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Differential Risk of Bottlenose Dolphin (*Tursiops truncatus*) Bycatch in North Carolina, USA

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Abstract

Common bottlenose dolphins (*Tursiops truncatus*) in North Carolina (NC) are vulnerable to fisheries bycatch (fisheries interactions [FI]), particularly in gillnets. Although observed bycatch is relatively rare, strandings with evidence of FI are common and can be used to evaluate relative levels of and influences on bycatch. Strandings from 1997 through 2012 that had evidence of FI (n = 191) or had no evidence of any type of human interaction (n = 170) were evaluated to assess effects of possible predictor variables (i.e., sex, age-class, season, area, and time period [TP]) on whether a stranding was FI (bycatch risk). Due to sample size constraints, contingency tables assessed variables singularly, and significant variables were used in a Generalized Linear Model. Bycatch risk varied among three sequential TPs with a significant decrease between TP1 and TP2 coincident with regulations that effectively closed the NC spiny dogfish (*Squalus acanthias*) gillnet fishery. Bycatch risk increased slightly during TP3 despite implementation of the Bottlenose Dolphin Take Reduction Plan, perhaps due to regulatory changes allowing for increased spiny dogfish effort. During TP2-3, more male than female strandings were recovered (p = 0.0224), but sex did not affect bycatch risk. Age-class (p < 0.0001) and season (p = 0.0308) were significant predictors of bycatch risk. Bycatch risk of older calves and subadults was 1.5 (summer) to 3.5 (spring) times greater than for an adult or young-of-year. Thus, young dolphins surviving past their first year of life, which typically experience low natural mortality, are experiencing fishery-related mortality at levels that appear to exceed natural mortality, at least as determined from stranding data. Bycatch risk was not affected by area despite spatial differences in the relative abundance of dolphins and gillnet effort. Additional studies are needed to determine the long-term effects of this anthropogenic pressure on population dynamics for stocks occurring in NC waters.

Key Words: bycatch, strandings, fisheries interactions, age-class, mortality, bottlenose dolphin, *Tursiops truncatus*

Introduction

Common bottlenose dolphins (*Tursiops truncatus*) are vulnerable to bycatch in a variety of fishing gears throughout their range (Noke & Odell, 2002; Díaz López, 2006; McFee et al., 2006; Wells et al., 2008; Byrd & Hohn, 2010; Allen et al., 2014; Byrd et al., 2014; Waring et al., 2016; Zappes et al., 2016). The circumstances around how a dolphin becomes entangled in gear are often a mystery as these events are rarely observed. Bottlenose dolphins may not always acoustically or visually detect gear and inadvertently swim into it (Mooney et al., 2007), although they have been seen changing the direction of travel to avoid both gillnets (Read et al., 2003) and stop nets (Byrd & Hohn, 2010). Dolphins may herd fish toward nets to prevent their escape when foraging (Cox et al., 2003), which could lead to occasional entanglements. Incidental entanglements may also be a result of dolphins' attempts to remove prey from fishing gear (depredation).

Depredation has been documented for gillnets in North Carolina (NC) (Read et al., 2003), gillnets and trammel nets in the Balearic Islands (Brotons et al., 2008), trammel nets in Sardinia (Lauriano et al., 2004), crab pots in Florida (Noke & Odell, 2002), and hook-and-line gear in Florida (Zollett & Read, 2006; Powell & Wells, 2011). Bottlenose dolphins also depredate trawlers and feed on discards or prey stirred up by or attracted to the gear (Corkeron et al., 1990; Fertl & Leatherwood, 1997; Gonzalvo et al., 2008; Jaiteh et al., 2013; Kovacs & Cox, 2014). Bottlenose dolphin depredation may not simply be during chance encounters with gear; in some cases, dolphins follow fishing vessels out to where they set or retrieve gear (Fertl & Leatherwood, 1997; Hagedorn, 2002; Noke & Odell, 2002; NC commercial fishermen, D. Beresoff, pers. comm., 30 November 2004, and P. Biermann, pers. comm., 6 November 2015). While depredation may provide an abundant food source with relatively low energetic costs, this behavior can be a potentially dangerous one due to risk of entanglement. The co-occurrence of fisheries and dolphin species, whether depredation is involved or not, may be because both are user groups targeting the same prey (Friedlaender et al., 2001; Lassalle et al., 2012).

Fisheries bycatch of bottlenose dolphins and other marine mammals has been documented by official observers (National Marine Fisheries Service [NMFS], 2004; Allen et al., 2014; Lyssikatos & Garrison, in press) and, to a lesser extent, by fishers who report its occurrence voluntarily or when interviewed (Lien et al., 1994; Díaz López, 2006; Allen et al., 2014; Waring et al., 2016; Zappes et al., 2016). Data from observer programs are used to provide an estimated level of bycatch (also called *take*) to compare to management goals. However, observer coverage is often limited or absent because it is expensive and not feasible for some fisheries (Moore et al., 2009; Byrd & Hohn, 2010). As a result, much of the evidence for bycatch comes from examining stranded animals for evidence of bycatch (fisheries interactions [FI]) such as attached gear and entanglement lesions (i.e., unhealed, linear lacerations or indentations in the skin) (Kuiken et al., 1994; Cox et al., 1998; Read & Murray, 2000; López et al., 2002; Byrd et al., 2008; Fruet et al., 2012). FI strandings cannot always be used to identify gear type or to extrapolate into total bycatch levels; however, the occurrence and relative levels of strandings are informative (Kuiken et al., 1994; Cox et al., 1998; Byrd et al., 2008).

Bycatch of the coastal form of bottlenose dolphins (Mead & Potter, 1995; Hoelzel et al., 1998; Rosel et al., 2009) has been documented along the mid-Atlantic coast of the U.S. by fisheries observers and by stranding networks that recover stranded animals with gear attached or entanglement lesions (Friedlaender et al., 2001; Byrd et al., 2008; Waring et al., 2016). This bycatch is of concern for the conservation of local stocks, which is particularly acute in North Carolina (NC) because of the small population sizes of two estuarine resident dolphin stocks that seasonally overlap with two coastal migratory dolphin stocks in coastal waters (Gorgone et al., 2014; Urian et al., 2014; Waring et al., 2016). Eight commercial fisheries in NC are known to interact with bottlenose dolphin stocks (U.S. Department of Commerce, 2016). The coastal gillnet fishery is the primary known source of bycatch (Waring et al., 2016; Lyssikatos & Garrison, in press). Only the coastal and estuarine gillnet fisheries, however, have observer coverage, with recent coverage ranging from 3% in coastal waters (federal observer coverage; Lyssikatos & Garrison, in press) up to 7 to 10% in estuarine waters (state observer coverage starting in 2010; U.S. Department of Commerce, 2013).

Observed bycatch is statistically rare (Lyssikatos & Garrison, in press); for example, fisheries observers have never documented bottlenose dolphin bycatch in estuarine waters and have documented only four dolphins as bycatch in coastal waters between 2010 and 2015 (Lyssikatos & Garrison, in press). With so few documented bycatch events, little is known about the events themselves, but some proportion of dolphins bycaught in fishing gear wash ashore as strandings. Between 1997 and 2008, 17% of all coastal bottlenose dolphin strandings (n = 1,039) in NC exhibited evidence of FI with some type of gear (Byrd et al., 2014). In fact, strandings positive for FI made up 50% of strandings for which it was possible to determine whether or not an interaction occurred. As a result, stranding data provide an opportunity to address questions related to bycatch events that cannot be addressed using available observer data.

Understanding the exact nature of dolphin interactions with fisheries is difficult, but some factors can be examined that may offer clues regarding influences on the risk of bottlenose dolphins becoming entangled. In NC, for example, stranded bottlenose dolphins with signs of FI have had a spatial or seasonal component associated with coastal gillnet fisheries targeting particular species such as spot (*Leiostomus xanthurus*) and spiny dogfish (*Squalus acanthias*) (Friedlaender et al., 2001; Byrd et al., 2008, 2014). In fact, when state and federal Fishery Management Plans (FMPs) for spiny dogfish significantly reduced gillnet fishing effort in NC starting in November 2000, reductions in estimated bycatch from observer data were mirrored with reductions in FI strandings (Byrd et al., 2008). Less is known, however, about factors affecting selectivity of bycatch such as age-class or sex. Studies outside of NC have purported that male bottlenose dolphins, especially young males in some cases, are more likely to engage in depredation or related behaviors (Corkeron et al., 1990; Powell & Wells, 2011) or become entangled in gear (Reynolds et al., 2000; Adimey et al., 2014). The objective of this study was to examine quantitatively whether there was differential risk of bycatch by sex and age-class, controlled for variables previously demonstrated to have a significant effect on strandings: a marked reduction in spiny dogfish gillnetting effort, geographic area, and season.

Methods

Basic "Level A" data (e.g., species, geographic position, length, and sex; Geraci & Lounsbury, 2005) on stranded bottlenose dolphins in NC from 1997 through 2012 were obtained from the National Marine Fisheries Service (NMFS) Marine Mammal Health and Stranding Response Database. For information regarding the stranding response effort in NC and data collection protocols, see Byrd et al. (2014). Data from 2013 to 2015 were excluded due to the high level of increased natural mortality as a result of an Unusual Mortality Event starting in 2013 (NMFS, 2015). Stranding records were examined first for their assignment of human interaction (HI) categories: Yes, No, or Could Not Be Determined (CBD) (Read & Murray, 2000). Then, strandings positive for HI were also scored positive for fisheries interaction (FI) when the evidence was the presence of entanglement lesions and/or attached gear, or they were scored as HI-Other when the evidence was non-fisheries related (e.g., mutilation without entanglement lesions or propeller wounds) (Byrd et al., 2008). Assignments to an HI category were made or routinely reviewed by experienced staff with substantial backgrounds and training to identify evidence for different types of HI. For this study, only strandings that were scored positive for FI (except for healed FI lesions) or negative for any type of HI (No) were included; thus, all CBD and HI-Other strandings were excluded. Data were further excluded if body length measurements were estimated, if they were from a partial carcass, or if the sex was unknown. Because of high natural mortality of neonates (Fernandez & Hohn, 1998), bottlenose dolphins <125 cm were excluded from the analysis to prevent the pulse (sharp increase) of neonates in spring from biasing the analyses (Byrd et al., 2014). Analyses were conducted with *SAS*, Version 9.4, and *JMP*, Version 11.2.1.

A suite of possible predictor variables was evaluated to determine their effect on a stranded dolphin being FI: season, area, habitat (coast or estuary), sex, age-class, and time period. The variables season, area, and habitat were chosen on the basis of known spatio-temporal variation in fishing activity (Steve et al., 2001). Seasons were defined as follows: winter (December-February), spring (March-May), summer (June-August), and fall (September-November). Strandings were plotted in *ArcMap*, Version 10.2.1, to determine habitat (coastal or estuarine); coastal strandings were further assigned to one of seven geographic areas (C1 to C7) (Figure 1). Strandings were assigned to one of four age-class categories, corresponding with potential behavioral differences, using predicted length-at-age curves (Read et al., 1993; Fernandez & Hohn, 1998). Young-of-Year (YOY) are highly dependent on mothers as nutritional weaning has not occurred (Wells, 2014), with predicted lengths up to 183 cm. Older calves are between 1 and approximately 3 y of age and generally are still associated with their mothers (Wells, 2014), with predicted lengths of 184 to 211 cm. Subadults are sexually immature animals generally independent from their mothers, although some animals may associate with their mothers for up to 6 y (Wells, 2014), with predicted lengths of 212 to 240 cm. Adults are > 240 cm; the same cut point was used for males and females even though there is sexual dimorphism in length (Read et al., 1993; Fernandez & Hohn, 1998). Lastly, strandings were assigned to one of three time periods that represented significant temporal events. Time Period (TP) 1 included data from January 1997 to October 2000, which was before the FMPs for spiny dogfish were implemented (Byrd et al., 2008). TP2 included data from November 2000 to April 2006, which was after implementation of the spiny dogfish FMPs but before implementation of the Bottlenose Dolphin Take Reduction Plan (BDTRP) to reduce bycatch in coastal gillnets (U.S. Department of Commerce, 2006). Finally, TP3 included data from May 2006 to December 2012, which was after implementation of the BDTRP.

A Generalized Linear Model (GLM) (*SAS* PROC LOGISTIC, link=logit) was used to determine the effect of possible predictor variables on the risk of a stranding being FI vs No (hereafter referred to as bycatch risk). Sample size did not allow for all variables to be examined simultaneously. Therefore, each variable was tested separately using contingency tables coupled with *post-hoc* multiple comparison tests, analysis of standardized residuals, or analysis of means for proportions (Nelson et al., 2005). Variables were considered for the final model if they were independently significant.

Results

From 1997 through 2012, 1,368 bottlenose dolphin strandings were recovered in NC (annual mean = 85.5, SD = 17.4). Of those, 60% (n = 821) were categorized as CBD (annual mean = 51.3, SD = 8.6). Of the remaining 547 strandings, 42% (n = 229) were categorized as FI (annual mean = 14.3, SD = 7.1), 50% (n = 274) were categorized as No for HI (annual mean = 17.1, SD = 5.8), and 8% (n = 44) were categorized as having evidence of HI other than FI (annual mean = 3.1, SD = 2.0). For the analysis, 142 of the 503 strandings classified as FI or No were excluded because they did not meet the remaining criteria: 19 animals were CBD for sex, 35 animals had estimated or partial lengths,

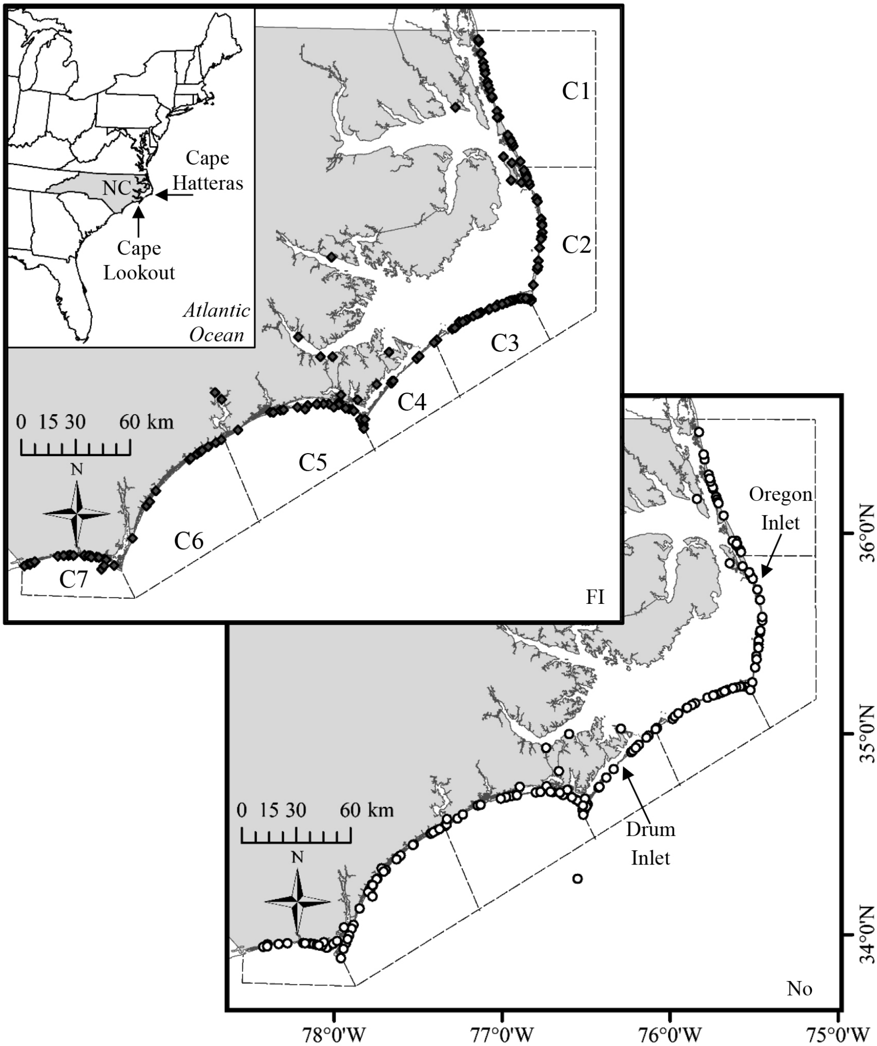

Figure 1. Locations of bottlenose dolphin strandings in North Carolina (NC) from 1997 through 2012 for strandings with evidence of fisheries interaction (FI) (top left) and strandings with no evidence of any type of human interaction (No) (bottom right). Dashed lines indicate demarcation among coastal areas (C1 to C7) used in the analyses. Locations in the ocean represent carcasses recovered floating and brought to shore.

one animal had only healed FI lesions, and 87 animals were < 125 cm. Of these 87, the smallest FI stranding was 119.5 cm; and of the eight animals between 119 and 124 cm, three were positive for FI (including the one cited above) and five were No. All of the criteria for inclusion were met by 361 bottlenose dolphin strandings (Figure 1): 191 categorized as FI and 170 categorized as No.

Results from the tests of single variables were mixed. A significant difference in the bycatch risk among TPs was found ($\chi^2 = 9.817$, $p = 0.0203$) (Figure 2). *Post-hoc* examination of standardized residuals indicated that the risk was greater in TP1 than TP2 (standardized residuals > |1.96|), but TP3 was not different than either TP1 or TP2 (standardized residuals < |1.96|). As a result, the analyses that followed used combined data from TP2 and TP3 (denoted as TP2-3), which is after the spiny dogfish FMPs were implemented and represents more current fishing practices. Analyses of TP1 were made as appropriate with the proviso that the spiny dogfish fishing effort was spatially and temporally restricted, precluding use of those predictor variables. For TP2-3 ($n = 235$), significant

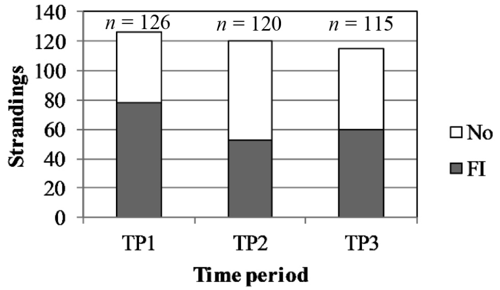

Figure 2. The number of bottlenose dolphin strandings (n = 361) categorized as FI (positive for fisheries interaction, gray) or No (no human interaction, white) among three Time Periods (TPs). There was a significant difference in bycatch risk among TPs ($\chi^2 = 9.817$, $p = 0.0203$), with risk being greater in TP1 than TP2, but no difference in risk between TP3 and either TP1 or TP2.

differences ($p < 0.05$) in bycatch risk were found for season, area, and age-class (Figure 3; Table 1). Areas C4 and C6 had significantly fewer strandings categorized as No; however, C4 also had the lowest total number of strandings (n = 12) among areas (all others had 25 or more). To test for a low sample-size effect, area C4 was excluded, and the test was repeated, resulting in no significant difference among areas ($\chi^2 = 10.1901$, $p = 0.1169$). As a result, the variable area was excluded from further analyses.

For TP2-3, age-class and season were significant predictors of bycatch risk (GLM, Age-class: Wald $\chi^2 = 29.6540$, $p < 0.0001$; Season: Wald $\chi^2 = 8.8917$, $p = 0.0308$). For age-class, bycatch risks for older calves and subadults were not different, and bycatch risks for YOYs and adults were not different (Table 2). However, the bycatch risks for older calves and subadults were significantly

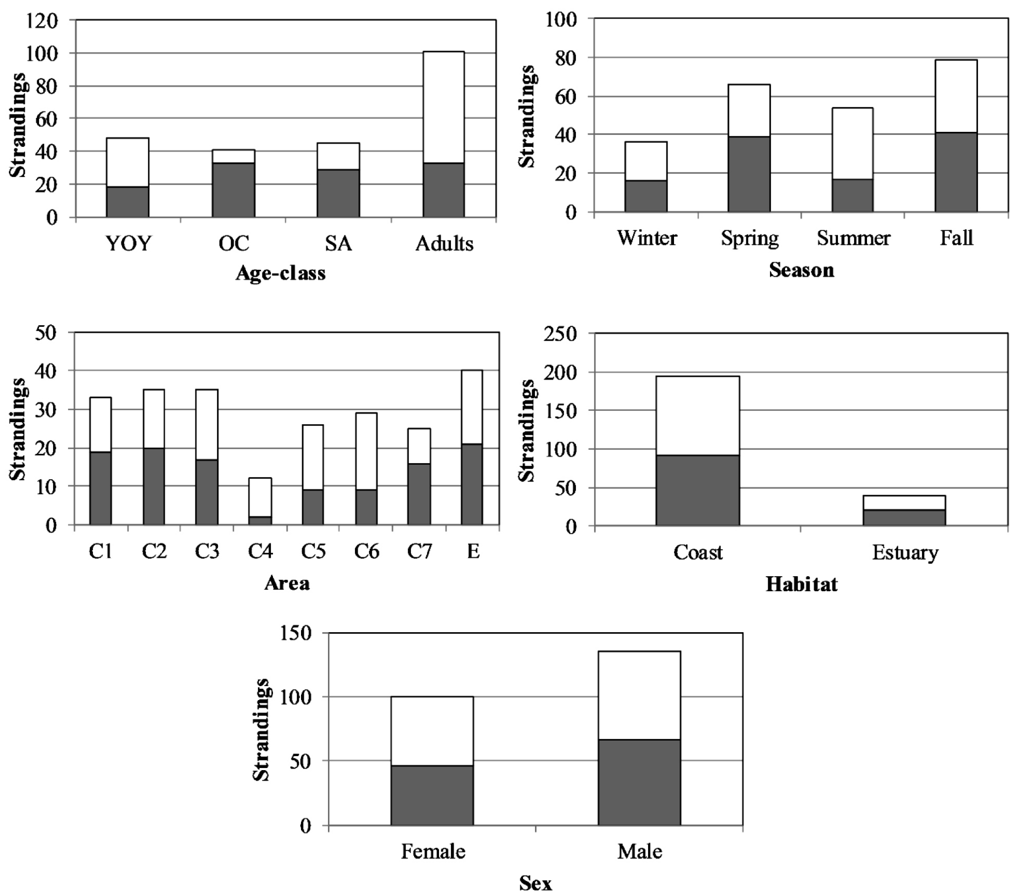

Figure 3. The number of bottlenose dolphin strandings (n = 235) during TP2-3 categorized as FI (positive for fisheries interaction, gray) or No (no human interaction, white) across five possible predictor variables. See Figure 1 to show locations of area abbreviations C1 to C7; E = Estuaries. Age-class categories are YOY (Young-of-Year), OC (Older calves), SA (Subadults), and Adults.

Table 1. Contingency table results of the probability of a bottlenose dolphin (*Tursiops truncatus*) stranding having evidence of fisheries interaction (FI) relative to having no evidence of any type of human interaction (No). Data include strandings from Time Period 2-3 (November 2000 through December 2012). Significant variables are italicized.

Variable	df	χ^2	*p* value
Season	*3*	*9.817*	*0.0202*
Area	*7*	*15.205*	*0.0335*
Habitat	1	0.376	0.5395
Sex	1	0.030	0.5819
Age-class	*3*	*33.833*	*< 0.0001*

Table 2. Contingency table results from multiple comparison tests performed on the significant predicators of bycatch risk in the Generalized Linear Models. Data were stratified into two Time Periods (TPs): after severe reductions in the spiny dogfish fishery (TP2-3) and before (TP1). For TP2-3, age-class and season were significant predictors of bycatch risk (Age-class: Wald $\chi^2 = 29.6540$, $p < 0.0001$; Season: Wald $\chi^2 = 8.8917$, $p < 0.0308$). For TP1, age-class was a significant predictor of bycatch risk (Wald $\chi^2 = 8.6861$, $p = 0.0338$). Significant comparisons are italicized.

Time periods	Contrast	χ^2	*p* value
TP2 & TP3	*YOY vs older calves*	*16.2539*	*< 0.0001*
	YOY vs subadults	*7.6039*	*0.0058*
	YOY vs adults	0.0725	0.7877
	Older calves vs subadults	2.5892	0.1076
	Older calves vs adults	*21.8808*	*< 0.0001*
	Subadults vs adults	*11.6776*	*0.0006*
	Fall vs spring	1.8551	0.1732
	Fall vs summer	3.4782	0.0622
	Fall vs winter	0.0215	0.8833
	Spring vs summer	*8.8648*	*0.0029*
	Spring vs winter	1.5766	0.2092
	Summer vs winter	2.0442	0.1528
TP1	YOY vs older calves	2.3741	0.1234
	YOY vs subadults	3.4424	0.0635
	YOY vs adults	0.0689	0.7930
	Older calves vs subadults	0.0881	0.7666
	Older calves vs adults	*4.2924*	*0.0383*
	Subadults vs adults	*6.0254*	*0.0141*

greater than for YOYs and adults (Figure 4). Among seasons, the only significant difference in bycatch risk was spring having greater risk than summer. Depending on season, an older calf to subadult dolphin stranding was approximately 1.5 to 3.5 times as likely to be positive for FI than an adult or a YOY (Figure 4).

The sex ratio of strandings overall (FI and No) was biased significantly toward males in all three TPs combined ($\chi^2 = 5.1219$, $p = 0.236$) and in TP2-3 ($\chi^2 = 5.2128$, $p = 0.0224$) (Figure 3), but not during TP1 when the sex ratio was not significant from 1:1 ($\chi^2 = 0.508$, $p = 0.48$). Given the biased sex ratio in TP2-3 and the previous anecdotal evidence of male bias in FI, sex and age-class were tested together in a GLM as possible predictor variables. Age-class still had a significant effect ($p < 0.001$), while sex did not ($p > 0.05$) (Figure 5)—that is, the relative risk remained constant despite more overall male strandings.

Given the effect of age-class as a predictor of bycatch risk following severe reductions in effort in the spiny dogfish fishery (i.e., TP2-3), differences among age-classes during TP1 were also tested; bycatch risk also varied among age-classes (Wald $\chi^2 = 8.6861$, $p = 0.0338$). Bycatch risks for

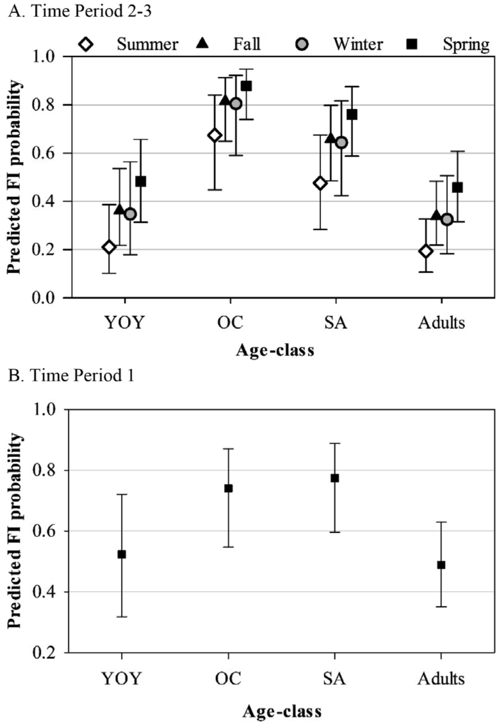

Figure 4. The predicted probabilities and confidence limits of a bottlenose dolphin stranding being FI (positive for fisheries interaction) vs No (no human interaction) during (A) TP2-3, for which season ($p = 0.0308$) and age-class ($p < 0.0001$) were significant predictor variables; and (B) TP1, for which age-class ($p = 0.0338$) was a significant predictor variable. Age-class categories are YOY (Young-of-Year), OC (Older calves), SA (Subadults), and Adults.

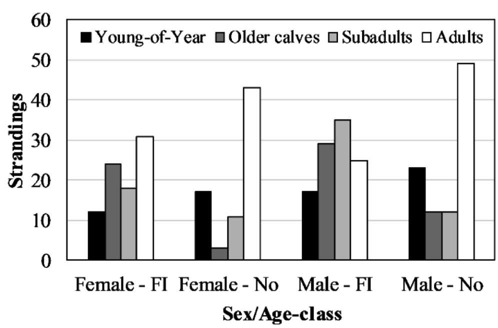

Figure 5. During TP2-3, the number of bottlenose dolphin strandings ($n = 235$) categorized as FI (positive for fisheries interaction) or No (no human interaction) by sex and age-class. For both females and males, the relative number of older calves and subadults that were positive for FI exceeded those with No evidence of human interaction in contrast to YOY and adult strandings.

YOYs and adults were not different, and risks for older calves and subadults were not different, similar to TP2-3. In contrast to TP2-3, during TP1, the risks for older calves and subadults were only different than adults but not YOYs (Table 2). Also, the predicted probability of an older calf to subadult being positive for FI was approximately 1.5 times greater than for an adult stranding (Figure 4).

Discussion

Age-class was a significant predictor of bycatch risk regardless of TP and season. While all age-classes were affected, the impact differed in that the proportion of older calves and subadults found stranded with signs of FI was greater than for YOY or adult animals. More importantly from a management perspective, bottlenose dolphins surviving the precarious first years of life and then typically experiencing relatively low natural mortality (i.e., older calves and subadults) (Caughley, 1966; Stolen & Barlow, 2003) are experiencing fishery-related mortality at levels that appear to exceed natural mortality, at least as determined from stranding data.

The current study does not address whether or not an individual, free-swimming bottlenose dolphin is more or less likely to become entangled in gear as a function of age. FI strandings were represented in all age-classes—from YOYs as small as 119.5 cm, which would be closely associated with their mothers, to adults. Other authors have speculated that calves and subadults may be more likely to become entangled in gear because they may be inexperienced around gear, engage in risky behavior, or seek out easier food resources (i.e., depredation) (Reynolds et al., 2000; Noke & Odell, 2002; Fruet et al., 2012). In Florida, however, bottlenose dolphin strandings that interacted with hook-and-line gear and free-swimming dolphins that depredated hook-and-line gear tended to be adults (and male) (Powell & Wells, 2011; Adimey et al., 2014). The tendency of individuals in certain age-classes to be more vulnerable to bycatch may differ among dolphin populations, gear types, and causes for entanglements.

While bycatch risk among age-classes showed similar patterns regardless of season, season was a significant predictor of risk overall. Seasonal variations in bycatch are likely affected by the intersection of changes in relative abundance of animals at risk of being bycaught and the inherent seasonality of many fisheries (de Boer et al., 2012). In NC, the gillnet fishery is the largest known contributor to bottlenose dolphin bycatch (Byrd et al., 2014; Waring et al., 2016), and fishing effort has been documented as being lowest in summer (Steve et al., 2001; Goodman Hall et al., 2013). While the lowest relative abundance of dolphins occurs in summer (Torres et al., 2005), low gillnet effort in summer is consistent with the findings in the current study of summer having the lowest bycatch risk. Temporal overlap alone does not fully explain bycatch risk, however. The current study found that bycatch risk was greatest in spring, although past studies have documented that relative dolphin abundance was greatest in the fall and gillnet effort was greatest during spring and fall (Steve et al., 2001; Torres et al., 2005). Using counts of FI strandings (i.e., not relative to No), Byrd et al. (2014) also found significant peaks in FI strandings during spring and fall. Differences in gear characteristics (e.g., soak times and mesh size) between spring and fall may further influence relative rates of bycatch risk.

Although there was a bias in the total number of males stranded, relative bycatch risk was not different for males and females. Male bias has been reported for strandings with evidence of FI (Stolen et al., 2007; Fruet et al., 2012; Adimey et al., 2014) and for *in situ* observations of FI (Corkeron et al., 1990; Finn et al., 2008; Powell & Wells, 2011) with the suggestions from authors that males are more likely to be entangled. Although interactions with fisheries and the resulting risk of entanglement may be greater for males in some cases, it is important to consider the findings in relation to any sex bias in overall strandings as was done in this study and in Adimey et al. (2014). More males were positive for FI than females during TP2-3; and had the FI data alone been analyzed, the conclusion in this study would be that bycatch risk was greater for males. Identifying bycatch risk requires empirical results not always available in prior studies (Reynolds et al., 2000).

Male bias in number of overall strandings of bottlenose dolphins has been reported in Brazil (Fruet et al., 2012), Ireland (McGovern et al., 2016), Spain (López et al., 2002), and some areas of the U.S. (Texas: Fernandez & Hohn, 1998; Mississippi: Mattson et al., 2006), but not all (South Carolina: McFee et al., 2006). Even within the same study area, on the eastern side of Florida (U.S.), male bias was reported for the dataset from 1997 to 2005 (Stolen et al., 2007), but not for the dataset from 1976 to 1983 (Hersh et al., 1990). In the current study, there was no male bias during a subset of the data, TP1.

It is unclear why more males are represented in the stranding records when it occurs. Some researchers have suggested that male bias for strandings of bottlenose dolphins (Stolen & Barlow, 2003) and common dolphins (*Delphinus delphis*) (Kuiken et al., 1994) may be due to different distribution patterns of males and females, making males more likely to strand after dying. Also, care should be taken when using stranding data to assess differences in sex ratios because males are less likely than females to become "unknown" for sex with decomposition (Stolen et al., 2007; Fruet et al., 2012). In this study, 19 strandings were excluded from the analysis because sex could not be determined (CBD). The stranding records for six of the 19 did not have information about why sex was CBD. The remaining 13 strandings were CBD for sex due to not being examined for sex (n = 3), scavenger damage (n = 4), mutilation (n = 1), and live release (n = 5) from gear. If all 19 strandings had actually been female, the overall sex ratio would not be significantly different from 1:1 ($\chi^2 = 1.52$, $p = 0.22$). However, if only seven of the 19 were male, the sex ratio would be significantly different from 1:1 ($\chi^2 = 3.8$, $p = 0.05$), indicating that male bias was not an artifact of female strandings being more likely to be CBD for sex.

The relative risk of a stranding being FI vs No was not different among areas of NC. This would indicate that on an individual level, a dolphin's risk of becoming entangled in gear does not change as a function of where the dolphin occurs. At first, this may seem counterintuitive because gillnet effort varies across the state with effort in estuarine waters (mean annual trips 2001 to 2012 = 35,261, SD = 5,437.7) being four to eight times greater than effort in coastal waters (mean annual trips 2001 to 2012 = 5,385, SD = 786.6) (North Carolina Division of Marine Fisheries [NCDMF], 2016). Within coastal waters, gillnet effort is greatest north of Cape Lookout (NCDMF, 2007), which is coincident with high numbers of dolphins (Torres et al., 2005). As a result, it might be expected that bycatch risk would be greater north of Cape Lookout, especially given the higher absolute numbers of FI strandings documented by Byrd et al. (2014), or in estuarine waters. However, because this study found that the bycatch risk was the same across areas, the absolute numbers of entangled dolphins may be a function of differences in the relative abundance of dolphins.

Overall bycatch risk changed throughout the time series in this study. It is not surprising that bycatch risk decreased between TP1 and TP2 as a previous study incorporating a portion of these data but using a different analytical approach resulted in a similar finding (Byrd et al., 2008). However, the addition of four more years of data to the time series indicates a potential increase in bycatch risk during TP3 despite additional regulations implemented on gillnet fisheries as a part of the BDTRP (U.S. Department of Commerce, 2006). Changes to the spiny dogfish FMPs have allowed for an increase in NC landings since 2009 (Atlantic

States Marine Fisheries Commission [ASMFC], 2011). In fact, the quota set for the 2012-2013 fishing year in NC (2,282 metric tons) (Skomal et al., 2013) was just over the average landings reported in NC during TP1 (2,250 metric tons) (ASMFC, 2011). Soak times during TP3, however, were constrained by federal regulations from the BDTRP prohibiting overnight sets of gillnets with mesh sizes used to target spiny dogfish (U.S. Department of Commerce, 2006). It is currently not known if increased effort in the spiny dogfish gillnet fishery has led to the increased bycatch risk demonstrated in the current study. However, of the four documented gillnet entanglements off NC by federal fisheries observers since 2009, two occurred in gear targeting spiny dogfish, while the other two were in gear targeting Spanish mackerel (*Scomberomorus maculatus*) and smooth dogfish (*Mustelus canis*) (Lyssikatos & Garrison, in press).

Similar to other studies involving stranded animals, a few biases should be considered. For example, this study assumes that an animal that was entangled in fishing gear is no more or less likely to become stranded than an animal that died of natural causes. Also, the relative proportions of FI and No strandings could be influenced by differing rates of strandings for which the presence or absence of evidence for fisheries entanglement is CBD. Assignment of CBD is influenced by factors such as decomposition, scavenger damage, and experience of the responder (Read & Murray, 2000; Byrd et al., 2014). This study assumes that the probability of true FI and No strandings being assigned as CBD is equivalent regardless of the variables (e.g., age-class and season) that were considered in the analyses. The assignment of No can be difficult because it requires that the entire body and skin remain sufficiently intact for assessment. In contrast, the assignment of FI requires only one entanglement lesion on one fin, which may make it seem like CBD strandings could be biased to include more strandings that had no FI. It is not uncommon, however, for strandings to be assigned as CBD when they have lesions that may have been from entanglement but are questionable (Byrd et al., 2014). Lastly, bottlenose dolphins in NC become entangled in a variety of different fishing gears (Byrd & Hohn, 2010; Byrd et al., 2014; Waring et al., 2016), and it is possible that the differences detected in age-class and season may vary among fisheries. It is not always possible to definitively assign an FI stranding to a particular fishery; and for those that have been assigned, the sample sizes were insufficient to test for differences among fisheries.

The results of this study indicate that there is a large bycatch risk in NC for young bottlenose dolphins surviving past their first year of life that otherwise would be expected to have a low mortality rate (Caughley, 1966). The impacts of this anthropogenic mortality on the stocks that occur in NC are yet to be investigated. Seasonal differences in bycatch risk align with other studies demonstrating concurrence of FI strandings with the seasonality of certain fisheries (Friedlaender et al., 2001; Byrd et al., 2008). In contrast, bycatch risk appears to be similar across different areas of the state despite spatial differences in the relative abundance of bottlenose dolphins (Torres et al., 2005; Waring et al., 2016) and densities of fishing gear, particularly gillnet fisheries (NCDMF, 2007; Lyssikatos & Garrison, in press).

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