Characterising an interaction between coastal bottlenose dolphins (*Tursiops truncatus*) and the spot gillnet fishery in southeastern North Carolina, USA

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ABSTRACT

The aim of this study was to characterise interactions between coastal bottlenose dolphins (*Tursiops truncatus* Montagu, 1821), and the autumn gillnet fishery in southeastern North Carolina, USA that targets spot (*Leiostomus xanthurus*). Beach based (conducted from April 1997 - January 1998) and aerial surveys (conducted from July 1998 - May 1999) were used to estimate the abundance of dolphins and gillnets in nearshore waters. Commercial spot landings records from Brunswick County, North Carolina were used as an index of prey abundance. Stranded bottlenose dolphins were evaluated using protocols developed to describe diagnostic evidence of human-induced fisheries mortality. During both survey periods, dolphin numbers, gillnet numbers and spot landings all peaked in October-November. Simultaneously, an increase in dolphin strandings bearing evidence of entanglement in gillnets (cuts, lacerations, or wrapping marks on their appendages) was observed. Four stranded dolphins were determined to have been killed in gillnets, and one dolphin was removed alive from a gillnet in October 1997. Six stranded dolphins were killed in gillnets in October and November 1998. Thus, 20-24% of the annual allowable human-induced mortality for all USA Atlantic coastal bottlenose dolphins could be attributed to monofilament gillnets targeting spot in October and November in southeastern North Carolina. Both recreational and commercial fishermen target spot in the autumn using gillnets and dolphin mortality may be attributable to both aspects of the fishery. Results of this study are cause for alarm because interactions between dolphins and coastal gillnets may be occurring at much larger spatial and temporal scales along the USA Atlantic coast. Understanding the relationships between the biological and anthropogenic variables leading to these interactions can facilitate conservative, pro-active, management ensuring that human-induced mortality is not negatively impacting populations of marine mammals, such as Atlantic coastal bottlenose dolphins.

KEYWORDS: BOTTLENOSE DOLPHIN; CONSERVATION; FISHERIES; GILLNETS; INCIDENTAL MORTALITY; FOOD/PREY; STRANDINGS; BYCATCH

INTRODUCTION

The spatial and temporal distributions of cetaceans are thought to be influenced, at least in part, by those of their prey (Wells *et al.*, 1980; Gaskin, 1982; Evans, 1987; Barros and Wells, 1998; Barco *et al.*, 1999). In southeastern North Carolina, USA commercial and recreational fishermen target spot (*Leiostomus xanthurus*) and other sciaenid fishes with monofilament gillnets (Philips *et al.*, 1989). Fishing effort (University of North Carolina at Wilmington, UNCW, aerial and beach based survey programme) and landings (North Carolina Department of Marine Fisheries, NCDMF, Wilmington, NC) peak in October and November. Concurrently, both the number of common bottlenose dolphins (*Tursiops truncatus* Montagu, 1821) sighted in near-shore, coastal waters and stranded dolphins on local beaches increase (UNCW Marine Mammal Stranding Network). Because spot and other sciaenid fish are major components of the diet of bottlenose dolphins (Barros and Odell, 1990; Mead and Potter, 1990) and are targets of a significant fishery (Philips *et al.*, 1989), interactions exist between bottlenose dolphins and the fishery.

Entanglement in fishing gear is the most common anthropogenic source of mortality for small cetaceans (Bjørge *et al.*, 1994; IWC, 1994; Read, 1994; Forney *et al.*, 1999; Hill and DeMaster, 1999; Waring *et al.*, 1999; Read and Murray, 2000). Bottlenose dolphins in the southeastern USA are known to be killed incidentally in shrimp trawls and menhaden seine fisheries (Reynolds, 1986), stop net and coastal gillnet fisheries in North Carolina (Padgett, 1995; NC stranding network) and Florida (Wells and Scott, 1994); the Virginia/North Carolina haul seine fishery; the southeast USA Atlantic shark gillnet fishery (NMFS, In review); and recreational fishing gear in Florida (Gorzelany, 1998; Wells *et al.*, 1998).

Since programmes to directly and systematically observe fisheries (targeted observer programmes) have only recently begun in southeastern North Carolina, it is difficult to estimate the magnitude of incidental mortality of Atlantic bottlenose dolphins in commercial fisheries (NMFS, In review). However, stranding records from 1993-1997 from Virginia to Florida suggest that each year, the number of bottlenose dolphins with evidence of human interaction as a cause of death approaches or exceeds the maximum annual take (i.e. human induced mortality) allowed under the USA Marine Mammal Protection Act (Potential Biological Removal, PBR; Waring *et al.*, 1999). For example, Waring *et al.* (1999) noted that

> ‘in 1997, 127 bottlenose dolphins stranded in North Carolina. Cause of death could be determined for only 58 of these animals, and of these 36 (62.1%) exhibited positive signs of fisheries interactions. If this percentage is consistent for all North Carolina stranded animals, it is possible that approximately 78 (62%) of the stranded animals died from human interactions in 1997’.

Therefore, PBR for coastal bottlenose dolphins along the USA Atlantic coast, which is currently set at 25 individuals (Waring *et al.*, 1999), may be exceeded by as much as three-fold in North Carolina waters alone.

Quantifying human-induced mortality, and associating it with specific fishing operations, is important for the conservation of coastal bottlenose dolphins. The goal of this study was to characterise such an interaction between dolphins and the spot gillnet fishery along the southeastern North Carolina coast. This characterisation requires

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quantitative data on the spatial and temporal patterns of: (1) dolphin mortalities attributable to gillnets targeting spot; (2) dolphin sightings; (3) gillnets; and (4) prey availability.

MATERIALS AND METHODS

Stranding records from the UNCW Marine Mammal Stranding Programme were used to describe the seasonality and magnitude of human-induced mortality in bottlenose dolphins from southeastern North Carolina. Dolphin strandings were used as an index of mortality, because almost all dolphins that become entangled in gillnets exhibit diagnostic lacerations, cuts, or indentations from net material (Read and Murray, 2000). Paramount to this aspect of the study is the effort and ability of stranding personnel to investigate each stranding and employ specific protocols to evaluate dolphins for evidence of mortality due to human interactions (Haley and Read, 1993). Seasonal numbers of bottlenose dolphins and gillnets were collected during two separate surveys: beach based (conducted from April 1997 - January 1998) and aerial (conducted from July 1998 - May 1999). Commercial gillnet landings from Brunswick County, North Carolina, were used as a proxy for spot abundance.

Beach based surveys

Weekly surveys, covering beaches and coastal waters to approximately one kilometre offshore (i.e. line of sight), were conducted from April 1997 through January 1998 along Sunset, Ocean Isle, Holden, and Long Beaches in Brunswick County, North Carolina (Fig. 1). Survey days and times were chosen primarily based upon weather conditions, and varied from week to week. These discontinuous surveys were carried out by driving to a series of public beach access sites that were spaced approximately 1km apart along the coast. Between one and three observers were used to survey the area. In order to view all of the beaches and coastal waters from the southwestern end of Sunset Beach to the northeastern end of Long Beach, binoculars were used when the distance between sites was too great to cover with the naked eye. The amount of time spent at each site varied with the amount of data being collected, but averaged five minutes. The time to drive from one observation site to the next ranged between 1-5 minutes. However, when transiting from one beach to the next, transit time took between 10-30 minutes. Surveys were conducted in Beaufort Sea States (BSS) less than 4. The data collected from these surveys included: time, geographic position (using Garmin 12XL hand-held GPS units), environmental conditions (sea state, weather, visibility) and marine mammal sightings (species and number of animals). Observations regarding fishing activity (e.g. number and type of gear, number of vessels actively fishing, observed haul backs of gear) included information on gear identification. Gillnets were identified by yellow (or yellow and pink) floats (NC Marine Fisheries regulations) and/or high-flier flags that were separated by distances appropriate for net lengths used in the region. Single floats, which could not be determined to be associated with another float were not counted as gillnets.

Aerial surveys

Weekly aerial surveys were conducted from July 1998 through May 1999 along the coastal and near-shore waters of North Carolina. As with beach based surveys, the day and timing of surveys were mostly dependant on weather conditions. For this study, only data from southeastern North Carolina were used, which included Sunset, Ocean Isle, Holden, and Long Beaches, as well as Bald Head Island (Fig. 1). Continuous surveys were flown in Cessna 172 single-engine airplanes at an altitude of 225 meters, at 145-160km/hour, approximately one kilometre offshore, in BSS less than 4. The team included a pilot, data recorder and one observer on either side of the plane. The data collected from this effort include environmental conditions (sea state,

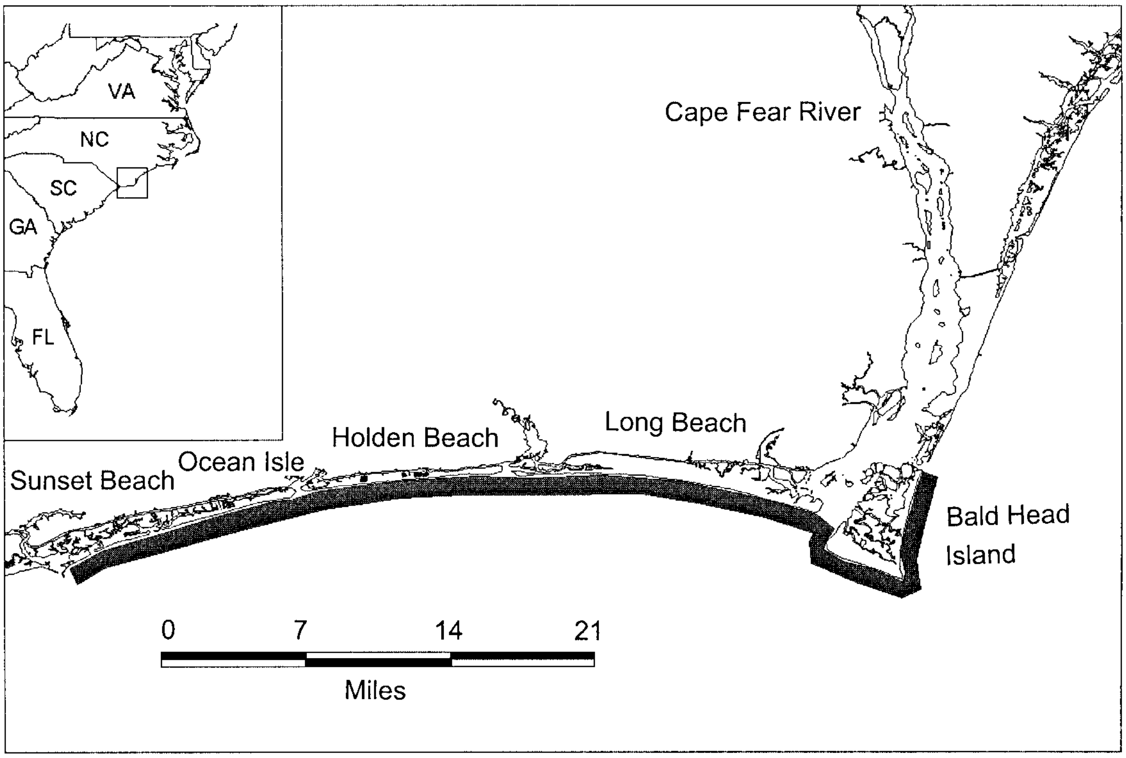

Fig. 1. Study site for beach based and aerial surveys in southeastern North Carolina including Brunswick County (Sunset Beach, Ocean Isle, Holden Beach and Long Beach) and Bald Head Island. Shaded area represents waters surveyed.

weather, glare, visibility), geographic positions (Garmin 12XL hand-held GPS unit with externally mounted antenna) of fishing activity (number and type of fishing gear, number and activity of vessels) and marine mammal and turtle sightings (species, number of animals and behaviour).

Landings data and description of fishery

The State of North Carolina has maintained comprehensive and accurate records of commercial fishing landings since 1994 (John Schoolfield, NCDMF, pers. comm.) Monthly commercial gillnet landings data from Brunswick County, North Carolina, from 1994-1999 were acquired from John Schoolfield at the North Carolina Division of Marine Fisheries, Wilmington, North Carolina. These data included gear type (sink or floating gillnet), month, fish landings (lbs converted to kg) and dollar value. Mean monthly landings of spot were analysed (Student's T-test) to determine a relative index of prey availability. Landings data represent the best method for estimating fishing effort for a target species because, to date, there exists no comprehensive description of coastal gillnet fishing practices in North Carolina.

Gillnets targeting spot (and to a lesser extent kingfishes, *Menticirrhus* sp.) are set very close to shore and are routinely anchored to the beach. These nets are positioned nearshore to catch spot that are migrating southward along the coast and emigrating out of estuaries to offshore spawning grounds in the autumn. Because fishing effort is timed specifically to these seasonal movements of spot, it is a temporally discrete fishery. Coastal gillnets used to catch spot are made of monofilament line and have varying stretch mesh sizes from less than two inches to greater than three inches. Sink gillnets are typical, with a depth of around 40 meshes. The length of net set is variable - recreational fishers are limited to 100 feet per net, and while commercial fishers do not have set limits on net length, they are typically longer than recreational nets (John Schoolfield, NCDMF, pers. comm.; Thorpe *et al.*, 2001).

Bottlenose dolphin strandings

The UNCW Marine Mammal Stranding Programme has responded to marine mammal strandings in southeastern North Carolina since 1995. Every beach in the study area is populated and patrolled daily by either marine patrol officers or municipality representatives. Consistent and timely reporting and recovery of stranded dolphins occurs throughout the study area. Every carcass is evaluated for evidence of mortality as a result of a human interaction using a standardised protocol (as described in Haley and Read, 1993 and Read and Murray, 2000). This protocol prompts examiners to describe body condition, and all external marks, penetrating wounds, mutilation, or scavenger damage found from external examination. Internally, the protocol requires an assessment of any haemorrhaging, lung contents, stomach contents, broken bones or other lesions. These data are used to determine if the carcass bears physical evidence consistent with, and diagnostic of, entanglement in fishing gear.

To ensure a conservative interpretation of human impact, it is paramount that examiners are able to discern diagnostic *versus* non-diagnostic evidence of mortality from entanglement in fishing gear. Dolphins that are incidentally caught in monofilament gillnets nearly always exhibit cuts, lacerations or wrapping marks on their bodies (Read and Murray, 2000). A stranded dolphin was positively scored for human-induced mortality only if there was diagnostic physical evidence such as that described above. In this study, each positively scored carcass was further investigated to describe the type of line or gear and, therefore, the type of fishing gear that was involved in the mortality. Animals that did not show any signs of entanglement were scored as negative for human interaction. Animals that were too decomposed to judge a conservative, yet definitive, cause of death were scored as 'CBD' (cannot be determined) for human interaction.

After assessing each carcass for evidence of human interaction and collecting complete Level A data (date, location, species, sex, length, condition), all animals were necropsied. During these examinations, photo- and video-documentation were made of all internal and external evidence of human interaction. Tissue samples and body compartment masses were also collected for several other bottlenose dolphin research projects. The degree of detail in each dissection and number of samples collected were dependent upon the condition of each carcass. All original data sheets for stranded animals are housed at UNCW.

Statistical analysis

Waypoints for dolphin and gear sightings, and strandings were downloaded into ArcView GIS 3.1 (ESRI Inc. California, USA) for spatial mapping. The aerial survey data were used to describe the temporal relationships between the numbers of bottlenose dolphins and gillnets sighted. Counts of bottlenose dolphins and gillnets for all aerial surveys were plotted with a line of best fit (spline) to show the temporal changes in abundance in southeastern North Carolina. A Spearman's rank correlation analysis was performed on dolphin and gillnet counts to test for a correlation between the two. Beach based survey data were used to further describe this temporal relationship using descriptive statistics (mean number of dolphins and gillnets per survey per month). Similarly, spot landings were plotted by month for comparison with gillnet counts from the survey efforts. Survey data were analysed to ensure that sea state introduced no bias on the sightability of dolphins or gillnets during each survey effort (i.e. that the months with the highest sighting rates did not also have the best sighting conditions). For each dolphin and gillnet sighting, Beaufort sea state was recorded. For each month, an average sea state was calculated from the total number of sightings. Regression analysis was then performed on the number of sightings versus the average sea state for each month. Survey data were entered into Microsoft Excel 8.0 and SAS Institute Inc. JMP IN 3.1 for archiving and analysis.

RESULTS

Beach based surveys (Table 1)

Between April 1997 and January 1998, 40 beach based surveys were completed. At least three surveys were carried out in each month, except for July ($n = 1$). A total of 169 gillnets was observed in only four of the ten months of surveys (June, October, November and January). The mean number of gillnets was highest in October (25.2 gillnets/survey) and November (9.0 gillnets/survey); they were virtually absent for most other months (Fig. 2). Bottlenose dolphins were seen in all months except May and July. A total of 1,081 bottlenose dolphins was counted, with elevated local abundance between August and December. The mean number of dolphins was over three-times higher in November (137.8 dolphins/survey) than in any other month (Fig. 2, Table 1).

Table 1

Mean numbers of gillnets and dolphins counted per survey, total commercial gillnet spot landings from Brunswick County, North Carolina, and stranded bottlenose dolphins investigated for evidence of human interaction as a cause of death, during beach-based surveys (April 1997 - January 1998).

Month	No. of surveys	Mean gillnets per survey	Mean dolphins per survey	Total spot landings (kg)	Bottlenose dolphin strandings	Positive human interaction
Apr. 1997	3	0	1.3	96.6	1	0
May 1997	3	0	0	28.1	1	0
Jun. 1997	7	0.9	1.9	76.2	1	0
Jul. 1997	1	0	0	910.8	1	0
Aug. 1997	5	0	9.8	756.2	1	1
Sep. 1997	4	0	39.3	3,396.1	0	0
Oct. 1997	5	25.2	27.6	41,191.9	6	5
Nov. 1997	4	9.0	137.8	53,447.2	2	0
Dec. 1997	4	0	39.8	767.5	0	0
Jan. 1998	4	0.3	2.5	30.4	0	0

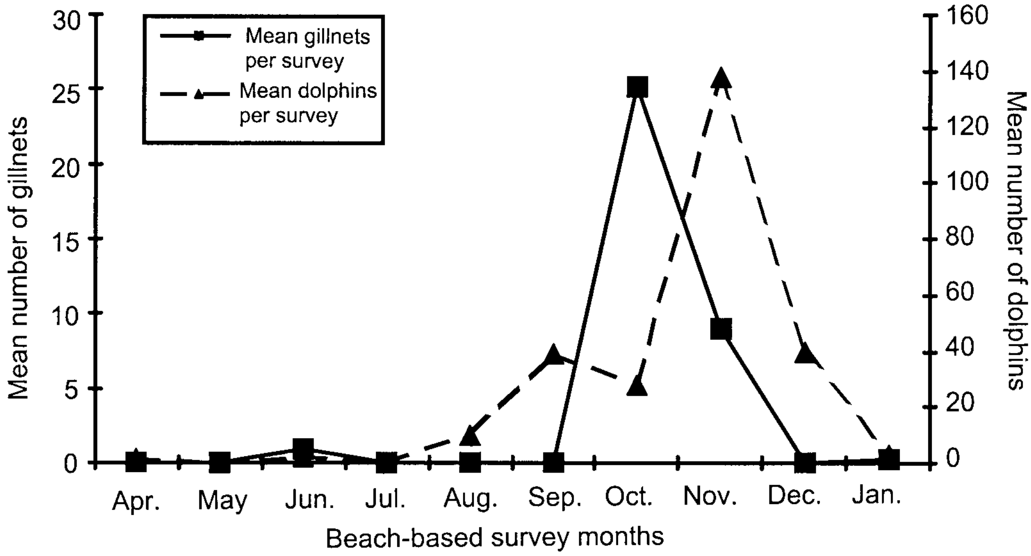

Fig. 2. Monthly means of gillnet and bottlenose dolphin counts from beach based surveys in Brunswick County, North Carolina, April 1997-January 1998.

Aerial surveys (Table 2)

Between July 1998 and May 1999, 39 aerial surveys were flown. At least three surveys were flown in every month except September ($n = 2$). Gillnets were seen in all months of the survey, except July and August, for a total of 352 gillnets (Fig. 3). The mean number of gillnets was highest in October (22.6 gillnets/survey) and November (37.7 gillnets/survey); it was substantially lower (eight or less) in all other months. Bottlenose dolphins were seen in all months surveyed for a cumulative total of 1,136 (Fig. 4). Bottlenose dolphin numbers were elevated between October and December. The mean number of dolphins was highest in October (85 dolphins/survey). Bottlenose dolphin and gillnet counts were plotted for each survey with a smooth-fit spline (Fig. 5),

Table 2

Mean numbers of gillnets and dolphins counted per survey, total commercial gillnet spot landings from Brunswick County, North Carolina, and stranded bottlenose dolphins investigated for evidence of human interaction as a cause of death, during aerial surveys (July 1998 - May 1999).

Month	No. of surveys	Mean gillnets per survey	Mean dolphins per survey	Total spot landings (kg)	Bottlenose dolphin strandings	Positive human interaction
Jul. 1998	4	0	16.5	361.5	0	0
Aug. 1998	4	0	15.8	23.1	0	0
Sep. 1998	2	3.5	17.5	5,027.2	0	0
Oct. 1998	5	22.6	85	37,784.0	7	5
Nov. 1998	3	37.7	40.3	55,004.4	4	1
Dec. 1998	3	5.7	32	2,165.5	0	0
Jan. 1999	4	4.3	14.5	n/a	1	1
Feb. 1999	3	3.3	14.3	129.7	1	0
Mar. 1999	3	5.7	29	21.3	0	0
Apr. 1999	4	8	17.3	79.8	1	0
May 1999	4	6.5	18.3	161.5	2	1

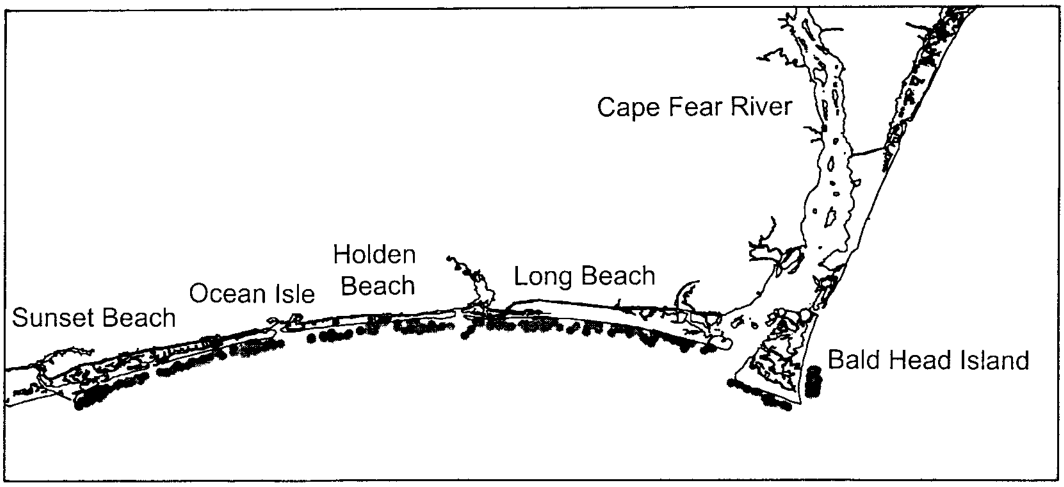

Fig. 3. GIS map of all gillnets observed in southeastern North Carolina from aerial surveys, July 1998-May 1999. Surveys for this time period extended from Sunset Beach to Bald Head Island and from the beach to 2km offshore.

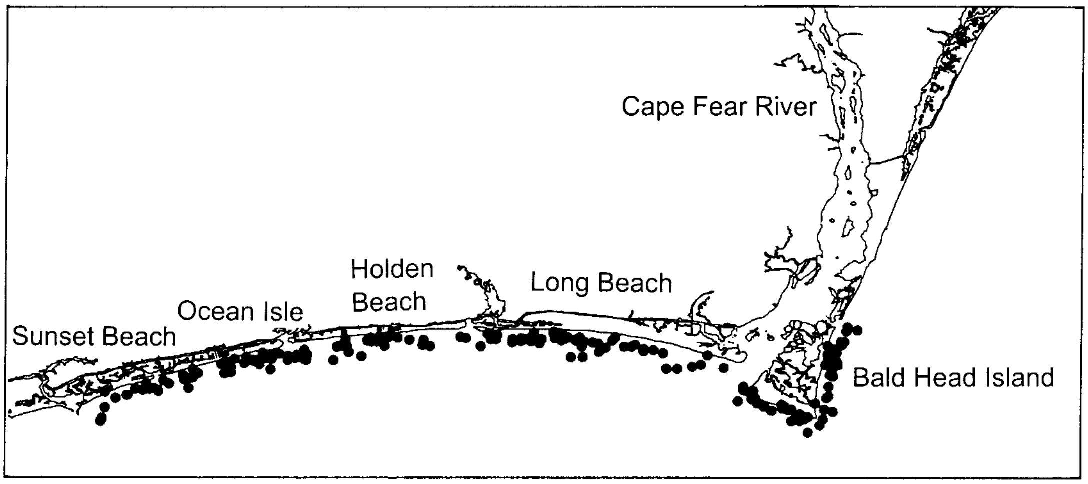

Fig. 4. GIS map of all bottlenose dolphin sightings in southeastern North Carolina from aerial surveys, July 1998-May 1999. Surveys for this time period extended from Sunset Beach to Bald Head Island and from the beach to 2km offshore.

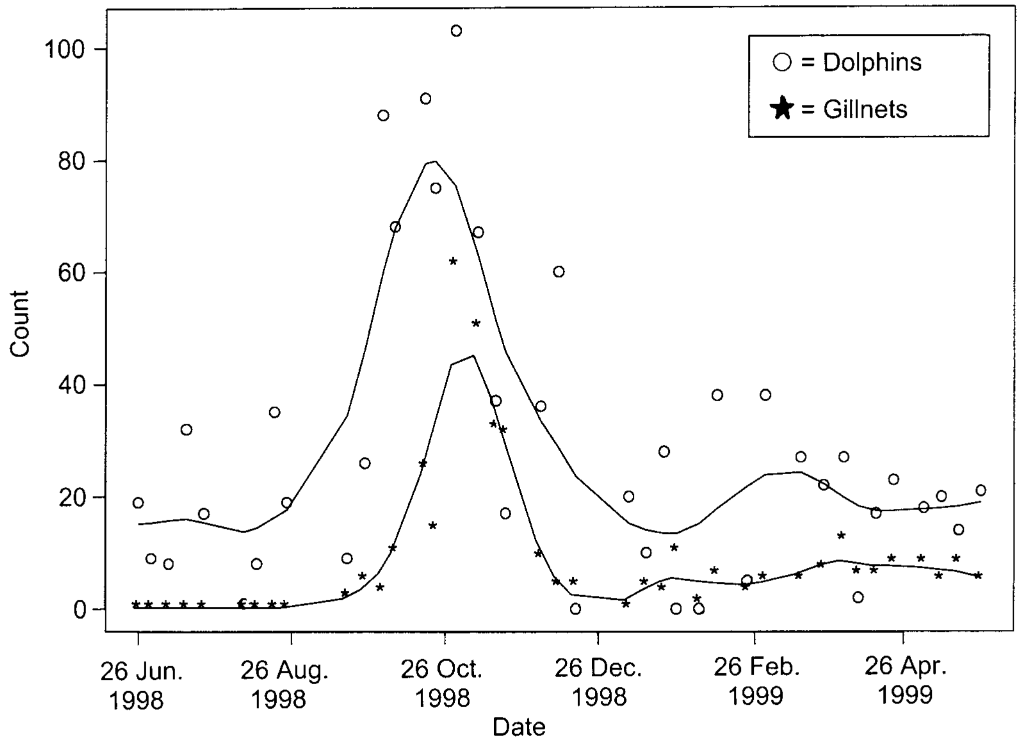

Fig. 5. Individual aerial survey counts of gillnets and bottlenose dolphins in southeastern North Carolina, July 1998-May 1999. Smooth-fit splines were fitted to both gillnet and bottlenose dolphin counts to show trends in abundance during the time of the survey. Spearman's rank correlation showed significant ($p < 0.005$) positive correlation between bottlenose dolphin and gillnet numbers.

showing their simultaneous peaks. A Spearman's rank correlation analysis revealed a significant positive correlation between bottlenose dolphins and gillnet numbers in southeastern North Carolina ($p < 0.005$).

Sightings data from aerial surveys revealed no monthly bias in dolphin or gillnet sightability due to sea state. Regression analysis revealed a slight negative trend in sightings of dolphins and gillnets with increased sea state. However, there was no significant correlation between the number of dolphin (R-square $= 0.03$, $p = 0.57$) and gillnet (R-square $= 0.08$, $p = 0.38$) sightings per month, and the average sea state during that time. Therefore, the sightings data, which demonstrate bottlenose dolphin and gillnet numbers peaking in October and November, with lower counts throughout the rest of the year, do not appear to be influenced by sea state conditions at the time of the survey.

Landings (Fig. 6)

For Brunswick County, the monthly mean commercial gillnet landings of spot (1994-1999) were significantly greater (up to two orders of magnitude greater) in October (71,288kg/month) and November (46,556kg/month) than in other months ($p < 0.01$). In 1994-1996, the highest monthly spot landings were recorded in November, while in 1997-1999, the highest landings were recorded in October. During both the beach based and aerial surveys, more spot were landed in November (53,447kg and 55,004kg respectively) than in any other month; October had the second highest landings (41,192kg and 37,784kg).

To determine whether the autumn gillnet fishery can be appropriately characterised as targeting spot, spot landings in Brunswick County, North Carolina were compared to those of other fish species. The only other fish landed in any measurable quantity were kingfishes. From 1994-1999, kingfish landings averaged 281.8kg in October and 781.8kg in November. These landings are significantly less ($p < 0.0002$) than landings of spot during the same time period.

Bottlenose dolphin strandings

Between April 1997 and May 1999, 28 bottlenose dolphins stranded in Brunswick County, North Carolina, and one dolphin was removed from a gillnet still alive (Fig. 7, Table 3). Nineteen of the 29 (66%) strandings[1] occurred in October and November. The cause of death, based upon results of the human interaction protocol, could be determined for 20 individuals; 13 (65%) were found to have died as a result of a human interaction.

During the months of the beach based survey, 12 bottlenose dolphins stranded, and one was removed from a gillnet alive (Table 1). Death as a result of a human interaction occurred in five of nine (56%) stranded dolphins for which cause of death could be determined. Four of these five animals were killed in October (the dolphin removed from gear was also in October). Three stranded dolphins from October showed diagnostic evidence of being caught in monofilament gillnets: cuts and wrap marks on the rostrum, dorsal fin, pectoral flippers and flukes (Fig. 8), while the other dolphin exhibited thicker braided line marks around the caudal keel and flukes. Two of the three animals that did not show signs of interaction were both small (105 and 113cm), and could be defined as neonates based upon their lengths (Mead and Potter, 1990; Urian *et al.*, 1996; Dearolf *et al.*, 2000).

[1] Including the single animal removed from a gillnet, which was considered to be a 'take' as defined under the USA Marine Mammal Protection Act, 1972.

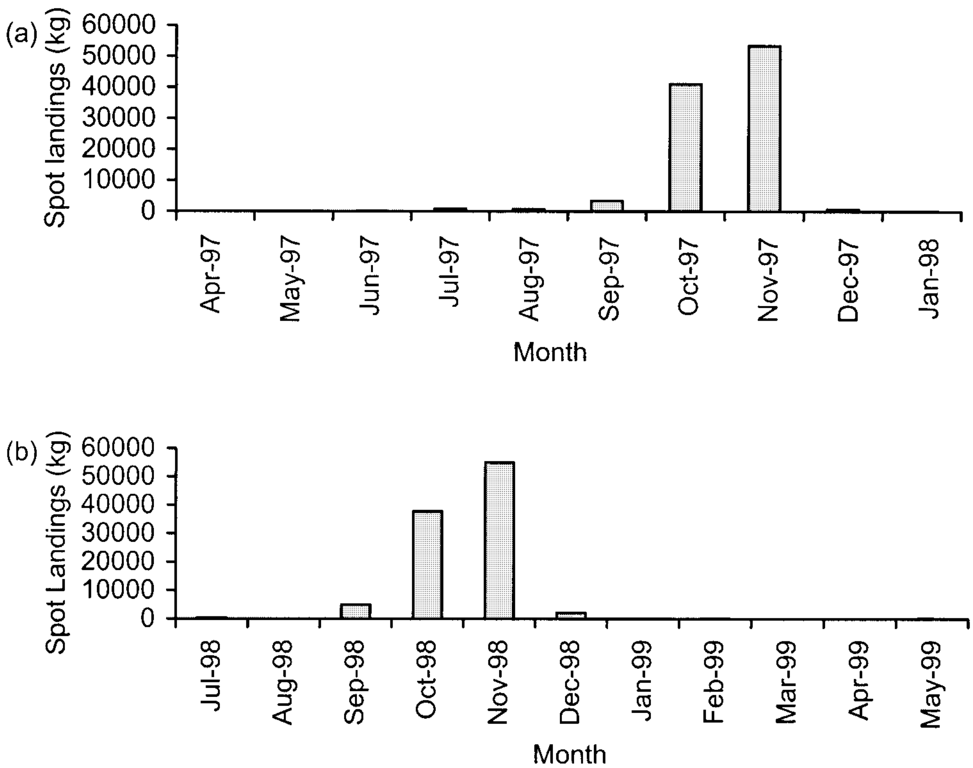

Fig. 6. Monthly commercial spot gillnet landings (kg) from Brunswick County, NC, during (A) beach based surveys, April 1997-January 1998 and (B) aerial surveys, July 1998-May 1999. Student's T-test showed October and November have significantly higher spot landings than other months ($p < 0.001$).

During the months of the aerial surveys, 16 strandings were reported (Table 2). Eight of eleven (73%) dolphins, for which cause of death could be determined, displayed diagnostic evidence of entanglement in gillnets. Five of these animals were killed in October, whilst one dolphin was killed in each of the months of November, January and May.

In Brunswick County, North Carolina, bottlenose dolphins die in monofilament gillnets most frequently in October ($n = 10$ from October 1997 and 1998), when both bottlenose dolphin and gillnet counts are high. In 1997, human-induced mortality from gillnets occurred in October when fishing effort was highest (25.2 gillnets/survey), landings were high (41,192kg) and dolphin abundance was

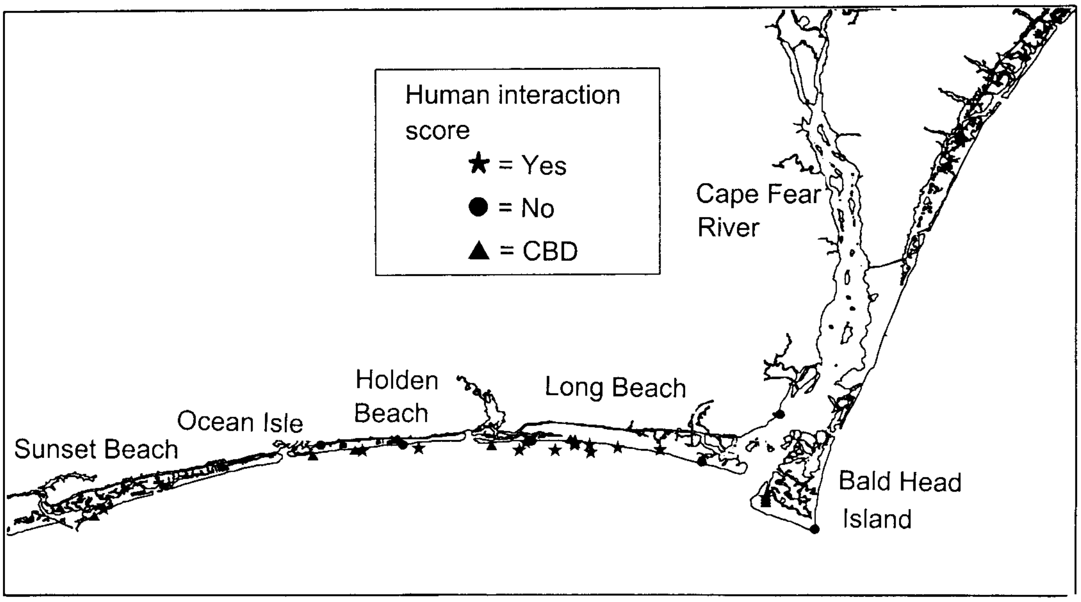

Fig. 7. GIS map of all bottlenose dolphin strandings in southeastern North Carolina, 1997-1999, and evaluations of the protocol to describe diagnostic evidence of human interaction as a cause of death (see Table 3 for explanation of Human Interaction Score).

Table 3

Level A data (field number, date, location, length, condition code, sex) and human interaction as a cause of death evaluation, for stranded bottlenose dolphins in southeastern, North Carolina, 1997-1999. Yes or No = diagnostic evidence of human interaction; CBD = cannot be determined due to decomposition or scavenger damage. Smithsonian Institution, SI Code: 1 (alive), 2 (fresh dead), 3 (moderate decomposition), 4 (advanced decomposition).

Field number	Strand date	Location	Lat./Long.	Length (cm)	SI code	Sex	Human interaction evaluation	Gear type
ASF012	15 Apr. 1997	Bald Head	33.865/78.000	100	3	M	No	
JLH001	14 May 1997	Southport	33.935/77.988	221	2	F	No	
ASF014	5 Jun. 1997	Bald Head	33.870/78.000	106	4	M	CBD	
ASF018	15 Jul. 1997	Bald Head	33.868/78.000	181	4	?	CBD	
ASF016	23 Aug. 1997	Long Beach	33.914/78.190	220 est.	2	M	Yes	Thick line
No number	3 Oct. 1997	Long Beach	33.910/78.117	N/e	1	N/e	N/a	Removed from gillnet
ASF017	4 Oct. 1997	Long Beach	33.913/78.151	232	2	M	Yes	Gillnet
ASF019	9 Oct. 1997	Long Beach	33.91278.217	207	3	F	CBD	
ASF021	11 Oct. 1997	Long Beach	33.913/78.151	162	2	F	Yes	Gillnet
WAM519	13 Oct. 1997	Holden Beach	33.908/78.320	249	3	F	Yes	Thick line
WAM520	14 Oct. 1997	Long Beach	33.913/78.139	181	2	F	Yes	Gillnet
ASF022	11 Nov. 1997	Bald Head	33.843/77.960	105	4	M	No	
JLD001	21 Nov. 1997	Holden Beach	33.912/87.352	113	3	F	No	
SDZ001	7 Oct. 1998	Long Beach	33.908/78.167	195	2	F	Yes	Gillnet
ASF030	14 Oct. 1998	Holden Beach	33.912/78.287	252	2	?	No	
DAP031	18 Oct. 1998	Long Beach	33.908/78.195	201	2	M	Yes	Gillnet
EKN001	19 Oct. 1998	Long Beach	33.907/78.138	190	3	M	Yes	Gillnet
EMM001	19 Oct. 1998	Long Beach	33.914/78.151	209	3	F	Yes	Gillnet
WAM542	19 Oct. 1998	Long Beach	33.914/78.150	219	3	M	Yes	Gillnet
EMM002	28 Oct. 1998	Holden Beach	33.904/78.359	224	4	M	CBD	
JLH002	2 Nov. 1998	Holden Beach	33.908/78.326	235	4	?	CBD	
SDZ002	3 Nov. 1998	Long Beach	33.917/78.155	105	3	F	CBD	
EMM003	4 Nov. 1998	Sunset Beach	33.856/78.532	245	4	M	CBD	
SDZ003	10 Nov. 1998	Holden Beach	33.910/78.275	240	3	F	Yes	Gillnet
ASF033	26 Jan. 1999	Sunset Beach	33.862/78.524	245	2	F	Yes	Gillnet
WAM545	28 Feb. 1999	Long Beach	33.914/78.185	246	2	F	No	
SDZ006	25 Apr. 1999	Holden Beach	33.341/77.960	164	3	M	No	
SDZ007	14 May 1999	Bald Head	33.863/78.560	159	4	F	CBD	
WAM549	29 May 1999	Long Beach	33.908/78.083	246	3	F	Yes	Gillnet

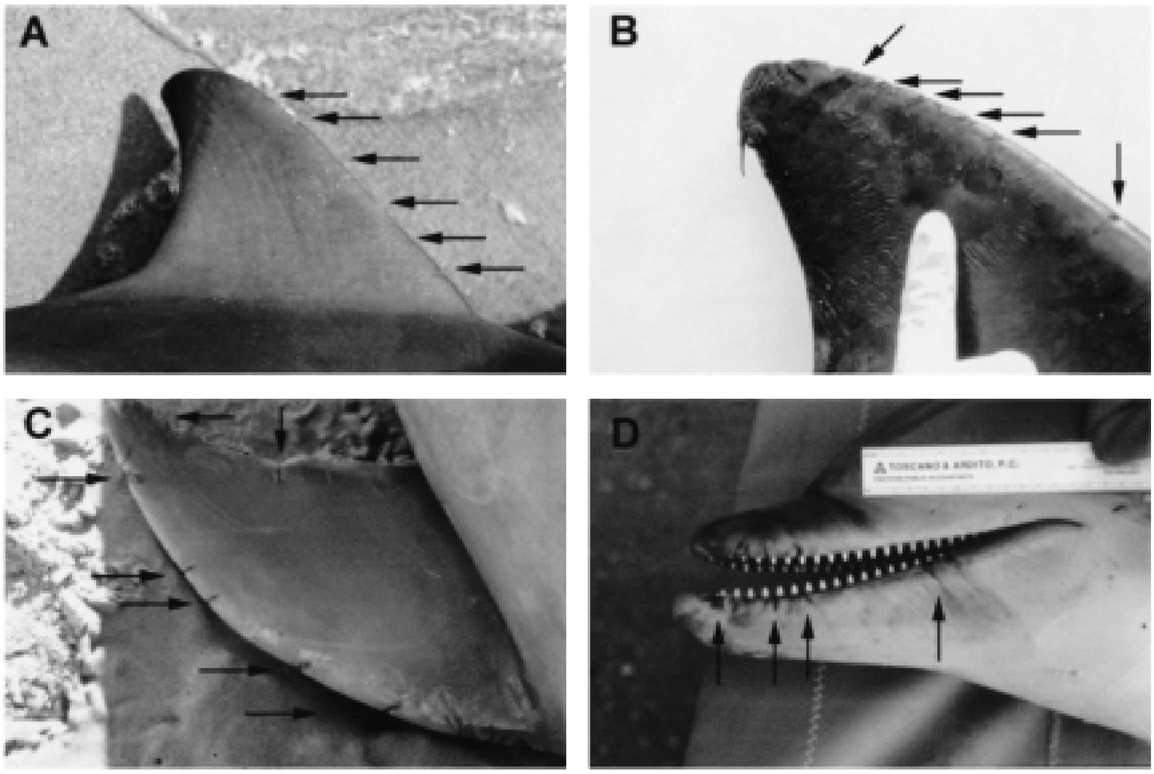

Fig. 8. Photographs of bottlenose dolphins bearing diagnostic evidence (wraps and line marks) of entanglement in monofilament gillnet. (A) Dorsal fin ASF021 (11 October 1997, Long Beach, North Carolina). (B) Dorsal fin of SDZ001 (7 October 1998, Holden Beach, North Carolina). (C) Pectoral flipper of ASF033 (26 January 1999, Sunset Beach, North Carolina). (D) Rostrum and mandibles of DAP031 (18 October 1998, Long Beach, North Carolina).

elevated (27.6 dolphins/survey), but not at its peak. In November 1997, fewer gillnets were seen (nine gillnets/survey), landings peaked (53,477kg), dolphin abundance was highest (137.8 dolphins/survey) and no human-induced mortality was documented. In 1998, human-induced mortality occurred most frequently in October when fishing effort (22.6 gillnets/survey) and landings (37,784kg) were high, and dolphin abundance was at its peak (85 dolphins/survey). In November 1998, gillnets (37.7 gillnets/survey) and landings (55,004kg) peaked while dolphin abundance dropped from its peak but remained elevated (40.3 dolphins/survey), and only one stranded dolphin is known to have died in a monofilament gillnet.

DISCUSSION

Movement patterns of delphinids appear to follow those of their potential prey (Young and Cockcroft, 1994), and diets are known to be determined by seasonal and spatial changes in the abundance of preferred prey (Hui, 1979; Evans, 1980; Leatherwood *et al.*, 1982; Pascoe, 1986; Selzer and Payne, 1988; Young and Cockcroft, 1994). Stomach contents of stranded bottlenose dolphins found along the Atlantic coast (Leatherwood *et al.*, 1978; Mead and Potter, 1990) and the southeastern United States (Gunter, 1942; Kemp, 1949; Barros and Odell, 1990; Barros and Wells, 1998) contained 39 genera of fish and five species of cephalopods (Barros and Odell, 1990). Sciaenid fishes (spot, weakfish, croaker, silver perch, mullet and sea trout) were the most common prey species found (Barros and Odell, 1990; Mead and Potter, 1990).

Spot are found in estuarine and coastal waters from Cape Cod to the Bay of Campeche, Mexico (Dahlberg, 1976; Ross, 1980), but are most abundant in the southeastern USA in summer and autumn (Philips *et al.*, 1989). Most spot spawn offshore over the outer continental shelf from October-March in waters above 17.5°C (Lewis and Judy, 1983; Philips *et al.*, 1989). Off North Carolina, spawning occurs in winter, 75-95km offshore (Lewis and Judy, 1983; Warlen and Chester, 1985; Philips *et al.*, 1989). Larval spot move inshore into estuaries by February where they remain until they migrate to sea in the autumn (Pacheco, 1962; Hester, 1975; Currin *et al.*, 1984; Philips *et al.*, 1989). In North Carolina, spot are the most abundant fish species that spawn on the continental shelf and migrate to estuaries (Philips *et al.*, 1989). Commercial fisheries (primarily gillnet) for spot are concentrated from the Chesapeake Bay through the Carolinas, with North Carolina having the largest commercial landings (Philips *et al.*, 1989).

In Brunswick County, North Carolina, commercial spot gillnet landings and gillnet abundance are strongly seasonal, peaking in October and November. Commercial spot gillnet landings, thus, can be considered to serve not only as a proxy for spot abundance, but also for fishing effort as gillnet counts and landings data follow similar monthly patterns. Both beach based and aerial survey efforts documented similar changes in the abundance of bottlenose dolphins in Brunswick County, North Carolina, which support other observations of bottlenose dolphin movement along the USA Atlantic coast (Kenney, 1990; Wang *et al.*, 1994; Barco *et al.*, 1999). Local dolphin abundance was low in spring and summer, and peaked in autumn (highest in November).

A significant positive correlation was found between bottlenose dolphins and gillnet numbers in southeastern North Carolina, showing that the two follow similar temporal patterns. Barco *et al.* (1999) found a positive correlation between bottlenose dolphin abundance and sea-surface temperature in Virginia. Water temperature may be a major influence on prey distribution and thus may effect bottlenose dolphin movements (Barco *et al.*, 1999). As noted earlier, spot spawn in offshore waters that are at least 17.5°C. What is not known, however, is the cue that drives spot to migrate out of estuaries. Potentially, the bottlenose dolphins that appear in southeastern North Carolina in the autumn are following spot from more northern latitudes as these fish emigrate from estuaries to offshore. Alternatively, dolphins may be following migrating spot out of estuarine and intracoastal waterways into coastal waters. Whatever the case, in southeastern North Carolina, when bottlenose dolphins, gillnets and spot landings increase, dolphins die in gillnets.

Ten of the eighteen bottlenose dolphins that stranded in southeastern North Carolina in October ($n = 9$) and November ($n = 1$) from 1997-1998 were killed in monofilament gillnets. An additional dolphin, whose subsequent fate is unknown, was cut out of a gillnet in October 1997. These ten documented mortalities represent a minimum number of coastal bottlenose dolphins that died due to entanglement in monofilament gillnets during this time period, since not all dolphins that die, regardless of the cause, strand on beaches (Waring *et al.*, 1999). This stranding pattern suggests that at least 20-24% of the total PBR for coastal bottlenose dolphins in each of these two years were taken within a two month period along a 41.5km stretch of beach in southeastern North Carolina. The small spatial and temporal scales across which these takes occurred is especially troubling, considering that monofilament gillnets are used during autumn and winter to catch spot (and other fishes) along a much larger area of coastline of the mid-Atlantic (Philips *et al.*, 1989). If spot migrate based on a temperature tolerance, it is possible that bottlenose dolphins and monofilament gillnets are co-occupying nearshore coastal waters along hundreds of kilometres of coastline for several months. If a similar magnitude of dolphin mortality occurs elsewhere, the number of bottlenose dolphins that die as a result of entanglement in monofilament gillnets could well exceed PBR. Therefore, these nets could be having significant, negative impacts on stocks of coastal dolphins, either migratory or resident.

Although work is ongoing, at present the stock structure of coastal bottlenose dolphins is not well understood (e.g. Hohn, 1997) and the stock identity of dolphins killed in gillnets in autumn in Brunswick County, North Carolina, is not yet known. Researchers using photo-ID (matching photographs of distinct dorsal fins in one location over time or between several locations over time) to link dolphin movements between various locations (i.e. Virginia Beach, VA; Beaufort and Wilmington, NC; Charleston, SC) along the USA Atlantic coast (e.g. Urian and Wells, 1996) can use photographs of dorsal fins from stranded individuals. Strandings can allow researchers to gain information regarding the stock identity of each bottlenose dolphin. Genetic analysis of skin samples from stranded individuals can in principle be used to assign each dolphin to a particular stock, provided identified management stocks can be genetically differentiated. Thus, each stranded dolphin bearing evidence of human interaction could be used to quantify human-induced mortality and its impact on separate stocks of coastal bottlenose dolphins.

One issue that cannot be addressed by stranding protocols, however, is whether a dolphin was killed in a commercial or a recreational gillnet (because in North Carolina, both types of fishermen use the same gear) and where it was killed (animals can drift far from the point of entanglement). Recently, the North Carolina Department of Marine Fisheries has implemented regulations to distinguish nets based upon the type of end markers or floats used (NCDMF, Wilmington, North Carolina). Recreational gear must have two solid yellow floats and one hot pink float, while commercial gear is only required to have yellow markers (North Carolina Department of Marine Fisheries). In the past year, UNCW aerial survey teams have begun noting the float colours for all gillnets. It is hoped that future analyses will be able to determine the relative amount of effort from both commercial and recreational gillnetting activities, as currently there is no regulation of recreational gillnetting in North Carolina for incidental takes of marine mammals.

Taylor *et al.* (2000) urge that marine mammal research be 'dedicated to estimating human-induced mortality because history has clearly demonstrated the inadequacy of relying on reports generated by the potentially affected resource users'. Currently, the models that are used to manage marine mammal populations in the USA mandate such monitoring. Stranding networks now have the ability to describe and quantify diagnostic evidence of human-induced mortality in marine mammals by employing rigorous protocols designed for this purpose (Haley and Read, 1993; Read and Murray, 2000). For example, Cox *et al.* (1998) documented the bycatch of harbour porpoises in coastal gillnet fisheries along the USA mid-Atlantic from stranded carcasses. Understanding the relationships between biological and anthropogenic variables leading to these interactions can facilitate conservative, pro-active management ensuring that human-induced mortality is limited to levels that do not negatively impact populations of marine mammals, such as Atlantic coastal bottlenose dolphins.

This study has described the types of data that are necessary to begin characterising the interactions between coastal bottlenose dolphins and a local fishery in southeastern North Carolina. Regular surveys and fisheries landing data were used to elucidate the spatial and temporal distributions of bottlenose dolphins, spot and monofilament gillnets. By analysing stranding records, this study has shown that gillnets set in southeastern North Carolina during the autumn, which are targeting spot, contribute substantially to the total allowable removal of coastal bottlenose dolphins annually.

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