three of these cases were documented as mortalities, but in each case there were complicating factors relative to the role of vessel strike as cause of death. The carcass of neonate C331 was recovered 2 d after birth, and it could not be determined whether the propeller and skeg marks on this first-born calf occurred before or after death. Four-yr-old male BRD2 died from propeller cuts to his caudal peduncle (see fig. 4 in Cunningham-Smith *et al*. 2006), but he was compromised prior to the boat strike. At the time of his death, BRD2 had entanglement scars at the anterior insertions of his fins, two nonembedded hooks in his stomach, a shark-bite scar, and he was 40% below the expected weight for a male his age. The third mortality, from blunt trauma, involved a 3-yr-old female, F177. She had been exposed to red tide (*Karenia brevis*) toxin, but the possible contribution of red tide intoxication to the mortality is unknown (brevetoxin concentrations: 12.5 ng/g in liver, 2.7 ng/g in urine, 32.1 ng/g in stomach contents).

In the other seven cases, the animals have survived the vessel strikes, and propeller cuts on the backs or dorsal fins have been observed to heal, although permanent disfigurement has been common (Table 3). Four of these cases, FB78, F108, F103, and FB09 were reported by Wells and Scott (1997). Three of these dolphins, FB78, F108, and FB09, were still alive in 2007, 11yr to 24 yr after the boat strikes (Fig. 6), and FB09 has successfully reared three calves since the injury. Another adult female, F111, was observed for 5 yr after the vessel strike to her torso, and raised one more calf (Fig. 6).

The other two cases (Table 3) involved the calves described above under entanglement injuries, PLAC and F201. Both of these dolphins suffered complications from monofilament line caught in existing boat propeller wounds, requiring intervention.

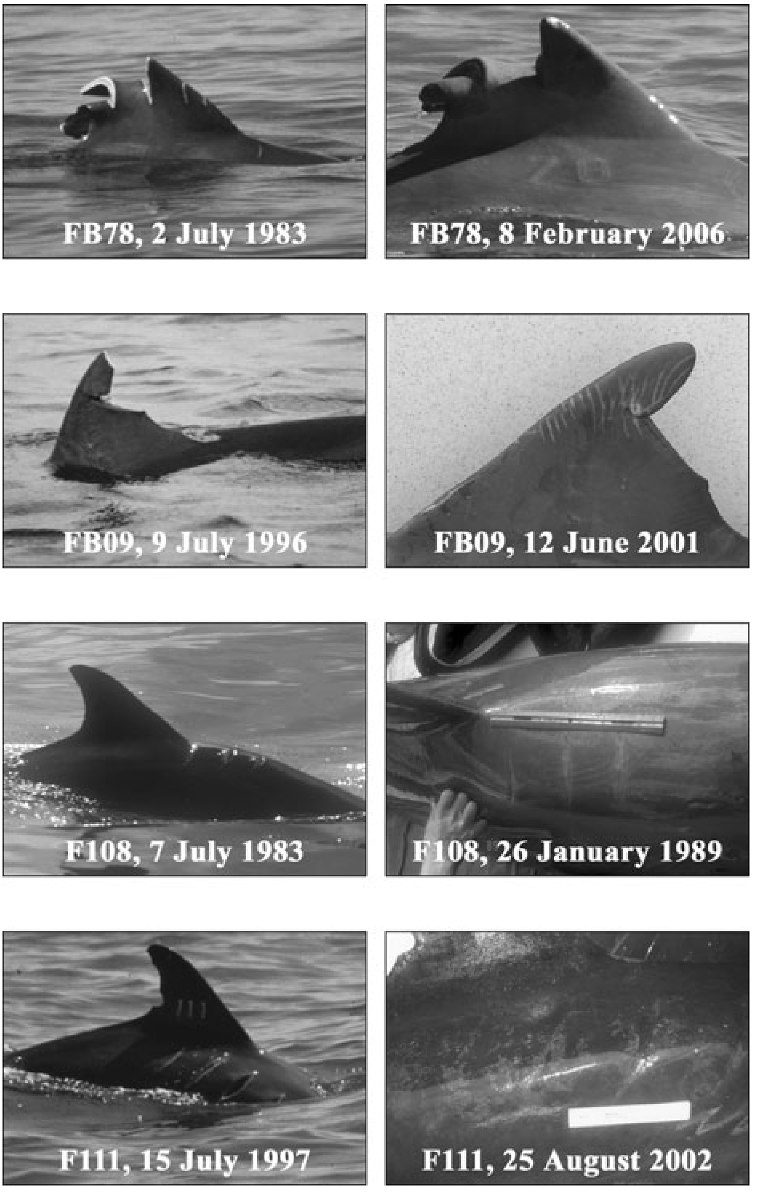

Figure 6. Fresh injuries and healing from presumed vessel strikes. Survival after injuries is indicated in Table 3.

A photographic series is shown that follows a 7-mo-old female calf C552 beginning on 8 January 2005 demonstrating healing of the kinds of wounds produced by boat propellers (Fig. 7). However, in this case the single deep cut could not be clearly classified as a vessel strike. The wound was mostly healed within 4 mo, by mid-May.

Figure 7. C552: Stages of healing of a deep wound of the kind produced by boat propellers.

Amputations of Unknown Origin

Cases involving major disfigurement or loss of significant fluke or dorsal fin tissue were monitored over time. Other cases of amputations and disfigurements were recorded, but lack the time-series information. The causes of each of these injuries are unknown. For perspective, it should be noted that the records presented here include only those cases in which the dolphins survived the injuries; the number of animals that did not survive comparable injuries is unknown.

Three dolphins (two males and a subadult female) missing significant portions of their flukes were monitored over periods of 301–10,685 d from the time they were first observed with the healed injuries (Fig. 8). All of these dolphins exhibited normal behaviors, and were able to move with other dolphins without obvious difficulty.

Thirty-two other dolphins with severe dorsal fin damage and disfigurements were observed over periods of 1 to more than 27 yr (Fig. S6). On average, these individuals survived at least 8.7 yr ($\pm$7.1 yr SD) with these injuries. Eight of these dolphins were known to be females (Fig. 9), and all of these females produced calves subsequent to the dorsal fin injuries.

Discussion

Long-term monitoring of resident dolphins has allowed the determination of the fates of animals suffering a variety of injuries, including ingestion of fishing gear, entanglements, vessel strikes, and amputations of unknown origins. Although the exact nature and severity of the observed injuries have varied greatly from animal to animal, a few consistent patterns have begun to emerge.

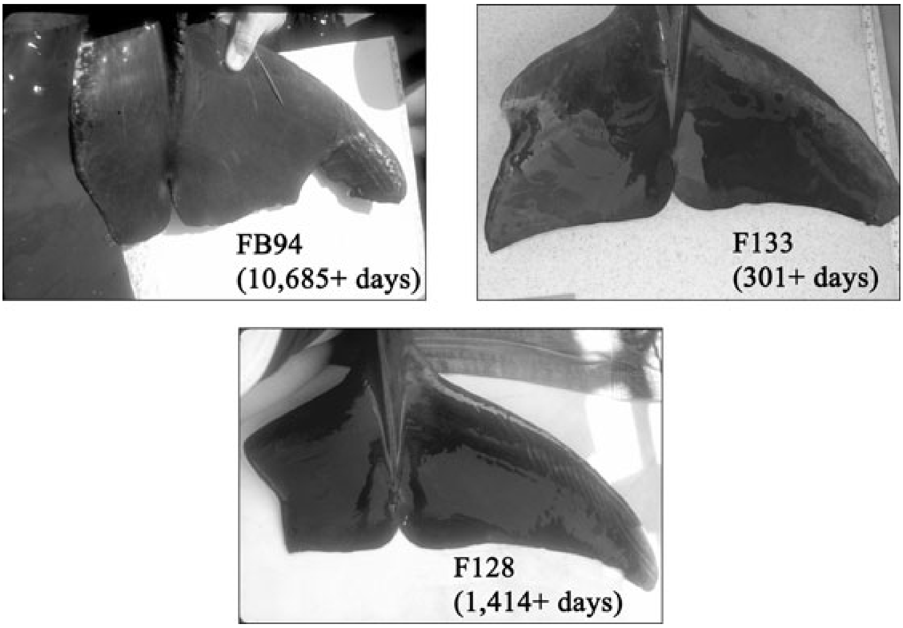

Figure 8. Cases of fluke amputations. The minimum number of days the animals survived with these injured flukes is given in parentheses.

Several kinds of injuries seem to have a high probability of leading to mortality. Ingestion of fishing gear, when it involves hooks becoming embedded in the throat, the "goosebeak" formed by the epiglottis and corniculate cartilages, or the esophagus, were found to be eventually fatal in all cases examined. Similarly, line wrapped around the goosebeak was fatal in all cases examined. Given the consistency of outcomes across this relatively small sample size of embedded hooks and entangled goosebeaks, it is reasonable to conclude from a precautionary perspective that ingested gear likely leads to mortality.

In addition to mortality due to suffocation, some forms of entanglement lead to injuries that should be considered serious, based on the likely fates of the animals in the absence of intervention. Multiple, constrictive wraps of line around the body, and especially at the insertions of the fins, lead to deep lacerations. In some cases, lines cut through soft tissue until they reach bone or sever the appendage. In addition to amputation, blood loss, infection, and/or impaired mobility can result from such wounds if they are not treated, as would be the case in offshore fisheries.

Mortalities from embedded or entangled ingested gear and constrictive external entanglements are not necessarily immediate. Ingestion injuries have not been evident to observers in the field, and have only been found upon necropsy, so the precise duration of such injuries prior to death is not known. The occurrence of significant weight loss suggests that the dolphins may survive for periods of weeks with embedded gear in their throat and esophagus or line wrapped around their goosebeak. Dolphins have been observed with external entangling fishing line over periods of up to months, as it works its way deeper into tissues. Constricting wounds tighten and cut deeper as pressure is placed on lines. In estuaries along the west coast of Florida,

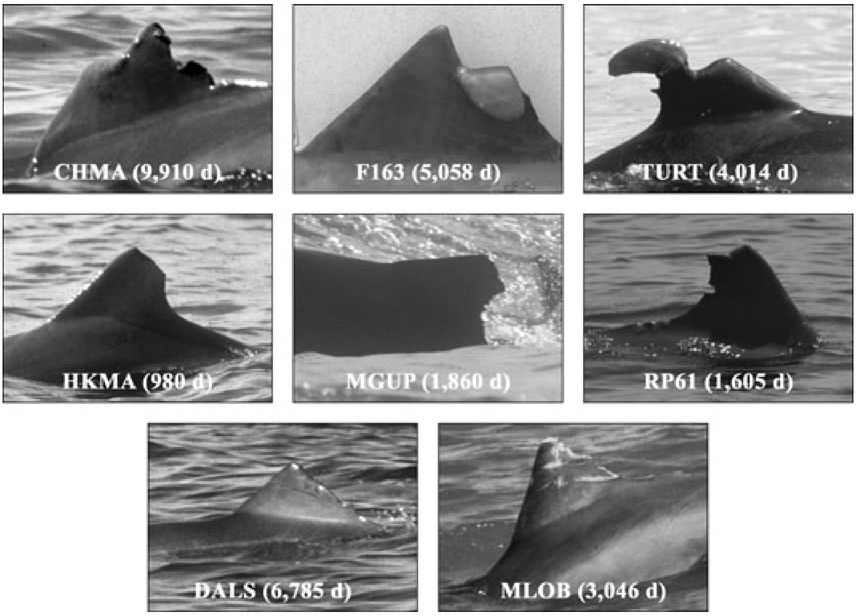

Figure 9. Adult females with severe dorsal fin injuries, exemplifying amputations of unknown origins. The minimum number of days the animals survived with these disfigurements is given in parentheses. All of these females produced calves subsequent to the dorsal fin injuries.

algae may collect on line over time, increasing drag and presumably increasing cutting forces on wrapped or embedded line. Crab trap float lines may or may not cause the same lacerations as fishing line, but they can lead to muscle trauma that may require weeks to heal, and which may interfere with mobility. The visibility and prolonged nature of external entanglements have provided opportunities to intervene in some cases, so the ultimate fates of the dolphins in the absence of treatment have not been determined. However, the nature of the wounds on rescued dolphins suggests that the gear would have led to death if left untreated. A reasonable precautionary approach would be to consider dolphins with ingested gear or severe constrictive entanglements around the flipper or fluke insertions as mortalities.

Other kinds of injuries appear to be survivable, at least in some cases. Vessel strike injuries from propellers on presumably healthy dolphins were usually survived if they involved only soft tissue, and not bones (see also van Waerebeek *et al.*, 2007). Scars from comparable deep lacerations resulting from shark attacks have been recorded on more than 22% of noncalf dolphins in Sarasota Bay (Wells *et al.* 1987). Dolphins have been observed to survive amputations or disfigurements of the distal ends of flippers, flukes, and dorsal fins from lines and undetermined causes. It is important to note, however, that evaluations of healed wounds do not take into account the possibility of immediate mortalities from similar injuries.

From a conservation perspective, injuries should be considered serious if they lead to mortality or interfere with reproduction. Most of the known female bottlenose dolphins along the central west coast of Florida that survived entanglements, vessel strikes, or amputations of unknown origins were subsequently observed with calves. Female false killer whales (*Pseudorca crassidens*) with severely damaged dorsal fins have also been observed with calves (Baird and Gorgone 2005). Thus, it appears that these major injuries have not precluded reproduction, but it has not been possible to determine whether reproduction by these injured dolphins occurred at the same rate or with the same level of success as might have occurred in the absence of the injury. It has not been possible to evaluate paternity patterns for males suffering major injuries. The dorsal fin and flukes serve in the cooling of the uterus (Rommel *et al*. 1993) and testes (Rommel *et al*. 1992, Pabst *et al.* 1995), so loss of significant portions of these appendages may be of concern relative to reproductive success.

Extrapolations of findings and conclusions from injuries to coastal bottlenose dolphins to other cetacean species facing similar issues, but with different gear or vessels must be done with caution and with consideration of the best information available from the specific situation of concern. However, in the absence of adequate information for specific species or fisheries, the bottlenose dolphins of Sarasota Bay can serve as a useful surrogate for modeling and assessing impacts. For example, Garrison (2007) summarized 94 cases of serious injuries to marine mammals (mostly pilot whales and Risso's dolphins) from the pelagic longline fishery during 1992–2004. In 60 cases, marine mammals were released with ingested hooks and trailing up to 20 m of monofilament line. The other 34 cases involved animals released with external entanglements, especially with monofilament in multiple wraps around the tail or body. Judging from observations of hooked and entangled bottlenose dolphins in Sarasota Bay, it seems likely that most of these injured dolphins eventually died from the gear.

The combination of long-term observations and photographic monitoring of identifiable individuals, health assessments, and stranding response is an effective approach for evaluating the outcome of injuries for inshore bottlenose dolphins. Although this entire combination may not be practical for many situations where human-induced injuries of small cetaceans are a concern, increased efforts to photo-identify potentially injured animals in the field, and comparisons with subsequent stranding records or observations of living animals could improve our understanding of the kinds of injuries that should be considered serious.

Acknowledgments

This work incorporated the efforts of many people and programs over periods of decades. Mote Marine Laboratory's SIP provided most of the information on injuries leading to mortalities, and the Chicago Zoological Society's Sarasota Dolphin Research Program provided the records on the living animals through the long-term efforts of staff and volunteers. We would like to acknowledge the assistance of Jay Gorzelany and Greg Early of the SIP with mortality records. Photographs were provided by a number of people, most notably Aaron Barleycorn, Katie McHugh, and Alex Costidis. Age determinations for some of the animals were provided by Aleta Hohn. Funding for field work, necropsies, and data analyses came from the J.H. Prescott Grants Program, Manatee and Sarasota Counties, Harbor Branch Oceanographic Institution-Protect Wild Dolphin Program, the National Marine Fisheries Service (SERO), Earthwatch Institute, Dolphin Quest, and Disney Wildlife Conservation Fund. Research was conducted under a series of Scientific Research Permits and letters of authorization issued by the National Marine Fisheries Service, with the approval of Mote Marine Laboratory's Institutional Animal Care and Use Committee. The article benefited from the comments of Karin Forney, Alex Aguilar, and three anonymous reviewers.

Literature Cited

Angliss, R. P., and D. P. DeMaster. 1998. Differentiating serious and non-serious injury of marine mammals taken incidental to commercial fishing operations: Report of the Serious Injury Workshop 1–2 April 1997 Silver Spring, MD. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-OPR-13. 48 pp. Available from NMFS, 1315 East-West Highway, Silver Spring, MD 20910.

Baird, R. W., and A. M. Gorgone. 2005. False killer whale dorsal fin disfigurements as a possible indicator of long-line fishery interactions in Hawaiian waters. Pacific Science 59:593–601.

Bossart, G. D., T. H. Reidarson, L. A. Dierauf and D. A. Duffield. 2001. Clinical pathology. Pages 383–436 *in* L. A. Dierauf and F. M. D. Gulland, eds. CRC handbook of marine mammal medicine. 2nd edition. CRC Press, New York, NY.

Cunningham-Smith, P., D. E. Colbert, R. S. Wells and T. Speakman. 2006. Evaluation of human interactions with a provisioned wild bottlenose dolphin (*Tursiops truncatus*) near Sarasota Bay, Florida, and efforts to curtail the interactions. Aquatic Mammals 32:346–356.

Forney, K. A., and D. R. Kobayashi. 2007. Updated estimates of mortality and injury of cetaceans in the Hawaii-based longline fishery, 1994–2005. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-412, 30 p.

Garrison, L. P. 2007. Interactions between marine mammals and pelagic longline fishing gear in the U.S. Atlantic Ocean between 1992 and 2004. Fishery Bulletin 105:408–417.

Gorzelany, J. F. 1998. Unusual deaths of two free-ranging Atlantic bottlenose dolphins (*Tursiops truncatus)* related to ingestion of recreational fishing gear. Marine Mammal Science 14:614–617.

Irvine, B., and R. S. Wells. 1972. Results of attempts to tag Atlantic bottlenose dolphins (*Tursiops truncatus*). Cetology 13:1–5.

Irvine, A. B., M. D. Scott, R. S. Wells and J. H. Kaufmann. 1981. Movements and activities of the Atlantic bottlenose dolphin, *Tursiops truncatus*, near Sarasota, Florida. Fishery Bulletin U.S. 79:671–688.

Irvine, A. B., R. S. Wells and M. D. Scott. 1982. An evaluation of techniques for tagging small odontocete cetaceans. Fishery Bulletin U.S. 80:135–143.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet and M. Podesta. 2001. Collisions between ships and whales. Marine Mammal Science 17:35–75.

Pabst, D. A., S. A. Rommel, W. A. McLellan, T. M. Williams and T. K. Rowles. 1995. Thermoregulation of the intra-abdominal testes of the bottlenose dolphin (*Tursiops truncatus*) during exercise. Journal of Experimental Biology 198:221–226.

Rommel, S. A., D. A. Pabst, W. A. McLellan, J. G. Mead and C. W. Potter. 1992. Anatomical evidence for a counter-current heat exchanger associated with dolphin testes. The Anatomical Record 232:150–156.

Rommel, S. A., D. A. Pabst and W. A. McLellan. 1993. Functional morphology of the vascular plexuses associated with the cetacean uterus. The Anatomical Record 237:538–546.

Scott, M. D., R. S. Wells and A. B. Irvine. 1990*a*. A long-term study of bottlenose dolphins on the west coast of Florida. Pages 235–244 *in* S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. Academic Press, San Diego, CA.

Scott, M. D., R. S. Wells, A. B. Irvine and B. R. Mate. 1990*b*. Tagging and marking studies on small cetaceans. Pages 489–514 *in* S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. Academic Press, San Diego, CA.

van Waerebeek, K., A. N. Baker, F. Félix, J. Gedamke, M. Iñiguez, G. P. Sanino, E. Secchi, D. Sutaria, A. van Helden and Y. Wang. 2007. Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. Latin American Journal of Aquatic Mammals 6:43–69.

WADE, P. R., AND R. P. ANGLISS. 1997. Guidelines for assessing marine mammal stocks: Report of the GAMMS Workshop, 3–5 April 1996 Seattle, WA. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-OPR-12. 93 pp. Available from NMFS, 1315 East-West Highway, Silver Spring, MD 20910.

WARING, G. T., E. JOSEPHSON, C. P. FAIRFIELD and K. MAZE-FOLEY, eds. 2007. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—2006. NOAA Technical Memorandum NMFS-NE-201. 378 pp. Available from NMFS, 166 Water Street, Woods Hole, MA.

WELLS, R. S. 1991. The role of long-term study in understanding the social structure of a bottlenose dolphin community. Pages 199–225 *in* K. Pryor and K. S. Norris, eds. Dolphin societies: Discoveries and puzzles. University of California Press, Berkeley, CA.

WELLS, R. S. 2002. Identification methods. Pages 601–608 *in* W. F. Perrin, B. Würsig and J. G. M. Thewissen, eds. Encyclopedia of marine mammals. Academic Press, San Diego, CA.

WELLS, R. S. 2003. Dolphin social complexity: Lessons from long-term study and life history. Pages 32–56 *in* F. B. M. de Waal and P. L. Tyack, eds. Animal social complexity: Intelligence, culture, and individualized societies. Harvard University Press, Cambridge, MA.

WELLS, R. S., AND M. D. SCOTT. 1994. Incidence of gear entanglement for resident inshore bottlenose dolphins near Sarasota, Florida. Report of the International Whaling Commission (Special Issue 15):629.

WELLS, R. S., AND M. D. SCOTT. 1997. Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. Marine Mammal Science 13:475–480.

WELLS, R. S., M. D. SCOTT AND A. B. IRVINE. 1987. The social structure of free-ranging bottlenose dolphins. Pages 247–305 *in* H. Genoways, ed. Current mammalogy. Volume 1. Plenum Press, New York, NY.

WELLS, R. S., K. W. URIAN, A. J. READ, M. K. BASSOS, W. J. CARR AND M. D. SCOTT. 1996*a*. Low-level monitoring of bottlenose dolphins, *Tursiops truncatus*, in Tampa Bay, Florida: 1988–1993. NOAA Technical Memorandum NMFS-SEFSC-385. 25 pp. Available from NMFS, SEFSC, 75 Virginia Beach Drive, Miami, FL 33149.

WELLS, R. S., M. K. BASSOS, K. W. URIAN, W. J. CARR AND M. D. SCOTT. 1996*b*. Low-level monitoring of bottlenose dolphins, *Tursiops truncatus*, in Charlotte Harbor, Florida: 1990–1994. NOAA Technical Memorandum NMFS-SEFSC-384. 36 pp. Available from NMFS, SEFSC, 75 Virginia Beach Drive, Miami, FL 33149.

WELLS, R. S., S. HOFMANN AND T. L. MOORS. 1998. Entanglement and mortality of bottlenose dolphins (*Tursiops truncatus*) in recreational fishing gear in Florida. Fishery Bulletin 96:647–650.

WELLS, R. S., H. L. RHINEHART, L. J. HANSEN, J. C. SWEENEY, F. I. TOWNSEND, R. STONE, D. CASPER, M. D. SCOTT, A. A. HOHN AND T. K. ROWLES. 2004. Bottlenose dolphins as marine ecosystem sentinels: Developing a health monitoring system. EcoHealth 1:246–254.

Received: 28 December 2007
Accepted: 25 February 2008

SUPPORTING INFORMATION

The following supporting information is available for this article online:

Figure S1. Study area along the central west coast of Florida.

Figure S2. Entanglement scars at the angle of the mouth gape on adult female F153, June 1989 (left) and June 1994 (right), years after the injuries.

Figure S3. FB28 in July 2007, showing monofilament strands stretched between the dorsal fin and right fluke. The raised white lesions are from a chronic fungal disease, lobomycosis, present for many years prior to the injury, and unrelated to the injury. The dorsal fin line was cut by our field team in July, but a small amount of line was still trailing from the right fluke as of May 2008.

Figure S4. Right fluke tip of F222 (A) with monofilament fishing line entanglement and algae fouling after about 1 mo, on 24 August 2005 and (B) without line on 24 April 2006. The line came off the animal without intervention.

Figure S5. Presumed entanglement scars on adult female dolphins. The numbers of calves produced by each female subsequent to the injury is shown in parentheses.

Figure S6. Dolphins of unknown sex with severe dorsal fin damage. The minimum number of days the animals survived with these disfigurements is given in parentheses.