Trends in bottlenose dolphin (*Tursiops truncatus*) strandings in South Carolina, USA, 1997-2003: implications for the Southern North Carolina and South Carolina Management Units

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ABSTRACT

Trends in marine mammal stranding rates over multiple years can provide useful information on life history parameters, seasonal and spatial distribution and both natural and human-induced mortality rates when compared with baseline data. Data of bottlenose dolphin (*Tursiops truncatus*) stranding rates in South Carolina, USA from 1997-2003 were analysed. The objectives of this study were to: (1) compare recent trends in strandings with baseline data (1992-1996) for South Carolina; (2) compare strandings between the Southern North Carolina Management Unit (SNCMU) and the South Carolina Management Unit (SCMU); (3) determine annual, seasonal and spatial trends in bottlenose dolphin strandings; (4) investigate seasonal reproductive trends; and (5) determine the extent to which humans may affect stranding rates (human interactions). Bottlenose dolphins stranded in South Carolina are assumed to be from at least two of the seven management units recognised by the National Marine Fisheries Service in the Western North Atlantic: the SNCMU and the SCMU. During the study period, 302 bottlenose dolphin strandings were reported in South Carolina and stranding counts were analysed using a Generalised Linear Model. Results showed that there were significantly more bottlenose dolphin strandings in the spring and autumn as compared with summer and winter. The effect of season was highly significant for the number of neonate strandings, suggesting a bimodal reproductive cycle in spring and autumn for the study area. A significant increase in the number of strandings of all age classes was found in the autumn for the northern portion of the State (SNCMU), supporting the assumption that bottlenose dolphins from the north migrate into South Carolina waters during this time of year. Rope entanglements was the most common source of human interaction, with the crab pot fishery the most prevalent source of fishery mortality in South Carolina. This study demonstrates the usefulness of a long-term stranding database by increasing knowledge of temporal and spatial patterns and for monitoring neonate and human-induced mortality.

KEYWORDS: STRANDINGS; BOTTLENOSE DOLPHIN; TRENDS; DISTRIBUTION; REPRODUCTION; SEASONALITY; FISHERIES; NORTH AMERICA; ATLANTIC OCEAN

INTRODUCTION

The accumulation of stranding data over several years allows for the analysis of trends such as yearly, monthly and seasonal stranding rates, gender, length and age class and occurrences of human-induced mortality (human interaction). Analyses of bottlenose dolphin (*Tursiops truncatus*) strandings in the Western North Atlantic (WNA) have become more commonplace since the inception of a national marine mammal stranding program formally initiated by the National Marine Fisheries Service (NMFS) in 1991 (Swingle and Barco, 1997; McFee and Hopkins-Murphy, 2002; McLellan *et al.*, 2002; Stolen *et al.*, 2002; Stolen and Barlow, 2003). These stranding datasets have provided useful information for managers on bottlenose dolphin stock structure, can be used to detect unusual mortality events and serve to monitor the health of living populations. This paper presents additional data on trends of bottlenose dolphin strandings in South Carolina from 1997-2003.

The WNA coastal bottlenose dolphin 'stock' is still considered depleted as determined under the US Marine Mammal Protection Act (Waring *et al.*, 2004), eleven years after the designation (Federal Register, 1993). A stock is considered to be depleted when it falls below its optimum sustainable population, or the number of animals which will result in the maximum productivity of the stock (16 U.S.C. 1362, Sec. 3)[1]. Scott *et al.* (1988) suggested one contiguous population of migratory bottlenose dolphins based on the patterns of strandings during the epizootic of 1987-88 in which greater than 700 bottlenose dolphins died on the east coast of the United States. Since then, much has been learnt about bottlenose dolphin population structure, mainly through photo-identification studies, genetic analyses and air and ship-board surveys. The population structure appears to be more complex (Hohn, 1997; McLellan *et al.*, 2002) than previously described (Scott *et al.*, 1988). At present, the WNA coastal bottlenose dolphin stocks are divided into seven management units (Waring *et al.*, 2004) as defined by NMFS. Coastal bottlenose dolphins stranded in South Carolina are assumed to be from two of these management units: the southern North Carolina management unit (SNCMU) ranging from Cape Lookout, North Carolina to Murrell's Inlet, South Carolina; and the South Carolina management unit (SCMU) ranging from Murrell's Inlet south to the Savannah River (Fig. 1). The extent to which bottlenose dolphins from either management unit influence the stranding dynamics in the other is an issue that could help researchers better understand the stock structure and movement patterns in this region.

The objectives of this study were to: (1) compare recent trends in strandings with baseline data (1992-1996) for South Carolina; (2) compare strandings between the Southern North Carolina Management Unit (SNCMU) and the South Carolina Management Unit (SCMU); (3) determine annual, seasonal and spatial trends in bottlenose dolphin strandings; (4) investigate seasonal reproductive trends; and (5) determine the extent to which humans may affect stranding rates (human interactions).

[1] 16 U.S.C. 1362 et seq. United States Congress. Marine Mammal Protection Act (MMPA) of 1972 as Amended.

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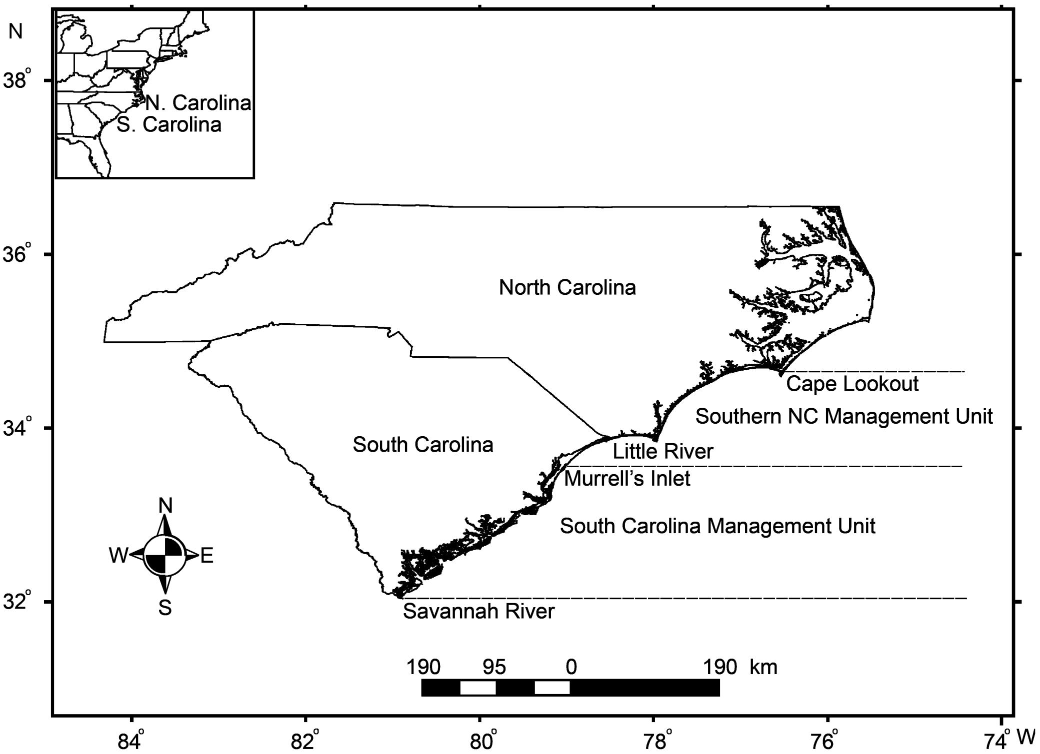

Fig. 1. Map of North Carolina and South Carolina, USA depicting the southern North Carolina Management Unit (Cape Lookout, NC to Murrell's Inlet, SC) and South Carolina Management Unit (Murrell's Inlet, SC to Savannah River).

METHODS

The South Carolina Marine Mammal Stranding Network (MMSN) has been a cooperative effort between the South Carolina Department of Natural Resources (SCDNR) and the National Ocean Service (NOS), Center for Coastal Environmental Health and Biomolecular Research (CCEHBR) in Charleston, South Carolina since 1991. For this study, the MMSN infrastructure and data collection methods have not changed since McFee and Hopkins-Murphy (2002) other than a change in State Coordinator on 1 August 2003. In short, strandings were reported by network volunteers and the public to SCDNR and NOS employees and basic information (Level A data: sex, length, species, stranding location, etc., as defined by Hoffman, 1991) on each carcass recorded. The extent to which humans may affect stranding rates (human interactions) was also evaluated. Bottlenose dolphins may show indications of human interaction in a number of ways: fishery-related mortality (e.g. rope wounds, gear attachment, hook and line, net markings), boat strikes, mutilation and blunt trauma. Additional data were included from necropsies of accessible animals.

Since the NMFS designation of the seven management units for the WNA bottlenose dolphins, analysis was conducted on stranded bottlenose dolphins that were assumed part of the South Carolina portion of the SNCMU (Little River Inlet, South Carolina south to Murrell's Inlet, South Carolina) and the SCMU (Murrell's Inlet south to Savannah River).

STATISTICAL METHODS

For analysing differences in expected stranding counts among seasons and management units, we applied a Generalised Linear Model (GLM) with a log link function and a Poisson error distribution. A Poisson log-linear model was most applicable for these types of data because the response outcome was a count and large counts were expected to be rare events. The fit of the model was evaluated by examining the residual deviance and Pearson Chi-Square statistic. These statistics divided by the degrees of freedom (df) were used to detect overdispersion and underdispersion in the model, indicating an inadequate model fit. When overdispersion was evident, a negative binomial error distribution in lieu of the Poisson model as a corrective measure was applied.

RESULTS

Yearly trends

During the period from 1997 to 2003, 302 bottlenose dolphin strandings were reported along the coast and estuaries of South Carolina. During this period, the number of bottlenose dolphin strandings ranged from 28 in 2002 to 68 in 2001, with a mean of 43.1 strandings per year. Strandings were notably higher in 2000 and 2001 (Fig. 2). In fact, the number of mortalities in 2000 and 2001 were significantly higher than what would be expected based on a statistical model of the number of strandings from previous years. Assuming that the number of strandings per year is a Poisson random variable with a mean calculated based on all prior years (1992-1999), the probability of observing 68 or more strandings (as in 2001) for a given year is less than 0.0001. The probability of observing 53 or more strandings (as in 2000) for a given year, is approximately 0.0005.

During the same period (1997-2003), the number of neonate (defined as a newborn having a folded dorsal fin or flukes or with unhealed umbilical remnants [or with both physical features]) strandings ranged from five in 1998 to 14 in both 2000 and 2001, with a mean of 8.3 strandings per year. The differences in the number of neonate strandings across years were not significant at the α=0.05 level (χ^2 test, p=0.08).

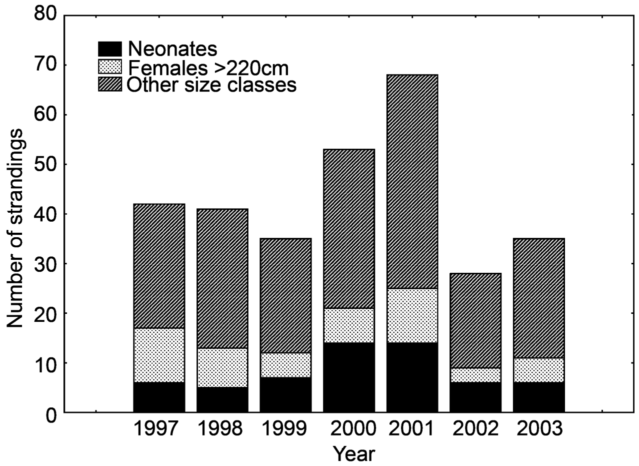

Fig. 2. Annual number of bottlenose dolphin strandings in South Carolina for the period 1997-2003.

Monthly trends

Over the seven-year period, the greatest number of reports (n=44, or 14.6%) of bottlenose dolphin strandings occurred during November and the least in both February and September (n=13, or 4.3%). The effect of month on the total number of strandings for the 1997-2003 period was significant (p=0.0012). However, when data were divided into two classes representing neonates and a combined class of all other ages (Fig. 3), the significance of month on the expected number of strandings was variable. While month remained a significant factor for the number of neonate strandings (p<0.001), it was not a significant factor for the remaining age classes (p=0.40). The combined age class was then further divided into two subclasses: sexually mature (>220cm) females (Odell, 1975; Mead and Potter, 1990) and males and remaining females. The expected number of strandings between months did not vary for either of these subclasses (p=0.38 and p=0.21, respectively).

Seasonal trends

An equal number of bottlenose dolphin strandings occurred in spring (April-June) and autumn (October-December) (n=85, 28.1%). Bottlenose dolphin strandings were lowest in winter (January-March) (n=62, 20.5%). The Poisson GLM applied to examine the effect of season on the total number of strandings for the 1997-2003 period indicated overdispersion (deviance/df=1.79), so the alternative negative binomial model was employed. The effect of season on the total number of strandings for the 1997-2003 period was not significant (p=0.16). Data were then divided into two classes representing neonates and a combined class of all other ages. The effect of season was highly significant for the number of neonate strandings (p=0.002), Poisson model (deviance/df=1.16), yet the effect of season on the remaining age classes remained insignificant (p=0.94). These results are consistent with earlier analyses of stranding data from South Carolina for the previous 5-year period, which suggested that neonate strandings occurred more frequently in the spring and autumn months as compared to the winter and summer months (McFee and Hopkins-Murphy, 2002).

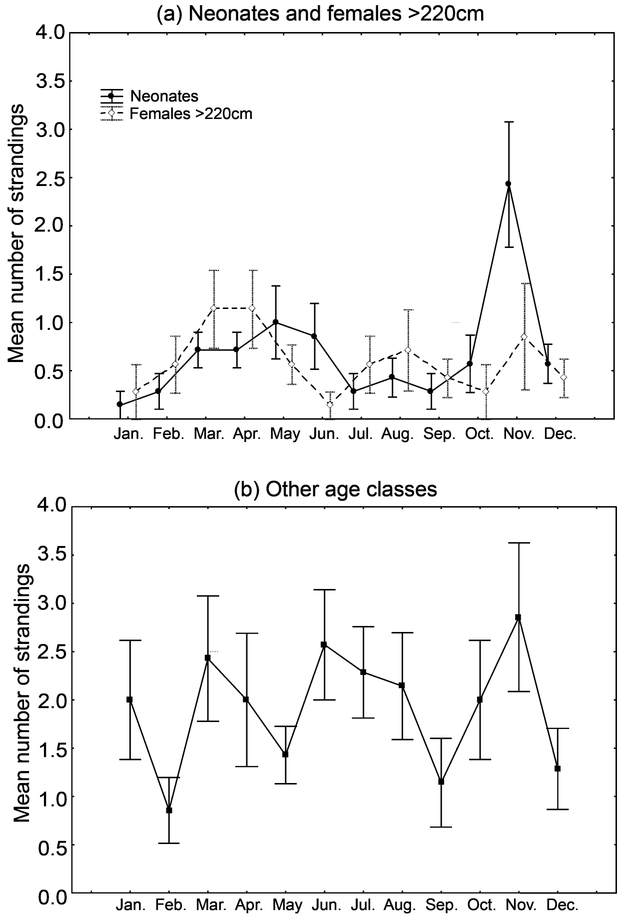

Fig. 3. Mean number of bottlenose dolphin strandings in South Carolina per month from 1997 to 2003. Graph (a) represents neonates and females greater than 220cm. Graph (b) represents all other age/sex classes. Whiskers represent standard errors.

To further explore the relationship between neonate strandings and season, spring/autumn versus winter/summer was contrasted. Differences between the two categories were highly significant (p<0.001), indicating an increased number of neonate strandings in the spring and autumn as compared to the winter and summer (Fig. 4). The highest number of neonate strandings was seen in autumn ($\bar{x}$ = 3.6), although this did not differ significantly (p=0.29) from the mean number of neonate strandings for spring ($\bar{x}$ = 2.6). The mean number of neonate strandings for the winter and summer seasons were significantly lower ($\bar{x}$ = 1.1 and $\bar{x}$ = 1.0, respectively).

The years 2000-2001 had an unusually high number of strandings, and in order to examine whether the inclusion of stranding data from these years could unduly influence results, the above analysis of neonate strandings across seasons, excluding data from 2000 and 2001, was repeated. While the results were less significant (p=0.045 for overall effect of season on number of neonate strandings) due to the reduced sample size, the overall conclusions did not change.

The Poisson model was used to determine if there was any effect of season in the SNCMU. The effect of season on the total number of strandings for the SNCMU was significant (p=0.002), confirming that there was a significant increase in strandings in autumn.

The seasonality of neonate strandings to determine if the bimodal distribution of neonate strandings (i.e. highest numbers in spring and autumn) was consistent across both management units was further examined. While neonate strandings were higher in the autumn for both management units (Fig. 5), only the SCMU appeared to show an increase in the number of strandings in the spring. A Poisson model was fitted using season and management zone as factors to determine whether or not the interaction term between the two factors would be significant. The interaction of season and management zone was significant ($p<0.001$), indicating seasonal strandings between the two management zones were dissimilar.

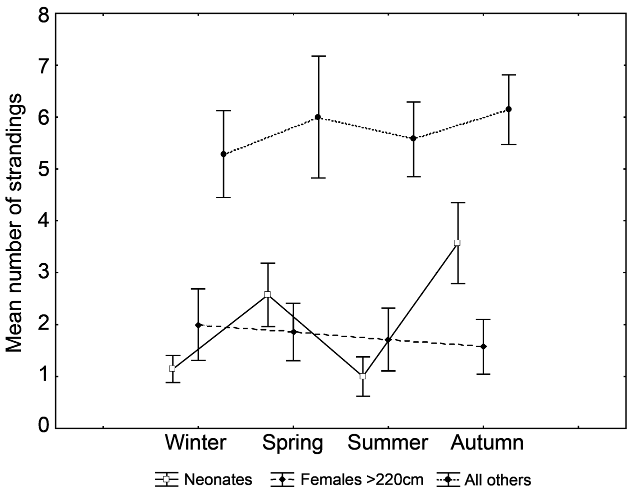

Fig. 4. Mean number of bottlenose dolphin strandings in South Carolina by season. Whiskers represent standard errors.

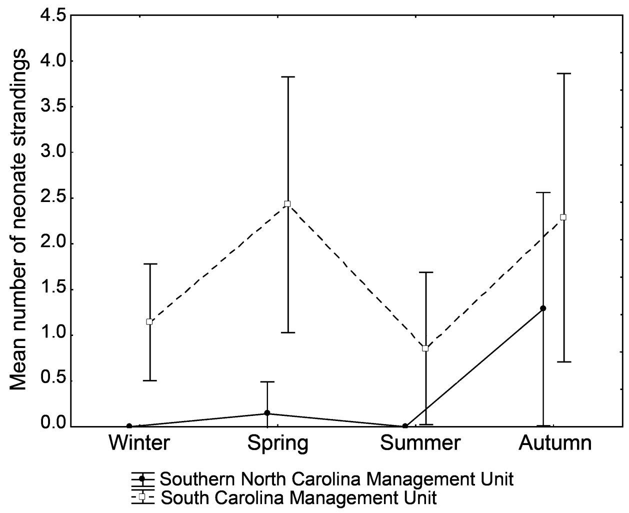

Fig. 5. Mean number of neonate strandings by season, divided into management zones. Whiskers represent standard errors.

Sex

The total number of stranded bottlenose dolphins with known sex was 229; 73 (24.2%) were of unknown sex. The sex ratio for 1997-2003 was 1.00:0.92, males (*n*=119) to females (*n*=110), not significantly different from parity (*p*=0.97).

Length classes

The total number of stranded bottlenose dolphins with known length was 271. Length data were stratified into five classes (McFee and Hopkins-Murphy, 2002):

class I (neonates-defined as a newborn having a folded dorsal fin or flukes or with unhealed umbilical remnants [or with both physical features]; <120cm);
class II (<184cm, young of the year);
class III (185-200cm, calves);
class IV (201-240cm, mostly physically immature, especially males); and
class V (>240cm, mostly mature).

Where both sex and length were known (*n*=175), males and females were distributed proportionately across the length classes with the exception of class III and class IV. In class III, males dominated (80%), whereas in class IV females dominated (65.4%).

Neonates

Neonates represented 21.4% (*n*=58) of the total number (*n*=271) of strandings of bottlenose dolphins with known length, ranging from 14.3% in 1998 to 30.4% in 2000. Strandings were found in every month of the year, but occurred more frequently in autumn (*n*=25, 43.1%) and spring (*n*=18, 31.0%). November had the greatest number of strandings (*n*=16), accounting for 64% of autumn strandings. Twenty-six neonates (44.8%) were <100cm and 16 (61.5%) of these stranded during the spring and autumn. Forty-nine of the neonates were of known sex, with a 1:1 ratio between females (*n*=25) and males (*n*=24).

Forty-seven (81.0%) neonates stranded in the SCMU, with most strandings occurring in spring (*n*=16) and autumn (*n*=16). Of the 11 neonates that stranded in the South Carolina portion of the SNCMU, nine (81.8%) stranded in the autumn.

Females =220cm

Reproductively mature females (i.e. those ≥220cm) represented 47.3% (*n*=52) of the total number (*n*=110) of females stranded. The proportion of females ≥220cm stranded each year ranged from 36.4% (2002) to 55% (1997). The proportion of females ≥220cm stranded was consistent from season to season.

Comparison with baseline stranding information

Stranding counts for the 1997-2003 time period with the baseline data from 1992-1996 (McFee and Hopkins-Murphy, 2002) were compared. The mean number of strandings per year for the 1997-2003 period was higher than the baseline period (*p*=0.049). When separated into neonate and non-neonate categories, the increase in the number of neonate strandings per year was significant (*p*=0.02), while the increase in the number of non-neonate strandings per year was not significant (*p*=0.06).

Human interaction

The total number of stranded bottlenose dolphins where there was clear evidence supporting either human interaction (HI) or no human interaction was 143 out of 302 (some 47%). Approximately 25% (*n*=36) of these strandings showed evidence of HI while 107 showed no signs of HI; 97% of HI animals occurred in the SCMU (Table 1). Incidents of rope entanglements, including confirmed entanglements in crab pot lines (*n*=6), accounted for 44.4% of HI cases. Incidence of confirmed HI with bottlenose dolphins was highest in August (*n*=9) and most prevalent from May to August (*n*=24). Rope and crab pot entanglements were most prevalent in July and August (*n*=9) and four of the six boat strikes were in June/July. Twenty-nine of the 36 bottlenose dolphins showing signs of HI were of known sex, with a 1:1 ratio between males

Table 1

Summary of bottlenose dolphin strandings in South Carolina involved with human interaction from 1997-2003. 'CBD' refers to the number of bottlenose dolphin strandings where human interaction could not be determined.

	1997	1998	1999	2000	2001	2002	2003	Total
Total dolphins stranded	42	41	35	53	68	28	35	302
Human interactions (HI)								
Rope marks	5	3	0	1	0	0	1	10
Crab pot	2	0	1	0	1	0	2	6
Boat strike	0	1	2	1	2	0	0	6
Mutilation	2	0	1	0	1	0	0	4
Net marks	1	1	0	0	0	1	0	3
Trammel net	0	0	0	0	0	2	0	2
Shrimp fishery	0	1	0	0	0	1	0	2
Monofilament	0	0	0	1	1	0	0	2
Blunt trauma	0	0	0	1	0	0	0	1
Total HI	10	6	4	4	5	4	3	36
No HI	16	10	11	19	20	13	18	107
CBD	16	25	20	30	43	11	14	159
% HI (-CBD)	38.5 (*n*=26)	37.5 (*n*=16)	26.7 (*n*=15)	17.4 (*n*=23)	20 (*n*=25)	23.5 (*n*=17)	14.3 (*n*=21)	25.2 (*n*=143)

(*n*=15) and females (*n*=14). Some 73% of the males were <221cm in length ($\bar{x}$ = 198cm), whereas 50% of the females were <220cm ($\bar{x}$ =189cm).

DISCUSSION

The analysis of a larger dataset of bottlenose dolphin strandings in South Carolina combined with baseline data (McFee and Hopkins-Murphy, 2002) has helped to further elucidate stranding trends. While data from our current study show many of the same trends as the baseline data (e.g. length class distribution, gender distribution, seasonal distribution, geographic distribution), the larger dataset has allowed us to include data that may add to the knowledge of stock structure of bottlenose dolphins in the southeastern United States and reproductive seasonality in South Carolina. In particular, our analysis produced four main findings: (1) bottlenose dolphin strandings were unusually high for 2000 and 2001; (2) neonate strandings in the SCMU are bi-modally distributed, with peaks in spring and autumn; (3) more bottlenose dolphins strand in the SNCMU in the autumn; and (4) based on recovery of carcasses, rope entanglements (including confirmed crab pot interactions) are the dominant source of apparent human-induced mortality.

Results from the analysis of yearly trends depicted unusual increases in bottlenose dolphin stranding rates for 2000 and 2001 in South Carolina. A similar trend was observed for these two years in Florida, but no appreciable difference in stranding rates was observed in the neighbouring states of Georgia and North Carolina (Southeastern United States Marine Mammal Stranding Database). The increase in Florida bottlenose dolphin strandings was likely due to two unusual mortality events (UME's) declared by NMFS for the Indian River Lagoon (2001) and the Florida Panhandle (1999-2000). Elevated strandings in a localised geographic area are to be reviewed by a panel of marine mammal experts before a UME can be declared under the MMPA (16 U.S.C. 1421c, Sec. 404)[2]. A harmful algal bloom was suspected as the cause of the Florida Panhandle UME (NMFS, 2004; Flewelling *et al.*, 2005) in which at least 120 animals died. It is unclear what caused the Indian River Lagoon UME in which 39 animals died (NMFS, 2004).

In South Carolina, there was no apparent explanation for the increase in bottlenose dolphin strandings in 2000-2001 other than an increase in neonate strandings, although this increase was not significant across years. Formalin-fixed samples collected from fresh dead animals during 2000 and 2001 for histological analysis by the Armed Forces Institute of Pathology (Washington, DC) did not reveal related causes of death. Additionally, the number of human interaction cases for this period was not elevated.

Recent studies (Hohn, 1997; McLellan *et al.*, 2002; Gubbins *et al.*, 2003) suggest that bottlenose dolphin stock structure is more complicated than the previous concept of a single coastal migratory stock in the WNA (Scott *et al.*, 1988). The NOAA Fisheries now recognises seven management units of coastal bottlenose dolphins in the WNA (Marine Mammal Commission, 2003; Waring *et al.*, 2004). Bottlenose dolphins stranded in South Carolina are believed to be from two of these units, the SNCMU and the SCMU. While data were not available from bottlenose dolphins stranded in the North Carolina portion of the SNCMU (Cape Lookout, NC to Little River Inlet, SC) for this study, our results showed that strandings significantly increased in the autumn in the South Carolina portion (Little River Inlet, SC to Murrell's Inlet, SC) of the SNCMU suggesting an influx of migrating bottlenose dolphins, possibly from the north. In Virginia, bottlenose dolphins are nearly absent by mid-November but reappear in spring (Swingle, 1994; Barco *et al.*, 1999). Water temperature was negatively correlated with dolphin abundance in Virginia (Barco *et al.*, 1999) and has been suggested as a possible cue for migrations (Mead and Potter, 1990). Bottlenose dolphins were found in high abundance in the winter between Cape Hatteras, North Carolina and Cape Lookout, North Carolina in an aerial survey of marine mammals of the Southeast US continental shelf, although most of these appeared to be from the offshore morphotype of bottlenose dolphins (Garrison *et al.*, 2003). Counts of bottlenose dolphins from boat transect surveys conducted between 1995 and 1998 in the coastal waters between Little River Inlet, SC and Murrell's Inlet, SC also indicated a greater than an order of magnitude increase in abundance in late autumn

[2] 16 U.S.C. 1421 et seq. United States Congress. Marine Mammal Protection Act (MMPA) of 1972 as Amended.

(Young and Peace, 1999). Monthly aerial survey data conducted from 1997-2003 by SCDNR from Murrell's Inlet, SC to Port Royal Sound, SC indicated a nearly 1.5× increase in bottlenose dolphin sightings during the autumn compared to that of the spring and summer and nearly a three-fold increase from winter (SCDNR unpublished data). It is plausible, therefore, that some of the SNCMU dolphins may migrate south into South Carolina (SC) in late autumn.

The increase in bottlenose dolphin strandings in autumn from Murrell's Inlet, SC to Little River Inlet, SC (i.e. southern portion of the SNCMU) can be partially explained by the large proportion (42.1%) of neonate strandings. Our results show that taken as whole for the state of South Carolina, there exists a bimodal neonate stranding cycle in the spring and autumn (Fig. 4). However, the two management units differ if reviewed separately. While the SCMU shows a bimodal neonate stranding cycle (spring and autumn), the southern portion of the SNCMU shows a unimodal distribution, with most neonate strandings in the autumn (Fig. 5). Thayer *et al.* (2003) noted that neonate strandings occurred more frequently in the spring, mostly north of Cape Lookout, NC, with a secondary, smaller scale peak of neonate strandings occurring south of Cape Lookout, NC in the autumn. This secondary peak in neonate strandings in the autumn south of Cape Lookout, NC supports what is observed in the southern portion of the SNCMU. Further investigation into the neonate stranding patterns of the North Carolina portion of the SNCMU is needed to determine if this is characteristic of the management unit as a whole.

Although bottlenose dolphins exhibit year-round calving cycles, reproductive seasonality can vary over large geographic regions or between local dolphin populations (Urian *et al.*, 1996). On the east coast of the United States, a bimodal neonate seasonal distribution was noted from the Indian River Lagoon, Florida (Urian *et al.*, 1996), while unimodal distributions were noted for North Carolina (Thayer *et al.*, 2003), the west coast of Florida (Waring *et al.*, 2004) and along the Texas coast (Fernandez and Hohn, 1998).

Fernandez and Hohn (1998) and Thayer *et al.* (2003) caution against the use of stranding data as an indicator of reproductive seasonality, as mortality of neonates may lie outside of the true birthing dates. Data from our study showed that 61.5% of the stranded neonates that were <100cm in length stranded in the spring and autumn. Assuming these animals were near-term foetuses or stillbirths, this, along with a bimodal neonate stranding cycle, would support a bimodal reproductive cycle in South Carolina.

The determination of human-induced mortality of bottlenose dolphins is difficult to assess. Many carcasses were too decomposed or lacked entangling gear. As a result, the number of HI cases may be underestimated. The results of this seven year study were similar to those of the baseline study (McFee and Hopkins-Murphy, 2002) in that rope entanglements was the most common source of HI and in the percentage of HI cases observed (25.2%; Table 1). HI cases are less frequent than in North Carolina and Virginia (53% and 49%, respectively), but more frequent than in Georgia (12%; Waring *et al.*, 2004). Entanglements of bottlenose dolphins in the crab pot fishery appear to be the most prevalent source of fishery-related mortality in South Carolina (Burdett and McFee, 2004). Mortality in fishing operations is the most common source of anthropogenic mortality for small cetaceans (IWC, 1994; Read and Murray, 2000; Friedlander *et al.*, 2001; McLellan *et al.*, 2002), but the fishery source varies from state to state. For instance, in North Carolina and Virginia, gill net fisheries appear to be the leading cause of anthropogenic mortality for bottlenose dolphins (Steve *et al.*, 2001; Read *et al.*, 2003; Read *et al.*, 2004; Rossman and Palka, 2004). In South Carolina, gillnet entanglements are rare as there are few gillnet fisheries. A study of the ocean American shad (*Alosa sapidissima*) fishery in South Carolina found no mortality of bottlenose dolphins in this fishery (McFee *et al.*, 1996) and the fishery was closed on 1 January 2005 (ASMFC, 1999). During the current study, two of the five bottlenose dolphins that showed signs of net entanglements were from a single trammel net set conducted by SCDNR's Marine Division in the Wando River, South Carolina. This mortality incident was the first in 15 years of dedicated trammel net fishing by SCDNR (~11,250 sets) (B. Roumillat, pers. comm.).

It has been suggested that bottlenose dolphin calves and subadults are more susceptible to human interactions than adults (Wells and Scott, 1994; Reynolds *et al.*, 2000). In our study, this was especially true with males even though mean length by gender was lower for females. This was similar to observations during the baseline study (McFee and Hopkins-Murphy, 2002). Interestingly, five of the six bottlenose dolphins that were struck by boats were <175cm and the other was a subadult (227cm). Inexperience around boats by primiparous females with dependent calves has been hypothesised for lower calf survivorship and the calf could hinder the avoidance capabilities of both mother and calf (Nowacek *et al.*, 2001). Curiosity, feeding behaviours, socialisation and inexperience around boats and fishery operations may also increase the vulnerability of calves to anthropogenic mortality.

Results from this seven year study into stranding rates of bottlenose dolphins in South Carolina demonstrated the value of a long-term database. Additional data from this study substantiated a bimodal reproductive cycle in South Carolina and significant seasonal changes in stranding rates were more easily recognised than from the baseline data alone. Future studies to elucidate more local reproductive strategies should include photo-identification studies currently being conducted in Charleston, Bulls Bay and North Inlet, South Carolina. Also, bottlenose dolphin stranding data from the entire southern North Carolina management unit should be compared with the South Carolina management unit to determine stranding trends of a broader geographical range. Results from the human interaction analyses clearly demonstrate the need to continue the investigation of anthropogenic mortality of bottlenose dolphins as these analyses are relevant to management decisions in the protection and conservation of this species.

ACKNOWLEDGEMENTS

The authors would like to thank the many South Carolina marine mammal stranding network volunteers, veterinarians, local governments and beach patrols for their continued support and response to marine mammal strandings. We would also like to thank the reviewers of this paper: Pat Fair, Eric Zolman and Kathy Moore of NOS and the anonymous reviewers of the *Journal of Cetacean Research and Management*. The following people have been instrumental in the recovery of carcasses and response to marine mammal strandings and to the data collection and analysis of tissues: Lauren Beddia, Leslie Burdett, Heidi

Hinkledey, Jessie Stenftenagel and Eric Zolman of NOS and NOS volunteers; Tom Murphy, Charlotte Hope, Mark Spinks, Dean Cain and Al Segars of SCDNR; Rebecca Pugh and Michael Ellisor from the National Institute of Standards and Technology; and Tom Lipscomb from the Armed Forces Institute of Pathology.

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Date received: August 2005
Date accepted: December 2005