Abstract—Fisheries management actions taken to protect one species can have unintended, and sometimes positive, consequences on other species. For example, regulatory measures to reduce fishing effort in the winter gillnet fishery for spiny dogfish (*Squalus acanthias*) off North Carolina (NC) also led to decreases in the number of bycaught bottlenose dolphins (*Tursiops truncatus*). This study found that a marked decrease in fishing effort for spiny dogfish in NC also corresponded with a marked decrease in winter stranding rates of bottlenose dolphins with entanglement lesions ($P=0.002$). Furthermore, from 1997 through 2002, there was a significant positive correlation ($r^2=0.79$; $P=0.0003$) between seasonal bycatch estimates of bottlenose dolphins in gill nets and rates of stranded dolphins with entanglement lesions. With this information, stranding thresholds were developed that would enable the detection of those increases in bycatch in near real-time. This approach is valuable because updated bycatch estimates from observer data usually have a time-lag of two or more years. Threshold values could be used to detect increases in stranding rates, triggering managers immediately to direct observer effort to areas of potentially high bycatch or to institute mitigation measures. Thus, observer coverage and stranding investigations can be used in concert for more effective fishery management.

Effects of commercial fishing regulations on stranding rates of bottlenose dolphin (*Tursiops truncatus*)

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The occurrence of beach-cast or stranded marine animals has been used to indicate fishery-induced (i.e., bycatch) mortality of marine birds (Salzman, 1989), turtles (Caillouet et al., 1991; Epperly et al., 1996), and mammals (Forney et al., 2001; Friedlaender et al., 2001). Direct documentation of bycatch mortality is obtained by placing trained observers on commercial fishing vessels (Edwards and Perrin, 1993; Epperly et al., 1995), but limited resources allow for observation of only a small proportion of fishing trips and a few types of fisheries. Additionally, updated bycatch estimates can take years to become available, preventing real-time responses to significant changes in bycatch rates. Strandings of marine animals, therefore, can serve as the primary, and sometimes the only, evidence of current bycatch mortality. Gear is rarely present on stranded animals; however, entanglement lesions on the epidermis of cetaceans can help identify animals that have been captured incidentally by fishing gear (Kuiken et al., 1994; Read and Murray, 2000).

Early indications of bottlenose dolphin (*Tursiops truncatus*) bycatch mortality off North Carolina (NC) came from stranding data. From 1993 through 1996, 29% of the 230 stranded bottlenose dolphins recovered in NC exhibited signs of entanglement in fishing gear (Waring et al., 1997). Early observer data (1993–96) were inconsistent with stranding data because only one entanglement was documented in the observer program (Waring et al., 1997). As a result, observer coverage was expanded in 1997 to include more of the various ocean-side gillnet fisheries (Waring et al., 1999).

The annual estimated bycatch mortality in ocean gill nets from November 1995 through October 2000 confirmed high levels of mortality of bottlenose dolphins off NC. All but one observed entanglement was that of the coastal morphotype, which is morphologically and genetically dis-
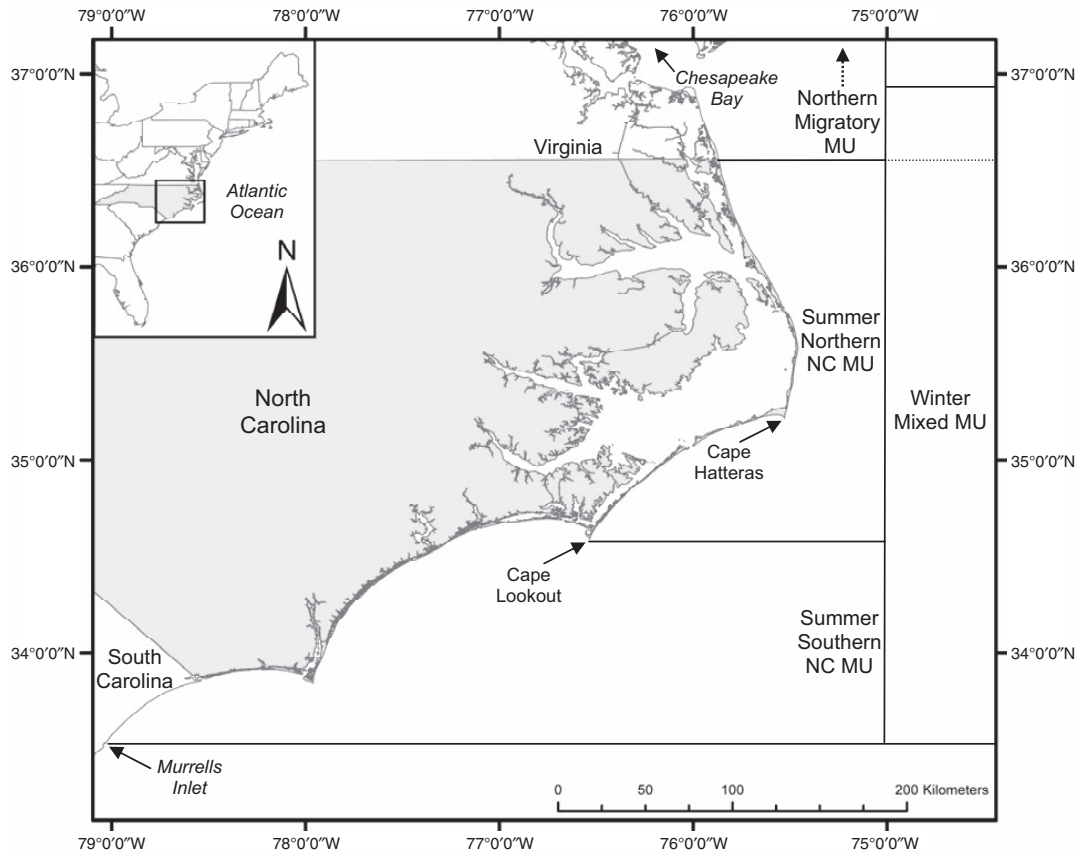
Figure 1

The coastal bottlenose dolphin (*Tursiops truncatus*) is divided into seasonal management units (MUs). During summer (May–October), two of the management units (MUs) occur off North Carolina (NC;) the northern NC MU and the southern NC MU. During winter (November–April), two summer MUs overlap with a third MU, the northern migratory MU, which occurs north of the Virginia-NC border during the summer. These three MUs are referred to collectively as the winter mixed MU (Waring et al., 2006). Solid horizontal lines represent latitudinal boundaries of MUs and does not imply offshore (i.e., longitudinal) distribution. The dashed horizontal line represents the northern boundary of the NC portion of the winter mixed MU.

tinct from the offshore morphotype (Mead and Potter, 1995; Hoelzel et al., 1998; Waring et al., 2002). The bycatch estimates for the coastal morphotype were stratified according to current stock structure of coastal bottlenose dolphins, which consists of seven seasonal management units (MUs) (Waring et al., 2002). Three of the MUs are seasonal off NC: the summer (May–October) northern NC MU, the summer southern NC MU, and the NC portion of the winter (November–April) mixed MU (see Fig. 1 for delineations of the units). Bycatch exceeded the potential biological removal (PBR) level (i.e., the sustainable anthropogenic mortality level) (MMPA 16 U.S.C. 1362 [20]; Barlow et al., 1995) for one of the two summer MUs and for the winter MU (Waring et al., 2002, 2006). During the summer, the annual estimated bycatch for the northern NC MU was 23 animals, exceeding the PBR level (20), and the annual estimated bycatch for the southern NC MU was zero, not exceeding the PBR level (10). For the winter mixed MU (NC

and VA submanagement units), the annual estimated bycatch was 180 animals, more than twice the PBR level (68). The majority of this bycatch (146 out of 180 animals) was attributed to the NC submanagement units (Rossman and Palka[1]). The spiny dogfish (FAO common name: picked dogfish) fishery was the primary contributor to the bycatch mortality in the winter mixed MU.

In 2005, new annual bycatch estimates, based on observer data from ocean gill nets from November 2000 through October 2002, became available (Rossman and Palka[1]; Waring et al., 2006). The new bycatch estimate for the summer northern NC MU decreased to eight animals per year and the new estimate for the NC win-

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[1] Rossman, M. C., and D. L. Palka. 2005. A review of coastal bottlenose dolphin bycatch mortality estimates in relation to the potential effectiveness of the proposed BDTRP. Bottlenose Dolphin Take Reduction Team Document No. 1-13-05F, 9 p. National Marine Fisheries Service, Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543.

ter mixed MU decreased to 19 animals per year; both estimates were below their corresponding PBR level. Reductions in bycatch estimates were attributed to a reduction in fishing effort, as measured in landings. In particular, fishing effort was drastically reduced for spiny dogfish, which was listed as overfished by the National Marine Fisheries Service (NMFS) in 1998 (Federal Register, 1998). Fishery Management Plans (FMPs) were implemented by NMFS for federal waters (Federal Register, 2000a, 2000b), and by state agencies for state waters (ASMFC[2]), to reduce fishing effort.

The purpose of this study was to conduct a *post-hoc* analysis of bottlenose dolphin strandings in NC in relation to fisheries bycatch estimates and spiny dogfish landings. First, the frequency of stranded dolphins exhibiting signs of fishery entanglement was examined to determine if this frequency reflected corresponding levels of estimated dolphin bycatch. Second, it was hypothesized that the frequency of those strandings would decrease concomitant with a reduction in spiny dogfish landings, but that the frequency of stranded dolphins without signs of entanglement would not change. Lastly, two methods for establishing stranding threshold levels were evaluated to determine if they could be used in real-time to detect increases in fisheries bycatch before revised bycatch estimates are available or when observer programs do not exist.

Materials and methods

Fishing-effort data

Monthly landings data on spiny dogfish caught in commercial ocean gill nets off NC from November 1997 through April 2005 were obtained through the Trip Ticket Program of the North Carolina Division of Marine Fisheries (NCDMF). These data were used to determine the timing and magnitude of effort reduction in the spiny dogfish fishery for comparison with the frequency of bottlenose dolphin strandings.

Stranding data

Data were derived from ocean-side bottlenose dolphin strandings in NC between November 1997 and April 2005 (n=580) and were stratified by season: winter (November–April) and summer (May–October). These seasons reflect both the seasonal definition for bottlenose dolphin MUs and the two commercial fishing seasons for spiny dogfish as defined by the FMP. November 1997 was chosen as the beginning of the winter season because this month marked the beginning of the first spiny

dogfish season in NC (November–April) for which there was consistent coast-wide coverage of the NC shore for strandings. April 2005 was the end of the last season for which landings data were available for this study.

All reported stranded bottlenose dolphins were evaluated for signs of human interaction (HI) and then classified as HI-yes (i.e., with signs of HI), HI-no (i.e., no signs of HI), or HI-CBD (could not be determined) (Kuiken et al., 1994; Read and Murray, 2000). Stranded dolphins categorized as HI-yes were further stratified as fishery interaction (HI-FI) (e.g., entanglement lesions or gear present) or HI-other (e.g., mutilation, propeller wounds evident). All stranded dolphins classified as HI-other in our data set (n=12) were mutilated but too decomposed to determine if entanglement lesions were also present; therefore, they were treated separately. Animals were categorized as HI-CBD when it could not be determined whether or not the animal exhibited signs of HI because of factors such as decomposition, significant damage by scavengers, or lack of experience on the part of the stranding responder.
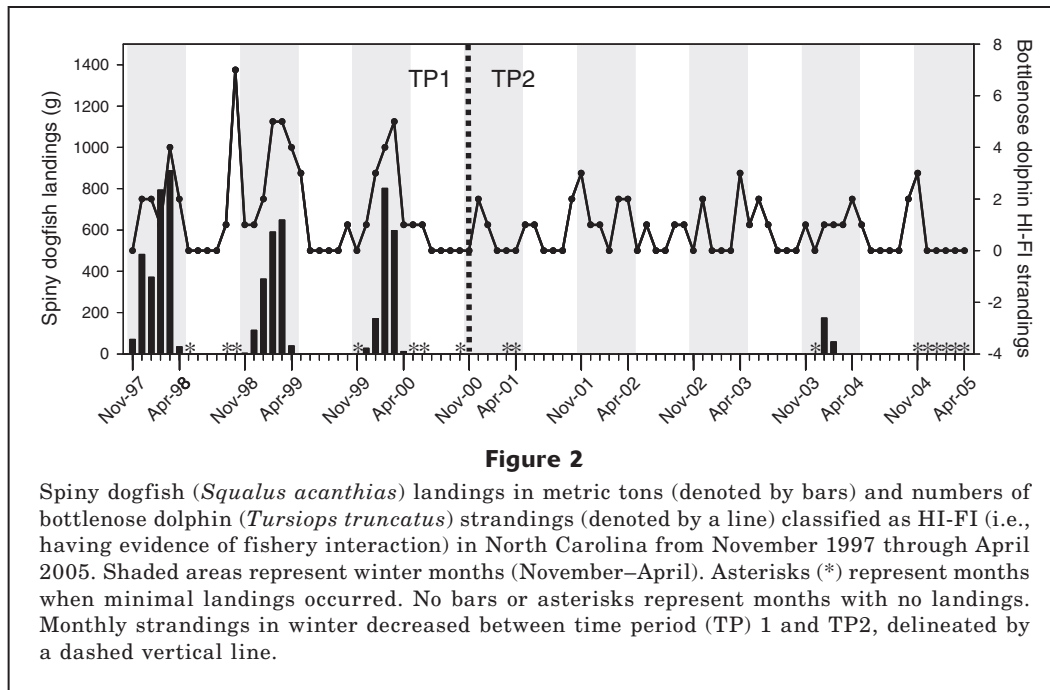
Several criteria were established for the stranding records used in this study. Animals genetically confirmed as being the offshore morphotype (n=6) were excluded so that comparisons could be made to bycatch data of coastal bottlenose dolphins. Animals <119 cm in total length (n=109), presumed to be neonates (Fernandez and Hohn, 1998), were also excluded to prevent a bias from the high natural mortality rates of neonates during the spring and fall birthing seasons (Hohn, 1980; Thayer et al., 2003). Unless they were classified as adults, stranded dolphins for which no total length was recorded were excluded (n=21). Dolphins removed from gear other than a gill net (e.g., trawlers, crab pots, hook-and-line gear) were also excluded (n=5).

Stranding rates through time were examined in relation to bycatch estimates and changes in fishing effort in the spiny dogfish fishery. Regression analyses (SAS, vers. 9.1, SAS Inst., Inc., Cary, NC) were used to compare the number of HI-FI strandings per season (winter and summer) per year to the corresponding bycatch estimates for ocean gill nets provided in Rossman and Palka.[1] Because stranding rates can never be less than zero, the regression line was forced through the origin. Rank-sum tests for each HI category were used to determine if the mean number of bottlenose dolphin strandings per month was different between the first time period (TP1: November 1997–October 2000), when bycatch estimates were greater than the PBR levels, and the second time period (TP2: November 2000–April 2005), when bycatch estimates were either less than PBR levels or were unknown. For the rank-sum tests, only winter data (November–April) were used after a preliminary investigation of spiny dogfish landings revealed that the fishery operates only off NC during those months.

Stranding thresholds

Two methods were used to calculate stranding thresholds. One calculation emulated a method currently

Figure 2

Spiny dogfish (*Squalus acanthias*) landings in metric tons (denoted by bars) and numbers of bottlenose dolphin (*Tursiops truncatus*) strandings (denoted by a line) classified as HI-FI (i.e., having evidence of fishery interaction) in North Carolina from November 1997 through April 2005. Shaded areas represent winter months (November–April). Asterisks (*) represent months when minimal landings occurred. No bars or asterisks represent months with no landings. Monthly strandings in winter decreased between time period (TP) 1 and TP2, delineated by a dashed vertical line.

used to help detect unusual mortality events (UME) for overall strandings by the Marine Mammal Health and Stranding Response Program (Wilkinson, 1996) and was termed the "UME threshold method." It was calculated as the mean number of strandings (in this case HI-FI) per month plus two standard deviations (SD). Stranding thresholds were calculated for each bottlenose dolphin MU in NC. For the NC winter mixed MU, data collected in TP2 were used. The stranding threshold was then compared to monthly HI-FI strandings during TP1 and TP2 to determine whether it serves as an adequate indicator of relative bycatch levels. For the summer northern NC MU, the stranding threshold also was calculated with data collected in TP2. For the summer southern NC MU, the stranding threshold was calculated with data from TP1 and TP2 because estimated bycatch levels never exceeded PBR levels in TP1.

The second method that was investigated to establish stranding threshold levels was based on the regression analysis of seasonal HI-FI strandings and estimated bycatch. This method used the maximum likelihood estimates to calculate the predicted values of bycatch and the 68% confidence intervals (CIs) and 95% CIs. The CI values of predicted bycatch rates were then evaluated to determine if they would be appropriate for identifying periods of elevated bycatch.

Results

From November 1997 through April 2005, NC gillnetters landed 6310 t (metric tons) of spiny dogfish. Landings occurred almost entirely in winter (November–April),

and less than 0.1% occurred in other months (Fig. 2). More than 96% of all landings occurred before November 2000 (TP1). During winter, mean landings were 2020 t (SD=561) per fishing season during TP1 and 49 t (SD=104) during TP2. After November 2000, 96% of these landings occurred during the 2003–04 fishing year.

During the same time period (November 1997 through April 2005), 439 bottlenose dolphin strandings met the criteria for inclusion in this study. Overall, more strandings occurred during winter than summer in each HI category (Table 1). For all years, HI-CBD strandings comprised 60% of winter (range: 45–69%) and 52% of summer (range: 25–65%) totals (HI-yes, HI-no, and HI-CBD). HI-FI strandings comprised 22% of winter (range: 11–35%) and 21% of summer (range: 11–33%) totals for all years. However, of strandings for which it was possible to determine whether an interaction occurred (HI-FI, HI-other, and HI-no), HI-FI strandings comprised 56% (range: 27–75%) of winter and 44% (range: 20–57%) of summer totals for all years.

Rates of HI-FI strandings had a similar pattern to that of bycatch estimates and effort in the spiny dogfish fishery. There was a significant positive relationship between the number of HI-FI strandings and the bycatch estimate per season ($r^2=0.79$, $P=0.0003$). Additionally, the mean number of winter HI-FI strandings per month was significantly greater during TP1 than TP2 ($P=0.001$) (Table 2). There was no significant difference in winter HI-no or HI-CBD strandings between TP1 and TP2. HI-FI strandings showed a monthly periodicity similar to that for fishing effort during TP1 (Fig. 2); four to six animals were recovered per month during the height of the fishery, compared to generally two or

Table 1

Numbers of bottlenose dolphin (*Tursiops truncatus*) strandings recovered ocean-side in North Carolina between November 1997 and April 2005. Strandings are listed by winter (W) (November–April), summer (S) (May–October), and all months (T), and categorized according to the human interaction (HI) classification: HI-yes (evidence of human interaction including HI-FI [evidence of fishery interaction], and HI-other [evidence of mutilation, propeller wounds]), HI-no (no signs of HI), and HI-CBD (human interaction could not be determined). For this study, data were not available (n/a) for the 2005 summer season (May–October) and thus totals for 2005 are for a partial year, denoted by an asterisk.

| | HI-yes | | | | | | HI-no | | | HI-CBD | | | Total | | |
| | HI-FI | | | HI-other | | | | | | | | | | | |
	W	S	T	W	S	T	W	S	T	W	S	T	W	S	T
1998 (Nov 97–Oct 98)	11	8	19	4	0	4	7	6	13	18	14	32	40	28	68
1999 (Nov 98–Oct 99)	18	4	22	0	0	0	6	5	11	27	17	44	51	26	77
2000 (Nov 99–Oct 00)	14	2	16	2	3	5	7	5	12	36	8	44	59	18	77
2001 (Nov 00–Oct 01)	3	4	7	1	0	1	7	3	10	17	7	24	28	14	42
2002 (Nov 01–Oct 02)	9	3	12	0	0	0	6	4	10	32	10	42	47	17	64
2003 (Nov 02–Oct 03)	5	4	9	1	1	2	6	4	10	24	3	27	36	12	48
2004 (Nov 03–Oct 04)	6	3	9	0	0	0	2	4	6	18	9	27	26	16	42
2005 (Nov 04–Apr 05)*	3	n/a	n/a	0	n/a	n/a	6	n/a	n/a	12	n/a	n/a	21	n/a	n/a
Total	69	28	97	8	4	12	47	31	78	184	68	252	308	131	439

less during TP2. One notable exception was in October 1998, when seven strandings occurred but minimal spiny dogfish landings were reported. Monthly HI-no and HI-other strandings showed no seasonal pattern across months and years (Fig. 3). Monthly HI-CBD strandings, however, showed a similar pattern to HI-FI strandings during TP1 and continued to show some periodicity afterwards, with increases primarily during winter months.

With the UME threshold method, the stranding threshold for HI-FI strandings for the NC winter mixed MU was 2.95. This threshold was exceeded 7 out of 18 months of the winter spiny dogfish fishing seasons during TP1, or 39% of the time (Fig. 4). During TP2, the threshold was exceeded as a result of bycatch in other fisheries in three months, or only 10% of the time: November 2001 from strandings south of Cape Lookout; April 2003 from strandings north of Cape Hatteras, and November 2004 from strandings south of Cape Lookout.

During summer, the stranding threshold produced by the UME threshold method for the northern NC MU was 1.77, and the stranding threshold for the southern NC MU was 2.19. The stranding threshold was exceeded three times for the northern NC MU, once during TP1 in May 1999 (6% of the time; 1 out of 18 months) and twice during TP2 in October 2001 and October 2004 (8% of the time; 2 out of 24 months) (Fig. 4). For the southern NC MU, the stranding threshold was exceeded only once, in October 1998 during TP1 (2% of the time; 1 out of 42 months) (Fig. 4).

With the use of the regression equation, the 68% CI and 95% CI values had wide bounds around the predicted bycatch estimates

Table 2

Mean (standard deviation [SD]) of monthly bottlenose dolphin (*Tursiops truncatus*) strandings by human interaction (HI) categories in the winter (November–April) during time period (TP) 1 (November 1997–October 2000) (n=18) and TP2 (November 2000–April 2005) (n=30). The HI categories are as follows: HI-FI (evidence of fishery interaction), and HI-other (evidence of mutilation, propeller wounds), HI-no (no signs of HI), and HI-CBD (human interaction could not be determined). For this study, data were not available (n/a) for the 2005 summer season (May–October) and thus totals for 2005 are for a partial year, denoted by an asterisk.

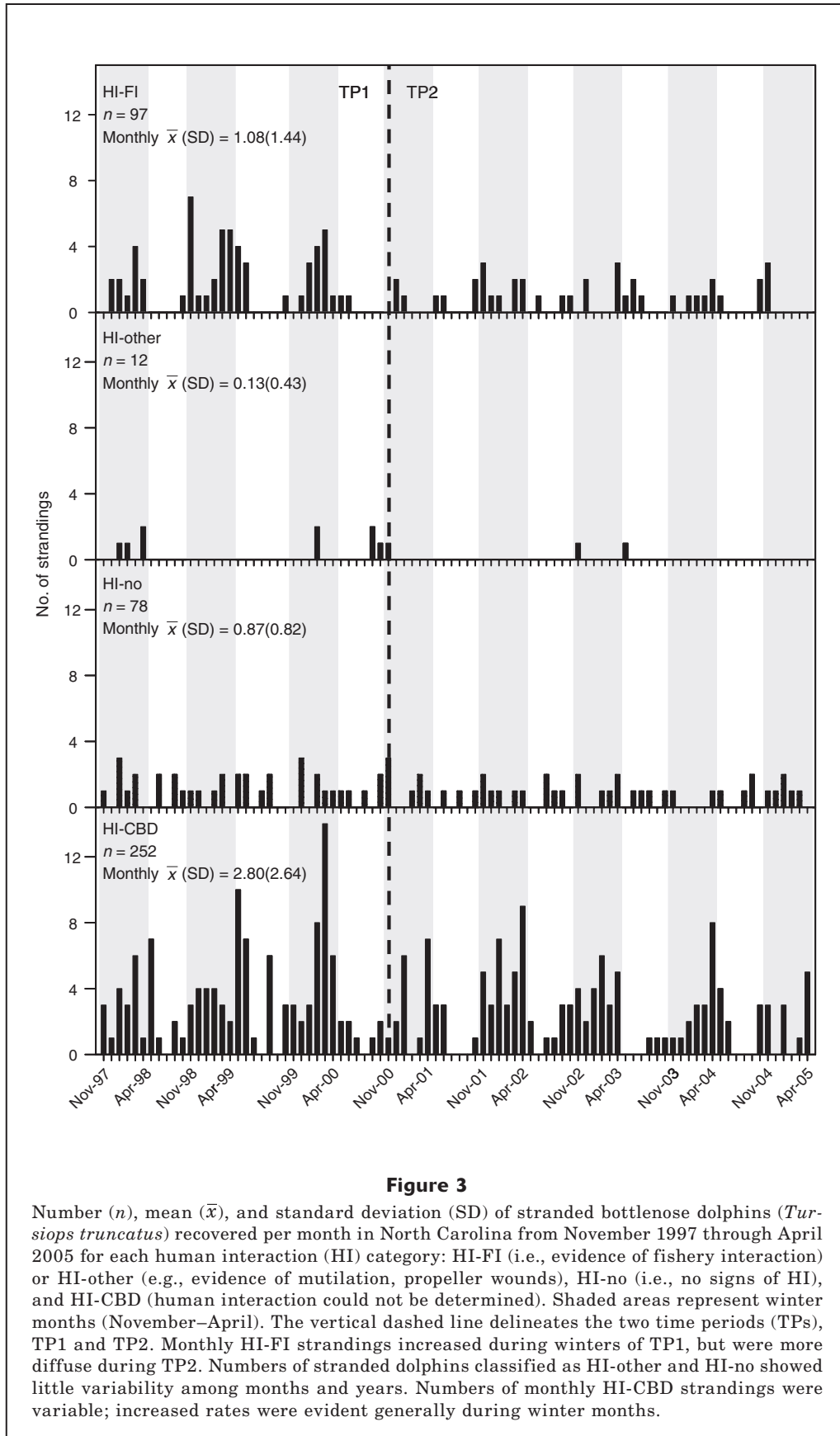| HI category	Time period	Mean (SD) per month	*P*-value
HI-FI	TP1	2.39 (1.72)	*0.001
HI-FI	TP2	0.87 (1.04)	
HI-other	TP1	0.33 (0.69)	0.11
HI-other	TP2	0.07 (0.25)	
HI-no	TP1	1.11 (1.02)	0.54
HI-no	TP2	0.90 (0.80)	
HI-CBD	TP1	4.50 (3.31)	0.16
HI-CBD	TP2	3.43 (2.45)	

Figure 3

Number (*n*), mean ($\bar{x}$), and standard deviation (SD) of stranded bottlenose dolphins (*Tursiops truncatus*) recovered per month in North Carolina from November 1997 through April 2005 for each human interaction (HI) category: HI-FI (i.e., evidence of fishery interaction) or HI-other (e.g., evidence of mutilation, propeller wounds), HI-no (i.e., no signs of HI), and HI-CBD (human interaction could not be determined). Shaded areas represent winter months (November–April). The vertical dashed line delineates the two time periods (TPs), TP1 and TP2. Monthly HI-FI strandings increased during winters of TP1, but were more diffuse during TP2. Numbers of stranded dolphins classified as HI-other and HI-no showed little variability among months and years. Numbers of monthly HI-CBD strandings were variable; increased rates were evident generally during winter months.

(Fig. 5). For example, the predicted bycatch for two HI-FI strandings per season was 14 animals, but may have equaled between −23 to 51 animals (68% CI) or −65 to

93 animals (95% CI). The lower CI bounds are negative statistically; however, in reality they cannot be less than the number of HI-FI strandings recovered.
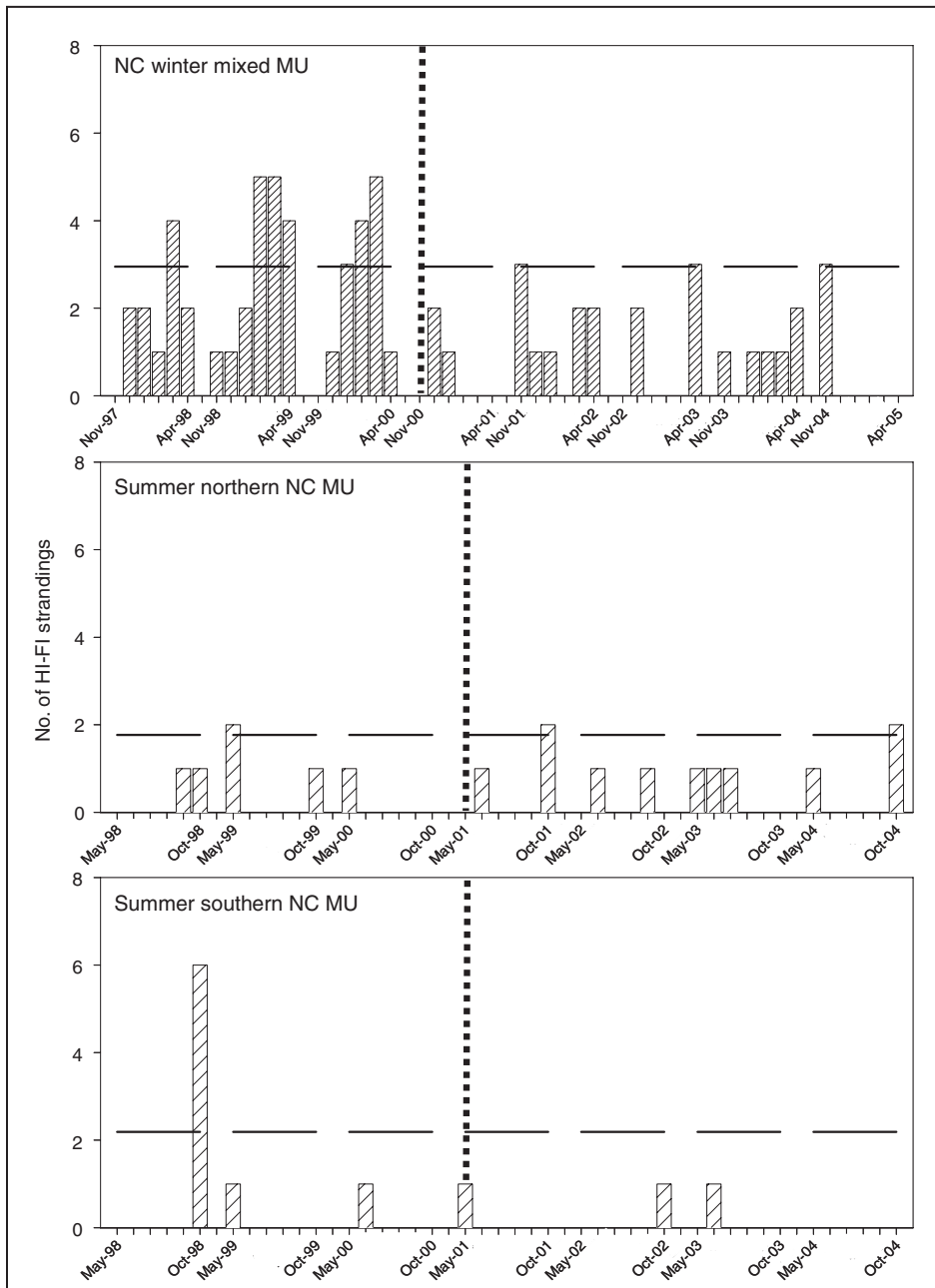

Figure 4

Number of bottlenose dolphin (*Tursiops truncatus*) strandings classified as HI-FI (i.e., having evidence of fishery interaction) per month and the stranding threshold (mean + 2 standard deviations; horizontal dashed lines) by seasonal management unit (MU) in North Carolina (NC). During winter (November–April), the threshold was exceeded seven out of 18 months during time period (TP) 1 and only three out of 30 months during TP2. During summer (May–October), the threshold was exceeded once during TP1 and twice during TP2 for the northern NC MU, and once during TP1 for the southern NC MU. The vertical dashed lines indicate separation between TP1 and TP2.
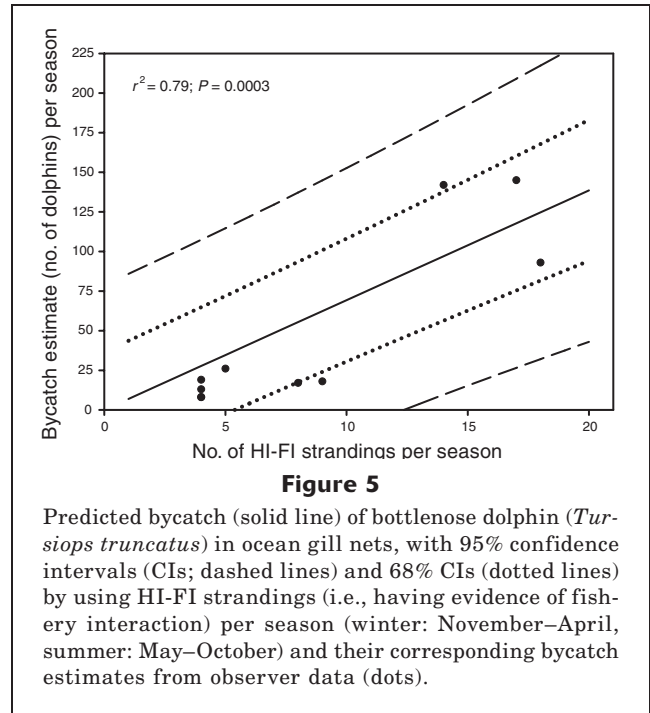
Discussion

This study provides a unique situation in which three concurrent data sets can be used to test the model of using strandings as an indicator of fishery bycatch. It was demonstrated that fisheries regulations can affect the level of dolphin bycatch mortality and that increases in bycatch mortality can be detected in near real-time by monitoring changes in stranding rates. There was a significant positive correlation between seasonal HI-FI strandings and bycatch estimates of bottlenose dolphins in gill nets. That correlation was mirrored by a marked decrease in winter stranding rates of bottlenose dolphins with entanglement lesions coincident with a marked decrease in the fishing effort for spiny dogfish off NC.

Many factors can influence the rate of deposition of dead dolphins on beaches. For example, the overall increases in the number of strandings during winter compared to summer are likely due, in part, to an increase in local bottlenose dolphin abundance when three MUs overlap off the NC coast (Waring et al., 2006). Within winter, stranding rates of HI-FI strandings were further influenced by changes in fishing effort for spiny dogfish between TP1 and TP2 (Table 2) rather than to changes in environmental factors such as wind direction and currents. This finding was consistent with the reduction in bycatch estimates (Rossman and Palka[1]) and the nonsignificant difference for HI-**no** strandings between the two time periods. There were reductions,

albeit insignificant, in the mean strandings per month for the HI-other and HI-CBD categories between TP1 and TP2. However, stranding rates for these categories could have been influenced by bycatch reductions. All stranded dolphins categorized as HI-other were found either with missing appendages, cuts on the abdomen, or both, but they were too decomposed for a determination of whether or not entanglement lesions were present. Fishermen occasionally cut appendages from a marine mammal to aid in the removal of the animal from their nets, or they slit the abdomen to aid in the sinking of the carcass, or do both (Kuiken et al., 1994; Read and Murray, 2000). It is likely, therefore, that a portion of the HI-other stranded dolphins were indeed entangled in fishing gear because of the mutilations they exhibited. Of the HI-CBD strandings, an unknown proportion was likely caused by fishing interaction, but decomposition obscured evidence of entanglement lesions. Reductions in bycatch would decrease rates of strandings categorized as HI-other and HI-CBD because of the portion of them that were really HI-FI but could not be identified as such.

Because the rate of HI-FI strandings is proportional to the number of bycaught animals, stranding rates may be used as a proxy to detect increases in bycatch mortality and to determine a threshold for triggering a management response. The CI values calculated with the regression analyses were too broad for this method to be useful for setting threshold values even though the *r*-squared (coefficient of determination) value was high (0.79). The UME threshold method proved more useful; the stranding threshold value for the NC winter mixed MU adequately identified elevated stranding levels during months when the spiny dogfish fishery was most active and bycatch levels were highest. Furthermore, with the UME threshold method we were able to identify other periods of elevated strandings during winter and summer.

The stranding thresholds calculated by the UME threshold method, while informative, have some limitations. First, stranding data between October 2002 and April 2005 were included in the calculations, but the corresponding bycatch estimates were not yet available. If new bycatch estimates for that time period exceeded PBR levels, then stranding thresholds would need to be recalculated after eliminating the corresponding stranding data. New thresholds may result in the identification of other months that exceed the revised stranding threshold because the current threshold would be biased upward. Another limitation of a stranding threshold is the level at which increased bycatch is apparent as HI-FI strandings. The bycatch estimate for years with an active spiny dogfish fishery was more than 7.5 times greater than bycatch estimates for years after an active fishery (Rossman and Palka[1]); our method of calculating a threshold may be too conservative in that it may not detect increases in strandings soon enough. Alternative methods to determine thresholds may be more sensitive and could be investigated by using this or a similar data set that

Figure 5

Predicted bycatch (solid line) of bottlenose dolphin (*Tursiops truncatus*) in ocean gill nets, with 95% confidence intervals (CIs; dashed lines) and 68% CIs (dotted lines) by using HI-FI strandings (i.e., having evidence of fishery interaction) per season (winter: November–April, summer: May–October) and their corresponding bycatch estimates from observer data (dots).

has periods of estimated bycatch that are greater and lesser than the PBR level.

Once an appropriate threshold is established and exceeded, a series of response actions can be triggered, as is done for UMEs (Wilkinson, 1996). Most importantly, active fisheries in the area would need to be identified. The possibilities for response actions then would vary from immediately increasing observer coverage in these fisheries to implementing emergency fishing regulations to reduce mortality (MMPA 16 U.S.C. 1387[118]) such as gear modifications, time and area closures, or limited soak durations. The advantage of an increase in observer coverage is to not only increase the precision of the bycatch estimate but to also document fishing practices and determine if practices have changed in a way that may be affecting the level of bycatch.

Stranding data provide valuable information about fisheries bycatch if there is consistent, thorough determination of human interaction and comprehensive coverage of shorelines to establish baseline data and to detect changes. For example, stranding data have served as indicators of bycatch in fisheries that do not have federal observer coverage, such as crab-pot, stop-net, pound-net, and inshore gillnet fisheries (Steve et al., 2001; Waring et al., 2002).

Additionally, stranding data provide additional information about bycatch in gillnet fisheries that have low observer coverage. Although observers have not documented a bottlenose dolphin entanglement in the gillnet fishery for spot (FAO name: spot croaker; *Leiostomus xanthurus*), stranding data indicated that bycatch had occurred. In 1997 and 1998, more than 50% of

stranded bottlenose dolphins that were found spatially and temporally concurrent with the spot fishery exhibited entanglement lesions (Friedlaender et al., 2001). In the current study, stranding thresholds were exceeded twice coincident in time (October and November) and place (south of Cape Lookout) with the typical gillnet season for spot (Steve et al., 2001), spanning both MU seasons. The disparity between bycatch and stranding data likely is due, in part, to low observer effort in nearshore waters of southern NC where the spot fishery is most active (Rossman and Palka[1]). In 2006, NMFS implemented an Alternative Platform Observer Program in NC whereby observers use an independent vessel to find and observe gill nets fished from small boats, which are commonly used in nearshore waters (Kolkmeyer et al., 2007) but difficult for traditional observers to get onboard. There is no observer program, however, for recreational gill nets, which are not regulated by the MMPA (MMPA 16 U.S.C. 1362[20]) but are commonly used in NC to target spot (NCMFC, 2003); thus, it is not known if or at what level bycatch occurs in the recreational fishery. Given the rate of HI-FI strandings, it is reasonable to assume that the PBR level was approached or exceeded because of mortality in the spot fishery during some years. However, one importance of a threshold value is to represent periods when fishery-related mortality does not exceed levels the population can sustain (i.e., PBR levels). In the case of the spot fishery, it is likely that the threshold values used in the present study are too high. Establishing threshold values is an iterative process, whereby values are adjusted according to changes in either PBR or bycatch estimates.

Management actions for the spiny dogfish fishery had unintentional but beneficial consequences on the bycatch of bottlenose dolphins. State and federal regulations severely decreased fishing effort off the NC coast (Federal Register, 2000b; ASMFC[2]), essentially closing the NC fishery in November 2000. For the 2003–04 season, NC was allowed a 227-t quota of spiny dogfish from state waters, about 7% of the average annual landings in NC before November 2000. Fishing effort occurred almost exclusively in January and February of 2004. Only two HI-FI stranded dolphins occurred in these months, one of which was wrapped in a large-mesh gill net (20.3-cm stretch mesh) more indicative of the striped bass (*Morone saxatilis*) fishery than spiny dogfish fishery (Steve et al., 2001). No bycatch was reported by federal observers on fishing vessels during the 2003–04 spiny dogfish fishery off NC (Rossman and Palka[1]). The soak times were shorter in the 2003–04 season than during previous years (Rossman and Palka[1]) due to trip limits imposed by the NCDMF and these likely contributed to a lower bycatch rate. Quota shares were not allocated on a state-by-state basis for the next fishing year (May 2004–April 2005) (ASMFC[2]) and, as a result, landings of spiny dogfish in NC were almost nonexistent.

Independently, managers enacted fisheries regulations for spiny dogfish that inadvertently decreased bottle-

nose dolphin bycatch. The opposite situation conceivably could occur; that is, fisheries regulations could alter fishing practices or effort in a manner that could increase dolphin bycatch. Gillnetters in NC are dynamic, altering their fishing practices in response to a variety of factors including changes in fishery regulations (Steve et al., 2001). Thus, researchers and managers need to be proactive, working towards managing species as an interrelated community and considering how regulations for one species may affect others.

These analyses indicate that, at least in some situations, strandings can serve as a near real-time indicator of fishery bycatch. Absolute estimates of bycatch mortality must be obtained using observer data, but the multi-year time lag associated with obtaining those estimates prevents real-time mitigation of that mortality. Near real-time detection of increased bycatch can also be used to direct observer effort to areas of potentially high bycatch. Thus, observer coverage and stranding investigations can be used in concert for more effective management.

Acknowledgments

Literature cited

Barlow, J., S. L. Swartz, T. C. Eagle, and P. R. Wade.
    1995.   U.S. Marine Mammal Stock Assessments: Guidelines for Preparation, Background, and a Summary of the 1995 Assessments.   NOAA Tech. Memo. NMFS-OPR-95-6, 73 p.
Caillouet, C. W., Jr., M. J. Duronslet, A. M. Landry Jr., D. B. Revera, D. J. Shaver, K. M. Stanley, R. W. Heinly, and E. K. Stabenau.
    1991.   Sea turtle strandings and shrimp fishing effort in the northwestern Gulf of Mexico, 1986–89.   Fish. Bull. 89:712–718.
Edwards, E. F., and C. Perrin.
    1993.   Effects of dolphin group type, percent coverage, and fleet size on estimates of annual dolphin mortality derived from 1987 U.S. tuna-vessel observer data.   Fish. Bull. 91:628–640.

Epperly, S. P., J. Braun, A. J. Chester, F. A. Cross, J. V. Merriner, and P. A. Tester.
> 1995. Winter distribution of sea turtles in the vicinity of Cape Hatteras and their interactions with the summer flounder trawl fishery. Bull. Mar. Sci. 56:547–567.

Epperly, S. P., J. Braun, A. J. Chester, F. A. Cross, J. V. Merriner, P. A. Tester, and J. H. Churchill.
> 1996. Beach strandings as an indicator of at-sea mortality of sea turtles. Bull. Mar. Sci. 59:289–297.

Federal Register.
> 1998. Magnuson-Stevens Act provisions; overfished fishery for spiny dogfish. Notification of an overfished fishery. Federal Register 63(69):17820–17821. Office of the Federal Register, National Archives and Records Administration (NARA), College Park, MD.
> 2000a. Fisheries of the northeastern United States; spiny dogfish fishery management plan. Final rule. Federal Register 65(7):1557–1571. Office of the Federal Register, NARA, College Park, MD.
> 2000b. Fisheries of the northeastern United States; spiny dogfish fishery. 2000 specifications. Interim final rule. Federal Register 65(87):25887–25891. Office of the Federal Register, NARA, College Park, MD.

Fernandez, S., and A. A. Hohn.
> 1998. Age, growth, and calving season of bottlenose dolphins, *Tursiops truncatus*, off coastal Texas. Fish. Bull. 96:357–365.

Forney, K. A., S. R. Benson, and G. A. Cameron.
> 2001. Central California gillnet effort and bycatch of sensitive species, 1990–1998. *In* Seabird bycatch: trends, roadblocks, and solutions (E. F. Melvin, and J. K. Parrish, eds.), p. 141–160. Univ. Alaska Sea Grant College Program, Fairbanks, AK.

Friedlaender, A. S., W. A. McLellan, and D. A. Pabst.
> 2001. Characterising an interaction between coastal bottlenose dolphins (*Tursiops truncatus*) and the spot gillnet fishery in southeastern North Carolina, USA. J. Cetacean Res. Manag. 3:293–303.

Hoelzel, A. R., C. W. Potter, and P. B. Best.
> 1998. Genetic differentiation between parapatric 'near-shore' and 'offshore' populations of the bottlenose dolphin. Proc. R. Soc. Lond. 265:1177–1183.

Hohn, A. A.
> 1980. Age determination and age related factors in the teeth of western north Atlantic bottlenose dolphins. Sci. Rep. Whales Res. Inst. 32:39–66.

Kolkmeyer, T., B. Guthrie, B. L. Byrd, and A. A. Hohn.
> 2007. Report on the alternative platform observer program in North Carolina: March 2006 to March 2007. NOAA Tech. Memo. NMFS-SEFSC-558, 20 p.

Kuiken, T., V. R. Simpson, C. R. Allchin, P. M. Bennett, G. A. Codd, E. A. Harris, G. H. Howes, S. Kennedy, J. K. Kirkwood, R. J. Law, N. R. Merrett, and S. Phillips.
> 1994. Mass mortality of common dolphins (*Delphinus delphis*) in south west England due to incidental capture in fishing gear. Vet. Rec. 134:81–89.

Mead, J. G., and C. W. Potter.
> 1995. Recognizing two populations of the bottlenose dolphin (*Tursiops truncatus*) off the Atlantic coast of North America: Morphological and ecological considerations. Int. Mar. Biolog. Res. Inst. Rep. 5:31–44. National Museum of Natural History, Smithsonian Institution, Washington, DC.

NCMFC (North Carolina Marine Fisheries Commission).
> 2003. North Carolina fisheries rules for coastal waters, 297 p. North Carolina Department of Environment and Natural Resources, North Carolina Division of Marine Fisheries, Morehead City, NC.

Read, A. J., and K. T. Murray.
> 2000. Gross evidence of human-induced mortality in small cetaceans. NOAA Tech. Memo. NMFS-OPR-15, 21 p.

Salzman, J. E.
> 1989. Scientists as advocates: the Point Reyes Bird Observatory and gill netting in central California. Conserv. Biol. 3:170–180.

Steve, C., J. Gearhart, D. Borggaard, L. Sabo, and A. A. Hohn.
> 2001. Characterization of North Carolina commercial fisheries with occasional interactions with marine mammals. NOAA Tech. Memo. NMFS-SEFSC-458, 57 p.

Thayer, V. G., A. J. Read, A. S. Friedlaender, D. R. Colby, A. A. Hohn, W. A. McLellan, D. A. Pabst, J. L. Dearolf, N. I. Bowles, J. R. Russell, and K. A. Rittmaster.
> 2003. Reproductive seasonality of western Atlantic bottlenose dolphins off North Carolina, USA. Mar. Mamm. Sci. 19:617–629.

Waring, G. T., E. Josephson, C. P. Fairfield, and K. Maze-Foley (eds.).
> 2006. Bottlenose dolphin (*Tursiops truncatus*): western North Atlantic coastal stock. *In* U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—2005. NOAA Tech. Memo. NMFS-NE-194, p. 89–99.

Waring, G. T., D. L. Palka, P. J. Clapham, S. Swartz, M. C. Rossman, T. V. N. Cole, L. J. Hansen, K. D. Bisack, K. D. Mullin, R. S. Wells, D. K. Odell, and N. B. Barros.
> 1999. Bottlenose dolphin (*Tursiops truncatus*): western North Atlantic coastal stock. *In* U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—1999, p. 128–135. NOAA Tech. Memo. NMFS-NE-153, 187 p.

Waring, G. T., D. L. Palka, K. D. Mullin, J. H. W. Hain, L. J. Hansen, and K. D. Bisack.
> 1997. Bottlenose dolphin (*Tursiops truncatus*): western North Atlantic coastal stock. *In* U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—1996. NOAA Tech. Memo. NMFS-NE–114, p. 128–133.

Waring, G. T., J. M. Quintal, and C. P. Fairfield (eds.).
> 2002. Bottlenose dolphin (*Tursiops truncatus*): western North Atlantic coastal stock. *In* U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—2002. NOAA Tech. Memo. NMFS-NE-169, p. 169–180.

Wilkinson, D. M.
> 1996. National contingency plan for response to unusual marine mammal mortality events. NOAA Tech. Memo. NMFS-OPR-9, 188 p.