Bycatch of bottlenose dolphins in South Carolina, USA, and an evaluation of the Atlantic blue crab fishery categorisation

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ABSTRACT

In the USA, commercial fisheries that interact with marine mammals are categorised according to the number of incidental takes of marine mammals relative to the defined Potential Biological Removal (PBR) for the population. Three categories exist for such commercial fisheries: Category I, II and III, each varying in the degree of regulation. Fishery categorisation is based on a five-year running average of the number of incidental entanglements in that fishery and is published annually in the Federal Register. The Atlantic blue crab (*Callinectes sapidus*) fishery is one of South Carolina's largest commercial fisheries in terms of volume and value and was recently re-categorised as a Category II fishery, resulting in heightened regulation. The Atlantic blue crab fishery exists in known areas of bottlenose dolphin (*Tursiops truncatus*) habitat; therefore, interaction between the two is probable. This study uses historical marine mammal stranding data and on-board investigations of the blue crab fishery in South Carolina to investigate the degree of fishery and dolphin interaction. Analysis of historical strandings showed that approximately 24% of the 42 entanglement cases in South Carolina from 1992-2003 resulted from the blue crab fishery. In nine of the 12 years examined, bottlenose dolphin mortality rates were found to be greater than or equal to 10% of the South Carolina Management Unit's PBR, which is significant according to the US Marine Mammal Protection Act's (MMPA) definitions for the Atlantic Coastal Stock of bottlenose dolphins. In addition, results from this study showed that the average number of bottlenose dolphin entanglements per year in the South Carolina blue crab fishery has exceeded 1% of PBR across a five-year period (1999-2003), which defines a Category II fishery. Thus, entanglement data from South Carolina from 1992-2003 support the re-categorisation of the blue crab fishery and the introduction of heightened regulations under the MMPA.

KEYWORDS: BOTTLENOSE DOLPHIN; FISHERIES; INCIDENTAL CATCHES; CONSERVATION; MANAGEMENT PROCEDURE

INTRODUCTION

Marine mammals and fisheries often utilise overlapping areas; therefore, interaction between the two is likely. Fisheries present a significant mortality threat to marine mammals, as they may be incidentally taken or killed in fishing gear, or their habitat may be damaged as a result of fishing practices (Beddington *et al.*, 1985; Perrin *et al.*, 1994; Fertl and Leatherwood, 1997; Read and Murray, 2000). Incidental entanglements of marine mammals in fishing gear might occur if the animals are distracted, manipulate fishing gear, behave carelessly during social interactions, or by mere accident (Fertl and Leatherwood, 1997; Anderson *et al.*, 1998). A primary goal of the US Marine Mammal Protection Act (MMPA) of 1972 and its 1994 Amendments was to reduce the incidental mortality and serious injury of marine mammals that result from fishing practices. To do so, fisheries managers and marine mammal conservationists must quantify the interaction between the two.

General management framework

The MMPA of 1972 was originally designed to prevent the depletion of marine mammal stocks as a result of anthropogenic factors. In addition, the Act was written to stimulate efforts to replenish stocks that were already considered in danger of extinction, and increase research to obtain more ecological information on marine mammals. Amendments were passed in 1994 to create a management scheme that was more focused on the human-caused mortality of marine mammals, termed bycatch (16 U.S.C. 1361 Sec. 2, 118)[1].

According to these amendments, commercial fisheries that incidentally take marine mammals are listed in the Federal Register as Category I, II or III. Each category is associated with a different degree of incidental mortality, and is therefore coupled with varying degrees of regulation. The categorisation is based on the number of marine mammals in a given stock that are annually taken, relative to the stock's Potential Biological Removal (PBR). PBR defines the number of individuals that can be taken per year from a stock, by human activities, in order to maintain or reach the stock's optimum sustainable population (OSP) (Barlow *et al.*, 1995). OSP describes the population size that maximises reproductive potential within the constraints of the habitat's carrying capacity. The goal of these regulations is to eventually reduce the incidental mortality rate of marine mammals in these fisheries to 'insignificant levels, approaching a zero mortality rate goal' (ZMRG). Mortality rates are considered insignificant when they equal less than 10% of a stock's PBR. ZMRG is not a defined number, rather a goal to encourage fisheries to reduce their incidental mortality levels in order to reach OSP (16 U.S.C. 1361 Sec. 2, 3, 118)[1].

Categorisation of commercial fisheries

The categorisation of fisheries is published annually in the Federal Register for a 90-day comment period, and re-examined annually based on new available data for each fishery listed in these categories (16 U.S.C. 1361 Sec. 117, 118 (c)(1))[1]. Category I fisheries frequently interact with marine mammals, or remove 50% or more of a stock's PBR. Category II fisheries, or fisheries that occasionally take marine mammals, include those that collectively remove more than 10%, or individually take 1-50% of a marine mammal stock's PBR. Fisheries that rarely interact with marine mammals, Category III fisheries, are collectively

[1] 16 U.S.C. 1361 et seq. United States Congress. Marine Mammal Protection Act (MMPA) of 1972 As Amended.

responsible for the removal of 10% percent or less of a stock's PBR, or 1% or less in a single fishery (16 U.S.C. 1361 Sec. 118)[1]. For Category I and II fisheries that incidentally take marine mammals beyond the stock's PBR, a take reduction plan is instituted. The short-term goal of a take reduction plan is to reduce the occurrence of incidental takes to a level below the PBR, ideally within six months after implementation. Ultimately, these plans outline the steps necessary to bring incidental take rates to levels approaching ZMRG (16 U.S.C. 1361 Sec. 118)[1].

Stranding analysis

Estimates of fishery-related mortality depend primarily on reporting by fishers, the National Marine Fisheries Service (NMFS) Marine Mammal Observer Program, and investigation of strandings. Sources of marine mammal mortality can sometimes be explained by evidence from necropsies of stranded animals (Cox *et al.*, 1998; Friedlaender *et al.*, 2001). External evidence of fishery entanglement often includes attached fishing gear, rope indentations on the epidermis, lacerated appendages, amputated appendages and net hatch marks on the epidermis (Cox *et al.*, 1998; Read and Murray, 2000; Friedlaender *et al.*, 2001; McFee and Hopkins-Murphy, 2002). Internally, entangled animals have been documented as having froth in the lungs and bronchi, stomachs full of fish remains and haemorrhaging below the skin at wound locations (Read and Murray, 2000).

Bottlenose dolphins in South Carolina

The population dynamics of bottlenose dolphins in South Carolina are not well documented, other than residence patterns in a river system located in the Charleston area (Zolman, 2002). Historically, bottlenose dolphins occurring in South Carolina were grouped as part of the Western North Atlantic Coastal Stock with a hypothesised habitat ranging from central Florida to New York (Scott *et al.*, 1988). However, recent genetic, stable isotope, telemetry and photo-identification studies have indicated a complex mixture of stocks, and the Western North Atlantic stock has been divided into seven management units (Waring *et al.*, 2002). Abundance estimates for each management unit were calculated from aerial survey data obtained in the winter and summer of 2002. Based on preliminary studies by Garrison *et al.* (2003), the abundance of dolphins occurring in the South Carolina management unit is approximately 2,300.

The categorisation of commercial fisheries is relative to an individual stock's PBR. For the South Carolina management unit, the PBR is set at 20 individual bottlenose dolphins (Palka, 2003). According to the categorisation scheme, Category I fisheries take at least 10 bottlenose dolphins each year incidental to fishing practices, whereas Category II fisheries collectively take at least 2.0 dolphins per year, or individually take 0.2 to 10 dolphins per year. Fisheries in South Carolina that are placed in the Category III listing, collectively take less than 2.0 dolphins, or individually take 0.2 dolphins or less per year.

Blue crab fishery in South Carolina

The blue crab fishery operates year-round, and is one of the largest commercial fisheries in South Carolina and the USA (Johnson *et al.*, 1998; Whitaker *et al.*, 1998). In South Carolina, the fishery typically ranks first in terms of weight landed and second in value (Whitaker *et al.*, 1998). The commonly used crab pot is a baited, two-foot cubed cage with four funnels through which crabs enter. Crab pots rest on the waterway's bottom and are connected to a buoy on the water's surface by a braided, sinking line, varying in length depending on the depth of placement. Although this fishery is year-round, the predominant fishing months in South Carolina estuarine waters are August to November (NMFS, 2003).

The goal of this study was to verify the categorisation of the Atlantic blue crab fishery, relative to marine mammal mortality, based on historic and current stranding data from South Carolina. Evidence from strandings and interviews with commercial crab fishers were used to validate the reclassification and quantify the interaction between bottlenose dolphins and the Atlantic blue crab fishery in South Carolina. This study provides an example of how the integration of stranding and interview data can be used to evaluate and verify management approaches designed to reduce the incidental mortality of marine mammals in commercial fisheries.

METHODS

General stranding record analysis

Analysis of historical stranding data began by sorting through the catalogued Marine Mammal Stranding Level A Data Report Forms (OMB No. 0648-0178) for all bottlenose dolphins suspected of fishery interaction in South Carolina. Pathology reports from the United States Armed Forces Institute of Pathology (USAFIP), and photo-documentation were also obtained for each of the suspected entanglement cases. Data obtained from the stranding, necropsy and pathology reports included stranding location and date, gross body condition, stranding event description, internal conditions and pathological signs of other sources of death. These data were compiled into summary tables and compared with entanglement evidence from 'confirmed' crab pot interactions to predict possible mortality sources. For this study, only animals with indications of fishery interaction such as rope abrasions, lacerated appendages, puncture wounds, net marks or internal pathologies associated with an acute death were considered in the analysis.

Photographs of each entanglement case were examined to note the location of the wounds along the dolphin's body, as well as wound patterns and dimensions. The widths of wounds in historical stranding records and photographs were noted and compared to a simulated wound study in which samples of rope varying in diameter were used to make impressions on the peduncle and dorsal fin of deceased dolphins in the laboratory. Samples of rope utilised by various fisheries were rubbed in a back and forth motion across the leading edge of the peduncle and dorsal fin in order to obtain an impression width associated with different diameters. The resulting widths were measured and recorded for each rope diameter, and then compared to the widths of wounds discovered on the entanglement cases.

Fisheries may be ruled out as potential entanglement sources based on the timing and location of fishing effort (Cox *et al.*, 1998). Temporal trends in total strandings and entanglements were identified on a yearly, monthly and seasonal basis. Months were divided into four seasons according to McFee and Hopkins-Murphy (2002) to observe trends during different times of the year. In addition, the geographic coordinate data from the stranding reports were used to view the spatial distribution of the fishery interaction cases in South Carolina.

Classification of fishery entanglement cases

A classification scheme was developed for the fishery entanglement cases based on the likelihood that the interaction was due to the blue crab fishery. The five classes included: (1) confirmed; (2) unconfirmed, probable; (3) unconfirmed, possible; (4) cannot be determined (CBD); and (5) other fishery. Stranded dolphins were classified as 'confirmed' (class 1) only if they were seen entangled in crab pot gear, or washed ashore with crab pot gear attached to the body. Dolphins with indications of rope marks on the body were typically placed into either the 'probable' or 'possible' category. The 'probable' entanglement cases (class 2) were distinguished from the 'possible' cases (class 3) based on the location of the entanglement wounds, the dimensions and patterns of entanglement wounds, internal body conditions and the geographic location of the entanglement cases. Dolphins placed in the 'CBD' category (class 4) had indications of fishery interaction such as net marks or lacerations, but because of decomposition or scavenging, the fishery that may have been responsible for the entanglement could not be determined. The 'other fishery' category (class 5) was created for entangled animals that had markings unrepresentative of the gear used by crab fishers, such as monofilament line and nets.

Table 1 outlines the criteria used to place animals in their respective categories, and Figure 1 depicts a flow chart that diagrams the steps used to classify the entanglements as 'confirmed', 'other fishery', 'probable' or 'possible'. Since the seasonality and location of commercial fisheries may fluctuate throughout the year, these parameters were also examined in relation to stranding events during the study period (see Fig. 2). Cox *et al.* (1998) noted that differences in fishing location and season relative to stranding date and location might narrow potential entanglement sources.

Fishery survey

A survey of blue crab fishers was conducted to gain fishers' perceptions of the degree of interaction between bottlenose dolphins and the blue crab fishery, as well as to determine if similar types of interaction seen in Florida's Indian River Lagoon (Noke and Odell, 2002) occur in South Carolina. Ten fishers, representing seven water bodies, were surveyed for this project. During these surveys, fishing practices and location, as well as the spatial overlap of the fishery and bottlenose dolphin habitat was noted during on-board interviews.

The names of commercially licensed blue crab fishers were obtained using guides, snowball sampling and convenience sampling techniques (Berg, 1989). Initial informants, or guides, provided contact information for other crab fishers in the Charleston area, thus snowballing the sampling list. In addition, local seafood stores and boat landings were visited to obtain further contact information for local crab fishers.

Most interviews occurred during fishing trips, but due to the unavailability of many crab fishers, a few were conducted by telephone. Semi-standardised interviews, or guided discussions, were conducted aboard fishing vessels, while specific survey questions were used for standardised telephone interviews (Berg, 1989). In several cases, the telephone interviews resulted in an offer to accompany the fisher during fishing trips.

Data obtained from the interviews were examined with content analysis, a technique to objectively identify data in text (Berg, 1989), to observe trends in fishing effort and gear, rate of crab pot loss and degree of interaction with bottlenose dolphins during fishing trips. Given that the crab fishers were not chosen at random and included a small sample size (n=10), statistical analysis of the results from interviews was not conducted.

RESULTS

Historic stranding analysis

From 1992-2003, a total of 440 bottlenose dolphin strandings were recorded in South Carolina. Of these 440 stranding events, the number of yearly strandings ranged from 28 in both 1992 and 2002, to 68 in 2001. The mean number of total strandings per year over the study period was 36.7 (SD±13.0). Over the 11-year period, most strandings occurred in the month of July (n=50), whereas the fewest strandings occurred in January and October (n=21). Seasonally, most bottlenose dolphin strandings in South Carolina occurred during spring (n=141), and the fewest in winter (n=89).

Approximately 10% (n=42) of the 440 bottlenose dolphin strandings showed evidence of fishery entanglement, as previously described. The number of fishery entanglements per year ranged from one (0.2% of total strandings) in 1994 and 2001, to 10 (2.3% of total strandings) in 1997. The mean number of entanglements each year between 1992 and 2003 was 3.5 (SD±2.5). The greatest number of entanglements (n=8, 19% of total entanglements) over the study period occurred in August, and fewest (n=1, 2.4% of total entanglements) in January and November. Most of the entanglements in South Carolina occurred during the summer (n=17, 40% of total) and the fewest entanglements occurred during autumn (n=5, 12% of total).

For the simulated wound study, the diameters of rope used for the tension tests ranged from 3/16 of an inch to 0.5 of an inch, with resulting wound widths ranging from 0.35cm to 1.60cm (Table 2). By knowing the widths of wounds seen on stranded carcasses, this study may help determine the diameter of rope by which the dolphin was entangled.

Table 1

Criteria used for classification of entanglements according to interaction with the blue crab fishery in South Carolina (1992-2003).

Classification	Criteria
Confirmed crab pot interaction	Stranded with gear, reported sighting with gear, freed from gear.
Unconfirmed, probable	Wounds and body condition very similar to confirmed cases (i.e. rope abrasions, stomach full of fish remains, robust body condition, froth in lungs and bronchi).
Unconfirmed, possible	Wounds and body condition similar to confirmed cases. Wounds may have resulted from other fishing practices and may not be characteristic of crab fishing gear (i.e. puncture wounds, lacerations, rope marks that may be post-mortem).
Cannot be determined (CBD), mutilation	Interaction with the crab fishery could not be determined. Animals showed signs of fishery interaction but carcass was too heavily mutilated or appendages were lost, preventing complete wound analysis.
Other fishery	Interaction with a fishery other than the crab fishery. Dolphins stranded with gear attached or showed evidence of entanglement not congruent with crab fishing gear (i.e. net hatch marks along body, monofilament lacerations).

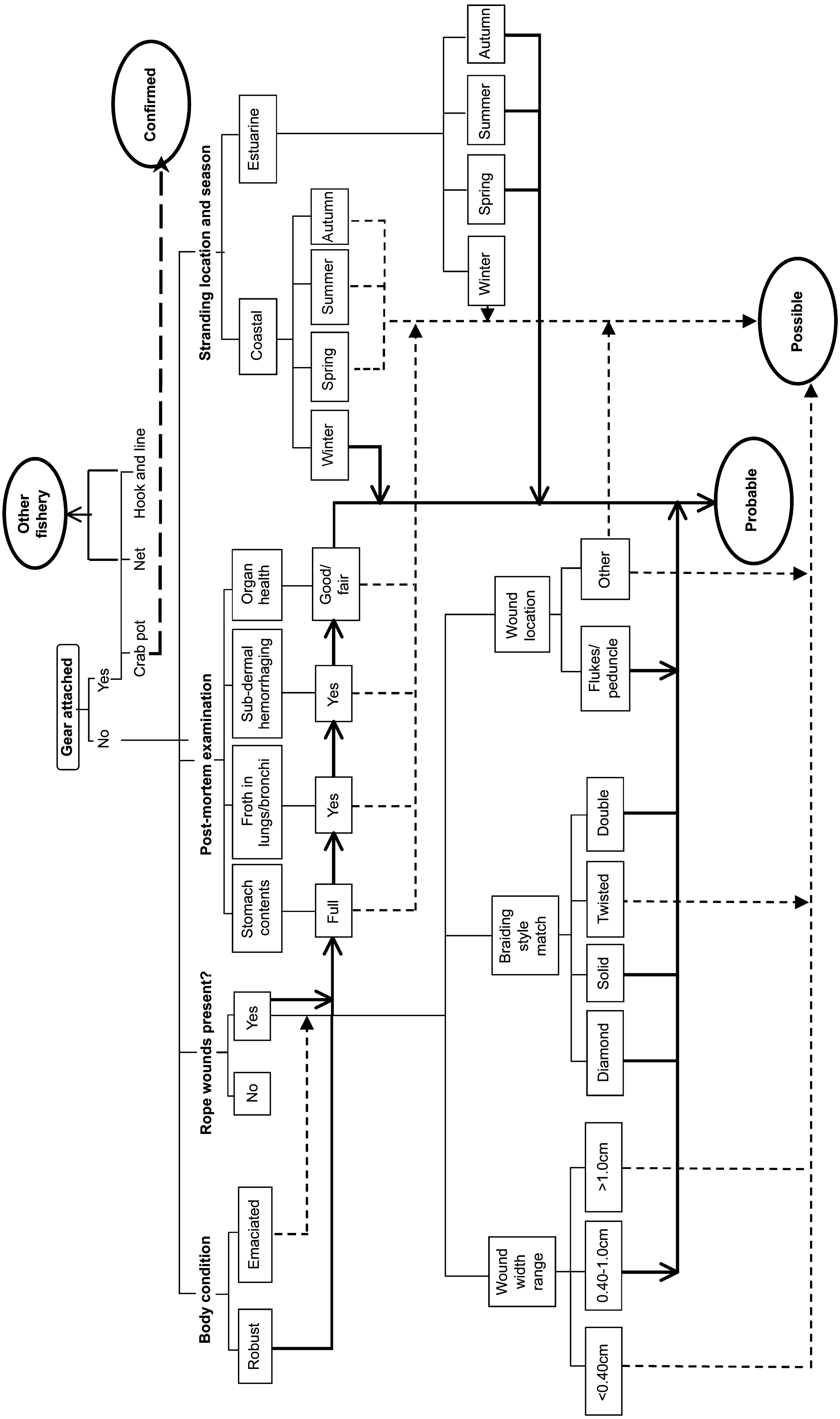

Fig. 1. Flow chart showing the classification process to distinguish ‘confirmed’, ‘probable’, ‘possible’ and ‘other fishery’ entanglements.

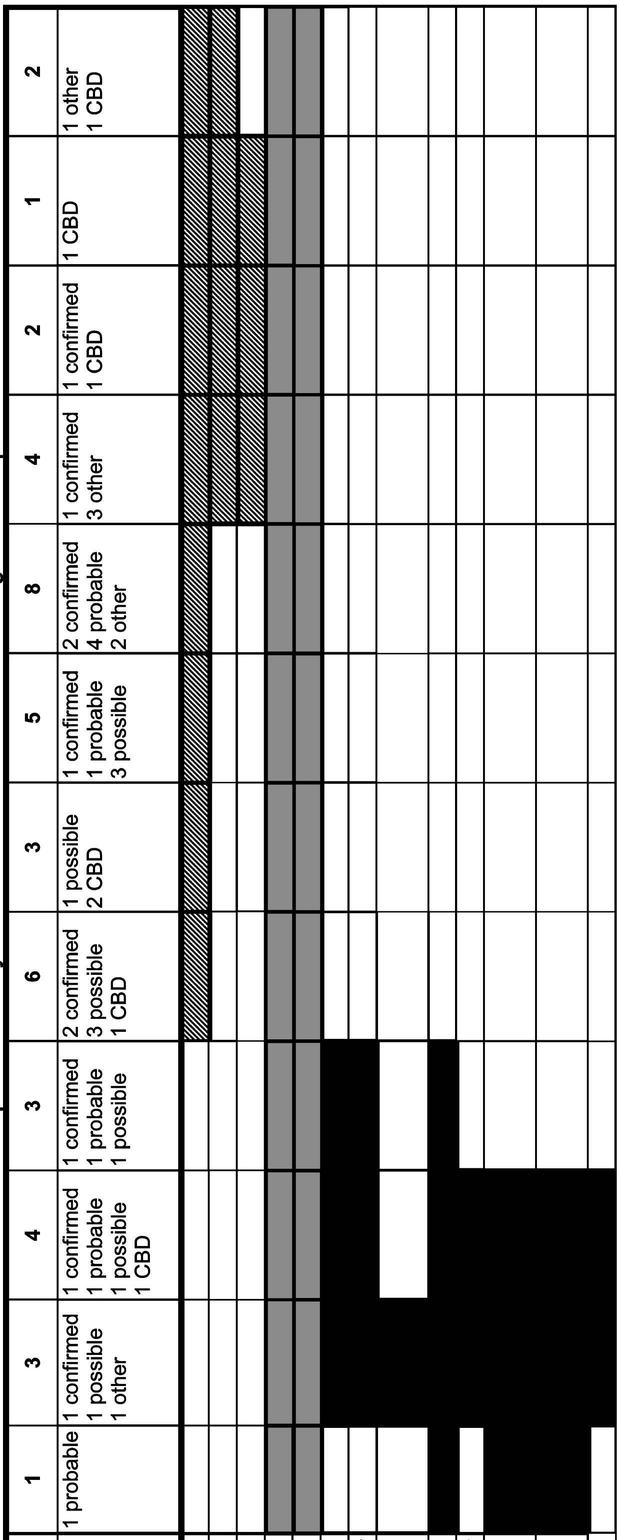

Fig. 2. Entanglements according to month and the seasonality of major commercial fisheries in South Carolina. Shaded regions are months in which fishing season operates.

Table 2

Rope diameter, location of applied tension, and wound width for each rope sample.

Rope diameter (in) and braiding style	Location of tension	Wound width (cm)	Average width
3/16 - solid	Peduncle	0.35	0.35
1/4 - diamond	Peduncle	0.4	
1/4 - solid	Peduncle	0.8	
1/4 - solid	Peduncle	0.75	
1/4 - loose hollow	Peduncle	0.8	
1/4 - loose hollow	Dorsal fin	0.75	0.7
9/32 - diamond	Peduncle	0.5	0.5
5/16 - diamond	Peduncle	0.6	
5/16 - solid	Peduncle	0.8	
5/16 - solid	Peduncle	0.95	
5/16 - double	Peduncle	1	
5/16 - pot warp	Dorsal fin	1	0.87
3/8 - solid	Peduncle	1.2	
3/8 - twisted	Peduncle	1.1	
3/8 - twisted	Peduncle	1.1	
3/8 - hollow	Peduncle	0.9	1.075
7/16 - double	Peduncle	1.2	
7/16 - double	Peduncle	1.25	1.225
1/2 - solid	Peduncle	1.6	
1/2 - twisted	Peduncle	1.3	1.45

Classification of bottlenose dolphin strandings

The 'confirmed' blue crab fishery entanglements constituted 23.8% (*n*=10) of total known entanglements since 1992 (Fig. 3). These dolphins were observed with gear attached to the body, or were freed from blue crab fishing gear. Generally, these animals were robust and healthy, and showed internal evidence of fishery interaction such as a stomach full of fish remains and foam in the lungs and bronchi, indicating asphyxiation. Stomachs full of fish remains may indicate fishery interaction as some theories suggest that marine mammals may actively forage in the presence of fishing gear or follow fisheries as they feed on discarded bait and manipulate gear to obtain food (Fertl and Leatherwood, 1997; Noke and Odell, 2002). In addition, the 'confirmed' cases often had approximately 1cm wide, haemorrhagic rope wounds located around the base of the flukes and occasionally on other parts of the body (Figs 4 and 5).

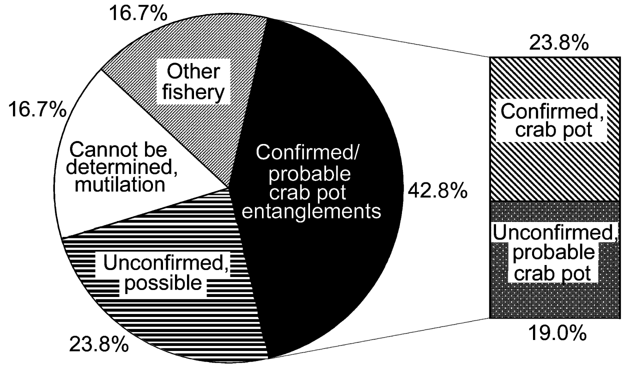

Fig. 3. Status of bottlenose dolphins entangled in the Atlantic blue crab fishery in South Carolina (1992-2003).

The ‘probable’ cases included 19% (n=8) of the total, and showed evidence of entanglement very similar to the ‘confirmed’ cases such as wound location pattern (e.g. around the base of the flukes), as well as a robust body, full stomach and foam in the lungs. However, because the animals did not have physical evidence of interaction with a crab pot (e.g. stranded with gear), these cases were considered probable crab pot entanglements.

Ten of the entanglements (23.8% of total) since 1992 were classified as ‘possible’ blue crab fishery interactions. These animals had evidence of entanglement similar to the ‘confirmed’ cases, but the entanglement indications could have resulted from other fisheries. Evidence of entanglement for the ‘possible’ cases included puncture wounds, lacerations and rope wounds that may have been post-mortem.

For the seven animals (16.7% of total entanglements) placed in the ‘CBD’ category, interaction with the blue crab fishery could not be determined. These animals had indications of human interaction, such as rope or net markings and amputated appendages, but often the carcass was too heavily decomposed for proper wound analysis.

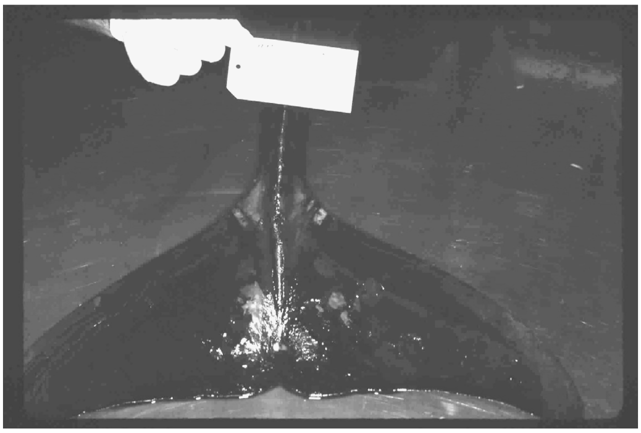

Fig. 4. Rope wounds for confirmed crab pot interaction (SC9731).

Fig. 5. Rope wounds on flukes of a confirmed crab pot entanglement (MMES2003089SC).

Bottlenose dolphins that were entangled in a fishery other than the blue crab fishery constituted 16.7% (n=7) of total entanglements. Evidence of entanglement for bottlenose dolphins grouped in this category included the attachment of fishing gear uncommon to the blue crab fishery, or external evidence incongruent with the ‘confirmed’ cases such as net hatch marks along the body or monofilament lacerations.

Table 3 summarises the reasons for the classification of each entanglement, and details the sex, length and location of the entanglement cases. According to the archived data, approximately 43% of the 42 entanglements in South Carolina from 1992-2003 were definitely or probably due to the blue crab fishery.

Fishery survey results

A total of 46.6 hours was spent in the field from May 2002 to February 2003. Ten different blue crab fishers were interviewed for this study aboard fishing vessels and via telephone, representing seven different water bodies. Twelve fishing trips were taken, and four telephone interviews were conducted.

The crab fishers surveyed typically place 50-190 pots in their fishing areas at one time. Several fishers mentioned that the numbers of pots set at a given time fluctuates with weather parameters and catch rate, as does the frequency with which they check their pots. Regulations require that crab fishers check their pots every five days (South Carolina Department of Natural Resources (SCDNR), 2001); therefore, pot replenishment ranges from once a week to every day. These crab fishers generally used two different rope diameters (1/4 of an inch and 5/16 of an inch) and fishing lines ranging from 30-85ft in length. Fishing line occurs in a variety of braiding styles; however, the crab fishers interviewed typically used diamond, solid and double braid. Menhaden (*Brevoortia tyrannus)* is the primary bait used in the fishery, and gear modifications to improve fishing efficacy included different coloured wire on parts of the pot, and heavy irons on the bottom of pots to prevent them from moving with currents.

The crab fishers reported an annual pot loss of as few as 20 pots to as many as 200. Reasons commonly given for such loss included theft, fast currents associated with spring tides, and boat traffic that cuts off buoys. Suggestions to reduce pot loss included stricter law enforcement of crab pot theft and vandalism, reducing competition among crab fishers, and decreased boat traffic in areas outside the main channels of waterways.

Dolphins were seen on 11 of 12 fishing trips, and group size ranged from one to four. The behaviour of dolphins during fishing operations included mill, close approach and travel (Irvine *et al.*, 1981; Noke and Odell, 2002). During fishing trips conducted for this study, the close approach behaviour was seen only once.

The types of interaction between bottlenose dolphins and the blue crab fishery that have been documented by Noke and Odell (2002) in the Indian River Lagoon were not reported by fishers in the Charleston area. An indication of dolphin interaction with the crab fishery in Florida included pots that were missing both bait and crabs (Noke and Odell, 2002). The crab fishers in this study stated that pots are sometimes retrieved absent of bait and crabs; however, they feel that the likely cause is theft by humans rather than dolphin interaction. While most crab fishers regularly see dolphins during fishing practices (75-100% of the time), they did not indicate that dolphins impede fishing progress or vice versa. Most of the fishers interviewed stated that dolphins occasionally approach the fishing vessel begging for food, and several admitted to feeding dolphins despite the prospect of a fine. Two of the crab fishers interviewed

Table 3

Classification, location, date, sex and length of bottlenose dolphin fishery interaction cases in South Carolina (1992-2003).

Field No.	Date	Location	Sex	Length	Classification	Criteria for classification
SC9202	6-Feb-92	Beaufort Co.	-	-	Confirmed	Crab pot line and buoy around flukes.
SC9206	12-Mar-92	Charleston Co.	-	-	CBD	Poor body condition; knife slice marks along body.
SC9212	20-May-92	Charleston Co.	-	242	Confirmed	Crab pot rope and float wrapped around tail.
SC9215	25-May-92	Beaufort Co.	-	218	Possible	Flukes entangled in yellow rope; line marks on peduncle.
SC9326	8-Jul-93	Beaufort Co.	F	227	Possible	Puncture wound between flippers; haemorrhagic lung.
SC9337	17-Nov-93	Horry Co.	F	210	CBD	81cm mid-ventral slit; puncture wounds.
SC9408	16-Mar-94	Beaufort Co.	F	230	Possible	Puncture wound; clean cut fish in esophagus; stomach mostly full.
SC9503	7-Feb-95	Horry Co.	F	250	Other	Parallel lacerations on flipper; haemorrhagic lung.
SC9509	5-Apr-95	Charleston Co.	M	264	Probable	3cm wide line marks on peduncle and edges of flukes; full stomach; haemorrhagic lungs.
SC9608	14-Mar-96	Beaufort Co.	M	145	Probable	Line marks at base of flukes and epidermis rubbed off; haemorrhagic lungs.
SC9611	8-Apr-96	Colleton Co.	F	265	Possible	Rope marks at base of flukes; internal data unavailable.
SC9628	18-Jun-96	Colleton Co.	M	262	CBD	Poor body condition; flukes amputated; full stomach.
SC9631	28-Aug-96	Colleton Co.	M	166	Probable	Rope marks on tail; full stomach.
-	16-Sep-96	Beaufort Co.	-	-	Confirmed	Dolphin disentangled from crab pot.
SC9636	22-Sep-96	Georgetown Co.	M	149	Other	Dolphin stranded entangled in gillnet.
SC9725	18-May-97	Charleston Co.	F	111	Possible	Tooth rake or net marks on dorsal fin; line marks on peduncle; haemorrhagic lungs; full stomach.
SC9726	1-Jun-97	Charleston Co.	M	145	Possible	Line marks on side of body; full stomach.
SC9730	23-Jun-97	Beaufort Co.	-	225	CBD	Poor body condition; flukes amputated; heavily scavenged.
SC9731	2-Jul-97	Charleston Co.	M	192	Confirmed	Dolphin retrieved from crab pot; rope marks (1.5cm wide) at base of peduncle; haemorrhagic lung; full stomach; good body condition.
SC9732	4-Jul-97	Colleton Co.	M	211	Probable	Rope marks around base of flukes and peduncle.
SC9733	9-Jul-97	Beaufort Co.	F	122	Possible	Rope marks at base of penducle (maybe post-mortem); empty stomach.
SC9734	2-Aug-97	Charleston Co.	-	-	Confirmed	Dolphin released from crab pot.
SC9735	10-Aug-97	Charleston Co.	F	238	Probable	Good body condition; rope marks (1cm wide) around peduncle and flukes; haemorrhagic lungs; full stomach.
SC9737	24-Aug-97	Colleton Co.	M	263	Probable	Rope marks (1cm wide) round peduncle; haemorrhagic lungs; partially full stomach.
SC9759	11-Dec-97	Georgetown Co.	M	195	CBD	Decapitated; dorsal fin and half of fluke cleanly cut off.
SC9804	13-Jan-98	Charleston Co.	F	176	Probable	Line marks (1cm wide) on flukes, peduncles; haemorrhagic lungs; full stomach.
SC9826	28-May-98	Charleston Co.	M	248	Possible	Line marks on side of body; left fluke cleanly cut off; haemorrhagic lungs.
SC9835	4-Jul-98	Charleston Co.	M	221	Possible	Line marks near flipper and around body; haemorrhagic lung; full stomach.
SC9846	2-Sep-98	Charleston Co.	-	-	Other	Net marks covering body.
-	27-Mar-99	Charleston Co.	-	-	Confirmed	Dolphin disentangled from crab pot.
SC9913	21-Apr-99	Beaufort Co.	F	243	Confirmed	Dolphin found dead entangled in crab pot; line marks (0.99-1.0cm wide) at base of flukes; haemorrhagic lungs.
SC9916	13-May-99	Charleston Co.	M	200	CBD	Peduncle cut off posterior to anal slit.
SC0006	25-Feb-00	Charleston Co.	F	203	Possible	Braided rope around rostrum; haemorrhagic lung.
SC0045	28-Sep-00	Beaufort Co.	F	239	Other	Hook found at base of tongue and monofilament line was wrapped around goosebeak.
-	16-Oct-00	Charleston Co.	-	-	Confirmed	Dolphin released from two crab pots.
SC0165	22-Oct-01	Beaufort Co.	M	180+	CBD	Tail and right flipper cut off.
SC0223	22-Aug-02	Berkeley Co.	F	201	Other	Dolphin entangled in trammel net.
SC0224	23-Aug-02	Beaufort Co.	F	152	Other	Dolphin entangled in lazy line of shrimp boat.
SC0236	11-Dec-02	Charleston Co.	F	229	Other	Net impressions on dorsal fin, fluke, and flipper.
SC0314	3-May-03	Charleston Co.	M	~250	Confirmed	Dolphin disentangled from crab pot.
SC0322	17-Aug-03	Charleston Co.	M	175	Confirmed	Dolphin died from entanglement in crab pot; haemorrhagic lungs; full stomach.
SC0323	21-Aug-03	Charleston Co.	M	261	Probable	Line marks on fluke (0.6cm wide) and dorsal ridge of fluke (1.4cm).

reported that dolphins had been entangled in their gear in the past; however, the animals were freed from fishing gear and subsequently swam away.

DISCUSSION

The use of stranding data to predict mortality

Stranding data provide critical information about the causes of marine mammal mortality. Investigation of stranded marine mammals may reveal indications of fishery interaction such as rope abrasions and net marks, or evidence of other types of human interaction such as boat strike wounds or dismemberment (Cox *et al.*, 1998; Read and Murray, 2000; Friedlaender *et al.*, 2001; McFee and Hopkins-Murphy, 2002). Necropsies of stranded animals may provide additional evidence of asphyxiation consistent with entanglement, such as froth in the lungs, or may provide pathological evidence of alternative sources of mortality such as disease.

Stranding data, however, underestimate total mortality. Not every animal that dies reaches shore, and not every animal that strands is discovered. In addition, incidental mortality in fisheries may be further underestimated because not every marine mammal that interacts with a fishery strands, and not every fishery-related stranding shows definitive evidence of entanglement (Cox *et al.*, 1998). The conclusions derived from this study, therefore, are based solely on available stranding data, and likely represent an underestimate of fishery-related mortality of bottlenose dolphins in South Carolina.

Classification

Stranding data showed that approximately 43% (n=18) of the bottlenose dolphin entanglements in South Carolina from 1992-2003 were either ‘confirmed’ or ‘probable’ crab pot entanglements, indicating that the blue crab fishery is a substantial source of mortality for bottlenose dolphins in South Carolina.

The classification of the 'confirmed' cases depended on physical evidence of interaction with the blue crab fishery. Five bottlenose dolphins (50% of all 'confirmed' cases) stranded with crab fishing gear attached to the carcass, including crab pot line and a buoy. Other animals in this category were either sighted with blue crab fishing gear attached to the body, or were freed from gear. In May 2003, a bottlenose dolphin was successfully disentangled from a crab pot line in an estuary near Morris Island, South Carolina (32°44'064N, 79°53'378W). The dolphin was entangled around the flukes, where the line was wrapped tightly three to four times. Continuing to breathe, the dolphin was held at the water's surface by the taut fishing line, and the animal's disposition was calm. In August 2003, this dolphin was captured during a capture-release project, and the dolphin seemed to be healthy, with healed entanglement wounds. The dimensions of the healed wounds from this previously entangled dolphin were compatible with the 'confirmed' cases documented by historic stranding reports. Crab pot line was wrapped around the base of the flukes, leaving wounds that were approximately 1cm in width. The rope was approximately 5/16 of an inch in diameter, corresponding with the fishery survey data. The wounds on this dolphin emphasised the importance of the simulated wound study. Different diameters of rope will leave wound impressions of varying widths; therefore, it is possible to measure the width of wounds on entangled animals and associate them with a particular rope diameter. The data obtained from the live entanglement reinforced the criteria that were used to classify the historic entanglement cases.

Distinguishing between the 'probable' and 'possible' cases was less obvious. The pictures, stranding reports and necropsy notes for the 'confirmed' cases were used as models for the placement of the other entanglement cases in their respective categories. In addition, the fisher interview data revealed that two diameters of rope are primarily used in the fishery, so knowing the widths of wounds that are created by these ropes may help to further distinguish between 'probable' and 'possible' entanglement cases. For example, one dolphin was classified as a 'probable' entanglement because of 1cm wide rope marks around the base of the peduncle and flukes, foam in the bronchi, a stomach full of fish and shrimp, and sub-dermal haemorrhaging at the site of the wound. These were indications of entanglement that were present in several of the 'confirmed' cases; however, it could not be classified as 'confirmed' because the gear was not attached to the animal.

Entanglements were categorised as 'possible' when the evidence of entanglement could have resulted from interaction with a fishery other than the blue crab fishery, or if the animal had wounds that may have occurred post-mortem. For example, one dolphin had a puncture wound and a partially severed pectoral flipper that could have resulted from contact with blue crab fishing gear, but could also be due to the gear of other fisheries. Another example of an animal placed in the 'possible' category had wounds that appeared to be post-mortem, as the rope marks could have resulted from line used to transport the animal for proper stranding response.

In many cases it appeared that there was an overlap of criteria used to classify the entanglement cases. There may have been animals placed in the 'probable' category that had similar entanglement evidence as the 'possible' cases; however, classification relied on a suite of criteria such as stomach content analysis, wound dimensions and locations, and internal indications of an acute death. The flow chart (Fig. 1) that was developed during the course of this study aided in determining 'probable' versus 'possible' victims of crab pot entanglement.

Fisheries may be ruled out as potential entanglement sources if the stranding occurred in a location that is not utilised by a particular fishery, or during a time that is not in season for that fishery. Generally, the confirmed entanglements occurred throughout the year, in the southern portion of the state, and often in the upper reaches of the estuaries. The blue crab fishery operates year-round and most crab pots are placed in estuarine areas. During peak times of entanglement (May, July and August), only the blue crab and the shrimp fishery are highly active (Fig. 2). Other large fisheries, such as the coastal ocean shad fishery, appear to have minimal impact on local dolphin populations (McFee *et al.*, 1996), but were considered in the classification. The shad fishery occurs between January and April, whereas the shrimp fishery occurs during the months from May through December. Even though an entanglement may occur during active fishing times, the location of the entanglement may be in an inactive fishing area. The 'probable' entanglements were examined in relation to the location and timing of the shad and shrimp fisheries. For example, three 'probable' entanglements occurred during active shad fishing times; however, only one case could possibly be a result of interaction with the fishery because of the stranding location. There were four 'probable' entanglements during the active shrimp trawl season; however, more data on the location of trawling activities are required before entanglements due to the shrimp fishery can be concluded. The classification of 'probable' entanglements is supported when the strandings occurred in areas that are not occupied by these other fisheries, and during times outside of the fishing seasons. Based on these results, location and seasonality may be contributing factors that would place an entanglement in the 'probable' rather than 'possible' category.

Fishery survey

When questioned on their perceptions of the interaction between their own fishery and bottlenose dolphins, crab fishers indicated that the interaction was minimal and not damaging to either group. Most fishers commented that they see dolphins almost every day, but that the dolphins and the fishery are independent of each other. Several crab fishers stated that sea turtles pose a greater risk to the fishery and fishing gear than dolphins.

Observations in the Charleston area did not provide evidence that bottlenose dolphins interact with the blue crab fishery as reported in Florida. According to Noke and Odell (2002), indicators of crab pot interaction in Florida included a close approach of a dolphin to the fishing vessel, a bait well door that had been pried open and the actual observation of dolphins manipulating pots. Of these indicators, the only one observed in this study was the close approach behaviour. Although several crab fishers commented that dolphins regularly approach their boat to beg for food, this behaviour was seen only once during fishing trips. The dolphin followed the boat closely while the fisher checked the crab pots, begging at the side of the boat where the pots were retrieved and replenished. Occasionally, the crab fisher reinforced the close approach behaviour by offering food.

Little is known about the mechanism of entanglement. Studies by Fertl and Leatherwood (1997) suggested that marine mammals become entangled in fishing gear because they actively feed near fishing operations and the dolphins in Florida actively manipulate crab pots to retrieve bait (Noke and Odell, 2002); however, this does not appear to be the case with the blue crab fishery in South Carolina. According to the fishers interviewed for this study, bottlenose dolphins in South Carolina are attracted to fishing vessels and regularly beg for food, but have not been observed 'tipping' crab pots.

Management issues

Recently, PBR for the South Carolina management unit was changed from 24 to 20 (Palka, 2003). Insignificant levels are approximated at less than 10% of PBR (Barlow *et al.*, 1995); therefore, insignificant mortality and serious injury for the South Carolina management unit would be less than 2 dolphins per year. Based on results from this study, there would be only 2 years (1994 and 2001) where incidental mortality and serious injury levels would be considered insignificant according to the MMPA.

In South Carolina, fisheries are classified as Category I if incidental take rates equal or exceed 10 bottlenose dolphins per year. Although there were 10 entanglements in 1997, the mortalities cannot be attributed to a single fishery. Based on this analysis of historical stranding data, there has not been a fishery that would qualify for a Category I listing in South Carolina.

The Atlantic blue crab fishery was recently re-categorised as a Category II fishery, which means that the number of entanglements in the South Carolina blue crab fishery must range from 0.2 to 10 dolphins annually. Based on the 'confirmed' blue crab fishery entanglements and the new PBR for the South Carolina management unit, the blue crab fishery has exceeded 1% of PBR for six of the 12 years studied. PBR is reviewed every eight years, resulting in a PBR of 20 for the South Carolina management unit until 2011. The categorisation of fisheries is based on a five-year running average of the number of entanglements in particular fisheries. In order for the blue crab fishery to be removed from a Category II classification, there must be a five-year average of entanglements that does not exceed 0.2 dolphins based on the PBR of 20. According to the results from this study in South Carolina, the five-year average (1999-2003) of bottlenose dolphin entanglements in the blue crab fishery is 0.6 per year, exceeding the threshold classification as a Category II fishery.

Recommendations

Accurate stranding records as well as comprehensive and clear photographic evidence of entanglements are essential in classification. Stranding reports and photographs must be accurate and detailed to provide sufficient criteria for classification. In this study, external evidence of entanglement was not always clearly photographed or documented with a scale for measurement, and the descriptions of wounds on the stranding reports were not consistently specific enough to classify an entanglement. In the future, stranding response personnel should have sufficient training that will ensure descriptive stranding reports and illustrative photographs.

Interviews aboard vessels are critical in obtaining accurate data on incidental mortality because under-reporting by fishers is suspected (Lopez *et al.*, 2003). Not all fishers report incidental takes of marine mammals during fishing practices. Fishers may be unaware of the time limit to report incidental takes, or they may be apprehensive to report an entanglement for fear of heightened regulation or individual reprimand. Public outreach should be improved to assure fishers that there are no legal ramifications for reporting, unless fishing illegally at the time. Fishers must also be convinced that reporting incidental mortality will not lead to a negative image of the fishery (Lopez *et al.*, 2003) or heightened regulations under the MMPA. Greater educational efforts should be made to clarify the penalties for neglecting to report an entanglement, as well as emphasise the importance of fishery-dependent data to estimate incidental marine mammal mortality in commercial fisheries.

Stranding data alone cannot accurately account for the degree of marine mammal interaction with fisheries. Trained observers aboard fishing vessels provide a quantitative estimate of the bycatch rates in large-scale fisheries (Cox *et al.*, 1998); however, for smaller fisheries, increased observer coverage may not necessarily provide more accurate mortality and interaction data. Observations aboard blue crab fishing vessels in the Indian River Lagoon were beneficial to document and describe the interaction with bottlenose dolphins, as they were seen manipulating crab pots there during fishing operations (Noke and Odell, 2002). In South Carolina, however, observer coverage may not be as beneficial because dolphins have not been observed tipping crab pots to steal bait. Data from the interviews with crab fishers indicate that there is minimal interaction between bottlenose dolphins and the fishery during fishing practices. The only clear indication that dolphins interact with the fishery is evidence from stranding events. In addition, the large number of commercial licenses that are issued annually, lengthy fishing season, and fluidity of the fishery may decrease the efficacy of observer coverage.

The PBR for the South Carolina management unit (20) has been calculated according to the best available data; however, this estimate may include both estuarine and coastal dolphins (Garrison, 2002). Management problems may arise for fisheries that exist in coastal areas but not in estuarine areas, and vice versa. As a result, fisheries that are not actually responsible for the incidental mortality of bottlenose dolphins may be subject to unnecessary regulations because bottlenose dolphins are combined into one management unit. Combining coastal and estuarine units may also provide an overestimate for PBR, further increasing regulatory difficulties. Because more data on residency patterns, genetic variability and behavioural differences among dolphins in South Carolina are needed before these animals can be divided into coastal and estuarine stocks, increased effort in photo-identification and genetic biopsies should be encouraged.

CONCLUSIONS

As methods to survey and identify marine mammal populations improve (i.e. aerial surveys, biopsies, photo-identification), abundance estimates improve also. The PBR for individual marine mammal populations is determined by the status of the stock, as is the categorisation of commercial fisheries that interact with marine mammals. As efforts to measure and estimate marine mammal populations continue to progress, management schemes to prevent the depletion of such populations become more effective.

The Atlantic blue crab fishery was re-categorised as a Category II fishery as a result of an increase in the number of entanglements documented by strandings data (W. McFee, pers. comm., 2003). According to the entanglement data for South Carolina from 1992-2003 (n=42), the blue crab fishery has taken bottlenose dolphins incidental to fishing practices at a rate that classifies their interaction as 'occasional' under the MMPA. The number of incidental takes of bottlenose dolphins in the blue crab fishery is not insignificant and is not progressing toward ZMRG; therefore, the Category II classification is justified.

ACKNOWLEDGEMENTS

We would like to begin by thanking the South Carolina blue crab fishers for their assistance with interviews and providing essential information on the interaction between their fishery and bottlenose dolphins. Also, the stranding records, necropsy reports and photographs would not exist without the committed efforts of the South Carolina stranding network volunteers and the South Carolina Department of Natural Resources. We also thank Rocky Mount Cord Co., Wellington Leisure Products, and the National Marine Fisheries Service (SERO office) for donating rope samples used in this study. Finally, we greatly appreciate the helpful comments and advice received from P. Becker, P. Fair, L. Schwacke, Z. Hart and two anonymous reviewers on earlier drafts of this paper.

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